CITY OF WARSAW, MISSOURI STORMWATER MANAGEMENT DESIGN CRITERIA

DIVISION V

SECTION 5600

STORM DRAINAGE SYSTEMS & FACILITIES

September 2022

DIVISION V

DESIGN CRITERIA

5600 STORM DRAINAGE SYSTEMS & FACILITIES

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5601.1 Introduction

These criteria provide uniform procedures for designing and checking the design of storm drainage systems under the rainfall and land characteristics typical of the Kansas City Metropolitan Area. This manual generally focuses on water quantity concerns including: conveyance, flow rates, and construction design parameters of stormwater systems. For an in-depth discussion of water quality design standards and Best Management Practices (BMPs) for the Kansas City Metropolitan area see the "Mid-America Regional Council and American Public Works Association; Manual for Best Management Practices for Stormwater Quality".

Federal law requires that "Waters of the United States may be disturbed only after permission is received from the City/County and permitted by the U.S. Army Corps of Engineers, if applicable. A jurisdictional determination by the Army Corps of Engineers shall be obtained prior to beginning design." Besides federal guidelines, specific criteria have been developed and are applicable to the types of drainage systems and facilities ordinarily encountered in local urban and suburban areas. Other special situations may be encountered that require added criteria or more complex technology than included herein such as maintaining or improving water quality. Any design procedure conforming to current accepted engineering practice may be used for the design of storm drainage systems in lieu of the computation methods presented in this manual, providing equivalent results are obtained and have been approved by the City/County Engineer. Drainage systems for all developments shall be designed assuming ultimate or built-out land-use conditions. The decision flowchart in Figure 5601-1, "Guide to Stormwater Management for Site Development", shall be used to determine the appropriate runoff controls (see end of this section).

5601.2 Definitions

Best Management Practice (BMP): Stormwater management practice used to prevent or control the discharge of pollutants to water of the U.S. BMPs may include structural or non-structural solutions, a schedule of activities, prohibition of practices, maintenance procedures, or other management practices. For a comprehensive discussion on BMPs refer to the "Mid-America Regional Council and American Public Works Association; Manual for Best Management Practices for Stormwater Quality".

City/County: The municipality or body having jurisdiction and authority to govern.

City/County Engineer: The municipal or county public works official or body having jurisdiction and authority to review and approve plans and designs for storm drainage systems.

Channel Lining: Includes any type of material used to stabilize the banks or bed of an engineered channel.

Design Storm: The combination of rainfall depth, duration, and distribution of a hypothetical rainfall event with a given likelihood of occurring in any year.

Detention Facility: A storm water management facility controlling storm water runoff from a site or watershed. The allowable runoff specified for detention facilities in Section 5608 is intended to manage maximum storm water release rates to minimize flooding and downstream erosion.

Detention Storage: The volume occupied by water above the level of the principal spillway crest during operation of a stormwater detention facility.

Development: Any activity, including subdivision, that alters the surface of the land to create additional impervious surfaces, including, but not limited to, pavement, buildings, and structures. Refer to Section 5601.3 for applicability.

Dry Detention: A detention facility that is designed for the temporary storage of water to control discharge rates from the facility and is normally dry between rainfall events.

Easement: Authorization by a property owner for the use by another for a specified purpose, of any designated part of the property.

Emergency Spillway: A device or devices used to discharge water under conditions of inflow that exceed the design outflow from the primary spillway detention facility. The emergency spillway functions primarily to prevent damage to the detention facility that would permit the sudden release of impounded water.

Engineer: See 'Registered Professional Engineer'.

Engineered Channel: An open drainage channel that has been explicitly designed to convey stormwater runoff in accordance with Section 5607 or as approved by the City/County engineer.

FHWA: Federal Highway Administration.

Floodplain: A relatively level surface of stratified alluvial soils on either side of a watercourse that is inundated during flood events.

Freeboard: The difference in elevation between the top of a structure such as a dam or open channel and the maximum design water surface elevation or high water mark. It is an allowance against overtopping by waves or other transient disturbances.

Impact Stilling Basin: A device that dissipates energy by allowing flowing water to strike a stationary surface therefore producing turbulence and energy loss. .

Impervious Surface: A surface that prevents the infiltration of stormwater.

Improved Channel: Any channel changed by grading or the construction of lining materials as approved by the City/County Engineer.

Incision: Adjustment of the channel bed elevation downwards, typically in response to some type of disturbance.

Increased Runoff: Increase in volume or peak flow of stormwater runoff.

Meander Amplitude: The linear distance between the apex of one meander and the apex of the next meander in a naturally curving stream.

Meander Length: The length measured along the thalweg of one complete waveform.

Meander Wavelength: The length of one complete waveform, measured as the straight-line linear distance along the valley between two analogous points on a waveform.

Low-Drop Structures: A step pool energy dissipation structure typically constructed out of rock or concrete with a design vertical drop of 2 feet or less per step.

Natural Channel: Any waterway with the ability to self-form by virtue of having at least one unfixed boundary. This includes drainage ways that may have been previously disturbed but through inactivity over time have begun to reform one or more characteristics of undisturbed streams.

Open Channel: A maintained earthen or lined waterway with an open water surface as approved by the City/County engineer.

Ordinary High Water Mark: A line on the bank established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas.

Owner: The owner of record of real property.

Point Bars: Depositional features generally occurring on the inside of stream bends and opposite cut banks.

Pools: A deep reach of a stream. The reach of a stream between two riffles; a small and relatively deep body of quiet water in a stream or river.

Primary Outlet Works: A device such as an inlet, pipe, weir, etc., used to discharge water during operation of a storage facility.

Principal Stream: Stream Segments included in FEMA Flood Insurance Studies where the limits of the 1% floodplain and 1% base flood elevations have been determined.

Redevelopment: Remodeling, repair, replacement, or other improvements to any existing structure, facility, or site.

Registered Professional Engineer: A licensed engineer who is registered with and authorized to practice engineering within the state of registration.

Riffles: Shallow rapids in an open stream, where the water surface is broken into waves by obstructions such as stream armoring or bedrock outcrop wholly or partly submerged beneath the water surface.

Sediment Storage: The volume allocated to contain accumulated sediments within a detention facility.

Site: A tract or contiguous tracts of land owned and/or controlled by a developer or owner. Platted subdivisions, industrial and/or office commercial parks, and other planned unit developments shall be considered a single site. This shall include phased development where construction at a tract or contiguous tracts of land may occur in increments.

Storm Drainage System: All of the natural and man-made facilities and appurtenances such as natural drainage paths, streams, pipes, culverts, bridges, open channels, swales, street gutters, inlets, retention/detention facilities, and stormwater BMPs/GSI which serve to convey and control surface drainage.

Stormwater Drainage Setback: preservation of vegetated areas adjacent to a natural drainage path or stream defined by a drainage easement with limitations on allowable development and uses. Stormwater drainage setbacks consist of channel, preservation, and limited-use setback widths.

Swale: An engineered channel conveying stormwater from more than two lots; often the swale is maintained by the property owner but an easement is required when requested by the City/County.

Thalweg: The deepest part of a channel cross-section. The dominant thread of stream flow creates the thalweg.

Top of Bank: The vertical point along a stream bank where an abrupt change in slope is evident, typically representative of the bank-full or channel-forming flow caused by approximately the 2-year design storm.

Tributary Area: All land draining to the point of consideration, regardless of ownership. Tributary area may also be referred to as watershed.

Waveform: A complete cycle of two channel bends in opposite directions.

Wet Detention: A detention facility that is designed to include permanent storage of water in addition to the temporary storage used to control discharge rates from the facility.

5601.3 General Requirements and Applicability

The design shall be accomplished under the direction of a Registered Professional Engineer qualified in the field of stormwater design. The design shall be based on land use in the tributary area as zoned, actually developed, or indicated by an adopted future land use plan, whichever basis produces the greatest runoff. Compliance with criteria shall be demonstrated through application and approval of a Stormwater Drainage Permit per Paragraph 5601.5, A.

This design criterion shall apply to all new development and redevelopment, including subdivision development and construction, which alters the surface of the land to create additional impervious surfaces, including, but not limited to, pavement, buildings, and structures with the following exceptions:

A. Exceptions for Existing Development: Improvements that cause an increased area of impervious surface on the site less than 1,000 square feet.

B. Exceptions for New Development:

1. Construction of any one new single family or duplex dwelling unit provided the total impervious area of the site is less than 5,000 square feet.
2. Construction on a site having previously provided stormwater management per the stormwater criteria adopted herein as part of a larger unit of development assuming fully developed conditions. If previously provided stormwater management for the project predates these standards, stormwater management shall be re-evaluated for compliance with the current requirements.

5601.4 Existing Drainage System

Existing drainage system component pipes, structures, and appurtenances within the project limits may be retained as elements of an improved system providing:

- They are in sound structural condition.
- Their hydraulic capacity, including surcharge, is equal to or greater than the capacity required by these criteria.

- Easements exist or are dedicated to allow operation and maintenance.

Discharge from an existing upstream storm drainage system shall be computed assuming its capacity is adequate to meet the performance criteria listed in Paragraph 5601.5. The computed discharge shall be used to design the new downstream system even if the actual capacity of the existing upstream system is less.

5601.5 Stormwater Management Requirements

Natural drainage paths and streams are to be preserved to the maximum extent practicable as site conditions permit. Requirements for preservation of natural drainage paths and streams are addressed in Section 5605. Engineered channels, the next highest priority system component, shall be designated and coordinated with the design of building lots and streets in accordance with the design criteria and performance standards addressed in Section 5607.

To the maximum extent possible, drainage systems, street layout and grades, lot patterns and placement of curbs, inlets and site drainage, and overflow swales shall be concurrently designed in accordance with the design criteria and performance standards set forth in this document. Curb and gutter may be omitted or modified where feasible in conjunction with other stormwater management practices including green stormwater infrastructure.

All improvements defined in Paragraph 5601.3 shall incorporate stormwater management measures to control runoff from the site. Allowable runoff from a site may be limited by the need to minimize downstream flood damage, prevent erosion, and/or minimize impacts to the ecology and water quality of the downstream drainage system. A layered approach to stormwater management level of service is applied to distribute the stormwater risk created from improvements throughout the watershed and provide protection for the community as a whole.

A. Stormwater Drainage Permit: A stormwater Drainage Permit per the City of Warsaw Code of Ordinances Chapter §405.020 is required to demonstrate compliance with this design criteria, as detailed in Section 5609.

B. Protection of Property

1. Property not reserved or designed for conveying storm water shall be protected from frequent inundation:

a. When the total drainage area including all upstream tributary area is less than 2 acres, protection may be provided by following the following lot-to-lot grading practices or by one of the conveyances described as follows.

1) Maintain natural drainage path preservation/overflow system per Paragraph 5601.5,C, 1. such that the freeboard requirements for protection of buildings are met.

2) When swales (engineered channels) are required for overflow systems, swales shall be approximately centered on the rear and/or side lot line with a minimum 15-feet drainage easement.

3) Lawn grading shall maintain slopes between 1% and 33% (3 horizontal : 1 vertical) graded to drain away from buildings. Grading shall be designed to avoid localized sumps with potential to create ponding or flooding issues within the property or between multiple properties. If localized sumps are unavoidable, a drainage system shall be required. Drainage system may include collection and conveyance. Retention designs using GSI/stormwater BMP are also encouraged, as defined in Section 8 of the MARC BMP

Manual. See the KCMO GSI Manual for detailed design and construction guidance of GSI/stormwater BMPs.

b. When the total drainage area is 2 acres or more, one or a combination of the following conveyances must be used to meeting the conveyance system requirements specified in Paragraph 5601.5 B

1) Enclosed pipe system

2) Engineered channel

3) Street gutter

4) Natural drainage path or stream

2. Buildings shall be protected from infrequent flooding by:

a. Providing a minimum of one-foot freeboard above the 100-year design storm stage based on a 10% temporal distribution, at any point along the drainage system, for openings in a building. For dry and wet detention facilities the 100-year design storm stage will be the water surface elevation of flow through the primary spillway.

b. Flood-proofing a building below the 100-year design storm with 10% temporal distribution water surface elevation plus one foot of freeboard, in accordance with the current edition of the International Building Code or as required by the City/County.

c. Non habitable accessory buildings are sometimes provided less protection by local City/County ordinances or policies. Consult the local authority for exceptions.

C. **Retention:** Stormwater retention shall be provided for the 0.5-inch design event over the tributary impervious area from the site. Retention-based facilities are designed to either capture and infiltrate or re-use the required retention volume with no discharge from the site for the minimum design event. Retention shall be provided in the form of GSI/stormwater BMPs, as defined in Section 8 of the MARC BMP Manual. See the KCMO GSI Manual for detailed design and construction guidance of GSI/stormwater BMPs. Retention requirements may be achieved in conjunction with detention storage, or independently.

D. **Detention:** Detention storage shall be maximized for the smaller, more frequent events while allowing larger, less frequent events to pass through the facility without overtopping the facility. Peak runoff control shall be provided for the 2-, 10-, and 100-year design storms for broad protection of the receiving system, including channel erosion protection and flood peak reductions over a range of design storm average recurrence intervals (ARI). Post-improvement peak discharge rates from the site shall not exceed the allowable release rates expressed in discharge rate per tributary area as follows:

a. 2-year design storm with median (50%) temporal distribution shall have a maximum release rate of 0.1 cfs/acre of drainage area without overtopping of the primary spillway

b. 10-year design storm with median (50%) temporal distribution shall have a maximum release rate of 0.2 cfs/acre of drainage area without overtopping of the primary spillway

c. 10-year design storm with 10% temporal distribution shall have a maximum release rate of 2.0 cfs/acre of drainage area with allowable discharge through the primary spillway without overtopping the facility

d. 100-year design storm with 10% temporal distribution shall have a maximum release rate of 3.0 cfs/acre of drainage area with allowable discharge through the primary spillway without overtopping the facility.

E. Conveyance: Generally, a stormwater drainage system is defined when the drainage area is 2 acres or more. As defined in Paragraph 5601.2, the stormwater drainage system may consist of natural drainage paths in combination with engineered channels and enclosed systems. A storm drainage system shall incorporate an overflow system that is capable of conveying flows in excess of the designed system capacity. Overflow systems can consist of natural drainage path preservation. Enclosed conveyance systems consisting of inlets, conduits, and manholes may be used to convey stormwater runoff where site conditions and open space requirements will not permit the use of natural drainage paths or engineered channels. Where used, such systems must be designed in accordance with design criteria and performance standards addressed herein.

1. **Natural Drainage Path Preservation and Overflow Systems**: Natural drainage paths shall be preserved to reduce the risk for property damage by designating space for the overland conveyance of stormwater for rainfall events exceeding the capacity of the engineered system. Natural drainage paths delineated from 2016 LiDAR data for the City of Warsaw are shown in Appendix A, for reference. Stormwater drainage setback requirements are defined in Section 5605. Each element of the stormwater drainage system (whether open, enclosed, retention, or detention) shall include an overflow element to a preserved natural drainage path. Overflow systems shall:

    a. Be designed to route downstream flows in excess of the engineered system design capacity.

    b. May include streets, natural drainage paths, engineered channels, redundant piping, spillways, parking lots, drives or combinations thereof.

    c. Limit the maximum water surface elevation generated by the 100-year design storm with the 10% temporal distribution to meet protection of property requirements.

    d. Conform to Paragraph 5605.2 Easements regarding easements and restricted uses for overflow systems within stormwater drainage setbacks.

2. **Open Systems**: Engineered channels, ditches, and swales shall be designed to convey the 10-year design storm with the 10% temporal distribution, as defined in Section 5602. Where feasible, open systems consisting of open or engineered channels shall be used if all of the following are met:

    a. The channel slope is less than or equal to 5 percent or where appropriate armoring techniques are used to prevent erosion.

    b. The 2-year design storm velocity is less than or equal to 5 feet per second (fps) or where appropriate armoring techniques are used to prevent erosion.

    c. When required stormwater drainage setbacks can be maintained.

3. **Enclosed Systems**: Enclosed systems consisting of underground pipes, culverts, and similar underground structures shall be used to convey stormwater at all locations where natural drainage paths or engineered channels are not feasible. Enclosed pipe systems shall convey the 10-year design storm assuming the temporal distributions per Section 5602, and be designed per Section 5603, as follows:

    a. **Gravity Flow Conditions**: 10-year design storm with median (50%) temporal distribution gravity flow conditions within the pipe system (e.g. no surcharging)

b. **Pressure Flow Conditions**: 10-year design storm with 10% temporal distribution pressure flow conditions with surcharging less than 0.5 feet below the lowest opening to the surface or structure rim elevation.

4. **Street Crossings:** Concentrated flow for open systems shall be conveyed under streets to prevent vehicles from being swept from the roadway during infrequent storms. These crossings may be bridges or culverts. Crossings shall be designed to completely convey flows without street overtopping in accordance with the design storms listed in Table 5601-1 based the 10% temporal distribution. Roadway classifications are defined per the Warsaw Livable Community Transportation Improvement Plan.

Table 5601-1: Level of Service for Street Crossings

Street Classification	Min. Design Storm
Principal Arterial	50-Year
Primary Connectors	25-Year
Minor Streets(1)	10-Year
(1) Secondary connectors also fall into the category of minor streets	

Further, concentrated flow in excess of the minimum design storm may only overtop the roadway if the following conditions are met:

a. The span of the structure opening is less than 20 feet.

b. The peak stormwater runoff from the 100-year design storm with 10% temporal distribution is 250 cfs or less unless a guard fence is installed on the downstream side of the roadway. Such overflow depths at low points in roadways during the 100-year design storm with 10% temporal distribution will be limited to 7 inches measured at the high point in the roadway cross section, typically at the upstream face of culvert headwall or roadway curb; except that it also shall not exceed 14 inches at the deepest point in the roadway cross section.

F. **Collection**: Inlet placement in roadway sections shall limit the allowable gutter spread to maintain one lane width for emergency vehicle access during the 10-year design storm with the median (50%) temporal distribution, as defined in Section 5602. Water spread may exceed these limits within 50 feet of a sump location, however, protection of property shall be maintained per Paragraph 5601.5, A. by limited over-topping of curb and/or flooding beyond the right-of-way.

5601.6 Waivers

The Developer may submit a stormwater Drainage Permit by a registered professional engineer that quantifies the problems and demonstrates that a waiver (exemption) of the requirement to provide stormwater management is appropriate. The City/County Engineer may waive requirements to address *unique* conditions or constraints:

A. **Stormwater Management Requirements:** Stormwater management requirements may be waived when supported by a Stormwater Drainage Permit performed in accordance with Section 5609 and approved by the City/County Engineer.

B. **Overflow Channels:** In previously developed areas, requirements to provide for 100-year design storm with 10% temporal distribution conveyance may be reduced by the City/County Engineer in circumstances where flood protection for the 100-year design storm is not reasonably attainable due to the location of damageable improvements with respect to the drainage system and where non-attainment is supported by an approved Drainage Permit.

5601.7 Other Requirements

Rules and regulations of other agencies also pertain to drainage systems which may or may not complement these criteria. When conflicts are encountered, the more stringent criteria shall govern.

The following agencies have jurisdiction over streams and/or drainage systems and often require permits. Other regulations, permits and requirements may not be limited to these agencies.

- Federal Emergency Management Agency.
- U.S. Army Corps of Engineers.
- Missouri Department of Natural Resources.
- Municipal Ordinances.

State and Federal regulations often establish requirements for a storm drainage project that impacts adjoining property, especially when a project causes a rise in water surface elevations. In addition to all Federal and State regulations the following shall be met:

- **Drainageways not designated a Special Flood Hazard Area (FEMA 1% Floodplain):** Construction of a storm drainage system, including grading and filling within a stormwater drainage setback is not permitted unless approved by the City/County.
- **Drainageways designated a Special Flood Hazard Areas (FEMA 1% Floodplain) and City/County participates in the National Flood Insurance Program**: When impacting adjoining properties, refer to the adopted Floodplain Management Ordinance for any requirements, in addition to all current FEMA regulations.

SECTION 5602 HYDROLOGY

5602.1 Scope

This section sets forth the hydrologic parameters to be used for computations involving the definition of runoff mass and peak rates to be accommodated by the storm drainage system. The methods to be used for calculating runoff mass and peak rates are intended for the design of drainage systems. The hydrologic calculations included are based on the *NOAA Atlas 14 Volume 8 Precipitation Frequency Atlas of the United States for Midwestern States* (NOAA, 2013), herein referred to as NOAA Atlas 14. The 6-hour temporal rainfall distributions were applied to the location of Warsaw, Missouri based on point precipitation frequency data from the NOAA Precipitation Frequency Data Server. Documentation of this data analysis can be found in the *Warsaw Stormwater Study: Hydrologic Analysis & Hydraulic Review* (Burns & McDonnell, September 2020).

5602.2 Computation Methods for Runoff

Runoff rates to be accommodated by each element of the proposed storm drainage system shall be calculated using the criteria of this section for land use runoff factors, rainfall, and system time. The following methods of computations are allowed:

A. Watersheds Less than 200 Acres: The Rational Method may be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 200 acres. The Rational Method is defined as follows:

$$Q = C \cdot i \cdot A$$

Where:

Q = Peak rate of runoff to system in cfs
C = Runoff coefficient as determined in accordance with Paragraph 5602.3
i = Rainfall intensity in inches per hour as determined in accordance with Paragraph 5602.6
A = Tributary drainage area (acres)

B. Baseline Unit Hydrograph Method: The following computer implementations of the unit hydrograph method are acceptable for all watersheds:

- SCS Technical Release No. 55 "Urban Hydrology for Small Watersheds", 2nd Edition, June 1986.
- SCS Technical Release No. 20 "Project Formulation - Hydrology", 2nd Edition, May 1983.
- U.S. Army Corps of Engineers, Hydrologic Engineering Center - "HEC-1Flood Hydrograph Package".
- U.S. Army Corps of Engineers, Hydrologic Engineering Center - "HEC-HMS Hydrologic Modeling System", current version.
- Other industry standard practices as approved by City/County Engineer.

Inputs for unit hydrograph procedures shall conform to the requirements of Paragraph 5602.3 through 5602.8.

C. Other Alternative Design Methods: Alternative design methods, including computer models may be employed so long as they produce runoff hydrographs to the system that are substantially the same as those calculated by the baseline method. To assess the equivalence of such methods, the Engineer shall prepare estimates using both the alternate design method and the baseline unit hydrograph method, and shall report for every sub-basin the following data from both: peak flow rate, lag time, runoff volume, and equivalent curve number based on total storm precipitation and direct runoff. Any discrepancy greater than

5% between the two models shall be clearly identified. Testing of equivalence is not required if the alternative method has been proven to the City/County to be consistently more conservative than the baseline unit hydrograph method or if the City/County has determined that the alternative method is reliably more accurate or appropriate for the design condition.

D. Regression Equations: Rural and urban regression equations prepared by the U.S. Geological Survey (USGS) for Missouri shall not be used as the sole input for project design, but are useful tools for evaluating design models. USGS StreamStats web application provides access to Geographic Information System analytical tools that are useful for stormwater planning. Rural regression formulas shall be used only to represent rural or pre- development conditions when significant basin storage does not exist. For urban watersheds a pre-development scenario of the basin model can be developed to compare to the rural regression, and then physically realistic adjustments can then be made to impervious percentages, ground cover, basin lag times, and channel routing to produce the urban scenario. Engineers shall use caution in interpreting regression equation results and acknowledge the range of standard error and uncertainty of both the regression formulas and the underlying gauge estimates.

5602.3 Runoff Coefficients

A. Rational Method "C": A composite runoff coefficient based on the actual percentages of pervious and impervious surfaces shall be used when feasible. The "C" value can be calculated from any type of land use and known percent impervious surface from the following equation:

$$C = 0.3 + 0.6 \cdot I$$

Where:

I = percent impervious divided by 100

B. SCS Runoff Curve Number Method "CN": SCS Curve Numbers shall be determined per SCS Technical Release No. 55. No soil disturbed by construction shall be assigned a Hydrologic Group classification of 'A' or 'B'.

C. Standard Land Use/Zoning Classifications: Runoff Coefficients relative to development, undeveloped land and land use may use the values indicated in Table 5602-1 for preliminary planning purposes. Drainage Permit shall reflect actual percent imperviousness for the site.

Table 5602-1: Runoff Parameters

Land Use / Zoning	Average Percent Impervious	Average Percent Pervious	Rational Method "C"[1]	SCS Curve Number by Hydrologic Soil Group[2]			
				A	B	C	D
Commercial & Business							
Local, Central and Commercial Business Districts (C-1, C-2, and C-3)	85	15	0.81	89	92	94	95
Residential							
Single Family and Two-Family Dwelling District (R-1 and R-2)	35	65	0.51	60	74	82	87
Multifamily Dwelling District (R-3)	60	40	0.66	74	83	88	91
Mobile Home District (R-4)	25	75	0.45	54	70	80	85
Churches & Schools	75	25	0.75	83	89	92	94
Industrial							
Light Industrial District (M-1)	60	40	0.66	74	83	88	91
Heavy Industrial District (M-2)	80	20	0.78	86	91	93	94
Parks, Cemeteries	10	90	0.36	45	64	76	82
Railroad Yard Areas	25	75	0.45	54	70	80	85
Open Space District (O) and Undeveloped Areas	0	100	0.3	39	61	74	80
All Surfaces							
Impervious: Asphalt, Concrete, Roofs, etc.	100	0	0.9	98	98	98	98
Turfed	0	100	0.3	39	61	74	80
Ponds/Permanent Water Surface	100	0	0.9	98	98	98	98

[1]Rational C is calculated based on average percent impervious per Paragraph 5602.3 A.
[2]SCS Curve Number calculated based on average percent impervious area (Purdue University, 2011)

D. Un-zoned, but Master Planned Areas: Areas whose future land use is defined by an adopted land use plan shall be assigned runoff coefficients for the land use indicated on such plan.

E. Agricultural and Unplanned Areas

1. Existing Conditions: For purposes of determination of development impact, undeveloped areas whose current land use is agriculture (crops, pasture, meadow, brush, woods) shall have an assumed maximum of 0% impervious area or a maximum Curve Number based on good hydrologic condition.
2. Proposed Conditions: Undeveloped areas designated as agricultural or those areas for which no specific land use is indicated shall be assigned a minimum of 35% impervious area based on good hydrologic condition with Hydrologic Soil Group 'C' for purposes of the design of storm drainage systems. Existing undeveloped land with a Hydrologic Soil Group of 'A' or 'B' shall be assigned a Hydrologic Soil Group of 'C' for the proposed (developed) condition if the

undeveloped land would be disturbed as a result of the development (e.g. Pasture with good hydrologic condition and Hydrologic Soil Group 'B' that will be open space for a park would be assign a Hydrologic Soil Group 'C').

5602.4 Rainfall Mass

The NOAA Atlas 14 Volume 8, 6-hour duration, median and 10% first-quartile rainfall distributions for Region 3 shall be used for all computations that employ the use of rainfall mass. The rainfall distribution for the median (50%) and 10% temporal distributions are reproduced in Table 5602-2.

Table 5602-2: Rainfall Mass

Time (hours)	Accumulated Percentage of Total Precipitation (%)	
	Median (50%) Temporal Distribution	10% Temporal Distribution
0	0	0
0.5	19.52	39.62
1.0	38.51	73.03
1.5	57.82	90.42
2.0	74.88	97.12
2.5	84.23	99.38
3.0	88.12	99.89
3.5	91.8	99.91
4.0	95.37	99.96
4.5	97.28	99.97
5.0	98.96	99.99
5.5	99.82	100
6.0	100	100

5602.5 Unit Hydrographs

The SCS Dimensionless Unit Hydrograph (either curvilinear or triangular) shall be the basis for computation of runoff hydrographs.

5602.6 Rainfall Intensity

Rainfall intensity shall be determined from Table 5602-3 per NOAA Atlas 14 Volume 8, 6-hour duration, median and 10% first quartile rainfall distributions for Region 3.

Table 5602-3: Rainfall Intensity (in/hr) for Warsaw, Missouri

Average Recurrence Interval (ARI)	Median (50%) Temporal Distribution	10% Temporal Distribution
1-Year	0.90	1.82
2-Year	1.04	2.12
5-Year	1.29	2.62
10-Year	1.51	3.07
25-Year	1.83	3.71
50-Year	2.08	4.22
100-Year	2.35	4.76

5602.7 Time of Concentration and Lag Time

Time of Concentration (T_C) is equal to the overland flow time to the most upstream inlet or other point of entry to the system, Inlet Time (T_I), plus the time for flow in the system to travel to the point under consideration, Travel Time (T_T).

$$T_C = T_I + T_T$$

A. Inlet Time: T_I shall be calculated by the following formula or determined graphically from Figure 5602-1, but shall not be less than 5.0 minutes nor greater than 15.0 minutes:

$$T_I = 1.8 \cdot (1.1 - C) \cdot \frac{D^{1/2}}{S^{1/3}}$$

Where:

T_I = Inlet time in minutes
C = Rational Method Runoff Coefficient as determined in accordance with Paragraph 5602.3
D = Overland flow distance parallel to slope in feet (100 feet shall be the maximum distance used for overland flow)
S = Slope of tributary area surface perpendicular to contour in percent

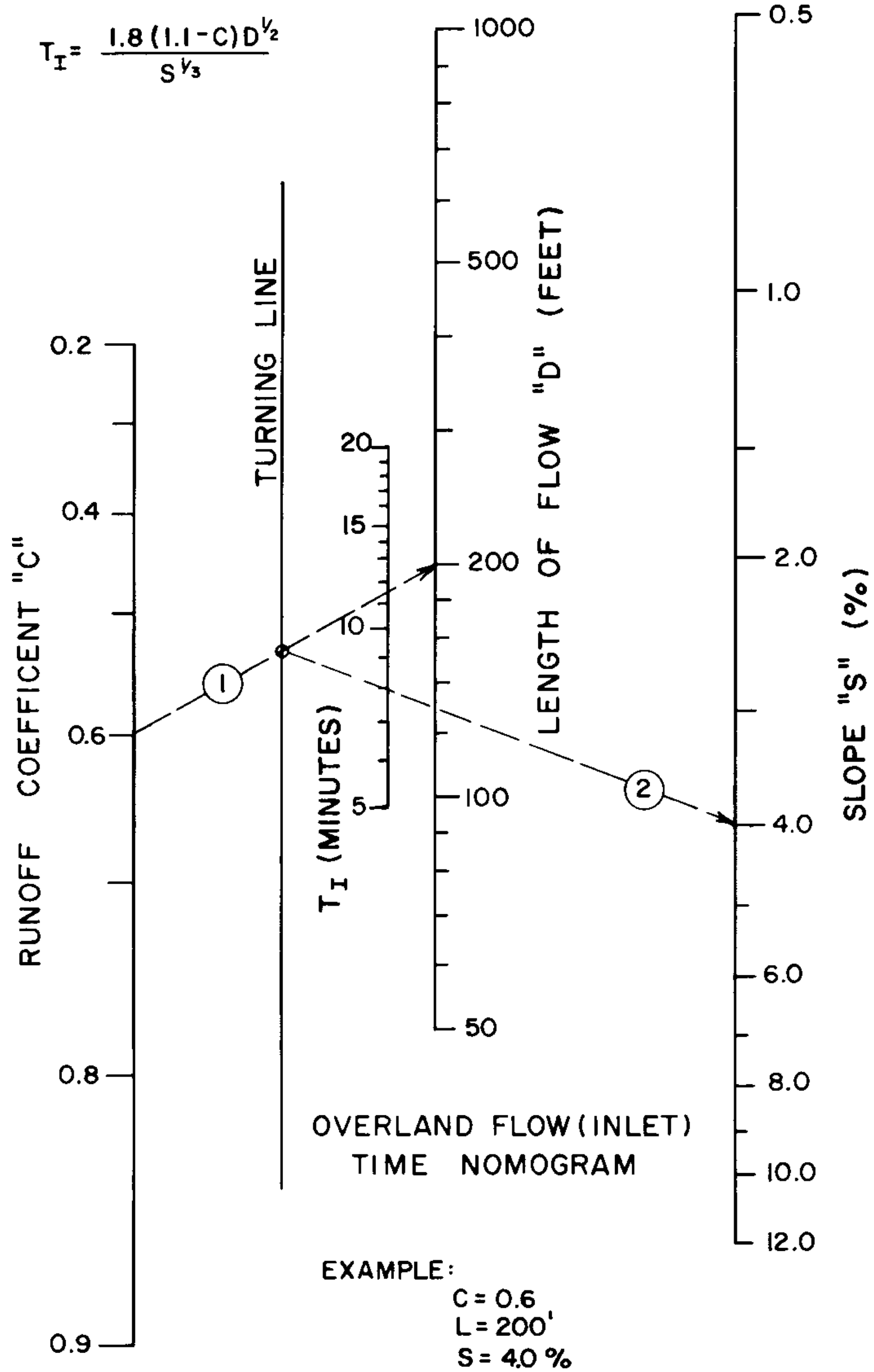


Figure 5602-1: Overland Flow (Inlet) Time Nomograph

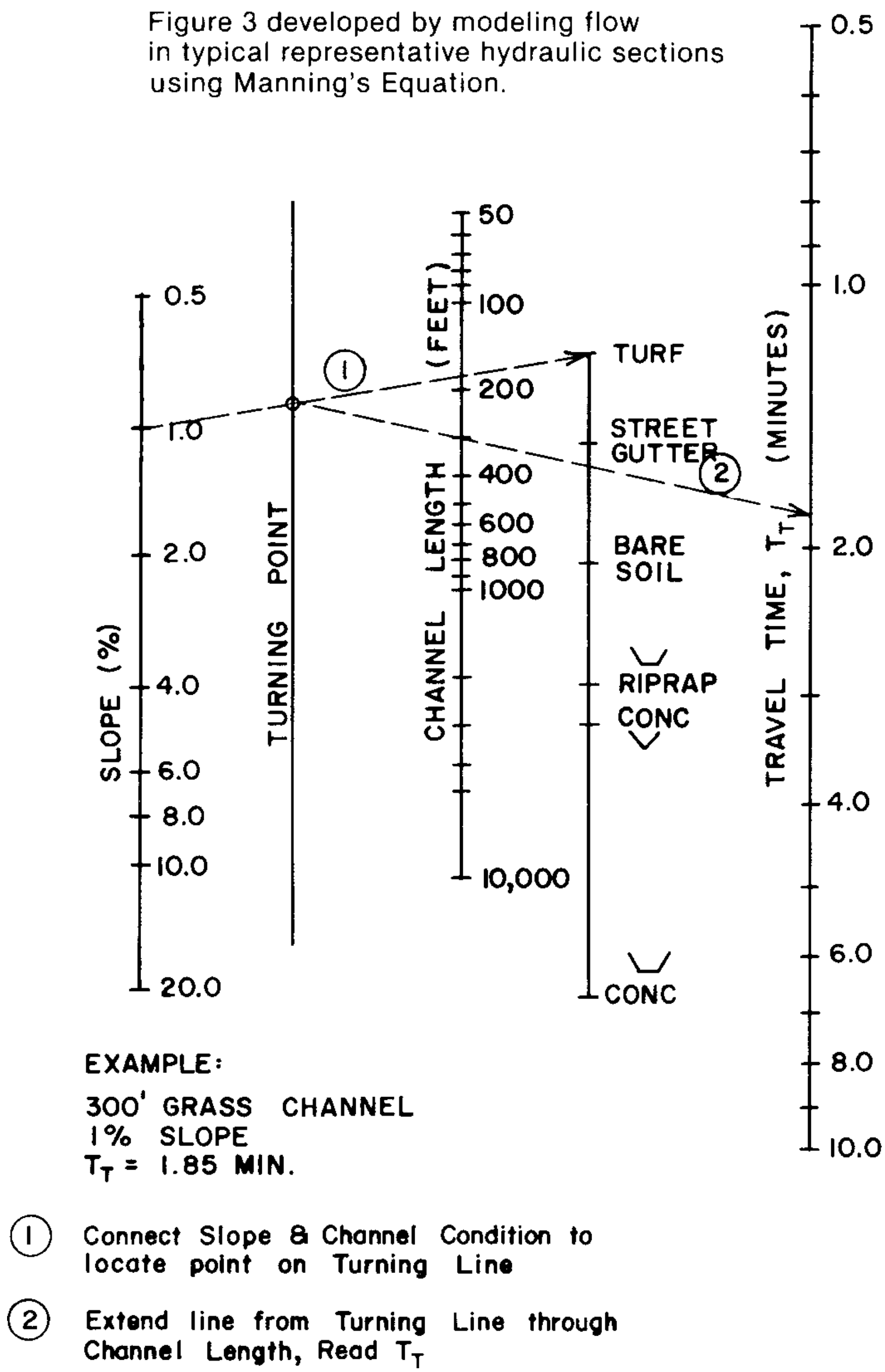


Figure 5602-2: Channel Flow Time Nomograph

B. Travel Time: T_T shall be calculated as the length of travel in the channelized system divided by the velocity of flow. Velocity shall be calculated by Manning's equation assuming all system elements are flowing full without surcharge. Travel time may be determined graphically from Figure 5602-2 in lieu of calculation.

To provide for future development when the upstream channel is unimproved, the Table 5602-4 shall be used for calculating T_T.

Table 5602-4: Travel Time Estimates for Future Development

Average Channel Slope (%)	Velocity (ft/sec)
< 2	7
2 to 5	10
> 5	15

C. Lag Time: Lag Time (T_L) is the calculated time between the maximum rainfall intensity of a storm and the point of maximum discharge on the outlet hydrograph. Lag Time is used instead of time of concentration for unit hydrograph models. It shall be calculated as 3/5th the time of concentration (Tc) given by Paragraph 5602.7 (A and B).

5602.8 Hydrograph Routing

Routing of hydrographs through storage elements or reservoirs shall be by modified-Puls level pool routing. Routing through channels shall be by the Muskingum-Cunge method. If the detention effect of significant storage in channels behind roadway embankments or culverts is to be modeled, the area impacted by the storage shall be modeled as a reservoir, and the remainder of the channel modeled using Muskingum-Cunge. Such incidental detention shall not be used for design discharge estimates unless allowed by the City/County and it can be reliably demonstrated that such storage will be maintained over the useful life of the proposed improvements.

5602.9 Calibration and Model Verification

All design discharge estimates should be calibrated to the extent possible using reliable gauge data, high water marks, or historical accounts. Model results should be evaluated to verify that they are reasonable as compared to observed data and standard practice. Engineers shall recognize the significant uncertainty associated with design discharge estimates and provide estimates that are protective of the public interest. To permit model verification, discharge rates (expressed as absolute discharge or discharge per acre of tributary area) relative to tributary area may be compared to regression equation results, gauge estimates, and/or known historical extremes.

SECTION 5603 HYDRAULICS

5603.1 Hydraulic Calculations for Pipes, Culverts, and Open Channels

A. Gravity versus Pressure Flow for Enclosed Systems: Two design philosophies exist for sizing storm drains under the steady uniform flow assumption. The first is referred to as open channel, or gravity flow design, in which the water surface within the conduit remains open to atmospheric pressure. Pressure flow design, on the other hand, requires that the flow in the conduit be at a pressure greater than atmospheric. For a given flow rate, design based on open channel flow requires larger conduit sizes than those sized based on pressure flow. Paragraph 5601.5 specifies hydraulic grade requirements associated with both gravity and pressure flow conditions. As hydraulic calculations are performed, frequent verification of the existence of the desired flow condition should be made.

Storm drainage systems can often alternate between pressure and open channel flow conditions from one section to another.

B. Gravity flow conditions, use Manning's formula shall be used as described below.

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

Where:

Q = Discharge, cubic feet per second
A = Cross sectional area of flow, square feet
n = Manning's roughness coefficient (see Table 5603-1)
R = Hydraulic radius, feet

$$R = \frac{A}{P}$$

S = Slope in feet per foot
P = Wetted perimeter in feet

C. Closed conduits flowing under pressure flow, the energy grade line (EGL) will be above the crown of the pipe. In this case, the Bernoulli equation shall be used to calculate pipe capacity:

$$\frac{p_1}{\gamma} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\gamma} + \frac{V_2^2}{2g} + z_2 + h_f + h_m$$

Where:

$\frac{p_1}{\gamma}$ = pressure head in the upstream system segment, feet

$\frac{V_1^2}{2g}$ = velocity head in the upstream system segment, feet

z_1 = elevation of the system invert in the upstream system segment, feet

$\frac{p_2}{\gamma}$ = pressure head in the downstream system segment, feet

$\frac{V_2^2}{2g}$ = velocity head in the downstream system segment, feet

z_2 = elevation of the system invert in the upstream system segment, feet

h_f = friction loss in the downstream system segment in feet

h_m = minor system losses in the downstream segment in feet

Pipe friction losses, h_f, may be calculated using the friction slope method, using the following derivation of Manning's equation from (FHWA, 1996).

$$h_f = S_f \cdot L$$

$$S_f = \frac{(Q \cdot n)^2}{\left(1.486 \cdot A \cdot R^{\frac{2}{3}}\right)^2}$$

Where:

S_f = friction slope, feet/foot (which is also the slope of the HGL)

Minor losses, h_m, shall be calculated by:

$$h_m = k \cdot \frac{v^2}{2g}$$

Where:

k = Coefficient as shown in Table 5603-2

A step-by-step procedure for manual calculation of the EGL using the energy loss method is presented in Hydraulic Engineering Circular No. 22 (HEC-22) Urban Drainage Manual (FHWA, 2013). For most drainage systems, computer evaluation utilizing continuous dynamic hydraulic modeling software are the most efficient means of evaluating the EGL and designing the system elements.

Table 5603-1: Manning's Roughness Coefficient Type of Channel	n
Closed Conduits	
Reinforced Concrete Pipe (RCPs)	0.013
Reinforced Concrete Elliptical Pipe	0.013
Corrugated Metal Pipe (CMPs):	
2⅔ x ½in. Annular or Helical Corrugations unpaved - plain	0.024
2⅔ x ½in. Annular or Helical Corrugations paved invert	0.021
3x1 in. Annular or Helical Corrugations unpaved - plain	0.027
3x1 in. Annular or Helical Corrugations paved invert	0.023
6x2 in. Corrugations unpaved - plain	0.033
6x2 in. Corrugations paved invert	0.028
24" diameter and smaller with Helical Corrugations.*	0.02
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Open Channels (Lined)	
Gabions	0.025
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of	
Dressed Stone	0.017
Random Stone	0.02
Cement Rubble masonry	0.025
Dry Rubble or Riprap	0.03
Gravel bottom, side of	
Random Stone	0.023
Riprap	0.033
Grass (Sod)	0.03
Riprap	0.035
Grouted Riprap	0.03
Open Channels (Unlined) Excavated or Dredged	
Earth, straight and uniform	0.027
Earth, winding and sluggish	0.035
Channels, not maintained, weeds & brush uncut	0.09
Stream	
Clean stream, straight	0.03
Stream with pools, sluggish reaches, heavy underbrush	0.1
Flood Plains	
Grass, no brush	0.03
With some brush	0.09
Street Curbing	
*Allowed only when the pipe length between structures is at least 20 pipe diameters	0.014

Table 5603-2: Head Loss Coefficients

Condition	k
Manhole, junction boxes and inlets with shaped inverts:	
Thru flow	0.15
Junction	0.4
Contraction transition	0.1
Expansion transition	0.2
90 degree bend	0.4
45 degree and less bends	0.3
Culvert Inlets:	
Pipe, Concrete	
Projecting from fill, socket end (grove end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove end)	0.2
Square edge	0.5
Round (radius=1/12D)	0.2
Mitered to conform to fill slope	0.7
Standard end section	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side or slope-tapered inlet	0.2
Pipe, or Pipe-Arch, Corrugated Metal	
Projecting from fill (no headwall)	0.9
Headwall or headwall and wingwalls square edge	0.5
Mitered to conform to fill slope, paved or unpaved slope	0.7
Standard end section	0.5
Beveled edges, 33.7º or 45º bevels	0.2
Side or slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dim. or beveled edges on 3 sides	0.2
Wingwalls at 30º to 75º to barrel	
Square edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension or beveled top edge	0.2
Wingwalls at 10º to 25º to barrel - square edged at crown	0.5
Wingwalls parallel (extension of sides) - square edged at crown	0.7
Side or slope-tapered inlet	0.2

Note: When 50 percent or more of the discharge enters the structure from the surface, “k” shall be 1.0.

D. Culverts: Classified as having either entrance or outlet control. Either the inlet opening (entrance control), or friction loss within the culvert or backwater from the downstream system (outlet control) will control the discharge capacity.

1. **Entrance Control**: Entrance control occurs when the culvert is hydraulically short (when the culvert is not flowing full) and steep. Flow at the entrance would be critical as the water falls over the brink. If the tailwater covers the culvert completely (i.e., a submerged exit), the culvert will be full at that point, even though the inlet control forces the culvert to be only partially full at the inlet. The transition from partially full to full occurs in a hydraulic jump, the location of which depends on the flow resistance and water levels. If the flow resistance is very high, or if the headwater and tailwater levels are high enough, the jump will occur close to or at the entrance. Design variables for culverts operating under entrance control may be determined from Figure 5603-1 through Figure 5603-7.

2. **Outlet Control**: If the flow in a culvert is full for its entire length, then the flow is said to be under outlet control. The discharge will be a function of the differences in tailwater and headwater levels, as well as the flow resistance along the barrel length. Design variables for culverts operating under outlet control may be determined from Figure 5603-8 through Figure 5603-14.

   Alternatively, refer to the Federal Highway Administration website for these charts (www.fhwa.dot.gov/bridge/hec05.pdf). Download applicable design manuals, reports, and FHWA hydraulics engineering such as Bridge Waterways Analysis Model (WSPRO), FHWA Culvert Analysis, and HDS 5 Hydraulic Design of Highway Culverts from www.fhwa.dot.gov/bridge/hydsoft.htm. These are applicable when flow in the upstream channel is subcritical.

E. Open Channels/Bridges: Proper evaluation of the velocity, depth, and width of flow requires analyses of the structures and conditions that impact the flow. Boundary flow conditions upstream and downstream from the open channel system must be established. The standard-step backwater method, using the energy equation, can be used to determine the depth, velocity, and width of flow. Major stream obstructions, changes in slope, changes in cross-section, and other flow controls can cause significant energy loss. In these cases, the energy equation does not apply and the momentum equation must be used to determine the depth, velocity, and width of flow.

5603.2 Analysis of Systems by Computer Models

Hydraulic calculations may also be made using industry standard continuous simulation hydraulic modeling software that dynamically routes stormwater flows.

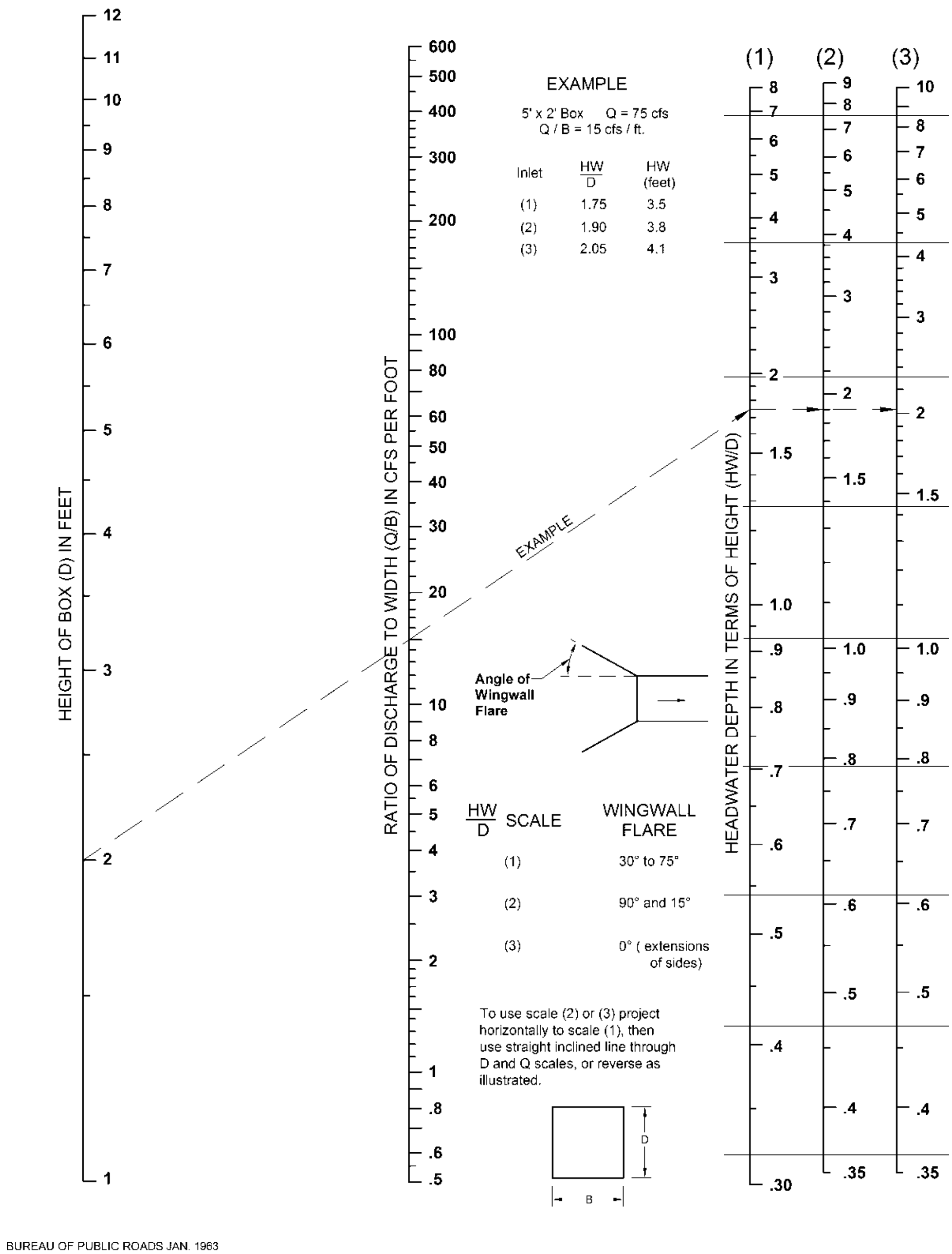


Figure 5603-1: Headwater Depth for Box Culverts with Inlet Control

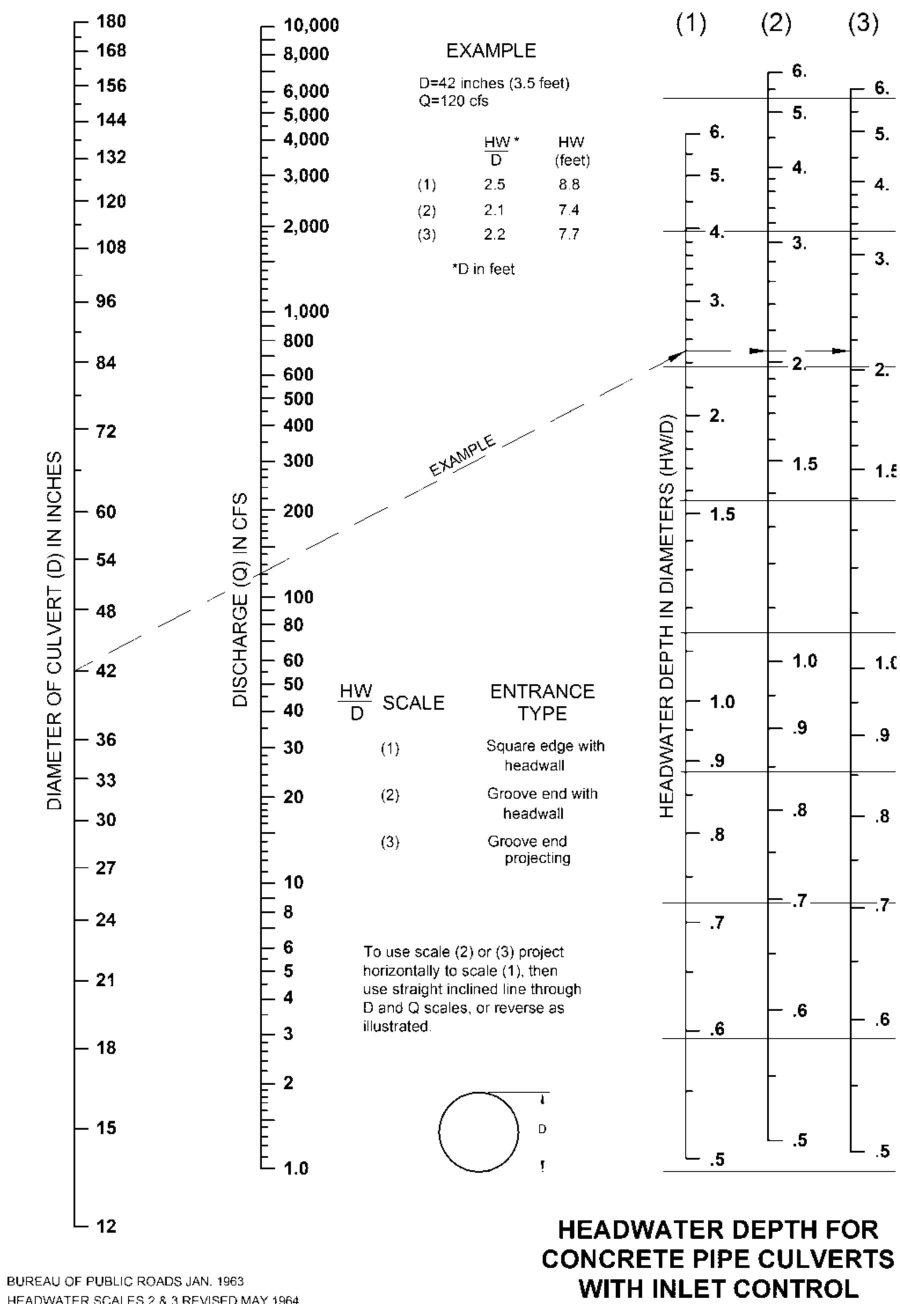


Figure 5603-2: Headwater Depth for Concrete Pipe Culverts with Inlet Control

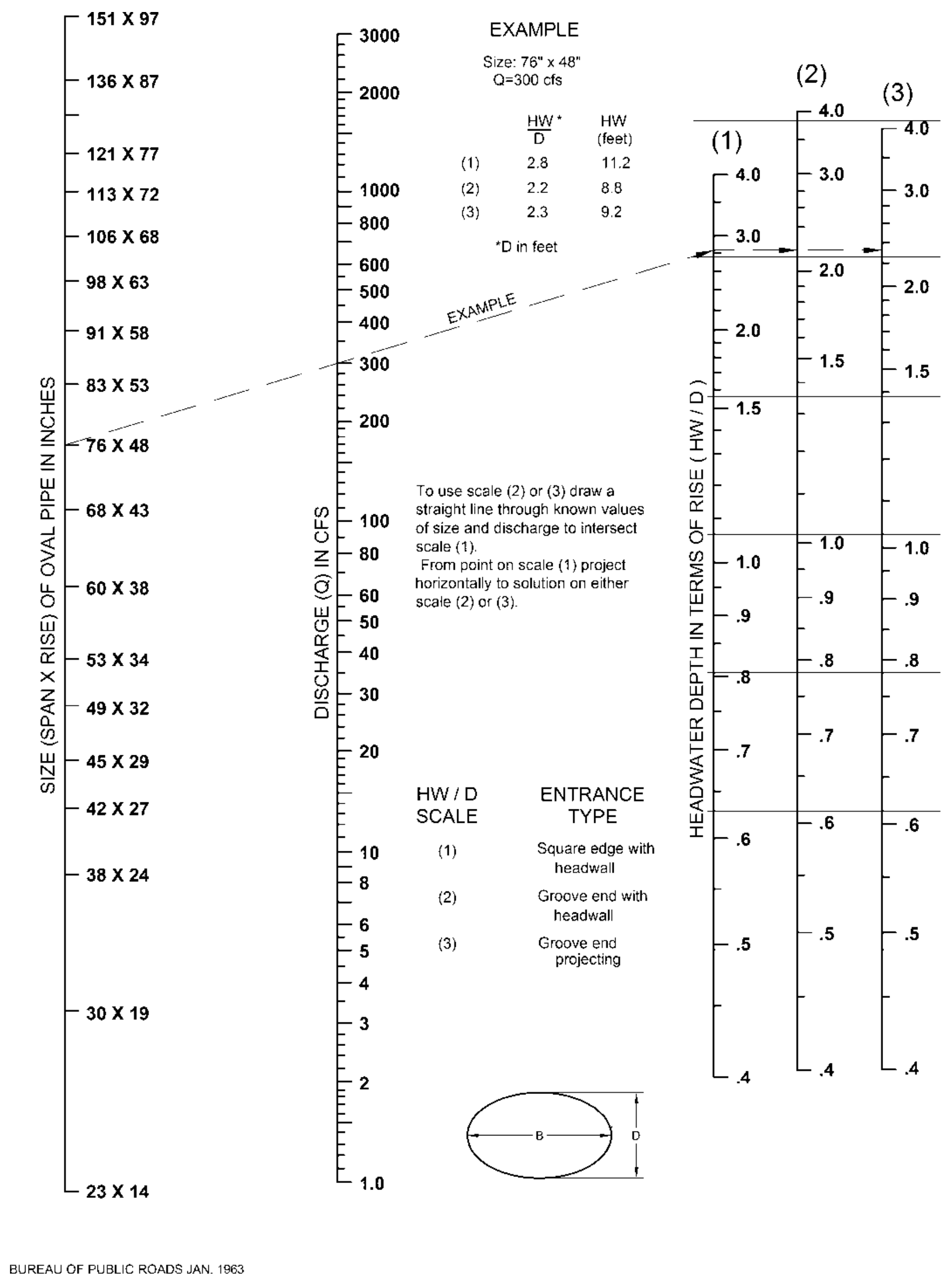


Figure 5603-3: Headwater Depth for Oval Concrete Pipe Culverts, Long Axis Horizontal with Inlet Control

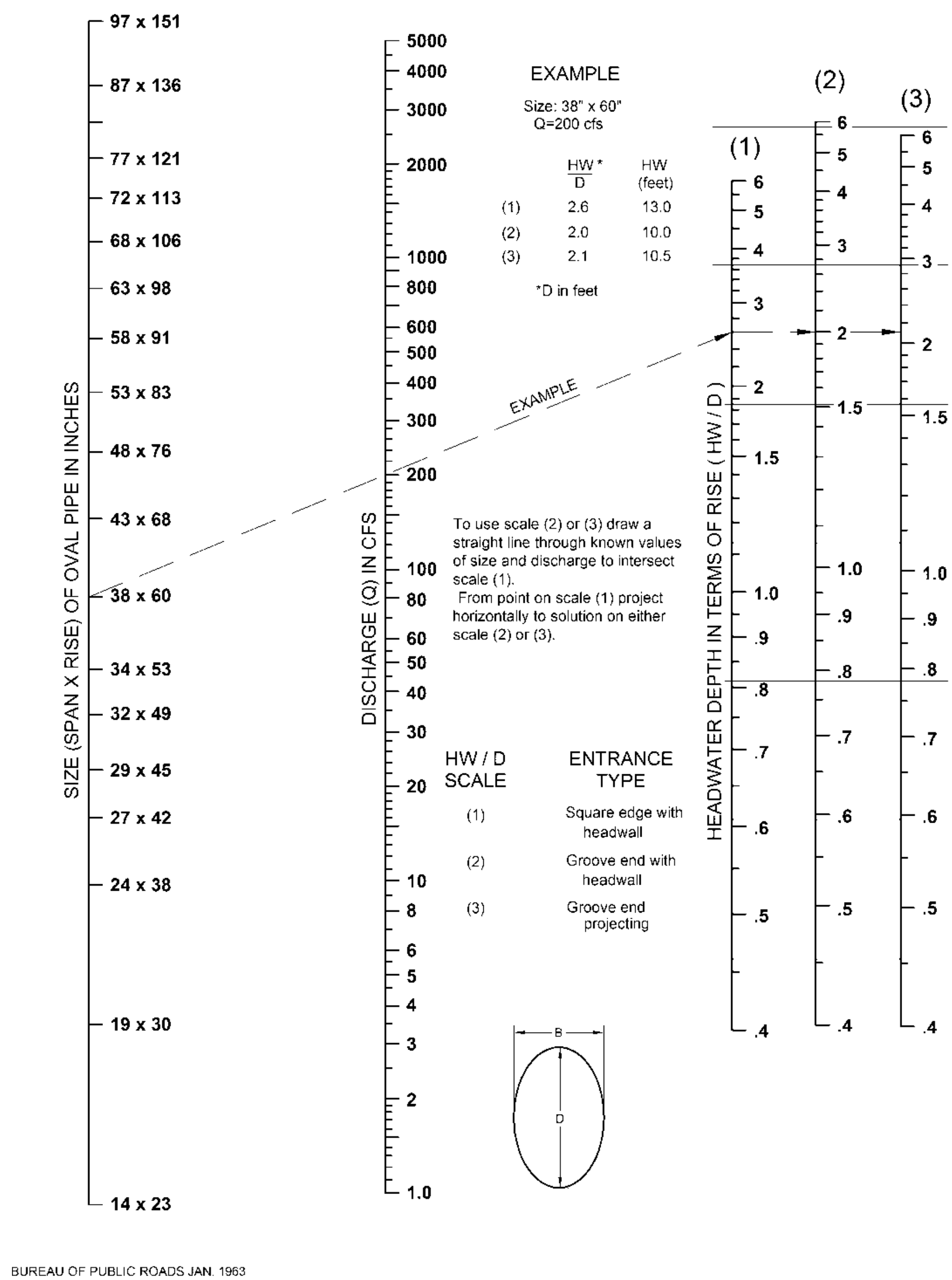


Figure 5603-4: Headwater Depth for Oval Concrete Pipe Culverts, Long Axis Vertical with Inlet Control

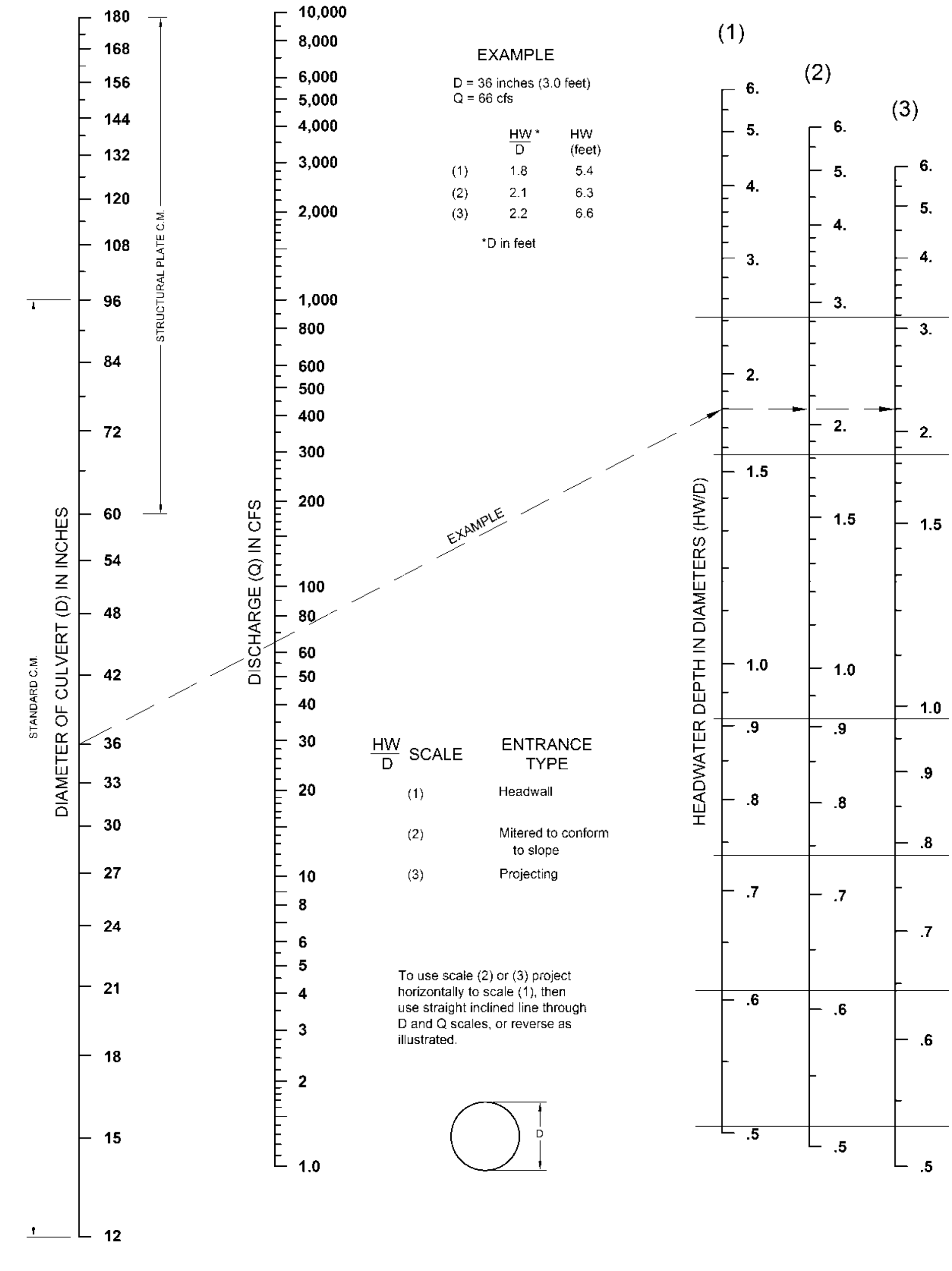


Figure 5603-5: Headwater Depth for Corrugated Metal Pipe Culverts with Inlet Control

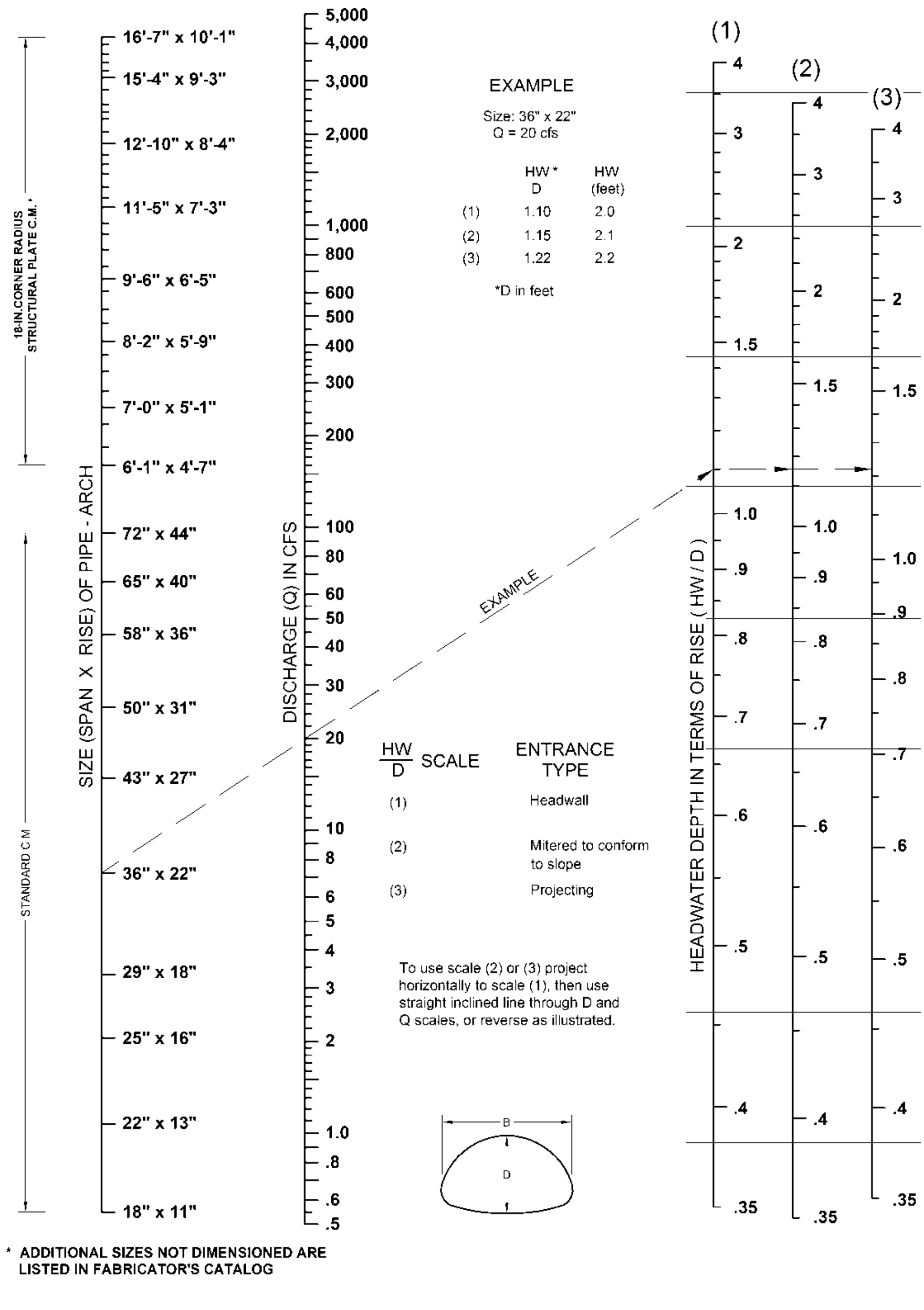


Figure 5603-6: Headwater Depth for Corrugate Metal Pipe – Arch Culvert with Inlet Control

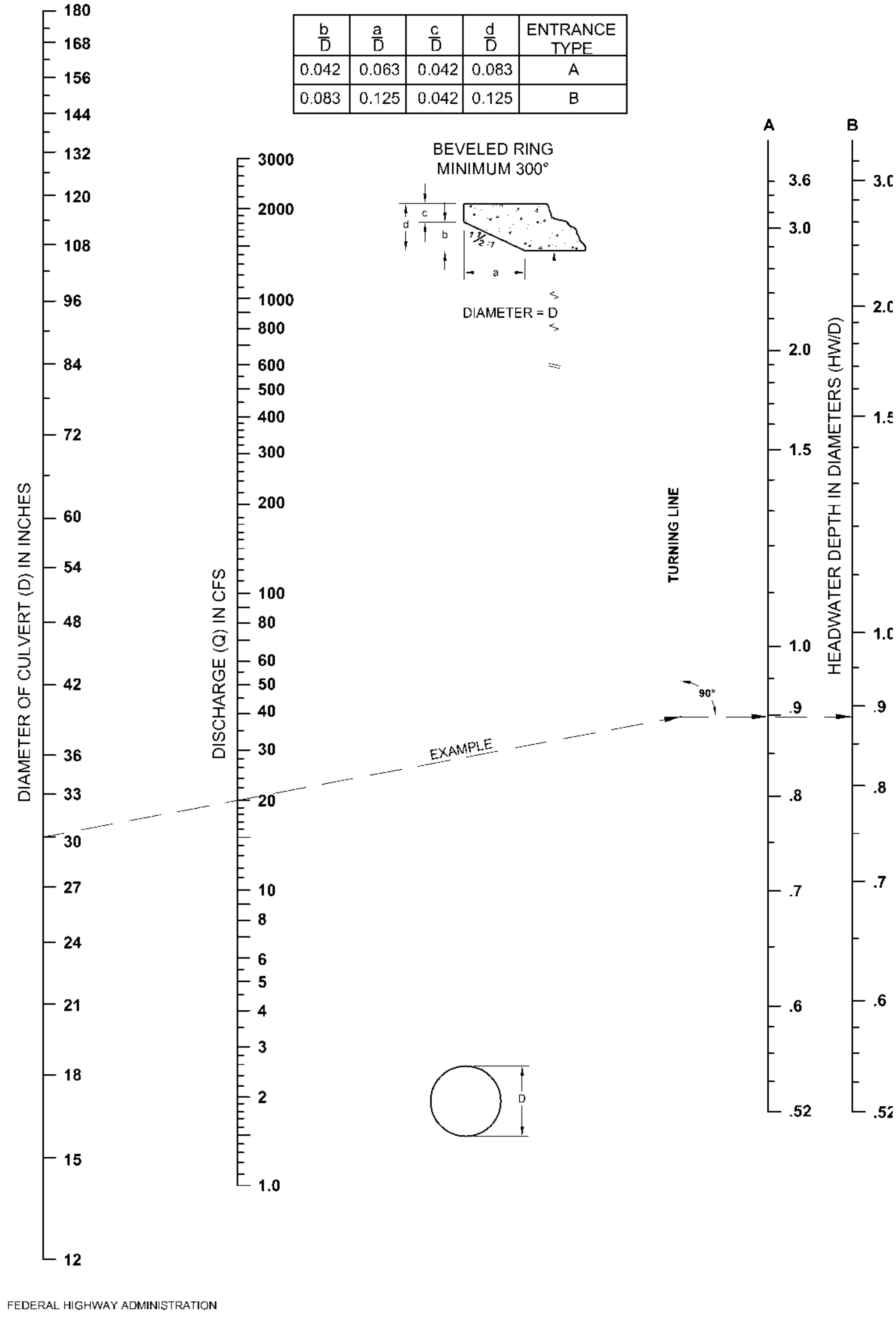


Figure 5603-7: Headwater Depth for Circular Pipe Culverts with Beveled Ring Inlet Control

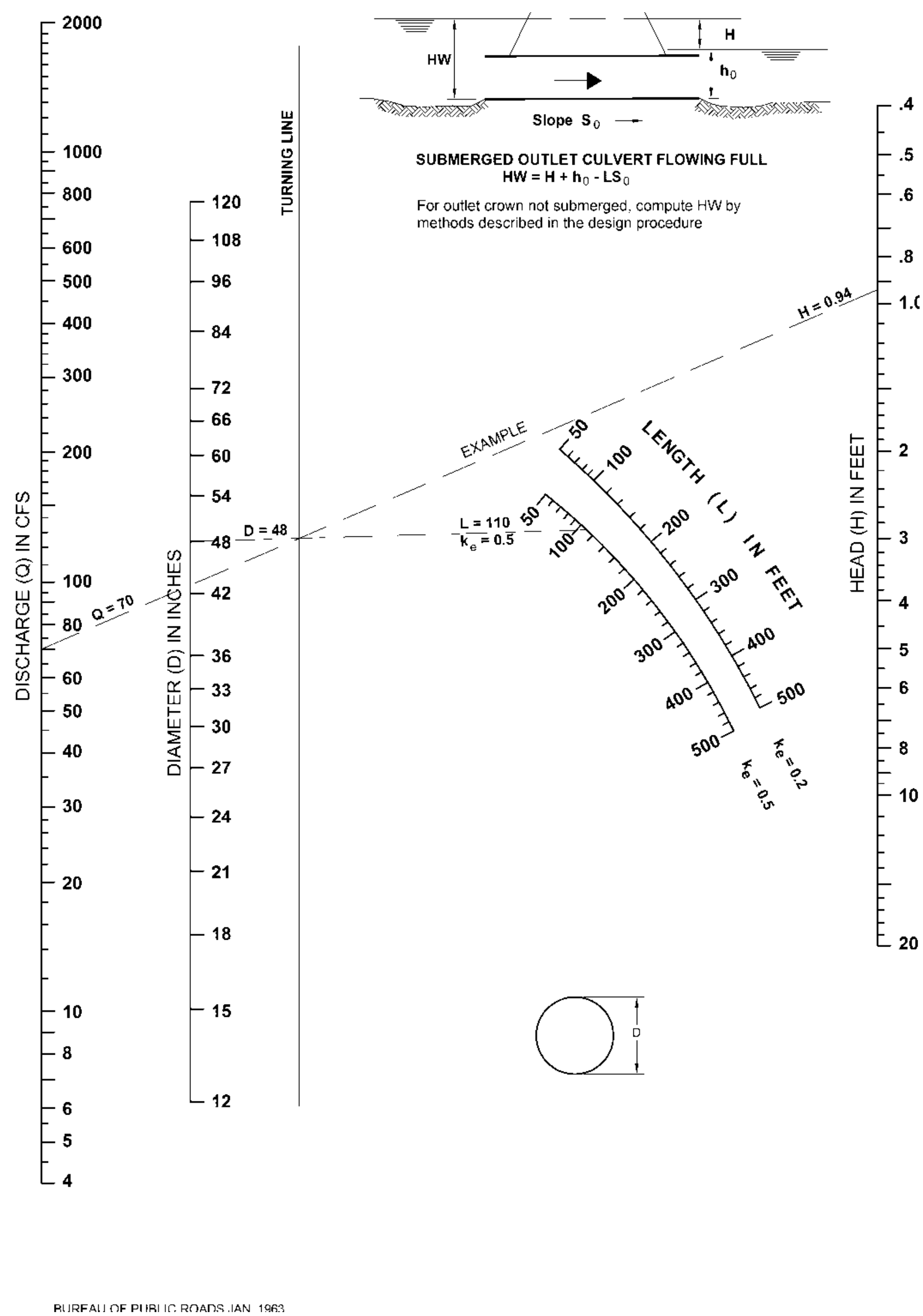


Figure 5603-8: Head for Concrete Pipe Culverts Flowing Full (n=0.12)

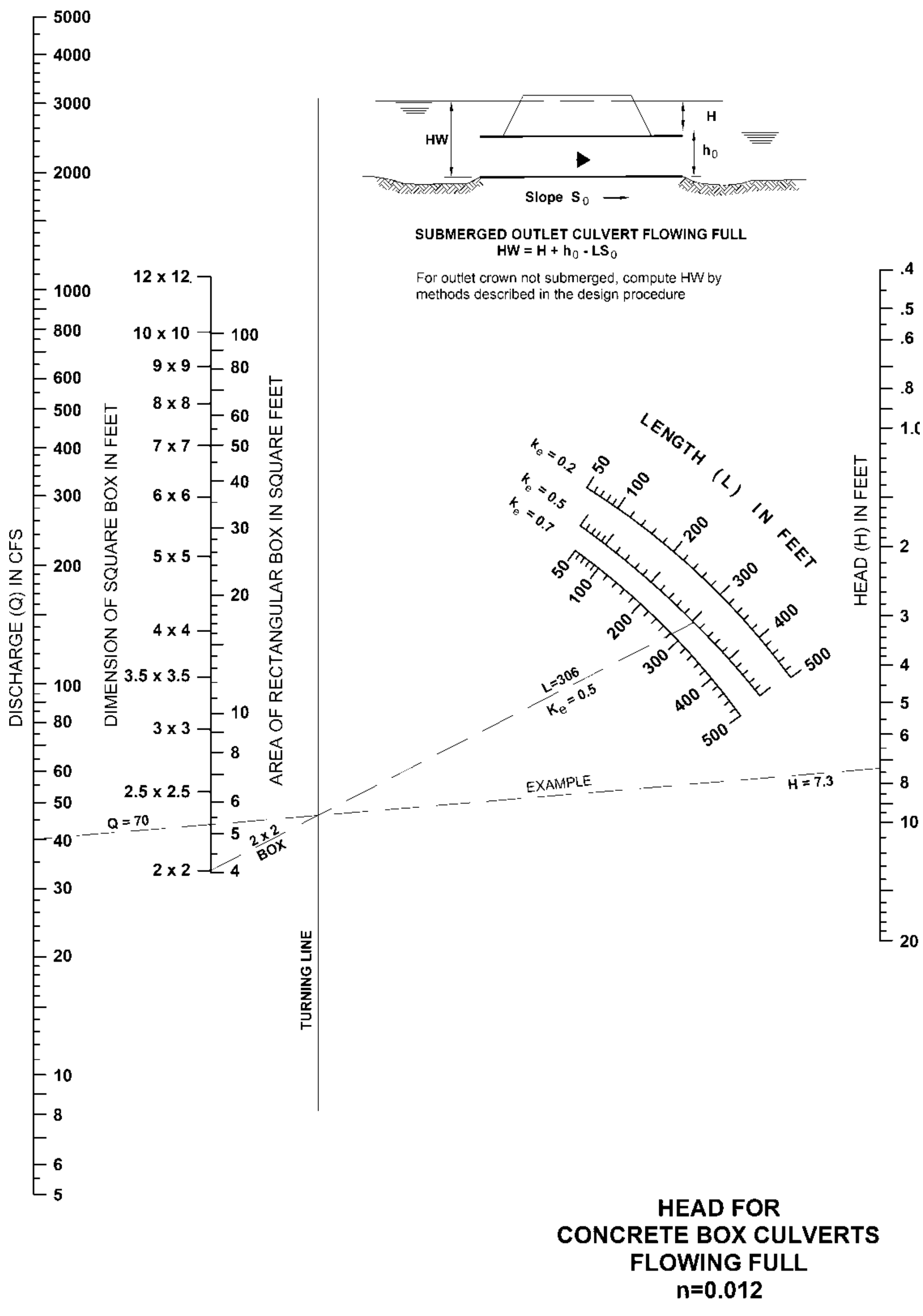


Figure 5603-9: Head for Concrete Box Culverts Flowing Full (n=0.012)

FIGURE 5603-10

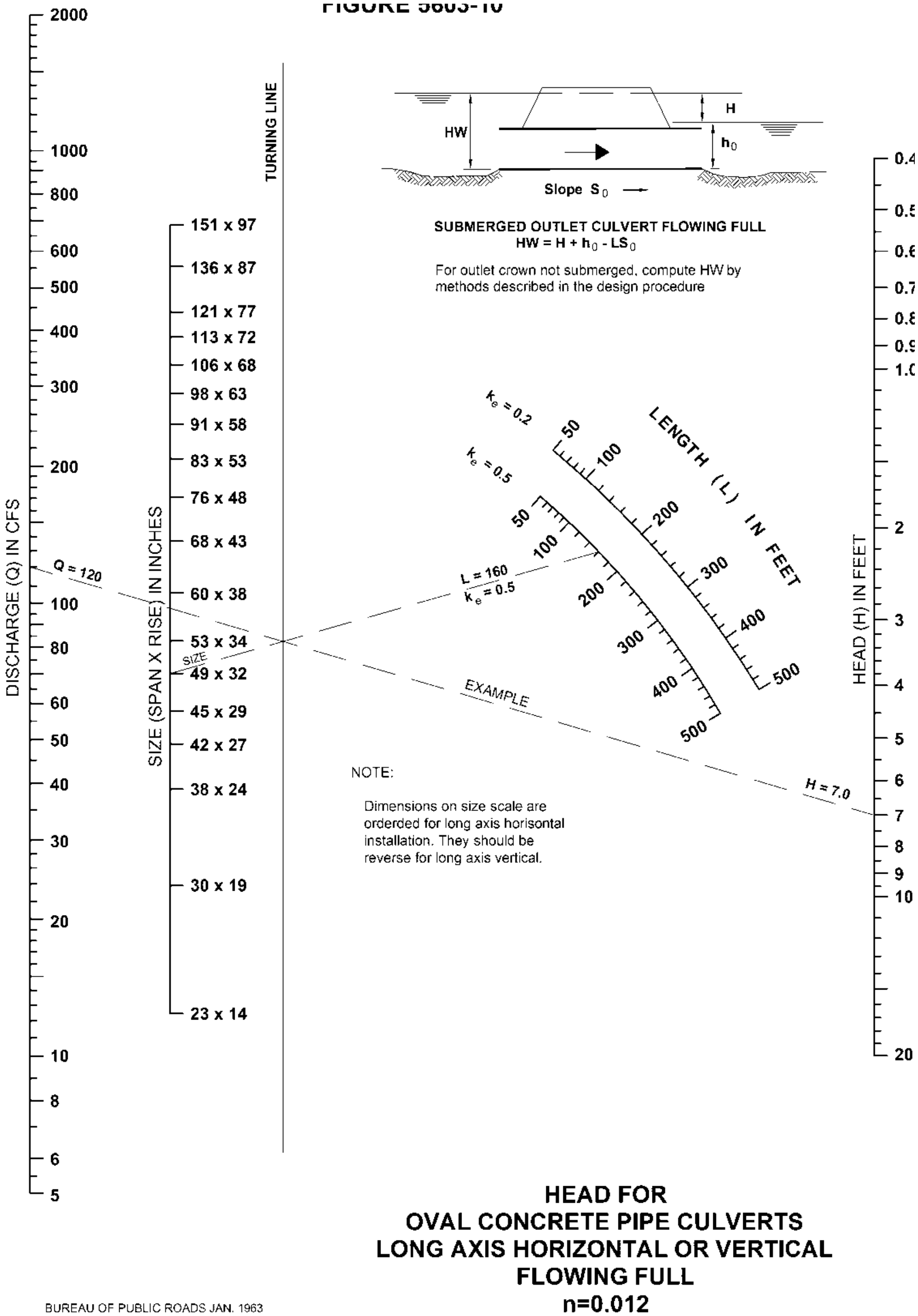


Figure 5603-10: Head for Oval Concrete Pipe Culverts, Long Axis Horizontal or Vertical Flowing Full (n=0.12)

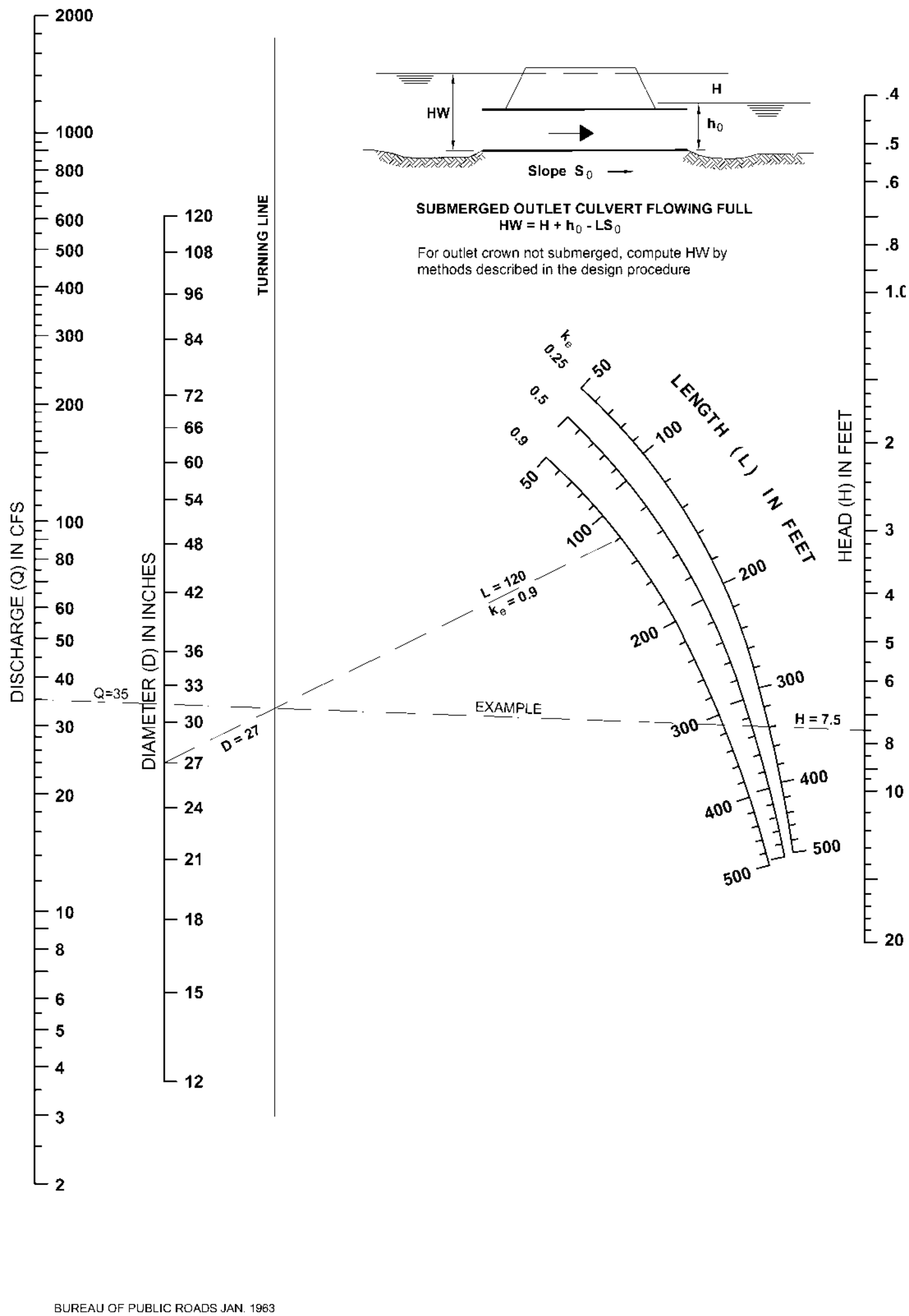


Figure 5603-11: Head for Standard Corrugate Metal Pipe Culverts Flowing Full (n=0.024)

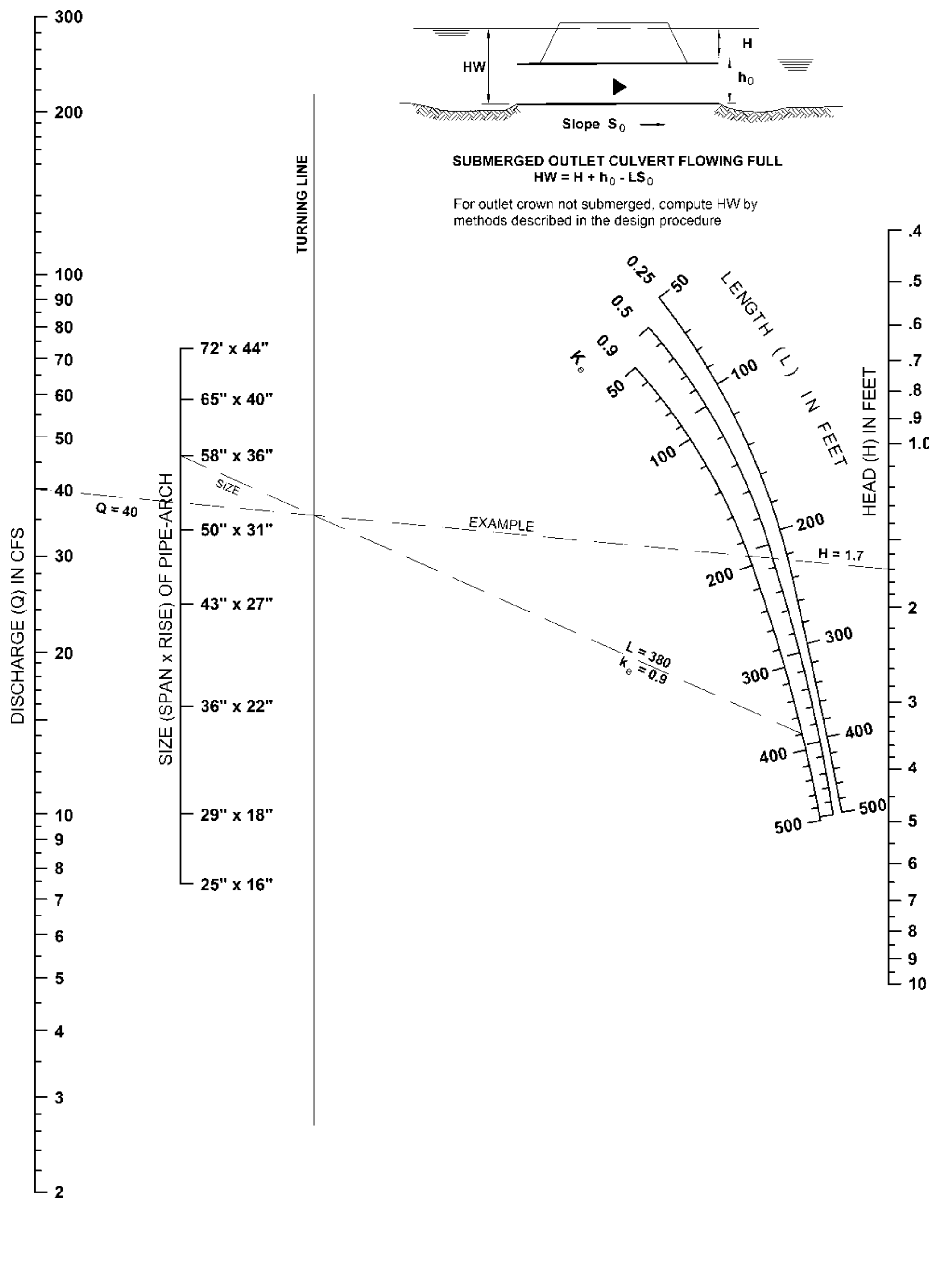


Figure 5603-12: Head for Standard Corrugated Metal Pipe-Arch Culverts Flowing Full (n=0.024)

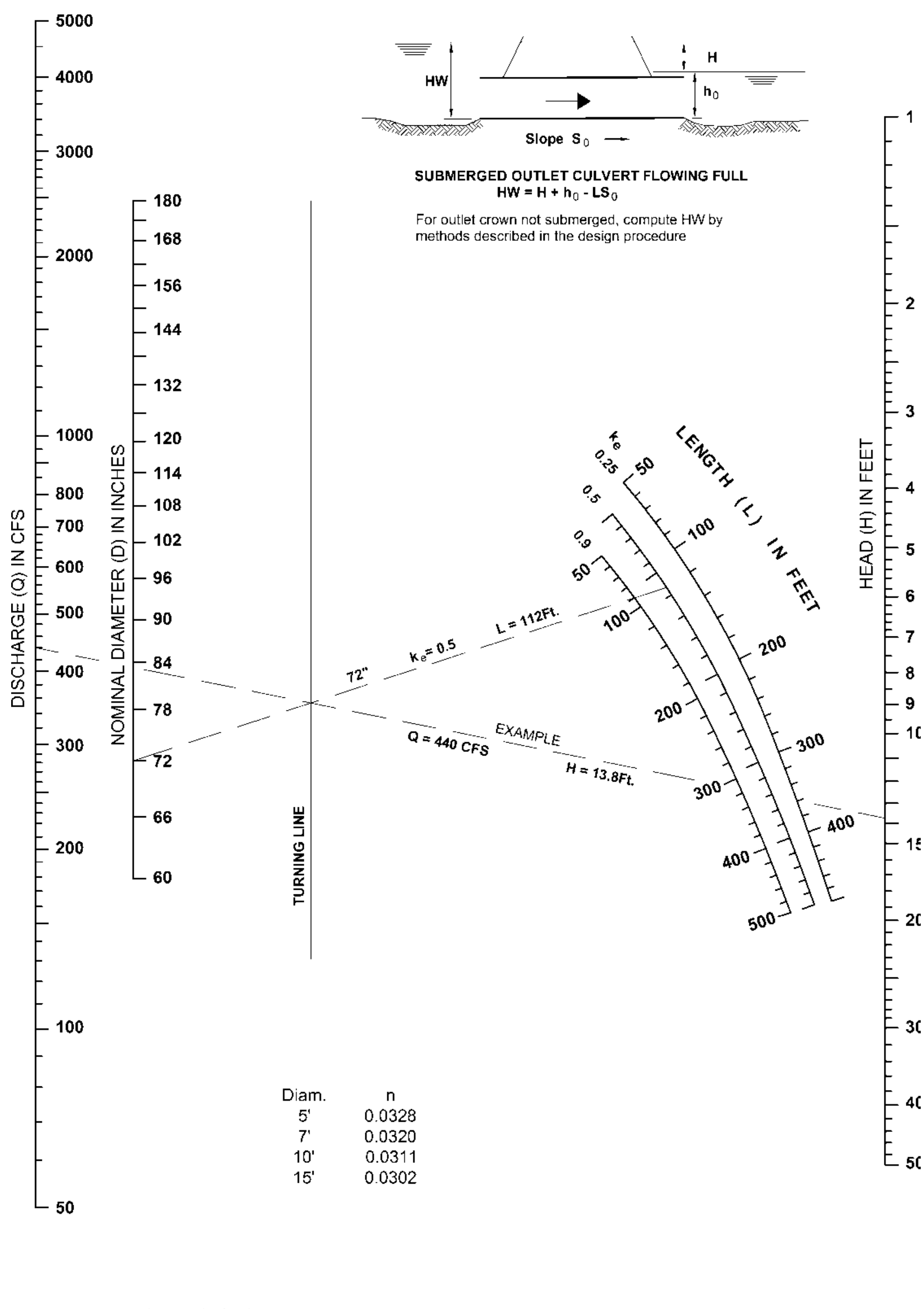


Figure 5603-13: Head for Structural Plate Corrugated Metal Pipe Culverts Flowing Full (n=0.0328 to 0.0302)

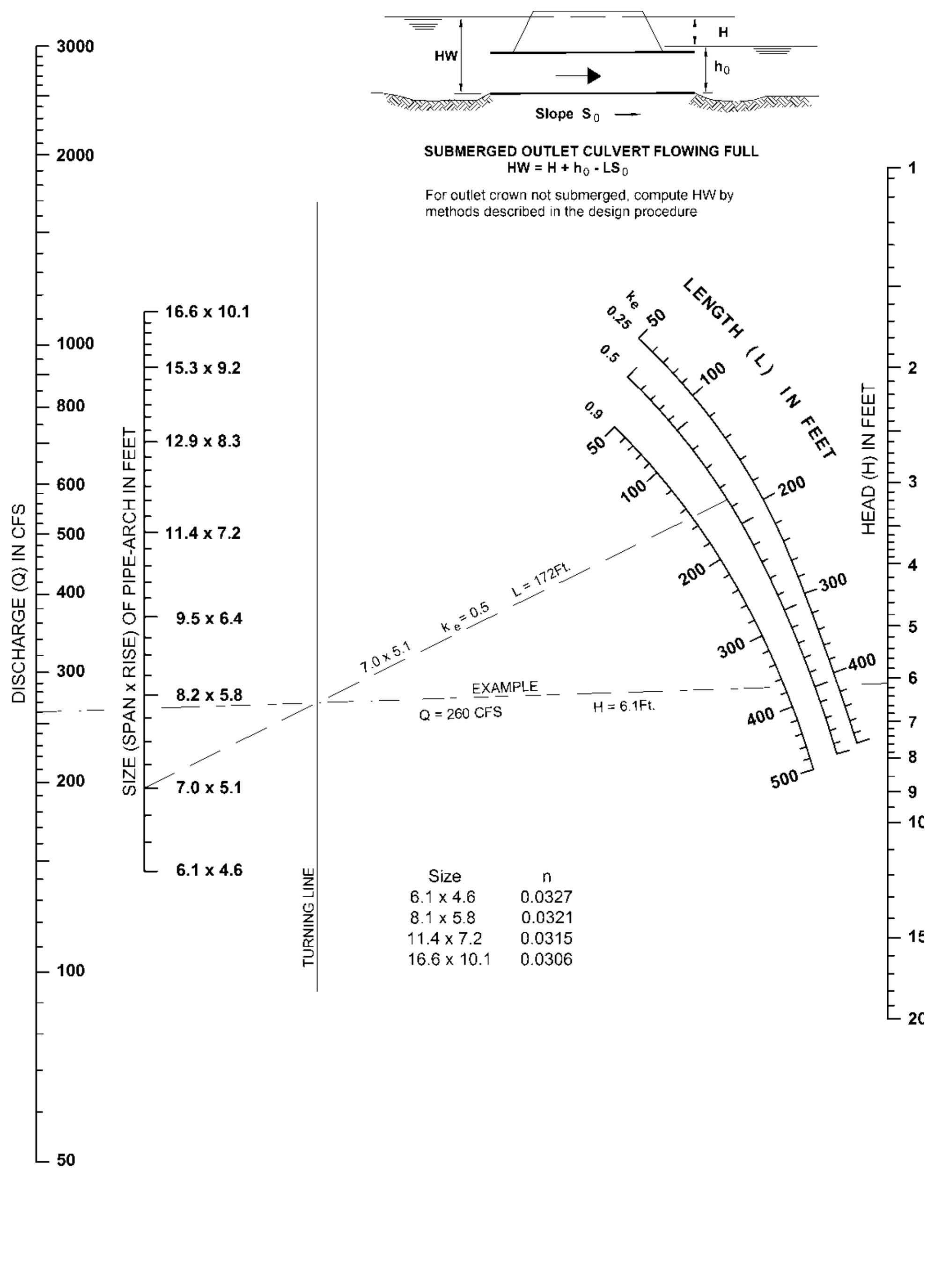


Figure 5603-14: Head for Structural Plate Corrugated Metal Pipe Arch Culverts, 18 inch Corner Radius, Flowing Full (n=0.0328 to 0.0302)

SECTION 5604 INLETS, MANHOLES AND JUNCTION BOXES

5604.1 Design Criteria

Stormwater inlet, manhole and junction box criteria is related to collection of stormwater from the surface and allowable hydraulic grade within the enclosed system. Collection design criteria focuses on inlet requirements in roadway applications within the public right-of-way and allowable spread of water in the street. Freeboard requirements focus on hydraulic grade elevations within the structures during the design storm.

A. Gutter Spread: Inlet placement in roadway sections shall limit the allowable gutter spread to maintain one lane width for emergency vehicle access during the 10-year design storm with the median (50%) temporal distribution, as defined in Section 5602. Water spread may exceed these limits within 50 feet of a sump location, however, protection of property shall be maintained per Paragraph 5601.5, A. by limited over-topping of curb and/or flooding beyond the right-of-way.

B. Freeboard: At all drainage structures and points of surface water entry into the enclosed drainage system, a minimum of 0.5-feet of freeboard shall be provided as measured from the lowest elevation of the inlet opening or structure rim elevation to the maximum water surface elevation in the inlet structure for the 10-year design storm with 10% temporal distribution, as defined in Paragraph 5601.5 and Section 5602.

5604.2 Inlet Design

Stormwater collection is the interception of stormwater runoff at specific locations. Stormwater collection is most often associated with stormwater inlets, which collect stormwater from roadways, parking lots, and other runoff generating surfaces and discharge the collected stormwater to the drainage system.

A. Inlet Placement: inlets should be placed at sump locations along the project corridor. On-grade inlets shall be placed at suitable intervals that are governed by the allowable gutter spread. Inlets should also be considered for the following geometric controls:

1. Immediately upstream of intersections, cross walks, and median breaks
2. Immediately upstream and downstream of bridges
3. Immediately upstream of superelevated sections of roadway

B. Gutter Spread: Gutter spread in roadway sections shall be calculated using the methods prescribed in Hydraulic Engineering Circular No. 22 (HEC-22) Urban Drainage Manual (FHWA, 2013) based on a composite curb and gutter section, as shown in Figure 5604-1 and parameters shown in Table 5604-1.

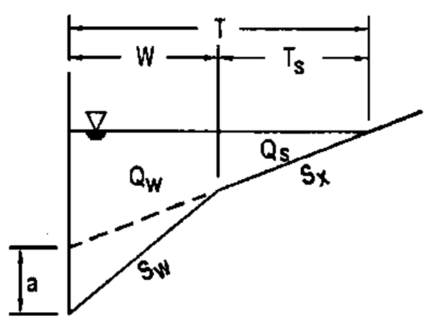


Figure 5604-1: Composite Curb and Gutter Section (Figure 4-1 of HEC-22, 2013)

C. Inlet Type: Curb opening inlets are preferred for use on public streets. Grate and combination inlets may be used as approved by the City/County Engineer.

D. Inlet Design: Inlets should be designed using the methods prescribed in Hydraulic Engineering Circular No. 22 (HEC-22) Urban Drainage Manual (FHWA, 2013), following the general procedures listed in this paragraph. HEC-22 parameters for APWA standard inlets are shown in Table 5604-1. Industry standard computer software models that follow HEC-22 may also be used for inlet design and gutter spread calculations.

Table 5604-1: Inlet Parameters for Curb Opening Inlets

Parameter	Curb Inlet Type 1 with C-1 Curb(6)	Curb Inlet Type 1	Curb Inlet Type 2	Curb Inlet Type 3
Inlet Location(1)	Designer Specified based on roadway geometry			
Units Conversion Factor, K_u (ft/ft)	0.6	0.6	0.6	0.6
Gutter Cross-Slope(2), S_w (ft/ft)	0.50	0.21	0.28	0.28
Curb Opening Height(2), H (in)	6	6	10	10
Width of Gutter(2)(3), *W* (ft)	1	2.3	3	3
Local Depression(4), a (in)	$12 * W * (S_w - S_X)$			
Street Cross-Slope, S_x (ft/ft)	Designer Specified based on roadway geometry			
Street Longitudinal Slope, S_L (ft/ft)	Designer Specified based on roadway geometry			
Curb Opening Length, L (ft)	Designer Specified based on required inlet length, intercept, and gutter spread relationship			
Manning's Coefficient(5), n	Designer Specified based on pavement type			

(1) Specify Inlet on Grade or Inlet in Sag based on location of inlet in roadway alignment (FHWA, 2013)
(2) APWA Division III Standard Drawings (Revised April 2019)
(3) As measured from edge of street to front face of inlet
(4) Local depression calculated per HEC-22 equation 4-6 (FHWA, 2013)
(5) Defined by pavement type per HEC-22 Table 4-3 (FHWA, 2013)
(6) Straight curb type C-1 directly abuts pavement without a gutter section. Unless designated in the table header as using type C-1 curb, all other parameters assume a standard CG-1 or CG-2 curb and gutter section.

E. Configuration: These minimum dimensions (shown in Table 5604-2 and illustrated by Figure 560**4-2**) apply to either the roll back or straight type curbs:

Table 5604-2: Minimum Inlet Configuration Dimensions

Description	Dimension
Opening length, inside	4.0 ft (min)
Width, perpendicular to curb line, inside	3.0 ft (min)
Setback curb line to face	1.0 ft (min)
Opening, clear height	6.0 in. (min)
Gutter transition length	
(a) Both sides in sump and upstream side on slopes	5.0 ft (min)
(b) Downstream on slopes	3.0 ft (min)

5604.3 Inverts and Pipes

The inverts of pipe(s) entering a drainage structure shall be at or above the invert of the pipe exiting from the structure and provide a minimum fall of the invert in the structure of 0.1 feet through the structure. The desirable fall across the invert is a minimum of 0.2 feet.

5604.4 Manholes and Junction Structures

The maximum spacing between manholes shall be 500 feet. A manhole or junction structure shall be located at any change in alignment of the pipe system and/or connection with other pipe systems.

5604.5 Loading Conditions for Structures

Loading shall be in accordance with Paragraph 5710.3.

5604.6 Street Grade on Vertical Curves

The following formula shall be used to determine the street grade (S_x) at any point on a vertical curve using plus for grades ascending forward and minus for grades descending forward, in feet per foot.

$$S_x = S_1 + \frac{x \cdot (S_2 - S_1)}{L}$$

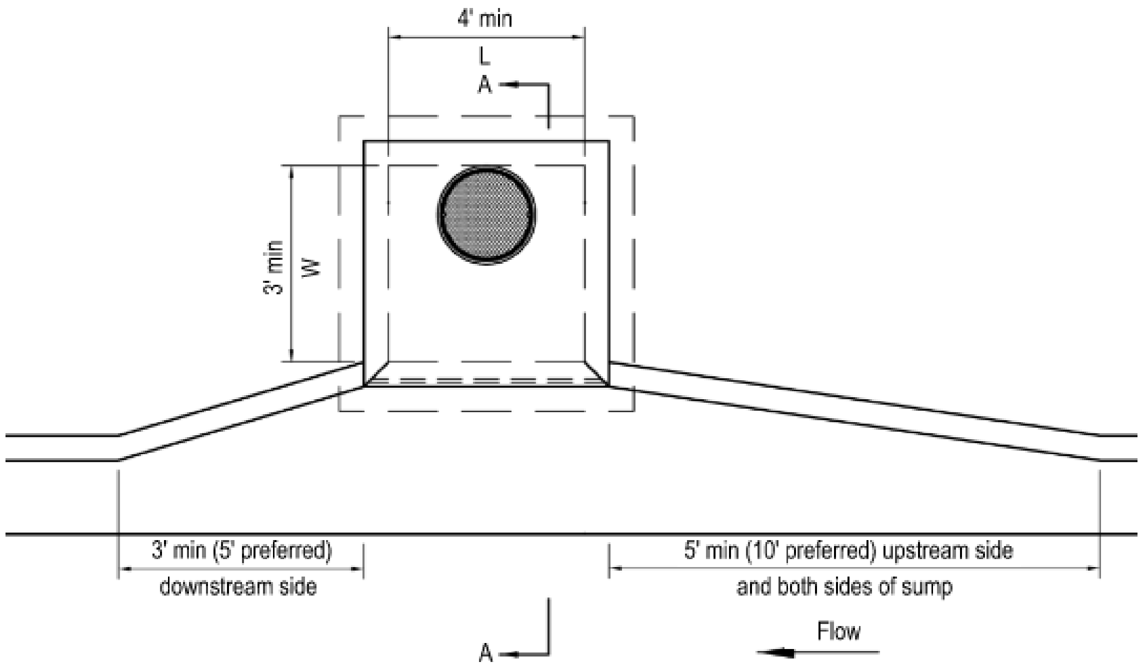
Where:

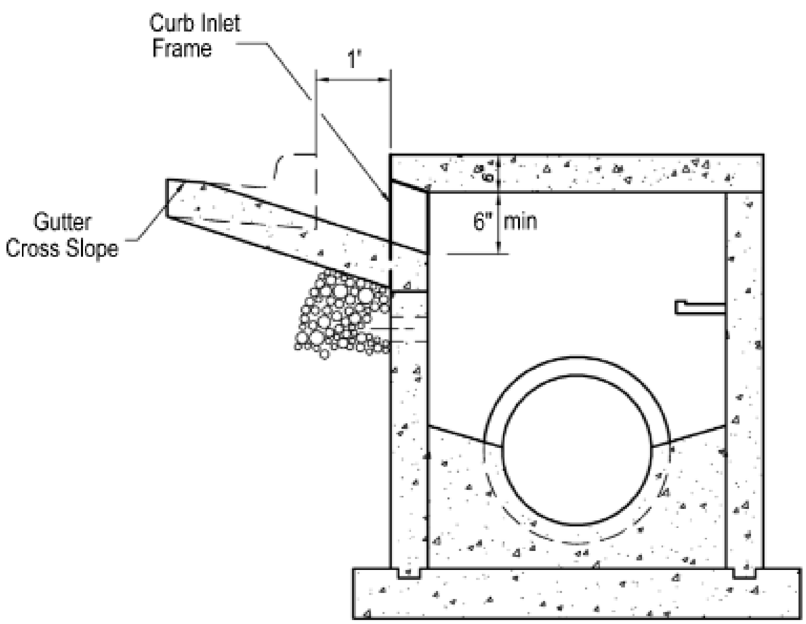
S_x = the street grade on a vertical curve at point x, in feet per foot

S_1 = the street grade at the PC of a vertical curve, in feet per foot

S_2 = the street grade at the PT of a vertical curve, in feet per foot

x = the distance measured from the PC to point x on a vertical curve, in feet
L = the total length of a vertical curve, in feet





SECTION A-A
Not to Scale

Figure 5604-2: Curb Inlet (10' Throat) Minimum Hydraulic Dimension

SECTION 5605 NATURAL DRAINAGE PATHS & STREAMS

5605.1 Design Criteria

This section sets forth requirements for the protection of natural drainage paths and streams as a conveyance for stormwater. Unless otherwise provided for by City, State, or Federal ordinance, regulation, or standards, existing streams shall be preserved and protected in accordance with this section. The City of Warsaw Code of Ordinances Chapter §405.070 Stormwater Management and Natural Area Protection Standards adopts requirements to preserve natural drainage paths through Stormwater Drainage Setbacks to protect the community's natural amenities. These policies are enforced during the planning phase of land development through requirement of a Stormwater Drainage Permit, as required by Chapter §405.020 and detailed in §405.030.

Natural drainage paths shall be preserved to reduce the risk for property damage by designating space for the overland conveyance of stormwater for rainfall events exceeding the capacity of the engineered system. Natural drainage paths delineated from 2016 LiDAR data for the City of Warsaw are shown in Appendix A, for reference. Stormwater drainage setback requirements are defined in Paragraph 5605.2. Each element of the stormwater drainage system (whether open, enclosed, retention, or detention) shall include an overflow element to a preserved natural drainage path. Overflow systems shall:

- **A.** Be designed to route downstream flows in excess of the engineered system design capacity.
- **B.** May include streets, natural drainage paths, engineered channels, redundant piping, spillways, parking lots, drives or combinations thereof.
- **C.** Limit the maximum water surface elevation generated by the 100-year design storm with the 10% temporal distribution to meet protection of property requirements.
- **D.** Conform to Paragraph 5605.2 Easements regarding easements and restricted uses for overflow systems within stormwater drainage setbacks.

5605.2 Easements

- **A. Natural Drainage Path Requirements:** Natural drainage paths and stream corridors shall be preserved and protected by limiting development activity in and adjacent to these areas to reduce risk of property damage from flooding and stream bank erosion, and to protect the safety of the public. Natural drainage paths delineated from 2016 LiDAR data for the City of Warsaw are shown in Appendix A, for reference**.**
    1. All final grading and drainage shall comply with applicable City/County and State requirements.
    2. To the maximum extent feasible, development shall preserve the natural drainage paths unique to each site as a result of topography and vegetation. Natural drainage paths may be modified on site only if outside of the stormwater drainage setback. If natural drainage paths are modified, appropriate stabilization techniques shall be employed.
    3. Streets, roads, private access roads and other vehicular routes shall, to the maximum extent feasible, not be within a natural drainage path.
    4. Grading shall be designed to ensure that drainage flows away from all structures and heavily used areas.
    5. Development shall be designed to mitigate all negative or adverse drainage impacts on adjacent and surrounding sites.

B. Stormwater Drainage Setbacks: Stormwater drainage setbacks shall be dedicated as a drainage easement to the City and apply to all land or development that includes natural drainage paths. The requirements for stormwater drainage setbacks are as follows:

1. The stormwater drainage setback shall start at the top of bank of the natural drainage path or stream, to be determined by topographic survey, and move outward on either side of the channel. If a top of bank cannot be determined, one of the following methods may be applied to define the top of bank for the stormwater drainage setback:
   a. Apply the assumed channel width to the centerline of the natural drainage path.
   b. Delineate the bank-full or channel-forming flow caused by approximately the 2-year design storm with the median (50%) temporal distribution.
2. Stormwater drainage setbacks shall be identified on the site plan and dedicated on the preliminary and final plats as a Drainage Easement.
3. Stormwater drainage setback widths have been determined based on tributary drainage area, as shown in Table 5605-1 and Figure 5605-1, with the following defined setback widths:
   a. **Channel Width**: centered on the natural drainage path is preserved for frequent stormwater flows with no other allowable uses.
   b. **Preservation Setback Width**: begins at the top of bank of the natural drainage path/stream and is preserved for vegetation or other forms of bank stabilization with no other allowable uses.
   c. **Limited-Use Setback Width**: extends a predetermined distance from the preservation setback or to the extents of the 100-year effective FEMA floodplain, whichever is greater. Allowable uses within the limited-use setback include community amenities such as trails and greenways, as well as utility rights-of-way.

Table 5605-1: Stormwater Drainage Setbacks

Drainage Area (acre)	Assumed Channel Width (feet)*	Preservation Setback Width (feet)	Limited-Use Setback Width (feet)	Total Setback Width (feet)
2 to < 10	5	5	-	15
10 to < 40	10	10	10	50
40 to < 160	30	30	10	110
160 to < 640	60	60	20	220
640+	80	80	20	280

*Actual channel width may differ from Assumed Channel Width values presented in table based on results of topographic survey.

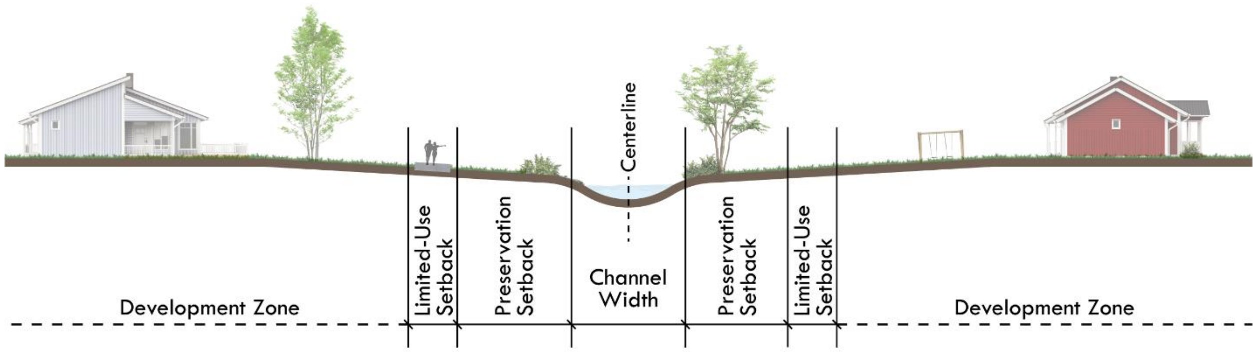


Figure 5605-1:Stormwater Drainage Setbacks

4. No construction or disturbance of any type, including clearing, grubbing, stripping, fill, excavation, linear grading, paving, or building is allowed in the setback widths except as falls within the allowable setback uses or by permission of the City/County Engineer. Dense stands of native vegetation shall be maintained, particularly in the preservation setback.
5. Unless otherwise accepted by the City/County, any maintenance of stormwater drainage setbacks shall be the responsibility of the property owner.
6. For work on existing facilities already located closer to the natural drainage path than allowed per these standards, the new construction shall not encroach closer to the drainage path. Bank stability concerns shall be addressed for improvements to existing land within the setback width.

5605.3 Natural Stream Benefits and Characteristics:

Natural streams provide numerous water quality, ecological, and quality of life benefits. Protection and preservation of natural streams is a national environmental objective, as set forth in the Clean Water Act. Streams and their associated wetlands provide critical habitat for plants and wildlife, water quality treatment, and improved infiltration of rainfall which lessens flood impacts, recharges groundwater, and preserves base flow. Streams provide recreational and open space in communities, improve aesthetics, provide natural landscapes, and enhance adjacent property values.

Stable streams in nature maintain a shape in plan, profile, and section that most efficiently transports the water and sediment supplied to them. The geometry and processes of streams involve unique terminology and concepts not common to engineered channels or pipe systems. Common features of stream geometry and characteristics are presented in Figure 5605-2and Figure 560**5-3**. Certain definitions are contained in Section 5601. More complete information regarding the character and function of streams is given in Interagency (2001).

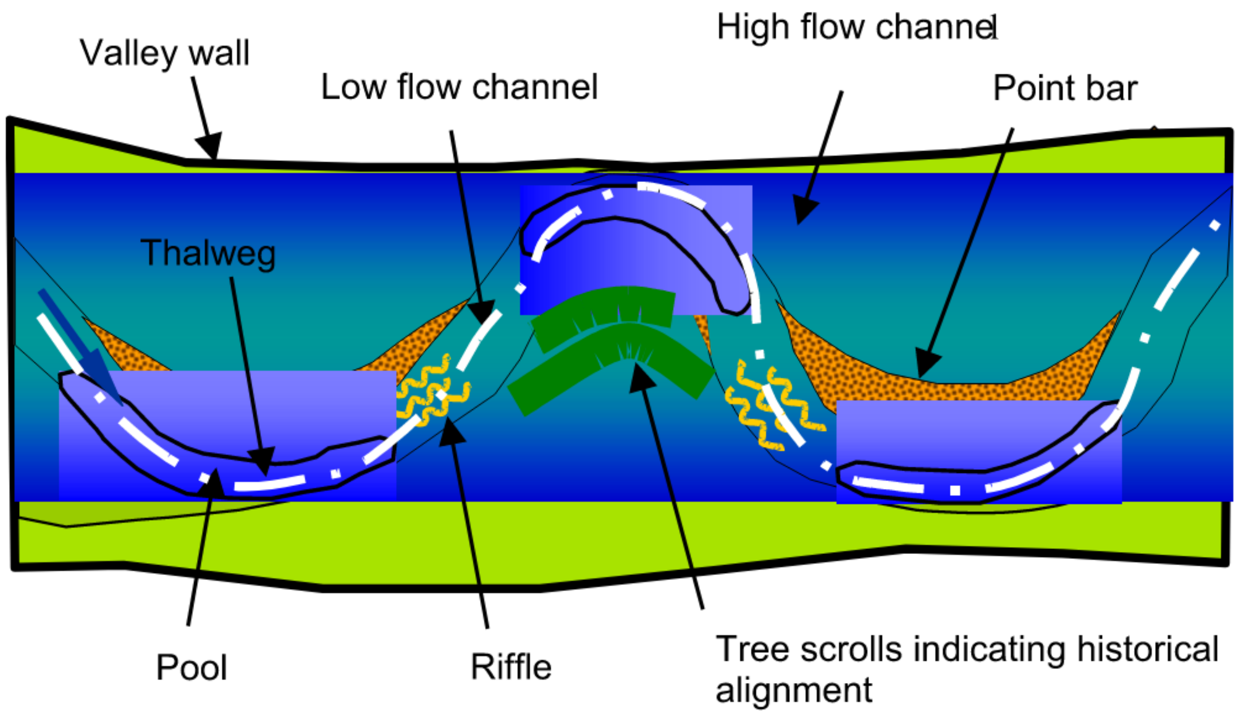


Figure 5605-2:Typical Stream Characteristics (1 of 2)

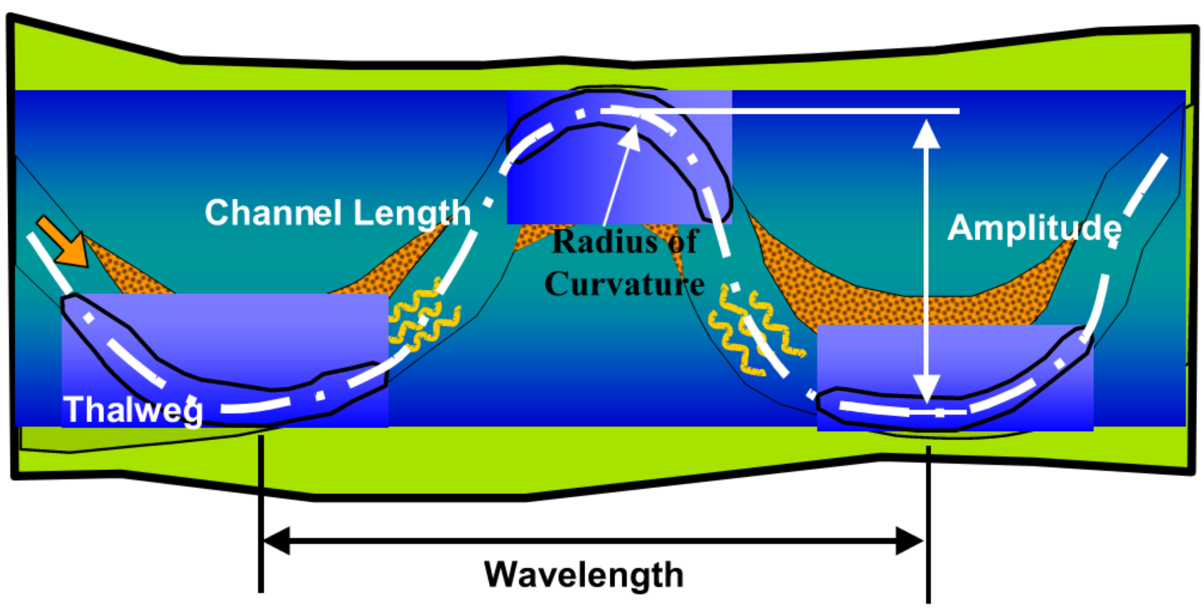


Figure 5605-3: Typical Stream Characteristics (2 of 2)

5605.4 In Stream Construction - General Requirements

Construction in natural drainage paths, streams or their setback widths shall conform to the general requirements of this subsection and to the appropriate specific requirements of the subsections following:

A. **Stream Assessment:** A stream assessment shall be conducted in accordance with Paragraph 5605.5 for all construction within the setback widths except for discharge outfalls, unless otherwise directed by the City/County Engineer.

B. Energy Management: The pre-project and post-project hydraulic and energy grade lines for the 2-year, 10-year, and 100-year design storm with 10% temporal distribution flows shall be plotted. The region of a stream where in-stream construction causes a change in these grade lines is considered the zone of influence. The extent of the zone of influence downstream shall be generally limited by energy dissipation and grade control. The upstream limit of the zone may extend a distance beyond the construction as a drawdown or backwater curve. Within the zone of influence, the energy of the flow on the channel will be evaluated for the potential of excessive scour, deposition, initiation of head cuts, or other instability. Use of vegetation to increase bank resistance and minimize increases or abrupt changes in velocities is recommended. Bank or bed stabilization may be required in areas of unavoidable velocity or depth increase.

C. Sediment Transport Continuity: The minimum post-project applied shear to the bed of the channel in the zone of influence at the 2-year, 10-year, and 25-year storm flow shall not be less than 90% of the minimum pre-project applied shear in the zone, so as to maintain the ability of the channel to transport sediment. If such shear stresses cannot be maintained, the engineer will evaluate the potential for future sediment removal or maintenance.

D. Transitions: In-stream structures shall be designed to gradually blend into the natural stream and provide a smooth transition of both geometry and roughness.

E. Repair of Disturbed Banks: The side slopes of banks where construction occurs shall be restored with vegetation in accordance with Paragraph 5605.13 as quickly as possible.

F. Professional Judgment: Streams are complex, variable, and strongly governed by local geology and climate. These standards are based on general guidelines of good practice on typical local streams and may not be optimal or sufficient in all cases. Specific requirements may be increased or waived by the City/County Engineer if conditions warrant and decisions should be guided by prudent engineering judgment.

5605.5 Stream Assessment

When conducted, a stream assessment will extend a minimum of one wavelength up and downstream of the area to be impacted by construction. It shall include the components listed below, except modified by the City/County Engineer to better fit project needs. An example submittal is shown in Figure 5605-4 and Figure 560**5-5**.

A. Plan Form Analyses and Inventory: The plan-view of the stream using aerial photographs or planning-level aerial survey shall be plotted to an appropriate scale. Field surveys of the entire reach study area are not required. The following items shall be shown:

- Ordinary high water mark.
- Top of bank.
- Ground contours (if available).
- Hydraulic grade line for "bank-full" conditions (see Paragraph 5605.5.B) and 100-year design storm with 10% temporal distribution .
- Thalweg, locations of riffles and pools, and spacing between riffles (see Paragraph 5605.5.C).
- Exposed bedrock, areas of differing bed and bank soil or rock materials, and the D_{50} and shear stress ratio at each riffle (see Paragraph 5605.5D)
- Active scour and depositional areas, point bars, and islands.
- Vegetation within the stormwater drainage setback widths, called out as mowed grass, mowed with trees, unmowed grass and plants, wooded, and bare. Trees greater than 6" diameter within 25 feet of the top of bank shall be located individually or by group. The species of dominant trees should be noted.

- Meander length, wavelength, meander amplitude, bank-full width, and radius of curvature for each bend.
- Total meander and valley length and sinuosity for the reach.
- Photographs of main channel, streamside vegetation, and each riffle, appropriately referenced to plan-view location.

B. Bank-full Width, Depth and Discharge: If directed by the City/County Engineer, the geomorphic "bank-full" width, depth, and discharge shall be estimated using field indicators as detailed in Chapter 7 of USDA (1994). If field indicators are not used, "bank-full" flow shall be estimated as the rural-conditions 2-year design storm with the median (50%) temporal distribution flow, and the bank-full width and depth estimated based on the dimensions of that flow through the existing channel. This assumption is intended to provide a rough upper estimate of the bank-full flow.

C. Longitudinal Profile and Sections: The elevations of the profile along the thalweg shall be field surveyed to the nearest 0.1 ft. and the following features noted: riffles, pools, exposed bed rock, and advancing head cuts (areas of bed elevation change that appear to be actively migrating upstream). The top of left and right bank and any field indicators of bank-full flow such as limits of woody vegetation or top of point bars shall be plotted at correct elevation along the profile. The bank-full flow and 100-year design storm with 10% temporal distribution flow profiles shall be plotted.

One field cross section shall be surveyed through each pool and riffle, and the depth and width of bank-full flow and floodplain for the 100-year design storm with 10% temporal distribution shall be shown on each section.

D. Bed and Bank Materials Analyses: The type of rock exposed in the bed and banks shall be identified. Bank soils shall be reported by Uniform Soil Classification using the visual-manual procedures (ASTM D 2488-00). The median (D_{50}) particle size shall be determined using the Wolman Pebble Count Method (USDA, 1994, Chapter 11). A shear stress ratio shall be calculated for each riffle based on the applied shear at bank-full flow divided by the critical shear of the D_{50} particle in the riffle, using methods and tables described below.

E. Critical Shear Stress Analysis: The shear stress ratio must be less than one at the extreme downstream point of any development in accordance with the guidelines below:

1. The average applied shear stress (τ_o) may be calculated from the hydraulic data as follows:

$$\tau_0 = \gamma \cdot R \cdot S$$

Where:

γ = the specific weight of water (62.4 lbs/ft^3)
R = hydraulic radius at bank-full flow (feet)
S = the water surface slope along the main channel bank full flow, averaged over several bends in the area of the intervention

Effective flow may be calculated using methods described in detail in USACE 2001 or may be assumed to be equivalent to the 2-year storm.

2. The critical shear stress (τ_c) is that at which particles in the bed or bank are entrained and scour ensues. Shield's method is used for calculating the calculating the critical shear stress of spherical, non-cohesive particles, as follows:

$$\tau_C = \theta \cdot (\gamma_s - \gamma) \cdot D_{50}$$

Where

γ_s = the specific weight of sediment

γ = specific weight of water (62.4 lb/ft3)

D_{50} = the median particle size in the surface layer of bed or banks

θ = the Shield's parameter (0.06 for gravel to cobble, 0.044 for sand)

There are limited methods for calculating τ_c for fine-grained material. Field or laboratory testing generally determines the critical shear stress for these materials. The most widely available source is Chow (1988). Table 7-3, p. 165 is particularly relevant. More recently, the USDA Agricultural Research Service National Sedimentation Laboratory has developed computer software for calculating toe scour (ARS Bank-Toe Erosion Model, Prototype, August 2001). As part of that software, there are look-up tables.

The combination of these two sources is presented in Table 5605-2 Critical shear stress may also be determined from Urban Water Resources Research Council (1992), Figure 9.6, p. 335.

In lieu of calculated values, the critical shear stress from Table 5605-2 may be used. Table 5605-2 presents critical shear for sediment-laden water and where noted, clear water. The user must exercise judgment as to future conditions. Clear water values may be used below a heavily piped area, concrete channels designed to contain the future flows or immediately below a managed detention pond.

3. The ratio of average boundary stress to critical stress is the shear stress ratio:

$$shear\ stress\ ratio = \frac{\tau_o}{\tau_c}$$

If bed and bank materials are distinct, then the shear stress ratio should be calculated for each. If the shear stress ratio of either stream bed or bank is greater than one, the channel is prone to near-term adjustment and any interventions should be designed to prevent accelerated erosion. If the bed consists of rock, then the shear stress ratio is not applicable, unless the rock is prone to fracturing, slaking, or break-up, in which case the median size of particle should be used for calculation of the ratio.

Table 5605-2: Critical Shear Stresses for Channel Materials

Material	Shear Stress (psf)
Granular Material	
Boulders (100 cm)	20.295
Boulders (75 cm)	15.222
Boulders (50 cm)	10.148
Boulders (25.6 cm)	5.196
Rip Rap	3.132
Cobbles (6.4 cm)	1.299
Cobbles and shingles	1.1
Cobbles and shingles, clear water	0.91
Coarse sand (1mm)	0.015
Coarse sand (1mm)	0.015
Coarse gravel, noncolloidal (GW), clear water	0.3
Coarse gravel, noncolloidal, (GW)	0.67
Gravel (2cm)	0.406
Fine gravel	0.32
Fine gravel, clear water	0.075
Fine sand (0.125 mm)	0.002
Fine sand (0.125 mm) (SP)	0.002
Fine sand (SW), (SP), colloidal	0.075
Fine sand, colloidal, (SW), (SP), clear water	0.027
Graded loam to cobbles, noncolloidal (GM)	0.66
Graded loam to cobbles, noncolloidal,(GM), clear water	0.38
Graded silts to cobbles, colloidal (GC)	0.8
Graded silts to cobbles, colloidal, (GC), clear water	0.43
Fine Grained	
Resistant cohesive (CL), (CH)	1.044
Stiff clay, very colloidal, (CL)	0.46
Stiff clay, very colloidal, (CL), clear water	0.26
Moderate cohesive (ML-CL)	0.104
Ordinary firm loam (CL-ML)	0.15
Ordinary firm loam, (CL-ML), clear water	0.075
Alluvial silts, colloidal (CL-ML)	0.46
Alluvial silts, colloidal,(CL-ML), clear water	0.26
Alluvial silts, noncolloidal (ML)	0.15
Alluvial silts, noncolloidal, (ML), clear water	0.048
Sandy loam, noncolloidal (ML)	0.075
Sandy loam, noncolloidal (ML), clear water	0.037
Silt loam, noncolloidal (ML)	0.11
Silt loam, noncolloidal, (ML), clear water	0.048
Shales and hardpans	0.67
Others	
Jute net	0.46
Plant cuttings	2.09
Well established dense vegetation to the normal low water	2.16
Geotextile (synthetic)	3.01
Large Woody Debris	3.13

Note: For non-cohesive soils, the table values are based on spherical particles and Shield equation, as follows: $\tau_c = \Theta(\gamma_s - \gamma)\,D$ where γ_s is the specific weight of sediment (165 pcf), γ is specific weight of water, D is the reference particle size, and Θ is the Shield's parameter (0.06 for gravel to cobble, 0.044 for sand). For cohesive soils the values are based on limited testing as reported in Chow (1988) and USDA (2001).

F. Plan-Form Ratios: The following ratios shall be calculated, and those that lie outside the typical range shall be noted. Streams are highly variable and ratios outsides these ranges do not necessarily indicate problems.

Table 5605-3: Plan-Form Ratios

Ratio	Typical Range
Meander length / Wavelength (sinuosity)	1.1 to 1.5
Meander length / Bank-full width	10 to 14
Radius of curvature / Bank-full width	2 to 5
Riffle Spacing / Bank-full width	5 to 7

G. Channel Condition Scoring Matrix: Using information summarized above, the channel condition scoring matrix given in Table 5605-4 shall be completed. A rating of 12 indicates a stream of moderate stability that will likely require only standard levels of protection during construction. A rating between 12 and 18 indicates that special measures may be necessary address those issues rated as poor in the assessment. Streams with a rating greater than 18 may exhibit significant system-wide instability. These streams should be studied in more detail by experts in river engineering and fluvial geomorphology. (This scoring system is newly developed and its results shall be considered provisional.)

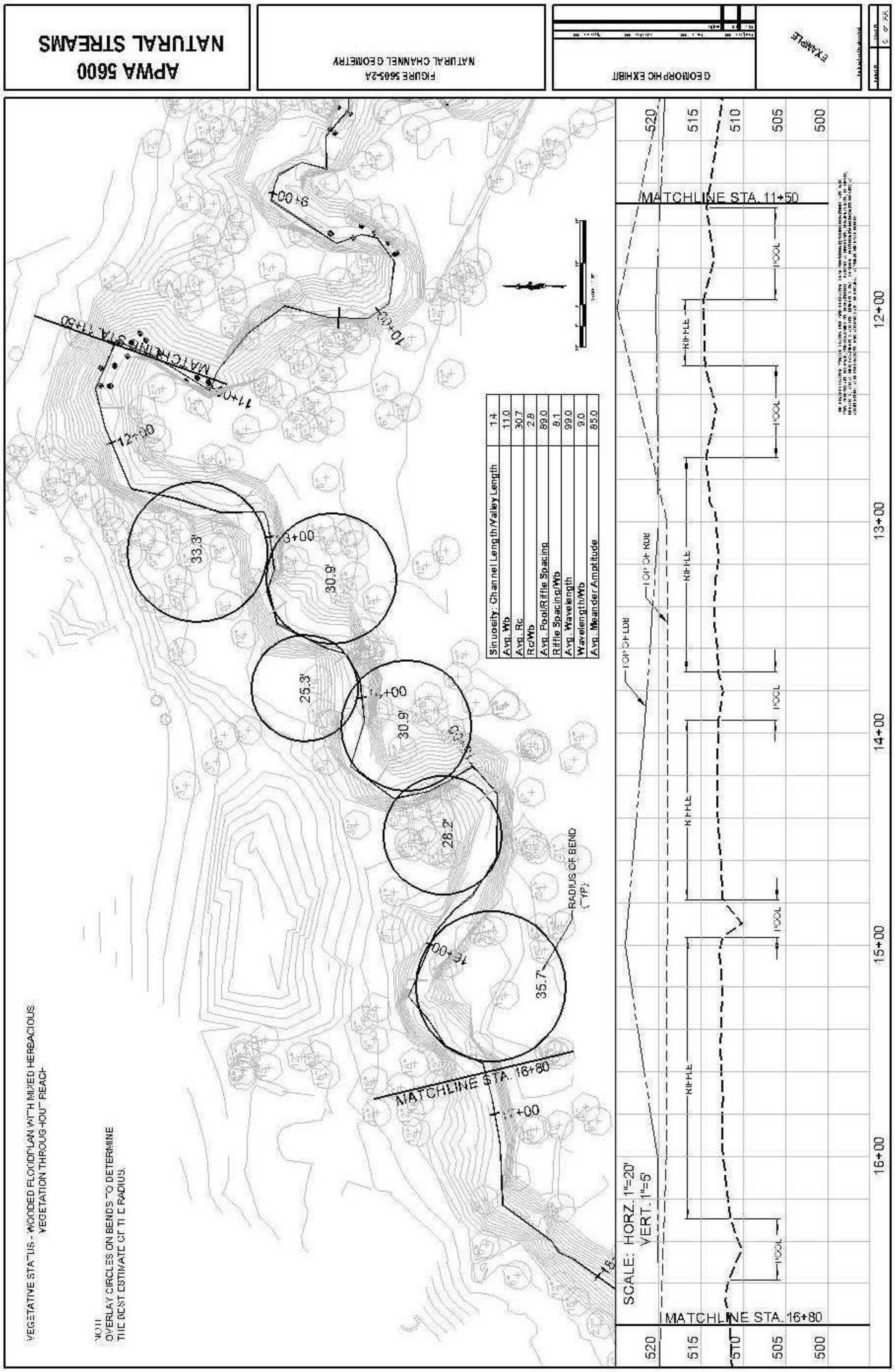


Figure 5605-4: Stream Assessment

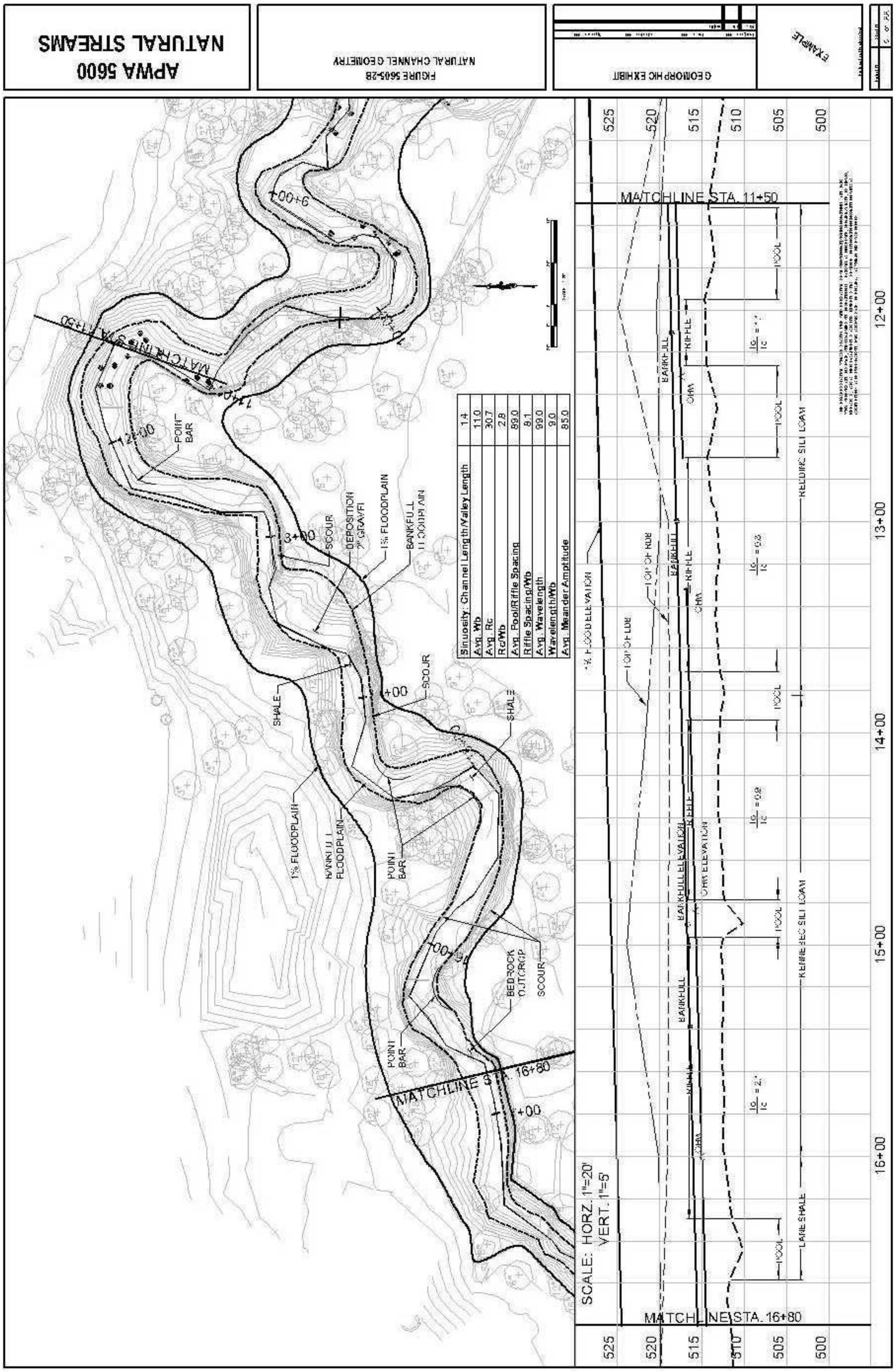


Figure 5605-5: Stream

5605.6 Discharge Outfalls

Discharge points for inflows from enclosed systems or constructed channels shall be designed as one of the following. Energy management and sediment continuity checks are not required; however, energy dissipation shall be provided to reduce post development shear stress to pre-development shear stress at the outfall:

A. Primary outfalls are those where the entire upstream channel is replaced by an enclosed system or engineered channel which discharges flow in line with the direction of the downstream segment. Energy dissipation should be provided at the outlet to reduce velocities per Paragraph 5606.4. Grade control downstream of the outlet and an energy dissipater should be provided to prevent undermining of the outfall by future head cuts per Paragraph 5605.10. The alignment and location of the outfall and associated energy dissipater and grade control should make a smooth transition into the downstream channel. Primary outfalls shall be used whenever the contributing drainage area of the outfalls is greater than 80% of the downstream channel.

B. Tributary outfalls are primary outfalls located on a tributary to a larger downstream segment. Energy dissipation and transition to natural stream flow should take place in the tributary at least one channel width upstream of the confluence per Paragraph 5606.4. Grade control in the tributary upstream of the confluence shall be provided if the tributary flow line is higher than the adjoining channel or if future incision of the adjoining channel is anticipated. Tributary outfalls may be used in all situations of tributary flow.

C. Lateral outfalls are small outfalls that discharge from the banks of a stream. Outfalls shall be located to enter on a riffle or from the outside of a bend, but should generally not enter from the inside of a bend. Outfall pipes shall be oriented to discharge with the direction of flow at a minimum of 10-15 degrees from a line perpendicular to the stream alignment. The invert shall be at or slightly below the top of the next downstream riffle. Outfalls shall be flush with or setback from the bank. The bank shall be shaped to provide a smooth transition and protected with reinforced vegetation (preferred) or rip- rap. If the outfall is in a bend, it shall be set back from the existing bank a sufficient distance to account for future meander migration, and the transition shall be graded and reinforced with vegetation. Riprap or hard armor protection should not be used in a bend. Perpendicular outfalls may only be used when the contributing drainage area of the outfall is less than 40% of that in the downstream channel.

D. Edge-of-buffer outfalls are discharge points in the outer half of the riparian buffer that return the discharge to diffused overland flow. Outfalls shall be designed to spread flow and allow overland flow and infiltration to occur. Overland flow shall be directed to run in the outer portion of the buffer parallel to the channel direction to increase length of flow and prevent short-circuiting directly into the stream. Low weirs and berms may be graded to direct flow and encourage short-term ponding. The buffer zone utilized for infiltration shall be maintained in dense, erosion-resistant grasses or grasses reinforced with turf- reinforcing mats designed to withstand the shear stresses of a 10-year design storm with 10% temporal distribution. Edge-of-buffer outfalls that are part of a system of upland drainage using multiple small, distributed overland swales and ditches instead of pipes may provide significant infiltration and water quality treatment. Edge-of-buffer outfalls shall only be used if each individual outfall can be designed to operate without scour or the formation of gullies.

5605.7 Culverts, Bridges, and Above Grade Crossings

A. Crossings should generally be located on a riffle. If the width of the crossing is large relative to the length of the riffle, then grade control structures shall be provided at the riffles upstream and downstream to isolate the impact of the crossings. If a crossing cannot be made at a riffle, avoid armoring a pool and place at-grade control structures at the riffle immediately upstream and downstream of the crossing. Maintain sediment transport continuity and avoid altering the channel cross-section.

B. Realignment of channels to accommodate crossings and their approach should be avoided and minimized as much as possible. Any areas relocated shall have the banks stabilized in accordance with 5605.13 and shall be included in the reach isolated by upstream and downstream grade control.

C. For bridges the multi-stage channel shape should be maintained and additional area to convey the design flow shall be above the elevation of the bank-full discharge.

D. For multi-cell pipe and culvert crossings that have a cumulative width larger than the bank-full width, those cells wider than the bank-full width shall have a flow line located at the lowest estimated bank-full depth, or a weir wall or other structure upstream of the culvert opening shall be installed with a height to prevent access to the cell during flows less than bank-full flow. The weir wall shall be designed so that the hydraulic efficiency at the 100-year design storm with 10% temporal distribution is not reduced. Without these features, the culvert may have a tendency to build up deposits and lose capacity or require frequent maintenance, particularly when crossings are located in sharp bends or streams with high sediment loads.

E. Culverts shall be designed so that there is minimal backwater effect at all flows up to the 25-year storm discharge. Energy management and sediment transport continuity shall be checked.

5605.8 Below Grade Stream Crossings

A. Below grade stream crossings primarily include utility pipelines. Crossings should generally be at riffles and grade control structures constructed at the riffle, in addition to or constructed integrally with any encasement of the line the utility may require. Utility encasements shall extend a minimum of five (5) feet into the stream bank on both the upstream and downstream sides of the crossing to account for the natural stream morphology. If a crossing is at a bend in the stream this minimum shall extend ten (10) feet into the stream bank.

B. If riffle crossing is not feasible, the crossing should be in a pool that is protected by a downstream grade control structure. The top of crossing elevation should be at least two feet below the top of grade control. Crossings under pools should not be armored directly, but are protected by downstream grade control.

C. Below grade crossings shall be perpendicular to and along a straight section of the stream whenever possible. If a perpendicular crossing is not feasible, the grade control protecting the crossing shall be perpendicular.

D. Constriction or alteration of the pre-existing channel shape shall be avoided. If alteration occurs, sediment transport continuity and energy management shall be verified. Stream banks shall be repaired using vegetative methods whenever possible and the hydraulic roughness of the repaired stream bank should match that of the undisturbed stream banks.

E. Utility structures or manholes should not be placed within the stream cross section, when possible. Consider stream morphology when placing structures. Generally avoid placement of structures on the outside bend of a stream.

F. Avoid utility crossings immediately downstream of a stormwater outfall.

5605.9 Grade Control

A. Where grade control structures are required, they shall be placed in locations where the stream bed profile will support the creation or continuance of a riffle. The flow line of the grade control shall match the existing riffle.

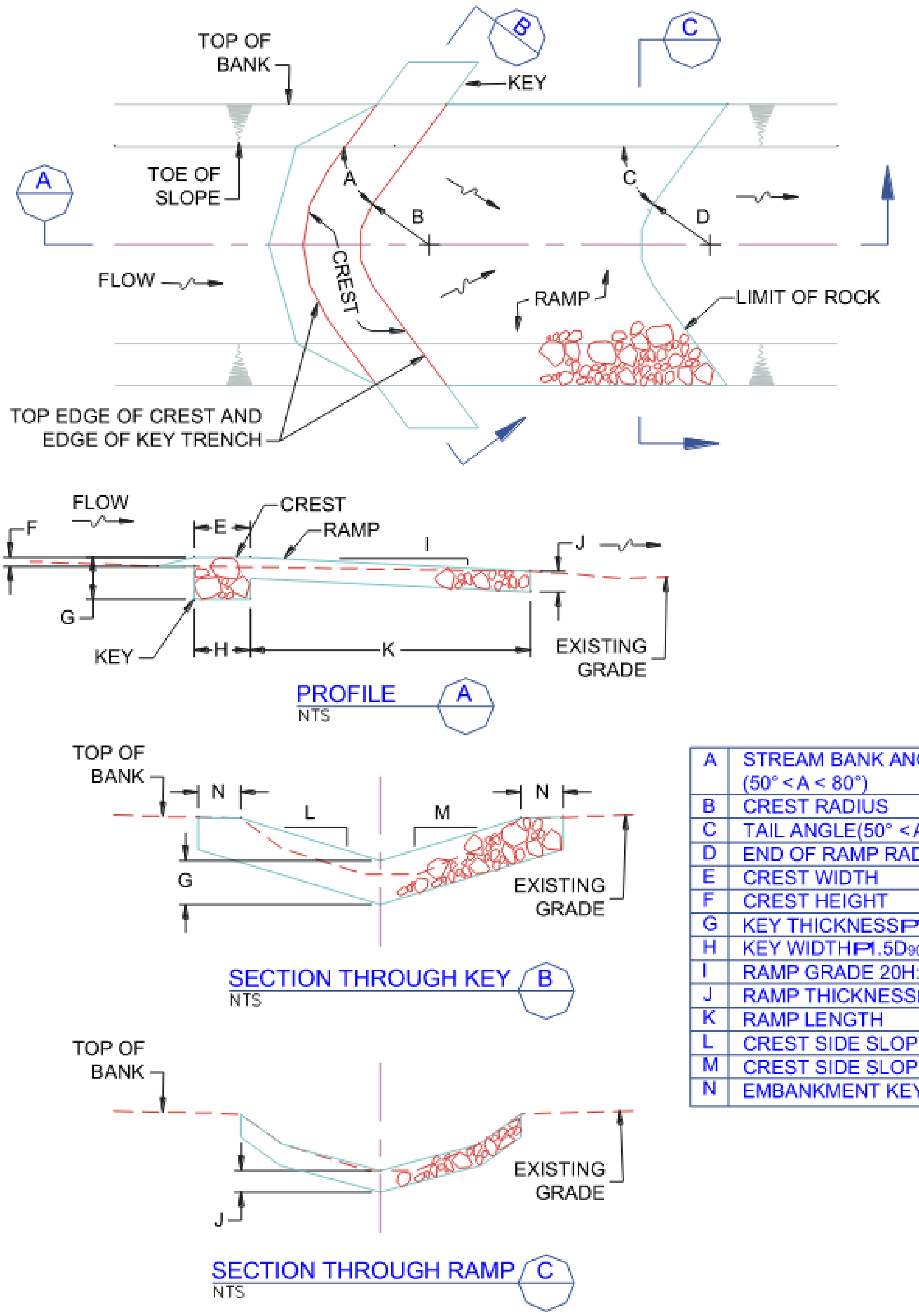
B. Where stream slope is less than 2%, the Newberry-style grade control structure detailed in Figure 5605-6 is recommended. Structures shall be constructed from durable stone sized using USACE methodology for steep channels (USACE EM 1110-2-1601, page 3-8, Equation 3-5). Rock shall generally comply with USACE gradations as given in (USACE EM 1110-2-1601, Hydraulic Design of Flood Control Channels, Chapter 3). Shotrock with sufficient fines to fill voids may be used. The use of filter fabric and uniform gradations of stone are discouraged in stream beds.

C. Where grades are in excess of 2%, low-drop step structures should be used.

D. Alternate styles of grade control may be approved by the City/County Engineer. Guidance for grade control design is given in Thomas et.al.

E. Construction of new grade controls structures may be waived by the City/County Engineer if it is determined that existing riffles are adequate to prevent or retard advancing head cuts, or if it is preferable to accept the risk of future head cut than to further disturb the channel.

F. When grade control is not part of a larger project, energy management and sediment continuity checks are not required.



A	STREAM BANK ANGLE (50° < A < 80°)
B	CREST RADIUS
C	TAIL ANGLE(50° < A < 80°)
D	END OF RAMP RADIUS
E	CREST WIDTH
F	CREST HEIGHT
G	KEY THICKNESS≥1.5D_{90}
H	KEY WIDTH≥1.5D_{90}
I	RAMP GRADE 20H:1V
J	RAMP THICKNESS≥1.5D_{100}
K	RAMP LENGTH
L	CREST SIDE SLOPE
M	CREST SIDE SLOPE
N	EMBANKMENT KEY

Notes

1. The depth of key trench shall be a minimum of 1.5 D90.The crest shall slope downward from the stream bank to the center of the structure to focus the flow to the channel center. The tail ramp is generally sloped at 20 horizontal to 1 vertical and dissipates energy gradually over it length. The upstream face is not perpendicular to the flow but has an upstream oriented "V" or arch shape in plan form.
2. For item A, Stream Bank Angle, and item C Tail Angle, the lower end of the range should be used for softer soils.
3. For items L and M, crest angle, the typical range is 5 to 1 to 10 to 1.

Figure 5605-6: Grade Control Structure

5605.10 Floodplain Fills

No fill shall be placed within the effective FEMA floodplain and/or floodway. Fill placed outside these limits shall not cause a rise in the FEMA effective floodplain beyond the limits of the property controlled by the developer. Fills placed within floodplain designated as a special flood hazard area by FEMA shall conform to FEMA and community floodplain management requirements. Energy management and sediment transport continuity shall be checked.

5605.11 Flood Control Projects

A. The flood control projects that increase conveyance capacity in streams should generally be limited to cases where existing buildings or infrastructure face significant damage or life and safety issues. Projects to lower floodplain elevations to facilitate new development near streams at lowered elevations should be avoided.

B. The portion of the channel within the effective floodplain should be left undisturbed if possible, with conveyance increases primarily from excavation of a larger cross sectional area in the over-bank. Excavated areas within the stormwater drainage setbacks should be revegetated with dense, native-type vegetation. Reducing roughness in the over-bank by paving or mowing to increase velocities should be avoided.

C. Flood control projects should be evaluated on a project by project basis, and abide by current, effective floodplain management regulations..

5605.12 Bank Stabilization Projects

A. Bank stabilization projects should generally be limited to cases where existing buildings or infrastructure face significant property damage or safety issues. Projects to stabilize banks to facilitate reductions in stormwater drainage setback widths for new construction should be avoided.

B. Prior to stabilization, the causes of the instability should be considered, including the stream's current phase of channel evolution (Interagency, 2001, Chapter 7) and direction of meander migration. Stabilization may be unnecessary if a channel has ceased incision and widening and is in the process of deposition and restoration. If stability issues appear widespread or complex, a systematic evaluation of the stream system by professionals with expertise in river engineering and fluvial geomorphology may be justified.

C. Instability caused by geotechnical failure (slumping of banks due to weak soils in the adjacent slopes) shall be distinguished from fluvial failure (erosion of banks caused by stream flows). For geotechnical issues, a geotechnical engineer shall evaluate the slope stability. Geotechnical designs shall provide for a 1.5 factor of safety (ratio of theoretical resisting forces to driving forces) against slope failure where it would endanger buildings, roadways, or other infrastructure, unless a lower factor of safety is approved by the City/County Engineer.

D. Bank stability projects should have a design life greater than the useful life of the facility being protected, or a life cycle cost analyses shall be performed that considers replacement and repair over the entire protection period. Responsible parties for future maintenance should be identified.

E. Stabilization should begin and end at stable locations along the bank. Bank stabilization should be limited to areas of potential erosion and are rarely required on the inside of bends. For long projects, stabilization may alternate from side to side and is rarely necessary across an entire cross section. The existing cross section should be mimicked to the extent practical and need not be planar or uniform over the entire length. Grade control shall be provided at the riffle both upstream and downstream of the stabilization to isolate it from the surrounding stream and protect the foundation from undercutting. Control at intermediate points for longer projects may also be required. Energy management and sediment transport continuity shall be checked, and energy dissipation provided if necessary.

F. "Hard-Armor" projects are those projects that use rip-rap, placed stone, gabions, retaining walls, or other rigid structures to provide geotechnical and fluvial stability. Such projects shall be designed in accordance with EM 1110-2-1205 (USACE, 1989), EM1110-2-1601 (USACE, 1994), or HEC-11 (FHWA 1989). Materials shall be sized to prevent dislodgement in the 100-year design storm with 10% temporal distribution. Gradation should comply with USACE or FHWA recommendations. Stones should be placed to maintain roughness and variations. All material shall be well placed to ensure interlock and stability. Materials shall be keyed into the bed and banks with adequate allowance for scour along the toe and the structure should have adequate foundation. Vertical walls should be avoided when possible as they tend to concentrate scour at their toe and are typically smoother than the natural channel.

G. Soil bioengineering involves the use of living vegetation in combination with soil reinforcing agents such as geogrids to provide bank stabilization by increasing soil shear resistance, dewatering saturated soils, and by reducing local shear stresses through increased hydraulic roughness.

1. Bio-engineering projects shall be designed in accordance with the principals of NRCS (1996) and Gray and Sotir (1996). Designs will be tailored to the urban environment by consideration of the requirement for immediate functionality upon construction, the extreme variability and high shear stress of urban flows and the availability of mechanized equipment and skilled operators.
2. Selection of plants and specifications for planting methods and soil amendments shall be prepared by a professional competent in the biological and stabilization properties of plants.
3. Plants selected shall be appropriate to local conditions and shall be native varieties to the greatest extent practical. Evaluation of local conditions includes assessment of site microclimate, bank slope, soil composition, strength and fertility, type and condition of existing vegetation, proximity to existing infrastructure, soil moisture conditions and likelihood of wildlife predation. Engineering factors influencing plant selection include frequency, height and duration of inundation, near-bank shear stress, size and volume of bed load as well as depth and frequency of scour.
4. Plants may be either locally harvested or purchased from commercial nurseries. When harvesting, no more than 10% of a given stand may be removed and no plant on the state rare or endangered species list may be harvested or damaged in harvesting operations. Plant material grown near the metropolitan area is adapted to local climatic conditions and is preferred over more remote sources. Some species such as red maple are particularly sensitive to locale and may only be used if locally available. Seed, plant plugs, rhizomes, whips, live stakes, bare root and container stock may be used. Turf grasses, noxious or invasive species shall not be used. A variety of plant species shall be used to provide greater reliability to a design. For critical functions such as protection from toe scour a minimum of three species should generally be employed.
5. Soil bioengineering methods are properly applied in the context of a relatively stable stream system, and relevant general requirements for all stream bank stabilization projects given in this section apply to bio-engineered projects. Soil bioengineering alone is not appropriate when the zone of weakness lies below the root zone of the plantings, or when rapid drawdown can occur, such as in a spillway or dam embankment.

H. Composite methods are those which employ both hard armor and soil bioengineering. Typically, armor for toe protection in critical locations is provided, with soil-bioengineering for the remainder. Design principles for both hard armor and soil-bioengineering shall be observed as appropriate.

I. In-stream Stability Structures: In-stream structures are used to focus flow, control grade, dissipate energy and selectively lower near-bank stress. Stream barbs, weirs, guide vanes, vegetative sills, longitudinal peak stone, and grade controls are among the more commonly used in-stream structures. When constructed of natural material such as rock, such structures also create aquatic habitat. They may be used alone or in combination with hard armor, bioengineering or composite methods. In-stream structure design is a river engineering practice and is beyond the scope of this standard. Preliminary guidance and references for the design of some common structures is given in Castro (1999) and Interagency (2001), Chapter 8 and Appendix A.

5605.13 Stream Restoration

Restoration of urban streams is defined as the re-establishment of natural channel geometry, materials and vegetative buffers with the intent of restoring natural geometry and functions to streams that have been disturbed or eliminated. While there are significant potential ecological and quality of life benefits from stream restoration, successful design is data-intensive and requires an interdisciplinary approach. Design of stream restoration projects is beyond the scope of this standard. Interagency (2001) describes the general procedures, benefits, and requirements of stream restoration.

5605.14 Comprehensive Stream Management:

The standards set forth in preceding sections provide a moderate degree of mitigation for potential damages from individual construction projects in streams of average stability. For more sensitive streams or to obtain a greater degree of protection, Cities or Counties may elect to implement comprehensive strategies for stream management. Such strategies should be based on specific investigations of the particular streams and watersheds in the city and consider local geology, geography, climate, and ecology. Strategies may include optimized or county stream buffers (see Paragraph 5605.3), hydrology controls, and comprehensive grade control. Detailed requirements for such studies and strategies are beyond the scope of this standard, and should be developed in consultation with professionals competent in river engineering and fluvial geomorphology. The following general recommendations may be considered:

A. **Hydrology Controls for Channel Protection:** Channels respond to changes in flow volumes and recurrence by altering width, depth, velocity, suspended load, meander radius, wavelength and pool and riffle. Avoiding significant changes in flow volume and recurrence should reduce the likelihood of major changes in stream form. Volume control may include practices that encourage infiltration, evapotranspiration, and short-term detention or retention. A successful strategy would require limitations on volume, duration and magnitude of post development discharges at a number of discharge points, including common storms such as the 1-year design storm. The tail of hydrographs would probably need to mimic groundwater base flow. The cumulative effect of multiple detention/retention structures on duration of high flows would be considered. The impact of large impoundments or retention lakes on trapping sediment and interrupting sediment transport would be considered. Volume control for channel protection would likely require significantly different control requirements than traditional detention practices that focused primarily on flood control from extreme events.

B. **Grade Control:** In watersheds subject to deep, rapid, and extensive incision or downcutting, a comprehensive program of controlling bed elevation (grade control) may be the most practical method of preserving stream function and avoiding future bank stability concerns. Streams with easily eroded soils and lacking in shallow bedrock are highly susceptible to extensive degradation. Existing and proposed crossing points such as culverts, bridges, and encased underground utilities should be incorporated into the program. Selection of grade elevations would be based on historical data, flooding or space constraints, restoration of wetlands and streambank hydrology, channel depths, and other relevant data.

Project:____

Stream Name and Location: ____

Evaluated by:________________Firm:___________________________Date:____________

Table 5605-4: Channel Condition Scoring Matrix

(adapted from Johnson, et al 1999)

Stability Indicator	Good (1)	Fair (2)	Poor (3)	Score (S)	Weight (W)	Rating S*W= (R)
Bank soil texture and coherence	cohesive materials, clay (CL), silty clay (CL-ML), massive limestone, continuous concrete, clay loam (ML-CL), silty clay loam (ML-CL), thinly bed limestone	sandy clay (SC), sandy loam (SM), fractured thinly bedded limestone	non-cohesive materials, shale in bank, (SM), (SP), (SW), (GC), (GM), (GP), (GW)		0.6	
Average bank slope angle	slopes ≤ 2:1 on one or occasionally both banks	slopes up to1.7:1 (60˚) common on one or both banks	bank slopes over 60˚ on one or both banks		0.6	
Average bank height	less than 6 feet	greater than 6 and less than 15 feet	greater than 15 feet		0.8	
Vegetative bank protection	wide to medium band of woody vegetation with 70-90% plant density and cover. Majority are hardwood, deciduous trees with well-developed understory layer, minimal root exposure	narrow bank of woody vegetation, poor species diversity, 50-70% plant density, most vegetation on top of bank and not extending onto bank slope, some trees leaning over bank, root exposure common	thin or no band of woody vegetation, poor health, monoculture, many trees leaning over bank, extensive root exposure, turf grass to edge of bank		0.8	
Bank cutting	little to some evident along channel bends and at prominent constrictions, some raw banks up to 4 foot	Significant and frequent. Cut banks 4 feet high. Root mat overhangs common.	Almost continuous cut banks, some over 4 feet high. Undercut trees with sod-rootmat overhangs common. Bank failures frequent		0.4	
Mass wasting	little to some evidence of slight or infrequent mass wasting, past events healed over with vegetation. Channel width relatively uniform with only slight scalloping	Evidence of frequent and significant mass wasting events. Indications that higher flows aggravated undercutting and bank wasting. Channel width irregular with bank scalloping evident	Frequent and extensive mass wasting evident. Tension cracks, massive undercutting and bank slumping are considerable. Highly irregular channel width.		0.8	

Table 5605-4: Channel Condition Scoring Matrix

(adapted from Johnson, et al 1999)

Stability Indicator	Good (1)	Fair (2)	Poor (3)	Score (S)	Weight (W)	Rating S*W= (R)
Bar development	narrow relative to stream width at low flow, well-consolidated, vegetated and composed of coarse bed material to slight recent growth of bar as indicated by absence of vegetation on part of bar	Bar widths wide relative to stream width with freshly deposited sand to small cobbles with sparse vegetation	Bar widths greater than ½ the stream width at low flow. Bars are composed of extensive deposits of finer bed material with little vegetation		0.6	
Debris jam potential	slight – small amounts of debris in channel. Small jams could form	moderate – noticeable debris of all sizes present	significant – moderate to heavy accumulations of debris apparent		0.2	
Obstructions, flow deflectors (walls, bluffs) and sediment traps	negligible to few or small obstructions present causing secondary currents and minor bank and bottom erosion but no major influence on meander bend	moderately frequent and occasionally unstable obstructions, noticeable erosion of channel. Considerable sediment accumulation behind obstructions	frequent and unstable causing continual shift of sediment and flow		0.2	
Channel bed material consolidation and armoring	massive competent to thinly bed limestone, continuous concrete, hard clay, moderately consolidated with some overlapping. Assorted sizes of particles, tightly packed and overlapped, possibly imbricated. Small % of particles < 4mm	shale in bed, soft silty clay, little consolidation of particles, no apparent overlap, moderate % of particles < 4mm	silt, weathered, thinly bedded, fractured shale, high slaking potential, very poorly consolidated, high % of material < 4mm		0.8	
Sinuosity	1.2 ≤ Sinuosity ≤ 1.4	1.1<Sinuosity <1.2	Sinuosity <1.1		0.8	
Ratio of radius of curvature to channel width	3 ≤ Rc/Wb ≤ 5	2 < Rc/Wb < 3, 5 < Rc/Wb < 7	2 < Rc /Wb, Rc /Wb > 7		0.8	
Ratio of pool-riffle spacing to channel width at elevation of 2-year flow	4 ≤ Length/Wb < 8	3 ≤ Length/Wb < 4, 8 < Length/Wb ≤ 9	3 < Length/Wb, Length/Wb > 9, unless long pool or run because of geologic influence		0.8	
Percentage of channel constriction	< 25%	26-50%	> 50%		0.8	
Sediment movement	little to no loose sediment	scour and/or deposition, some loose sediment	near continuous scour and/or deposition and/or loose sediment		0.8	

TOTAL ____

Table 5605-5: Characteristics of Certain Plants for Bio-Engineering

Common Name	Botanical Name	Forms Available	Comments* (see notes below)
Sandbar willow	Salix exigua	Live stake, whip, bare root	Shrub willow, stoloniferous, favors granular soils, inundation and scour tolerant, requires full sun, extensive fibrous roots
Peachleaf willow	Salix amygdaloides	Live stake, whip, bare root	Shrub willow, stoloniferous, favors granular soils, inundation and scour tolerant, requires full sun, extensive fibrous roots
Buttonbush	Cephalanthus occidentalis	Live stake, whip, bare root, container	Shrub, sun or shade, stoloniferous, tolerates extended inundation, high aesthetic value, nectar source
Silky dogwood	Cornus ammomum	Live stake, bare root	Roots from cutting with root hormone, shade tolerant, stoloniferous, shallow, fibrous roots
Roughleaf dogwood	Cornus drummondii	Bare root, container	Most sun and drought tolerant dogwood, extensive fibrous roots
River birch	Betula nigra	Bare root, B&B	High root tensile strength, rapid establishment, high aesthetics
Black walnut	Juglans nigra	Bare root, B&B	Check for juglome toxicity in rest of palette, deep arching roots, buttressing effect in rock soils, canopy species
Switch grass	Panicum virgatum	Seed, plant plug	Deep, high tensile strength roots, aggressive, may out compete other warm season grasses, good for mesic to dry sites
Arrowwood viburnum	Viburnum dentatum	Bare root, container	Highly adaptable to range of soil, moisture and sun conditions, understory shrub, high aesthetic value
Little blue stem	Schizachyrium scoparium	Seed, plant plug, container	Deep, high tensile strength roots, adaptable to dry sites, full sun to light shade

Notes:

Stoloniferous species, those with the ability to sprout from a network of near-surface stems, are used in high stress applications to protect against toe scour. The stoloniferous species form dense colonies and quickly regenerate when damaged.

Common riparian species such as black willow, box elder, and most poplar species should not be used in soil bioengineering applications in urban areas. Populus deltoides (eastern cottonwood) should be used only sparingly and where deep, loam soil is present. If the site is infested with Phragmites spp (common reed), bamboo, Phalaris arundinacea (reed canary grass), and polygonum spp (knotweed), the design must include a plan to positively eliminate the weedy species. While plant selection is site-specific the following species have broad applicability in urban streams.

SECTION 5606 ENCLOSED PIPE SYSTEMS

5606.1 Design Criteria

Enclosed conveyance systems consisting of inlets, conduits, and manholes may be used to convey stormwater runoff where site conditions and open space requirements will not permit the use of natural drainage paths or engineered channels. A storm drainage system shall incorporate an overflow system that is capable of conveying flows in excess of the designed system capacity. Overflow systems can consist of natural drainage path preservation. Enclosed pipe systems shall convey the 10-year design storm assuming the temporal distributions per Section 5602, and be designed per Section 5603, as follows:

- **A. Gravity Flow Conditions:** 10-year design storm with median (50%) temporal distribution gravity flow conditions within the pipe system (e.g. no surcharging)
- **B. Pressure Flow Conditions**: 10-year design storm with 10% temporal distribution pressure flow conditions with surcharging less than 0.5 feet below the lowest opening to the surface or structure rim elevation.
- **C. Street Crossings:** Concentrated flow for open systems shall be conveyed under streets to prevent vehicles from being swept from the roadway during infrequent storms. These crossings may be bridges or culverts. Crossings shall be designed to completely convey flows without street overtopping in accordance with the design storms listed in Table 5606-1 based the 10% temporal distribution. Roadway classifications are defined per the Warsaw Livable Community Transportation Improvement Plan.

Table 5606-1 Level of Service for Street Crossings

Street Classification	Min. Design Storm
Principal Arterial	50-year
Primary Connectors	25-year
Minor Streets(1)	10-year

(1) Secondary connectors also fall into the category of minor streets

Further, concentrated flow in excess of the minimum design storm may only overtop the roadway if the following conditions are met:

1. The span of the structure opening is less than 20 feet.
2. The peak stormwater runoff from the 100-year design storm with 10% temporal distribution is 250 cfs or less unless a guard fence is installed on the downstream side of the roadway. Such overflow depths at low points in roadways during the 100-year design storm with 10% temporal distribution will be limited to 7 inches measured at the high point in the roadway cross section, typically at the upstream face of culvert headwall or roadway curb; except that it also shall not exceed 14 inches at the deepest point in the roadway cross section.

5606.2 Easements

Permanent drainage easements shall be dedicated to the City for all components of the storm drainage facilities and allow the City right of entry per the City of Warsaw Code of Ordinances Chapter §700.270. Easement width shall not be less than 15 feet, or the outside width of the pipe or conveyance structure plus 10 feet; whichever is greater. Easements shall be centered on the pipe.

- **A. Permanent:** The City/County Engineer may require wider easements when other utilities are located within the same easement and/or when the depth of cover is greater than 4 feet.
- **B. Temporary:** Temporary construction easements of sufficient width to provide access for construction shall be acquired when the proposed work is located in areas developed prior to construction.

5606.3 Capacity

Capacity shall be determined in accordance with Section 5603. Minimum design pipe size shall be 6-inch in diameter.

5606.4 Pressure Flow

After considering the discussion presented in Paragraph 5603.1 A, an enclosed system may be designed to operate with pressure flow, for the design storms specified in Paragraph 5601.5, if all the following conditions are met:

- **A.** The Hydraulic Grade Line (HGL) must be 0.5 feet below any openings to the ground or street at all locations.
- **B.** Watertight joints capable of withstanding the internal surcharge pressure are used in the construction.
- **C.** Appropriate energy losses for bends, transitions, manholes, inlets, and outlets, are used in computing the HGL.
- **D.** Energy methods (Bernoulli's equation) must be used for the computations.

5606.5 Energy Dissipation

The outfall, as defined in Paragraph 5605.6, of all enclosed systems shall include energy dissipation sufficient to transition outlet flows to velocities and applied shear stresses consistent with the normal flow conditions in the receiving channel for the range of flows up to and including the 100-year design storm with 10% temporal distribution. Calculations, at a minimum, should include the 2-year, the 10-year and the 100-year design storms with 10% temporal distributions.

Energy dissipation for lateral outflows to streams and edge of buffer outfalls to riparian buffers shall follow the guidance in Paragraph 5605.6. Effective energy dissipating structures shall be provided if necessary to meet the requirements stated in Tables 5605-2 and 5606-2. Examples of energy dissipating structures are:

- Check Dams
- Level Spreaders
- Hydraulic Jump Basins
- Impact Baffle Basins
- Plunge Pool and Plunge Basin
- Slotted-Grating or Slotted Bucket Dissipaters
- Stilling Basins
- Rock Revetment
- Internal Pipe Rings

Grade control shall be provided downstream of the dissipator or shall be constructed integrally with it. The suitability of each method is site dependent and subject to approval by the City/County Engineer. Table 5606-2 lists methods and applicability.

Table 5606-2: Energy Dissipation Counter Measures

Counter Measure	Functional Applications		Suitable Environment			
	Vertical Control	Horizontal Control	Dam Outlets	Small Culverts	Large Culvert	References
Check Dam	X	O	X	X	X	2, 6
Level Spreaders	X	X	O	X	O	1
Hydraulic Jump Basins	X	X	X	X	X	1, 3
Impact Baffle Basins	X	X	X	X	X	1
Plunge Pool & Plunge	X	O	X	X	X	1
Slotted-Grating or Slotted Bucket Dissipators	X	X	X	O	X	1
Stilling Basins	X	O	X	X	X	1, 2, 3, 4, 5, 6
Rock Revetment	X	X	X	X	X	1, 2, 6
Internal Pipe Rings	X	O	N/A	X	N/A	

LEGEND

X = Suitable Countermeasure

0 = Marginal Countermeasure

REFERENCES

1. Design of Small Dams 1987 United States Department of Interior
2. HEC 23
3. Hydraulic Design of Stilling Basins and Energy Dissipaters
4. HEC-14 FHWA Hydraulic Design of Energy Dissipaters for Culverts and Channels
5. U.S. Army Corps ff Engineers, 1994 Hydraulic Design of Flood Control Channels
6. Hydraulic Design Series (HDS-6)

NOTE: Other means may be used for Energy Dissipation and Stream Stability by designers as accepted by the City/County.

Energy dissipaters shall be designed according to the criteria and procedures defined in professionally acceptable references. Several such references include:

- United States. Department of the Interior. Bureau of Reclamation. Design of Small Dams. 1987 ed. Denver: GPO, 1987.
- United States. Department of the Interior. Bureau of Reclamation. A Water Resource Technical Publication. Engineering Monograph No. 25. Hydraulic Design of Stilling Basins and Energy Dissipaters. 1978 ed. GPO, 1978.
- Federal Highway Administration (FWHA), 1983. Hydraulic Design of Energy Dissipaters for Culverts and Channels, Hydraulic Engineering Circular (HEC) No. 14.
- US Army Corps of Engineers, 1994. Hydraulic Design of Flood Control Channels, US Army Corps of Engineers Engineer Manual EM 1110-2-1601.

- Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance (Latest Edition), National Highway Institute, HEC No. 23.
- River Engineering for Highway Encroachments, Highways in the River Environment, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA NHI 01-004, December 2001.

5606.6 Velocity within the System

The velocity within the system shall be between 3 and 20 feet per second.

5606.7 Loading

A. **Cover:** Minimum depth of cover shall be 18 inches. Designer shall consider pipe material and loading conditions for additional cover needs.

B. Minimum Loading Conditions:

1. Live load: H-20.
2. Unit Weight of soil cover: 120 lbs/ft^3.
3. Rigid pipes shall be bedded and backfilled to provide a minimum factor of safety of 1.5 at the 0.01-inch crack loading condition.

SECTION 5607 ENGINEERED CHANNELS

5607.1 Design Criteria

The criteria in this section apply to open channels that are not natural. Streams are covered in Section 5605. A storm drainage system shall incorporate an overflow system that is capable of conveying flows in excess of the designed system capacity. Overflow systems can consist of natural drainage path preservation. Engineered channels, ditches, and swales shall be designed to convey the 10-year design storm with the 10% temporal distribution, as defined in Section 5602.

5607.2 Easements

Permanent drainage easements shall be dedicated to the City and allow the City right of entry per the City of Warsaw Code of Ordinances Chapter §700.270. .

A. Engineered Channels: Easements shall be as wide as the top of bank width; plus 10 feet on each side. Easements shall be continuous between street rights-of-way. When an improved channel begins or ends at a point other than the right-of-way of a dedicated street, a 15-foot or wider easement graded so as to permit access by truck shall be dedicated from the end of the channel to a street right-of-way. These are minimum requirements.

Generally, easements shall be required for swales that collect stormwater runoff from more than two acres per Stormwater Drainage Setback requirements defined in 5605.2, or as required by the City/County.

B. Roadside Channels: Roadside ditches are engineered channels that are located wholly or partly within the street right-of-way. When the entirety of the roadside ditch extents is within the street right-of-way, an easement is not required. Otherwise, roadside ditches shall have a dedicated easement from the street right-of-way extending to 10 feet outside of the top of the outside bank of the channel.

5607.3 Freeboard

Freeboard shall not be required above the design headwater pool elevation at culvert entrance.

5607.4 Channel Linings

A. Minimum lining height shall be the selected design storm water profile plus at least a 0.5-foot freeboard.

B. All channel linings, except turf, shall contain provision for relieving back pressures and water entrapment at regular intervals.

C. Lining height on the outside bend of curves shall be increased by:

$$y = \frac{D}{4}$$

Where:

y = Increased vertical height of lining in feet
D = Depth of design flow in feet

Increased lining height shall be transitioned from y to zero feet over a minimum of:

$30 \times y$ feet downstream from the point of tangency (P.T.).
$10 \times y$ feet upstream from the point of curvature (P.C.).

5607.5 Lining Material

The types of lining material listed in Table 5607-1 shall be used to control damage and erosion. All riprap, grouted riprap, and gabion linings shall be designed with a filter fabric in conformance with Paragraph

2605.2.C.2. The design of the lining material shall protect the channel for conditions up to the 100-year design storm with the 10% temporal distribution or the maximum channel capacity, whichever is less.

Other types of lining materials not specifically listed in Table 5607-1 may be used when approved by the City/County Engineer.

Concrete lined open channel bottoms are prohibited, unless a waiver to this criterion is granted by the City/County Engineer.

Table 5607-1: Permissible Shear Stresses for Lining Material

Lining Category	Lining Type	Permissible Shear Stress (lbs/ft^2)
General	Erosion Control Blankets	1.55-2.35
	Turf-Reinforced Matrix	----
	(TRMs): Unvegetated:	3.0
	Vegetated:	8.0
	Geosynthetic Materials	3.01
	Cellular Containment	8.1
	Woven Paper Net	0.15
	Jut Net	0.45
	Fiberglass Roving:	---
	Single	0.60
	Double	0.85
	Straw With Net	1.45
	Curled Wood Mat	1.55
	Synthetic Mat	2.00
Vegetative (See Table 5607-2)	Class A	3.70
	Class B	2.10
	Class C	1.00
	Class D	0.60
	Class E	0.35
Gravel Riprap	25 mm	0.33
	50 mm	0.67
Rock Riprap	150 mm	2.00
	300 mm	4.00
Bare Soil	Non-Cohesive	See Figure 5607-1
	Cohesive	See Figure 5607-2

Table 5607-2:Classification of Vegetal Covers as to Degree of Retardance

Retardance Class	Cover	Condition
A	Weeping Love Grass	Excellent stand, tall (average 760 mm)
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 910 mm)
B	Kudzu	Very dense growth, uncut
	Bermuda Grass	Good stand, tall (average 300 mm)
	Native Grass Mixture (little bluestem, bluestem, blue gamma, and other long and short Midwest grasses)	(Good stand, unmowed)
	Weeping lovegrass	Good stand, tall (average 610 mm)
	Lespedeza sericea	Good stand, not woody, tall (average 480 mm)
	Alfalfa	Good stand, uncut (average 280 mm)
	Weeping lovegrass	Good stand, unmowed (average 330 mm)
	Kudzu	Dense growth, uncut
	Blue Gamma	Good stand, uncut (average 280 mm)
C	Crabgrass	Fair stand, uncut 250 to 1200 mm
	Bermuda grass	Good stand, mowed (average 150 mm)
	Common Lespedeza	Good stand, uncut (average 280 mm)
	Grass-Legume mixture – summer (orchard grass, redtop, Italian ryerass, and common lespedeza)	(Good stand, uncut (150 to 200 mm)
	Centipedegrass	Very dense cover (average 150 mm)
	Kentucky Bluegrass	Good stand, headed (150 to 300 mm)
D	Bermuda grass	Good stand, cut to 60-mm height
	Common Lespedeza	Excellent stand, uncut (average 110 mm)
	Buffalo grass	Good stand, uncut (80 to 150 mm)
	Grass-legume mixture—fall, spring (orchard grass, redtop, Italian, ryegrass, and common lespedeza)	(Good stand, uncut (100 to 130 mm)
	Lespedeza sericea	After cutting to 50-mm height. Very good stand before cutting
E	Bermuda grass	Good stand, cut to height 40-mm
	Bermuda grass	Burned stubble
Note: Covers classified have been tested in experimental channels. Covers were green and generally uniform.		

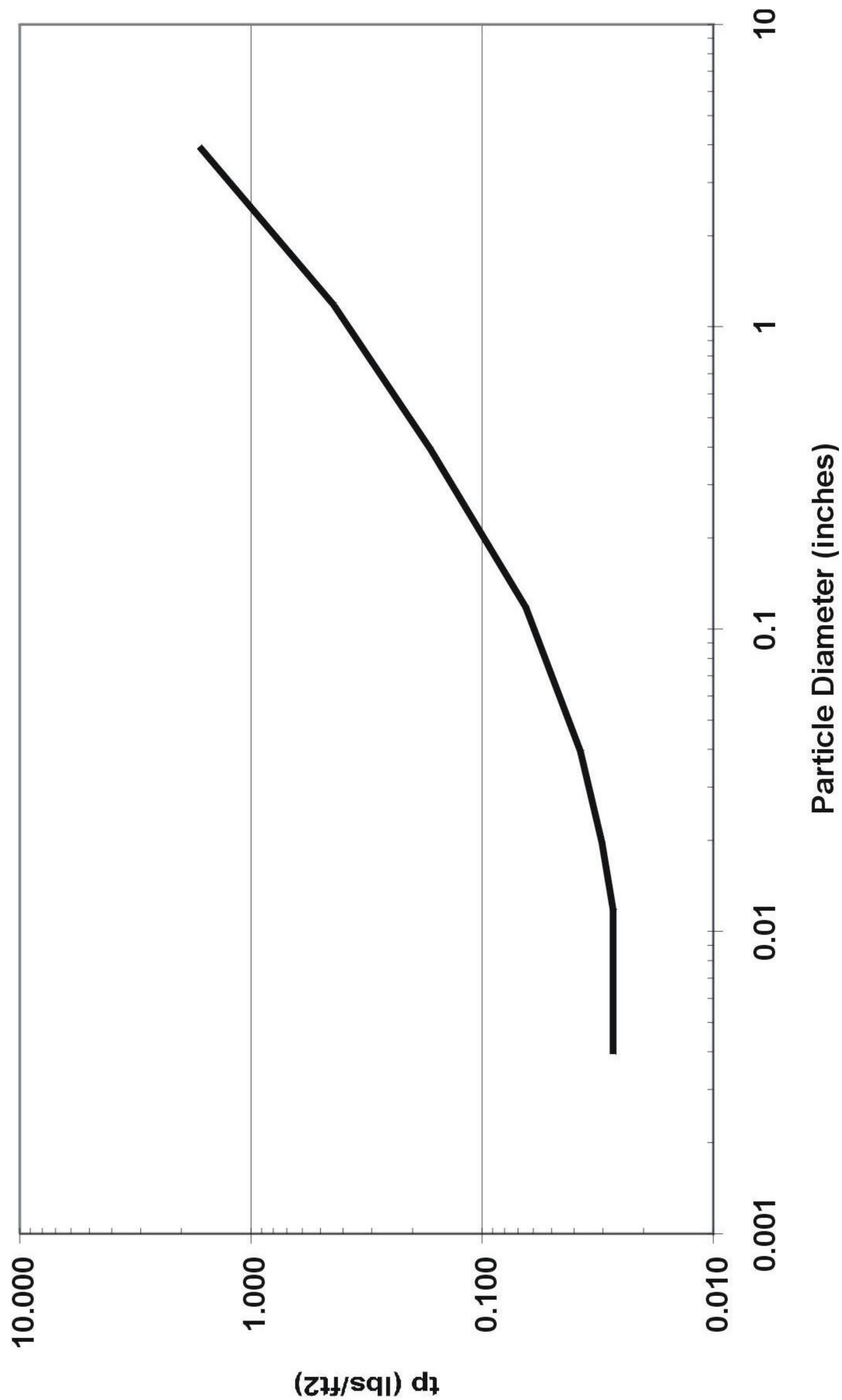


Figure 5607-1: Permissible Shear Stresses for Non-Cohesive Soils

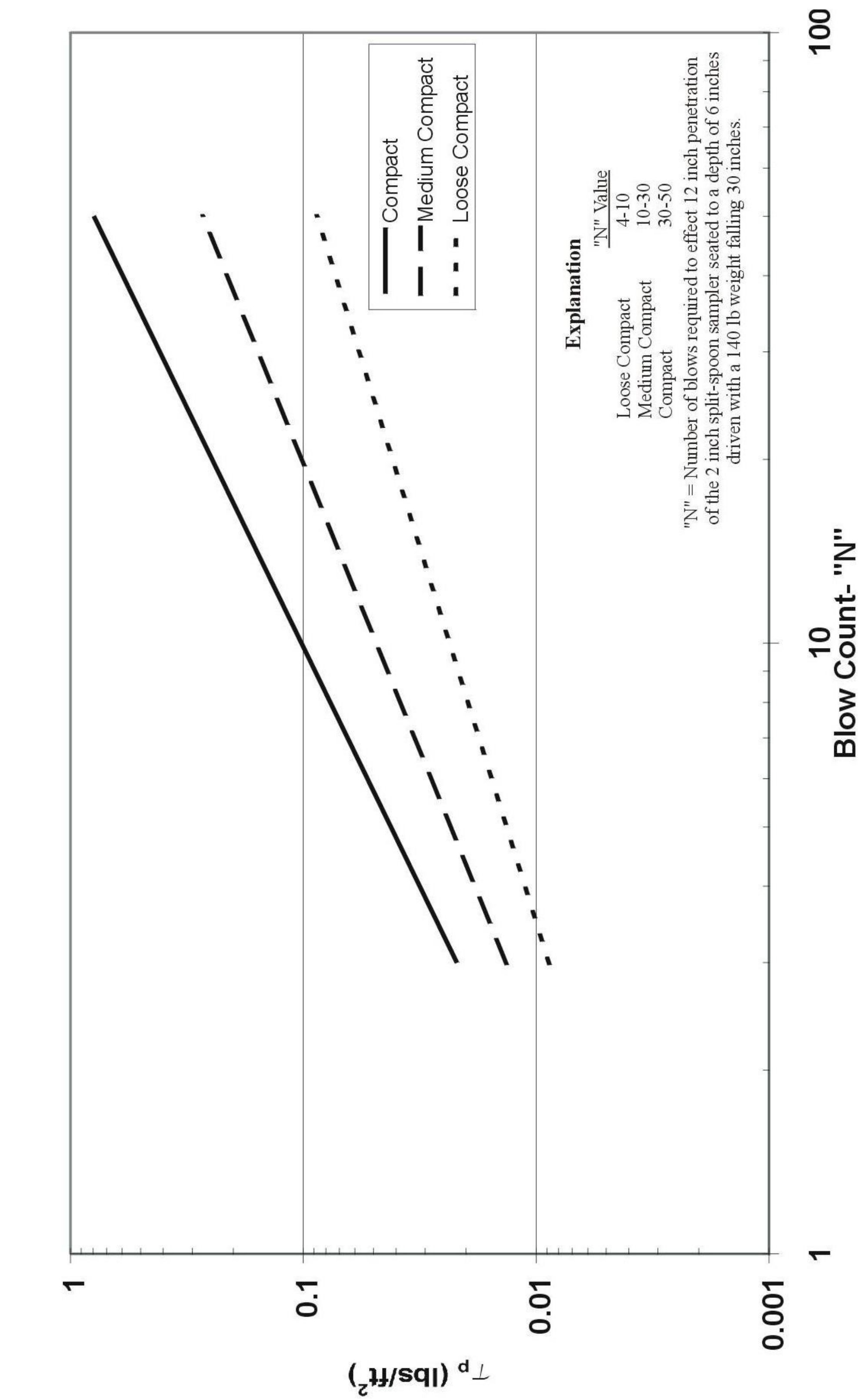


Figure 5607-2: Permissible Shear Stresses for Cohesive Soils

5607.6 Side Slopes

A. Side slopes shall have a vegetated or other lining material cover. Bare soil is not permitted.

B. Side slopes shall not be steeper than:

   1. 3:1 (horizontal:vertical) for vegetative lining; 4:1 is preferred.

   2. 2.5 horizontal to 1 vertical for all other lining materials, unless a geotechnical analysis indicates a steeper slope can be used.

   3. Flatter if necessary to stabilize slopes.

5607.7 Alignment Changes

Alignment changes shall be achieved by curves having a minimum radius of:

$$R = \frac{V^2 \cdot W}{8D}$$

Where:

R = Minimum radius on centerline in feet
V = Design velocity of flow in feet per second
W = Width of channel at water surface in feet
D = Depth of flow in feet

5607.8 Vertical Wall Channels

Vertical walls may be used for structural lining of improved channels when site conditions warrant; subject to the following special requirements:

A. Walls shall be designed and constructed to act as retaining walls.

B. Adequate provisions shall be made for pedestrian entry/exit from the channel.

5607.9 Energy Management

A. Use of grade control structures can be used to manage boundary shear.

B. Energy dissipation structures should be designed in accordance with Section 5606.

SECTION 5608 STORMWATER RETENTION AND DETENTION

5608.1 Design Criteria

This section governs the requirements and design of stormwater detention and retention facilities.

A. Retention: Stormwater retention shall be provided for the 0.5-inch design storm over the tributary impervious area from the site, calculated as follows:

$$Retention\ Volume, V_R = \frac{P_R * I * A}{12}$$

Where:

P_R = Retention rain event, 0.5 inches
I = Impervious percentage (%)
A = Project drainage area (acres)

B. Detention: Stormwater detention shall be provided for peak runoff control of the 2-, 10, and 100-year design storms. Post-improvement peak discharge rates from the site shall not exceed the allowable release rates expressed in discharge rate per tributary area in Table 5608-1.

Table 5608-1: Allowable Release Rate by Tributary Area

Design Storm Average Recurrence Interval	Temporal Distribution	Allowable Release Rate by Tributary Area (cfs/acre)
2-Year	Median (50%)	0.1
10-Year	Median (50%)	0.2
10-Year	10%	2.0
100-Year	10%	3.0

5608.2 Access and Easements

Permanent access and buffers must be provided for maintenance of detention and retention facilities with the following minimum requirements:

A. The water surface of the 100-year design storm storage pool shall be a minimum of 10 feet from building structures unless impermeable liners are used. A greater distance may be necessary when the retention/detention facility might compromise foundations or slope stability.

B. A 15-feet-wide access strip, with slopes less than 5 horizontal to 1 vertical, shall be provided around the perimeter of the facility, unless it can be demonstrated that all points of the facility can be maintained with less access provided.

C. The property owner shall also maintain a minimum 15-feet-wide access route to the facility(ies) from a street or parking lot with slopes no greater than 5:1 (horizontal: vertical) in any direction.

D. Structures, inlet pipes, outlet pipes, spillways, and appurtenances required for the operation of the facility shall also be provided access which is no less than easement widths established in Paragraphs 5606.2 and 5607.2.

E. Provisions shall be made to permit access and use of auxiliary equipment to facilitate emptying, cleaning, maintenance, or for emergency purposes.

F. Detention and retention facilities shall be maintained by the property owner. If the detention facility is not maintained by the property owner or involves multiple ownerships, easements must be dedicated to the party responsible for maintenance. All drainage easements shall allow the City right of entry per the City of

Warsaw Code of Ordinances Chapter §700.270. At a minimum the dedicated easements shall include: 1) the detention pond extending 15-feet from top of embankment or 15-feet from the exterior toe of the embankment slope; 2) appurtenances; and 3) access required by Paragraphs 5608.2.B through 5608.2.D.

5608.3 Maintenance and Continued Performance

Maintenance responsibility for all elements of the detention and retention facility should be designated prior to construction. However, when no designation is made the property owner shall be considered the responsible party. Annual or more frequent inspections shall be made by the responsible party to document that all inlet and outlet structures are functional as per the design and the facility has storage capacity as designed.

5608.4 Retention Criteria

A. Retention-based facilities are designed to either capture and infiltrate or re-use the required retention volume with no discharge from the site for the minimum design event. Retention shall be provided in the form of GSI/stormwater BMPs, as defined in Section 8 of the MARC BMP Manual. For detailed design and construction guidance of GSI practices/stormwater BMPs, see the KCMO GSI Manual. The KCMO GSI Manual includes design guidance for sizing of GSI practices, design considerations and checklists for GSI components, design detail templates, construction specification templates, as well as establishment and maintenance recommendations.

B. To the maximum extent practicable, retention facilities shall be designed and constructed to use vegetative, rather than mechanical, measures.

C. Retention volume shall be provided such that surface ponding is limited to a maximum of 12 inches and draws down within 48 hours after the rain event. Drawdown time may be calculated as follows:

$$t_{drawdown} = \frac{V_{ponding}}{A_{inf} * \left(\frac{k_{sat}}{12}\right)}$$

Where:

$t_{drawdown}$ = Time to draw down surface ponding (hours)
$V_{ponding}$ = Volume of surface ponding layer (acre-ft)
A_{inf} = Infiltration area of retention facility interface with in-situ soils (acres)
K_{sat} = saturated hydraulic conductivity of in-situ soils (inches per hour)

D. Retention requirements may be achieved in conjunction with detention storage, or independently.

5608.5 Detention Criteria

In addition to the foregoing criteria, the following shall be applicable, depending on the detention alternative(s) selected:

A. **Wet Detention Facility:** For detention facilities designed with permanent pools:

1. Sediment Forebay: A sediment forebay shall be provided to trap coarse particles. Refer to the MARC BMP Manual for typical design specifications and configurations of sediment forebays.

2. Minimum Depth: The minimum normal depth of water before the introduction of excess stormwater shall be four feet plus a sedimentation allowance of not less than 5 years accumulation. Sedimentation shall be determined in accordance with the procedures shown in Figure 5608-1.

3. Depth for Fish: If the pond is to contain fish, at least one-quarter of the area of the permanent pool must have a minimum depth of 10 feet plus sedimentation allowance.
4. Side Slopes: The side slopes shall conform as closely as possible to regraded or natural land contours, and should not exceed three horizontal to one vertical with four to one side slopes being preferred. Slopes exceeding this limit shall require erosion control and safety measures and a geotechnical analysis.
5. Refer to the MARC BMP Manual when designing wet detention facilities for stormwater detention and retention.

B. Dry Detention Facility: For detention facilities designed to be normally dry:

1. **Interior Drainage for non-BMP Facilities**: Grading must be incorporated to facilitate interior drainage to outlet structures. Grades for drainage facilities shall not be less than 0.5 percent on turf. Interior drainage design should not facilitate short circuiting of the facility for the design events.
2. **Earth Bottoms:** Earth bottoms shall be vegetated.
3. **Side Slopes:** The side slopes of dry detention facilities should be relatively flat to reduce safety risks and help to lengthen the effective flow path. Slopes shall not be steeper than 3 (horizontal) to 1 (vertical), with four to one side slopes being preferred.
4. Refer to the MARC BMP Manual when designing dry detention facilities for stormwater detention and retention.

C. Underground Detention: Underground detention facilities consisting of subsurface storage chambers may be allowed at the discretion of the City/County Engineer. Requests for underground detention must be submitted as a Request for Variance in the Drainage Permit and shall meet the following requirements:

1. A minimum of two (2) access points shall be provided for maintenance and inspection activities.
2. Maintenance access points should be located at opposite ends of the system, and horizontal bends in the alignment greater than 45 degrees.
3. Maintenance access points shall be sized accordingly for maintenance activities.
4. Maintenance access points should be at least 6 inches in any dimension for 45-degree vertical bends.
5. Maintenance access points should be at least 8 inches in any dimension for 90-degree vertical bends.

D. Green Roof/Rooftop Storage: Detention storage may be met in part by detention on roofs, as a green roof. Details of such designs shall include the depth and volume of storage, details of outlet devices and down drains, elevations and details of overflow scuppers, and emergency overflow provisions. Connections of roof drains to sanitary sewers are prohibited. Design loadings and special building and structural details shall be subject to approval by the City/County Engineer.

E. Parking Lot Storage: Paved parking lots may be designed to provide temporary detention storage of stormwater on a portion of their surfaces. Generally, such detention areas shall be in the more remote portions of such parking lots. Depths of storage shall be limited to a maximum depth of nine inches, and such areas shall be located so that access to and from parking areas is not impaired.

F. General Provisions

1. Detention facilities shall have 1,000 acres or less area tributary to the facility.
2. If the detention facility embankment meets state classification parameters for a dam, then facility shall be designed per state requirements. Dams shall permitted through the state following state guidelines.
3. All lake and pond development must conform to local, state, and federal regulations. Legal definitions and regulations for dams and reservoirs can be found in the Missouri Code of State Regulations, Division 22.

G. Computational Methods

1. Time of Concentration and Travel Time: Refer to Section 5602 for acceptable hydrology methods.
2. Hydrograph Routing: The storage indication method (Modified Puls) of routing a hydrograph through a detention facility may be utilized. Reference: (Chow, 1964). If retention and detention are provided within the same facility, the retention component shall be designed to store the retention volume with no outflow from the facility. Routing of the other larger storms is then done independently, assuming the retention volume is available and modeling all outlet orifices as part of the rating curve.

H. Detention Facility Size: Owners/engineers may utilize methodology outlined in (SCS, 1986). 6-hour duration, first quartile temporal distributions for Region 3 from NOAA Atlas 14 Volume 8 shall be the required storm hyetograph as defined in Table 5602-2. Maximum detention storage shall be based upon the allowable release rate defined in Table 5608-1 and upon the developed condition for the site.

I. Primary Outlet: The primary outlet shall be designed to meet the following requirements:

1. All allowable discharge from the detention facility when inflow is equal to or less than the 2-year and 10-year design storms with median (50%) temporal distribution shall be via the primary outlet system.
2. The design discharge rate via the outlet shall continuously increase with increasing head and shall have hydraulic characteristics similar to weirs, orifices or pipes.
3. Detention time for any design storm shall not exceed 72 hours after the peak or center of mass of the inflow has entered the detention facility.
4. Wet detention facilities shall be designed with a non-clogging outlet such as a reverse-slope pipe, or a weir outlet with a trash rack. A reverse-slope pipe draws from below the permanent pool extending in a reverse angle up to the riser and establishes the water elevation of the permanent pool. Because these outlets draw water from below the level of the permanent pool, they are less likely to be clogged by floating debris.
5. All openings shall be protected by trash racks, grates, stone filters, or other devices approved by the City/County Engineer. Minimum orifice size shall be per the current version MARC BMP Manual. See MARC BMP Manual Sections 8.6, 8.10 and 8.12 for design guidance and typical details for low-flow outlets and trash rack designs. Note that multiple design options are available for non-clogging low flow outlets and debris collection and designers are encouraged to select the best design for their site.

J. Primary Spillways: The primary spillway may either be combined with the outlet works or be a separate structure or channel meeting the following criteria:

1. **Elevation:** Primary spillways shall be designed so that the top of the embankment is 0.5 feet or more above the maximum water surface elevation in the detention facility attained by the maximum design storm for the facility. The 10-year and 100-year design storms with 10% temporal distribution may utilize the primary spillway to safely pass the peak discharge but shall not exceed the maximum release rates and shall not overtop the embankment.
2. **Capacity:** In cases where the impoundment/primary spillway is not regulated by either State or Federal agencies, the primary spillway shall be designed to pass the 100-year design storm with 10% temporal distribution with 0.5 feet of freeboard from the design stage to the top of dam, assuming zero available storage in the facility and zero flow through the primary outlet. This design provides an added level of protection in the event of a clogged primary outlet or a subsequent 100-year design storm that occurs before the flood pool from the initial storm event recedes to the principal outlet elevation.

K. Drawdown Provision: Drain works consisting of valves, gates, pipes, and other devices as necessary to completely drain the facility in 72 hours or less when required for maintenance or inspection shall be provided.

L. Retention facilities shall be designed with sufficient volume to capture the required Retention Volume (V_R) tributary to the facility. Multiple facilities may be required to meet retention requirements for the entire site. Retention facilities may provide storage capacity in the surface ponding layer, subsurface soil, aggregate or piping layers, or a combination thereof. The provided retention volume may be calculated as follows:

$$V_{provided} = \sum_{layer} n \cdot V_{layer}$$

Where:

$V_{provided}$ = Retention volume provided by the green stormwater infrastructure/post-construction permanent stormwater BMP facility
n = porosity of layer material (decimal) per Table 5608-2
V_{layer} = Volume of layer material (acre-ft)

Table 5608-2: Porosity Assumptions for Common Materials

Material	Description	Porosity (n)
Clean[1] Gravel	ASTM C33 Coarse Aggregates No. 2 No. 3 No. 56 No. 57	0.40
Clean[1] Pea Gravel	ASTM C33 Coarse Aggregates No. 8 No. 89 No. 9	0.35
Sand	ASTM C33 Fine Aggregate	0.32
Bioretention Soil Media (BSM)	Sandy Clay Loam (NRCS Soil Texture Classification)	0.30

Notes:
(1) "Clean" shall indicate washed aggregates, free of fines, as determined by less than 1% passing the No. 200 sieve.

M. Erosion Control: Primary outlet works, emergency spillways, and drain works, as well as conveyance system entrances to detention facilities, shall be equipped with energy dissipating devices as necessary to limit shear stresses on receiving channels. See Tables 5605-2 and 5606-2 for shear stress criteria.

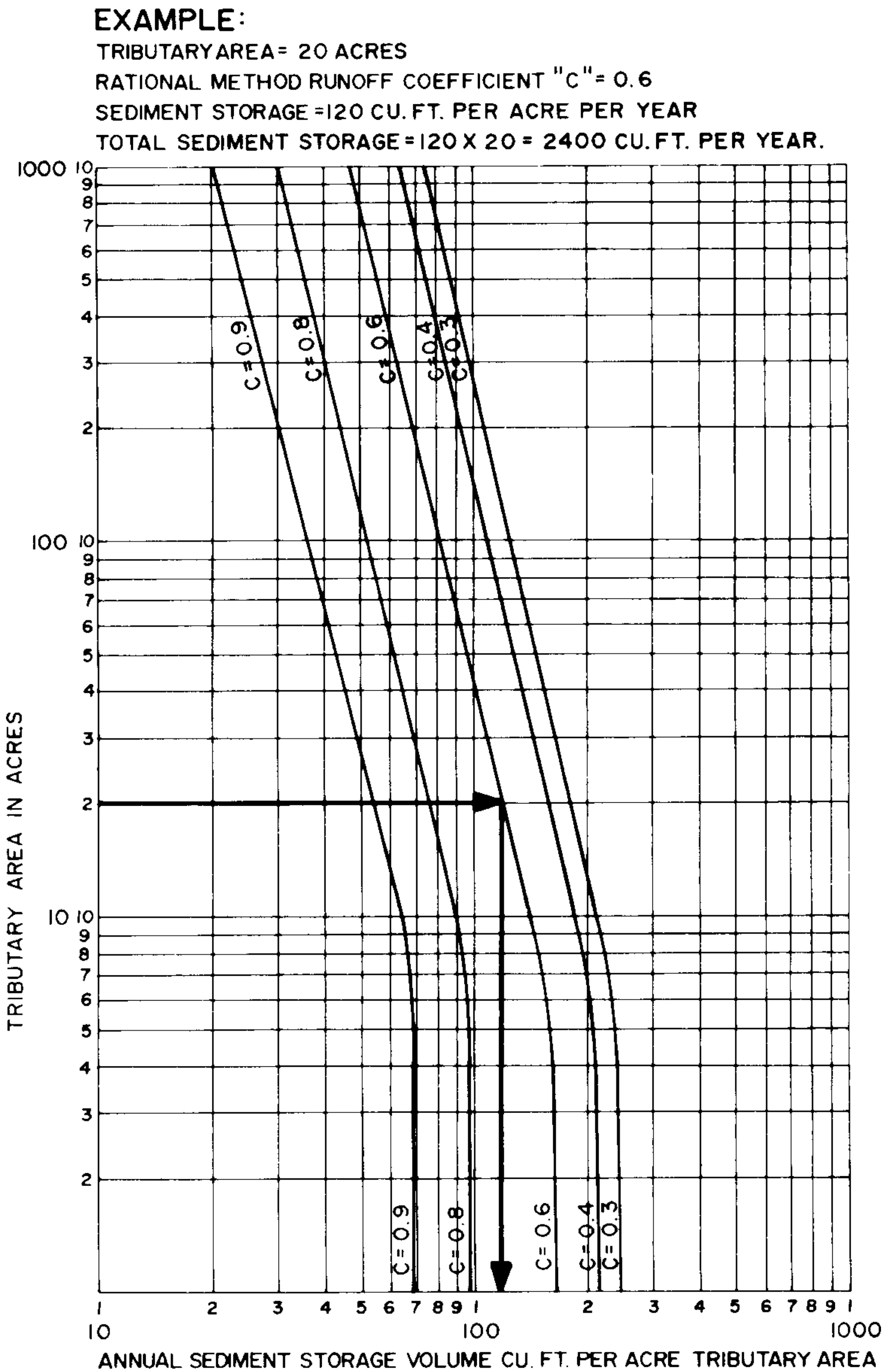


Figure 5608-1: Annual Sediment Storage

SECTION 5609 SUBMITTAL REQUIREMENTS

5609.1 Scope

The section governs the preparation of the Stormwater Drainage Permit and construction plans for the stormwater management components of projects.

5609.2 Stormwater Drainage Permit Requirements

A Stormwater Drainage Permit per the City of Warsaw Code of Ordinances Chapter §405.020 is required to demonstrate compliance with this design criteria. The purpose of the drainage permit is to identify existing and potential drainage issues and delineate required stormwater infrastructure early in the development process so that stormwater management is proactively planned for with improvements. The Stormwater Drainage Permit shall include the following items and associated project details:

A. **Watershed Location Map**: designer shall develop a watershed location map to identify the project's location within the watershed, which shall depict the following:

1. Watershed boundary and area (acres)
2. Delineated drainage area to the project (acres)
3. Natural drainage paths (may reference Appendix A Warsaw Natural Drainage Paths, 2016 LiDAR-based delineation)
4. Water bodies (lakes, rivers, streams, creeks, wetlands, etc.)
5. Stormwater retention/detention facility location(s) in watershed affecting stormwater management at project site (if applicable)
6. Conveyance route for overflow system to downstream destination of runoff

B. **Existing and Proposed Site Conditions Maps**: the designer shall develop a Site Conditions Map to compare existing site drainage with proposed site drainage. This map is used to verify that proposed site conditions mimic natural topography, maintain overland drainage paths, and provide appropriate stormwater drainage setbacks to protect natural resources. The following shall be depicted on the Site Conditions Map:

1. Existing Site Conditions
   - **a.** Existing contours
   - **b.** Aerial imagery
   - **c.** Water bodies (lakes, rivers, streams, creeks, wetlands, etc.)
   - **d.** Utilities, including existing stormwater infrastructure
   - **e.** Natural drainage paths
   - **f.** Parcel boundaries
   - **g.** Impervious surfaces and types (i.e. building, parking lot, etc.)
   - **h.** Key statistics (areas of boundaries, area of impervious surfaces, etc.)
2. Proposed Site Conditions
   - **a.** Proposed contours including finished floor elevation (FFE) and lowest opening elevation (LOE) information
   - **b.** Utilities, including existing stormwater infrastructure

c. Overland drainage paths

d. Parcel boundaries

e. Impervious surfaces and types (i.e. building, parking lot, etc.)

f. Stormwater improvements (i.e. detention/retention facilities, open and enclosed conveyance systems, storm drainage structures, etc.)

g. Drainage easements depicting maintained stormwater drainage setbacks and dimensions

C. **Stormwater Improvement Calculation Tables**: include the following calculation tables for applicable stormwater drainage system components, detailed in the Stormwater Drainage Permit application.

1. Hydrology
2. Conveyance
3. Collection (Inlets)
4. Retention
5. Detention

5609.3 Type of Sheets in Construction Plans

The plans shall include all information necessary to build and check the design of storm drainage systems and related appurtenances. The plans shall be arranged as required by the City/County Engineer. Applicable standard plans of City/County may be included in whole or by reference.

Plans shall be sealed by a Registered Professional Engineer in the state of Missouri and shall be submitted to the City/County for review.

The plans shall consist of:

A. Title sheet

B. General layout sheets

C. Plan and profile sheets

D. Cross-section sheets including GSI/stormwater BMP section details

E. Drainage area map and table

F. Standard and special detail sheets

G. Traffic control plans (if required)

H. Temporary erosion control plans including control and protection plans for GSI/stormwater BMPs

I. Grading plans (if required) including retention and detention design parameters

J. Property line and easement sheets (if required)

K. Each sheet shall contain a sheet number, including the individual sheet number and the total number of sheets, proper project identification and all revision dates.

L. Engineer’s seal shall appear on the title sheet and other sheets as required by the State licensing requirements.

5609.4 Sheet Sizes

The suggested sheet size is 22 inches by 34 inches (full-size) with all text legible when printed to half-size scale (11 inches by 17 inches). All sheets in a given set of plans shall be of the same size. Plan and profile shall be drawn on combined or separate plan and profile sheets to minimum scales indicated herein.

5609.5 Scales

Plans shall be drawn at the minimum scales indicated in Table 5609-1. Other scales may be needed to clearly present the design. Bar Scales shall be shown on each sheet for each scale.

Table 5609-1: Drawing Scales

Drawing Type	Scale
Plan	1 inch = 20 feet
Profile	
Horizontal	1 inch = 5 feet
Vertical	1 inch = 20 feet
Cross Sections	
Horizontal	1 inch = 5 feet
Vertical	1 inch = 10 feet
Drainage Area Map	
Onsite	1 inch = 5 feet
Offsite	1 inch = 10 feet
Structural Plans	¼ inch = 1 foot

5609.6 Required Information for Title Sheet:

- **A.** Name of project
- **B.** Project number
- **C.** Index to sheets
- **D.** A location map adequately showing the project location in relation to major streets, with north arrow and scale. Map shall be oriented with north arrow up
- **E.** A signature block for City/County approval
- **F.** Name, address and telephone number of the consulting engineer and owner/developer as well as signature block for the owner/developer
- **G.** A legend of symbols shall be shown that apply to all sheets
- **H.** List containing name and telephone number of each utility company and state One-Call system
- **I.** Engineer's seal, signed and dated
- **J.** Other information as per City/County requirements

5609.7 Required Information for General Layout Sheet:

- **A.** General Notes: Minor construction notes shall appear on the proper plans and profile sheets
- **B.** North arrow and bar scale. North arrow shall be oriented up or to the right
- **C.** Surveyed or aerial base map detail indicating existing man-made or natural topographical features, such as buildings, fences, trees, channels, ponds, streams, etc., and proposed and existing utilities

D. Subdivision information including, but not limited to, rights-of-way; property and lot lines; existing and proposed easements; subdivision nomenclature; street names; and other pertinent information impacting the project

E. Identification and location of all existing and proposed drainage features

F. Elevation and location of all applicable benchmarks: datum shall be as required by the City/County. A minimum of two (2) benchmarks are required for each project

G. Survey control line or base line with adequate ties to land lines

H. Locations of test borings if taken

I. Existing and finish grade contours at intervals of 2.0 feet or less in elevation; or equivalent detail indicating existing and finish grades and slopes

J. A uniform set of symbols subject to the approval of the City/County

K. Addresses of homes abutting the projects, and current homeowner names associated with properties impacted by the project

5609.8 Required Information for Plan and Profile Sheets:

A. North arrow and bar scale. North shall be oriented such that profile alignments are shown from downstream to upstream, left to right, respectively.

B. Ties to permanent reference points for each system

C. A uniform set of symbols subject to the approval of the City/County

D. Existing man-made and natural topographic features, such as buildings, fences, trees, channels, ponds, streams, etc., and all existing and proposed utilities

E. Identification and location of each storm drainage segment and existing utilities affecting construction

F. Length, size and slope of each line or channel segment. The profile shall indicate the hydraulic grade line of the underground as well as the overland design flows

G. Right-of-Way, property, easement lines and street names

H. The 1 percent floodplain and setback from the top of bank of an open channel to any building

I. Location of test borings

J. Existing and finish grade contours at intervals of 1.0 feet or less in elevation; or equivalent detail in profiles and cross-sections indicating existing and finish grading

K. Headwater elevation at the inlet end of each culvert

L. Invert elevations in and out and top elevations of each structure shall be shown.

M. Each utility line crossing the alignment shall be properly located and identified as to type, size and material. This information shall be to the best information available and provided through records, field prospecting and or excavation

N. Test borings representing depth of drilled hole and refusal elevation if applicable

O. All station and invert elevations of manholes, junction boxes, inlets and other significant structures

P. The profile shall show existing grade above the centerline as a dashed line, proposed Finish grades or established street grades by solid lines; and shall show the flow line of any drainage channel, either improved or unimproved, within 50-feet of either side of centerline. Each line shall be properly identified. The proposed sewer shall be shown as double solid lines properly showing the top and bottom of pipe

Q. All structures shall be shown and labeled with appropriate drawing references

5609.9 Cross-Section Sheets

Cross-sections shall be drawn for all open channels and GSI/stormwater BMPs. Sections for channels shall be at appropriate intervals not greater than 50 feet or at any changes to the section geometry. Additional cross sections shall be drawn at all structures and intersecting drainage systems. Cross sections shall also provide for overflow drainage paths that are designated to convey overland flows in excess of underground system capacity. The following shall be indicated on each section:

A. Ties from centerline to base line.

B. Existing and proposed grades.

C. Elevation of proposed flow-lines.

D. Cut and fill end areas if required for bid quantities.

E. GSI/stormwater BMPs sections shall specify media depths and pertinent piping/structure configurations and elevations. A summary table shall be included summarizing GSI/stormwater BMP target and provided storage volumes. This information may be included with the cross-sections, or, the grading plan sheets per Paragraph 5609.14. See the KCMO GSI Manual for additional recommendations and details to include for GSI components.

5609.10 Drainage Area Map

The drainage area map shall be supported by a drainage table tabulating the physical properties of the drainage sub-basins, as well as the hydrologic and hydraulic properties of the design. The drainage map shall have the following.

A. North arrow and bar scale. North shall be oriented up or to the right.

B. Drainage area boundaries for all watersheds including sub-watersheds of analysis including pass through waters, inlet drainage areas, culvert drainage areas and other points of interest.

C. Natural drainage paths (may reference Appendix A Warsaw Natural Drainage Paths, 2016 LiDAR-based delineation).

D. Drainage system nomenclature matching that on the “designed” systems shown in the plans.

5609.11 Standard and Special Detail Sheets

Detail sheets shall be included to show all details of appurtenances, materials and construction. Details shall conform to the requirements of the City/County and are to be drawn clearly and neatly with proper identifications, dimensions materials and other information necessary guide desired construction. Details shall be provided for all GSI/stormwater BMP components specified in the cross sections (Paragraph 5606.9) and grading plans (Paragraph 5609.14). See the KCMO GSI Manual for additional recommendations and details to include for GSI components.

5609.12 Traffic Control Plans (if required)

Traffic control plans shall conform to design and principals contained the most recent copy of Manual of Uniform Traffic Control Devices (MUTCD).

5609.13 Temporary Erosion Control Plan Sheets

A. Each temporary erosion control feature designation shall be shown in its proper location on the plans

B. Temporary erosion control devices shall be detailed in the plans as necessary.

- **C.** Notes shall be included in the plans indicating that the erosion control systems shall be monitored throughout the project life and maintained and adjusted as necessary to control erosion.
- **D.** Erosion control plans shall be shown and be designed specific to each phase of development or construction.
- **E.** Erosion control plans shall provide for internal site erosion control and protection for all green stormwater infrastructure/post-construction permanent stormwater BMPs. Internal erosion control plans shall include identification and protection of areas and soil/aggregate media intended for infiltration with notes describing maintenance requirements for protection measures, timing for installation, replacement, and permanent removal.

5609.14 Grading Plan Sheets (if required)

Grading plan sheets shall be included as required by the City/County. The grading plans shall incorporate information concerning the changes in the land geometry to accommodate the development. It shall include but not be limited to:

- **A.** Existing and proposed contours
- **B.** Contour and/or spot elevations for all retention/detention facilities, including GSI/stormwater BMPs. Include a summary table specifying facility stage (elevation), storage, and discharge relationships with associated design storm water surface elevations.
- **C.** Building and finished floor elevations
- **D.** Curb elevations
- **E.** Retaining wall elevations
- **F.** Sufficient spot elevations to verify storage depths, slope and finished grade elevation requirements meet the design criteria specified herein.

5609.15 Property Line and Easement Sheets

Separate property line and easement sheets may be required to adequately show required stormwater drainage setbacks. The information on this sheet shall be sufficient to display the existing and proposed property line and easement changes relative to the project.

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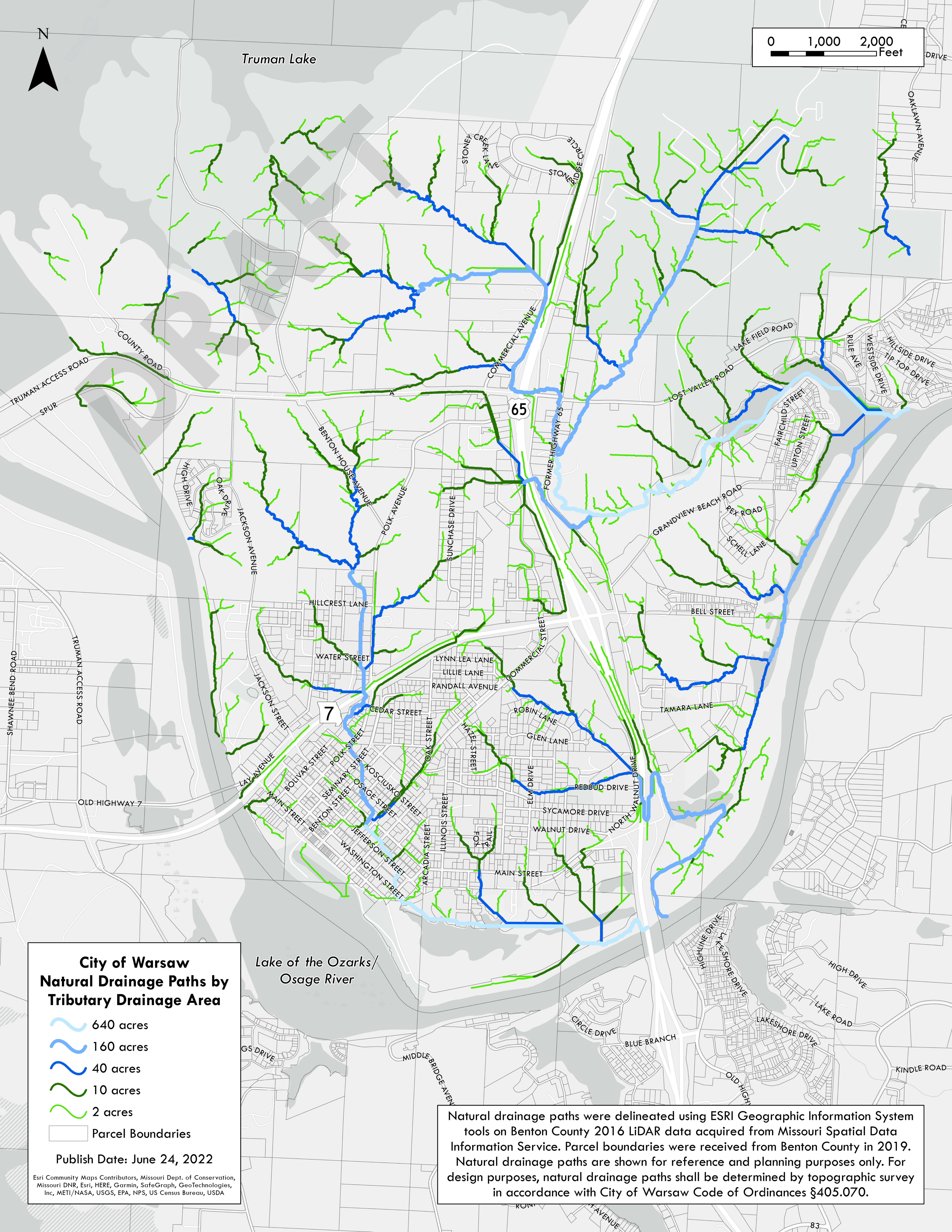
APPENDIX A

Warsaw Natural Drainage Paths

(2016 LiDAR-based delineation)



N
Truman Lake
0 1,000 2,000 Feet
DRAFT
Lake of the Ozarks/ Osage River
TRUMAN ACCESS ROAD
SPUR
COUNTY ROAD
A
65
7
83
STONEY CREEK LANE
STONE RIDGE CIRCLE
COMMERCIAL AVENUE
FORMER HIGHWAY 65
LAKE FIELD ROAD
LOST VALLEY ROAD
RULE AVE
WESTSIDE DRIVE
HILLSIDE DRIVE
TIP TOP DRIVE
OAKLAWN AVENUE
FAIRCHILD STREET
UPTON STREET
GRANDVIEW BEACH ROAD
REX ROAD
SCHELL LANE
BELL STREET
TAMARA LANE
HIGH DRIVE
OAK DRIVE
JACKSON AVENUE
BENTON HOUSE AVENUE
POLK AVENUE
SUNCHASE DRIVE
HILLCREST LANE
WATER STREET
LYNN LEA LANE
LILLIE LANE
RANDALL AVENUE
COMMERCIAL STREET
CEDAR STREET
ROBIN LANE
GLEN LANE
JACKSON STREET
SHAWNEE BEND ROAD
TRUMAN ACCESS ROAD
LAY AVENUE
OLD HIGHWAY 7
BOLIVAR STREET
POLK STREET
SEMINARY STREET
KOSCIUSKO STREET
OSAGE STREET
BENTON STREET
MAIN STREET
OAK STREET
HAZEL STREET
ELM DRIVE
REDBUD DRIVE
NORTH WALNUT DRIVE
SYCAMORE DRIVE
WALNUT DRIVE
JEFFERSON STREET
WASHINGTON STREET
ARCADIA STREET
ILLINOIS STREET
FOX TRAIL
MAIN STREET
HIGHLINE DRIVE
LAKESHORE DRIVE
HIGH DRIVE
LAKE ROAD
LAKESHORE DRIVE
CIRCLE DRIVE
BLUE BRANCH
MIDDLE BRIDGE AVENUE
KINDLE ROAD
OLD HIGHWAY
City of Warsaw
Natural Drainage Paths by Tributary Drainage Area
640 acres
160 acres
40 acres
10 acres
2 acres
Parcel Boundaries
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Natural drainage paths were delineated using ESRI Geographic Information System tools on Benton County 2016 LiDAR data acquired from Missouri Spatial Data Information Service. Parcel boundaries were received from Benton County in 2019. Natural drainage paths are shown for reference and planning purposes only. For design purposes, natural drainage paths shall be determined by topographic survey in accordance with City of Warsaw Code of Ordinances §405.070.