

Think NATURAL RESOURCES
Town of CLAYTON STORMWATER



**TOWN OF CLAYTON
STORMWATER DESIGN MANUAL**

10/18/2024

STORMWATER DESIGN MANUAL

(Last Revised 10/18/24)

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Section 1 – INTRODUCTION & GENERAL GUIDELINES

(Last revised 10/18/24)

1.1 INTRODUCTION AND PURPOSE

These standards are meant to interpret and clarify the Stormwater Design Guidelines of the Town of Clayton, as described in Section 6.15 *Stormwater* of the Town of Clayton UDO, as applicable.

The Town's land use and development policies are discussed in broad terms as "livability", "public safety", and "variety of housing mix." The Town of Clayton's UDO, Section 4 *Land Uses*, contains community-wide goals and objectives which emphasize the existing character of the Town and its neighborhoods. The UDO also deals with the more specific concepts such as types of use, lot sizes, parking, zoning, and the like.

The Unified Development Code/UDO also requires that development and re-development activities properly manage and control stormwater runoff rates, volume, pollutants, and erosion and sedimentation as necessary to protect and safeguard the environment, property, health, safety, and welfare of the citizens within the Town's jurisdiction.

However, even these more specific terms can be interpreted in a variety of ways, especially where a specific location is being considered. Therefore, the Town of Clayton's Stormwater Design Manual has been prepared to help designers involved with land development in Clayton and its planning ETJ to understand, before they begin, what will most likely be acceptable in this jurisdiction. These standards are intended to compliment and supplement the general design guidelines included in the Code of Ordinances.

Specific design criteria set forth herein provide a ready reference of those practices and techniques acceptable to the Town. The Town also encourages design professionals to consider site characteristics closely in their design and to seek new and better practices and techniques for complying with Town development policies and regulations. If, in response to the characteristics of a particular site, innovative practices, and/or technological changes, a designer can make a valid case for application of standards that modify or substitute for the design standards contained herein, he or she is encouraged to do so.

Where alternative standards can be shown to conform to applicable policies and regulations, the Town may accept such alternative standards in lieu of the standards contained herein. Similarly, where a particular site is characterized by a large number or extent of impediments to developing land in compliance with applicable policies and standards, or where technological changes provide for practices and techniques that better ensure compliance, the Town itself may modify or substitute additional standards for the design standard continue herein.

These standards include deadlines for improvements. The Town Manager may allow extensions of deadlines provided these extensions:

1. Will not conflict with the intent of these standards and other land development regulations, and
2. Include a practical justification for an extension.

1.2 DISCLAIMER

To the best of their ability, the author(s) of this manual ensured that the material is accurate and reliable for use by others in the development of stormwater management plans and calculations. It is the final responsibility of the design professional to ensure that any methods, procedures and techniques specified in this manual are appropriate for a given situation. The Town of Clayton does not accept responsibility for any cost, loss, damage or injury resulting from the use of this manual.

1.3 COMPLIANCE

Compliance with these standards shall be required at the time the property is developed, whenever a major increase in intensity of use is created as determined by the Town Manager, or whenever a use change occurs as outlined in the Town of Clayton's Code of Ordinances.

The Town Manager may exempt modifications to existing developments from individual provisions of these standards where, in the opinion of the Town Manager, compliance with those provisions would create a practical hardship upon the property owner and where the modification does not increase a nonconformity.

The Design Manual, Standard Specifications, and Standard Details will be updated as necessary from time to time, and the revised page(s) will be available from the Engineering Department and on the Town's website at <http://www.townofclaytonnc.org/>

1.4 ENGINEERING DIRECTOR

The Engineer Director shall be responsible for interpretation and implementation of the stormwater management and design criteria for the Town of Clayton. Approval from other applicable agencies may be required.

1.5 TOWN OF CLAYTON STORMWATER MANAGEMENT

It is the policy of the Town of Clayton that all developed land within the Town Limits has adequate stormwater facilities and controls to ensure the protection and safety of life and property. The Town may accept stormwater management systems for maintenance if the system provides drainage for streets that have been accepted for maintenance by the Town provided such facilities adequately address the NPDES regulations and have been designed and constructed in accordance with the provisions of the Town of Clayton Code of Ordinances/UDO, and the latest revision to the following documents which are herein made part of this manual by reference:

- The North Carolina [Erosion and Sediment Control Planning and Design Manual](#).
- NCDEQ Division of Energy, Mineral, and Land Resources, [Stormwater Design Manual](#).

- Town of Clayton *Manual of Specifications, Standards, and Design*.

1.6 PERMITS

- A. **Plan approvals, Permits:** Prior to commencing construction, all plan approvals and applicable permits shall be obtained. A preconstruction conference with the Town Inspector must also be held prior to commencing any construction.
- B. **Encroachment Permits:** An encroachment permit will be required from any Contractor or Developer wishing to excavate or place storm drainage structures on either a NCDOT or Municipal public right-of-way.
- C. **Pavement Cuts:** Pavement cuts in streets shall be repaired in accordance with the specific requirements of public agency on whose street or roadway the utility is being placed, as well as any other applicable requirements dictated in the approved encroachment permit. Open cut crossings shall otherwise adhere, as applicable, to specification Section **02275, Trenching, Backfilling & Compaction of Utilities**.
- D. Developer must obtain all other State and Local permits, as applicable (Air Quality, Erosion and Sedimentation Control, Zoning, etc.)
- E. **Plan Review and Observation Fees:** All plan review and observation fees must be paid prior to approval of project. Refer to the current Town fee schedule for applicable fees.
- F. Approval of Stormwater Management Plans and Calculations by the Town of Clayton does not complete the Town of Clayton review process. All other applicable Town Departments, State, and Federal agencies must also approve the plan as warranted. It shall be the sole responsibility of the Owner/ Developer/ Designer to acquire all applicable approvals.

1.7 WETLANDS, WATERSHEDS, BUFFERS

All stream impacts by crossings, pipe placement, excavation, regrading, clearing, maintenance, etc., shall be subject to the applicable US Army Corps of Engineers 404 and NCDEQ DWQ 401 permit requirements in affect at the time of the permit application. Construction within jurisdictional wetlands and buffers shall conform to the applicable permit requirements of the issuing agency.

1.8 EROSION AND SEDIMENTATION CONTROL AND NPDES MONITORING, CONTROLS, AND LIMITATIONS FOR PERMITTED DISCHARGES

The Project Engineer shall submit a sedimentation and erosion control plan to the Town and obtain all necessary construction permits. The Contractor shall follow both local and state requirements regarding sedimentation and erosion control. Construction methods shall minimize sedimentation and erosion.

It is the Contractor's responsibility to periodically monitor the Stormwater Discharge Outfall points at the specified frequency and maintain reports as outlined in these specifications.

A. Final Limitations and Controls for Stormwater Discharges

During the period beginning on the effective date of the permit and lasting until expiration, the Owner (Permittee) is allowed and authorized to discharge stormwater associated with construction activity. Such discharges shall be controlled, limited, and monitored as specified below.

1. The Contractor shall implement the Erosion & Sedimentation Control plan, which has been approved by the Town. The approved plan is considered a requirement or condition of the general NPDES permit. Deviation from the approved plan, or approved amendment to the plan, shall constitute a violation of the terms and conditions of this general permit except that deviation from the approved plan will be allowed:
 - a. To correct an emergency situation where sediments are being discharged off the site, or
 - b. When minor modifications have been made for the purpose of improving the performance of the erosion and sedimentation control measures and notification of the minor modification has been made to the NCDEQ.

Such a deviation from the approved plan shall be noted on the approved plan maintained at the job site. During active construction, a copy of the approved plan shall be maintained on the site.

2. Equipment utilized during the construction activity on a site must be operated and maintained in such a manner as to prevent the potential or actual pollution of the surface or ground waters of the state. Fuels, lubricants, coolants, and hydraulic fluids, or any other petroleum products, shall not be discharged onto the ground or into surface waters. Spent fluids shall be disposed of in a manner so as not to enter the waters, surface, or ground of the state and in accordance with applicable state and federal disposal regulations. Any spilled fluids shall be cleaned up to the extent practicable and disposed of in a manner so as not to allow their entry into the waters, surface or ground, of the state.
3. Herbicide, pesticide, and fertilizer usage during the construction activity shall be consistent with the Federal Insecticide, Fungicide, and Rodenticide Act and shall be in accordance with label restrictions.
4. All wastes composed of building materials shall be disposed of in accordance with North Carolina General Statutes, Chapter 130A, Article 9 – *Solid Waste Management*, and rules governing the disposal of solid waste (North Carolina Administrative Code Section [15A NCAC 13B](#)).
5. The Contractor, for the Permittee, shall control the management and disposal of litter and sanitary waste from the site such that no adverse impacts to water quality occur.

B. NCG01 General Permits

Contractor and developer to abide by all requirements and conditions of [NCG01 General Permit](#) as part of NPDES compliance.

1.9 EASEMENTS

Drainage easements are required for all public and private drainage systems which carry water from the Town right of way or Town owned property. This includes commercial developments with out-parcels, phased development and other developments with surrounding land under the same ownership at the tract being developed.

1.9.1. Public Drainage Easement Maintenance

Property owners are responsible for routine grounds maintenance such as grass mowing and trash or debris removal and should ensure that systems are kept free of yard waste such as grass clippings, tree trimmings, and leaves that may block the flow of water. No structures, fences, walls, HVAC equipment, trees, shrubs, hardscapes or other items that obstruct maintenance vehicles may be installed within drainage easements (see paragraph [7.2.5 Final Plat Notes](#)). The Town maintains the drainage system and structures within the easement to allow for proper function of the system. The Town will clean the ditch if it is blocked by natural causes.

The Town may deny acceptance of any drainage system that does not provide the proper legal authority for access, operation and maintenance of the system.

1.9.2. Drainage Easements Requirements:

- A. For all culverts, all new or existing open channels or watercourses that carry water from public rights-of-way or convey water from adjoining property across the developing property. Width of the easements shall be per [Table 1.2](#) below.

Table 1.2
Drainage Easement Widths for Culverts

Description	Min. Easement Width
Up to 24"	20 ft.
36" to 48"	30 ft.
Larger than 48"	Width of Pipe + 30 feet
Open Channels	Top of Bank Width + 20 ft.

- B. For all stormwater control measures, the SCM shall be located in a stormwater easement with a minimum width of 15 feet beyond the top of bank or toe of slope and as necessary to provide access for maintenance. The SCM system includes the side slopes, forebay, riser structure, SCM device, basin outlet, dam embankment and emergency spillway.
- C. For all new or existing open channels or watercourses with peak flows of 15 cubic feet per second or more for the 10-year storm.

- D. At other locations deemed appropriate by the Engineering Director or Stormwater Administrator.

1.9.3. Additional Easement Requirements:

- A. Appropriate drainage easements must be secured prior to the submission of the construction plat if the easement(s) is entirely or partially located offsite.
- B. Access easements, dedicated to the Town, shall be provided for access and repair of velocity dissipaters, headwalls, and other structural portions of the drainage system located outside of the right-of-way, which are immediately adjacent to and directly associated with the Town owned portion of the drainage system. These easements are requested to allow Town staff access to repair and maintain those drainage facilities located immediately adjacent to the right-of-way, which would endanger the roadway should they fail.
- C. Adequate easements shall be provided to allow access for construction equipment, taking into consideration the limitations that may be imposed by embankment slopes or other obstacles.
- D. Drainage easements containing only storm drainage facilities should be centered over the culvert or watercourse.
- E. All drainage easements should be recorded based on field surveys, following construction, to ensure that the drainage structure or watercourse is centered within the easement (unless specifically offset). Where this is not possible, a note shall be added to recorded plats establishing that easements are to be centered over the pipe or channel.
- F. Consideration shall be given for deeper cuts (generally greater than 12") by including an additional construction easement (usually 10'-20').
- G. All drainage easements shall be designed to tie into existing easements, existing watercourses or to other appropriate locations when possible.
- H. Easements shall be fully accessible (in slope and width) by rubber-tired vehicles in their entirety.
- I. Drainage easements for ditches that convey stormwater across lot lines shall be provided. Private drainage easements which cross property lines are the responsibility of HOA to maintain.
- J. Public drainage easements shall be located in open space to the maximum extent practicable.
- K. Public drainage easements should NOT be combined with other utility easements. The easements may overlap but the physical utility shall not encroach on the easement of another utility.
- L. **Final Plat:** The following notes shall be placed on all Final Plats that require drainage easements or SCMs:

- i. “The drainage easements and stormwater control measures shown hereon are required on the property to meet Town and state stormwater regulations. Property Owner may be subject to enforcement actions if the maintenance easement is obstructed or stormwater control measure is removed, relocated or altered without prior Town approval.”
- ii. “No structures, fences, walls, HVAC equipment, trees, shrubs, hardscapes or other items that obstruct maintenance vehicles may be installed within drainage easements. Per the Operation and Maintenance Agreement recorded in the Register of Deeds, the property owners grant the Town the right, privilege and easement across the property for the purpose of inspecting, monitoring, etc., the stormwater control measure as needed. Note that maintenance of the drainage easement is the responsibility of the underlying property owner, who shall maintain the easement to allow positive conveyance of stormwater.”

Section 2 – HYDROLOGIC ANALYSIS

The purpose of this section is to establish standard design procedures and criteria for the performance of hydrologic analyses in the Town of Clayton. Development and re-development within the Town of Clayton jurisdiction is required to manage stormwater in accordance with Town UDO. This section of the Design Manual provides information on the design and application of acceptable means and measures to comply with the requirements of that Ordinance.

Acceptable stormwater management practices include those found in this Design Manual and in the latest edition of the NCDEQ Division of Energy, Mineral, and Land Resources [Stormwater Design Manual](#), which is herein made part of this manual by reference. The Town reserves the right to modify, amend or otherwise change these accepted practices as may be necessary to achieve stated stormwater management goals.

2.1 HYDROLOGIC DESIGN

Hydrologic design includes evaluation of impacts that development has on stormwater runoff. The evaluation involves selecting the required design storm ([Table 2.1](#)) and using accepted hydrologic methodology to design storm drainage infrastructure, stream crossings, detention/retention facilities, etc., as necessary to meet the applicable requirements and the performance standards of the Town's Land Use Plan. Designers must evaluate the impacts of proposed stormwater management practices both on-site and on adjacent properties, structures, and roadways.

[Table 2.1](#) lists return periods for determining design storm and check storm discharges for different facility types. The check storm analysis should indicate that surcharge or overflow discharges will be conveyed in a controlled manner that will not cause public health or safety risk.

Table 2.1
Design and Check Storms

FACILITY	DESIGN STORM (SCS 24-HOUR DURATION)	CHECK STORM (SCS 24-HOUR DURATION)
Arterial Roadways	25-year	100-year
Collector streets	25-year	100-year
Local Roadways	10-year	25-year
Bridges/Box Culverts, Stream Crossings ¹	50-year	100-year
Open channels – normal runoff	10-year	25-year
Cross-drainage and drainage areas >1 square mile	25-year	-
Adjacent to building structures w/ flooding potential	100-year	-
SCM Structures/Non-structures	Per NCDEQ Stormwater Design Manual	
Drainage facilities for residential development accepting lot runoff only (no roadway discharge)	2-year	10-year
Drainage Facilities providing diffuse flow	10-year	25-year
Drainage Facilities for Parking Lot	10-year	25-year
Spillway structure for impoundment (i.e. detention/retention facilities)	25-year	100-year
Curb & gutters, curb & gutter inlets	2-year, 5 minute TC	-

¹ For regulatory Floodways, the Design Storm is the 100-year return period.

Where conflicts arise between applicable NCDEQ and Town design storm requirements, the more restrictive of the two shall govern.

Table 2.2

I-D-F Table

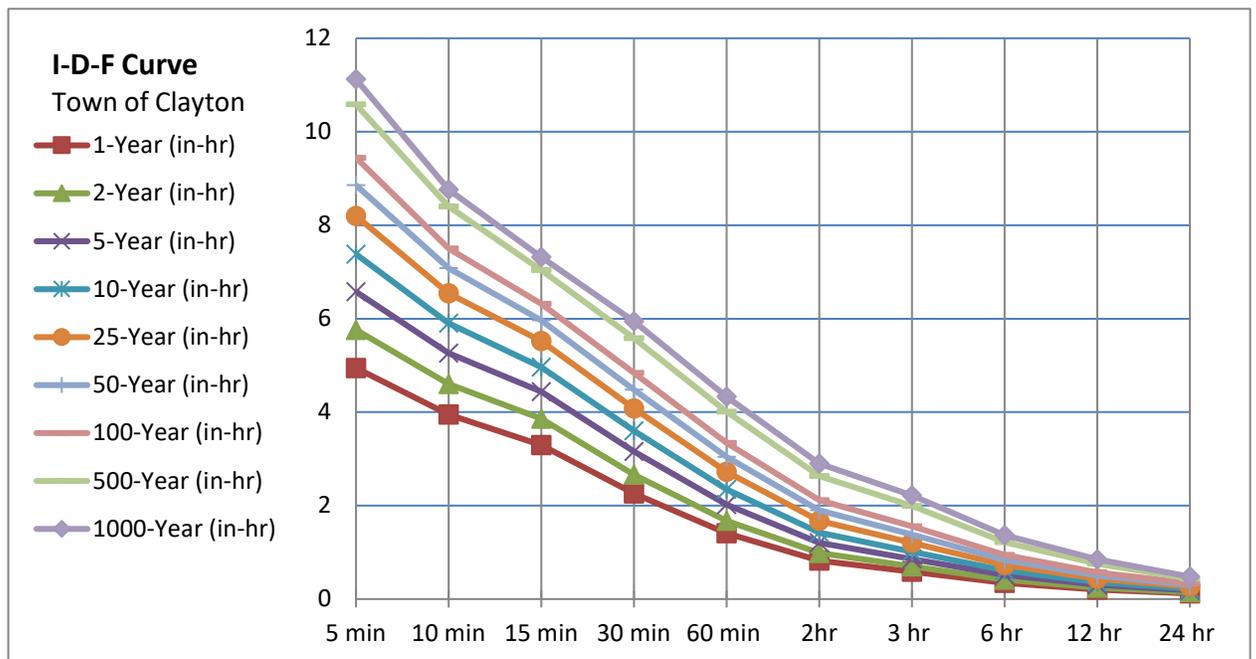
Return Period (years)	Duration									
	5 min	10 min	15 min	30 min	60 min	2hr	3 hr	6 hr	12 hr	24 hr
1-Year (in-hr)	4.94	3.95	3.29	2.26	1.41	0.83	0.58	0.35	0.21	0.12
2-Year (in-hr)	5.76	4.60	3.86	2.66	1.67	0.99	0.70	0.42	0.25	0.15
5-Year (in-hr)	6.58	5.26	4.44	3.16	2.02	1.21	0.86	0.51	0.30	0.19
10-Year (in-hr)	7.38	5.90	4.96	3.60	2.35	1.42	1.01	0.61	0.36	0.22
25-Year (in-hr)	8.20	6.54	5.52	4.08	2.72	1.68	1.21	0.73	0.44	0.26
50-Year (in-hr)	8.86	7.08	5.96	4.48	3.04	1.90	1.38	0.84	0.50	0.30
100-Year (in-hr)	9.44	7.50	6.32	4.84	3.34	2.12	1.56	0.95	0.57	0.34
500-Year (in-hr)	10.58	8.40	7.04	5.58	4.01	2.64	1.99	1.22	0.75	0.43
1000-Year (in-hr)	11.12	8.76	7.32	5.94	4.33	2.90	2.22	1.37	0.85	0.48

Source:

Point Precipitation Frequency Estimates From NOAA Atlas 14

Clayton, North Carolina Latitude: 35.6408° Longitude -78.4663° W 300 feet

Station: Clayton 3W: Site ID: 31-1820



Section 3 – PIPE GEOMETRIC DESIGN & MATERIALS

3.1 TOWN OF CLAYTON STORM DRAINAGE PIPE CRITERIA

The following criteria apply to storm drainage pipe under public streets within public rights-of-way, and/or within public drainage easements.

3.2 PIPE SIZE

The minimum pipe inside diameter is 15 inches.

3.3 PIPE MATERIAL – APPLICATIONS

- A. **General:** Use pipe type and placement conditions in accordance with Town **Paragraph 2.1 of Specification Section 02630.**

3.4 PIPE GRADE

- A. **MINIMUM PIPE SLOPE:** It is desirable to maintain a self-cleaning velocity in the storm drain to prevent deposition of sediments and subsequent loss of capacity. For this reason, storm drains should be designed to maintain full-flow pipe velocities of 3 fps or greater. This criteria results in a minimum flow velocity of 2 fps at a flow depth equal to 25% of the pipe diameter. Minimum slopes required for a velocity of 3 fps can be computed using the form of Manning's equation given below. Alternately, the "minimum" pipe slopes shown in [Table 3.1](#) can be used.

$$S = 6.4 \left(\frac{nV}{D^{0.67}} \right)^2 \quad (3.1)$$

$$S = 6.4 \left(\frac{NV}{D^{0.67}} \right)^2$$

Table 3.1¹
Minimal Pipe Slopes

D (in)	n =		
	0.012	0.013	0.024
12	0.0037	0.0043	0.0147
15	0.0027	0.0032	0.0109
18	0.0021	0.0025	0.0086
24	0.0015	0.0017	0.0058
30	0.0011	0.0013	0.0043
36	0.0008	0.0010	0.0034
42	0.0007	0.0008	0.0028
48	0.0006	0.0007	0.0023
54	0.0005	0.0006	0.0020
60	0.0004	0.0005	0.0017
66	0.0004	0.0004	0.0015
72	0.0003	0.0004	0.0013
84	0.0003	0.0003	0.0011

¹Slopes shown in table are based on 2 fps with flow depth at 25% of pipe diameter. Given slopes will yield 3 fps at full flow.

- B. **ACCEPTABLE VARIATION IN SLOPE:** The maximum permitted grade variation in post-construction pipe grade shall be -10% of the design grade. The computation of the post-construction pipe grade shall be based on a post-construction field survey. The grade shall be computed by taking the actual difference between the invert in and invert out of the pipe run divided by the actual pipe length. Pipe runs laid at less than the approved design grade must be removed and re-laid. The requirement to verify the pipe grades shall be at the Engineering Director's discretion. Verification of grades should be completed when installed slopes are questionable or in drainage locations where pipe slopes or installation of pipes are critical.

Example:

Design Grade: 0.005 ft/ft or 0.5%

Field Check of Grade:

*Surveyed Invert in = 96.50
less Surveyed Invert out = 96.04
Difference = 0.46 ft*

Actual Pipe Run Length = 100 ft (not measured C-C of Boxes!)

Slope = $\frac{0.46}{100} = .0046$ or 0.46%

Variation Check:

*Design Grade 0.50%
Actual Grade 0.46%
Difference: 0.04%*

Allowable deviation is 10% of Design Grade = 0.10 x 0.50% = 0.05%

Allowable deviation of 0.05% > 0.04% allowable deviation... VARIATION OK!

3.5 ENERGY LOSSES

Energy losses in pipe runs and structures must be estimated to overcome changes in momentum or turbulence at outlets, inlets, bends, transitions, and junctions in addition to the standard pipe friction loss. The following are the minimum standards to help determine the energy loss in the system for catch basins, drop inlets and junction boxes.

**Table 3.2a
Minimum Structure Invert Drop**

DEFLECTION ANGLE OF EFFLUENT LINE	DROP ¹
0-45°	0.1 ft or value computed from Table 3.2c
45°-90°	0.2 ft.
>90°	Only with detailed calcs showing headwater/tailwater conditions on influent/effluent pipes and impact on pipe, min drop > than the effluent pipe diameter

CHANGE IN PIPE SIZE	DROP ¹
Increase in pipe size	Crowns of pipe to match
Decrease in pipe size	Submit detailed study on effect of effluent line. Indicate any special provisions for maintenance resulting from increased velocity, headwater, etc.

¹Drops of less than that shown may be approved with the approval of the Engineering Director or Stormwater Administrator.

Table 3.2b
Inlet Coefficients
Outlet Control, full or partly Full Entrance Head Loss

$$H_e = K_e \frac{v^2}{2g}$$

Type of Structure and Design of Entrance	Coefficient K_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
¹ End-section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° 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
¹ End section conforming to fill slope	0.5
Beveled edges, 33.7° or 45° 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
Round on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30° to 75° to barrel	
Square-edged at crown:	0.4
Crown edge rounded to radius of ½ barrel dimension or beveled top edge	0.2
Wingwall at 10° to 25° 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: ¹"End-section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to a headwall in both inlet and outlet control. Some end sections incorporating a closed taper in their design have a superior hydraulic performance.

Ref: Norman, J. M., Houghtalen, R. J., and Johnston, W J., 1985. *Hydraulic Design of Highway Culverts*. HDS No. 5, Federal Highway Administration, McLean, VA.

Table 3.2c
Head Loss Coefficients

$$H_{ah} = K_{ah} \left(\frac{v_o^2}{2g} \right) \quad H_{ah} = K_{ah} \left(\frac{V_o^2}{2g} \right)$$

Structure Configuration	K_{ah}
Inlet – straight run, square edge	0.5
Inlet – angled through	
90°	1.50
60°	1.25
45°	1.10
22.5°	0.70
Manhole – straight run, min	0.15
Manhole – angled through	
90°	1.00
60°/120°	0.85
45°/135°	0.75
22.5°/157.5°	0.45

Ref: HEC No. 22, Table 7-5

3.6 PIPE ALIGNMENT:

- A. **Run Length:** The length of individual storm drain runs is dictated by storm drainage system configuration constraints and structure locations. Storm drain system constraints include inlet locations, maintenance equipment limits, access hole and junction box locations, etc. Where possible, storm drains should be straight between access boxes and shall not exceed the maximum run length between access boxes shown in [Table 3.3](#), unless otherwise approved by the Engineering Director or Stormwater Administrator.

Table 3.3
Maximum Pipe Run Length Between Structures

PIPE MATERIAL	SIZE (inches)	MAXIMUM RUN LENGTH (feet)
Reinforced Concrete Pipe	15 to 24	300
	30 to 36	400
	42 and 54	500 ¹
	60 and larger	1000 ¹
Double walled HDPE or HP PP Pipe	15 to 48	425
Corrugated Aluminum	Same criteria as RCP	

¹If catch basin spacing exceeds 300 feet, calculations justifying increased spacing shall be provided. See also [Curb Inlet Design – Gutter Spread, Section 10.4](#) and [Curb Inlet Design, Section 4.6](#).

²This length may be exceeded with approval by the Engineering Director on a case-by-case basis.

- B. **Alignment:** To reduce impact to utilities, all storm drain lines shall follow the curb line as much as practical (i.e. none behind curb or in street in curves).
- C. **Curved Pipe:** When approved by the Engineering Director or Stormwater Administrator, curved storm drains are permitted where necessary to conform to the street layout or avoid obstructions. Long radius bends, with beveled ends, are available from supplies and are the acceptable means of changing direction in pipes larger than 48 inches in diameter. The radius of curvature specified should coincide with the standard curves available from the supplier for the pipe diameter and class being used or otherwise fabricated by the supplier to conform to the radius required and approved by the Town.

Deflecting non-beveled standard pipe joints to obtain the necessary curvature is not permitted.

Pipes sizes 48 inches and smaller should not be designed with curves.

- D. **Pipe Bedding:** Bedding for culverts within public rights-of-way shall conform to Storm Drainage Section 02630, 3.1.2B (RCP) and Section 02630.1.3.C as applicable.

3.7 STRUCTURE PLACEMENT REQUIREMENTS:

A. **Pipes 48-inches or less:**

1. At vertical changes in grade
2. At horizontal changes in direction
3. At maximum run lengths shown in [Table 3.3](#). If a catch basin is not required, structure shall be a manhole junction box. No blind junction boxes are permitted (manhole access must be provided).
4. At all junction of 2 or more pipes
5. At all catch basins

B. **Pipes greater than 48 inches but less than 66 inches:**

1. Same as for Pipes 48 inches or less except:
 - a. *When approved by the Engineering Director or Stormwater Administrator, the horizontal change in direction is to be effected by a horizontal curve as an alternate means of changing pipe direction and the maximum run length is less than that required in [Table 3.3](#). However, the Engineering Director or Stormwater Administrator, at their discretion, may approve an integral riser for manhole access along a curve as a substitute for a manhole junction box should the curve length exceed the maximum permitted run length.*

C. **Pipes 66 inches in diameter and larger:**

1. Same as for Pipes greater than 48 inches but less than 66 inches except:
 - a. The main drain line and integral risers for a catch basins and manholes, inclusive of steps in the riser section only, shall be designed and

manufactured to carry the weight of the riser, grate and frame and any superimposed traffic loads. Risers shall be eccentric. If the main slope exceeds 1%, a standard manhole or manhole junction box will be required to be provided.

3.8 PIPE TERMINAL ENDS

- A. Headwalls/endwalls shall be provided for pipes with diameters larger than 36 inches unless alternative end treatments are approved by the Engineering Director or Stormwater Program Administrator. Flared-end sections may be used with pipes 36-inch or less in diameter.
- B. This requirement is also applicable at driveway culverts.

3.9 PIPE CAMBER IN ROADWAY FILL EMBANKMENTS

A roadway embankment exerts more load on the foundation at the center of the embankment than at the toe of the slope. Consequently, more settlement will occur in the center area of the embankment fill which will yield a corresponding settlement of the conduit. To avoid sag vertical deflection in the longitudinal pipe section, the bedding profile can be cambered longitudinally. The upstream half of the pipe may be laid on almost a flat grade and the downstream half on a steeper grade. The mid-ordinate of the curve should be determined by a Geotechnical Engineer.

3.10 COVER

Both the minimum and maximum cover must be considered in the design of storm drainage systems. Minimum cover limits are established to ensure the conduits structural stability under live and impact loads. With increasing fill heights, dead load becomes a controlling factor.

For the Town of Clayton, cover requirements shall conform to [Table 3.4](#). In cases where these criteria cannot be met, the storm drains should be evaluated to determine if they are structurally capable of supporting the imposed loads provided the reduced cover is allowed by the Engineering Director or Stormwater Administrator.

Maximum cover limits are controlled by fill and other dead loads. Maximum permitted height of cover is shown below in [Table 3.4](#). For heights exceeding these limits, the Engineer shall submit to the Engineering Director or Stormwater Administrator calculations showing the bury depth is satisfactory. The calculations shall consider pipe bedding, trench width, bury, pipe class, soil arching, live and/or dead loads as applicable, and material (flexible or rigid), etc.

**Table 3.4
Maximum Cover Depths**

Conditions	Minimum Cover Depth (ft)	Maximum Cover Depth
Roadways	*	*
Residential Driveways	1	*
Commercial Driveways	*	*
Non-traffic bearing	1	*
PP & HDPE	*	*
Corrugated Aluminum	*	Submit supporting documentation*

*See NCDOT *Pipe Material Selection Guide* (202 or latest revision) for minimum and maximum bury depths for RCP, CSP, CAAP, and Double Walled PP (gray) and HDPE Pipe

3.11 STRUCTURES IN RELATION TO STREAMS/FLOODPLAINS:

Storm drainage manholes, pipe, or other drainage structures shall be located so that they will not interfere with free discharge of the flood flows of the stream to which they are proposed to tie. Portions of manholes above grade subject to hydrodynamic forces of flooding shall be designed to resist the flood forces with a safety factor of 2.5. Considerations shall be given for impact from debris.

Section 4 – CULVERT DESIGN

The purpose of this section is to establish standard procedures and criteria for Culvert Design for the Town of Clayton.

4.1 INTRODUCTION

A drainage system shall be designed and constructed by the developer to provide for the proper drainage of the surface water of the development and the drainage area of which it is part. The storm drainage system shall follow existing topography as nearly as practical. Additional design information shall be submitted to indicate that provision has been made for the adequate disposal of surface water without any damage to the developed or undeveloped land downstream or below the proposed development. A copy of all drainage computations shall be submitted, clearly stating any assumptions made.

The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off-site areas, assuming ultimate development in accordance with the current zoning regulations and the Land Use Plan.

4.2 PIPE CULVERT DESIGN - GENERAL

Private drainage culverts and public drainage culverts within a subdivision or site development sub-basin shall be designed according to this section.

Pipe culverts shall be aligned parallel to the longitudinal axis of the channel, as much as possible, to ensure maximum hydraulic efficiency and to minimize erosion. In areas where a change in alignment is necessary, the change shall be accomplished upstream of the culvert in the open channel. Appropriate erosion protection shall be provided.

Pipe culverts crossing beneath the roadway shall be designed to span from ditch line to ditch line.

4.3 ROADWAY DRAINAGE SYSTEM

The road storm drainage system shall serve as the primary drainage system and shall be designed to carry roadway, adjacent land, and building stormwater drainage. No stormwater shall be permitted into the Town's sanitary sewer system.

4.4 DESIGN FREQUENCY

The design criteria for storm drainage shall be based upon the data prepared by NC Department of Transportation [Guidelines for Drainage Studies and Hydraulic Design](#), latest revision, USDOT Federal Highway Administration [Urban Drainage Design Manual](#), Hydraulic Engineering Circular No. 22, the [NC Erosion and Sediment Control Planning and Design Manual](#), NCDEQ Division of Water Resources [Stormwater Design Manual](#), the SCS [National Engineering Field Manual for Conservation Practices](#), or other acceptable calculation procedures.

The minimum design frequency for culverts shall conform to [Table 2.1](#), Section 2, Hydrologic Analysis.

4.5 HYDRAULIC DESIGN OF CULVERTS

4.5.1. FLOW TYPE ASSUMPTIONS

The design procedures presented here assume that flow within each storm drain segment is steady and uniform. This means that the discharge and flow depth in each segment are assumed to be constant with respect to time. Also, since storm drain conduits are typically prismatic, the average velocity through a segment is considered to be constant.

In actual storm drainage systems, the flow at each inlet is variable, and flow conditions are not truly steady or uniform. However, since the usual hydraulic methods employed in storm drain design are based on computed peak discharges at the beginning of each run, it is a conservative practice to design using the steady uniform flow assumption.

4.5.2. OPEN CHANNEL VS. PRESSURE FLOW

Two design philosophies exist for sizing storm drain under the steady uniform flow assumption. The first is referred to as open channel or *gravity flow design*. To maintain open channel flow, the segment must be sized so that the water surface within the conduit remains open to atmospheric pressure. For open channel flow, flow energy is derived from flow velocity (kinetic energy), depth (pressure), and elevation (potential energy). If the water surface through the conduit is to be maintained at atmospheric pressure, the flow depth must be less than the height of the conduit.

Pressure flow design on the other hand, requires that flow in the conduit be at a pressure greater than atmospheric. Under this condition, there is no exposed flow surface within the conduit. In pressure flow, flow energy is again derived from flow velocity, depth, and elevation. The significant difference here is that the pressure head will be above the top of the conduit, and will not equal the depth of flow in the conduit. In this case, the pressure head rises to a level represented by the hydraulic grade line.

The question of whether open channel or pressure flow should control design has been debated among various highway agencies. For a given flow rate, design based on open channel flow requires larger conduit sizes than those based on pressure flow. While it may be more expensive to construct storm drain systems design based on open channel flow, this design procedure provides a margin of safety by providing additional headroom in the conduit to accommodate an increase in flow above the design discharge. This factor of safety is often desirable since the methods of runoff estimation are not exact, and once placed, storm drains are difficult and expensive to replace.

However, there may be situations where pressure flow design is desirable. For example, on some projects, there may be adequate headroom between the conduit and inlet/access hole elevation to tolerate pressure flow. In this case, a significant cost savings may be realized over the cost of a system designed to maintain open channel flow. Also, in some cases it may be necessary to use an existing system which must be placed under pressure flow to accommodate the proposed design flow rate. In instances such as these, there

may be advantages to making a cursory hydraulic and economic analysis of a storm drain using both design methods before making a final selection.

Under most ordinary conditions, it is recommended that storm drains be sized based on a gravity flow criteria at flow full or near full. Designing for full flow is a conservative assumption since the peak flow actually occurs at 93% full. However, where shallow bury or headroom is critical and/or where the maximum permitted headwater over a street storm inlet must be verified not to exceed the given criteria, the system may have to be analyzed based on pressure flow criteria. However, the Town of Clayton will accept either method.

An example of pressure flow and gravity flow are shown in [Section 10.3](#).

4.5.3. HYDRAULIC GRADE LINE (HGL)

For enclosed piping systems, the HGL shall not exceed the crown of the pipe elevation for the 10-year, 24-hour storm event.

The HGL shall not exceed the top of structures or the gutter line elevation, as applicable, for the 25-year, 24-hour storm event.

4.5.4. METHODOLOGY

The Town of Clayton uses the design procedures of Hydraulic Design Series No. 5 (*HDS-5*) for the design of pipe culverts. *HDS-5* was designed to analyze flow in pipes using many different variables. The procedures in the *Urban Drainage Design Manual*, HEC-22, also may be utilized. HEC-22 utilizes many of the same procedures in pipe culvert analysis with references to *HDS-5*.

4.6 CURB INLET DESIGN

Curb storm drainage inlets shall be provided at intervals along roadways. Where these inlets connect to storm sewers, a catch basin shall be installed with the inlet.

NCDOT [Guidelines for Drainage Studies and Hydraulic Design](#), latest revision, or the USDOT Federal Highway Administration *Urban Drainage Design Manual*, [Hydraulic Engineering Circular No. 22](#), Chapter 4, as applicable, shall be used for curb inlet design.

For curb and gutter inlets, a minimum intensity of 2 year storm at 5 minute time of concentration shall be used in all computations (from [Table 2.1](#)). Table 2.1 lists return periods for determining design storm and check storm discharges for different facility types.

Inlet spacing and sizing shall be adequate to limit the spread of water to ½ the travel lane into the roadway. The travel lane is the outside lane and does not include the gutter section. Allowances shall be given for the potential of clogging at sumps. Due to clogging characteristics, the use of slotted drains alone are not recommended in sag locations. See also [Table 3.3, Maximum Pipe Run Length Between Structures](#) and [Curb Inlet Design – Gutter Spread, Section 10.4](#).

Table 4.6
Recommended Clogging Factors in Sump Condition¹

Number of Units	Grated Inlet	Curb Opening Inlet
1	0.50	0.12
2	0.35	0.08
3	0.25	0.05
4	0.15	0.03

Storm drainage inlets will be placed so that crosswalks will not be flooded during the design storm intensity.

Further information on **curb inlet design** and **gutter spread** is found in [Section 10.4](#).

4.7 EROSION CONTROL

All erosion and sediment control measures shall be designed in accordance with the [NC Erosion and Sediment Control Planning and Design Manual](#), and the NCDEQ Division of Energy, Mineral and Land Resources [Stormwater Design Manual](#). These manuals contain valuable information and tools for developing plans to minimize soil erosion and prevent sedimentation pollution associated with land-disturbing activities.

Erosion and Sedimentation Control is under the jurisdiction of the Town of Clayton. Refer to the Town of Clayton UDO, section 6.14 *Soil Erosion & Sedimentation Control* for applicable requirements.

All individuals that obtain a state or locally approved erosion and sedimentation control plan that disturbs one acre or more of land are required by the U.S. Environmental Protection Agency to obtain coverage under the N.C. Department of Environmental Quality Construction General Permit No. NCG010000 (NCG01). The requirements in NCG01 for temporary or permanent ground cover may differ from the ground cover, or stabilization, requirements in this chapter. It is the responsibility of the person conducting the land disturbing activity to ensure compliance with the NCG01.

¹ Table 10.1, Urban Hydrology and Hydraulic Design, James C. Y. Guo, Water Resources Publication, LLC, (Observed Conditions).

Section 5 – OPEN CHANNEL DESIGN

The purpose of this section is to establish standard procedures and criteria for Open Channel Design for the Town of Clayton.

5.1 INTRODUCTION

Open channels, where allowed, shall be designed according to the following criteria. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off-site areas, assuming ultimate development in accordance with the current zoning regulations and the Comprehensive Land Use Plan.

5.1.1. OFF-ROAD DRAINAGE SYSTEM

The design of the off-road drainage system shall include the watershed affecting the development and shall be extended to a watercourse or drainage way adequate to receive the storm drainage. Swales and channels shall be constructed true to definition and shall join the contours of the surrounding topography in such a manner that will create a gently rolling natural appearance. Side drainpipes along side property lines shall be extended to the back drainage easement.

When the drainage system is outside of the road right-of-way, the subdivision shall make provision for dedicating an easement to the Town of Clayton to provide for the future maintenance of said system.

5.1.2. REQUIRED DOCUMENTATION FOR OPEN CHANNEL DESIGNS

The following information must be submitted to the Town of Clayton for the design of open channels, but is not limited to the following:

- A. Vicinity Map: A vicinity map of the site and subject reach.
- B. Site Map: A detailed map of the area and subject reach.
- C. Drainage Map: A drainage map showing existing and proposed drainage area boundaries along with all sub-area delineations and all areas of existing or proposed development.
- D. Discharge Calculations: Discharge calculations specifying the methodology and key assumptions used, along with computed discharges at key locations. The designer's calculations shall include the runoff from the property being developed and the runoff from contributing off site areas, assuming ultimate development in accordance with the current zoning regulations and the Land Use Plan.
- E. Hydraulic Calculations: Hydraulic calculations specifying the methodology used. All assumptions and values of design parameters must be clearly stated.
- F. Plotted Cross-Sections: Typical existing and proposed cross-sections.

- G. When sizing channels, consideration shall be given to ultimate build out. Base flow may require incorporation of a trapezoidal low flow channel in the main trapezoidal ditch section.

5.2 OPEN CHANNEL DESIGN

The proper hydraulic design of a channel is of primary importance in ensuring that flooding, sedimentation and erosion problems do not occur.

Equations and nomographs are shown in [Section 10.5 Open Channel Design](#) for the convenience of the designer.

The following general criteria should be used in the design of open channels:

5.2.1. DESIGN FREQUENCIES FOR OPEN CHANNEL DESIGN

The design criteria for storm drainage shall be based upon the data prepared by NC Department of Transportation *Guidelines for Drainage Studies and Hydraulic Design*, USDOT Federal Highway Administration *Urban Drainage Design Manual*, [Hydraulic Engineering Circular No. 22](#), the [NC Erosion and Sediment Control Planning and Design Manual](#), NCDEQ Division of Energy, Mineral, and Land Resources [Stormwater Design Manual](#), or other acceptable calculation procedures.

All open channels in the Town of Clayton shall be designed to contain the peak runoff from the frequency storm shown in [Table 2.1](#), which includes the design to have sufficient freeboard to provide for adequate drainage of lateral storm sewers. Properties over which the surface waters are conveyed, from the development site to discharge point, shall not be adversely affected.

In those cases where channel modifications are necessary to control increased flow from proposed development, proposed water surface profiles are restricted such that the 100-year flood profile under existing conditions shall not be increased. If the capacity of the existing channel downstream of the project is less than the 100-year design discharge, consideration shall be given for more frequent events to ensure that the severity and frequency of downstream flooding is not increased.

5.2.2. CHANNEL GEOMETRY, SLOPE & VELOCITY

A. CHANNEL SIDE SLOPE

In grass-lined channels, the normal maximum side slope shall be no steeper than 3 horizontal to 1 vertical (3:1), which is the practical limit for mowing equipment. In some areas, local soil conditions may dictate the use of side slopes flatter than 3:1 to ensure slope stability.

B. CHANNEL BOTTOM WIDTH

In grass-lined channels, the minimum channel bottom width shall be 2 feet. In concrete-lined channels, the minimum bottom width shall be 2 feet except where concrete lined "V" shaped roadside ditches are used.

C. CHANNEL FLOW-LINE SLOPE

Slope of the channel flow-line (invert) is generally governed by topography and the energy head required for flow. Since flow-line slope directly affects channel velocities, channels should have sufficient grade to prevent significant siltation. However, slopes should not be so large as to create erosion problems. In the Town of Clayton, unless approved by the Engineering Director, the minimum recommended longitudinal slope shall be 0.4 percent (0.004). The use of flatter slopes must be approved by the Engineering Director. The maximum channel invert slope will be limited by the maximum flow velocities given in [Table 5.1](#). Appropriate channel drop structures may be used to limit channel invert slopes in steep areas.

D. CHANNEL FLOW VELOCITIES

Excessive flow velocities in open channels can cause erosion and destabilize side slopes and may pose a threat to safety. Velocities, which are too low, may allow the deposition of sediment and subsequent channel clogging. [Table 5.1](#) provides desirable average and maximum permissible design velocities based on 10-year storm peak runoff rates for newly vegetated or armor-lined channels.

Table 5.1
Flow Design Velocities for Newly Vegetated and Armored Channels

Channel Description	Average Velocity (Feet Per Second)	Maximum Velocity (Feet Per Second)
Grass Lined: Predominantly Clayey Soils	3.0	4.0
Grass Lined: Predominantly Sandy Soils	2.0	4.0
Rip-Rap Lined	5.0	8.0
Concrete Lined	6.0	10.0

5.2.3. CHANNEL PROTECTION

A. DRAINAGE WAYS

The development shall adequately protect all ditches and drainage ways to the satisfaction of the Town. Ditches and open channels shall be stabilized, seeded, and mulched, turf reinforced, sodded or armored, depending on grades and types of soils. As a general rule, ditches and channels, when permitted, shall be lined a follows:

**Table 5.2
Minimum Ditch Liners Requirements^a**

Grade	Liner
grades up to 1 percent	Seeded, mulched and tacked
grades of 1 to 4 percent	Turf Reinforcement/ Sod
grades over 4 percent	Armored

^aAll liners selected are to be designed in accordance with the requirements of the Erosion and Sediment Control Planning and Design Manual

Seeding, sodding, and armoring operations shall be in compliance with the [NCDOT Standard specifications for Roads and Structures](#), latest edition. It is not sufficient to have planted according to these specifications. There must be a good stand of permanent grass to meet this requirement. Calculation shall be made to determine the need for riprap outlet protection at pipe outlets.

B. EASEMENTS

The watercourse or ditch easement shall be wide enough to contain said ditch with ample clearance for the operation of maintenance equipment. The minimum easement width shall be 20 feet. See [Table 1.2](#).

C. DOWNSTREAM PROTECTION

Stream banks and channels downstream from the development shall be protected from increased degradation by accelerated erosion caused by increased velocity of runoff from the construction activity. Supporting calculations may be required at the discretion of the Town Stormwater Program Manager.

The construction activity shall be planned and conducted in such a manner that the velocity of storm water runoff in the receiving watercourse at the point of discharge resulting from the 10-year storm after development shall not exceed the greater of:

1. The velocity as determined from the velocity in the [NC Erosion and Sediment Control Planning and Design Manual](#), or
2. The velocity in the receiving watercourse determined for the 10-year storm prior to development.

If neither 1 nor 2 can be met, the channel below the discharge point shall be designed and constructed to withstand the expected velocity.

Measures applied alone or in combination to satisfy the intent of this paragraph are acceptable if there are no objectionable secondary consequences. Innovative techniques and ideas will be considered and may be used when shown to have the potential to produce successful results. Some alternatives are to:

- a. Avoid increases in surface runoff volume and velocity by including measures to promote infiltration to compensate for increased runoff from areas rendered impervious.
- b. Provide energy dissipaters at outlets of storm drainage facilities to reduce flow velocity at the point of discharge from the development; these may range from simple riprap sections to complex structures.
- c. Protect watercourses subject to accelerated erosion by improving cross-sections and/or providing erosion resistant lining.

D. UPSTREAM PROTECTION

1. Maximum allowable high water levels should be established along the storm drainage system prior to initiating hydraulic evaluations.
2. The headwater elevation of existing streams or pipe culverts upstream of the proposed development shall not be increased above the pre-development elevations from either the design storms shown in [Table 2.1](#) or from a 100-year 24-hour storm event, whichever is greater.
3. Small drainage basins upstream of the proposed development shall be given consideration for the potential of flooding due to short duration high intensity storm events.
4. When applicable, evaluation of an upstream drainage basin shall be given consideration for the potential of grate clogging (i.e. yard and roadway grated inlets). Assume a clogging factor of 50% for single grates in a sump condition.
5. Any evaluation of the upstream drainage basin shall consider the potential impact of flooding existing upstream basements or near grade finished floors (slab-on-grade or crawl space) and make allowances to prevent the new development from increasing the pre-existing high water elevation.

E. CHANNEL EROSION CONTROL

Erosion protection is necessary to ensure that channels maintain their capacity and stability and to avoid excessive transport and deposition of eroded material. All Erosion and Sediment Control Plans measures shall be designed in accordance with the [NC Erosion and Sediment Control Planning and Design Manual](#), latest revision.

Erosion and Sedimentation Control Plans, permit applications, and fees shall be submitted in to the Town of Clayton

Section 6 – STORMWATER MANAGEMENT DESIGN

The purpose of this section is to provide a guide for the design of stormwater management concerning Phase II Stormwater and Neuse River Nutrient Management regulations.

6.1 INTRODUCTION & OBJECTIVE

The Phase II stormwater permitting programs were established under the Federal Clean Water Act of 1972. The delegation of that program was accepted by the NC Division of Water Resources (DWQ), a section of NC Department of Environmental Quality (NCDEQ). Based on the requirements from the Clean Water Act, the following are goals that required under the Phase II program:

- Public education and outreach on stormwater impacts,
- Public involvement and participation,
- Illicit discharge detection and elimination,
- Construction site stormwater runoff control,
- Post-construction stormwater management for new development and redevelopment, and
- Pollution prevention/good housekeeping for municipal operation.

This manual is being implemented to provide guidance and design methodology for the post-construction stormwater management for new development and redevelopment within the Town of Clayton limits and ETJ. This manual is intended to provide technical information in support of Section 6.15 of the Town of Clayton UDO, and possible strategies to meet the requirements set by the Ordinance.

The Town of Clayton is required to comply with NPDES Phase II regulations and Neuse River Nutrient Management Strategy for stormwater runoff and this manual provides the information needed to design and treat stormwater runoff in accordance with both regulations.

Designer to refer to the NCDEQ Division of Energy, Mineral, and Land Resources [Stormwater Design Manual](#), and this Manual. Note that in any discrepancy between the NCDEQ Stormwater Design Manual and the Town of Clayton Manual of Specifications, Standards and Design, or other regulations or ordinances, the more stringent of the requirements apply.

6.1.1 Applicability and Exemptions:

Per the Stormwater Management Ordinance, requirements of this section shall apply to all development and redevelopment, including but not limited to: Site Plan Approval, Subdivision Approval, and grading approval, unless exempt pursuant to this section within the Town of Clayton Planning Jurisdiction. Refer to Definitions within Section 8.3 *Terms Defined* of the Town of Clayton UDO.

A. Exemptions:

1. Single-family detached, duplex, and manufactured home dwellings and recreational development and redevelopment that cumulatively disturbs **less than one (1) acre** and are not part of a larger common plan of development or sale are exempt from the provisions of this chapter, unless deemed otherwise by the Stormwater Administrator.
2. Commercial, industrial, institutional, single-family attached and multi-family residential, or local government development and redevelopment that cumulatively disturbs **less than one-half (0.5) acre** and are not part of a larger common plan of development or sale are exempt from the provisions of this chapter.
3. Development and redevelopment that disturb less than a stated area threshold are not exempt if such activities are part of a larger common plan of development or sale that exceeds the relevant threshold, even though multiple, separate or distinct activities take place at different times on different schedules.
4. Activities that are exempt from permit requirements of Section 404 of the federal Clean Water Act as specified in 40 CFR 232 (primarily, ongoing farming and forestry activities) are exempt from the provisions of this chapter.
5. Per the requirements of 15A NCAC 02B .0711 and the Town's Phase II Permit NCS000559, new development undertaken by a local government solely as a public road project shall be deemed compliant with the purposed of this chapter if it meets the riparian buffer protection requirements of The Neuse River Buffer Rules.

For these public road projects, the following shall be done to the maximum extent practicable (MEP):

- Minimize BUA;
 - Divert runoff away from surface waters; and
 - Implement BMPS and SCMs.
6. Existing impervious surfaces established prior to November 1, 2008, as determined through aerial photography, permits, plans, etc. however, if the impervious area limits are reduced after November 1, 2008 and the previously impervious area is reestablished as pervious for a period of one year or more, the impervious area is no longer exempt.
 7. See also the exclusions listed under Section 6.14.2B *Exclusions From Regulate Land-Disturbing Activity* of the Town of Clayton UDO.

6.1.2 Stormwater Standards

A. General Standards:

All development and redevelopment to which this chapter applies shall comply with the standards of this subchapter. The approval of the Stormwater Permit shall require

enforceable restriction on property usage that runs with the land, such as a recorded deed restriction or protective covenants, to ensure that future development and redevelopment maintains the site consistent with the approved project plans.

B. Neuse River Estuary Nutrient Management Requirements:

Nitrogen loads contributed by the proposed development shall not exceed **3.6 pounds per acre per year** as documented by the latest NCDEQ-approved nutrient accounting tool, (i.e., the NCDEQ [SNAP Tool](#)). Refer to **Section 6.3**.

C. All stormwater control measures used to meet these requirements shall be designed to have a minimum of eighty-five (85%) percent average annual removal for Total Suspended Solids (TSS). Refer to [Section 7.2.1](#).

D. Control and Treatment of Runoff Volume:

1. Stormwater systems shall be designed to control and treat runoff volume generated from all surfaces by **one (1) inch of rainfall**: the treatment volume. The treatment volume shall not exceed the maximum ponding depth and be drawn down pursuant to standards specific to each practice as provided in the Design Manual.
2. To minimize flooding and to ensure that the integrity and nutrient processing functions of receiving waters and associated riparian buffers are not compromised by evasive flows, stormwater flows from development or redevelopment shall not contribute to degradation of waters of the State.

At a minimum, the development and redevelopment shall not result in a net increase in peak flow leaving the site from pre-development conditions for the **1-year, 24-hour storm; 2-year, 24-hour storm; and 10-year, 24-hour storm events; and 25-year 24-hour storm events**.

6.2 GENERAL PROCEDURES

Per the Stormwater Management Ordinance/UDO, a Stormwater Permit is required for all development and redevelopment within the Town of Clayton limits and ETJ. The Permit must be applied by the developer or owner of the site where the development is proposed. The developer or owner must sign the Permit Application and provide the required development information as listed below in [Section 6.2.1](#).

Prior to submitting the Stormwater Permit, it is recommended that the owner/developer and his/her consultant schedule a meeting for a Pre-Design Conference with the Stormwater Administrator. This Conference may help with the overall understanding and expectations for the site development and the requirements that will need to be met for the Town of Clayton. The discussions will be centered on the information needed per this design manual and will cover other site-specific concerns or questions that could arise during the design of the site.

All plans and calculations shall be prepared by a qualified registered North Carolina professional engineer, surveyor, soil scientist or landscape architect, and the engineer, surveyor, soil scientist or landscape architect shall perform services only in their area of

competence, and shall verify under seal that the design of all stormwater management facilities and practices meets the submittal requirements for complete applications, that the designs and plans are sufficient to comply with applicable standards and policies found in the Design Manual, and that the designs and plans ensure compliance with the Stormwater Management Ordinance.

6.2.1 Stormwater Permit Application

The Stormwater Permit Application package should be inclusive of all necessary materials to understand the design and how the site will be developed in relation to stormwater management. At a minimum, the application must be submitted with the items as detailed in the Stormwater Permit Application Checklist, including:

- Stormwater Permit Application
- Stormwater Permit Application Checklist
- Stormwater Management Plans and Details, including Landscaping Plan if applicable
- Stormwater Management Statement/ Calculations/ Runoff Maps
- NCDEQ [SNAP Tool](#), latest version (in PDF and .xlsx)
- NCDEQ [Supplement EZ Forms](#) for each SCM, if applicable
- Documentation of approval from NCDEQ/COE, if required.

Preliminary subdivision plats that do not include all completed items WILL NOT be considered complete and may not be included on the Planning Board agenda.

6.2.2 Stormwater Management Statement/Narrative

A Stormwater Management statement or narrative is required with all plans submissions to help the Stormwater Administrator determine how the stormwater management facility was designed. The statement must be sent in with the preliminary subdivision plat for either commercial or residential subdivisions. The statement will be approved and reviewed by the Town of Clayton Engineering Director or Stormwater Administrator. If the design has not changed between the preliminary and the construction plat, then resubmission of the Stormwater Management Statement will not be necessary. If substantial changes were made to the stormwater management for the site, a modified Stormwater Management Statement must be submitted for review and approval by the Town of Clayton.

At a minimum, the Stormwater Management Statement must include:

1. Development name and address.
2. Developer/Owner and Consultant contact information.
3. A description of the existing site.
4. A description of the proposed development or construction activity.
5. An impervious area calculation for both existing site and proposed site conditions.
6. A description of the stormwater impacts the proposed development or construction activity may have on the surrounding properties. This includes

identifying upstream and downstream drainage facilities potentially affected by the new development and the ability of the existing drainage ways to handle the additional runoff.

7. A description of the proposed stormwater management facility and how they will be designed, constructed, maintained and operated to:
 - a. Minimize the adverse effects on the quality of stormwater runoff from the development,
 - b. Provide SCM's to maximize infiltration, minimize connected impervious surfaces and minimize concentrated flows,
 - c. Provide distributed stormwater runoff to minimize offsite impacts and provide sheet flow into existing vegetated buffers,
 - d. Extend the time of concentration to the maximum practical level.
 - e. Preserve and protect the natural drainage ways,
 - f. Respect the practical limits of public and private drainage facilities,
 - g. Protect neighboring properties from unreasonable adverse effects resulting from the development,
 - h. Prevent flooding within the development and on surrounding properties, and
 - i. Limit the impacts of stormwater runoff discharging into or from the site or obtain approvals and easements from the affected property owners.
8. Estimated cost for construction and continued maintenance of the SCM(s).
9. A vicinity map showing the location of the site within the Town limits. The scale of the map shall be adequate to show the area in question with reasonable depiction of streets to determine the exact location of the site. The minimum scale shall be no less than 1"=400'.
10. A USGS Quadrangle map with the site location depicted on the map.
11. A copy of the Johnston County Soil Survey with the site location depicted on the map. The map must be from the official publication. The website version can be used for soil breakouts and design but cannot be used for stream determination.
12. Additional supporting documentation as included on the Stormwater Permit Checklist.

6.3 NEUSE RIVER NUTRIENT MANAGEMENT REQUIREMENTS

On June 22, 1999, The Environmental Management Commission adopted the Neuse River Basin: Nutrient Sensitive Waters Management Strategy: [Protection and Maintenance of Riparian Buffers \(15A NCAC 2B .0233\)](#). The purpose of the rule is to protect and preserve the riparian buffers in the Neuse River Basin to maintain their nutrient removal functions. The Town of Clayton requires all site plans and subdivisions submitted for Town review to have all streams identified and riparian buffers noted on the maps where applicable.

The Neuse River Riparian Buffer rules apply to all existing streams, lakes, ponds or other bodies of water if the feature is shown on either the most recent version of a 1:24,000 scale (7.5 minute) quadrangle topographic map prepared by the USGS or the most recent version of the soil survey map prepared by the NRCS. The Neuse River Riparian Buffer rules implement and pertain to a 50' Riparian Buffer around all water features as noted above. Exemptions from the Neuse River Basin Rules for riparian buffers along surface waters that appear on the maps must be obtained in writing from the NCDEQ Division of Water Resources.

Approval from the Division of Water Resources (DWR) will be required prior to the Town of Clayton Stormwater Permit approval for any sites that appear to be impacting riparian buffers. For more information on allowable activities within a riparian buffer or along a stream or for detailed information for exemptions from the riparian buffer rule, contact the NCDEQ DWR Raleigh Regional Office at (919) 791-4200, or at <https://www.deq.nc.gov/about/divisions/water-resources/water-planning/nonpoint-source-planning/neuse-nutrient-strategy#RiparianBuffers-2777>

All proposed development and construction activity located near or adjacent to a riparian buffer must adhere to the Neuse River Basin Rules. In particular, the following items must be addressed, where applicable, on all Stormwater Management Plans:

1. All surface waters, as shown on the USGS Quadrangles or Johnston County Soil Survey, must be shown on the proposed plan.
2. All riparian buffers must be appropriately labeled on the proposed plan and final plat. Riparian buffers must extend 50 feet from the top of bank for streams or the edge of normal water levels for ponds and other impoundments.
3. Where development requires the disturbance of a riparian buffer, documentation of approval from NCDEQ DWR is required. If the project is considered exempt, documentation or an explanation should be provided noting this, utilizing the conditions stated in the Neuse River Basin Rules.
4. Diffuse flow must be provided for all stormwater runoff entering the riparian buffer. The following guidelines should be utilized:
 - a. Development located near riparian buffers should minimize large concentrated discharge points. By providing multiple outlets for stormwater runoff and maintaining natural drainage patterns, the stormwater runoff impacts from new development can be minimized.
 - b. Documentation must be provided, indicating that the proposed development has provided sheet flow at all discharge points where required. Appropriate calculations and details should be included.
 - c. Additional methods to provide diffuse flow will be reviewed and approved on an individual basis. Developers and design professionals may request a pre-design conference to determine if a proposed facility will be accepted.
 - d. The NCDEQ *Division of Energy, Mineral and Land Resources*, Level Spreader Design Guidelines, latest revision, can be utilized except sod shall be utilized.

- e. Discharge that will flow into an existing, non-buffered draw or stream, prior to entering the riparian buffer will be exempt from the diffuse flow requirement.
5. All stormwater facilities proposed to create sheet flow must be contained within permanent drainage easements and have Operation and Maintenance Agreement and/or guidelines provided in the restrictive covenants. The Operation and Maintenance Agreements and the restrictive covenants must be recorded.

6.3.1. Nitrogen Reduction

The Neuse River Basin – Nutrient Sensitive Waters Management Strategy: [Basin Wide Stormwater Requirements \(15A NCAC 2B .0235\)](#) and the Town of Clayton Stormwater Management Ordinance requires development to reduce nitrogen loading by installing SCMs, both structural and non-structural, or by offsetting payments to NC Division of Mitigation Services (DMS) or a local nutrient mitigation bank.

Designer to refer to the NCDEQ Division of Energy, Mining and Land Resources [Stormwater Design Manual](#), and this Manual. Note that in any discrepancy between the NCDEQ Stormwater Design Manual and the Town of Clayton Manual of Specifications, Standards and Design, or other regulations or ordinances, the more stringent of the requirements apply.

6.3.2. Total Nitrogen Loading Calculations

- A. Nitrogen loads contributed by the proposed development shall not exceed **3.6 pounds per acre per year**.
- B. Redevelopment subject to this chapter that would replace or expand existing structures or improvements and would result in a net increase in built-upon area shall have the option of either meeting the loading standards identified in subsection or meeting a loading rate that achieves the following nutrient loads compared to the existing development: thirty-five (35) percent reduction for nitrogen.
- C. The developer shall determine the need for engineered stormwater controls to meet these loading rate targets by using the latest NCDEQ-approved nutrient accounting tool, i.e., the NCDEQ [SNAP Tool](#).

6.3.3. Nitrogen Export Reduction Options

NCDEQ DWQ requires that the total nitrogen loading be less than **3.6 lbs/ac/yr** for any development in the Town of Clayton jurisdiction. There are three options to reduce this export as listed:

- A. SCMs as described in [Section 7](#) can be installed to reduce the nitrogen loading rate from the development. The rate or removal is dependent on the type of SCM utilized as noted in the NCDEQ Stormwater Design Manual.
- B. A onetime payment (offset payment) can be paid to NC DMS or a local nutrient mitigation bank, or

- C. A combination of SCMs and offset payment.

6.3.4. Partial Offset of Nutrient Control Requirements

- A. Development shall attain a maximum nitrogen loading rate on-site of six pounds per acre (**6 lbs/ac/yr**) per year for single-family detached and duplex residential development, and ten pounds per acre per year (**10 lbs/ac/yr**) for other development, including multi-family residential, commercial, and industrial, and shall meet any requirements for engineered stormwater controls otherwise imposed by this article.
- B. A developer subject to this article may achieve the additional reductions in nitrogen and phosphorus loading required by this article by use of the following options:
 - i. Purchasing offset credits from an approved private seller with a project located in the same eight-digit Hydrologic Unit Code (8-digit HUC) as the proposed development. Refer to the North Carolina Department of Environmental Quality (NCDEQ) [Division of Mitigation Services](#) (DMS) for approved mitigation banks with applicable and eligible credits in Clayton.
 - ii. Making offset payments to the NC [Division of Mitigation Services](#) (DMS) contingent upon acceptance of payments by that program.
- C. Documentation and proof of purchase for offset credit options is required prior to construction plan approval.
- D. Any offsite measures permitted by the Ordinance shall meet the requirements of 15A NCAC 02B .0273 (2) through (4) and 15A NCAC 02B. 0240.

6.4 IMPERVIOUS AREA CALCULATIONS

All Stormwater Management Permit applications must include calculations documenting the total proposed impervious area within the development. Impervious areas are defined as all surfaces composed of material that impedes or prevents natural infiltration of water into the soil. Examples of impervious surfaces include pavement, concrete, gravel and roofed surfaces.

For single-family residential subdivisions, where the exact building footprint per lot is unknown, a maximum impervious surface area for the site for each lot can be utilized to determine compliance with the maximum impervious area allowed within the development. The following criteria should be adhered to when using this option:

- A. A reasonable impervious area per lot must be used in the calculations. Documentation that the area used will be adequate for the intended use is required. A typical plot plan or analyses of existing impervious area in surrounding, comparable developments can be provided to meet this requirement.
- B. The Town prefers residential developments to utilize a maximum impervious area per lot as opposed to an average area per lot. If the development must utilize an average impervious area, reasonable explanation must be provided. If an average impervious area is used, the developer must track the development internally and provide annual (or as requested) updates to the Town.

- C. The Town reserves the right to request as-built documentation from the developer, verifying that the proposed maximum impervious areas have not been exceeded.
- D. The Town encourages additional impervious area per lot be provided for future expansion by the homeowner (e.g., 100-500 sf per lot for sheds, screened porches or additions).
- E. All impervious area within the proposed right-of-way, but outside of the edge of roadway pavement must be included in the allowable impervious area per lot.
- F. The maximum impervious area allowed per lot (or average) must be recorded on the Final Plat and noted in the restrictive covenants recorded for the subdivision. The following note can be followed as an example to meet this requirement:
 - Impervious area includes all buildings, sheds, sidewalks, covered porches, driveways, and surfaces such as gravel, concrete, asphalt, brick, slate or stone that impeded the infiltration of water into the soil. The maximum impervious area allowed per lot should include any impervious area proposed within the portion of the right-of-way between the edge of roadway pavement and the front of the lot line.

If a development area includes existing impervious areas, all impervious areas to remain must be included in the total impervious area calculations. Existing impervious areas that are removed are not required to be included in the maximum allowable impervious area limits. However, any existing impervious area that existed prior to adoption of either the Watershed Protection Regulations or the Neuse River Watershed Regulations is grandfathered.

Section 7 – STORMWATER CONTROL MEASURES

7.1 INTRODUCTION

Management of nonpoint source discharge is a stated goal of the 1987 Water Quality Act. An important source of these pollutants is stormwater runoff from urban and developing areas. This runoff has the potential to degrade water quality in all types of waters, including, among others, those classified as water supply watersheds, shellfish areas, and nutrient sensitive waters. The management of stormwater runoff through nonstructural controls (e.g., low-density development) is the preferred method of reducing pollution from urban areas. In cases where low density is not feasible, engineered stormwater controls are a viable solution to reducing pollution. However, proper design, and subsequent management, of these engineered solutions is essential for adequate pollutant removal.

DWQ's approach to water quality management of stormwater in surface drinking water supply watersheds, the 20 coastal counties, and areas near High Quality and Outstanding Resource Waters is based first on minimizing impervious surfaces and; secondly, on treating stormwater runoff from these surfaces. The rules contained in [15A NCAC 2H .1000](#) for wet detention basins provide information on the appropriate volume of runoff to be controlled and the corresponding basin size configuration. North Carolina Stormwater Management rules also allow for the construction of alternative SCM's that meet the pollutant removal design standard of 85% removal of total suspended solids (TSS). This section, along with the standard details, is meant to supplement the rules in the NCAC by providing design checklists and details, their design criteria, and their assumed TSS removal. These guidelines are not meant to replace the rules.

Designer to refer to the NCDEQ Division of Energy, Mineral, and Land Resources [Stormwater Design Manual](#), and this Manual. Note that in any discrepancy between the NCDEQ Stormwater Design Manual and the Town of Clayton Manual of Specifications, Standards and Design, or other regulations or ordinances, the more stringent of the requirements apply.

7.2 SUPPLEMENTAL TOWN REQUIREMENTS FOR SCMs

The NC Department of Environmental Quality (NCDEQ), Division of Energy, Minerals, and Land Resources has published a [Stormwater Design Manual](#), that is updated continuously. The Town of Clayton has adapted the information and minimum design criteria in this publication for guidance in designing water quality SCM's.

7.2.1. Total Suspended Solids (TSS) Removal

As described in section 6.15.8 of the [Town of Clayton UDO](#), nitrogen loading standards in this article are supplemental to, not replacements for, stormwater standards otherwise required by federal, state, or local law, including without limitation any riparian buffer requirements applicable to the location of the development. This includes, without limitation, the riparian buffer protection requirements of [15A NCAC 2B.0714](#).

All stormwater control measures used to meet these requirements shall be designed to have a minimum of eighty-five (85%) percent average annual removal for TSS.

7.2.2. Freeboard

A minimum of one (1) foot of freeboard shall be provided for above ground SCM's for the 100-year, 24-hour storm event.

A minimum of six (6) inches of freeboard shall be provided for underground SCM's for the 100-year, 24-hour storm event.

7.2.3. Fencing

Fencing shall be installed around above ground SCMs unless otherwise approved by the Stormwater Administrator on a case by case basis. Fencing shall be constructed of high-quality materials, such as decorative blocks, brick, stone, treated wood, wrought iron, black vinyl coated chain link fence, or vinyl or treated wood privacy fence and details/shop drawings approved by the Stormwater Administrator prior to plan approval.

Fencing shall be owned/maintained by the owner/HOA and shall be installed prior to final SCM certification. See also paragraph 7.2.5, below.

7.2.4. SCMs Not to be on Single-Family Lots

SCMs shall not be located on private single-family lots if serving other lots. Refer to easement requirements in [Section 1.9.3](#).

7.2.5. Final Plat Notes

The following notes shall be placed on all Final Plats that require drainage easements or SCMs:

- A. "The drainage easements and stormwater control measures shown hereon are required on the property to meet Town and state stormwater regulations. Property Owner may be subject to enforcement actions if the maintenance easement is obstructed or stormwater control measure is removed, relocated or altered without prior Town approval."
- B. "No structures, fences, walls, HVAC equipment, trees, shrubs, hardscapes or other items that obstruct maintenance vehicles may be installed within drainage easements. Per the Operation and Maintenance Agreement recorded in the Register of Deeds, the property owners grant the Town the right, privilege and easement across the property for the purpose of inspecting, monitoring, etc., the stormwater control measure as needed. Note that maintenance of the drainage easement is the responsibility of the underlying property owner, who shall maintain the easement to allow positive conveyance of stormwater."
- C. "The maximum impervious area allowed per lot (or average) is _____ sf. Impervious area includes all buildings, sheds, sidewalks, covered porches, driveways, and surfaces such as gravel, concrete, asphalt, brick, slate or stone that impeded the infiltration of water into the soil. The maximum impervious area allowed per lot should include any impervious area proposed within the portion of the right-of-way between the edge of roadway pavement and the front of the lot line." (Refer to [Section 6.4](#)).

7.3 DETAILS

The **Standard Details:** Refer to NCDEQ Division of Energy, Mineral, and Land Resources [Stormwater Design Manual](#). Note that in any discrepancy between the NCDEQ and Town of Clayton requirements, the more stringent of the requirements apply.

Section 8 - INSPECTION & ACCEPTANCE

8.1 LIMITS OF PUBLIC OWNERSHIP AND MAINTENANCE RESPONSIBILITY:

- A. All drainage easements carrying water from the right of way or public property shall be public and maintained by the Town of Clayton.
- B. The Town of Clayton assumes no liability or responsibility for adjudicating disputes between property owners regarding non-publicly generated storm water.
- C. Drainage systems maintained by NCDOT as part of its State highway system.
- D. **Detention/Retention/Water Quality Pond & Other SCM's:** The Town will not accept these areas/structures for maintenance; however, the Town reserves the right to enter to routinely inspect these areas and address any items that would cause SCM(s) to be noncompliant. This will be done in an emergency situation without notice. Under normal conditions, the Town will contact the owner/developer to have said items addressed. If unable to do so within a reasonable time, the Town reserves the right to charge the owner/developer for any expense incurred by the Town in doing so.

8.2 LIMITATION OF CONSEQUENTIAL DAMAGE TO PRIVATE FACILITIES LOCATED ON PUBLIC EASEMENTS

All public easements including storm sewer are to remain clear of obstructions. No buildings, fences, trees, shrubs or other obstructions shall be placed in any easement. Driveways, walkways, asphalt and parking lots may be permitted in easements; however, the Town reserves the right to remove such asphalt, concrete, base course and sod as necessary to access its facility in the case of emergency. Pavement or concrete will be replaced with a **patch**. Sod will be replaced with Fescue or rye seeding. The Town will **not** be responsible for replacing a property owner's sod after repairing a drainage line.

8.3 ITEMS NEEDED FOR ACCEPTANCE

- A. Record drawings need to be submitted after final inspection and prior to acceptance.
- B. Bond will be required to be submitted. Bond amount of 20% of the construction cost but no less than \$3,000.
- C. All public stormwater structures shall be surveyed and tied into the NC State grid for upload into GIS. A record drawing shall be submitted to the Town of Clayton for approval with the record drawing certificate on the plan. Once approval of the record drawings are obtained, a hard copy with a CAD drawing (formattable to GIS) must be submitted to the Engineering Director or Stormwater Program Administrator.

8.4 INSPECTIONS:

8.4.1 The following items must be inspected during and after installation of storm drainage lines and appurtenances:

- A. All boxes and manholes for presence of weep holes, formed inverts, castings, pipe flushed against inside wall of box, steps and location of steps, proper corbelling of brick/block in accordance with the details and specs, wall thickness and depth of manhole.
- B. Pipe for cracks.
- C. Removal of debris and sediment in both pipe and box.
- D. Rip rap outlet protection and filter fabric, stilling basin compliance with plan if applicable.
- E. Armor protection of ditches (concrete and/or temporary liners), scour, and erosion.

8.4.2 All inspections must be scheduled at least 24 hours prior to when needed. Inspections will be performed in the order received. Every effort will be made to accommodate the time of request; however, this cannot be guaranteed.

8.4.3 Upon completion of construction the developer shall request a warranty inspection. Upon completion of all punch list items, the provision of a set of acceptable record (as-built) drawings, and the submission of engineer's certifications, a 1-year warranty period shall commence.

8.4.4 Per UDO Section 6.15.9, a completed Annual SCM Certification form shall be provided to the Stormwater Administrator beginning one year from the date of as-built certification and each year thereafter on or before the date of the as-built certification.

8.5 WARRANTY:

If a developer fails to complete warranty items, future projects of the developer shall not be reviewed by the Department of Public Works and Utilities. In addition, the Town may take additional legal action against the developer.

8.5.1 New development draining to an existing regional pond:

- A. In order to ensure compliance of all post construction stormwater structures installed as either part of the Neuse Nitrogen Stormwater Program or Watershed Supply Protection Regulations, the Town has adopted a policy to not allow any new construction which drains to a regional pond to either receive a final plat or a Certificate of Occupancy if the receiving regional pond is out of compliance at the time the new construction is complete.
- B. The Town will not accept any new development which drains to an existing regional pond unless the regional pond is in compliance with current Town of Clayton Stormwater regulations.

C. ***Regional SCM's must be inspected by the Town and in compliance prior to signing of a final plat of issuance of a Certificate of Occupancy.***

D. Developers are encouraged to contact the Town's Stormwater Administrator to perform a site inspection well in advance of the desired time of Certificate of Occupancy (C.O.) or final plat. Failure to do so may lead to delays in C.O. or final plat issuance due to non-compliant Best Management Practices.

8.5.2 Warranty and Defects Guarantee: Upon the acceptance of facilities, utilities or streets for permanent maintenance, a 1-year warranty for all improvements shall become effective. This warranty must be satisfactory to the Town of Clayton. In addition, the subdivider shall provide surety in the amount of 15% of the total construction cost to guarantee the correction of all defects in such facilities, utilities, or streets that occur within the warranty period described above.

For the purposes of this section, the term "defects" refers to any condition in publicly dedicated facilities, utilities or streets that requires the Town to make repairs to such improvements over and above the normal amount of maintenance that they would require. If such defects appear, the warranty may be enforced regardless of whether the facilities, utilities, or streets were constructed in accordance with the requirements of this ordinance.

8.5.3 During the 1-year warranty period, the developer shall repair any latent defects which occur. At the end of the 1-year warranty period the developer shall request a final inspection. Upon successful completion of all warranty items the developer shall be released from maintenance responsibilities for the warranted construction.

8.5.4 Warranty repairs to the following common problems shall be as follows:

- A. Street pavement trench failures shall be repaired in accordance with the Town Manual of Specifications, Standards, and Design as well as at the direction of the Engineering Director.
- B. If more than 3 trench failures occur within a longitudinal distance of 800 feet on any segment of a street, the Town may require a 1-inch overlay once repairs have been completed.
- C. Cracks in sidewalk and/or curb and gutter shall be repaired by removing and re-pouring such sections as necessary.
- D. All storm sewer systems, ditches and gutters shall be free of debris, dirt or silt;
- E. All drainage and street appurtenances shall be in perfect condition and properly exposed.

All other defects shall be corrected in accordance with the recommendations of the Town's Engineer or his representative.

8.6 Annual Inspections

Even though the Town of Clayton will not maintain Stormwater Control Measures (SCMs), the [Sections 8.4](#) and [8.6](#) above apply and will be required prior to the final CO or Final

Plat. A warranty inspection will not be required; however, a yearly maintenance inspection and certification by a registered professional. Per Section 6.15.9 of the UDO, a completed Annual SCM Certification Form shall be provided to the Stormwater Administrator beginning one year from the date of as-built certification and each year thereafter on or before the date of the as-built certification.

Section 9 – FINANCIAL

9.1 NEW SUBDIVISION AND NEW CONSTRUCTION EXCLUDED

Construction of storm drainage in any new development shall be the sole responsibility of the developer at his/her expense and shall be installed in accordance with the Manual of Specifications, Standards, and Design.

9.2 PRIVATE PROPERTY – OTHER THAN NEW SUBDIVISIONS:

9.2.1 The Town will issue permits for the installation of storm drains crossing private property other than in new subdivisions within the Town's corporate limits under the following conditions:

- A. The storm drain to be installed will carry storm drainage water discharged from an existing Town street ("Public" Water) or streets dedicated for public street purpose and accepted for maintenance by the Town.
- B. The property owner(s) will furnish the Town, without cost, a duly executed good and sufficient easement, conveying to the Town such perpetual right-of-way determined by the Engineering Director as necessary for the installation and maintenance of the storm drain, the form and sufficiency of such easement to be determined by the Town Attorney (easement is defined as a right, as a right of way, afforded to the Town of Clayton for limited use of another's real property). The Town will not be responsible for any shrubs, trees or structures within the right-of-way and permanent structures may not be built by owner(s) over the right-of-way.
- C. At the time of the property owner's application to the Town, the storm drain system to be installed is to be located on property on which a residential, commercial, or industrial building has existed for a period of 60 months and the desirability or necessity for such installation is not due to a planned expansion or modification of such existing building nor to an expansion or modification made to such existing building within a 60 month period prior to the date of such application.
- D. The pipe, size, alignment, grade, length, discharge point, structural accessories (such as manholes, headwalls, catch basins, junction boxes), and other specifications shall be as determined by the Engineering Director.
- E. The installation of proposed drainage structure shall be in compliance with the Division of Energy, Mineral, and Land Resources Stormwater Design Manual and the corresponding standard details and specification of the MSSD.

9.2.2 It shall be the policy of the Town to improve sections of open ditch in sufficient length as determined by the Engineering Director.

9.2.3 Notwithstanding, all ditch improvements are subject to the applicable regulations governing wetlands, waters of the US, buffers, etc. as promulgated by the US Army Corps of Engineers and NCDEQ, Division of Water Resources; such regulations taking

precedent over any permitted practice or policy stated herein. As such, requests for rerouting or piping existing ditches or streams shall be subject to all federal, state, and local regulations which may prohibit the disturbance of applicable ditches, wetlands, streams, etc.

- 9.2.4** Storm drainage crossing private property which does not carry storm drainage from an existing Town street or streets dedicated for public street purposes and accepted by the Town for maintenance is the responsibility of the property owner(s) and the Town, therefore, will not participate in the installation.

Section 10 – EXAMPLE PROBLEMS

10.1 CALCULATING RUNOFF – RATIONAL METHOD

10.1.1 Rational Method

The Rational Method represents an accepted method for determining peak storm runoff rates for small watersheds that have a drainage system unaffected by complex hydrologic situations such as ponding areas and storage basins. It is generally recommended that in the Town of Clayton that Rational Method be used for areas of less than 50 acres.

The Rational Method is based on a direct relationship between rainfall intensity and runoff, and is expressed by the following equation:

$$Q = CiA \quad \text{Equation 10.1.1}$$

Where, $Q \rightarrow$ The peak rate of runoff in cubic feet per second (cfs). Actually, Q is in units of inches per hour per acre. Since this rate of inches-acre/hour differs from cubic feet per second by less than one percent, the more convenient units of cfs are used.

$C \rightarrow$ The dimensionless coefficient of runoff representing the ratio of peak discharge per acre to rainfall intensity (i).

$i \rightarrow$ The average intensity of rainfall in inches per hour for a period of time equal to the time of concentration for the drainage area at the point of interest.

$A \rightarrow$ The area in acres contributing runoff to the point of interest during the critical storm duration.

Basic assumptions associated with the Rational Method are:

- 1) The frequency or recurrence interval of the peak discharge is equal to the frequency of the average (uniform) rainfall intensity associated with the critical storm duration.
- 2) The computed peak rate of runoff at the point of interest is a function of the average rainfall intensity during a period of time equal to the time of concentration at that point.
- 3) The time of concentration is the critical storm duration. This is discussed under [Section 10.1.4](#).
- 4) The ration of runoff rate to rainfall intensity, C , is uniform during the storm duration.
- 5) Rainfall intensity is uniform during the storm duration.
- 6) The contributing area is the area that drains to the point of interest within the critical time of concentration.

10.1.2 Rational Method Runoff Coefficient (C)

In relating peak rainfall rates to peak discharges, the runoff coefficient "C" in the Rational Formula is dependent on the character of the surface of the drainage area. The rate and volume of runoff that reaches a storm drainage system depends on the relative porosity (**imperviousness**), ponding character, slope, and conveyance properties of the surface. Soil type, vegetative condition, and the presence of impervious surfaces, such as asphalt pavements and the roofs of buildings, are the major determining factors in selecting an area's "C" factor. The type and condition of the surface determines its ability to absorb precipitation and transport runoff.

The rate at which a soil absorbs precipitation generally decreases as rainfall continues for an extended period of time. The soil absorption or infiltration rate is also influenced by the presence of soil moisture before a rain (**antecedent precipitation**), the rainfall intensity, the depth of the ground water table, the degree of soil compaction, the porosity of the subsoil, vegetation, ground slopes, depressions, and storage. On-site inspections and aerial photographs may prove valuable in evaluating the nature of the surface within the drainage area.

The runoff coefficient "C" is difficult to precisely determine. Its use in the Rational Method implies a fixed ratio of runoff rate to rainfall intensity for any given drainage area, which in reality is not the case. A reasonable coefficient must be chosen to represent the integrated effects of infiltration, detention storage, evaporation, retention, flow routing, and interception, all of which affect the time distribution and peak rate of runoff. Proper use of the Rational Method requires judgment and experience on the part of the engineer, especially in the selection of the runoff coefficient.

Coefficients for specific surface types can be used to develop a composite runoff coefficient based in part on the percentage of different types of surfaces in the drainage area. This procedure is often applied to typical "sample" blocks as a guide to the selection of reasonable values of the coefficient for an entire area.

For the runoff coefficient "C" for various residential districts and specific surface types, refer to either Table 8.03b of the [Erosion and Sediment Control Planning and Design Manual](#), the NCDOT [Guidelines for Drainage Studies and Hydraulic Design](#), Table 3, or other approved recognized sources or publications of such data.

Most drainage areas will consist of several different types of development types. In these cases, the designer should develop a Composite Runoff Coefficient. The accepted procedure is simply to weight the individual coefficients according to the area taken by each category.

The Composite Runoff Coefficient is expressed as the following:

$$C_c = \frac{\sum(C_i A_i)}{\sum A_i} \quad \text{Equation 10.1.2}$$

Where, $C_c \rightarrow$ The Composite Runoff Coefficient (dimensionless).

A_i → The area taken by an individual category of composition.

C_i → The runoff coefficient for the individual area.

10.1.3 Rational Method Rainfall Intensity (i)

Rainfall intensity (i) is the average rainfall rate in inches per hour which is considered for a particular basin or sub-basin. The rainfall intensity is determined on the basis of design rainfall duration and design frequency of occurrence. The **design rainfall duration** is equal to the critical time of concentration for all portions of the drainage area under consideration that contribute flow to the point of interest. The **frequency of occurrence** used in design computations is a statistical variable that is established by design standards or chosen by the engineer as a design parameter. It is usually expressed in terms of the average storm recurrence interval in years.

See [Table 2.1](#) for the Intensity-Duration-Frequency (IDF) Table for the Town of Clayton. Data is also presented as an IDF Curve in [Table 2.2](#).

10.1.4 Time of Concentration (t_c)

The **time of concentration** used in the rational equation is the time of concentration for the entire drainage area upstream of the point of interest. The **critical time of concentration** is the time of concentration which results in the maximum peak runoff rate from all or part of the upstream drainage area at the point of interest. This may be equal to or less than the time of concentration. Runoff from a watershed usually reaches a peak at the time when the entire drainage area is contributing. However, the runoff rate may reach a peak prior to the time when the entire upstream drainage area is contributing. In such instances, only the portions of the drainage area able to contribute flow at the point of interest during the critical time of concentration should be used in determining the peak discharge.

The time of concentration is based on a relationship between the hydraulic length of the watershed and the height of the most remote point in the watershed above the point of interest. The Kirpich Equation [Bureau of Reclamation, 1974] defines the time of concentration and is expressed by the following equation:

$$t_c = \frac{\left[\frac{L^3}{H} \right]^{0.385}}{128} \quad \text{Equation 10.1.3}$$

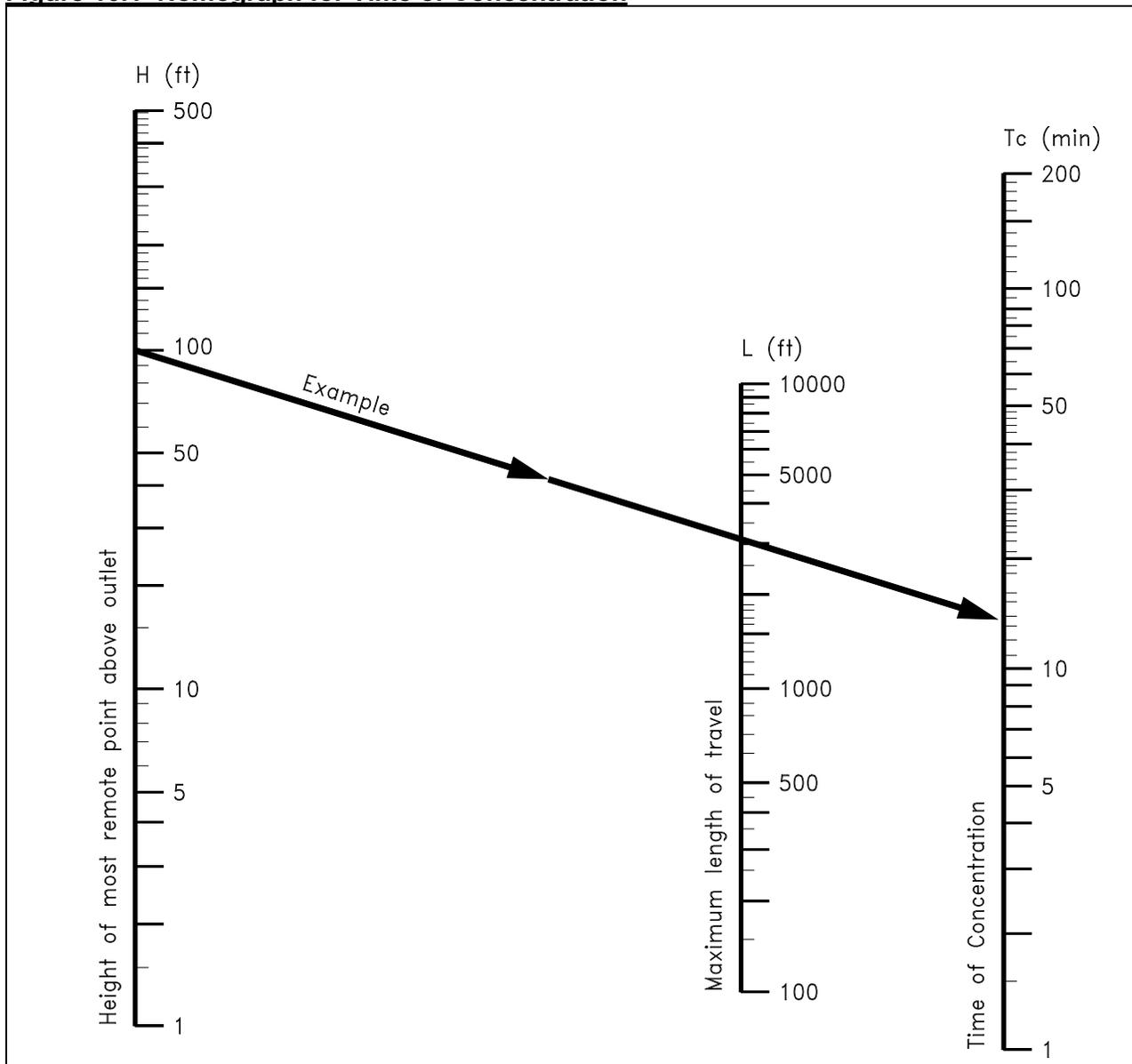
Where, t_c → The time of concentration, which is equal to the time it takes runoff to travel from the most remote point in the basin to the point of interest.

L → The hydraulic length of the watershed, which is the overland flow distance from the most remote point in the basin to the point of interest, measured in feet.

H → The height of the fall between the most remote point in the basin and the point of interest. The elevation difference along the hydraulic length, measured in feet.

Assuming the time of concentration equals the duration of the storm event in [Table 2.2](#), The IDF curve can now be used to determine the rainfall intensity, (i). Storms of less than 15 minutes of duration are not considered in standard practice. In Clayton a time of concentration of 5 minutes can be assumed.

[Figure 10.1](#) provides a nomograph to determine time of concentration.

Figure 10.1 Nomograph for Time of Concentration

Source: "E & S Control Planning and Design Manual," [DEHNR, May 1994 Revised]

Notes:

- 1) Use nomograph t_c for natural basins with well-defined channels, for overland flow on bare earth, and for mowed-grass roadside channels.
- 2) For overland flow, grassed surfaces, multiply t_c by 2.
- 3) For overland flow, concrete or asphalt surfaces, multiply t_c by 0.4.
- 4) For concrete channels, multiply t_c by 0.2.

10.1.6 Rational Method Drainage Area (A)

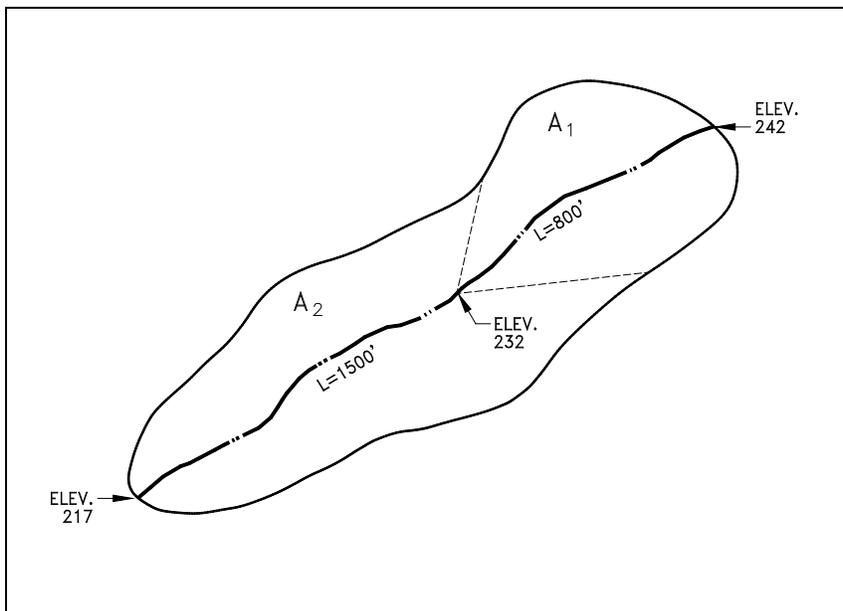
As mentioned previously, the drainage area used in determining peak discharges is the portion of the area that contributes flow to the point of interest within the critical time of concentration. The boundaries of the drainage area may be determined through the use of topographic maps, supplemented by field surveys where topographic data has changed or where the contour interval is too great to distinguish the direction of flow. A drainage area map shall be provided for each project. The drainage area contributing to the system being designed and the drainage sub-area contributing to each inlet point shall be identified. The boundaries of each drainage area must follow actual drainage divides rather than artificial land divisions as used in the design of sanitary sewers. The drainage divide lines are determined by pavement slopes, downspout locations, grading of lawns, and many other features that are introduced by the urbanization process

10.1.7 Overview of Rational Method Analysis [Malcom, 1989]

The following are the steps to be taken in determining the peak discharge for a particular point of interest:

- 1) Delineate the watershed contributing to the point of interest and determine the drainage area in acres. (The terms "watershed" and "drainage area" are synonymous.)
- 2) Determine the time of concentration for the watershed.
- 3) Determine the rainfall intensity for the designated return period at the time of concentration.
- 4) Determine the composite runoff coefficient.
- 5) Apply the Rational Equation to obtain the peak discharge.

Example 10.1



Example 10.1

Use the Rational Method to find the 10 year design runoff for the area shown above.
This is a hypothetical drainage system.

A1 → Basin Area = 5 acres
 Multi-Family Residential District

A2 → Basin Area = 10 acres
 Business District

Solution:

1. Time of Concentration: Using Equation 10.1.3 and the given information determine the time of concentration (t_c).

Area A₁:

$$t_c = \frac{\left[\frac{L^3}{H} \right]^{0.385}}{128} = \frac{\left[\frac{800^3}{(242 - 232)} \right]^{0.385}}{128} = 7.26 \text{ min}$$

Area A₂:

$$t_c = \frac{\left[\frac{L^3}{H} \right]^{0.385}}{128} = \frac{\left[\frac{1500^3}{(232 - 217)} \right]^{0.385}}{128} = 12.83 \text{ min}$$

Therefore, the total time of concentration for the entire basin is 7.26 + 12.83 = 20.09 minutes, use 20 minutes. In lieu of using Equation 10.1.3, the Kirpich Equation, [Figure 10.1](#) could have been used to graphically solve for the Time of Concentration.

2. Rainfall Intensity: Using the IDF curve, [Figure 2.3](#), and the above calculated $t_c = 20$ minutes, *assuming the time of concentration (t_c) is equal to the duration (T) of the storm*, determine the Rainfall Intensity (10-yr Storm).

$$i = 4.64 \text{ inches/hour}$$

3. Runoff Coefficient:

Using Equation 10.1.2, determine the composite “C” factor.

$$C_c = \frac{\sum (C_i A_i)}{\sum A_i} = \frac{(0.60 \times 5) + (0.80 \times 10)}{(5 + 10)} = 0.73$$

4. Calculate the 10 year design storm peak runoff:

Using Equation 10.1.1 and the above solved equations, determine the peak flow runoff (10-yr Storm).

$$Q = CiA = 0.73 \times 4.64 \times 15 = 50.81 \text{ cfs}$$

10.2 CALCULATING RUNOFF – SCS METHOD

Situations requiring a complete flood hydrograph, and not just peak discharge, SCS TR-20 method should be used to determine total volume of runoff.

The total volume of runoff is dependent on the characteristics of the soil and the degree of urbanization of the area (i.e. percent of impervious cover). Loss rate totals may be estimated using the **SCS Curve Number** methodology developed by the Soil Conservation Service [SCS, 1972].

[Figure 10.2](#) provides graphs for the determination of runoff volume for a given rainfall depth and SCS Curve Number.

The SCS provides information on relating soil group type to curve number as a function of soil cover, land use type and antecedent moisture conditions. The SCS soil classification system uses four groups, as follows:

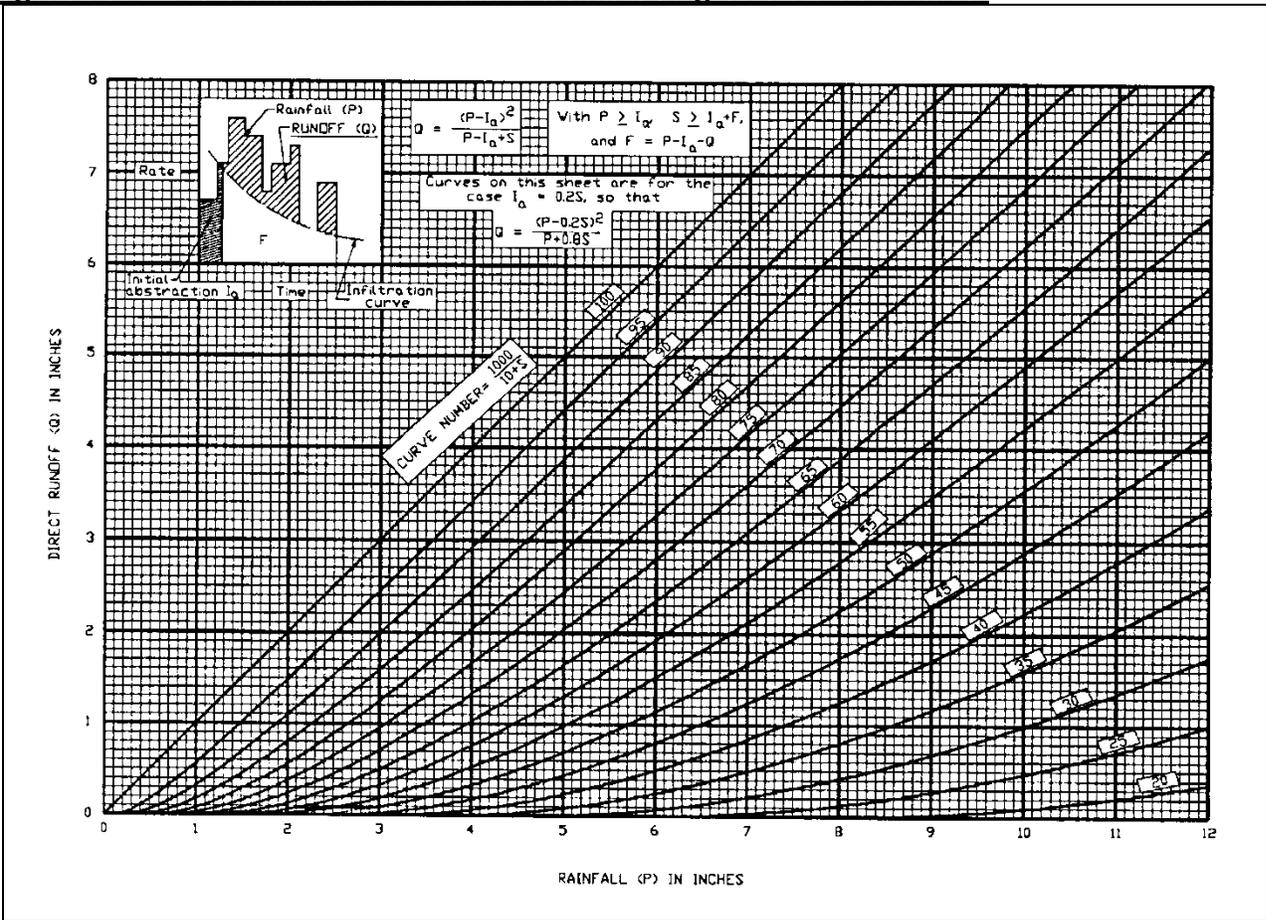
Group A:	deep sand, deep loess, aggregated silts
Group B:	shallow loess, sandy loam
Group C:	clay loams, shallow sandy loam, soils low in organic content, soils usually high in clay
Group D	soils that swell significantly when wet, heavy plastic clays, certain saline soils

All other factors being equal, Group A soils have the lowest runoff potential and Group D soils have the highest runoff potential.

Usually, the best source of information for determining the SCS soil group for a particular drainage area is the *Soil Survey of Johnston County, North Carolina* [SCS].

Refer to the NCDEQ [Erosion and Sediment Control Design Manual](#), Tables 8.03e through 8.03g for the SCS Curve Numbers for each of the four SCS soil groups. The tables are also organized according to the SCS cover complex, which consists of three factors: land use, land treatment or practice, and hydrologic condition. For example, the land use for a particular area may be "Row crops". If the land treatment or practice is "Straight row" and the hydrologic condition is "Good", then the SCS Curve Number would range from 67 to 89, depending on the soil group.

Figure 10.2 Determination of Runoff Volume Using SCS Curve Number



Source: "Drainage Criteria Manual for Montgomery County Texas," [Dodson, 1989]

$$S = \frac{1000}{CN} - 10 \tag{Equation 10.2.1}$$

$$Q^* = \frac{(P - 0.2S)^2}{P + 0.8S} \tag{Equation 10.2.2}$$

The Volume of runoff is now found by multiplying runoff depth by the watershed area.

$$V = Q^* A \tag{Equation 10.2.3}$$

Where, $S \rightarrow$ Ultimate Soil Storage, measured in inches.

$P \rightarrow$ Precipitation depth, measured in inches. The depth of precipitation varies from any given Storm Event. To determine inches of rainfall, the designer should use *Technical Paper Number 40, Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years*, [Hershfield, 1961].

Q^* → The runoff depth, measured in inches. The asterisk has been added to distinguish the use of Q^* , which is a depth and the usual use of Q , which is a discharge.

V → The total volume of runoff for the design storm in cubic feet.

A → The area in acres contributing runoff to the point of interest. The area in these equations is to be measured in SQUARE MILES.

Example 10.2

Use the SCS Method to determine the total volume of runoff for the following given data for the 10-yr, 24-hr storm. The basin size is 300 acres (0.469 Square Miles). The composite CN is 80. *This is a hypothetical system.*

Solution:

Estimate the Runoff Volume:

- a. Use TP-40 ([Table 2.2](#)) to determine the depth of rainfall for the 10 year -24 hour Storm.

$$P_{10,24} = 5.44 \text{ inches}$$

- b. Using Equation 10.2.1, Equation 10.2.2, Equation 10.2.3 and the above given information determine the Runoff Volume.

$$S = \frac{1000}{CN} - 10 = \frac{1000}{80} - 10 = 2.5 \text{ inches}$$

$$Q^* = \frac{(P - 0.2S)^2}{P + 0.8S} = \frac{(5.44 - 0.2(2.5))^2}{5.44 + 0.8(2.5)} = 3.28 \text{ inches}$$

$$V = Q^* A = (3.28)(300) = 984 \text{ acre-inches}$$

This volume can be used with Malcom's Method to develop the inflow hydrograph.

10.3 CULVERT DESIGN

As described in [Section 4.5.3](#), the Town of Clayton uses the design procedures of Hydraulic Engineering Circular No. 5 (*HEC 5*) for the design of pipe culverts. *HEC 5* was designed to analyze flow in pipes using many different variables. These variables, which affect the hydraulic capacity of a culvert, cause the pipe system to function as either an inlet-controlled pipe section or an outlet-controlled pipe section. **Inlet control** means that the discharge in the culvert is limited by the hydraulic and physical characteristics of the inlet alone. These include headwater depth, culvert barrel shape, barrel cross sectional area, and the type of inlet edge. For inlet control, the barrel roughness, length, and slope are not factors in determining culvert capacity.

Under **outlet control**, the discharge capacity of the culvert is dependent on all of the hydraulic variables of the structure. These include headwater depth, tailwater depth, barrel shape, cross-sectional area, barrel roughness, slope, and length.

In all culvert design, **headwater**, or depth of ponding at the entrance to the culvert is an important factor in culvert capacity. The headwater depth (HW) is the vertical distance from the invert at the culvert entrance to the energy grade line of the approaching flow. Due to low velocities in most entrance pools and the difficulty in determining velocity head in any flow, the energy line can often be assumed be the same as the water surface.

For culverts under outlet control, **tailwater depth** is an important factor in computing both headwater depth and the hydraulic capacity of the culvert. If flow in the channel downstream of the culvert is sub-critical, a computer-aided backwater analysis or calculation of normal depth is warranted to determine the tailwater elevation. If the downstream flow is super-critical, tailwater depth is not a factor in determining the culvert's hydraulic capacity.

10.3.1 Inlet-Controlled Flow

Under inlet control, the culvert entrance may or may not be submerged. However, inlet-controlled flow through the culvert barrel is free surface flow in all cases. When the culvert inlet is submerged, the most reliable means for determining discharge is with standard empirical relationships. Nomographs which plot headwater vs. discharge for various culvert sizes and shapes under inlet control have been developed on the basis of laboratory research with models and full scale prototypes ([Figure 10.3.4](#)).

10.3.2 Outlet-Controlled Flow

The culvert barrel may be full or partially full for culverts with outlet control flow for part or all of the barrel length. Both the headwater and tailwater may or may not submerge the culvert.

If the culvert is flowing full, the energy required to pass a given quantity of water is stored in the head (H). From energy considerations it can be shown that H is the difference between the hydraulic grade line at the outlet and the energy grade line at the inlet (expressed in feet).

When a given discharge passes through a culvert, stored energy, represented by the total head (H), is dissipated in three ways: A portion is lost to turbulence at the entrance (H_e); a portion is lost to frictional resistance in the culvert barrel (H_f); and a portion is lost as the kinetic energy of flow through the culvert dissipated in the tailwater (H_o). From this, the following relationship is evident:

$$H = H_e + H_f + H_o \quad \text{Equation 10.3.1}$$

The entrance loss (H_e) is determined by multiplying the culvert velocity head by an entrance loss coefficient k_e . Table 10.3 lists values for the entrance loss coefficient.

Table 10.3 Entrance Loss Coefficients for Concrete Pipe Culverts

Type of Structure and Design of Entrance	Coefficient
Projecting from fill, socket end (groove-end)	0.20
Projecting from fill, square cut end	0.50
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.20
Square-edge	0.50
Rounded (radius = 0.5D)	0.20
Mitered to conform to fill slope	0.70
End section conforming to fill slope	0.50
Beveled edges (33.7 degree or 45 degree bevels)	0.20
Side- or slope-tapered Inlet	0.20

Source: [FHWA, 1985]

The exit loss (H_o) is generally set equal to the culvert velocity head and the downstream flow velocity is assumed to be zero. An expression for the friction loss (H_f) is derived from Manning's equation:

$$H_f = \left(\frac{29n^2L}{R^{1.33}} \right) \frac{V^2}{2g} \quad \text{Equation 10.3.2}$$

Where, $n \rightarrow$ Manning's roughness coefficient.

$L \rightarrow$ The culvert barrel length, measured in feet.

$R \rightarrow$ The hydraulic radius, measured in feet.

$g \rightarrow$ The gravitational constant (32.2 ft/sec^2).

$V \rightarrow$ The mean velocity of flow in the culvert, measured in ft/sec .

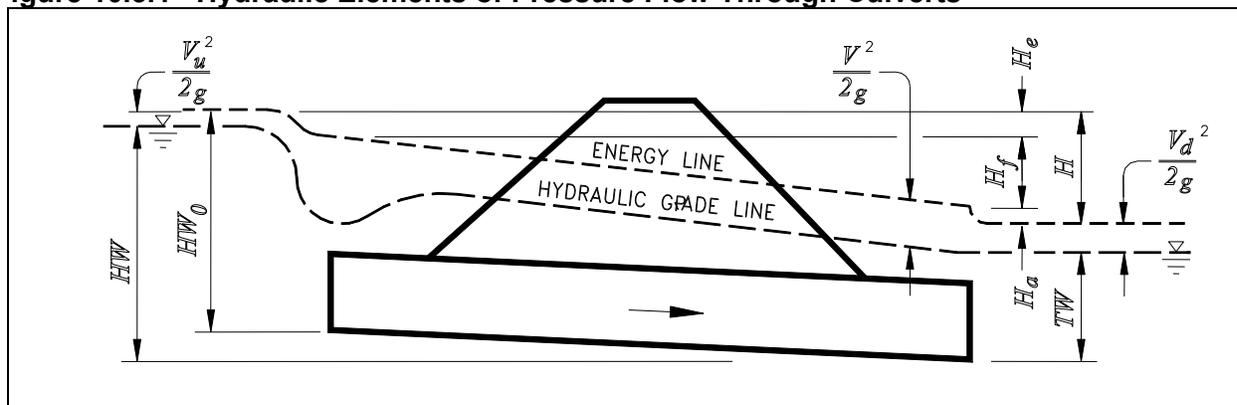
Rearranging Equation 10.3.1 and substituting it into Equation 10.3.2, it is seen that for full flow:

$$H = 1 + k_e + \left(\frac{29n^2L}{R^{1.33}} \right) \frac{V^2}{2(32.2)} \quad \text{Equation 10.3.3}$$

Equation 10.3.3 may be solved using the full flow nomographs, [Figures 10.3.4](#) and [10.3.5](#). Each nomograph is drawn for a particular barrel shape and material and a single value of Manning's "

n " as noted on the respective charts. These nomographs may be used for other values of " n " by modifying the culvert length as directed in the instructions for use of the full-flow nomographs.

Figure 10.3.1 Hydraulic Elements of Pressure Flow Through Culverts



Source: [FHWA, 1985]

Figure 10.3.1 represents the various hydraulic elements of pressure, or full, flow through a culvert and reveals graphically that the head (H) is equivalent to the vertical distance between the energy grade line at the inlet and the energy grade line at the outlet. It also reveals the following relationship for full flow conditions:

$$H = H_e + H_f + H_o = HW + SL - \frac{V^2}{2g} - TW \quad \text{Equation 10.3.4}$$

Where, HW → The headwater depth, measured in feet.

TW → The tailwater depth above the invert of the culvert outlet, measured in feet.

S_o → The culvert barrel slope, measured in feet/feet.

If the downstream flow velocity is neglected, Equation 10.3.4 becomes:

$$H = HW + S_o L - TW \quad \text{Equation 10.3.5}$$

In culvert design it is generally required that the depth of the headwater (HW) be determined.

Rearranging Equation 10.3.5, the following expression for HW is derived:

$$HW = H + TW - LS_o \quad \text{Equation 10.3.6}$$

When the culvert outlet is submerged by the tailwater, the above equation can be solved directly to determine HW . However, when the tailwater is below the crown of the culvert, it becomes necessary to redefine d_2 , which is taken as the greater of the following two values:

1) TW

2) $(d_c + D)/2$

Where, $d_c \rightarrow$ The critical depth in the culvert as read from the appropriate chart, measured in feet.

$TW \rightarrow$ The tailwater depth above the invert of the culvert outlet, measured in feet.

$D \rightarrow$ The height of the culvert, measured in feet.

Step by Step Culvert Design Procedure

It is possible by solving complex hydraulic computations to determine the probable type of flow under which a culvert will operate for a given set of conditions. However, such computations can be avoided by determining the headwater necessary for a given discharge under both inlet and outlet flow conditions. The larger of the two will define the type of control and the corresponding headwater depth.

The culvert design procedures presented here are based on information provided in the Federal Highway Administration publication *Hydraulic Design of Highway Culverts* [FHWA, 1985]. [Figures 10.3.3](#) to [10.3.5](#) cover a range of pipe and box culverts commonly used in drainage design. These nomographs correspond to Charts 1 through 15 and 29 through 40 in *Hydraulic Design of Highway Culverts*, [FHWA, 1985].

The following is the recommended procedure for selection of culvert size:

Step 1: List design data.

- a) Design discharge (Q), in cfs, with return period.
- b) Approximate length (L) of culvert, in feet.
- c) Slope of culvert (S_o). If grade is given in percent, convert to slope in feet per feet.
- d) Allowable headwater depth, in feet, which is the vertical distance from the culvert invert (flow-line) at the entrance to the water surface elevation permissible in the headwater pool or approach channel upstream from the culvert.
- e) Flow velocities in the channel upstream and downstream of the proposed culvert location.
- f) Type of culvert for first trial selection, including barrel material, barrel cross-sectional shape and entrance type.

Step 2: Determine the first trial culvert size.

Since the procedure given is one of trial and error, the initial trial size can be determined in several ways:

- a) Past experience and engineering judgment.
- b) By using an approximating equation such as $Q/6 = A$ from which the trial culvert dimensions are determined. "A" is the culvert barrel cross-sectional area and 6 is an estimate of barrel velocity in feet per second.
- c) Initially, utilize the inlet control nomographs for the culvert type selected. An HW/D ratio must be assumed, say $HW/D = 1.5$, along with the given Q to determine a trial culvert size.

If any trial size is too large in dimension because of limited height of embankment or availability of size, multiple culverts may be used by dividing the discharge appropriately among the number of barrels used. Raising the embankment height or the use of pipe arch and box culverts with width greater than height should also be considered. Final selection should be based on applicability and costs.

Step 3: Find headwater depth for trial culvert size.

a) Assuming Inlet Control

- 1) Using the trial size from Step 2, find the headwater depth (HW) by use of the appropriate inlet control nomograph. Tailwater (TW) conditions are to be neglected in this determination. HW in this case is found by multiplying HW/D obtained from the nomographs by the height of culvert (D).
- 2) If HW is greater or less than allowable, try another trial size until HW is acceptable for inlet control before computing HW for outlet control.

b) Assuming Outlet Control

- 1) Approximate the depth of tailwater (TW), in feet, above the invert at the outlet for the design flood condition in the outlet channel.
- 2) For tailwater (TW) elevation equal to or greater than the top of the culvert at the outlet, set d_2 equal to TW and find HW by using Equation 10.3.7.

$$HW = H + TW - LS_o \quad \text{Equation 10.3.7}$$

- 3) For tailwater (TW) elevations less than the top of the culvert at the outlet, find headwater (HW) by Equation 10.3.7 as in Step b(2) above except that:

$$d_2 = (d_c + D)/2 \text{ or } TW \text{ (whichever is greater)}$$

Note: Headwater depth determined in Step b(3) becomes increasingly less accurate as the headwater computed by this method falls below the value:

$$D + (1 + k_e) \frac{V^2}{2g}$$

- c) Compare the headwater depths obtained in Step 3(a) and Step 3(b) (Inlet Control and Outlet Control). The higher headwater governs and indicates the flow control existing under the given conditions for the trial size selected.
- d) If outlet control governs and the HW is higher than is acceptable, select a larger trial size and find HW as instructed under Step 3(b). (Inlet control need not be checked, since the smaller size was satisfactory for this control as determined under Step 3(a).)

Step 4: Try additional culvert types or shapes.

Determine their size and HW by the above procedure.

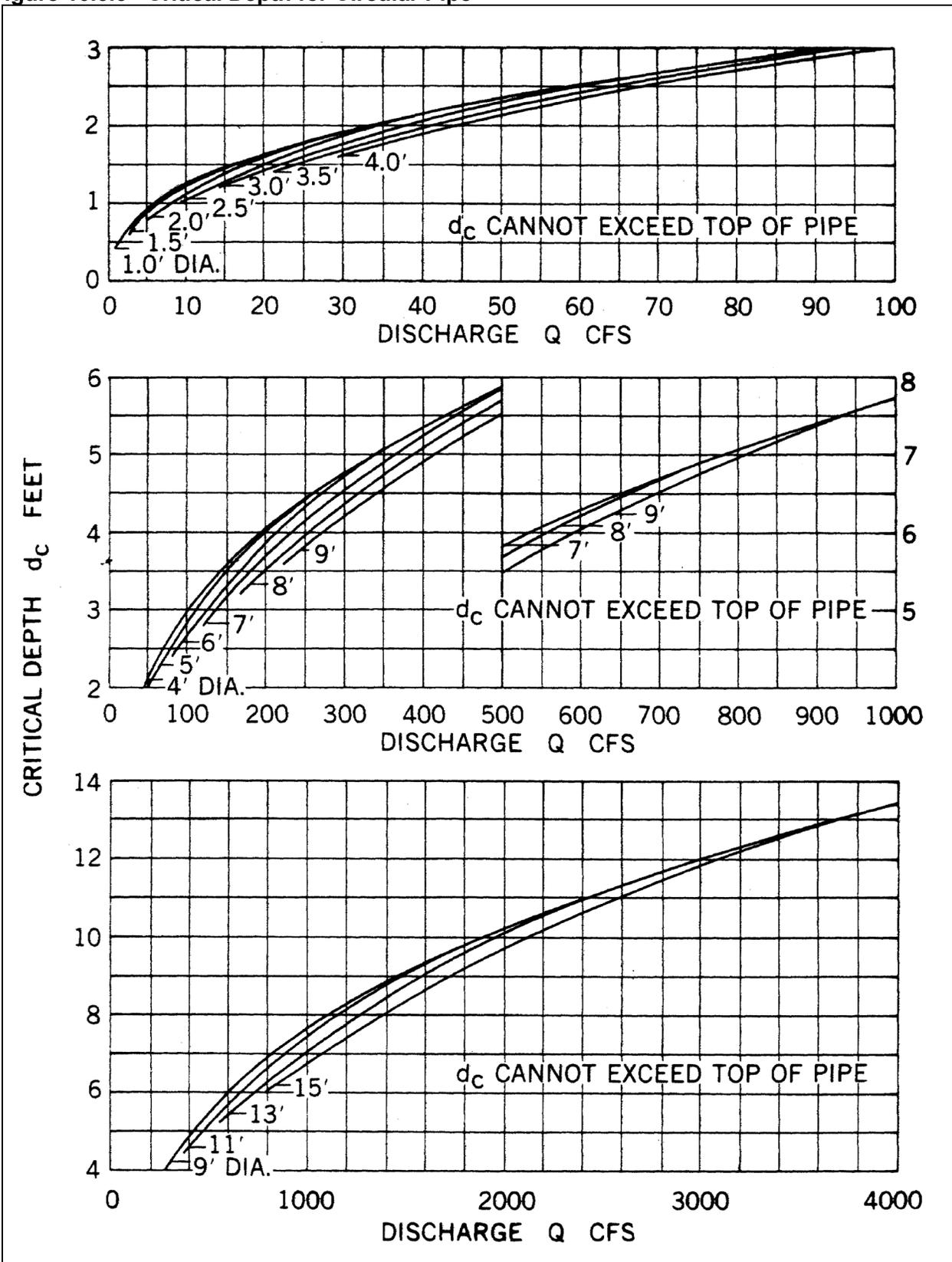
Step 5: Compute outlet velocities for size and types of Culverts to be considered in selection and determine need for channel protection.

- a) If outlet control governs in Step 3(c) above, outlet velocity equals $\frac{Q}{A_0}$, where A_0 is the cross-sectional area of flow in the culvert barrel at the outlet. If d_c or TW is less than the height of the culvert barrel, use A_0 corresponding to d_c or TW depth, depending on whichever gives the greater area of flow. A_0 should not exceed the total cross-sectional area A of the culvert barrel.
- b) If inlet control governs in Step 3(c), outlet velocity can be assumed to equal mean velocity (V) in open-channel type flow as computed by Manning's equation for the rate of flow, barrel size, roughness and slope of culvert selected.

Step 6: Record final selection of culvert with size, type, allowed and computed headwater, outlet velocity and economic justification.

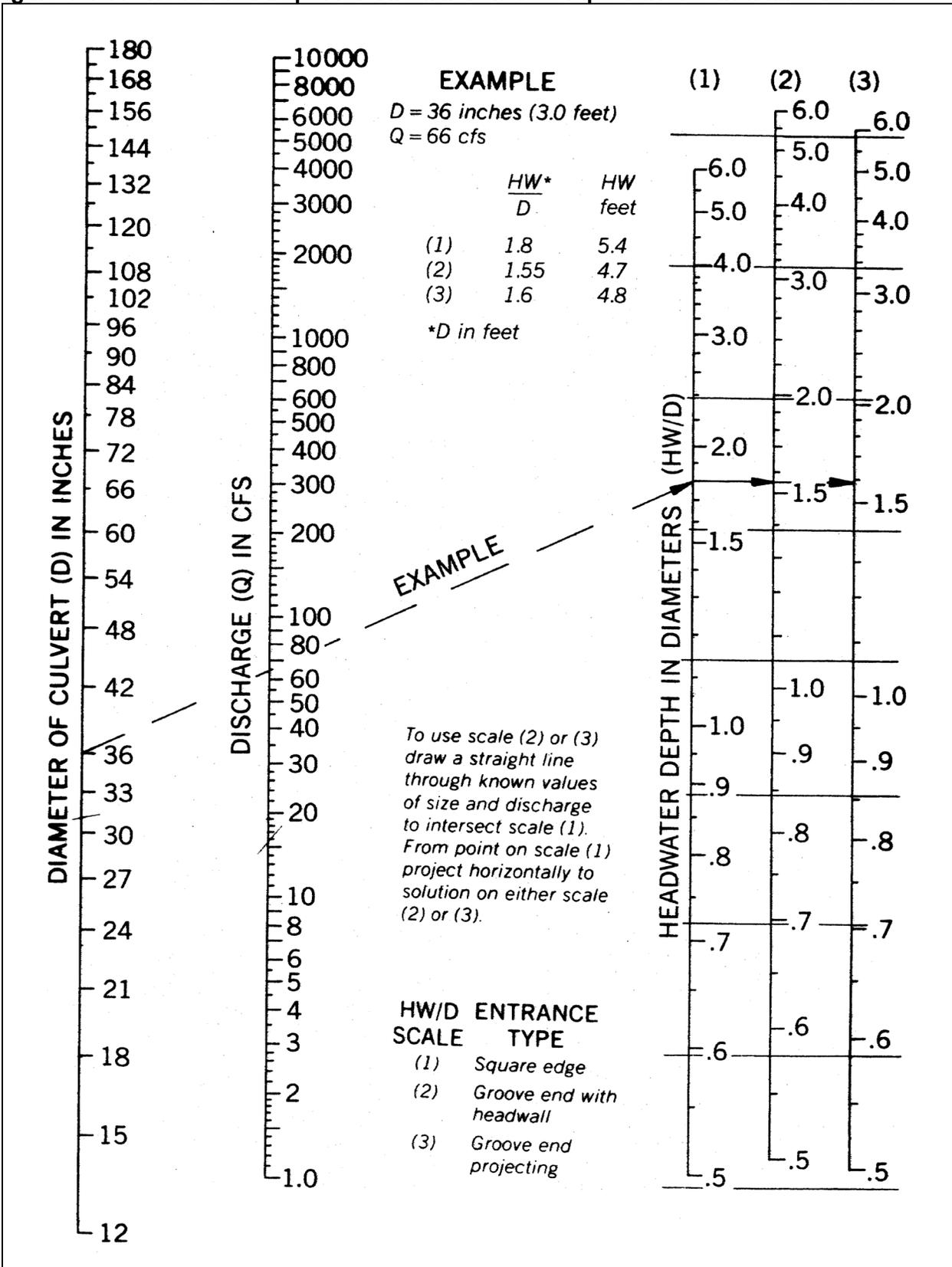
[Figure 10.3.2](#) provides a Culvert Design Form that may be used to record the culvert computations and related data.

Figure 10.3.3 Critical Depth for Circular Pipe



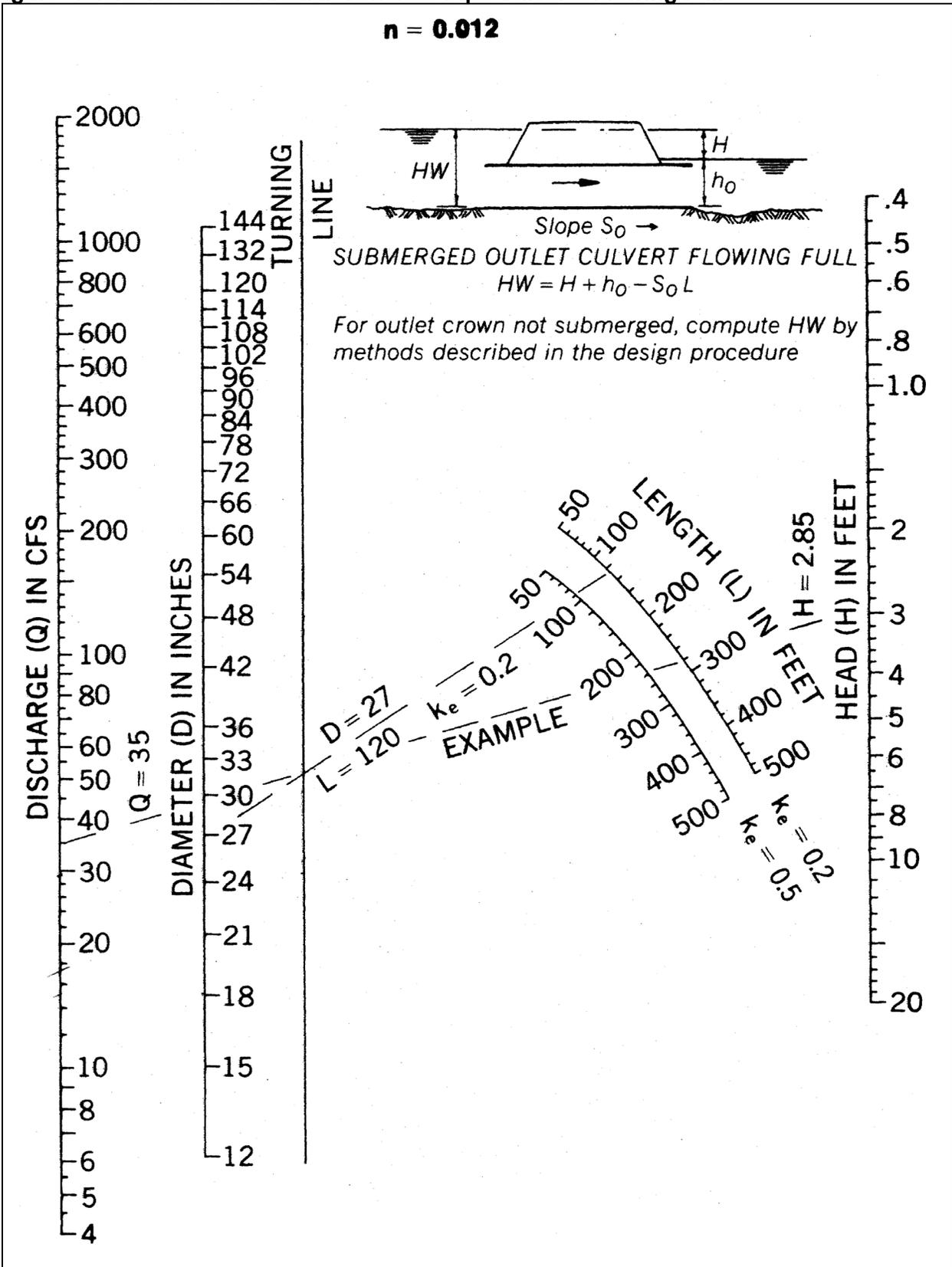
Source: [Bureau of Public Roads, 1963]

Figure 10.3.4 Headwater Depth for Circular Concrete Pipe Culverts with Inlet Control



Source: [Bureau of Public Roads, 1963]

Figure 10.3.5 Head for Circular Concrete Pipe Culverts Flowing Full



Source: [Bureau of Public Roads, 1963]

10.4 CURB INLET DESIGN – GUTTER SPREAD

As described in [Section 4.6](#), the Town of Clayton uses the design procedures of USDOT Federal Highway Administration *Urban Drainage Design Manual*, [Hydraulic Engineering Circular No. 22](#), Chapter 4, as applicable, for curb inlet design. *HEC 22* was designed to analyze flow in gutters and the interception capacity of grate, curb-opening and slotted drain inlets as well as combination inlets.

The curb inlet design procedure is based on the standard Town of Clayton curb inlet. Inlets capture most of the water entering the pipe system. The following procedure is used to locate inlets, however, other factors shall be considered such as location of the low points, intersections and layout of the pipe system (See [Section 3.6](#) and [Section 4.6](#)).

- a. Determine the maximum gutter flow from the nomograph “Flow in triangular gutter sections” ([Figure 10.4.1](#)). The known values of S = Street longitudinal slope, S_x = Street cross slope, T = 6 feet (the maximum allowable spread), and n = Manning’s roughness coefficient are used to solve for the gutter capacity, Q .
- b. Determine the location of the inlet using the rational formula rearranged such that:

$$A = \frac{Q}{Ci} \quad \text{Equation 10.4.1}$$

Where, $Q \rightarrow$ The peak rate of runoff in cubic feet per second (cfs). Actually, Q is in units of inches per hour per acre.

$C \rightarrow$ The dimensionless coefficient of runoff representing the ratio of peak discharge per acre to rainfall intensity (i).

$i \rightarrow$ The average intensity of rainfall in inches per hour for a period of time equal to the time of concentration for the drainage area at the point of interest.

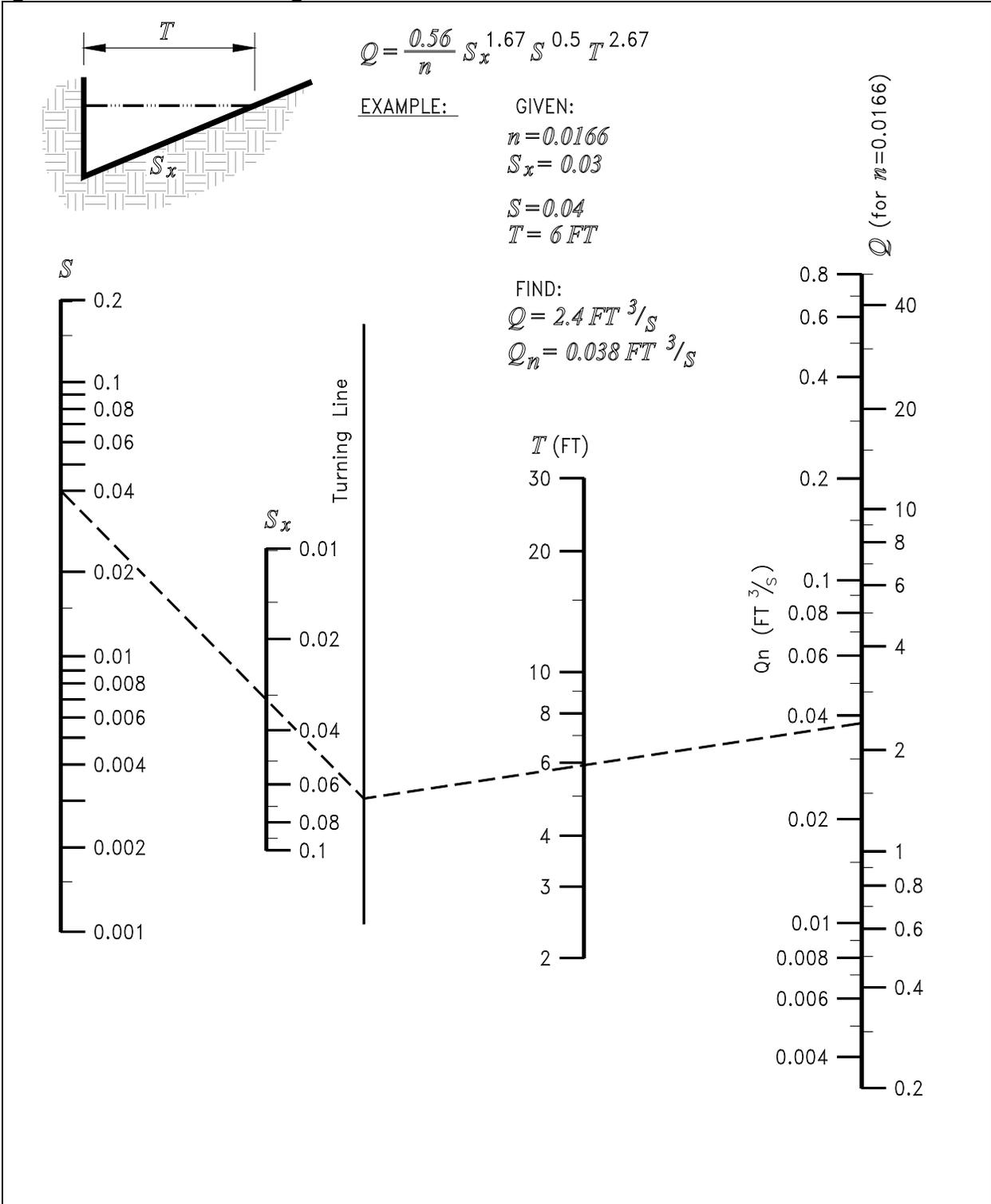
$A \rightarrow$ The area in acres contributing runoff to the point of interest during the critical storm duration.

Locate the first inlet by trial and error using the existing site contours and the proposed designed plan such that the area of the sub-drainage area does not exceed the capacity determined using Equation 10.4.1. Remember to check the “ C ” value for the actual area determined.

- c. The next inlets are located utilizing [Figure 10.4.1](#) and [10.4.2](#). Determine the required curb opening length, L_t , and enter in [Figure 10.4.3](#), with the ratio L/L_t where L is the actual curb opening in feet for Town of Clayton standard curb inlets. This will yield the percentage of flow intercepted by each basin. The remainder of this flow shall be considered in determining the location of the next downstream inlet. This procedure

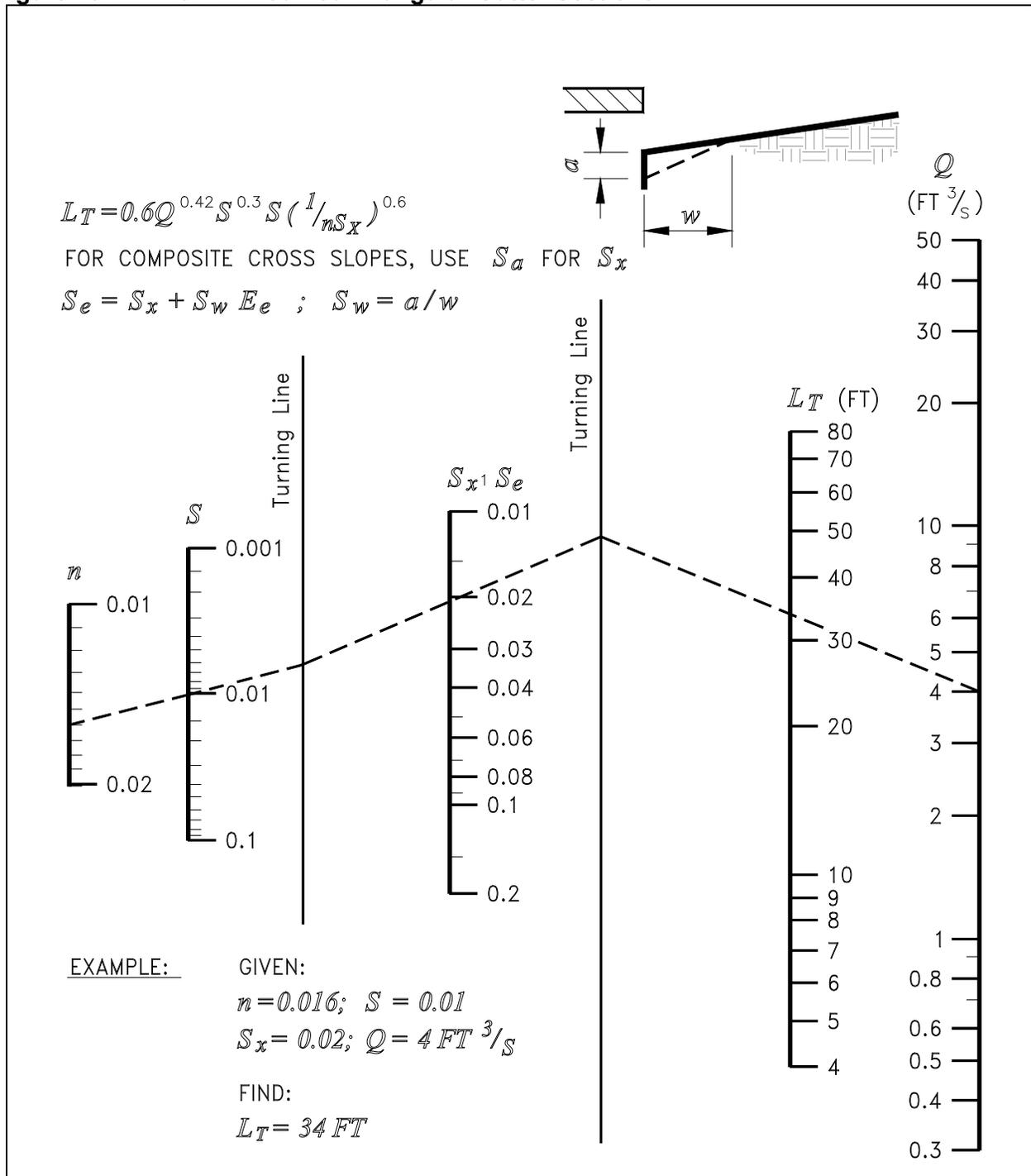
is repeated as necessary. Do not exceed the maximum pipe run length between structures as noted in [Table 3.3 \(Section 3.6\)](#).

Figure 10.4.1 Flow in Triangular Gutter Sections



Source: [FHWA-TS-84-202]

Figure 10.4.2 Flow in Modified Triangular Gutter Sections



Source: [FHWA-TS-84-202]

Source: City of Wilmington Technical Standards and Design, [July 1996]

10.5 OPEN CHANNEL DESIGN

As described in [Section 5.2](#), the proper hydraulic design of a channel is primary importance to ensure that flooding, sedimentation and erosion do not occur.

10.5.1 THE MANNING EQUATION

The Manning equation is an empirical relationship which relates friction slope, flow depth, channel roughness, and channel cross-sectional shape to flow rate. The **friction slope** is a measure of the rate at which energy is being lost due to channel resistance. When the channel slope and the friction slope are equal ($S_f = S_o$), the flow is uniform and the Manning equation may be used to determine the depth for uniform flow, commonly known as the **normal depth**.

The Manning equation is as follows:

$$V = \left(\frac{1.49}{n} \right) R^{2/3} \sqrt{S_f} \quad \text{Equation 10.5.1}$$

or

$$Q = \left(\frac{1.49}{n} \right) A R^{2/3} \sqrt{S_f} \quad \text{Equation 10.5.2}$$

Where, $Q \rightarrow$ Total discharge (cfs)

$V \rightarrow$ Velocity of flow (ft/sec)

$n \rightarrow$ Manning coefficient of roughness (dimensionless), an experimentally determined value which is a function of the nature of the channel lining ([Table 10.5.1](#)).

$A \rightarrow$ Cross-sectional area of the flow (ft²)

$R \rightarrow$ Hydraulic radius of the channel (ft) (flow area/wetted perimeter). Wetted perimeter is the distance along the perimeter of the cross section against which water is flowing. It DOES NOT include the free water surface.

$S_f \rightarrow$ Friction slope, the rate at which energy is lost due to channel resistance. Longitudinal slope of the water surface (feet fall/feet run). If flow is uniform, it is also the slope of the invert of the channel.

The area (A) and the hydraulic radius (R) are written in terms of the depth (y_o). Knowing the discharge (Q), Manning " n " value, and the channel slope (S_o), Equation 4.02 can be solved by trial to find normal depth (y_o).

10.5.1.1 Manning 'n' Values

The Manning “*n*” value is an experimentally derived constant which represents the effect of channel roughness in the Manning equation. Considerable care must be given to the selection of an appropriate “*n*” value for a given channel due to its significant effect on the results of the Manning equation. [Tables 10.5.1](#) through [10.5.5](#) provide a listing of “*n*” values for various channel conditions.

Table 10.5.1 Manning Roughness Coefficient for Excavated or Dredged Channels

Type of Channel and Description	Minimum	Normal	Maximum
Earth, straight and uniform			
Clean, recently completed	0.016	0.018	0.020
Clean, after weathering	0.019	0.022	0.025
Gravel, uniform section, clean	0.022	0.025	0.030
With short grass, few weeds	0.022	0.027	0.033
Earth, winding and sluggish			
No vegetation	0.023	0.025	0.030
Grass, some weeds	0.025	0.030	0.033
Dense weeds or plants in deep channels	0.030	0.035	0.040
Earth bottom and rubble sides	0.028	0.030	0.035
Stony bottom and weedy banks	0.025	0.035	0.040
Cobble bottom and clean sides	0.030	0.040	0.050
Dragline-excavated or dredged			
No vegetation	0.025	0.028	0.033
Light brush or banks	0.035	0.050	0.060
Rock cuts			
Smooth and uniform	0.025	0.035	0.040
Jagged and irregular	0.035	0.040	0.050
Channels not maintained and brush uncut			
Dense weeds, high as flow depth	0.050	0.080	0.112
Clean bottom, brush on sides	0.040	0.050	0.080
Same, highest stage of flow	0.045	0.070	0.110
Dense brush, high stage	0.080	0.100	0.140

Source: [Chow, 1959]

Table 10.5.2 Manning Roughness Coefficient for Lined or Built-Up Channels

Type of Channel and Description	Minimum	Normal	Maximum
Metal			
Unpainted Smooth steel surface	0.011	0.012	0.014
Painted smooth steel surface	0.012	0.013	0.017
Corrugated metal	0.021	0.025	0.030
Cement			
Neat, surface	0.010	0.011	0.013
Mortar	0.011	0.013	0.015
Wood			
Planed, untreated	0.010	0.012	0.014
Planed, creosoted	0.011	0.012	0.015
Unplaned	0.011	0.013	0.015
Wood plank with battens	0.012	0.015	0.018
Concrete			
Trowel finish	0.011	0.013	0.015
Float finish	0.013	0.015	0.016
Finished, with gravel on bottom	0.015	0.017	0.020
Unfinished	0.014	0.017	0.020
Concrete on good excavated rock	0.018	0.020	---
Concrete on irregular excavated rock	0.022	0.027	---
Gravel bottom			
sides of Formed concrete	0.017	0.020	0.025
sides of Random stone in mortar	0.020	0.023	0.026
sides of Dry rubble or rip-rap	0.023	0.033	0.036
Brick			
Glazed	0.011	0.013	0.015
in cement mortar	0.012	0.015	0.018
Asphalt			
Smooth	0.013	0.013	---
Rough	0.016	0.016	---
Vegetated lining	0.030	---	0.500

Source: [Chow,1959]

Table 10.5.3 Manning Roughness Coefficient for Minor* Natural Streams

Type of Channel and Description	Minimum	Normal	Maximum
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but some stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of, timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070

Source: [Chow, 1959] *Note: A "minor stream" is one which has a top width of less than 100 feet at flood stage.

Table 10.5.4 Manning Roughness Coefficient for Major* Natural Streams

Type of Channel and Description	Minimum	Normal	Maximum
Regular section with no boulders or brush	0.025	---	0.060
Irregular and rough section	0.035	---	0.100

Source: [Chow, 1959]

*Note: A “major stream” is one with a top width of more than 100 feet at flood stage. The n value is less than that for minor streams of similar description because banks offer less effective resistance.

Table 10.5.5 Manning Roughness Coefficient for Flood Plains

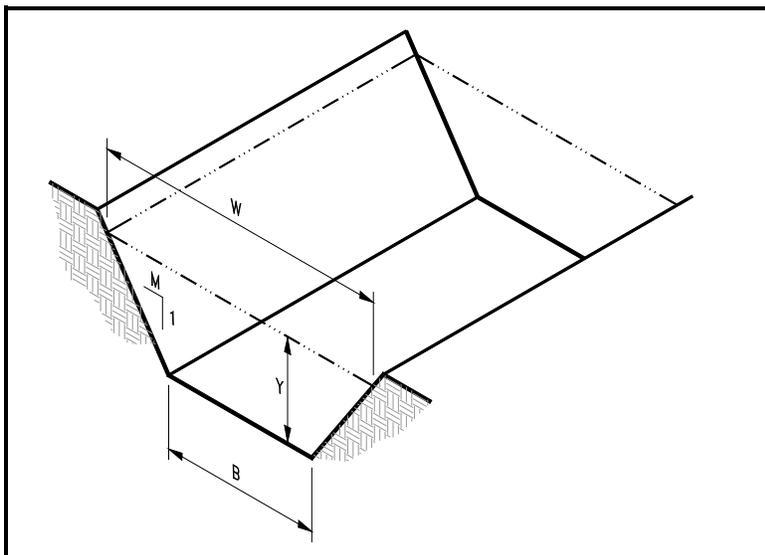
Type of Channel and Description	Minimum	Normal	Maximum
Pasture, no brush			
Short grass	0.025	0.030	0.035
High grass	0.030	0.035	0.050
Cultivated areas			
No crop	0.020	0.030	0.040
Mature row crops	0.025	0.035	0.045
Mature field crops	0.030	0.040	0.050
Brush			
Scattered brush, heavy weeds	0.035	0.050	0.070
Light brush and trees, in winter	0.035	0.050	0.060
Light brush and trees, in summer	0.040	0.060	0.080
Medium to dense brush, in winter	0.045	0.070	0.110
Medium to dense brush, in summer	0.070	0.100	0.160
Trees			
Dense willows, summer, straight	0.110	0.150	0.200
Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
Same as above, w/ heavy growth of sprouts	0.050	0.060	0.080
Heavy stand of timber, a few down trees, little undergrowth, flood-stage below branches	0.080	0.100	0.120
Same as above, w/ flood stage reaching branches	0.100	0.120	0.160

Source: [Chow, 1959]

10.5.2 TRAPEZOIDAL CHANNEL DESIGN

In trapezoidal design applications, [Figure 10.5.1](#) and Equations 10.5.3 through 10.5.6 help define the variables used to solve the Manning equation.

Figure 10.5.1 Typical Trapezoidal Channel



Where, $W \rightarrow$ Top width of flow, measured in feet.

$B \rightarrow$ Bottom width of the channel, measured in feet.

$y \rightarrow$ Depth of flow, measured in feet.

$M \rightarrow$ Side slope ratio (ft. horizontal / ft. vertical). (For a 2 to 1 side slope, the value of M is 2.)

$P \rightarrow$ Represents the wetted perimeter.

The following equations are derived geometrically, and the units of the variables are consistent with those given above:

$$A = By + M y^2 \quad \text{Equation 10.5.3}$$

$$P = B + 2y\sqrt{(1 + M^2)} \quad \text{Equation 10.5.4}$$

$$W = B + 2 M y \quad \text{Equation 10.5.5}$$

$$R = \frac{A}{P} \quad \text{Equation 10.5.6}$$

10.5.3 MANNING ROUGHNESS COEFFICIENT – IMPROVED CHANNELS

The values of the Manning roughness coefficient listed in [Table 10.5.6](#) should be used in the design of channel improvements. Alternative values should be discussed with the Engineering Director.

Table 10.5.6 Manning Roughness Coefficient for Improved Channels

Channel Cover	"n" Value
Bare Soil	0.025
Grass-Lined	0.040
Rip-Rap Lined	0.070
Concrete Lined	0.013

10.5.4 CHANNEL EROSION CONTROL

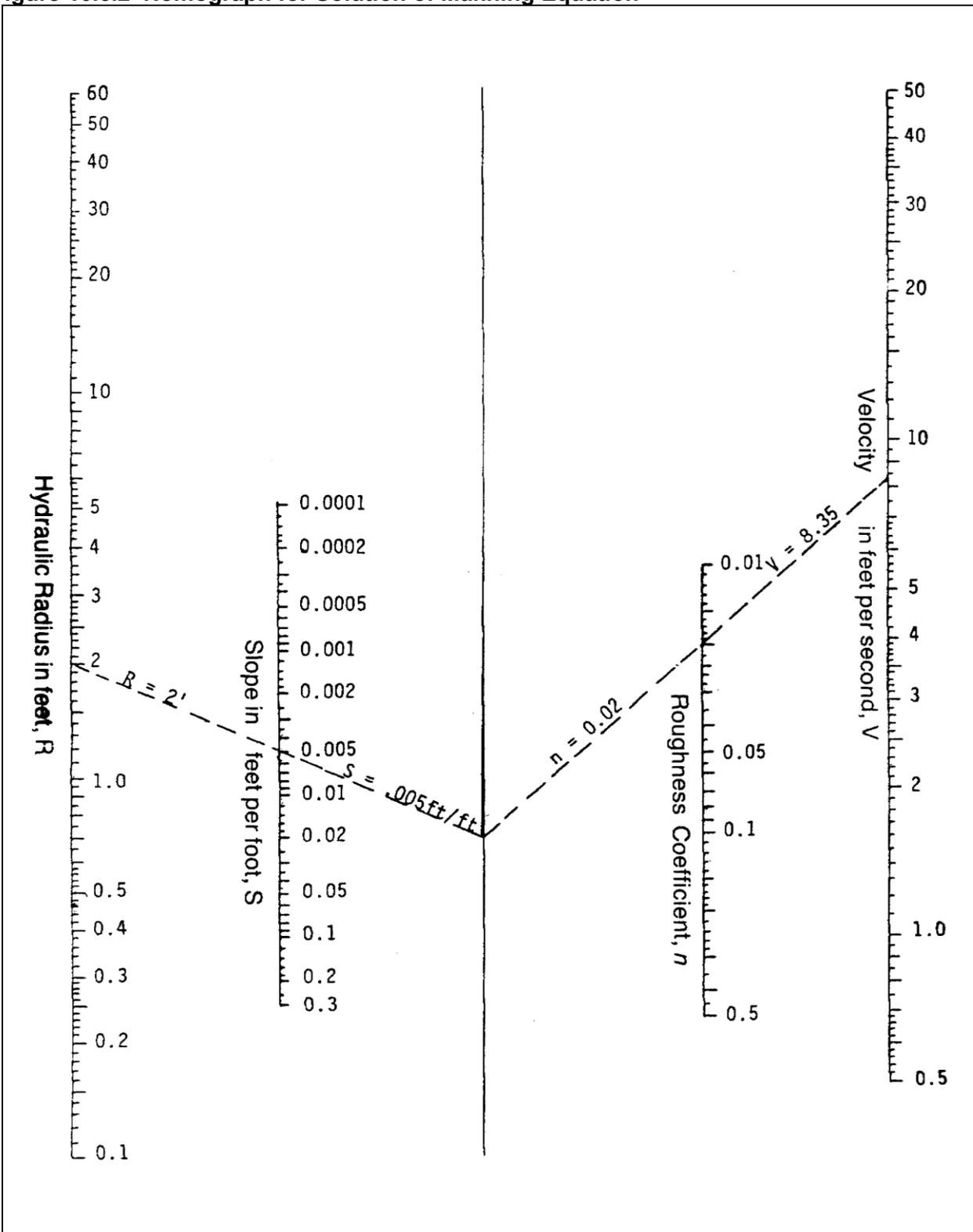
Erosion protection is necessary to ensure that channels maintain their capacity and stability and to avoid excessive transport and deposition of eroded material.

All erosion and sediment control measures shall be designed in accordance with the North Carolina Sedimentation Pollution Control Act of 1973. The Designer is to reference the *Erosion and Sediment Control Planning and Design Manual*, [NCDEQ, latest edition]. This manual contains valuable information and tools for developing plans to minimize soil erosion and prevent sedimentation pollution associated with land-disturbing activities.

10.5.5 OPEN CHANNEL DESIGN AIDS

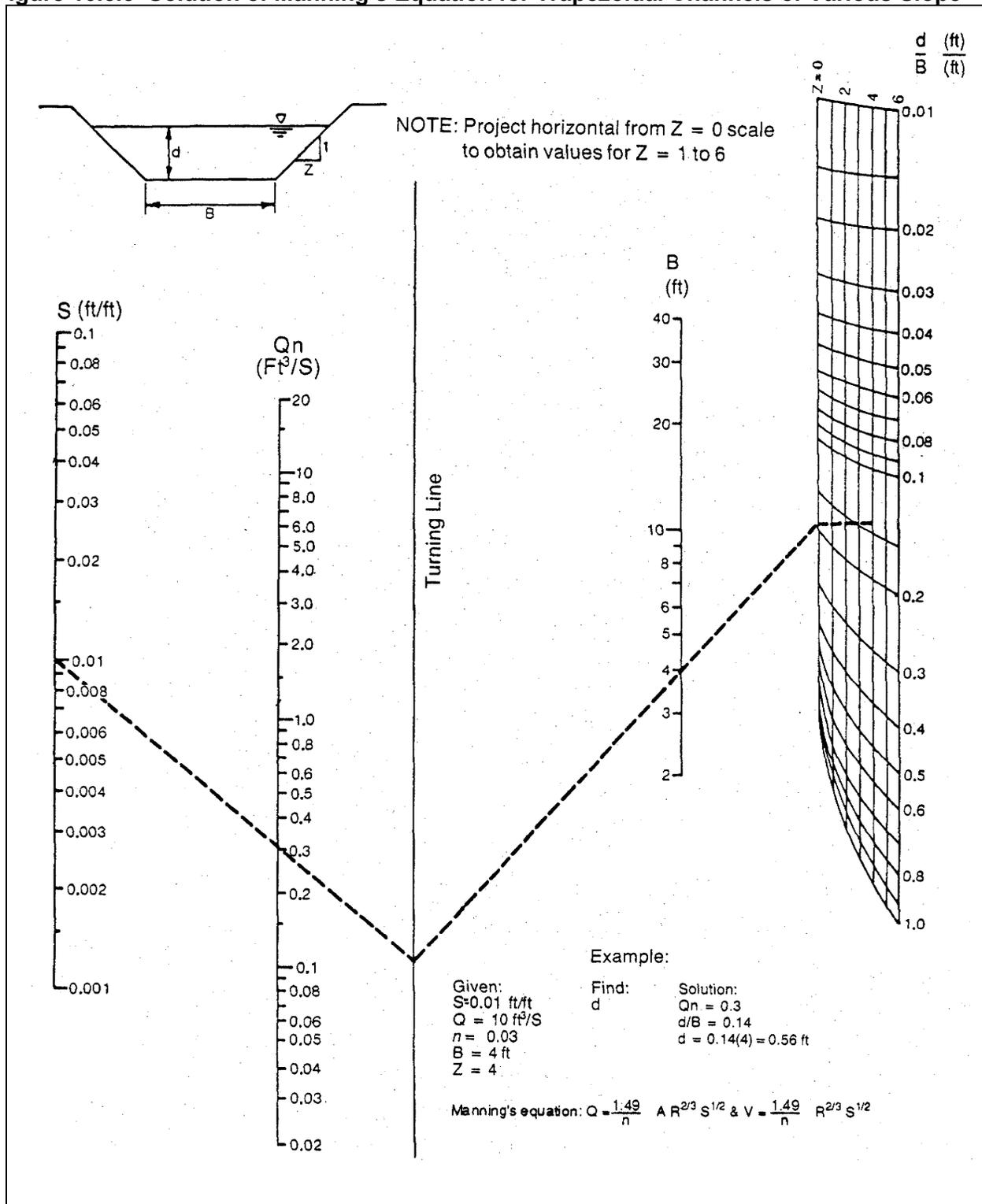
[Figures 10.5.2](#) to [10.5.7](#) provide assistance to the designer of open channels.

Figure 10.5.2 Nomograph for Solution of Manning Equation



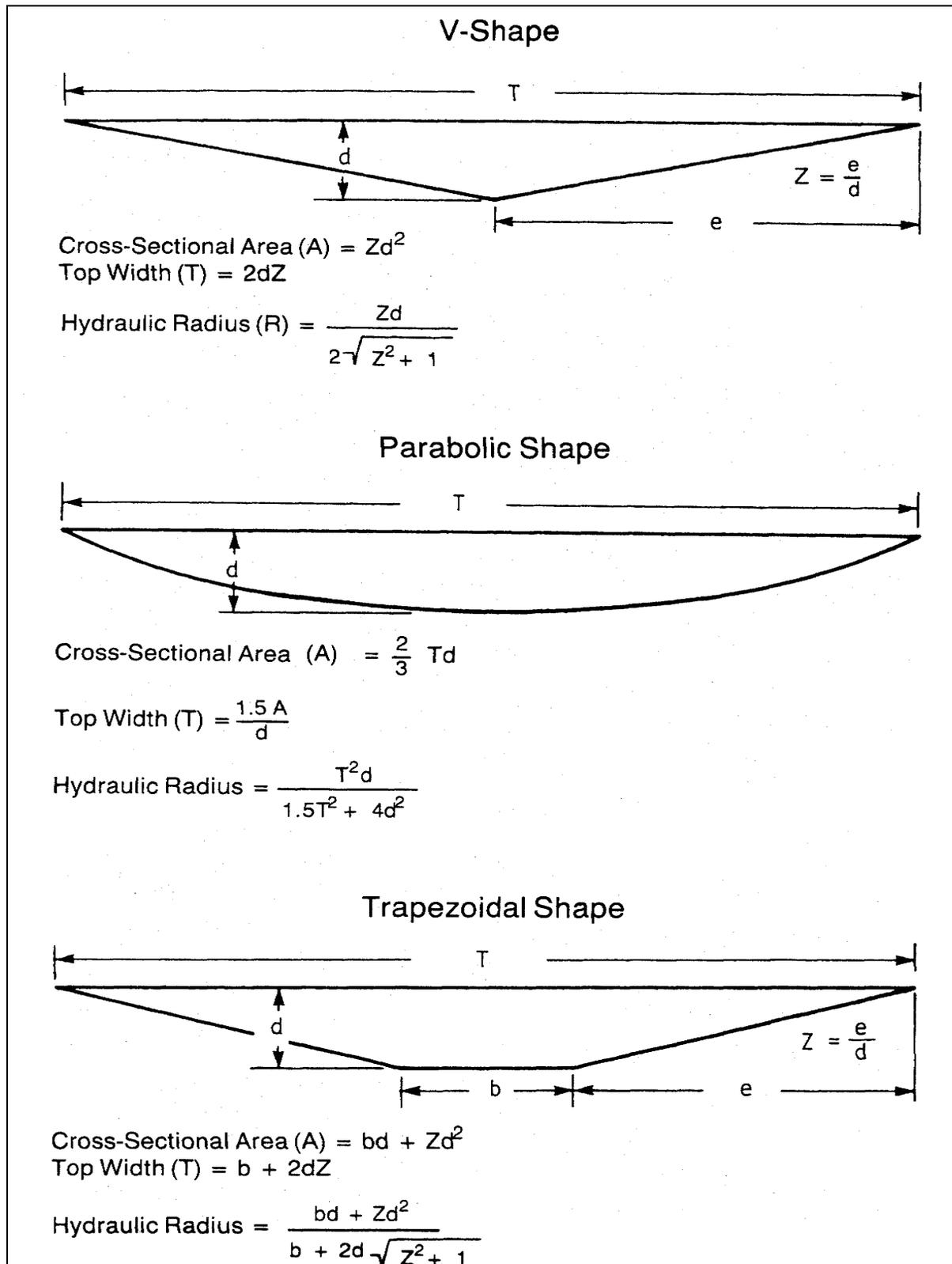
Source: [FHWA – HEC-15,1988]

Figure 10.5.3 Solution of Manning's Equation for Trapezoidal Channels of Various Slope



Source: [FHWA – HEC-15, 1988]

Figure 10.5.4 Channel Geometries for V-Shape, Parabolic and Trapezoidal Channels



Source: ["E&S Control Planning and Design Manual," DEHNR, May 1994 Revised]

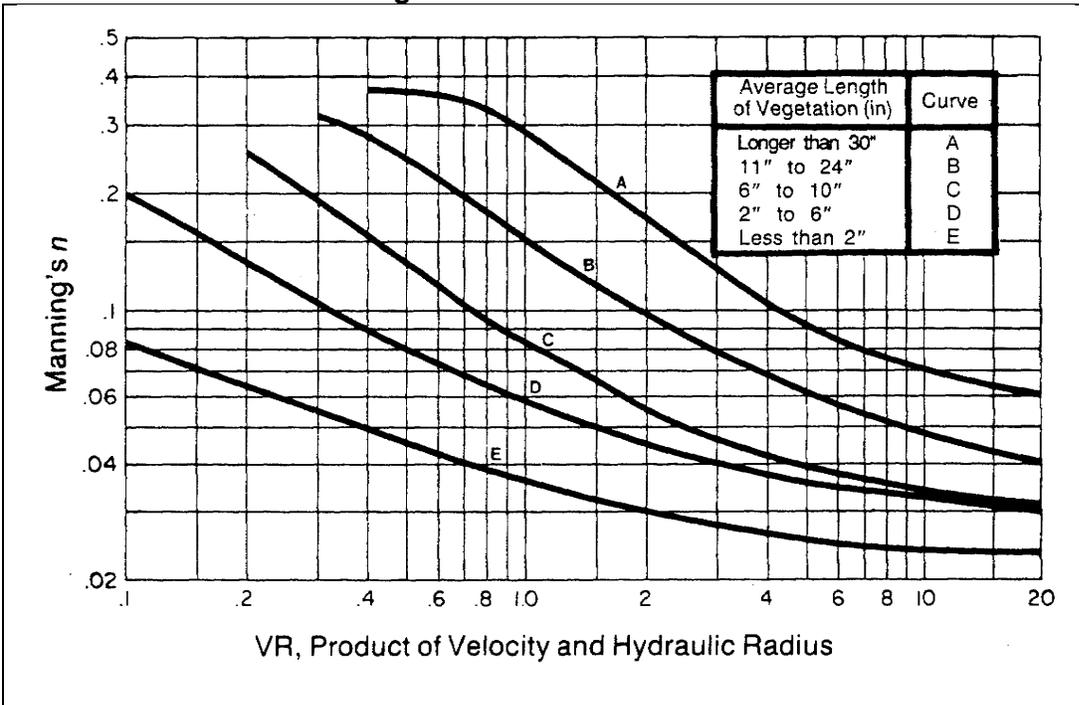
Figure 10.5.5 Maximum Allowable Design Velocities¹ for Vegetated Channels

Typical Channel Slope Application	Soil Characteristics ²	Grass Lining	Permissible Velocity ³ for Established Grass Lining (ft/sec)
0-5%	Easily Erodible Non-Plastic (Sands & Silts)	Bermuda grass	5.0
		Tall Fescue	4.5
		Bahia grass	4.5
		Kentucky bluegrass	4.5
		Grass-legume mixture	3.5
	Erosion Resistant Plastic (Clay Mixes)	Bermuda grass	6.0
		Tall Fescue	5.5
		Bahia grass	5.5
		Kentucky bluegrass	5.5
		Grass-legume mixture	4.5
5-10%	Easily Erodible Non-Plastic (Sands & Silts)	Bermuda grass	4.5
		Tall Fescue	4.0
		Bahia grass	4.0
		Kentucky bluegrass	4.0
		Grass-legume mixture	3.0
	Erosion Resistant Plastic (Clay Mixes)	Bermuda grass	5.5
		Tall Fescue	5.0
		Bahia grass	5.0
		Kentucky bluegrass	5.0
		Grass-legume mixture	3.5
>10%	Easily Erodible Non-Plastic (Sands & Silts)	Bermuda grass	3.5
		Tall Fescue	2.5
		Bahia grass	2.5
		Kentucky bluegrass	2.5
	Erosion Resistant Plastic (Clay Mixes)	Bermuda grass	4.5
		Tall Fescue	3.5
		Bahia grass	3.5
		Kentucky bluegrass	3.5

Source: USDA-SCS Modified

NOTE: ¹ Permissible Velocity based on 10-yr storm peak runoff.² Soil erodibility based on resistance to soil movement from concentrated flowing water.³ Before grass is established, permissible velocity is determined by the type of temporary liner used.

Figure 10.5.6 Manning's n Related to Velocity, Hydraulic Radius and Vegetal Retardance



Source: [E&S Control Planning and Design Manual," DEHNR, May 1994 Revised]

Figure 10.5.7 Retardance Classification for Vegetal Covers

Retardance	Cover	Condition
A	Reed canary grass	Excellent stand, tall (average 36")
	Weeping love grass	Excellent stand, tall (average 30")
B	Tall fescue	Good stand, uncut (average 18")
	Bermuda grass	Good stand, tall (average 12")
	Grass-legume mixture (tall fescue, red fescue, sericea lespedeza)	Good stand, uncut
	Grass mixture (timothy, smooth brome grass, or orchard grass)	Good stand, uncut (average 20")
	Sericea lespedeza	Good stand, not woody, tall (average 19")
	Reed canary grass	Good stand, cut (average, 12-15")
	Alfalfa	Good stand, uncut (average 11")
C	Tall fescue	Good stand (8-12")
	Bermuda grass	Good stand, cut (average 6")
	Bahia grass	Good stand, uncut (6-8")
	Grass-legume mixture-Summer (orchard grass, redtop, and annual lespedeza)	Good stand, uncut (6-8")
	Centipede grass	Very dense cover (average 6")
	Kentucky bluegrass	Good stand, headed (6-12")
	Redtop	Good stand, uncut (15-20")
D	Tall fescue	Good stand, cut (3-4")
	Bermuda grass	Good stand, cut (2.5")
	Bahia grass	Good stand, cut (3-4")
	Grass-legume mixture-Fall-spring (orchard grass, redtop, and annual lespedeza)	Good stand, uncut (4-5")
	Red fescue	Good stand, uncut (12-18")
	Centipede grass	Good stand, cut (3-4")
	Kentucky bluegrass	Good stand, cut (3-4")
E	Bermuda grass	Good stand, cut (1.5")
	Bermuda grass	Burned stubble

Modified from: USDA-SCS, 1969. Engineering Field Manual.

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