CITY of HAYS
DESIGN CRITERIA
STORM DRAINAGE SYSTEMS AND FACILITIES

December 1998
Revised January 2015

DESIGN CRITERIA

STORM DRAINAGE SYSTEMS AND FACILITIES

1 GENERAL

1 Introduction: These criteria provide uniform procedures for designing and checking the design of storm drainage systems under the rainfall and land characteristics typical of the Hays, Kansas. Specific criteria have been developed and are applicable to the types of drainage systems and facilities ordinarily encountered in local urban and suburban areas. Other special situations may be encountered that require added criteria or more complex technology than included herein. Any design procedure conforming to current accepted engineering practice may be used for the design of storm drainage systems in lieu of the computation methods presented in these criteria, providing equivalent results are obtained.

1.2 Definitions:

A. Bank Line: The line of intersection, above the normal depth of flow at design capacity, of the side slope of an open channel and the adjacent ground.

B. **Best management practices** and **BMPs:** means a defined set of activities, prohibitions, pollution prevention and educational practices, maintenance procedures, and other management practices designed to prevent or reduce the discharge of pollutants directly or indirectly into stormwater, receiving waters, or stormwater conveyance systems. Best management practices and BMPs also include treatment practices, operating procedures, and practices to control site runoff, spillage and leaks, sludge and water disposal, and drainage from raw materials storage.

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

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

D. Controlled Area: That part of the tributary area for which a detention facility is designed to control peak discharge rates.

E. **Retention/Detention Storage:** The volume occupied by water above the level of the spillway crest during operation of a storm water retention/detention facility.

F. **Dry Detention Facility:** Any detention facility designed to permit no permanent impoundment of water.

G. **Developer**: Any person, partnership, association, corporation, public agency, or governmental unit proposing to or engaged in Adevelopment≅ as defined below; except the widening, resurfacing, or other improvement to existing streets, alleys, and sidewalks.

H. **Development:** Any activity, including subdivision, that alters the surface of the land to create additional impervious surfaces, including, but not limited to, pavement, buildings, and structures.

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

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

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

L. **Improved Channel:** A channel that has been altered by previous construction.

M. **Natural Channel**: An existing channel that has not been altered by previous construction.

N. **Owner:** The owner of record of real property.

O. **Principal Spillway:** A device such as an inlet, pipe, weir, etc., used to discharge water during operation of the facility under the conditions of the 100 year or less return frequency.

P.

Q.

R. **Registered Professional Engineer:** A licensed engineer who is registered with and authorized by the Kansas State Board of Technical Professions.

S. **Return Frequency:** The statistical average interval between rainfalls of equal magnitude.

T. **Sediment Storage:** The volume allocated to contain accumulated sediments within a retention/detention facility.

U. **Site:** A tract or contiguous tracts of land owned and/or controlled by a developer or owner. Platted subdivisions, industrial and/or office-commercial parks, and other planned unit developments shall be considered a single site.

V. **Storm Drainage System:** All of the natural and manmade facilities and appurtenances such as ditches, natural channels, pipes, culverts, bridges, open improved channels, inlets, and retention/detention facilities which serve to convey surface drainage.

W. **Storm Water Retention/Detention Facility:** A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold runoff for a short period of time and then release it to the surface and storm water management system. Also, all facilities incorporating retention/detention storage of storm water in or on any of the following:

1. Roofs of buildings or structures also used for other purposes.
2. Paved or surfaced areas also used for other purposes.
3. Enclosed or underground pipes or structures on private property when the surface is used for other purposes.

X. **Tributary Area:** All land draining to the point of consideration, regardless of ownership.

Y. **Wet Retention/Detention Facility:** A retention/detention facility that is designed to include permanent storage of water in addition to the temporary storage used to control discharge rates from the facility. Wet Retention/Detention Facilities are restricted in the City of Hays.

1.3 General Requirements: The design shall be accomplished under the direction of a Registered Professional Engineer. The design shall also be based on land use in the tributary area as zoned, actually developed, or indicated by an adopted future land use plan, whichever basis produces the greatest runoff. Drainage design shall use natural conveyances, principles of integrated site design, green infrastructure and the use of practices to reduce the generation of runoff.

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

1. They are in sound structural condition.

2. Their hydraulic capacity, including surcharge, is equal to or greater than the capacity required by these criteria.

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

Discharge from an existing upstream storm drainage system shall be computed meeting the hydraulic capacity of this criteria. The computed discharge shall be used to design the new downstream system even if the actual capacity of the existing upstream system is less.

1.5 System Types and Applications:

A. Open Systems: Maximum feasible use shall be made of existing drainage ways, open channels and drainage swales that are designed and coordinated with the design of building lots and streets. Open systems which must be protected from driveway, fence, landscaping and other encroachment must be detailed on plats with permanent rights-of-way or easements, as appropriate. The design professional shall make all reasonable attempts to incorporate water quality improvements in their conveyance design.

B. Enclosed Systems: Enclosed systems consisting of underground pipes, culverts, and similar functional underground structures shall not be used to convey stormwater unless overland conveyance is proven infeasible by the design engineer. Short sections of pipe are allowable in order to reduce risk to adjacent properties and to drain stormwater best management practices.

C. Stormwater Retention/Detention Facilities: Retention/Detention facilities shall be provided in connection with the development of land. Retention/Detention facilities shall be designed, to the maximum extent practicable, as water quality structures in accordance with the "Post Construction Stormwater Best Management Practices" manual of the City of Hays.

Operation and maintenance plans are required to be developed for all retention/detention structures and best management practices built under these drainage standards. These are to be supplied to the city engineer.

In lieu of providing stormwater retention/detention facilities, the downstream conveyance system be improved to accommodate all increased runoff with out causing flooding, and to contain all increased flows within the conveyance system, if approved by the City Stormwater Administration.

D. **Overflow Systems:** Each conveyance element of the stormwater drainage system (whether enclosed or open) shall include an overflow system having sufficient hydraulic capacity to convey, when combined with the 5-year conveyance system, the peak discharge generated by a 100-year return period storm discharge without damage to land or buildings and such that the 100-year discharge water surface elevation plus one foot freeboard, is equal to or below the lowest elevation at which water may enter any proposed or existing building or structure.

E. Best Management Practices: Stormwater Best Management Practices shall be installed in all developments as required by Chapter 53 of the City of Hays Zoning and Subdivision regulations.

1.6 Waivers: The City Engineer may waive requirements to provide specific types of stormwater elements as follows:

A. **Detention/Retention Facilities:** Retention/Detention may be waived and/or release rates other than those released by Section 6 may be approved by the City Engineer when:

A detailed hydraulic study indicates that a retention/detention facility would increase the downstream peak rate of discharge by creating a delayed peak that would coincide with a peak from an upstream area and thereby increasing the total discharge. The hydraulic study must be comprehensive enough to show that more multiple retention/detention schemes show an increase in peak flows.

B. **Study:** The Developer provides an adequate study by a registered professional engineer that quantifies the problems and demonstrates that a waiver of the requirement to provide retention/detention facilities is appropriate.

C. **Overflow Channels:** In previously developed areas, requirements to provide for 100-year storm conveyance may be reduced in circumstances where 100-year protection is not reasonably attainable due to the location of damageable improvements with respect to the drainage system.

1.7 Other References: Other agencies have criteria and regulations pertaining to drainage systems which may complement this criteria. When conflicts are encountered, the most rigorous criteria shall govern.

A. Federal Insurance Agency-Floodplain Regulations and Implementing Ordinances Adopted by Municipalities: Drainage systems designed within the limits of the designated 100-year floodplain on the principal stream shall be designed to convey the flood as defined by applicable published floodplain information studies. For areas located in FIA Zone A outside the detailed study area, the Developer shall prepare studies and calculations establishing the floodplain, and floodway elevation and width. These calculations shall be submitted to the reviewing agency for approval.

B. Kansas Department of Agriculture: Rules and regulations of the Water Resources Board shall apply.

1.8 Return Frequencies: Enclosed and open channel conveyance system components shall be designed for the following return period storms, irrespective of the land use in which the system is located or the land use in the drainage area tributary to the system:

A. In-System Capacity:

1.	Floodway in 100-year Flood Plain	100-year
2.	Bridges, Pipes, and Culverts Crossing Arterial Streets	50-year
3.	All other System Components	5-year

The combination of publicly-owned rights of way, drainage easements, pipes, streets and open channels shall convey the 100-year storm event in all new development.

B. Overflow Channels: The combined capacity of the overflow channel and in-system conveyance element shall be sufficient to convey the 100-year storm at all locations; except that an overflow depth not exceeding seven (7) inches at the lowest point of the traveled way will be permitted where culverts cross streets.

SECTION 2 HYDROLOGY AND HYDRAULICS

2.1 Scope: This section sets forth the hydrologic parameters to be used for computations involving the definition of runoff mass and peak rates to be accommodated by the storm drainage system.

2.2 Runoff Coefficients: Runoff Coefficients relative to development and land use shall be in line with accepted engineering practices. Readily available values are available in literature for the Rational Method and TR-55.

Land areas not zoned; but whose future land use is defined by an adopted land use plan, shall be assigned runoff coefficients for the land use indicated by such plan. Undeveloped areas designated as agricultural or those for which no specific future land use is indicated shall be assigned a minimum of 35 percent impervious surface for purposes of the design of storm drainage systems (C = 0.35, CN = 78).

As an alternative to the above coefficients; and for areas not listed above (planned building groups, shopping centers, trailer parks, etc.) A composite runoff coefficient based on the actual percentages of pervious and impervious surfaces shall be used. All runoff coefficients (C) and Curve Numbers (CN) used in stormwater runoff calculations are subject to approval by the City Engineer.

The predevelopment Curve Number for Hydrologic Soil Group B soils that the design engineer must use is 58. For Hydrologic Soil Group C soils, the predevelopment Curve Number is 71. Unless better data is presented, the United States Department of Agriculture most recent soil survey shall be used when determining the Hydrologic Soil Class of a soil.

2.3 Rainfall Mass: The U.S. Soil Conservation Service (SCS) Type 2 twenty-four-hour rainfall distribution shall be used for all computations that employ the use of rainfall mass. That rainfall distribution is reproduced as follows:

TIME IN HOURS	ACCUMULATED RAINFALL IN PERCENT OF 24-HOUR RAINFALL
0	0
2.0	2.22
4.0	4.80
6.0	8.00
8.0	12.00
9.0	14.70
9.5	16.30
10.0	18.10
10.5	20.40
11.0	23.50
11.5	28.30
11.75	38.70
12.0	66.30
12.5	73.50
13.0	77.20
13.5	79.20
14.0	82.00
16.0	88.00
20.0	95.20
24.0	100.00

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

2.5 Rainfall Intensity: Rainfall intensity shall be determined from the Rainfall Intensity Table as developed by the Kansas Department of Transportation for Ellis County. For calculations using the rational method, the duration of the rainfall to be used is equal to the Time of Concentration (Tc). T_C is equal to the overland flow time to the most upstream inlet or other point of entry to the system, Inlet Time, (T_I), plus the time for flow in the system to travel to the point under consideration Travel Time, (T_T). ($T_C = T_I + T_T$).

A. Inlet Time: T_I shall be calculated by the following formula or determined graphically from Figure 2, but shall not be less than 5.0 minutes nor greater than 20.0 minutes:

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

T_I = Inlet Time in minutes.

C = Rational Method Runoff Coefficient as determined in accordance with paragraph 2.2

D = Overland flow distance parallel to slope in feet.
(300-feet shall be the maximum distance used for overland flow)

S = Slope of tributary area surface perpendicular to contour in percent.

B. Travel Time: T_T shall be calculated as the length of travel in the channelized system divided by the velocity of flow. Velocity shall be calculated by Manning=s equation assuming all system elements are flowing full without surcharge. Travel time may be determined graphically from Figure 3 in lieu of calculation.

To provide for future development when the upstream channel is unimproved, the following table shall be used for calculating T_T.

AVERAGE CHANNEL SLOPE, PERCENT		VELOCITY IN FT/SEC
<2		7
2 TO 5		10
>5		15

2.6 Computation Methods for Runoff: Runoff rates to be accommodated by each element of the proposed storm drainage system shall be calculated using the foregoing criteria for land use runoff factors, rainfall, and system time. The following alternative computation methods are acceptable. Other methods, including computer models may be employed so long as they produce calculated runoff to the system that is substantially the same as that calculated by the foregoing criteria:

A. **Watersheds Less than 600 Acres:** The Rational Method may be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 600 acres. The Rational Method is defined as follows:

Q = K C I A, where

Q = Peak rate of runoff to system in cubic feet per second (c.f.s.)

C = Runoff coefficient as determined in accordance with Paragraph 2.2

I = Rainfall intensity in inches per hour as determined in accordance with Paragraph 2.4

A = Area of watershed in acres.

K = Dimensionless coefficient to account for antecedent precipitation as follows; except the product of AC≅*≅K≅ shall not exceed 1.0.

YEARS RETURN <u>FREQUENCY</u>		**<u>AK≅</u>**
10 and less		1.0
25		1.1
50		1.2
100		1.25

B. **All Watersheds:** The following methods are acceptable for all watersheds.

1. SCS Technical Release No. 55 - AUrban Hydrology for Small Watersheds,≅ 2nd Edition, June 1986.

2. SCS Technical Release No. 20 - AProject Formulation - Hydrology,≅ 2nd Edition, May 1983.

3. U.S. Army Corps of Engineers, Hydrologic Engineering Center - AHEC-1 Flood Hydrograph Package.≅

4. U.S. Environmental Protection Agency, AStorm Water Management Model≅ (SWMM)

Copies of the above publications and microcomputer programs based thereon are available for purchase through National Technical

Information Service, U.S. Department of Commerce, Springfield, VA 22161. The SWMM program is also available from the Environmental Research Laboratory, Office of Research and Development, U.S. EPA, Athens, Georgia. The HEC-1, HEC-2 and TR-55 packages are also available for a nominal fee from PC-TRANS Software Distribution at the University of Kansas.

2.7 Hydraulic Calculations for Pipes, Culverts, and Open Channels: Computations shall be by Manning=s formula:

$$Q = \frac{(1.486)A}{n} (R^{2/3}) (S^{2})$$ where:

Q = Discharge in cubic feet per second (c.f.s.)

A = Cross sectional area of flow in square feet.

n = Roughness Coefficient (see Table A).

R = Hydraulic radius (R = A/P) in feet.

S = Slope in feet per foot.

P = Wetted perimeter in feet.

Minor losses shall be calculated by:

$h = k (V^2/2g)$ where:

h = Head loss in feet.

V = Velocity of flow in feet per second at point of interest.

2g = 64.4 feet per second per second.

k = Coefficient as shown in Table B.

Hydraulic calculations for open channels may also be made by the U.S. Army Corps of Engineers AHEC-2 Water Surface Profiles, computer program.

2.8 Entrance Control: Design variables for culverts operating under entrance control shall be determined from appropriate Charts in Section 8.

2.9 Outlet Control: Design variables for culverts operating under outlet control shall be determined from appropriate Charts in Section 8.

SECTION 3 INLETS, MANHOLES, AND JUNCTION BOXES

3.1 Inlet Design:

A. Type: Only approved standard curb opening inlets shall be used on public streets, except as approved by the City Engineer.

B. Capacity: Inlet capacity shall be rated at 80 percent of the theoretical capacity to allow for partial obstruction and clogging.

C. Configuration: Curb inlets shall be as follows (illustrated by Figure 21):

Opening length, inside	2.5 ft. (min)
Width, perpendicular to curb line, inside	1.92 ft. (min)
Setback curb line to face	0.0 ft. (min)
Opening, clear height	6.0 in. (min)
Gutter depression at inlet	3.0 in. (min)
Gutter transition length	
(a) Both sides in sump and upstream side on slope	5.0 ft. (min)
(b) Downstream side on slopes	3.0 ft. (min)

3.2 Freeboard Requirements: Any opening which surface water is intended to enter (or may backflow from) the system shall be 0.5-feet or more above an elevation calculated as follows:

1. Invert elevation of the outlet channel (pipe) of the structure, plus;

2. Depth (diameter) of the outlet channel (pipe), plus;

3. "h" minor losses as determined by Section 2.7. When 50 percent or more of the discharge enters the structure from the surface, "k" shall be 1.0.

3.3 Inverts and Pipes: The crown(s) of pipe(s) entering a structure shall be at or above the crown of the pipe exiting from the structure and provide a minimum fall of the invert in the structure of 0.2-feet for straight flow through the structure or 0.5-feet fall for all other types of flow (bends more than 22.5 deflection angle, multiple lines entering, enlargement transition,...ect.) through the structure. The desirable minimum fall across the invert is 0.5-feet.

3.4 Gutter Flow: Inlets shall be located to limit the width of flow in street gutters at the time of peak discharge of a 5-year return period storm to the following limits:

BACK TO BACK OF CURB STREET WIDTH IN FEET	MAXIMUM ALLOWABLE SPREAD IN EACH OUTSIDE CURB LANE FROM BACK OF CURB IN FEET
32 or less	10.5
Over 32 to 36	11.5
Over 36	12.0
Divided Roadways	As above for each direction roadway
Arterial and Collector Street Intersections and Pedestrian Crosswalks	6.0

3.5 Gutter Capacity: Izzardəs Formula or Figure 22 shall be used to determine gutter flow:

$$Q = 0.56 \frac{z}{n} (S^{2})(D^{2/3})$$ where:

Q = The gutter flow in cubic feet per second (c.f.s.).

Z = The reciprocal of the average cross-slope, including gutter section
in feet per foot.

S = The longitudinal street grade in feet per foot.

D = The depth of flow at curb face in feet.

n = Manningəs “n” see Table A.

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

$Sx = S_1 + X (S_2 - S_1)$ where:

Sx = The street grade on a vertical curve at point x, in feet per foot.

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

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

X = The distance measured from the PC to point x on a vertical curve,in feet.

L = The total length of a vertical curve, in feet.

3.7 Loading Conditions for Structures: shall be in accordance with Section HS-20-44 in streets and roadways.

SECTION 4 ENCLOSED PIPE SYSTEMS:

4.1 Easements: Permanent easements shall be dedicated to the City for operation and maintenance of the storm drainage facilities. Easement width shall not be less than 15-feet, or the outside width of the pipe or conveyance structure plus 10-feet; whichever is greater. Easements shall be centered on the pipe.

A. **Permanent:** The City Engineer may require wider easements when other utilities are located within the same easement and/or when the depth of cover is greater than 4-feet.

B. **Temporary:** Temporary construction easements of sufficient width to provide access for construction shall be acquired when the proposed work is located in areas developed prior to construction.

4.2 Capacity: Capacity shall be based on either inlet or outlet control, whichever condition indicates the least capacity. Minimum design pipe size shall be 18-inch diameter. Pipes installed for the purpose of draining Best Management Practices may be smaller than 18 inches in diameter.

4.3 Surcharge: An enclosed system may be designed to operate with surcharge if the following conditions are met:

1. The Hydraulic Grade Line (HGL) must be 0.5-feet below any openings to the ground or street at all locations.

2. Watertight joints capable of withstanding the internal surcharge pressure are used in the construction.

3. Appropriate energy loses for bends, transitions, manholes, inlets, and outlets, are used in computing the HGL.

4.4 Energy Dissipation: The outfall of all enclosed systems shall be designed so that the exiting velocity does not exceed the following. Permanent, vegetative turf reinforcement mat or gabions shall be used in accordance with manufacturer specifications for energy dissipation. Effective energy dissipating structures shall be provided if necessary to meet these requirements:

OUTLET CHANNEL TYPE	**MAXIMUM EXITING VELOCITY**
Natural or Unimproved Channel	5 ft./sec.
Grass Lined Channel	5 ft./sec.
Grass Lined Channel with erosion protection (Geotextiles, etc.,)	7 ft./sec.
Improved Channel with Riprap Lining (Only with City approval)	10 ft./sec.
Concrete Lining, or Gabion Revetment or Excavated in Rock, requires approval of City Engineer	15 ft./sec.

4.5 Velocity Within the System: The velocity within the enclosed system shall be between 3 and 20-feet per second for the design storm.

4.6 Loading:

A. Cover: Minimum depth of cover shall be 12-inches.

B. Minimum Loading Conditions:

1. Live load: HS-20
2. Unit Weight of soil cover: 120 pcf.
3. Rigid Pipes shall be bedded and backfilled to provide a minimum factor of safety of 1.5 at the 0.01-inch crack loading condition.
4. Flexible pipes such as High Density Polyethelyne may be used in all locations when installed according to manufactuer's specifications. All flexible pipes must have a legitimate 100-year life expectancy.

SECTION 5 OPEN CHANNELS

5.1 Easements: Permanent easements shall be dedicated to the City for operation and maintenance of open channels.

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

B. Natural Channels: Natural open channel easements shall be the area between the lines of intersection of the natural ground with a plane 12-inches above the design water surface, plus 10-feet measured horizontally on each side thereof. However, the width of the easement shall not be less than 30-feet and the width shall be increased if necessary to permit access by truck along the entire length of the channel.

5.2 Freeboard:

1. No in-channel freeboard is required above the 100-year frequency design storm water surface profile elevation.

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

5.3 Channel Linings:

1. All improved channels shall be lined to the minimum of the 5-year frequency design storm water profile elevation plus 0.5-foot freeboard minimum.

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

3. Lining height on the concave side of curves shall be increased by:

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

   y = Increased vertical height of lining in feet.

   D = Depth of design flow in feet.

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

   a. 30(y) feet downstream from the point of tangency (P.T.).

b. 10(y) feet upstream from the point of curvature (P.C.).

5.4 Lining Material: The following types of lining material and minimum thickness shall be used to control damage and erosion. All riprap, grouted riprap, and gabion linings shall be designed with a filter fabric.A. Improved Open Channels: Below the 5-year hydraulic grade line + 0.5-foot Freeboard elevation:

DESIGN FLOW VELOCITY – FPS	LINING MATERIAL
All velocities	Permanent geotextiles and other reinforcement devices which allow vegetative growth. Material selection and installation shall be within manufacturer's specifications.
0 to 10	Riprap - 15-inches minimum thickness (Riprap may be used only if approved by the City)
0 to 15	Grouted riprap, gabion revetment or paved concrete only if approved by the City
Over 15	Paved concrete or sound in situ bedrock only if approved by the City

B. **Overflow Open Channels:** Above the elevation of the 5-year hydraulic grade line + 0.5-foot Freeboard:

DESIGN FLOW VELOCITY – FPS	LINING MATERIAL
All velocities	Initial construction shall include either temporary or permanent reinforcement matting to ensure minimal erosion during vegetative establishment phase, even in low-velocity channels where vegetation is sufficient for erosion control. Material selection and installation shall be within manufacturer's specifications.

DESIGN FLOW VELOCITY – FPS	LINING MATERIAL
0 to 10	Riprap - 15-inches minimum thickness (Only if approved by the City)
0 to 15	Gabion revetment or paved concrete (Only if approved by the City)
Over 15	Paved concrete or sound in situ bedrock (Only if approved by the City)

C. **Other Lining Materials:** Other types of lining materials not specifically listed above may be used when approved by the City Engineer.

5.5 Side Slopes: Side slopes shall not be steeper than:

1. 4 horizontal to 1 vertical for turf lining.
2. 3 horizontal to 1 vertical for all other lining materials.
3. Flatter if necessary for stability of slopes.
4. As approved by the City

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

$R = \frac{V\text{-}W}{8D}$ where:

R = Minimum radius on centerline in feet.

V = Design velocity of flow in feet per second

W = Width of channel at water surface in feet

D = Depth of flow in feet

5.8 Vertical Wall Channels: Vertical walls may be used for structural lining improved channels; subject to the following special requirements:

1. Walls shall be designed and constructed to act as retaining walls.
2. Adequate provisions shall be made for pedestrian entry/exit from the channel.

SECTION 6 STORMWATER DETENTION AND RETENTION

6.1 Scope: This section governs the requirements and design of stormwater retention/detention facilities.

6.2 Easements: Easements shall be dedicated to the city to provide adequate access for inspection, construction, and maintenance of all retention/detention facility components. The owner shall dedicate the retention/detention facility and easements upon completion of construction and approval by the City Engineer, when appropriate, in accordance with Chapter 53 – Stormwater Management. This shall be land occupied by the facility, plus a 20-foot wide strip around the perimeter of the highest elevation attained by the design storage volume, plus an excess easement 20-feet in width between the facility and a public street.

6.3 Maintenance and Continued Performance: Maintenance of private retention/detention facilities shall be the responsibility of the property owner(s) and shall include:

1. Debris removal and cleaning
2. Cutting of vegetation
3. Repair of erosion
4. Removal of silt
5. Maintenance of structural facilities, including outlet works, not located in a public drainage easement.
6. Annual or more frequent inspections to assure that the retention/detention basin has full storage capacity and all inlet and outlet structures are fully functional.

6.4 Performance Criteria:

A. General Provisions: The criteria set forth herein are applicable to retention/detention facilities:

1. Having 1,000 acres or less area tributary to the facility.
2. Dams which are greater than 10-feet in height but do not fall into state or federal requirement categories shall be designed in accordance with NRCS Technical Release No. 60 or other acceptable engineering standards.
3. Other agencies have criteria and regulations pertaining to drainage systems which may complement this criteria. State and federal laws

and regulations pertaining to dams shall take precedence over this criteria to the extent that retention/detention facilities may be classified as dams thereunder.

a. Federal Insurance Agency - Floodplain Regulations and Implementing Ordinances Adopted by Municipalities: Drainage systems designed within the limits of the designated 100-year floodplain on the principal stream shall be designed to convey the flood as defined by applicable published floodplain information studies. For areas located in FIA Zone AA≅ outside the detailed study area, the Developer shall prepare studies and calculations establishing the floodplain, elevation and width. These calculations shall be submitted to the reviewing agency for approval.

b. Kansas State Board of Agriculture: Regulations of the Water Resources Division shall apply.

B. Release Rate: The maximum release rate from any development for the 100-year and more frequent storms shall not exceed pre-development flow rates. When areas outside the development are also tributary, their inflow hydrograph(s) may be added to the above maximum release rate to determine the total maximum release rate. If the downstream conditions dictate a lower release rate, then the above release rates do not govern.

C. Retention/Detention Basin Size: For purposes of evaluation, projects will be classified in two categories according to the acreage of tributary area.

1. Less than 10 acres: Volume of retention/detention for projects having 10 acres or less tributary to the retention/detention facility may be evaluated using either the Simplified Volume Figure 11 or by the more precise methods set forth in Section 6.4.C.2.

2. Over 10 acres: For projects of more than 10 acres tributary area the owners/engineers may utilize methodology outlined in Technical Release No. 55 Urban Hydrology for Small Watersheds, June 1986. A Type II rainfall distribution shall be the required storm hydrograph. Hydrologic simulation models shall be based on not less than Antecedent Moisture Condition II. Retention/Detention storage shall be based upon the allowable release rate during the 5-year, 25-year and 100-year frequency, 24-hour storm event with the development in place but the designer shall check the more frequent storm event discharges to insure that the discharge does not exceed allowable release rate under any storm frequency.

D. Principal Spillways: The principal spillway shall be designed to meet the following requirements:

1. The principal spillway shall be designed to function without requiring attendance or operation of any kind or requiring use of equipment or tools, or any mechanical devices.

2. All discharge from the retention/detention facility when inflow is equal to or less than the 100-year inflow shall be via the principal spillway(s).

3. The design shall allow for discharge of at least 80 percent of the retentiondetention storage volume within 24 hours after the peak or center of mass of the inflow has entered the retention/detention basin.

4. The design discharge rate via the principal spillway shall continuously increase with increasing head and shall have hydraulic characteristics similar to weirs, orifices or pipes.

   Two stage outlet works are required. One stage is designed for the 5-year frequency stormwater runoff and the other stage would be for the 100-year frequency, 24-hour stormwater event runoff.

E. Emergency Spillways: The emergency spillway may either be combined with the principal spillway or be a separate structure or channel. Emergency spillways shall be designed so that their crest elevation is 0.5-foot or more above the maximum water surface elevation in the retention/detention facility attained by the 100-year storm.

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

G. Erosion Control: Principal spillways and outlet works, as well as conveyance system entrances to retention/detention basins, shall be equipped with energy dissipating devices as necessary to limit the peak discharge velocity. See Section 4 for velocity criteria.

H. Location: The retention/detention facility shall be located at or near the lowest point of the project so that all of the on-site runoff will be directed into the retention/detention facility unless approved by the City.

Flows from offsite upstream areas may be bypassed around the retention/detention facility. The allowable release rate may be modified, with the approval of the City Engineer, to bypass the offsite flows if the flows are to pass through the retention/detention facility. Allowable release rates will not be modified if the pass through will compromise the effectiveness of the retention/detention facility.

I. Appearance and Use: To the extent possible, the retention/detention facility should be designed to achieve a park -like appearance without adding appreciable to the maintenance effort. Landscaping and plantings should be considered to create a pleasing appearance. Multi-use, with emphasis on recreational uses is encouraged.

6.5 Retention/Detention Methods: In addition to the foregoing criteria, the following shall be applicable, depending on the retention/detention alternative(s) selected:

A. Wet Bottom Basins/Retention Facility: For basins designed with permanent pools (restricted use by approval of the City only):

1. Minimum Depths: The minimum normal depth of water before the introduction of excess stormwater shall be four feet plus a sedimentation allowance of not less than 5 years accumulation determined in accordance with Figure 6. The side slopes of dry and wet basins shall conform as closely as possible to natural land contours, and should not exceed three horizontal to one vertical. Slopes exceeding this limit shall require erosion control and safety measures.

2. Depth for Fish: If the pond is to contain fish, at least one-quarter of the area of the permanent pool must have a minimum depth of ten-feet plus sedimentation allowance.

B. Dry Bottom Basins/Detention Facility: For basins designed to be normally dry:

1. Interior Drainage: Provisions must be incorporated to facilitate interior drainage to outlet structures. Grades for drainage facilities shall not be less than one percent on turf. Concrete trickle channels with a minimum gradient of one percent, shall be used as needed to conduct storm water from turfed bottom areas to the outlet structure.

2. Earth Bottoms: Earth bottoms shall be seeded or sodded.

3. Multipurpose Feature: These shall be designed to serve secondary purposed for recreation, open space, or other types of use which will not be adversely affected by occasional or intermittent flooding, if possible.

C. Anti-Clogging Protection: Trash racks or other approved devices shall be installed where required to insure that the principal spillway(s) will remain functional.

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

E. Parking Lot Storage: Paved parking lots may be designed to provide temporary detention storage of stormwater on a portion of their surfaces. Generally, such detention areas shall be in the more remote portions of such parking lots. Depths of storage shall be limited to a maximum depth of seven inches for automobile parking and 12-inches in truck parking areas. Such areas shall be located so that access to and from parking areas is not impaired.

F. Other Storage: All or a portion of the retention/detention storage may also be provided in underground or surface retention/detention areas, including, but not limited to, oversized storm sewers, vaults, tanks, swales, etc.

6.6 Computation Methods:

A. Time of Concentration and Travel Time: Use methods as outline in Technical Release No. 55, Urban Hydrology for Small Watersheds, Chapter 3.

B. Temporary Storage Volume: A preliminary value of the storage requirement may be obtained through methods outlined in Technical Release No. 55, Chapter 6, as calculated by HEC-1 or other acceptable methods. The storage shall be checked during routing of design hydrographs through the basin and adjusted appropriately.

C. Hydrograph Routing: The storage indication method (Modified Plus) of routing a hydrograph through a retention/detention basin may be utilized. Reference: Introduction to Hydrology, by Warren Viessman, Jr., John W. Knapp, Gary Lewis, Second Edition, Section 7-2.

6.7 Required Submittals: The Owner shall submit the following information and data to the City Engineer.

1. Elevation-area-volume curves for the storage facility including notation of the storage volumes allocated to runoff, sediment, and permanent residual water storage for other uses (wet basins only).

2. Inflow hydrographs for the 5-year, 25-year and 100-year frequency, 24-hour design storms.

3. Stage-discharge rating curves for each spillway and for combined spillway discharges.

4. Routing curves for the 5-year, 25-year and 100-year recurrence interval design storms with time plotted as the abscissa and the following plotted as ordinates:

   a. Cumulative inflow volume.
   b. Cumulative discharge.
   c. Stage elevation.
   d. Cumulative storage.

6.8 Additional Requirements:

A. Access: Provisions shall be made to permit access and use of auxiliary equipment to facilitate emptying, cleaning, maintenance, or for emergency purposes. Multiple access points to underground retention/detention facilities shall be provided including access directly to the outlet structure.

B. Underground Storage: Underground retention/detention facilities shall be designed with adequate access for maintenance (cleaning and sediment removal). Such facilities shall be provided with positive gravity outlets. Venting shall be sufficient to prevent accumulation of toxic or explosive gases.

SECTION 7 PLAN REQUIREMENTS

7.1 Scope: This section governs the preparation of plans for stormwater system projects.
7.2 General: The plans shall include all information necessary to build and check the design of storm drainage systems. The plans shall be arranged as required by the City Engineer. Standard drawings of the City shall be included by reference only. Plans shall be sealed by a Registered Professional Engineer and shall be submitted to the City Engineer for review and approval.

7.3 Scale: Plans shall be drawn at the following minimum scales. Larger scales may be needed to clearly present the design. Bar scales shall be shown on each sheet for each scale.

Plan:	1-inch=	50-feet
Profile:		
Vertical:	1-inch=	10-feet
Horizontal:	1-inch=	50-feet
Cross Sections:		
Vertical:	1-inch=	5-feet
Horizontal:	1-inch=	5-feet
Drainage Area Map:		
On-site:	1-inch=	200-feet
Off-site	1-inch=	1,000-feet
Structural Plans:	1/4-inch =	1-foot
Graphic Drawings:		Varies

7.4 Required Information:

A. **Drainage Area Map:** A drainage map shall be included and shall contain the following:

1. Ridge line of the area tributary to each principal element of the system.

2. Note the area in acres.

3. Note the runoff coefficient C for each area.

B. **Plan View:** All designed storm drainage systems shall be drawn in plan view and shall contain the following:

1. North arrow and bar scale.
2. Ties to permanent reference points for each system located outside of the street right-of-way.
3. Identification and location of each pipe, inlet, structure, and existing utility affecting construction.
4. Right-of-way, property, and easement lines. The 100-year flood plain and setback from the top of bank of an open channel to any building.
5. Existing manmade and natural topographic features, such as buildings, fences, trees, channels, ponds, streams, etc., and all existing and proposed utilities.
6. Location of test borings.
7. Existing and finish grade contours at intervals of 2.0-feet or less in elevation; or equivalent detail indicating existing and finish grades and slopes.
8. A uniform set of symbols subject to approval by the City Engineer.
9. The centerline of open channels within 50-feet of an enclosed drainage system and showing the direction of flow.
10. The existing and proposed drainage systems 100-feet upstream and 100-feet downstream from the development.
11. Off-Site easements and improvements to a minimum of 100 feet beyond the site.

C. **Profile View:** All designed storm drainage systems shall be drawn in profile view and shall contain the following:

1. Existing and finish surface grade along the center line of pipe (except street centerline may be used when construction includes street construction).
2. Length, size and slope of each line or channel segment. Slope shall be expressed in percent.
3. Headwater elevation at the inlet end of each culvert.
4. Flow line (invert elevation in and out at each structure).

5. Each existing utility line crossing the alignment shall be properly located and identified as to type, size and material.

6. Test borings.

7. All station and invert elevations of manholes, junction boxes, inlets or other structures.

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

9. All manholes, inlets or other structures shall be shown and labeled with appropriate AStandard Drawing≅ designation.

D. Cross Sections: Cross sections shall be drawn for all open channels. Sections shall be at appropriate intervals not greater than 100-feet. Additional sections shall be drawn at all structures and intersecting drainage systems. The following shall be indicated on each section:

1. Ties from centerline to baseline.

2. Existing and proposed grade line.

3. Elevation of the proposed flow line.

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

5. The area one foot above the 100-year flood elevation.

E. Design Information for Each Part of the System: The plans shall present design information for each culvert, structure, facility, pipe and channel segment and shall contain the following:

1. Tributary area in acres.

2. Design discharge and capacity in cubic feet per second.

3. Runoff coefficient C, design storm return frequency rainfall intensity and Manning=s An.≅

4. Discharge velocity at design flow.

5. Hydraulic grade line.

6. Type and grade of material (gage, class....etc.)

Schedules which indicate all variable dimensions and elevations covered by standards or Atypical≅ drawings shall be shown on the plans. All design details for nonstandard structures shall be indicated on the plans. A minimum of one plan view and one sectional view shall be shown on the plans for each structure. Additional views may be required if necessary to clearly define the design. A reinforcing bar list is not required. However, the grade, type, size and location of the bars shall be clearly indicated on the plans.

SECTION 8   FIGURES AND TABLES
FIGURE 1   RAINFALL

RAINFALL INTENSITY TABLE

ELLIS COUTNY KANSAS
(revised June 1997)

This table contains average rainfall intensities in inches per hour.

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
			RETURN PERIOD				
0:05	4.49	5.28	6.39	7.20	8.37	9.29	10.20
0:06	4.18	4.95	6.06	6.85	7.99	8.89	9.78
0:07	3.93	4.68	5.77	6.55	7.67	8.54	9.41
0:08	3.72	4.46	5.53	6.29	7.38	8.23	9.08
0:09	3.54	4.26	5.31	6.05	7.11	7.94	8.76
0:10	3.38	4.08	5.10	5.82	6.86	7.66	8.46
0:11	3.24	3.92	4.91	5.61	6.61	7.40	8.17
0:12	3.11	3.77	4.74	5.42	6.39	7.15	7.90
0:13	3.00	3.64	4.58	5.24	6.18	6.92	7.65
0:14	2.89	3.51	4.43	5.07	5.99	6.70	7.41
0:15	2.79	3.40	4.29	4.92	5.81	6.51	7.20
0:16	2.70	3.29	4.17	4.78	5.65	6.33	7.00
0:17	2.62	3.20	4.05	4.65	5.50	6.16	6.82
0:18	2.54	3.11	3.94	4.53	5.36	6.01	6.66
0:19	2.46	3.02	3.84	4.42	5.23	5.87	6.50
0:20	2.39	2.94	3.75	4.31	5.11	5.73	6.35
0:21	2.33	2.86	3.66	4.21	5.00	5.61	6.21
0:22	2.27	2.79	3.57	4.12	4.89	5.49	6.08
0:23	2.21	2.73	3.49	4.03	4.78	5.37	5.96
0:24	2.15	2.66	3.42	3.94	4.69	5.26	5.84
0:25	2.10	2.60	3.34	3.86	4.59	5.16	5.73
0:26	2.05	2.54	3.28	3.78	4.50	5.06	5.62
0:27	2.01	2.49	3.21	3.71	4.42	4.97	5.51
0:28	1.96	2.44	3.15	3.64	4.33	4.87	5.41
0:29	1.92	2.39	3.09	3.57	4.25	4.79	5.31
0:30	1.88	2.34	3.03	3.50	4.18	4.70	5.22
0:31	1.84	2.29	2.97	3.44	4.10	4.62	5.13
0:32	1.80	2.25	2.92	3.38	4.03	4.54	5.04
0:33	1.77	2.21	2.87	3.32	3.96	4.46	4.96
0:34	1.74	2.17	2.82	3.27	3.90	4.39	4.88
0:35	1.70	2.13	2.77	3.21	3.83	4.32	4.80
0:36	1.67	2.09	2.72	3.16	3.77	4.25	4.72
0:37	1.64	2.06	2.68	3.11	3.71	4.18	4.65
0:38	1.62	2.02	2.64	3.06	3.65	4.12	4.58
0:39	1.59	1.99	2.59	3.01	3.60	4.05	4.51
0:40	1.56	1.96	2.55	2.97	3.54	3.99	4.44
0:41	1.54	1.93	2.52	2.92	3.49	3.93	4.38
0:42	1.51	1.90	2.48	2.88	3.44	3.88	4.31
0:43	1.49	1.87	2.44	2.84	3.39	3.82	4.25
0:44	1.47	1.84	2.41	2.80	3.34	3.77	4.19
0:45	1.44	1.82	2.37	2.76	3.30	3.72	4.14
0:46	1.42	1.79	2.34	2.72	3.25	3.67	4.08
0:47	1.40	1.77	2.31	2.68	3.21	3.62	4.03
0:48	1.38	1.74	2.28	2.65	3.17	3.57	3.97
0:49	1.36	1.72	2.25	2.61	3.13	3.53	3.92
0:50	1.35	1.69	2.22	2.58	3.09	3.48	3.87

Ellis County

Page 1

Figure 1

RAINFALL INTENSITY TABLE

ELLIS COUTNY KANSAS
(revised June 1997)

This table contains average rainfall intensities in inches per hour.

DURATION, HR:MIN	RETURN PERIOD 1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:51	1.33	1.67	2.19	2.55	3.05	3.44	3.83
0:52	1.31	1.65	2.16	2.52	3.01	3.40	3.78
0:53	1.29	1.63	2.14	2.49	2.98	3.36	3.73
0:54	1.28	1.61	2.11	2.46	2.94	3.32	3.69
0:55	1.26	1.59	2.09	2.43	2.91	3.28	3.65
0:56	1.25	1.57	2.06	2.40	2.87	3.24	3.61
0:57	1.23	1.55	2.04	2.37	2.84	3.20	3.57
0:58	1.22	1.53	2.01	2.34	2.81	3.17	3.53
0:59	1.20	1.52	1.99	2.32	2.78	3.13	3.49
1:00	1.19	1.50	1.97	2.29	2.75	3.10	3.45
1:05	1.12	1.42	1.87	2.18	2.61	2.94	3.28
1:10	1.07	1.35	1.78	2.07	2.48	2.80	3.12
1:15	1.02	1.29	1.70	1.98	2.37	2.68	2.98
1:20	0.97	1.23	1.62	1.89	2.27	2.56	2.85
1:25	0.93	1.18	1.55	1.81	2.17	2.45	2.73
1:30	0.89	1.13	1.49	1.74	2.09	2.36	2.62
1:35	0.85	1.08	1.43	1.67	2.01	2.26	2.52
1:40	0.82	1.04	1.38	1.61	1.93	2.18	2.43
1:45	0.79	1.00	1.33	1.55	1.86	2.10	2.34
1:50	0.76	0.97	1.28	1.49	1.79	2.02	2.25
1:55	0.73	0.93	1.23	1.44	1.73	1.95	2.18
2:00	0.71	0.90	1.19	1.39	1.67	1.88	2.10
2:05	0.68	0.87	1.15	1.34	1.61	1.82	2.03
2:10	0.66	0.84	1.11	1.30	1.56	1.76	1.96
2:15	0.64	0.81	1.08	1.26	1.51	1.70	1.90
2:20	0.62	0.79	1.04	1.22	1.46	1.65	1.84
2:25	0.60	0.76	1.01	1.18	1.42	1.60	1.78
2:30	0.58	0.74	0.98	1.14	1.37	1.55	1.73
2:35	0.57	0.72	0.95	1.11	1.33	1.51	1.68
2:40	0.55	0.70	0.93	1.08	1.30	1.46	1.63
2:45	0.54	0.68	0.90	1.05	1.26	1.42	1.59
2:50	0.52	0.66	0.88	1.02	1.23	1.39	1.54
2:55	0.51	0.65	0.86	1.00	1.20	1.35	1.50
3:00	0.50	0.63	0.83	0.97	1.17	1.32	1.47
3:15	0.47	0.59	0.78	0.91	1.09	1.23	1.37
3:30	0.44	0.56	0.73	0.85	1.02	1.15	1.28
3:45	0.42	0.53	0.69	0.81	0.97	1.09	1.21
4:00	0.40	0.50	0.66	0.77	0.92	1.03	1.15
4:15	0.38	0.48	0.63	0.73	0.87	0.98	1.09
4:30	0.37	0.46	0.60	0.70	0.83	0.94	1.04
4:45	0.35	0.44	0.58	0.67	0.80	0.90	1.00
5:00	0.34	0.42	0.55	0.64	0.77	0.86	0.96
5:15	0.33	0.41	0.53	0.62	0.74	0.83	0.92
5:30	0.31	0.39	0.51	0.60	0.71	0.80	0.89
5:45	0.30	0.38	0.50	0.57	0.69	0.77	0.86
6:00	0.29	0.37	0.48	0.56	0.66	0.75	0.83

Figure 1

RAINFALL INTENSITY TABLE

ELLIS COUTNY KANSAS
(revised June 1997)

This table contains average rainfall intensities in inches per hour.

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
			RETURN PERIOD				
6:30	0.27	0.34	0.45	0.52	0.62	0.70	0.78
7:00	0.26	0.32	0.42	0.49	0.59	0.67	0.74
7:30	0.24	0.30	0.40	0.47	0.56	0.63	0.70
8:00	0.23	0.29	0.38	0.44	0.53	0.60	0.67
8:30	0.21	0.27	0.36	0.42	0.51	0.57	0.64
9:00	0.20	0.26	0.34	0.40	0.48	0.55	0.61
9:30	0.19	0.25	0.33	0.38	0.46	0.52	0.58
10:00	0.18	0.24	0.31	0.37	0.44	0.50	0.56
10:30	0.18	0.23	0.30	0.35	0.43	0.48	0.54
11:00	0.17	0.22	0.29	0.34	0.41	0.47	0.52
11:30	0.16	0.21	0.28	0.33	0.40	0.45	0.50
12:00	0.15	0.20	0.27	0.32	0.38	0.43	0.48
13:00	0.14	0.19	0.25	0.30	0.36	0.40	0.45
14:00	0.13	0.17	0.24	0.28	0.33	0.38	0.42
15:00	0.13	0.16	0.22	0.26	0.32	0.36	0.40
16:00	0.12	0.15	0.21	0.25	0.30	0.34	0.38
17:00	0.11	0.15	0.20	0.23	0.28	0.32	0.36
18:00	0.11	0.14	0.19	0.22	0.27	0.30	0.34
19:00	0.10	0.13	0.18	0.21	0.26	0.29	0.32
20:00	0.10	0.13	0.17	0.20	0.24	0.28	0.31
21:00	0.09	0.12	0.16	0.19	0.23	0.27	0.30
22:00	0.09	0.12	0.16	0.19	0.22	0.25	0.28
23:00	0.09	0.11	0.15	0.18	0.22	0.24	0.27
24:00	0.08	0.11	0.15	0.17	0.21	0.24	0.26

Figure 1

FIGURE 2

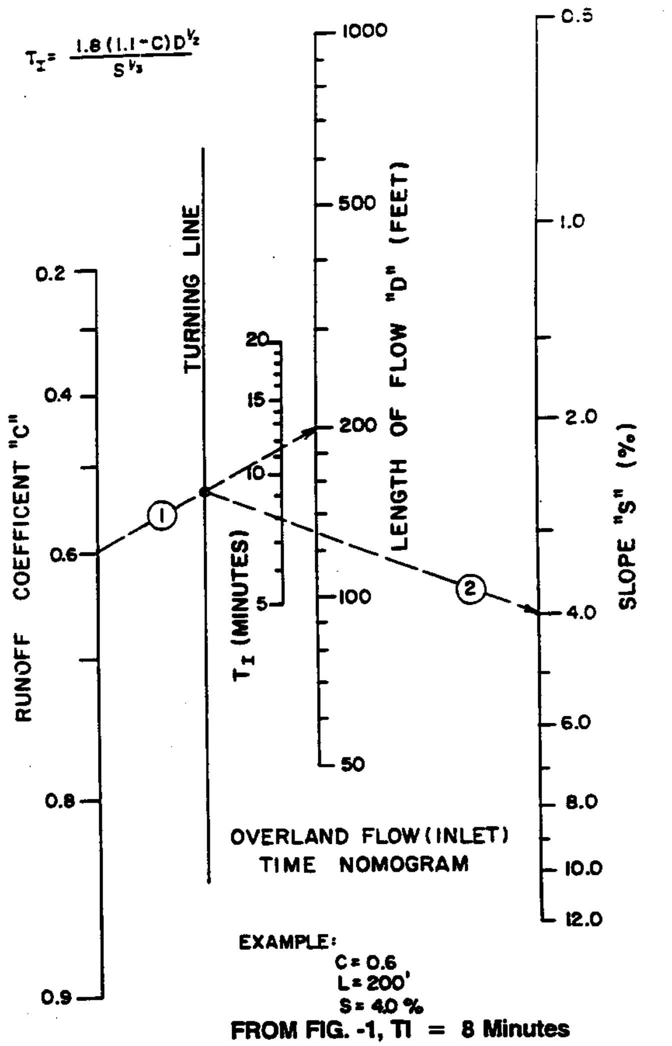


Figure 2

FIGURE 3 CHANNEL FLOW TIME NOMOGRAM

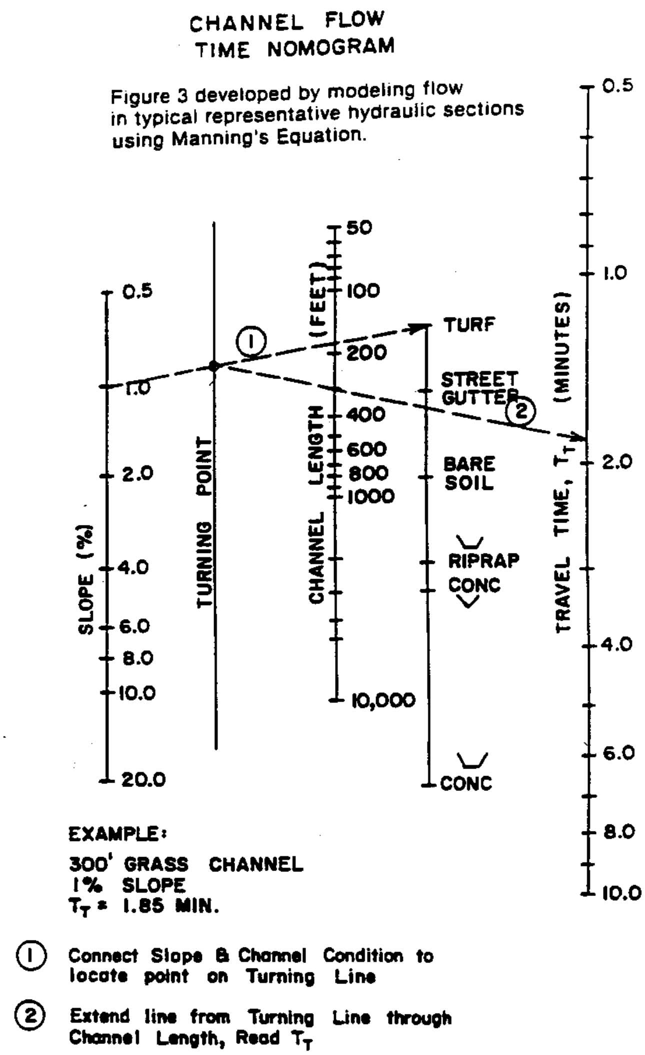
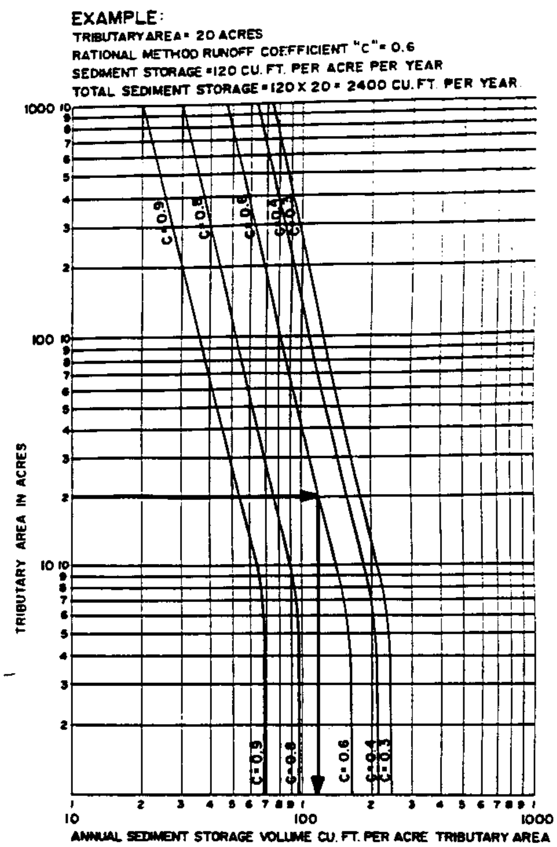


Figure 3

FIGURE 6



ANNUAL SEDIMENT STORAGE

Figure 6

Table A

MANNING=S ROUGHNESS COEFFICIENT n

Type of Channel

Closed Conduits	**n**
Reinforced Concrete Pipe	0.013
Reinforced Concrete Elliptical Pipe	0.013
Corrugated Metal Pipe:	
2 2/3 x 2 in. Annular Corrugations unpaved-plain	0.024
2 2/3 x 2 in. Annular Corrugations paved invert	0.021
3 x 1 in. Annular Corrugations unpaved-plain	0.027
3 x 1 in. Annular Corrugations paved invert	0.023
6 x 2 in. Corrugations unpaved-plain	0.033
6 x 2 in. Corrugations paved invert	0.028
Vitrified Clay Pipe	0.013
Asbestos Cement Pipe	0.012
Open Channels (Lined)	
Gabions	0.025
Concrete	
Trowel Finish	0.013
Float Finish	0.015
Unfinished	0.017
Concrete, bottom float finished, with sides of	
Dressed Stone	0.017
Random Stone	0.020
Cement Rubble masonry	0.025
Dry Rubble or Riprap	0.030
Gravel bottom, side of	
Random Stone	0.023
Riprap	0.033
Grass (Sod)	0.030
Riprap	0.035
Grouted Riprap	0.030
Open Channels (Unlined) Excavated or Dredged	
Earth, Straight and uniform	0.027
Earth, winding and sluggish	0.035
Channels, not maintained, weeds & brush uncut	0.090
Natural Stream	
Clean Stream, straight	0.030
Stream with pools, sluggish reaches, heavy underbrush	0.100
Flood Plains	
Grass, no brush	0.030
With some brush	0.090
Street Curbing	0.014

Table B

HEAD LOSS COEFFICIENT k

Condition	k
Manhole, junction boxes and inlets with shaped inverts:	
Thru flow	0.15
Junction	0.4
Contraction transition	0.1
Expansion transition	0.2
90 degree bend	0.4
45 degree and less bends	0.3
Culverts outlet	
Culverts inlets:	
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
Round (radius = 1/12 D)	0.2
Mitered to conform to fill slope	0.7
Standard end section	0.5
Beveled edges, 33.7E or 45Ebevels	0.2
Side-or-slope-tapered inlet	0.2
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrel dimension, or beveled edges on 3 sides	0.2
Wingwalls at 30E to 75E to barrel	
Square edged at crown	0.4
Crown edge rounded to radius of 1/12 barrel dimension, or beveled top edge	0.20

Note: When 50 percent or more of the discharge enters the structure from the surface Ak≅ shall be 1.0. See 5603.2.3.

Condition	k
Wingwall at 10E to 25E to barrel	
Square edged at crown	0.5
Wingwall parallel (extension of sides)	
Square edged at crown	0.7
Side-or-slope-tapered inlet	0.2

Insert figure 7

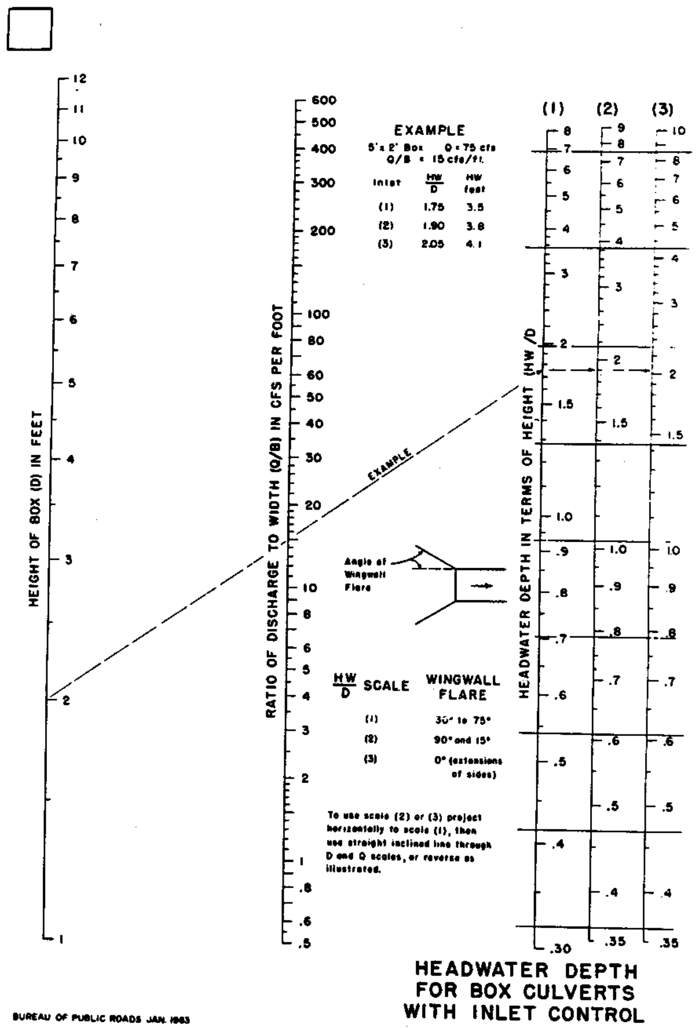


Figure 7

insert figure 8

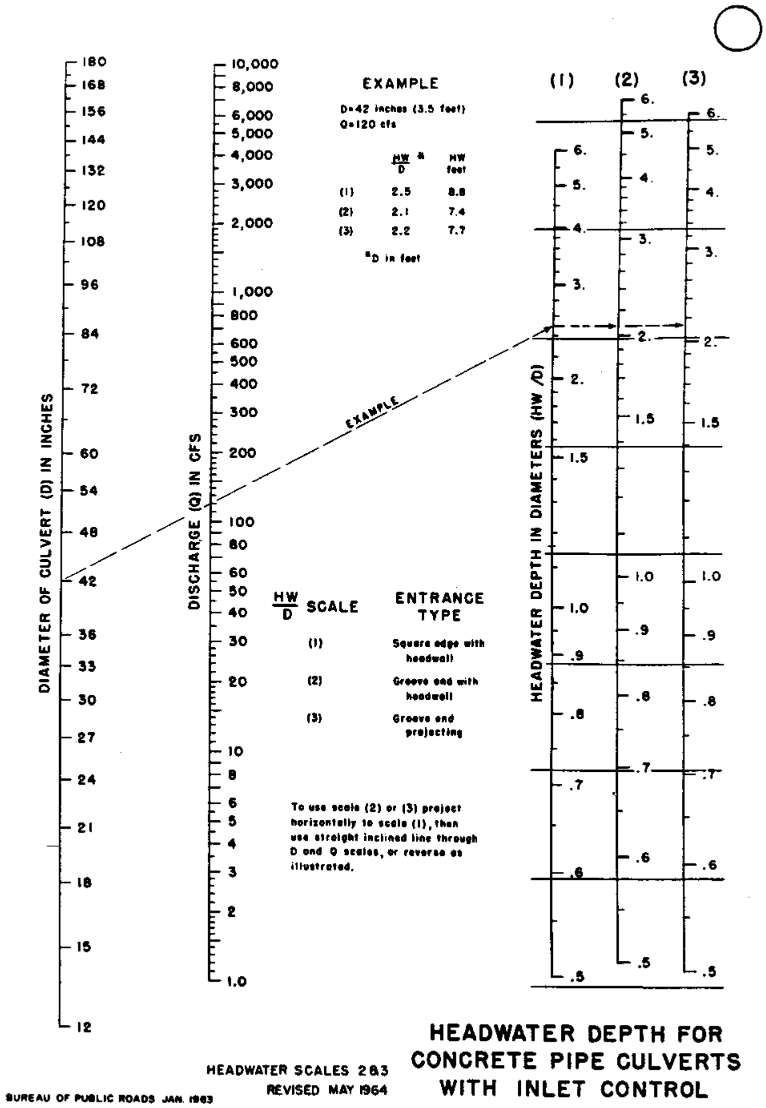


Figure 8

insert figure 9

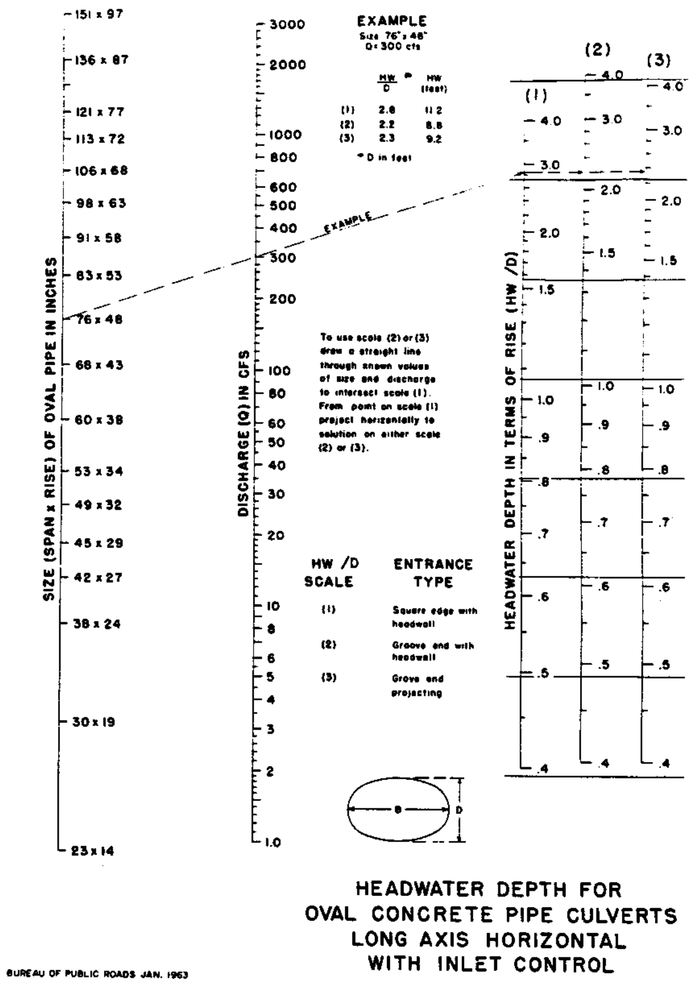
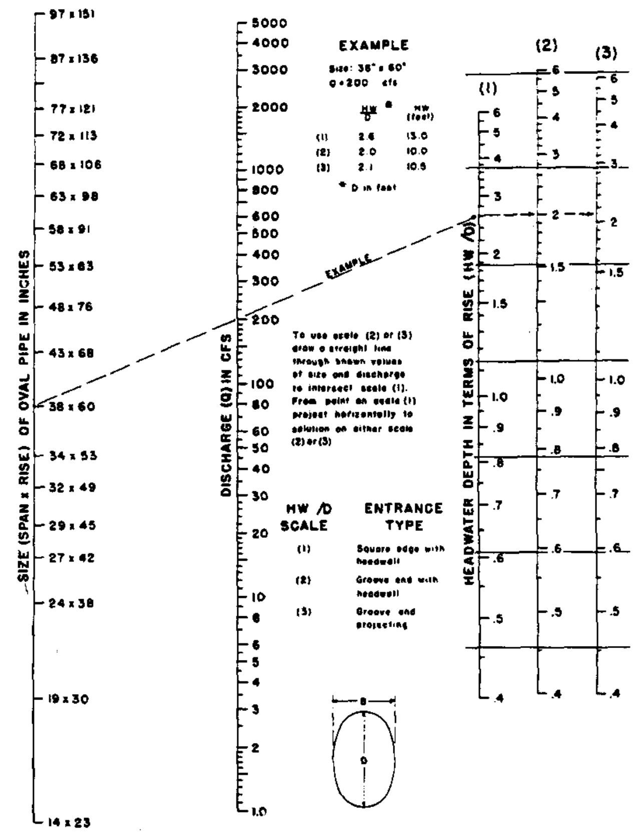


Figure 9

insert figure 10



HEADWATER DEPTH FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS VERTICAL
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

Figure 10

insert figure 11

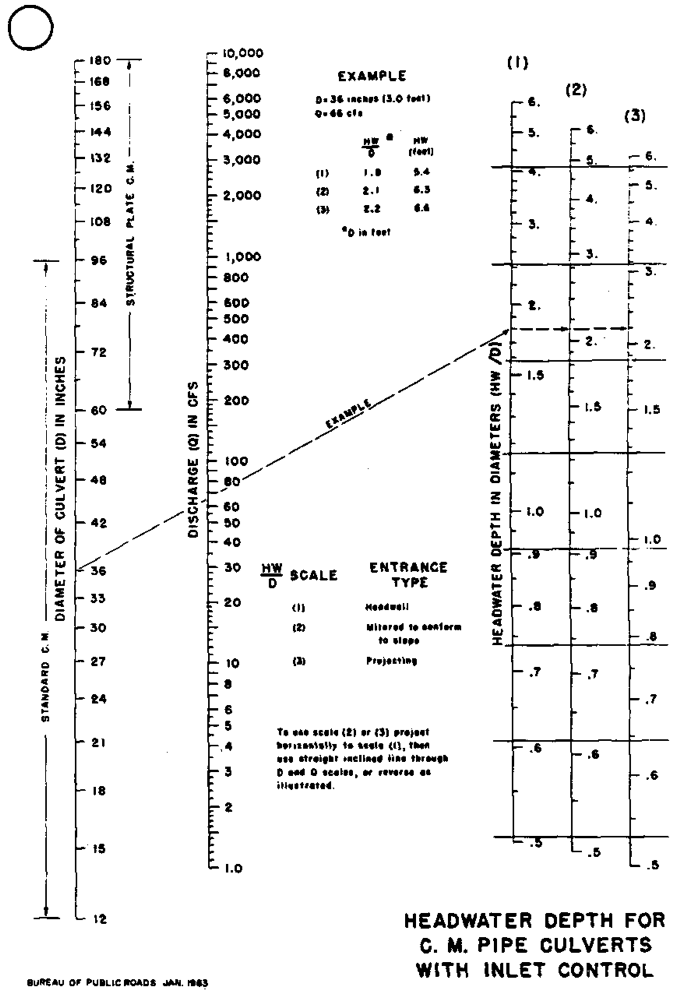


Figure 11

insert figure 12

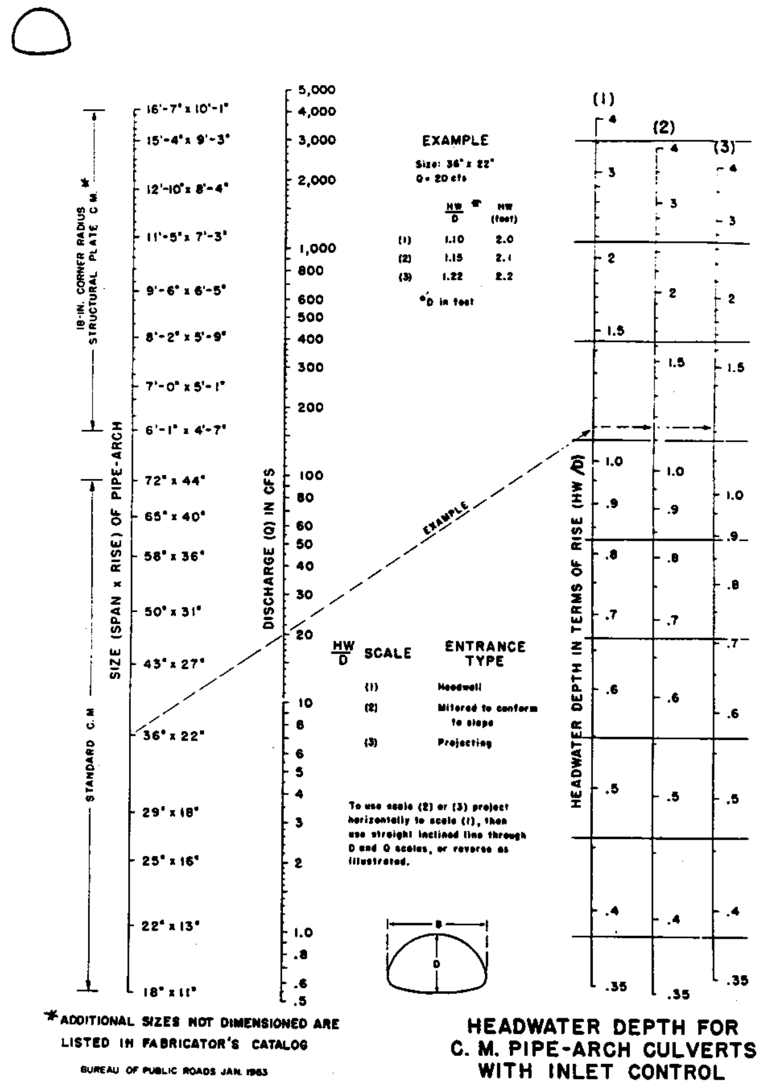


Figure 12

insert figure 13

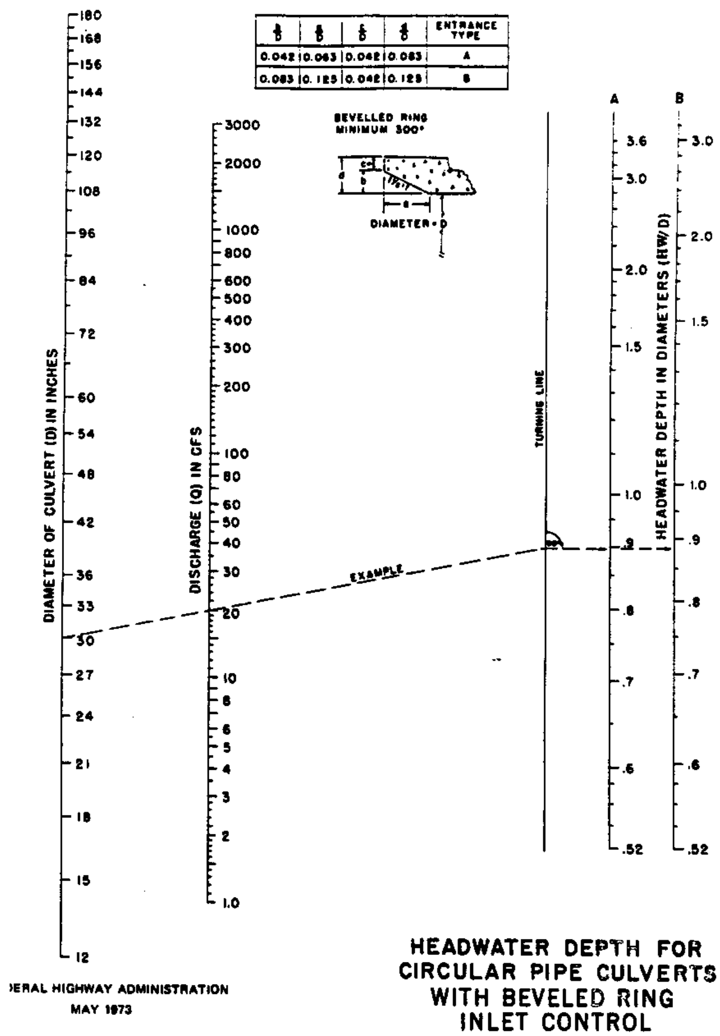


Figure 13

insert figure 14

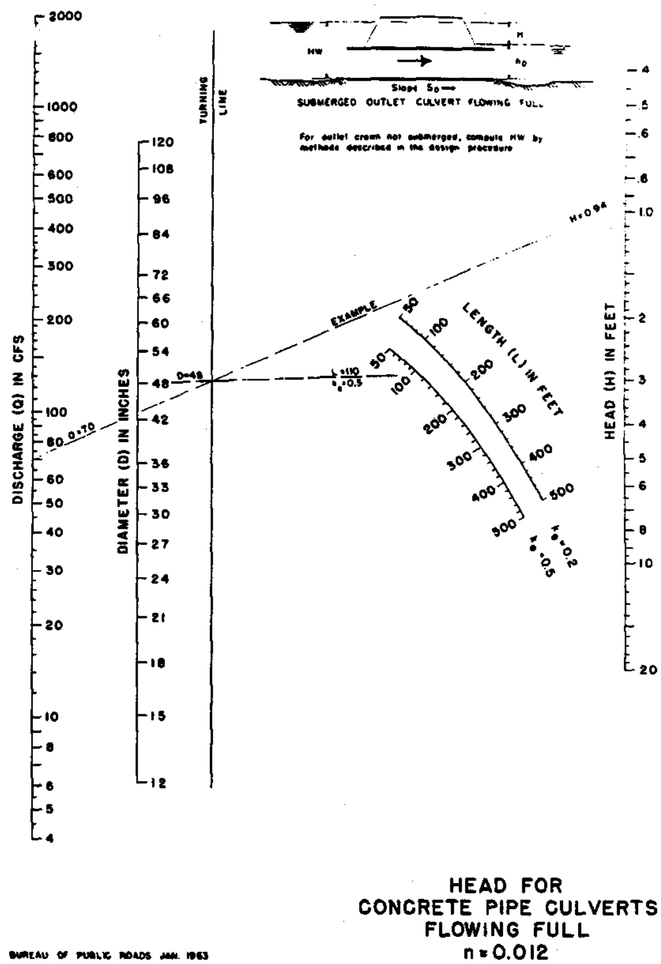
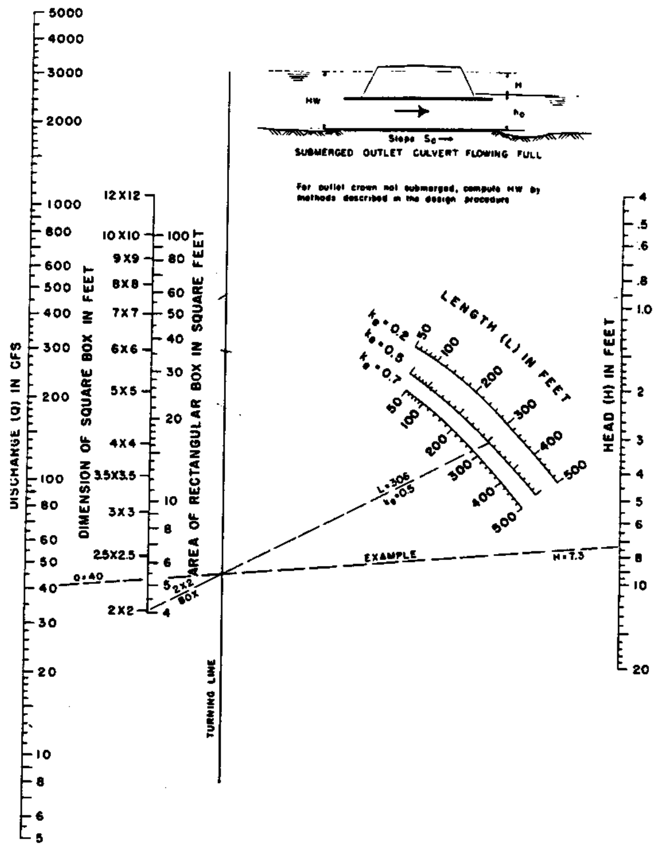


Figure 14

insert figure 15



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

AU OF PUBLIC ROADS JAN. 1963

Figure 15

insert figure 16

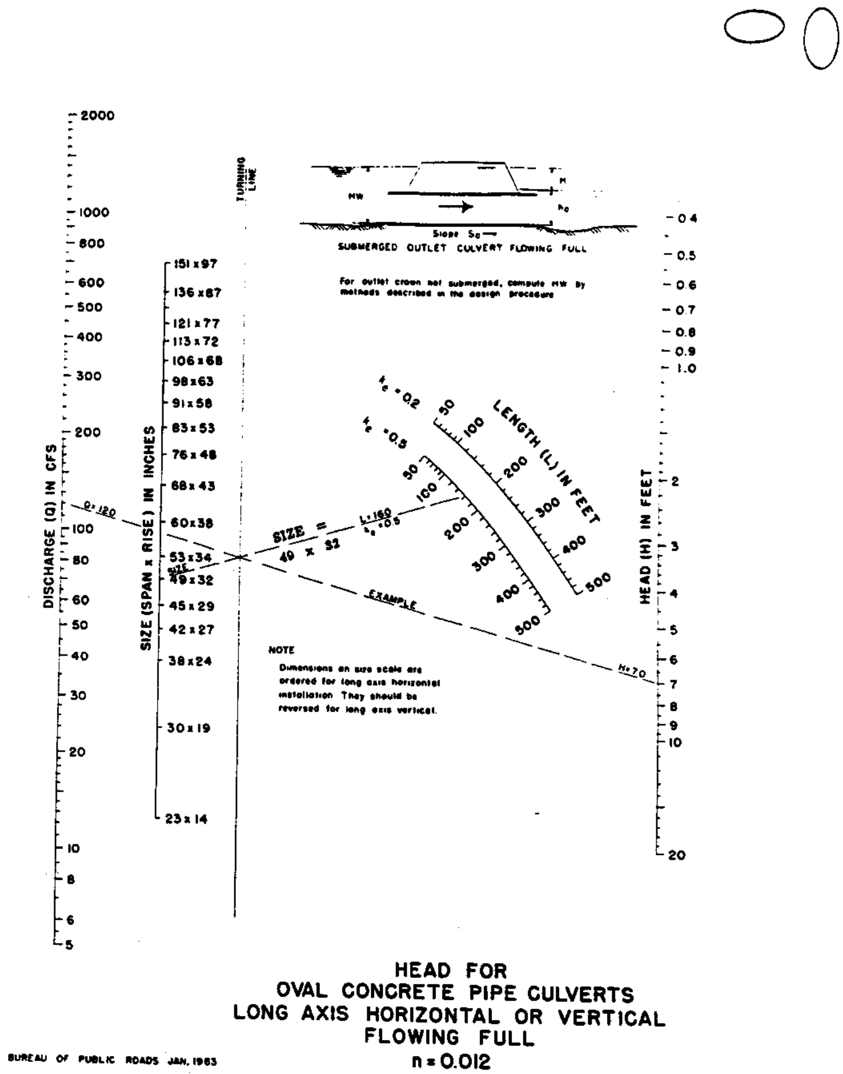
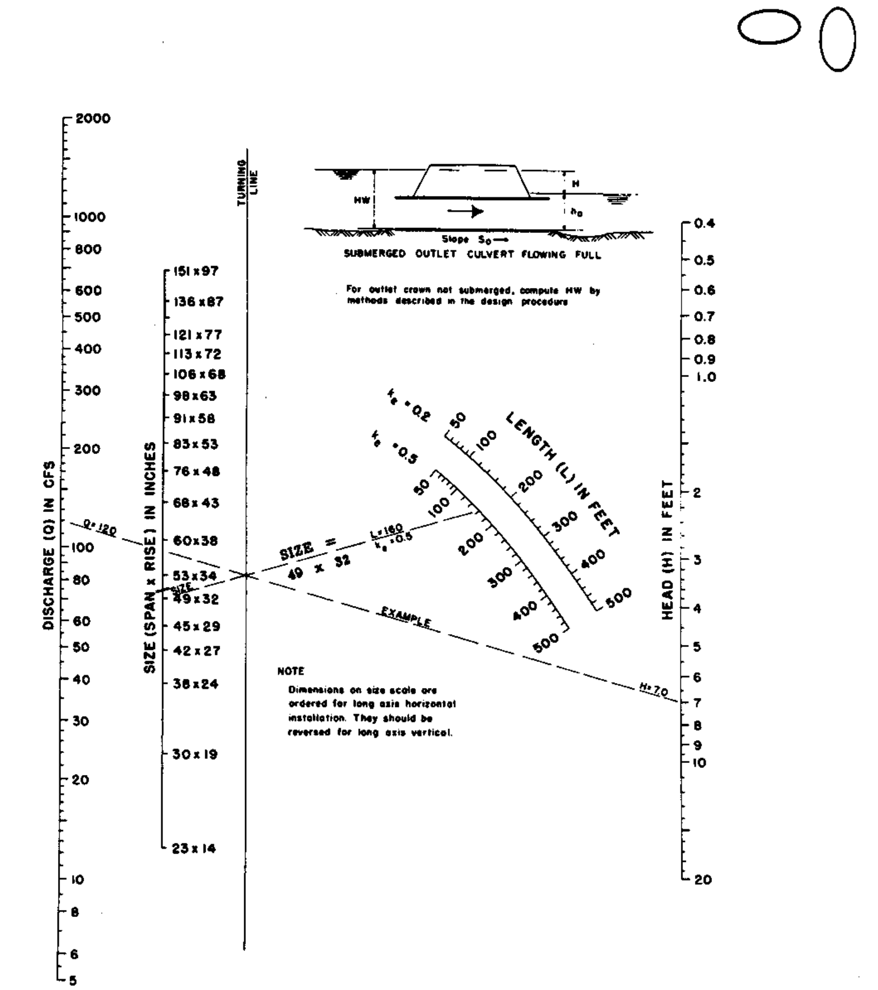


Figure 16

insert figure 17

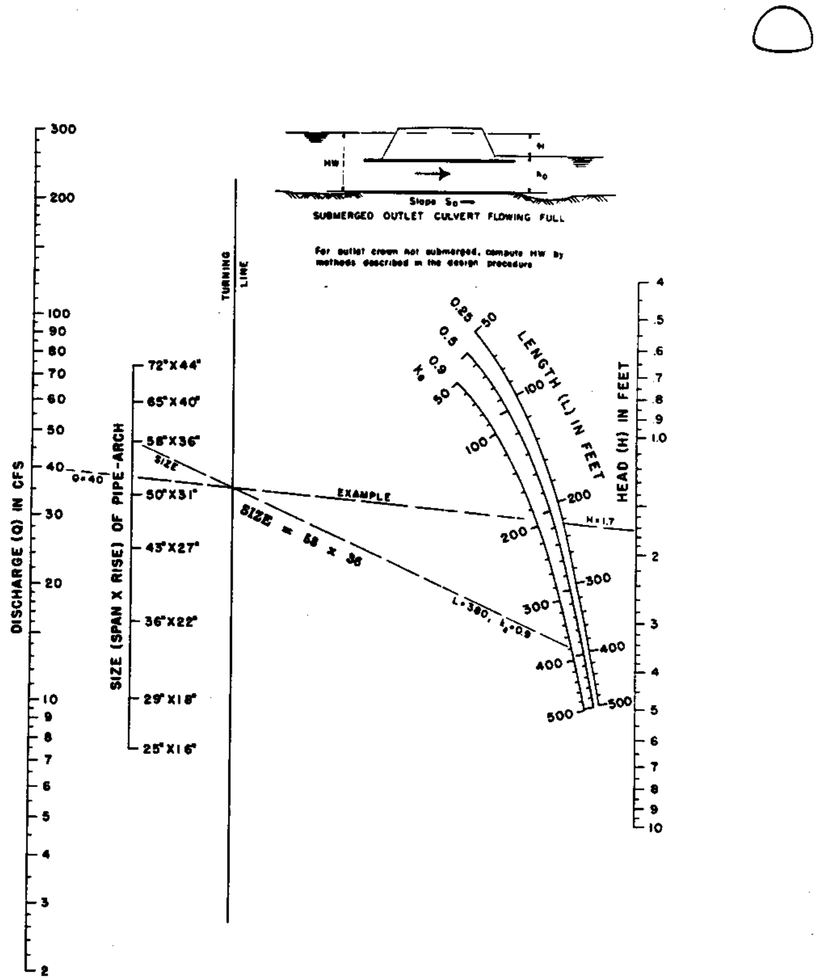


HEAD FOR
OVAL CONCRETE PIPE CULVERTS
LONG AXIS HORIZONTAL OR VERTICAL
FLOWING FULL
$n = 0.012$

BUREAU OF PUBLIC ROADS JAN. 1963

Figure 17

insert figure 18



HEAD FOR
STANDARD C. M. PIPE-ARCH CULVERTS
FLOWING FULL
n=0.024

BUREAU OF PUBLIC ROADS JAN. 1963

Figure 18

insert figure 19

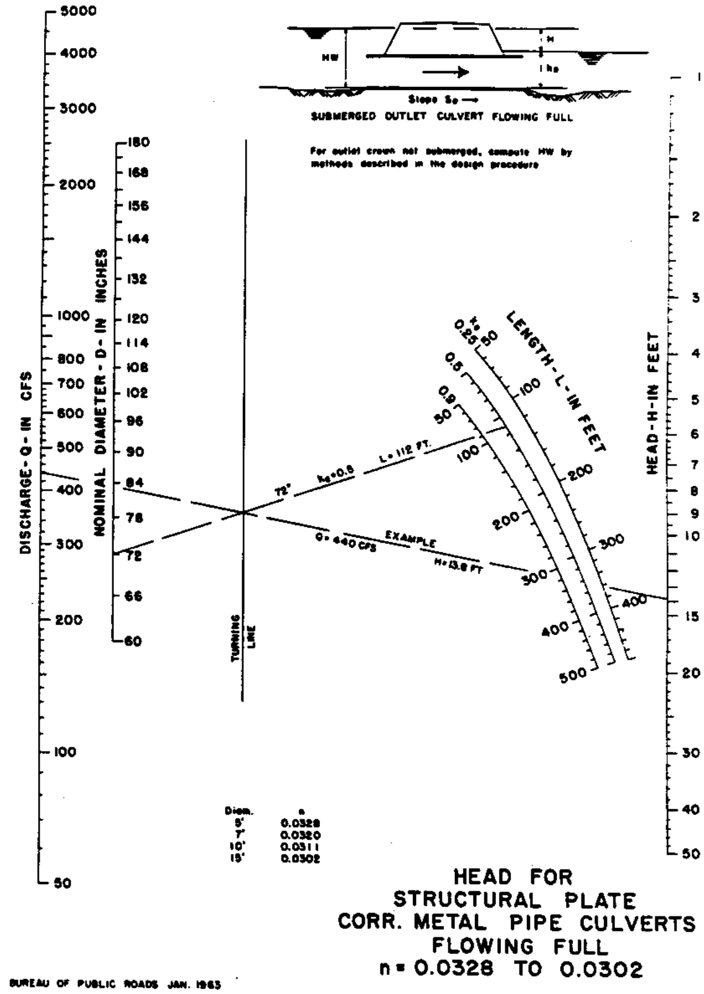
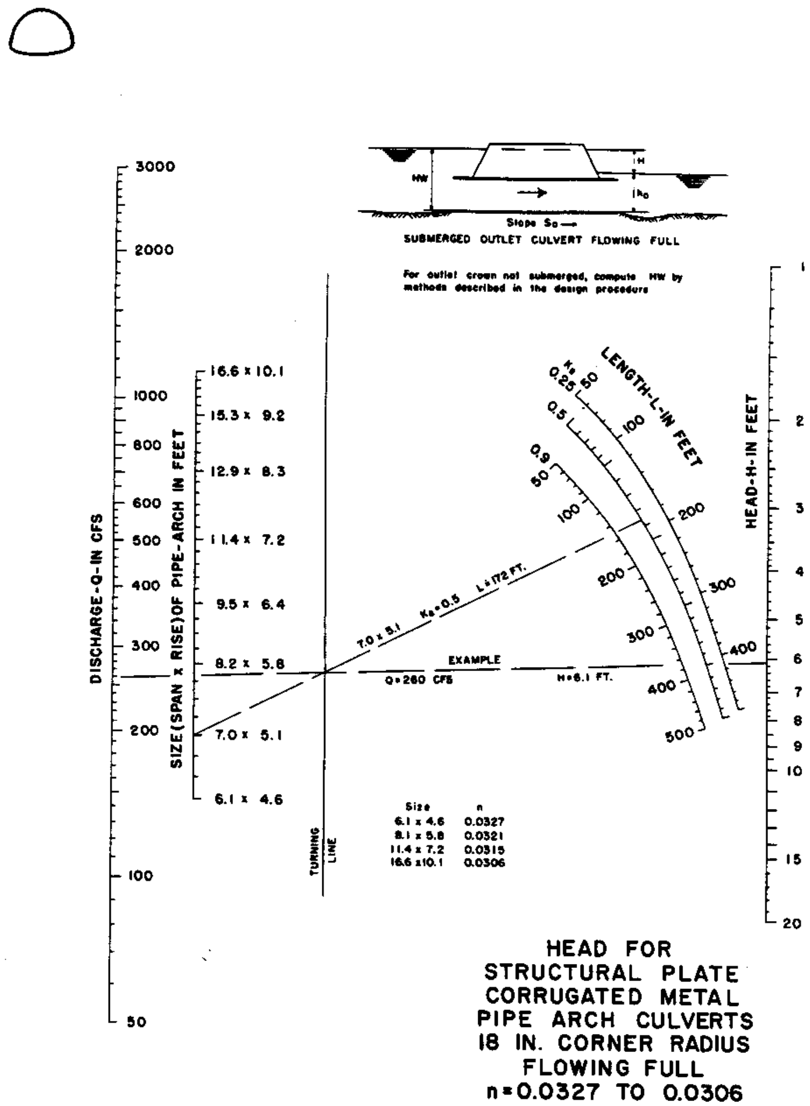


Figure 19

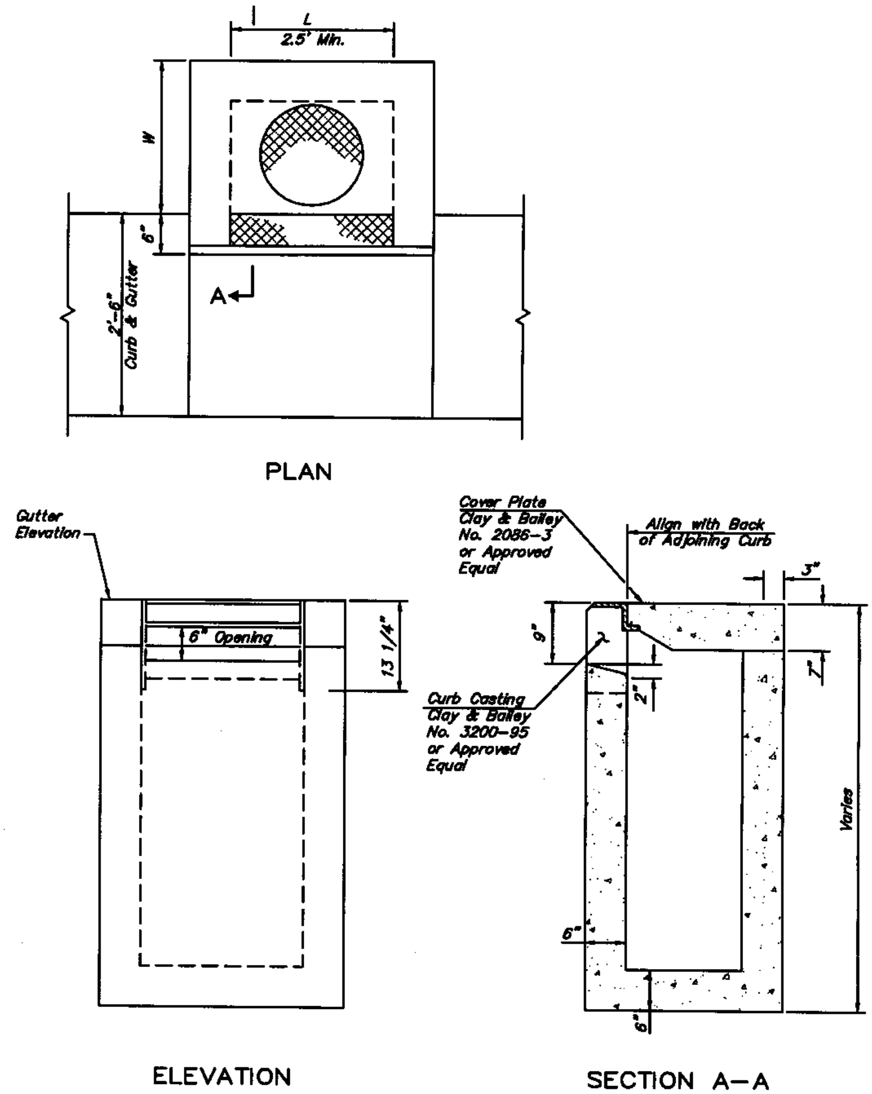
insert figure 20



BUREAU OF PUBLIC ROADS JAN. 1963

Figure 20

insert figure 21



STANDARD CURB INLET

Figure 21

TABLE 8-1
CURB INLET CAPACITY
FOR
12.0-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	2.7	G	G	G	G	G	G	G
1	3.7	G	G	G	G	G	G	G
2	5.3	5.3	G	G	G	G	G	G
3	6.5	5.4	5.6	5.7	G	G	G	G
4	7.5	5.4	5.9	6.0	6.8	7.1	7.3	7.4
6	9.1	5.6	6.4	6.5	7.4	8.1	8.5	8.9
8	10.6	5.7	6.8	6.9	8.0	9.0	9.4	9.8
10	11.8	6.4	7.2	7.9	9.1	10.1	10.6	11.1
12	12.9	7.1	7.9	8.6	10.0	11.2	11.7	12.2
14	14.0	7.6	8.6	9.4	10.8	12.1	12.7	13.2

NOTES & REFERENCES:

1. Inlet capacities derived from AThe Design of Stormwater Inlets≅ John Hopkins University, 1956.

2. Gutter capacity calculated by Izzard=s Equation.

3. Inlet capacity is for 1/4" per foot street crown and inlet throat and transition geometry per Figure 8-0.

4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.

5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.

6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

7. AG≅ indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

TABLE 8-2
CURB INLET CAPACITY
FOR
11.5-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	2.4	G	G	G	G	G	G	G
1	3.3	G	G	G	G	G	G	G
2	4.7	G	G	G	G	G	G	G
3	5.7	5.5	G	G	G	G	G	G
4	6.6	5.3	5.9	6.0	6.3	6.6	6.6	6.6
6	8.1	5.1	6.1	6.5	7.2	7.9	8.1	8.1
8	9.4	5.7	6.3	6.9	8.0	8.9	9.1	9.2
10	10.5	6.3	7.0	7.7	9.7	9.9	10.1	10.3
12	11.5	6.9	7.7	8.4	10.8	10.8	11.1	11.4
14	12.4	7.6	8.5	9.3	10.8	12.0	12.4	12.4

NOTES & REFERENCES:

1. Inlet capacities derived from AThe Design of Stormwater Inlets≅ John Hopkins University, 1956.

2. Gutter capacity calculated by Izzard=s Equation.

3. Inlet capacity is for 1/4" per foot street crown and inlet throat and transition geometry per Figure 8-0.

4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.

5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.

6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

7. AG≅ indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

TABLE 8-3
CURB INLET CAPACITY
FOR
10.5-FOOT GUTTER SPREAD

GUTTER SLOPE IN PERCENT	GUTTER CAPACITY C.F.S.	CURB INLET DESIGN CAPACITY C.F.S. FOR INLET LENGTH						
		4 FOOT	5 FOOT	6 FOOT	8 FOOT	10 FOOT	11 FOOT	12 FOOT
0.5	1.8	G	G	G	G	G	G	G
1	2.6	G	G	G	G	G	G	G
2	3.7	G	G	G	G	G	G	G
3	4.5	G	G	G	G	G	G	G
4	5.1	4.6	4.8	5.1	G	G	G	G
6	6. 3	4.9	5.3	5.7	6.3	7.2	G	G
8	7.3	5.1	5.7	6.3	7.2	G	G	G
10	8.2	5.9	6.6	7.2	8.1	G	G	G
12	8.9	6.3	7.1	7.8	8.9	G	G	G
14	9.6	6.9	7.7	8.4	9.6	G	G	G

NOTES & REFERENCE:

1. Inlet capacities derived from AThe Design of Stormwater Inlets≅ John Hopkins University, 1956.

2. Gutter capacity calculated by Izzard=s Equation.

3. Inlet capacity is for 1/4" per foot street crown and inlet throat and transition geometry per Figure 8-0.

4. Gutter deflectors are required for inlets on slopes of 4 percent and steeper.

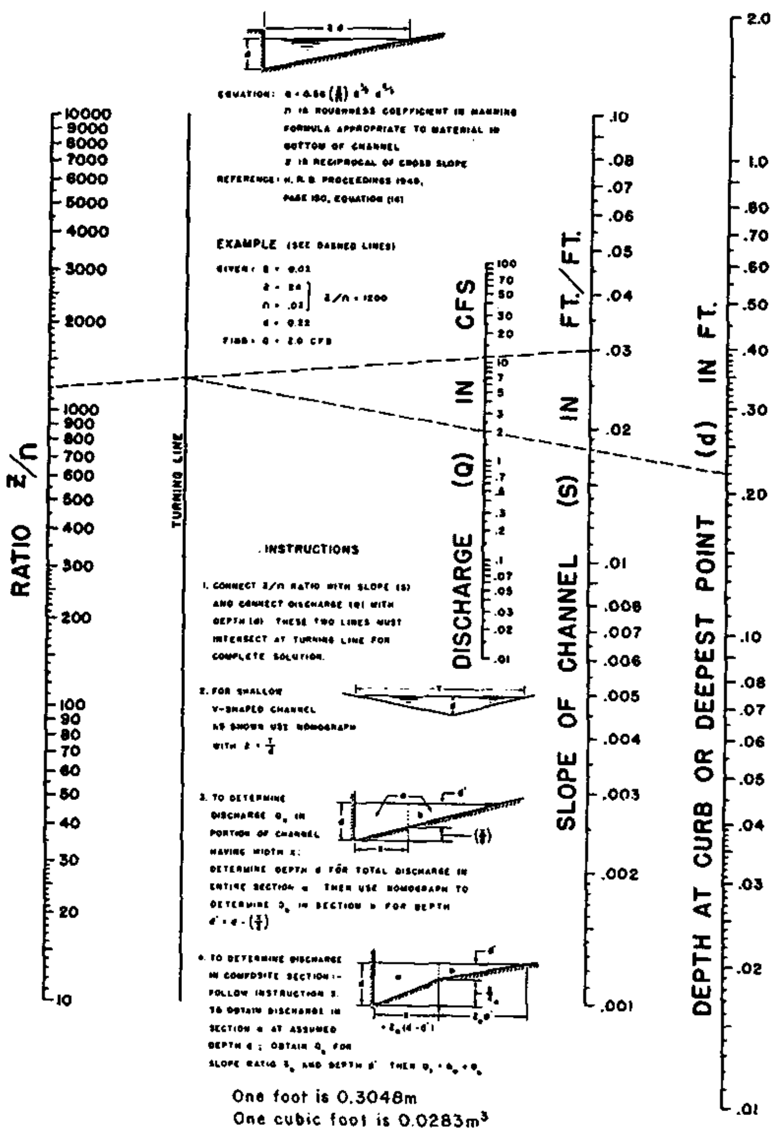
5. Linear interpolation within the range of the table is permitted for slopes and corresponding capacities not shown.

6. Reduce above theoretical capacities by 20% for clogging allowance per Section 5603.1.B.

7. AG≅ indicates inlet capacity is greater than gutter capacity and the 20% capacity reduction is not required.

Insert figure 22

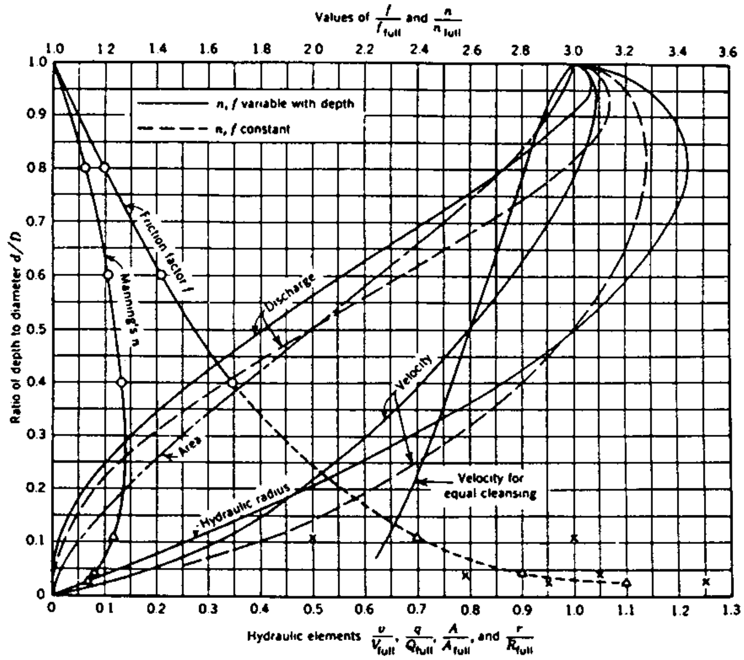
NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS



(After FHWA)

Figure 22

insert figure 23



v = Actual velocity of flow (fps)

V_{full} = Velocity flowing full (fps)

q = Actual quantity of flow (cfs)

Q_{full} = Capacity flowing full (cfs)

A = Area occupied by flow (ft^2)

A_{full} = Area of pipe (ft^2)

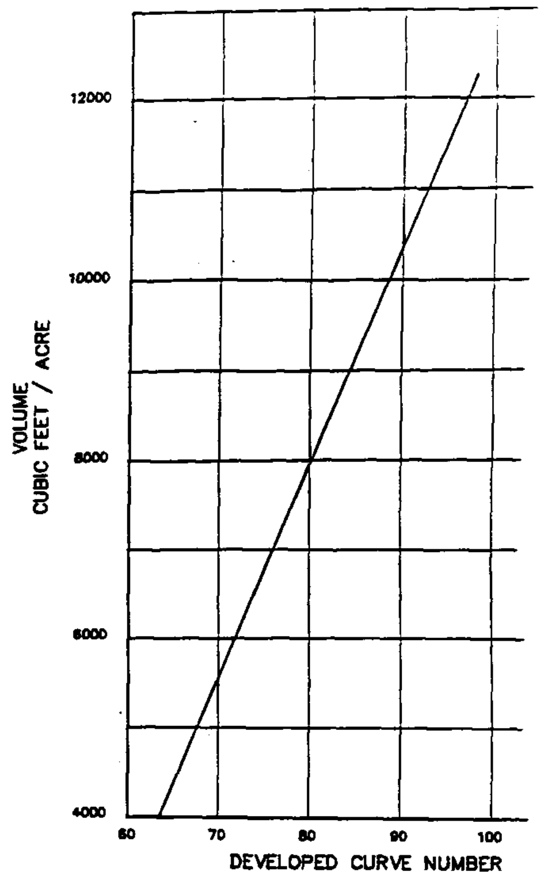
r = Actual hydraulic radius (ft.)

R_{full} = Hydraulic radius of full pipe (ft.)

HYDRAULIC ELEMENTS OF CIRCULAR CONDUITS (2)

Figure 23

insert figure 24



STORM WATER DETENTION
VOLUME REQUIREMENT
(SIMPLIFIED OPTION)

NOTES:

1. For Release Rates - See Section 5606.4.B.

2. The developed curve number for the site is to be determined in accordance with TR-55 "Urban Hydrology for Small Watersheds.

SIMPLIFIED VOLUME CHART
FOR DETENTION FACILITIES

Figure 24