THE COLONY
City by the Lake

ENGINEERING DESIGN MANUAL

MAY 2007

CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

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PART I - GENERAL

1.01 PURPOSE

The purpose of the Engineering Design Manual is to provide a set of guidelines for designing streets, thoroughfares, drainage facilities, water lines, wastewater lines, other public improvements and preparing construction plans for such facilities which are to be owned, operated and/or maintained by the City of The Colony, Texas. These guidelines shall be used by the Engineering Department, Department of Public Works and other City departments, Consulting Engineers employed by the City for the above described improvement projects, and Engineers for private developments in the City of The Colony and its extra-territorial jurisdiction as well as for plat approval, issuance of building permits, issuance of earthwork permits, approval of construction plans by the Engineering Department, site plan approval, and for other construction within public rights-of-way and easements subject to Section 245 of the Texas Local Government Code. All projects shall meet state and federal requirements.

1.02 SCOPE

The scope of this section of the Design Manual includes the various design elements, criteria, standards and instructions required for the design of streets, thoroughfares, drainage facilities, water lines, wastewater lines, and other public improvements.

1.03 STANDARD CONSTRUCTION DETAILS

In addition to the guidelines contained in this manual, the Engineering Department maintains drawings entitled "STANDARD CONSTRUCTION DETAILS", which are to be used in conjunction with this Design Manual in the preparation of engineering plans.

1.04 CORRELATION OF MANUAL AND STANDARD CONSTRUCTION DETAILS

The Engineering Design Manual and Standard Construction Details are complementary and what is called for by one shall be binding as if called for by both.

In case of conflict between the Engineering Design Manual and Standard Construction Details, the City reserves the right to make the interpretation that is in the best interests of the City.

1.05 UTILITY ASSIGNMENTS

Utilities are to be located in public rights-of-way in the location shown in Appendix "A". The City Engineer shall determine the location of utilities where special circumstances prevent the standard utility assignments from being used.

1.06 GENERAL NOTES

All construction plans for the projects described above shall contain the applicable general notes listed in Appendix "B".

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PART II – PAVING

PART II - PAVING

I. STREET AND THOROUGHFARE CLASSIFICATIONS

1.01 GENERAL

City streets and thoroughfares are classified into several types according to their use and locations as indicated in Table II-1. The basic types include the residential streets which provide direct access and frontage to adjacent properties, collectors which serve as the distributor-collector routes and provide direct access to adjacent properties, and major divided thoroughfares which carry high volumes of traffic through urban areas. Each traffic artery is made up of elements which are related to the use of that particular facility. These elements include right-of-way, pavement width, median width if required, arrangement of traffic lanes and parking lanes, curb radii at intersections and other characteristics.

II. STREET AND THOROUGHFARE GEOMETRICS

2.01 GENERAL

Geometrics of city streets and thoroughfares may be defined as the geometry of the curbs or pavement areas which governs the movement of traffic within the confines of the right-of-way. Included in the geometrics are the pavement, widths, degree of curvature, width of traffic lanes, parking lanes, or turning lanes, median width separating opposing traffic lanes, median nose radii, curb radii at street intersections, crown height, cross fall, geometric shapes of islands separating traffic movements and other features.

TABLE II-1

STREET AND THOROUGHFARE
GEOMETRIC STANDARDS

STREET TYPE	PVMT WIDTH	MIN ROW WIDTH	LANES	PARKING	MINIMUM PAVEMENT PARKWAY	MEDIAN	MINIMUM DESIGN THICKNESS	DESIGN SPEED
ALLEY	10'	15'	1-10'	0	2.5'	N/A	7"	10
RESIDENTIAL								
A	31'	50'	1-14'	2-8'	9.5'	N/A	6"	30
COLLECTOR								
2U-C	37'	60'	2-10'	2-8'	11.5'	N/A	7"	35
4U-B	45'	60'	4-11'	0	7.5'	N/A	8"	40
4U-A	61'	80'	5-12'	0	9.5'	N/A	8"	40
MAJOR								
4D-C	2 - 25'	100'	4-12'	0	9'	32'	8"	45
6D-B	2 - 34'	100'	6-11'	0	9'	14'	8"	45
6D-A	2 - 37'	120'	6-12'	0	16'	14'	8"	55
REGIONAL MAJOR (FM 423)								
R6D – A	2 – 40'	140'	3 – 12'	0	15'	32'	10"	45
R8D – A	2 – 52'	164'	4 – 12'	0	15'	32'	10"	45

NOTE: All dimensions are to back of curb.
Geometric Standards for Regional Major Streets are subject to approval by TxDOT.

2.02 DESIGN VEHICLES

The geometrics of city street and thoroughfare intersections vary with the classification of intersecting streets. Criteria for the geometric design of intersections must be based on certain vehicle operating characteristics, and vehicle dimensions. The American Association of State Highway and Transportation Officials (AASHTO) has standardized vehicle criteria into three general designs, and this vehicle data is published in the AASHTO Publication, "A Policy on Geometric Design of Highways and Streets", dated 2001. In the design of street and thoroughfare intersections for The Colony, these vehicle designs are adopted for use. Table II-2, Intersection Design Standards, shall be used for intersection design.

TABLE II-2

INTERSECTION DESIGN STANDARDS
(All dimensions are minimums)

	A_1*	A_1+	A_1#	A_2*	A_3	B	C	D	E	F	R_1	R_2	Corner Clip
R6D-A & R8D-A(1)	275’	150’	100’	150’	150’	150’	10’	330’	600’	60’	50’	50’	25 X 25
6D-B & 6D-A	275’	150’	100’	150’	150’	150’	10’	330’	600’	60’	50’	50’	25 X 25
4D-C	200’	150’	100’	150’	150’	150’	10’	330’	600’	60’	50’	50’	25 X 25
4U-A	200’	150’	100’	150’	150’	150’	N/A	330’	N/A	N/A	40’	40’	20 X 20
4U-B	150’	150’	100’	150’	150’	150’	N/A	300’	N/A	N/A	40’	40’	20 X 20
2U-C	100’	150’	100’	100’	150’	150’	N/A	270’	N/A	N/A	30’	30’	15 X 15
A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	30’	30’	10 X 10

* When intersecting street is a principal or minor arterial.
+ When intersecting street is a collector or a rural road.
# When intersecting street is a local street.
** For dual left-turn standards, consult Engineering Department
A_1 and A_2 may be increased to allow for stacking truck traffic.
(1) Subject to approval by TxDOT.
Corner clip based on 90 degree intersection, may be adjusted for angled intersection.
Radius and corner clip are based on highest classification street at intersection.

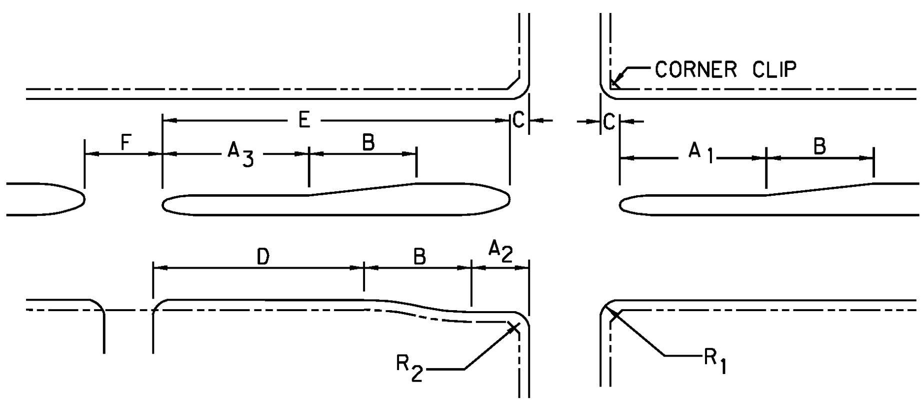

FIGURE II-1
INTERSECTION DESIGN DIAGRAM

2.03 DESIGN SPEED

The design speed is a primary factor in the horizontal and vertical alignment on city streets and thoroughfares. Design features such as curvature, superelevation, radii for turning movements and sight distance are directly related to the design speed. The design speed also affects features such as lane widths, pavement width, pavement cross-fall, pavement crown, and clearance.

The design speed is defined as the approximate maximum speed that can be maintained safely by a vehicle over a given section of road when conditions are so favorable that the design features of the roadway govern. The speed limit or posted speed is the maximum legal speed set by local authorities for a certain roadway or area. The design speed should always be greater than the likely legal speed limit for secondary and major thoroughfares.

The various street and thoroughfare classifications, which make up the system within the City, require different design speeds according to their use and location. Presented in Table II-1 are the minimum design speeds for the various classifications within the City of The Colony. Lower design speeds may be required for all classifications for unusual conditions of terrain or alignment.

2.04 HORIZONTAL GEOMETRICS

a. General

The horizontal geometrics of city streets and thoroughfares include the segment of geometric design associated with the alignment, intersections, pavement widths, and related geometric elements. The various classifications, utilizing the design speed as a control, must have certain horizontal and vertical geometrics to provide a safe economical facility for use by the public. All curves shall provide proper sight distances.

b. Horizontal Curves and Superelevation

The alignment of city streets and thoroughfares is usually determined by the alignment of the existing right-of-way or structures which cannot be relocated. Changes in the direction of a street or thoroughfare are minimized by constructing a simple curve having a radius which is compatible with the speed of vehicular traffic. To increase the safety and reduce discomfort to drivers traversing a curved portion of a street or thoroughfare, the pavement may be superelevated.

Curvature in the alignment of major thoroughfares and collectors is allowed under certain conditions, but greater traffic volume and higher vehicle speeds which accompany these facilities tend to increase accidents on curving roadways. Curves in the alignment of residential streets usually provide aesthetic values to the residential neighborhoods without affecting the orderly flow of traffic or sacrificing safety.

A recommended minimum radius of curvature for vehicle design speed and pavement cross-slopes is shown in Table II-3. These are based on traffic consisting of typical present day automobiles operating under optimum weather conditions. There are other important considerations in the design of curves on city streets and thoroughfares including the location of intersecting streets, drives, bridges and topographic features. When superelevation is required on collectors and major thoroughfares, the following basic formula shall be used:

$$R = \frac{V^2}{15\,(e + f)}$$

where:

e = rate of roadway superelevation, foot per foot

f = Side friction factor (See Table II-3)

V = vehicle design speed, mph

R = radius of curve in feet

TABLE II-3

MINIMUM CENTERLINE RADIUS
FOR ROADWAYS

Rate of Superelevation (In./Ft.)	Residential	Collector		Major	
	DESIGN SPEED (MPH)				
	30	35	40	45	55
-1/2	500	710	930	1290	1925
-3/8	465	655	855	1175	1755
-1/4	430	605	790	1080	1615
-1/8	400	565	740	1000	1495
0	375	530	690	935	1395
+1/8	355	495	650	875	1305
+1/4	335	470	610	820	1225
+3/8	320	445	580	775	1155
+1/2	300	420	550	730	1090

Street Classification	Side Friction Factor (f)
Residential Streets	0.160
Collector Streets	0.155
Major Thoroughfares	0.145

c. Turning Lanes

Turning lanes are provided at intersections to accommodate left-turning and right-turning vehicles. The primary purpose of these turning lanes is to provide storage for the turning vehicles. The secondary purpose is to provide space to decelerate from normal speed to a stopped position in advance of the intersection or to a safe speed for the turn in case a stop is unnecessary. Left turn lanes at intersections are usually 12 feet in width. When turning traffic is too heavy for a single lane and the cross street is wide enough to receive the traffic, two turning lanes may be provided.

The location of the median nose at the end of the left turn lane should be located so that left turning traffic will clear the median nose while making a left turn. Other considerations include adequate clearance between the median nose and through traffic on the intersecting thoroughfare and locations of the median nose to properly clear the pedestrian crosswalks.

Minimum length of left turn lanes for major thoroughfares shall be as specified in Table II-2.

The actual length shall be approved by City Engineer based upon projected left turn volume.

d. Street Intersections

The intersection at grade of major thoroughfares, collector streets, and residential streets shall be at ninety (90) degree angles. Intersections not a ninety (90) degree angle may be approved by the City Engineer. Lanes shall be aligned for safe passage through the intersection.

e. Sidewalks

The purpose of the public sidewalks is to provide a safe area for pedestrians. The Colony requires that sidewalks be constructed with the paving of streets or when building construction occurs, in all residential areas and wherever pedestrian traffic may be generated and that all sidewalks conform to state laws for barrier free construction.

The standard concrete sidewalk is 4 feet in width for residential areas and 5 feet in width for commercial areas. The edge of the sidewalk located nearest the street right-of-way is normally 2 feet from the right-of-way line. Special sidewalk designs to include a 6-foot sidewalk located adjacent to the street will be considered for approval where warranted. In areas where screening walls are required, sidewalks shall be constructed against the screening wall. One foot of width shall be added to all sidewalks abutting retaining walls.

Sidewalk alignments may be varied to avoid the removal of trees or the creation of excessive slopes when approved by the City Engineer. A waiver for deletion of the requirement for sidewalk shall be submitted in writing and will become effective only upon City Council approval.

2.05 VERTICAL ALIGNMENT

a. Street Grades

The vertical alignment of city streets and thoroughfares should be designed to insure the safe operation of vehicles and should allow easy access to adjacent property. A travelway which is safe for vehicles is dependent on criteria which consider operating speeds, maximum grades, vertical curves and sight distance. In addition to these considerations, other factors related to vertical alignment include storm drainage, crown and crossfall and the grade and right-of-way elevation relationship.

1. Minimum Grades

   Minimum longitudinal grades for streets and thoroughfares are required to insure proper flow of surface drainage toward inlets. Minimum grades are five tenths percent (0.5%) for all pavement. Valleys across intersection shall be a minimum of five tenths percent.

2. Maximum Grades

   Maximum longitudinal grades shall be compatible with the type of facility and the accompanying characteristics including the design speed, traffic conditions and sight distance.

   Major and secondary thoroughfares must move large volumes of traffic at faster speeds and flatter grades will better accommodate these characteristics. Truck and bus traffic on these type facilities often controls traffic movement, particularly if steep grades prevent normal speeds. The normal maximum street grades allowed are shown in Table II-4. Steeper grades may be permitted for short lengths where topographical features or restricted alignment require.

TABLE II-4

MAXIMUM STREET GRADES

Street Types	Normal Maximum Grade In Percent
Residential	8%
Collector	6%
Major	6%

b. Vertical Curves

When two longitudinal street grades intersect at a point of vertical intersection (PVI) and the algebraic difference in the grades is greater than one percent (1%) for design speed less than 45 mph or one-half (0.5%) for design speeds greater than 45 mph, a vertical curve is required. Vertical curves are utilized in roadway design to effect a gradual change between tangent grades and should result in a design which is safe, comfortable in operation, pleasing in appearance and adequate for drainage. The vertical curve shall be formed by a simple parabola and may be a crest vertical curve or a sag vertical curve.

c. Stopping Sight Distance

1. Crest Vertical Curve

When a vertical curve is required, it must not interfere with the ability of the driver to see length of street ahead. This length of street, called the stopping sight distance, should be of sufficient length to enable a person in a vehicle having a height of 3.50 feet above the pavement and traveling at design speed to stop, before reaching an object in his path that is 0.5-foot in height.

The minimum stopping sight distance is the sum of two distances: one, the distance traversed by a vehicle from the instant the driver sights an object for which a stop is necessary, to the instant the brakes are applied; and the other, the distance required to stop the vehicle after the brake application begins.

The minimum safe stopping sight distance and design speeds are shown in Table II-5. These sight distances are based on each design speed shown and a wet pavement. The length of crest vertical curve required for the safe stopping sight distance of each street type may be calculated using the formula L = KA and the values of K for a crest vertical curve shown in Table II-5.

2. Sag Vertical Curve

When a sag vertical curve is required, the vertical curve shall be of sufficient length to provide a safe stopping sight distance based on headlight sight distance. The minimum length of sag vertical curve required to provide a safe stopping sight distance may be calculated using the formula L = KA and values of K for a sag vertical curve are shown on Table II-5.

TABLE II-5

MINIMUM LENGTH OF VERTICAL CURVE

CREST VERTICAL CURVE	SAG VERTICAL CURVE
L = KA where	L = KA where
L = Minimum Length Vertical Curve required for safe stopping	L = Minimum Length Vertical Curve required for Headlight Control
K = Horizontal Distance in feet requires to affect a one percent change in gradient	K = Horizontal Distance in feet required to affect a one percent change in gradient
A = Algebraic Difference in grade	A = Algebraic Difference in grade

Street Type	Design Speed	Safe Stopping Sight Distance	Normal Crest Vertical Curve K	Normal Sag Vertical Curve K	Minimum Length of Curve
Residential	30	200	19	37	60
Collector	35	250	29	49	100
Collector	40	305	44	64	100
Major	45	360	61	79	120
Major	55	495	114	115	150

d. Intersection Grades

The grade of an intersecting street with the principal street gutter should not generally be more than four percent (4%) either up or down within the first 20 feet beyond the curb line of the principal street. Grade changes greater than one percent (1%) will require vertical curves.

The grade of street or thoroughfare, particularly at its intersections with another street, is of prime importance in providing a safe, comfortable riding surface. The intersection design of two major thoroughfares shall include grades which will result in a plane surface or at least a surface which approximates a plane surface. Grades in excess of 3% should be avoided. A maximum grade of 2% is desirable. A vehicle traveling on either thoroughfare should be able to traverse the intersection at the design speed without discomfort. For intersections involving streets of different classifications, the profile of street with the lesser classification shall be adjusted to meet the profile of the street with the higher classification. No valleys across major thoroughfares or collectors will be allowed. To accomplish a smooth transition, crossfall toward the median of one lane of each thoroughfare may be required. The use of storm drainage inlets in the median shall be avoided if possible.

In drawing the grades of intersecting thoroughfares in the profile view of plan/profile sheets, profiles of all four profiles shall be shown as a continuous line through the intersection. All intersections where any street is classified as a collector or thoroughfare shall be contour graded with minimum contour intervals of 0.2 feet.

e. Street Cross Section

For curbed streets, the right-of-way shall be graded to drain to the street at a slope of 1/4" per foot. Street back slopes and embankment slopes shall not be steeper than 4:1.

2.06 SIGHT DISTANCE AT INTERSECTIONS

An important consideration in the design of city streets and thoroughfares is the vehicle attempting to cross the street or thoroughfare from the side street or drive. The operator of the vehicle attempting to cross should have an unobstructed view of the whole intersection and a length of the thoroughfare to be crossed sufficient to permit control of the vehicle to avoid collisions. The minimum sight distance considered safe under various assumptions of physical conditions and driver behavior is related directly to vehicle speeds and to the resultant distance traversed during perception and reaction time and during braking. This sight distance, which is termed intersection sight distance, can be calculated for different street or thoroughfare widths and for various grades upwards and downwards. Intersection sight by AASHTO publication "A Policy On Geometric Design of Highways and Streets", 2001. Sight distance requirements are defined by Table II-6 and Figure II-2. As a minimum visibility triangles shall be provided as shown in Figure II-3.

TABLE II-6

SIGHT DISTANCE REQUIREMENTS

Design Speed (mph)	Stopping Sight Distance (feet)	Intersection Sight Distance for passenger Cars (feet)
30	200	335
35	250	390
40	305	445
45	360	500
55	495	610

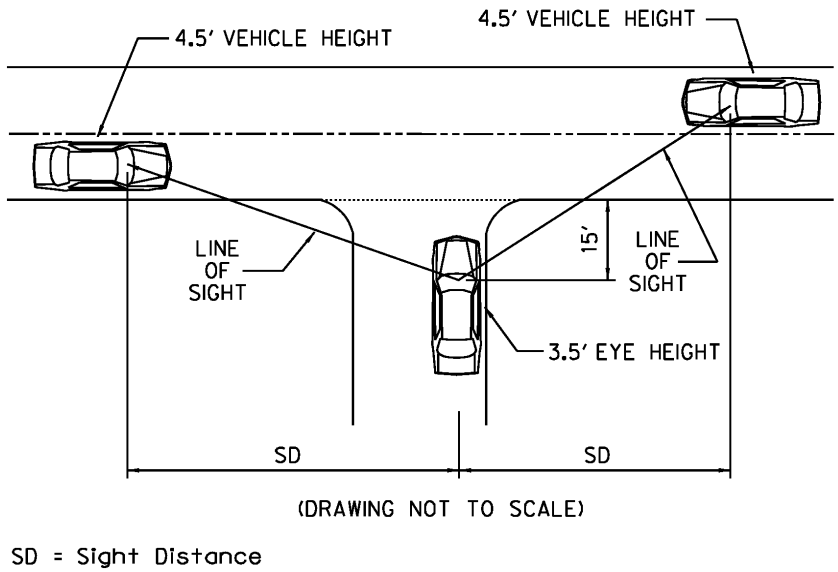

FIGURE II-2
SIGHT DISTANCE REQUIREMENTS

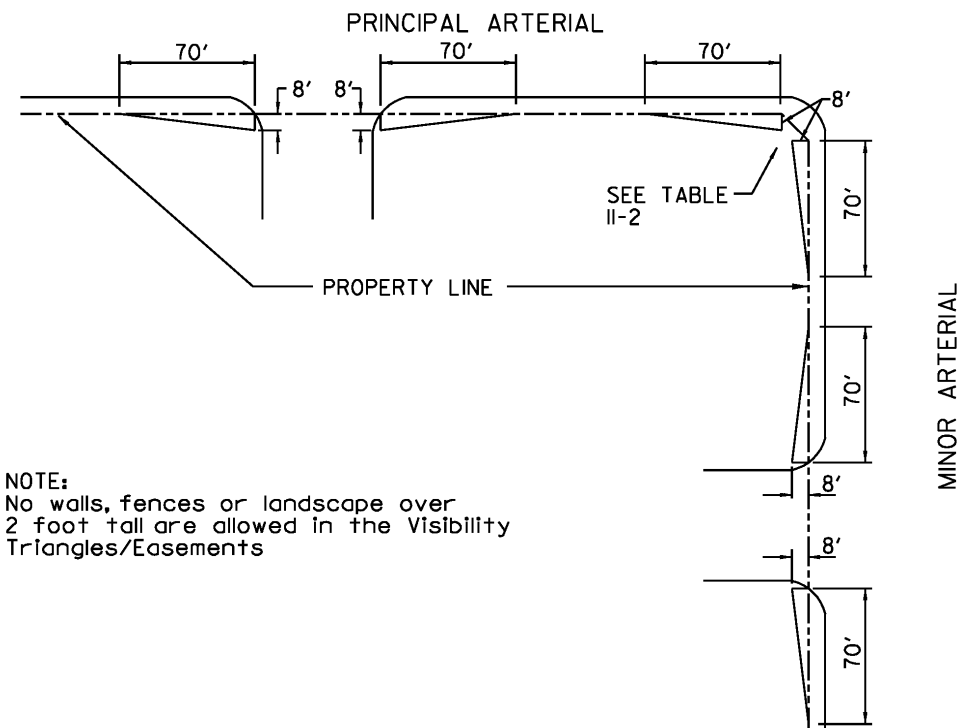

FIGURE II-3
VISIBILITY TRIANGLES

2.07 MEDIAN OPENINGS

The following standards for median openings are established to facilitate traffic movement and promote traffic safety:

Major Streets

Median openings will normally be permitted at all intersections with dedicated city streets. Exceptions would be at certain minor streets where due to unusual conditions a hazardous situation would result.

Midblock median openings or other openings with turns permitted into adjacent property will not normally be permitted unless all the following conditions exist:

a. The property to be served is a significant traffic generator with demonstrated or projected trip generation of not less than two hundred and fifty (250) vehicles in a twelve-hour period.

b. The median opening is not less than 600 feet from another median opening.

2.08 CUL-DE-SACS

The maximum length of any cul-de-sac shall be 600 feet measured from curb line of the intersecting street to the radius point of turn around. The right-of-way radius shall be 50 feet and the curb radius 40 feet within the cul-de-sac turn around. All cul-de-sac turnarounds shall be visible from the intersecting street.

III. DRIVEWAY STANDARDS

3.01 DRIVEWAY REQUIREMENTS

Driveways shall be governed by Tables II-7 and II-10. Refer to Figures II-1 and II-4.

TABLE II-7

DRIVEWAY REQUIREMENTS

	Residential (Min) (Max)	Industrial (Min) (Max)	Commercial (Min) (Max)
A - Driveway Throat Width			
Local	15 – 28 ft	40 ft	30 – 40 ft
Collector	15 – 28 ft	40 – 60 ft *	30 – 40 ft
Minor Arterial	N/A	40 – 60 ft *	30 – 60 ft
Principal Arterial	N/A	40 – 60 ft *	30 – 60 ft
Driveway Curb Radius			
Local	5 ft	30 ft	20 ft
Collector	5 ft	40 ft	25 ft
Minor Arterial	N/A	40 ft	30 ft
Principal Arterial	N/A	50 ft	35 ft
B - Minimum Centerline Driveway Spacing Along			
Local	15 ft	110 ft	70 ft
Collector	25 ft	110 ft	120 ft
Minor Arterial	N/A	160 ft	170 ft
Principal Arterial	N/A	250 ft **	230 ft
Driveway Angle	90°	90°	90°
C - Minimum Distance from Driveway to Intersection			
Local	50 ft	100 ft	100 ft
Collector	50 ft	100 ft	120 ft
Minor Arterial	N/A	175 ft	150 ft
Principal Arterial	N/A	175 ft	150 ft
Maximum Approach Grade			
Local / Collectors	10%	6%	6%
All Others	10%	6%	6%
Right Turn Requirement	10%	6%	6%

* Can be wider based on site requirements.
** Driveways should be used jointly at median openings.
Based on 40 mph.
Driveway width plus radius must be contained within the property frontage, between the extended property lines.
State Standards, if more restrictive, shall apply to SH 121 and FM 423.

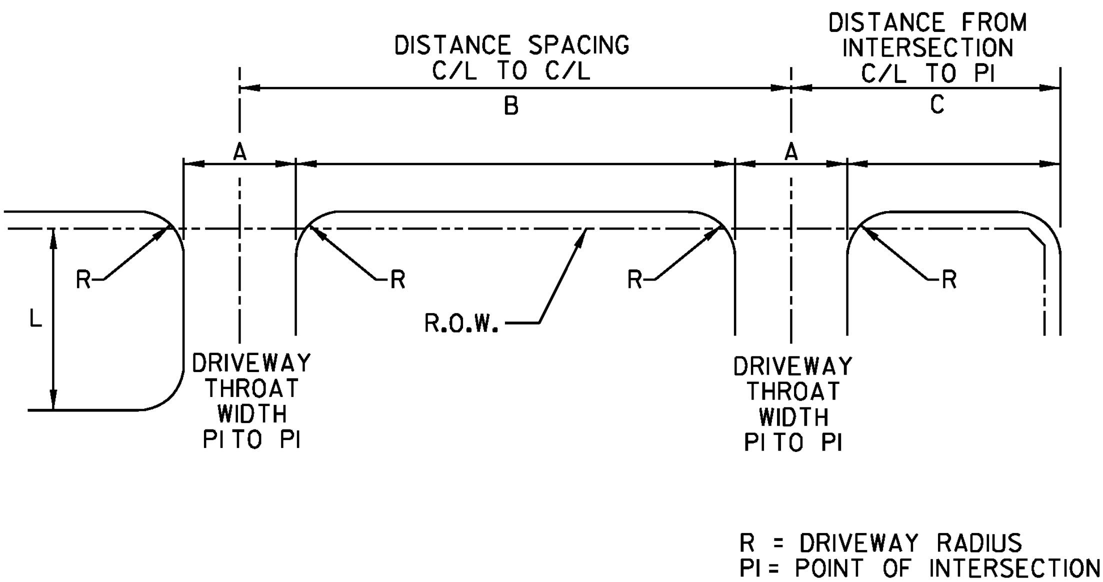

FIGURE II-4
DRIVEWAY REQUIREMENTS

TABLE II-8

MINIMUM DRIVEWAY STORAGE LENGTH (L)
(See Figure II-4)

Number of Parking Spaces per Driveway	Minimum Storage Length* (feet)
Less than 50	18
50 to 200	50
More than 200	78

* Storage length is defined as the distance between the street right-of-way line and the first intersecting aisleway on the side.

IV. TRAFFIC IMPACT ANALYSIS GUIDELINES

4.01 DEFINITIONS – THE FOLLOWING TERMS ARE USED IN THIS ARTICLE.

a. Projected traffic volumes – The number of vehicles that are expected/calculated to exist on streets after completion of the project.

b. Study area – The boundaries in which the study is conducted.

c. TIA (Traffic Impact Analysis) – An in-depth analysis of traffic.

d. Traffic queuing – A line of waiting vehicles.

e. Trip distribution – Estimates of percentage distribution of trips by turning movements from the proposed development.

f. Trip generation summary – A table summarizing the trip generation characteristics of the development for the entire day including AM and PM peak periods, rates and units used to calculate the number of trips.

g. Non-site traffic – Traffic not created or associated with the traffic generated by the project.

4.02 PURPOSE

The purpose of a Traffic Impact Analysis (TIA) is to assess the effects of specific development activity on the existing and planned roadway system. It is the intent of this ordinance to make traffic access planning an integral part of the development process.

4.03 APPLICABILITY

a. A Traffic Impact Analysis (TIA) will be required at the time of platting for land developments that are expected to meet a threshold level of change as described in Section 4.04, "When Traffic Impact Analysis (TIA) is Required". The City reserves the right to require a TIA for land developments that do not meet the threshold requirements, but may impact a sensitive area with traffic issues or may be a known public concern.

b. A Traffic Impact Analysis (TIA) will be required when there is a request to amend the Thoroughfare Plan.

4.04 WHEN TRAFFIC IMPACT ANALYSIS (TIA) IS REQUIRED

a. A TIA will be required of the property owner (or designated agent) when an activity or change to the property occurs and any of the following occur:

1. More than 500 Peak Hour Trip (PHT) generation
2. More than 5,000 vehicle trips per day generation
3. More than 100 acres of property is involved
4. Any changes or alterations to the City Thoroughfare Plan

b. The property owner (or designated agent) shall perform and submit to the City of The Colony Engineering Department a TIA performed at a minimum as established in Section 4.06, "Traffic Impact Analysis Requirements". The TAI must be signed and sealed by a professional engineer, registered to practice in Texas, with experience in Transportation Engineering sufficient to assess traffic impacts.

c. The engineer conducting the study must be approved by the City of The Colony Public Works Department prior to performing the study. The City of The Colony Public Works Department must approve all TIA's before final acceptance. After acceptance of the TIA, the review process will determine further actions.

4.05 ROLES OF APPLICANT AND CITY

A TIA that is required of the applicant by the City of The Colony is part of the development review and approval process. The primary responsibility for assessing the traffic impacts associated with a proposed development rest with the applicant. The City serves in a review capacity for this process.

4.06 TRAFFIC IMPACT ANALYSIS (TIA) REQUIREMENTS

a. The Traffic Impact Analysis (TIA) must be prepared and evaluated by a consultant who meets the qualifications described in Section 4.04 (b) to perform such studies.

b. The analysis is required to contain at a minimum, the following:

1. Traffic Analysis Map

(a) Land Use, Site and Study Area Boundaries, as defined (provide map).

(b) Existing and Proposed Site Uses.

(c) For TIA's where land use is the basis for estimating projected traffic volumes, existing and Proposed Land Uses on both sides of boundary streets for all parcels within the study area (provide map).

(d) Existing and Proposed Roadways and Intersections of boundary streets within the study area of the subject property, including traffic conditions (provide map).

(e) All major driveways and intersecting streets adjacent to the property will be illustrated in sufficient detail to serve the purposes of illustrating traffic function. This may include showing lane widths, traffic islands, medians, sidewalks, curbs, traffic control devices (traffic signs, signals, and pavement markings), and a general description of the existing pavement condition.

(f) Photographs of adjacent streets of the development and an aerial photograph showing the study area.

2. Trip Generation and Design Hour Volumes (provide table).

(a) A trip generation summary table listing each type of land use, the building size assumed, average trip generation rates used (total daily traffic and a.m./p.m. peaks), and total trips generated shall be provided.

(b) Vehicular trip generation may be discounted in recognition of other reasonable and applicable modes, e.g., transit, pedestrian, bicycles. Trip generation estimates may also be discounted through the recognition of passby trips and internal site trip satisfaction. All such estimates shall be subject to the approval of the Transportation Services Director.

(c) Proposed trip generation calculations for single-story commercial properties shall be based on a Floor-to-Area (building size to parcel size) ratio of 0.25 or more.

3. Trip Distribution (provide figure by Site Exit/Entrance). The estimates for percentage distribution of trips by turning movements to/from the proposed development.

4. Trip Assignment (provide figure by site entrance and boundary street). The direction of approach of site-attracted traffic via the area's street system.

5. Existing and Projected Traffic Volumes (provide figure for each item). Existing traffic volumes are the numbers of vehicles on the streets of interest during the time periods listed below, immediately prior to the beginning of construction of the land development project. Projected traffic volumes are the number of vehicles, excluding the site-generated traffic, on the streets of interest during the time periods listed below, in the build-out year.

(a) A.M. Peak Hour site traffic (including turning movements) if significant impact.

(b) P.M. Peak Hour site traffic (including turning movements).

(c) Weekend Peak Hour site traffic (including turning movements).

(d) A.M. Peak Hour total traffic including site-generated traffic and Projected Traffic (including turning movements).

(e) P.M. Peak Hour total traffic including site-generated traffic and Projected Traffic (including turning movements).

(f) Weekend Peak Hour total traffic including site-generated traffic and Projected Traffic (including turning movements).

(g) For special situations where peak traffic typically occurs at non-traditional times, e.g., major sporting venues, entertainment venues, large specialty Christmas stores, etc., any other Peak hour necessary for complete analysis (including turning movements).

(h) Total daily existing traffic for street system in study area.

(i) Total daily existing traffic for street system in study area and new site traffic.

(j) Total daily existing traffic for street system in study area plus new site traffic and projected traffic from build-out of study area land uses.

6. Capacity Analysis (provide Analysis Sheets in Appendices).

(a) A capacity analysis shall be conducted for all public streets, intersections and junctions of major driveways with public streets, which are significantly impacted (as designated by the City Traffic Engineer or Transportation Services Director), by the proposed development within the previously defined study boundary.

(b) Capacity analysis will follow the principles established in the latest edition of the Transportation Research Board's *Highway Capacity Manual* (HCM), unless otherwise directed by the Transportation Services Director. Capacity will be reported in quantitative terms as expressed in the HCM and in terms of traffic Level of Service.

(c) Capacity analysis will include traffic queuing estimates for all critical applications where the length of queues is a design parameter, e.g., auxiliary turn lanes, and at traffic gates.

7. Conclusions and Requirements.

(a) Roadways and intersections, within the Study Area, that are expected to operate at Level of Service D, E, or F, under traffic conditions including projected traffic plus site-generated traffic must be identified and viable recommendations made for raising the traffic conditions to Level of Service C or better (Level of Service A or B).

(b) Level of Service "C" is the design objective for all movements and under no circumstances will less than Level of Service "D" be deemed acceptable for site and non-site traffic including existing traffic at build-out of the study area. The Transportation Services Director must approve a Level of Service "D".

(c) For phased construction projects, implementation of traffic improvements must be accomplished prior to the completion of the project phase for which the capacity analyses show that they are required. Plats for project phases subsequent to a phase for which a traffic improvement is required may be approved only if the traffic improvements are completed or bonded.

(d) Voluntary efforts, beyond those herein required, to mitigate traffic impacts are encouraged as a means of providing enhanced traffic handling capabilities to users of the land development site as well as others.

(e) Traffic mitigation tools include, but are not limited to, pavement widening, turn lanes, median islands, access controls, curbs, sidewalks, traffic signalization, traffic signing, pavement markings, etc.

(f) The applicant will provide five (5) copies of the Draft Report for review and nine (9) copies of the Final Report for submittal.

8. Other Items

(a) The City Engineer may require other items be included in the TIA above those listed above.

V. PAVEMENT DESIGN

5.01 STANDARD STREET AND THOROUGHFARE PAVEMENT DESIGN

All new roadways within the City of The Colony shall be constructed of reinforced concrete. Asphalt pavements may be used for temporary construction if approved by the City Engineer. Table II-10 shows the required pavement thickness for rigid pavement and the subgrade requirements for certain soil conditions for various street and thoroughfare types within the City of The Colony. The procedure for using this table requires that a soils investigation be made including obtaining soil auger borings, classifying the soils encountered and determining the strength and physical properties of the underlying and supporting soils system in moisture content, and unit dry weight (see 5.02 – Geotechnical Investigation Required). For each soil classification encountered, the plasticity index shall be calculated and depending whether the P.I. is less or more than the critical percentage shown, the subgrade design shall consist of a 6-inch compacted subgrade or a lime or cement treated subgrade as shown in Table II-10. Table II-10 also presents the recommended pavement thickness of portland cement concrete pavement for the various street and thoroughfare types.

5.02 GEOTECHNICAL INVESTIGATION REQUIRED

A geotechnical investigation must be performed for all new developments within the City of The Colony containing public streets, private streets and private parking lots. As a minimum, the study must address the following:

- general soil and groundwater conditions
- earthwork recommendations
- recommendations for pavement subgrade type, depth, and concentration
- guidelines for concrete pavement design

The investigation must be based on samples obtained from drilling or from excavations on the site. Samples must be tested in a laboratory. Tests must include as a minimum:

- moisture content and soil identification
- liquid and plastic limit determination
- unit weight determination
- Eades and Grim lime series tests
- soluble sulfate tests

The geotechnical investigation must be performed by a qualified geotechnical firm. A report with findings and recommendations must be prepared. The report shall bear the seal of a licensed engineer in the State of Texas.

5.03 GUIDELINES FOR STABILIZATION OF SUBGRADE SOILS CONTAINING SULFATES

Lime induced heaving has been a cause of pavement failures in the North Texas area. Basically four components are the culprits in sulfate induced stress in stabilized soils: calcium, aluminum, water, and sulfates. Together, and in the proper combination, these components will produce calcium-aluminate-sulfate-hydrate minerals with an expansion potential as large as 250%.

The best approach when dealing with lime stabilization of clay with significant soluble sulfate content is to force the formation of the deleterious minerals prior to compaction. If these minerals form during the mellowing period before placement and compaction, no damage will be done to the pavement. This can be done by providing adequate mellowing time (time delay between application of stabilizer and compaction of the stabilized soil) and with addition of adequate water.

Generally if the total level of soluble sulfates is below 3,000 ppm, by weight of soil, then lime stabilization is not of significant concern.

Sulfate levels of moderate to high risk are those between 3,000 ppm and 10,000 ppm. These soils should be treated by the double lime application method. In this method one-half of the lime is mixed with the soil and excess water. Mixing water should be applied to bring the soil to at least 3% to 5% above optimum for compaction and maintained at that level through the mellowing period. The mellowing period should be at least 72 hours. After that time, the second half of the required lime is mixed followed by compaction. Double treatment does not require twice the required lime, but rather the required lime placed in two separate treatments.

Sulfate levels of high risk, between 8,000 ppm and 10,000 ppm, should be treated with a double application of lime as required for moderate to high risk soils, but the mellowing period should be extended to a minimum of 7 days.

Soils with a sulfate level higher than 10,000 ppm are not suitable for lime stabilization. Other strategies for dealing with these soils may include removal and replacement or blending with other soils to reduce the concentration of sulfates. The geotechnical report must recommend alternative strategies for subgrades with high levels of sulfates. Alternative strategies are subject to approval by the City Engineer.

The above guidelines were obtained from a paper and sponsored by the Lime Association of Texas, dated August 2000, and titled “Guidelines for Stabilization of Soils Containing Sulfates”.

5.04 ALTERNATE PAVEMENT DESIGN

The Department of Public Works will consider an alternate pavement design in lieu of selecting a design from Table II-10, particularly when there are circumstances which warrant an individual design.

TABLE II-10

STANDARD STREET AND THOROUGHFARE PAVEMENT DESIGN

Subgrade Requirements

Facility Type	Usual Crown	P.I. less Than 15	P.I. = 15 or Greater (1)	Conc. Pvmt. (2)
Private Parking Lot		6” Compacted	6” Lime	5”
Fire Lane and Driveways		6” Compacted	6” Lime	6”
Alley	4” Inverted	6” Compacted	6” Lime	7”
Residential A	5”	6” Compacted	6” Lime	6”
Collector 2U-C	5”	6” Compacted	6” Lime	7”
Collector 4U-B	6”	6” Lime	6” Lime	8”
4U-A	8”	6” Lime	6” Lime	8”
Major 6D-A, 6D-B, and 4D-C	¼” /ft.	6” Lime	6” Lime	8”
Regional Major R6D-A, and R8D-A	¼”/ft.	8” Lime	8” Lime	10” Conc./ 4” HMAC

NOTE: 1) Minimum 6% by dry unit weight of hydrated lime.
2) Twenty-eight day concrete compressive strength shall not be less than 4,000 psi.

VI. PERMANENT LANE MARKINGS

6.01 PAVEMENT MARKINGS PLAN

Permanent lane markers shall be installed in accordance with the pavement markings plan and Pavement Marking Standard Details.

VII. LANDSCAPING IN PUBLIC RIGHT-OF-WAY

7.01 GENERAL

All unpaved public medians and parkways shall be landscaped with a minimum of four inches of topsoil, sodded or seeded in accordance with seeding requirements in the standard details and irrigated with a properly designed and installed system. Irrigation system must be designed and installed in accordance with the City of The Colony Parks Department Irrigation standards.

7.02 METERING

All water usage shall be metered and paid for by the developer until landscaping is accepted by the City. Developers shall pay administrative fees, meter costs, and meter deposits, but shall be exempt from impact fees for meters installed on City right-of-way. The developer shall install an above-ground enclosure box with RPZ with enclosurein accordance the Standard Details on the service side of the meter. Within medians, no plantings or irrigation facilities shall be permitted within areas five feet or less in width or in median noses. Those areas shall be covered with brick pavers in accordance with the Standard Details.

7.03 OTHER REQUIREMENTS

a. Minimum landscape requirements will be established by the Parks Department. The Parks Department maintains a list of approved plantings and irrigation components.

b. Trees or upright plantings must not be planted within 30 feet of intersections or utility poles. City staff may require greater setback for safety based on line of sight issues.

c. An 8-inch wide concrete mow strip shall be installed between all planting beds and grassed areas.

d. Seeded or sodded areas of medians shall be bermed a minimum of 6 inches.

e. Only trees with a mature height less than 30 feet may be planted closer than 20' either side of an overhead line. No trees shall be directly under utility lines.

f. Trees to planted within the medians of divided roadways that are ultimately planned for widening by constructing additional lanes in the median shall not be planted within the path of future lanes. Trees shall not be planted within five (5) feet of existing or proposed curbs. Future lanes widening shall be shown on the landscape plans.

g. Trees shall not be planted within five feet of existing or proposed water lines.

h. Irrigation systems shall be designed to meet all other City Ordinances.

7.04 PLAN SUBMITTAL REQUIREMENTS

Landscape construction plans shall be submitted as part of the overall construction plans associated with the related project. Plans shall be consistent with Parks Master Plan and standards. Plans shall bear license seal of the designer. The plans shall include the following:

a. A scale drawing (1" = 40' or 1" = 20'), prepared on 22" by 34" sheets clearly indicating the location, type, size and description of all proposed landscape materials and existing utilities.

b. The name of the project, name and address of the Developer, north arrow, scale, and legend.

c. The configuration, location, type and size of all irrigation, piping heads and controllers.

d. All details necessary to provide a constructible installation.

7.05 OWNERSHIP AND MAINTENANCE

a. Upon final acceptance, all landscape and irrigation materials within medians and rights of way shall become the property of the City.

b. Landscape areas shall be maintained by the Developer or owner for a minimum of one year. Within one year the City will assume responsibility if 80% grass cover is obtained and all plantings are in a healthy condition. Developer maintenance will continue until adequate coverage is obtained.

VIII. STREET LIGHT REQUIREMENTS

8.01 GENERAL

Street lights shall be installed in all new subdivisions. The Developer shall pay the costs for all street lighting. Street light luminaries shall be high pressure sodium (HPS) or metal halide (MH). Street light materials and design shall be approved by the Director of Public Works.

8.02 STREET LIGHT REQUIREMENTS BY STREET CLASSIFICATION

Street light installations will vary according to the classification of street. In general installations will be as follows:

a. Residential Streets: For residential streets, street lights shall be installed at each intersection, at major curves, at ends of cul-de-sacs, and at intervals of between 200 and 400 feet. Luminaires shall be either 100 Watt HPS or 175 Watt MH and mounted on poles at least 11 feet high as shown on standard details for street lights.

b. Collector Streets: For collector streets, street lights shall be installed at each intersection, at major curves, and at intervals of between 200 and 400 feet. Luminaires shall be either 100 Watt HPS or 175 Watt MH and mounted on poles at least 11 feet high with pole type to be approved by the Director of Public Works.

c. Major Arterials: For major arterial streets, street lights shall be installed at each intersection, at major curves, and at intervals of between 200 and 300 feet. Luminaires shall be either 250 Watt HPS or 250 Watt MH and mounted on poles at least 30 feet high with pole type to be approved by the Director of Public Works. Where a major arterial traverses a single-family neighborhood light fixtures shall be either 100 Watt HPS or 175 Watt MH and mounted on poles at least 11 feet high with pole type to be approved by the Director of Public Works.

8.03 STREET LIGHT LOCATIONS

Street lights shall be installed in the public right-of-way, in a location at least three (3) feet behind the face of curb. Where there is no curb, street lights shall be installed at least eight (8) feet from the edge of pavement. Street lights on major arterials shall be installed in the median, where a median exists. In conjunction with the development of any subdivision, street light location and installation shall be coordinated with TXU Electric or Coserv Electric and the Director of Public Works. Installations in state right-of-way shall be coordinated with TxDOT and the Director of Public Works.

8.04 PLAN SUBMITTAL REQUIREMENTS

Street light plans shall be submitted as part of the overall construction plans associated with the related project. The plans shall include the following:

a. A layout of the entire subdivision showing the location of each street light.

b. A plan for the location of underground conduits. All street lights shall be served by underground electric unless approved in writing by the Director of Public Works. All wiring shall be placed in minimum two (2) inch schedule 40 PVC conduit.

c. Standard street light details.

8.05 <u>COSTS</u>

The developer shall be responsible for all engineering and plan preparation costs required for installation of street lights.

CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

PART III - DRAINAGE

PART III - DRAINAGE

I. HYDROLOGY

1.01 METHODS OF DETERMINING DESIGN DISCHARGE

The Rational Method for computing storm water runoff is to be used for the hydraulic design of facilities serving a drainage area of less than 200 acres. For drainage areas 200 acres to 600 acres, the runoff is to be calculated by both the Rational Method and the Unit Hydrograph Method with the larger of the two values being used for hydraulic design. For drainage areas of 600 acres and larger, the Unit Hydrograph shall be used.

The design of all drainage facilities shall be based on ultimate development of upstream drainage areas.

1.02 DESIGN CRITERIA

a. Design According to Rational Formula

When calculating the quantity of storm runoff, rainfall intensity will be determined from the U.S. Department of Commerce Technical Paper No. 40, "Rainfall Frequency Atlas of the United States". For design of hydraulic facilities in the City of The Colony, the applicable formulas are as follows:

$$I = \frac{b}{(T_c + d)^e}$$

Where T_c = Time of concentration (minutes)

I = Rainfall intensity (in/hr)

b, d, & e = Constants for the design frequency storm

The above equations are represented graphically in Figure III-1.

TABLE III-1

RAINFALL INTENSITY CONSTANTS

Rainfall Frequency	2-year	5-year	10-year	25-year	50-year	100-year
b	51	65	77	90	102	107
d	8.0	8.5	8.5	8.5	8.5	8.0
e	0.789	0.777	0.779	0.781	0.780	0.769

The storm frequency used for this determination will be according to the facility to be designed as listed in Table III-2. Emergency overflows where used are to be located at sags and T-intersections of streets and designed to prevent erosion and surface water damage.

TABLE III-2

DESIGN FREQUENCY FOR DRAINAGE FACILITY TYPE

Drainage Facility	Storm Frequency
Closed conduit storm drains with emergency overflow (within the ROW and drainage easement) to give a combined capacity of 100-year frequency	10 years (Closed System)
Closed conduit storm drains with no emergency overflow	100 years
Earth and lined channels (open) plus a minimum of 2 feet freeboard above to the top of the bank for earth channels a 1 foot freeboard for lined channels above to the top of the channel lining	100 years
Culverts (pipe or concrete box)	100 years
Bridges, low point bridge beams or similar bridge deck supporting structure to be 2 feet above the fully developed 100-year flood.	100 years

b. Unit Hydrograph Methods

The unit hydrograph technique is used to transform rainfall excess to sub-basin runoff. Two techniques are used, depending on the size of the sub-basin, to develop synthetic unit hydrographs. These methods are the dimensionless and Snyder unit hydrographs. The dimensionless unit hydrograph can be used for all sub-basins where the total basin (i.e., total area of all sub-basins at the design point) is draining less than 2,000 acres (3.13 sq mi). Snyder's unit hydrograph can be used for all sub-basins where the total basin is draining greater than 2,000 acres.

The hydrograph methodologies presented herein are employed in the HEC-1 or HEC-HMS computer program. HEC-1 or HEC-HMS (latest version) should be used for hydrologic modeling. All FEMA accepted models will be allowed. All other models shall be converted. For a current listing of FEMA accepted models go to www.fema.gov/fhm/en_modl.shtm.

1. Dimensionless Unit Hydrograph

The dimensionless unit hydrograph can be used for all sub-basins where the total basin is draining less than 2,000 acres. A single parameter, time of lag (T_l), is used to determine the shape of the unit hydrograph. T_l is the lag time from the center of mass of the rainfall excess to the peak of the unit hydrograph. T_l is calculated as 0.6 times the time of concentration (T_c) for the sub-basin. The peak flow (Q_p) and time to peak (T_p) are computed as:

$$T_l = 0.6T_c$$

$$T_p = 0.5\Delta t + T_l$$

$$Q_p = \frac{484A}{T_p}$$

where:

T_l	=	Time of lag, hours (hrs);
T_c	=	Time of concentration, hrs;
T_p	=	Time of peak, hrs;
Δt	=	Time step, hrs;
Q_p	=	Peak flow, cfs; and
A	=	Sub-basin area, square miles (sq mi).

TABLE III-3

RATIOS FOR DIMENSIONLESS UNIT HYDROGRAPH

Time Ratios (t/T_p)	Discharge Ratios (Q/Q_p)
0	.000
.1	.030
.2	.100
.3	.190
.4	.310
.5	.470
.6	.660
.7	.820
.8	.930
.9	.990
1.0	1.000
1.1	.990
1.2	.930
1.3	.860
1.4	.780
1.5	.680
1.6	.560
1.7	.460
1.8	.390
1.9	.330
2.0	.280
2.2	.207
2.4	.147
2.6	.107
2.8	.077
3.0	.055
3.2	.040
3.4	.029
3.6	.021
3.8	.015
4.0	.011
4.5	.005
5.0	.000

The ordinates of the unit hydrograph (Q) are computed from the data in Table III-3 at any time t as a ratio of the peak flow rate (Q/Q_p). The time of concentration is to be calculated as herein. The time step, or time of incremental rainfall, should not be greater than $\Delta t <= 0.29\ T_l$.

2. *Snyder Unit Hydrograph*

Snyder's unit hydrograph can be used for all sub-basins where the total basin is draining greater than 2,000 acres. Two parameters, Snyder's T_l and C_p, are used to determine the peak flow, time of peak, and widths of the unit hydrograph at 50 percent and 75 percent of the peak flow. The peak flow is computed as:

$$Q_p = 640\ C_p\ \frac{A}{T_l}$$

where:

- T_l = Lag time from the midpoint of the unit rainfall duration to the peak of the unit hydrograph, hrs;
- C_p = Snyder's coefficient that accounts for flood wave and storage in the sub-basin;
- Q_p = Peak flow rate, cfs; and
- A = Sub-basin area, sq mi.

A value of 0.72 shall be used for C_p. T_l is known to be a function of a parameter (i.e., C_t) with an unknown value that accounts for sub-basin slope and storage.

Since the Snyder method does not produce a complete hydrograph, Clark's unit hydrograph method is used with Snyder's T_l and C_p to compute a complete unit hydrograph. First, Snyder's T_l and C_p are used to estimate initial Clark parameters. A unit hydrograph is generated using the Clark method with the estimated Clark parameters. Snyder parameters are then computed from the Clark unit hydrograph. The Clark parameters are then adjusted to reduce the error between the Snyder parameters (C_p and T_l) and the Snyder parameters computed with the Clark unit hydrograph (C_p' and T_l'). The Snyder parameters are computed from the Clark unit hydrograph using:

$$C_p' = Q_p\ (T_p - 0.5\ \Delta t\ )\ /\ (C\ A)$$
$$T_l' = 1.048\ (T_p - 0.75\ \Delta t\ )$$

where:

C_p', Q_p, T_l', Δt, A, and T_p are as previously defined; and C = Conversion factor.

Since T_l is a function of C_t, which has an unknown value, one of two direct procedures are to be used to determine T_l. These methods are the time of concentration method and the Dallas-Fort Worth urbanization curves method.

If the sub-basin has an area of less than 1,000 acres (1.56 sq mi), the time of concentration (T_c) method shall be used to determine T_l. Snyder's lag time, T_l, is calculated as follows:

$T_l = 0.6\ T_c$

where:

T_c = Time of concentration (hrs)

For sub-basins draining greater than 2,000 acres, the Dallas-Fort Worth urbanization curves shall be used to determine T_l. To determine T_l, first determine the percent urbanization of the sub-basin (use 100 percent for fully developed) and a sub-basin parameter, N; where:

$$N = L\frac{L_{ca}}{S_{st}^{\ 0.5}}$$

where:

- N = Sub-basin parameter;
- L = Stream distance from the downstream point of design to the upper limit of the sub-basin, mi.;
- L_{ca} = Stream distance from the downstream point of design to the centroid of the sub-basin, mi.;
- S_{st} = Weighted slope of the flow path from 0.10L to 0.85L, ft/mi.

T_l values for clay and sandy soils as a function of N and percent urbanization are calculated as follows:

$$T_l = 10^{0.3833\times\log_{10}(N)+I_p-\frac{BW\times\%URB}{100}}$$

where:

I_p = -0.02687 for clay soils and 0.24304 for sandy soils, these are the calibration points defined as the log of T_p where

$$\log_{10}(L\times\frac{L_{ca}}{S_{ss}}\times 0.5)=1$$ and URB = 0%, hrs;

BW = 0.30103 for clay soils and 0.26991 for sandy soils, these are the log of the width between each 20 percent urbanization line; and

%URB = Percent urbanization within the sub-basin.

If the sub-basin has both clay and sandy soils, an area-weighted value of T_l should be used.

3. Synthetic Storm

A synthetic storm time-distribution, i.e. hyetograph, is developed based on depth-duration data using a triangular distribution centered on the mid-point of the total storm duration. The point depth-duration data in Table III-4 shall be used to develop hyetographs. Since the rainfall depths are at points, these values should be adjusted per Figure 15 in TP-40 if the drainage area is greater than 9.6 sq mi.

If necessary, other frequency storms shall be determined, using methodologies specified in Bulletin #17B, *Flood Flow Frequency*.

A minimum 5-minute rainfall depth and 3-hour storm duration is to be used for all sub-basins where the total basin is draining less than 200 acres. A minimum 15-minute rainfall depth and 24-hour storm duration is to be used for all sub-basins where the total basin is draining greater than 200 acres.

TABLE III-4

DEPTH-DURATION DATA

Return Period (years)	Point Rainfall Depths (inches)							
	5-min	15-min	1-hr	2-hr	3-hr	t-hr	12-hr	24-hr
1	0.39	0.76	1.49	1.81	1.99	2.41	2.80	3.21
2	0.49	1.04	1.85	2.22	2.45	2.91	3.45	3.95
5	0.57	1.22	2.45	3.00	3.30	3.90	4.70	5.40
10	0.63	1.36	2.86	3.55	3.85	4.65	5.50	6.40
25	0.73	1.56	3.35	4.15	4.55	5.45	6.50	7.50
50	0.80	1.71	3.82	4.65	5.15	6.20	7.35	8.52
100	0.87	1.87	4.25	5.20	5.70	6.92	8.40	9.55
500	1.00	2.20	5.40	6.60	7.40	8.80	10.50	12.00

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c. Rainfall Excess

Regardless of which methodology is used precipitation losses occur due to evaporation, interception, depression storage and infiltration. The losses are evaluated and subtracted from the total rainfall amount to determine the rainfall *excess.* The rainfall excess is the portion of the rainfall that reaches the storm drainage system.

Rainfall excess shall be determined by one of these two loss methodologies: Curve Number (*CN*) loss model or initial and constant-rate loss model, and shall at a minimum, comply with FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners*. The *CN* approach shall be used in conjunction with the SCS Dimensionless Unit Hydrograph technique (Section 5.4A) and the initial and constant-rate method shall be used with the Snyder's Unit Hydrograph technique (Section 2).

The types of soils in a sub-basin are determined from the latest versions of the *Soil Survey of Denton County, Texas.* Soils in Hydrologic Soil Groups A and B are sandy soils, while soils in Hydrologic Groups C and D are clay soils. Copies of this information are available at the office of the City Engineer or online.

Curve Number (CN)

For the Curve Number method a single parameter, *CN*, is used to evaluate the loss rate. Table III-5 contains *CN* values based on type of soil and type of land use. If the *CN* value varies for a sub-basin, an area-weighted *CN* value must be determined.

The percent imperviousness of the sub-basin is included in the *CN* values for urban and residential districts. For all other land uses the percent impervious shall be determined by the engineer and applied to the base curve number found in Table III-5. For sub-basins with more than one land use, an area-weighted percent impervious is to be used.

Initial and Constant-Rate

Three parameters, an initial loss, a constant loss rate and a percent impervious, are used in the initial and constant-rate method to compute losses. In areas assumed to be pervious all rainfall is lost until the volume of the initial loss is satisfied then rainfall is lost at the constant rate for the remainder of the hyetograph. In areas assumed to be impervious no losses occur.

The initial and constant-rate parameters are determined based on the type of soil (i.e., clay or sand) in the sub-basin. When the sub-basin has both clay and sandy soils area-weighted values should be used for the initial loss and constant loss rate parameters. This method is most appropriate when calibration data is available but previous investigations can be used to estimate parameters. In absence of gage data or previous investigations the default values in Southwest Fort Worth Hydrology (SWFHYD or NUDALLAS) can be used. Those values can be found in Table III-6. If values other than the recommended ones are used, documentation is required justifying their use.

TABLE III-5

RUNOFF CURVE NUMBERS FOR URBAN AREAS

----Cover description----		Curve numbers for ----Hydrologic soil group -----			
Cover type and hydrologic condition	Average percent Impervious area	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries. etc.)					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	80	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c)					

[1]Average runoff condition, and I_a=0.28[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN=98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

TABLE III-6

RECOMMENDED INITIAL AND CONSTANT-RATE LOSSES

	Sand (Group A & B)		Clay (Group C & D)	
	Initial	Constant	Initial	Constant
1 year	2.10	0.26	1.50	0.20
2 year	2.10	0.26	1.50	0.20
5 year	1.80	0.21	1.30	0.16
10 year	1.50	0.18	1.12	0.14
25 year	1.30	0.15	0.95	0.12
50 year	1.10	0.13	0.84	0.10
100 year	0.90	0.10	0.75	0.07
500 year	0.60	0.08	0.50	0.05
SPF	0.60	0.08	0.50	0.05

The percent impervious input represents the percentage of the sub-basin covered by impervious cover such as streets, parking lots and structures. All precipitation on the areas is considered excess and unlike the *CN* technique the impervious areas must be accounted for independently of the pervious land uses. Recommended percent impervious values can be found in Table III-7 below.

TABLE III-7

RECOMMENDED PERCENT IMPERVIOUS VALUES

Landuse	Approximate Percent Impervious
Undeveloped	0%
Residential	
1/8 Acre	65%
1/4 Acre	38%
1/3 Acre	30%
1/2 Acre	25%
1 Acre	20%
2 Acre	12%
Commercial	85%
Industrial	72%

d. Design According to FEMA-FIA Requirements

All streams having floodway or flood plain designation by FEMA-FIA must be designed to meet the requirements of these agencies and the City of The Colony's Flood Prevention Ordinance.

1.03 RUNOFF COEFFICIENTS AND TIME OF CONCENTRATION

Runoff coefficients, as shown in Table III-8, shall be the minimum used, based on total development under existing land zoning regulations. Where land uses other than those listed in

Table III-8 are planned, a coefficient shall be developed utilizing values comparable to those shown. Larger coefficients may be used if considered appropriate to the project by the Engineer.

Times of concentration shall be computed as shown in Chapter 5, HYDROLOGY, of the Texas State Department of Highways and Public Transportation, "Hydraulic Design Manual", latest edition.

II. DESIGN OF DRAINAGE FACILITIES

2.01 FLOW IN GUTTERS AND INLET LOCATIONS

Storm drain conduits in streets shall begin at the point where the depth of flow based on a 10-year storm exceeds the top of curb, or the spread of water exceeds the limits as set forth below. For pavement sections that do not have curbs, including alleys, the 100-year storm shall be contained in the right-of-way. The combined capacity of the storm drain conduit and street right-of-way must always exceed the discharge from the 100-year storm. For systems draining large areas, the combined capacity may be exceeded by the 100-year storm. At the point the capacity is exceeded, additional inlets must be provided to intercept overflow so that the 25-year storm is conveyed in the storm drain conduit.

2.02 FLOW IN DRIVEWAYS AND INTERSECTIONS

Where possible, inlets should be placed upstream of street intersections to prevent large amounts of water flowing across the intersection. No more than 4.0 cfs may cross an intersection in a 10-year flood. In no event shall surface drainage from a 10-year frequency flood be permitted to cross any street classified as a collector or major thoroughfare. A maximum of 1.0 cfs may cross a thoroughfare at an intersection with another thoroughfare or collector.

At an intersection, only one street shall be crossed with surface drainage and this street shall be limited to local streets.

Not more than 5.0 cfs may discharge to a street from a driveway or alley during a 10-year storm and in no case shall the flow entering the street cause the capacity of the street to be exceeded downstream.

The use of the street for carrying storm water shall be limited to the following:

SPREAD OF WATER - 10 YEAR STORM FREQUENCY

- Major thoroughfares (divided) - One traffic lane on each side to remain clear.
- Collector streets - One traffic lane to remain clear.
- Residential streets - Six inch (6") depth of flow at curb or no lanes completely clear.
- Alleys - Contained within the paved surface.

TABLE III-8

RUNOFF COEFFICIENTS AND MAXIMUM INLET TIMES

ZONE	ZONING DISTRICT NAME	RUNOFF COEFFICIENT "C"	MIN. INLET TIME IN MINUTES
SF	Single-Family Dwelling District	0.50	15
D	Duplex Dwelling District	0.60	15
TH	Townhouse Dwelling District	0.80	10
MF-1	Multiple Family Dwelling District 1	0.80	10
MF-2	Multiple Family Dwelling District 2	0.80	10
PD	Planned Development District	Variable*	
MH	Mobile Home District	0.55	15
A	Agricultural District	0.30	20
P	Parking District	0.95	10
O-1	Office District	0.90	10
O-2	Office District	0.90	10
NS	Neighborhood Service District	0.95	10
SC	Shopping Center District	0.95	10
GR	General Retail District	0.95	10
LC	Light Commercial District	0.90	10
HC	Heavy Commercial District	0.90	10
I	Industrial District	0.90	
BP	Business Park	0.90	10

NON-ZONED LAND USES

LAND USE	RUNOFF COEFFICIENT "C"	MIN. INLET TIME IN MINUTES
Church	0.85	10
School	0.75	10
Park	0.40	15
Cemetery	0.50	15
Street & Highway Right-of-Way	0.95	10

*Based on equivalent zoning district classification.

2.03 CAPACITY OF STREETS AND ALLEYS

Flow In Gutters

The drainage capacities of streets and alleys shall be determined by Manning's Formula using an 'n' value of 0.016. Streets and alleys shall be designed to flow within the pavement during a ten (10) year flood. When street and alley slope is less than 5 feet per 1,000, the hydraulic capacity of the street and right-of-way shall be determined assuming a slope of 3 feet per 1,000. Where a flow of water is required to turn in direction, the height of the pavement against which the water is directed shall not be less than the depth of water flow plus the velocity head of the water plus 2 inches. Where water is discharged from a street or alley directly into an open watercourse, it shall be discharged through an approved type of inlet or through a concrete lined structure with an energy dissipator if the velocity exceeds 6 fps.

Computed pavement flow depths within the pavement and right-of-way shall be shown on the plans in tables with the location (include sags and false sags), flood frequency, flow, type and size of street or alley, and slope of street or alley. There shall be two tables of pavement flow depths, one for the 10-year on-grade and 25-year at sag and the other for the 100-year flood. When street grade is less than 0.50%, inlets shall be provided to remove storm water from the street such that flows at sump inlets do not exceed the values presented in Table III-9.

Split curb gutters shall be appropriately analyzed for area, wetted perimeter, and hydraulic radius for use in Manning's formula. Streets and alleys on grade shall be designed to flow within the pavement for the 10-year flood and the 100-year flood shall be contained within the right-of-way (ROW). If adjacent structures have finished floors lower than two feet below the top of the curb or pavement and the flow is subcritical, then the 100-year flood shall be maintained within the pavement. If the 100-year flow is supercritical and the adjacent structures are lower than two feet below the top of curb then the energy grade line must be contained within the pavement. Streets at sags shall be designed to flow not more than curb deep for the 25-year flood and the 100-year flood shall be contained within the ROW. At sags in alleys, the 100-year flood shall be contained within the pavement. At sags, split curbs, where grades are 1.0-percent or less, and other locations where grades are relatively flat it shall be demonstrated that the 10-year flood is within the pavement and the 100-year flood is conveyed within the ROW.

TABLE III-9

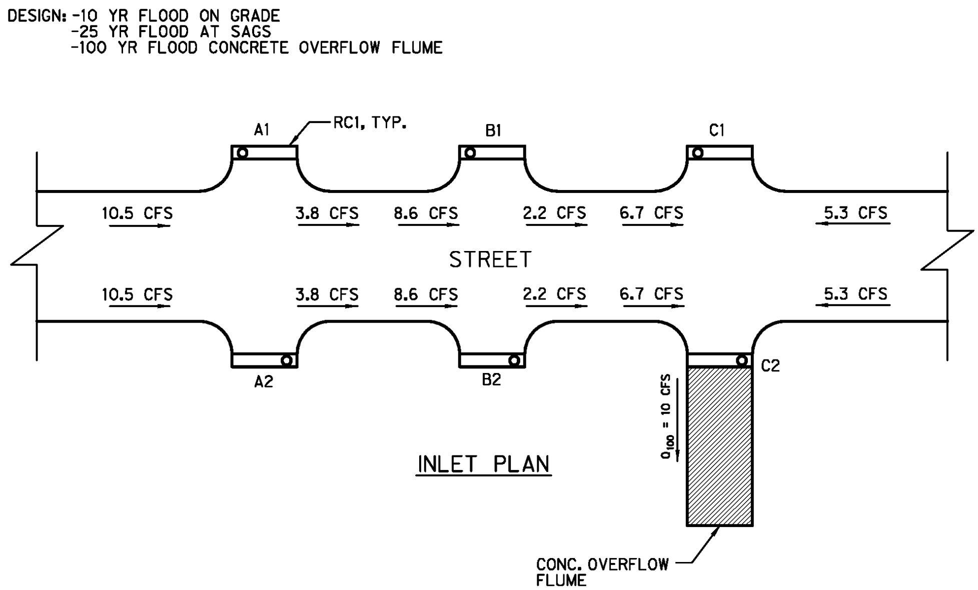
MAXIMUM FLOW AT SAGS

	Maximum Flow (cfs)	
Type of Street	Flow Confined to Street	Flow Confined to ROW
Alley	2.5	2.5
31’ B-B	12.2	35.2
37’ B-B	9.1	33.5
41’ B-B	10.1	37.3
2x25’ B-B Divided	25.5	65.6

Note: B-B = back of curb to back of curb. Data in table are the total flow in both gutters (or both sides of divided street) from one direction and are not applicable to streets with split curbs.

FIGURE III-1

INLET PLAN



At sags in streets, the 25-year flood shall be collected in the storm drain with a concrete channel for the 100-year overflow. As an option, the 100-year flood may be collected in the storm drain with an earthen overflow swale. The swale shall have maximum 25-percent side-slopes and be in a 15' drainage easement. In all cases, the downstream storm drainage system shall be adequate to collect and convey the flow. At sags in alleys the 100-year flood shall be collected in a storm drain with an earthen overflow swale.

Special cases arise when a street is designed with "false sags". A false sag is a sag that has a high point adjacent to it. If the flow backups at the inlets in a false sag, it can overflow the adjacent high point and continue down grade in the ROW; thereby, minimizing the depth of flooding at the sag. Generally, to limit grade changes in the street and still minimize the possible depth of flooding, false sags are located near intersections. Inlets in false sags may be designed for the 10-, 25-, or 100-year flood. If the inlets in a false sag are designed for the 10-year flood, then the 25- and 100-year flood overflows (assuming critical flow over the high point) shall be contained at the sag within the street and ROW, respectively. If the inlets in the false sag are designed for the 25-year flood, then the 100-year flood overflow (assuming critical flow over the high point) shall be contained within the ROW at the sag. If the inlets in the false sag are designed for the 100-year flood, then the gutter at the high point can be no higher than the ROW at the sag. Alleys may not have false sags.

The hydraulic grade in a street at a false sag shall be computed with the following formula. Values of specific energy (E_c) for critical flow in City standard streets are presented in Table III-10.

$$HG = El_{gutter} + d_c + V_c^2 / 2g = El_{gutter} + E_c$$

where:

HG = Elevation of the hydraulic grade at the sag, feet (ft);
El_{gutter} = Flowline elevation of the gutter at the adjacent high point, ft;

d_c = Critical depth of overflow in the high point gutter, ft;
V_c = Critical velocity of overflow in the high point gutter, feet per second (fps);
g = 32.2 = Acceleration of gravity, ft/sec/sec; and
$E_c = d_c + V_c^2 / 2g$ = Specific energy at critical flow, ft.

TABLE III-10

CRITICAL FLOW IN STREETS AS A FUNCTION OF SPECIFIC ENERGY

Specific Energy E_c (ft)	31' B-B Street	37' B-B Street	45' B-B Street	2x25' B-B Divided Street
0.1	0.1	0.1	0.1	0.1
0.2	0.7	0.6	0.8	1.6
0.3	1.7	1.6	2.1	4.4
0.4	3.8	3.5	4.3	8.7
0.5	7.4	6.4	7.9	15.0
0.6	13.0	12.0	14.4	24.4

Note: B-B = back of curb to back of curb. Data in table are the total flow in both gutters (or both sides of divided street) and are not applicable to streets with split curbs.

2.04 SIZING AND LOCATION OF INLETS

For determining the size and locations of inlets, the following shall be used as a minimum:

TABLE III-11

MINIMUM INLET LENGTH

Street Grade	Length of Inlet Opening for Each cfs of Gutter Flow
Sags	0.6 Feet
Less than 2%	1.0 Feet
2% to 3.5%	1.5 Feet
Greater than 3.5%	2.0 Feet

The Engineer may use the above values for inlet design or use the methodology contained in Appendix "E"

2.05 STARTING TAILWATER CONDITIONS FOR OUTFALLS TO TRIBUTARIES

These guidelines may be used to determine coincident flood flows in a receiving stream at the confluence with a tributary. The flood elevation for the coincident flow in the receiving stream may be used for starting hydraulic grade line calculations for closed storm drain systems. These guidelines may only be used if the receiving stream has an upstream drainage of 200-acres or greater and are limited to closed storm drain systems draining 200 acres or less.

TABLE III-14

RECEIVING STREAM COINCIDENT FREQUENCY FLOOD

Tributary Frequency Flood (years)	Basin Area Ratio				
	≤ 3:1	>3:1	>50:1	>500:1	>5,000:1
1	1	1	1	1	1
2	2	1	1	1	1
5	5	2	2	1	1
10	10	5	5	2	1
25	25	10	10	5	2
50	50	25	10	10	2
100	100	50	25	10	2

The coincident frequency flood for a receiving stream is presented in Table III-14 as a function of the flood frequency in the tributary and the basin area ratio. The basin area ratio is the drainage area of the receiving stream upstream of the confluence divided by the drainage area of the tributary.

An exception to the use of this guideline to determine a coincident flood is for the evaluation of the maximum velocity requirement for a tributary. When evaluating the maximum velocity requirement in a tributary, the flow in the receiving stream downstream of the confluence shall be assumed to be the same as in the tributary.

2.06 STARTING TAILWATER CONDITIONS FOR LAKE LEWISVILLE

When Lake Lewisville is downstream of the proposed storm drain, the following elevations at Lake Lewisville may be used for residential streets and alleys when all of the following criteria are met. Collectors, minor arterials and principal arterials must use the starting water elevations specified in paragraph 2.05 above.

a. Using a starting elevation of 531.0 at Lake Lewisville, the hydraulic grade at the inlets shall be 1.0 foot below the top of curb for the 100-year flood at the low point and for the 10-year floodfor inlets on grade. The spread of water for the 10-year floodshall not exceed top of curb for inlets on grade and the 100-year floodshall be contained within the right-of-way. Positive overflow shall be provided for the 100-year flow for a water elevation of 537.0’ on Lake Lewisville.

b. Using a starting elevation of 537.0 at Lake Lewisville, the hydraulic grade at the inlets shall be 1.0 foot below the top of curb for the 2-year floodat the low point and for inlets on grade. The spread of water for the 2-year floodshall not exceed top of curb for inlets for inlets on grade and the 100-year floodshall be contained within the right-of-way, including the overflow at low points.

c. The minimum finished floor of all structures shall be the higher of 539.0 or 2 feet above the 100-year floodelevation and the top of curb for residential streets shall be no lower than 538.0 or 1 foot above the 100-year flood elevation.

2.07 HYDRAULIC DESIGN OF CLOSED CONDUITS

STORM DRAIN DESIGN

Storm water runoff typically is carried in a closed conduit when the runoff can be carried in a pipe of seventy-two (72) inches in diameter or smaller; or where it is necessary for the protection of adjacent facilities that the storm water be carried in an enclosed facility.

a. Design Criteria

All closed conduit storm drains shall meet the following criteria:

1. All driveway culverts shall be RCP class III minimum. Sloped headwalls shall be provided at each end of the culvert.

2. Interceptor, trunk, and mains shall have a minimum diameter of 24” and laterals shall have a minimum diameter of 18”;

3. Curb inlets in sag locations shall have storm drain laterals with a minimum diameter of 24”;

4. Box closed conduit interceptor, trunk, mains, and laterals shall have minimum dimensions of 2’ x 2’ (3’ x 1’ boxes may be allowed at driveways with height restrictions) with approval of the City Engineer;

5. Storm drains shall be tied together with pre-fabricated wyes at a 45° or 60° angle and be aligned vertically centerline to centerline;

6. City standard sloped headwalls and erosion protection shall be constructed at all inlets and outfalls on closed conduits. Headwalls shall be placed at or outside the right-of-way lines;

7. Access points (junction boxes) shall be located at vertical changes in grade and no greater than 500’ apart in storm drains less than 6’ in diameter or height and no greater than 1,000’ apart in larger conduits, or where pipes connect at an angle greater than 60°;

8. Inlets shall be connected to mains with lateral conduits and shall not be used as manholes or junctions on mains;

9. Private storm drains (excluding roof drains) shall have a minimum diameter of 12” and shall be RCP or corrugated with smooth inside HDPE or PVC (specify pipe and embedment);

10. All storm drains shall be ASTM C-76 reinforced concrete pipe or ASTM C-789/C-850 storm drain box, except those that drain and are located in single family backyards may be corrugated smooth inside HDPE or PVC (specify pipe and embedment);

11. Provide concrete collar, as per City standard, at pipe size changes.

b. Design Parameters

In addition to the criteria listed above, there are several general design parameters to be observed when designing storm drains that will tend to alleviate or eliminate common problems of storm drain performance:

1. Select storm drain size and slope so that the velocity of flow will increase progressively down the system or at least will not appreciably decrease at inlets, bends or other changes in geometry or configuration. Storm drain size shall not decrease downstream.

2. For all storm drain junctions other than manholes and junction boxes, manufactured wye connections should be used, and the angle of intersection shall not be greater than 60 degrees. This includes discharges into box culverts and channels. Special circumstances may require cut-ins instead of manufactured wye connections; the use of cut-ins require a design detail on the plans and must be approved by the City Engineer.

3. Inlet laterals will normally connect only one inlet to the trunk line. Special circumstances requiring multiple inlets to be connected with a single lateral shall be approved by the City Engineer.

4. Storm drain pipes shall be reinforced concrete pipe, minimum Class III, or stronger, as required by the storm drain standard details.

5. Plastic pipe will not be allowed in public easements and rights-of-way. Plastic pipe may be used on private property only if authorized by the City Engineer.

6. The cover over the crown of circular pipe should be at least two feet and should be based on the type of pipe used, the expected loads and the supporting strength of the pipe. Box sections should normally have a minimum of one foot of cover; however, direct traffic may be allowed in special situations with the approval of the City Engineer.

7. All storm drain outfalls shall be into channels, creeks or natural water ways. The angle of intersection shall not be more than 60°. The outfall structure shall be as per Figure III-11 or as approved by the City Engineer.

c. Slug Flow

1. Slug flow occurs when air bubbles moving downstream in a closed conduit coalesce in to large air pockets that reverse flow and move upstream (refer to *Air-Water Flow In Hydraulic Structures*, H.T. Falvey, US Dept. of Interior, 1980). As the large air pockets or slugs move upstream, the hydraulic capacity of the conduit is reduced. Closed conduit storm drains should be designed with slopes less than 10-percent to avoid possible loss of hydraulic capacity resulting from slug flow.

2. When a closed conduit storm drain is to be designed with a slope (S_o) greater than 10-percent (i.e., $S_o > 0.10$), the larger diameter pipe as determined based on hydraulics and slug flow shall be used in the design. The minimum pipe diameter (D_{min} in inches) for slug flow shall be determined using the following formulas.

Where $0.10 < S_o \leq 0.20$, then $D_{min} = 9\,Q^{0.4}$; or where $0.20 < S_o < 1.00$, then $D_{min} = 6.6 (Q^2 / S_o)^{0.2}$.

Computations for slug flow shall be presented on the construction plans for all conduits with slopes greater than 10-percent.

d. Calculation of the Hydraulic Grade Line

1. For closed conduits, the hydraulic grade for the 10- and 25-year floods shall be a minimum of 2.0’ below the top of curb at inlets and manholes.

2. If the closed conduit is designed for the 100-year flood, the hydraulic grade shall be a minimum of 1.0’ below the top of curb at inlets and manholes.

When determining the beginning hydraulic grade, the engineer shall consider discharge flow conditions, conduit size and shape, existing and future site conditions, future extension of the storm drain, and downstream flow conditions. The beginning hydraulic grade for storm drain calculations shall be at the top of conduit, a known hydraulic grade, critical depth, or by the slope-area method, as appropriate for flow conditions. Hydraulic grade line computations should begin upstream for supercritical flow and downstream for subcritical and full conduit flow (i.e., pressure flow). Conservation of energy shall be maintained throughout the calculation of the hydraulic grade line.

If a system is discharging directly in to a stream, then the analysis shall begin at the higher of the coincident flood elevation on the receiving stream, the top of conduit, or a calculated hydraulic grade line considering future downstream extension of the storm drain. If the hydraulic grade is based on future downstream extension, information on the future downstream system shall be provided on the plans.

For storm drains being connected to an existing downstream storm drain, the hydraulic grade line should be tied to the hydraulic grade line for the coincident frequency flood in the downstream storm drain. To determine the starting hydraulic grade for the proposed storm drain, it is necessary to analyze the hydraulics of the downstream drainage system. It is the engineer’s responsibility to evaluate all data employed in the analysis, including any data used from existing plans or provided by the City. If assumptions are required to avoid laborious calculations on the downstream drainage system, consult with the City Engineer. If the existing downstream system is undersized, downstream flooding cannot be increased (this may require detention) and the proposed system should be designed to accommodate future downstream drainage improvements.

The ending hydraulic grade line should be tied to the hydraulic grade line for the same frequency flood in the upstream existing or future storm drain. If the hydraulic grade is based on future upstream extension, information on the future upstream system should be provided to verify the proposed system is adequately sized for the future upstream hydraulic grades.

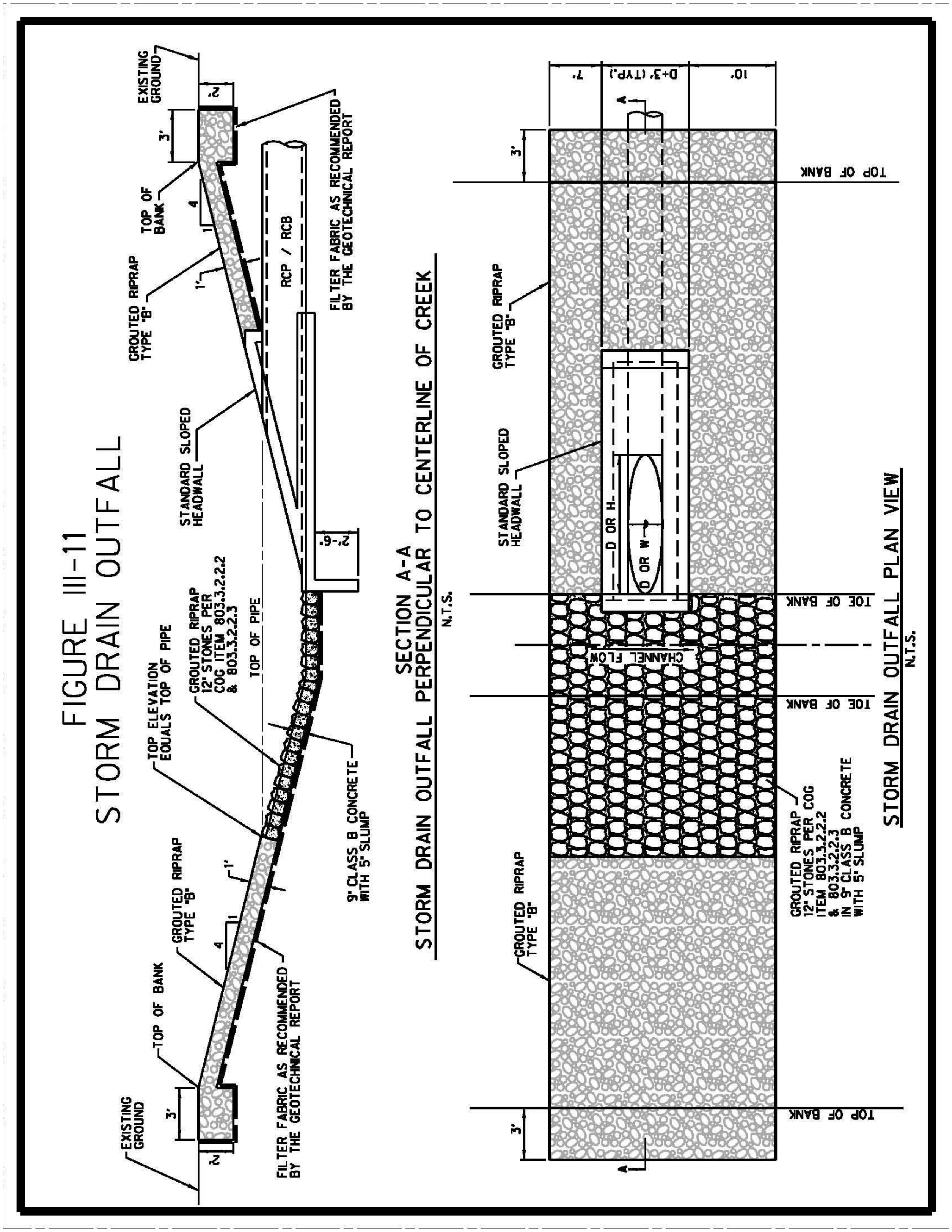


FIGURE III-11
STORM DRAIN OUTFALL
EXISTING GROUND
TOP OF BANK
GROUTED RIPRAP TYPE "B"
TOP ELEVATION EQUALS TOP OF PIPE
GROUTED RIPRAP 12" STONES PER COG ITEM 803.3.2.2.2 & 803.3.2.2.3
TOP OF PIPE
STANDARD SLOPED HEADWALL
RCP / RCB
FILTER FABRIC AS RECOMMENDED BY THE GEOTECHNICAL REPORT
9" CLASS B CONCRETE WITH 5" SLUMP
2'-6"
3'
2'
4
1
1'
SECTION A-A
STORM DRAIN OUTFALL PERPENDICULAR TO CENTERLINE OF CREEK
N.T.S.
TOE OF BANK
CHANNEL FLOW
D OR H
D OR W
D+3' (TYP.)
7'
10'
A
GROUTED RIPRAP 12" STONES PER COG ITEM 803.3.2.2.2 & 803.3.2.2.3 IN 9" CLASS B CONCRETE WITH 5" SLUMP
STORM DRAIN OUTFALL PLAN VIEW
N.T.S.

e. Pressure Flow

Computation of the hydraulic grade line is to proceed by a direct procedure proceeding from downstream to upstream. The computations shall account for friction and other changes in the hydraulic grade caused by structures, bends, expansions, contractions, junctions, and obstructions.

Q_A,, Q_C,, V, $V^2 / 2g$, and S_f shall be shown on the plans.

Friction losses shall be computed using Manning's formula with an n of 0.013 for all storm drain conduits. The following formulas shall be used to compute changes in the hydraulic grade caused by friction losses.

$$\Delta HG = L\ S_f$$

and

$$S_f = V^2\ n^2 / (2.22\ R^{1.333})$$

and

$$R = A / P$$

where:

ΔHG = Change in hydraulic grade, ft;
L = Length of closed conduit, ft;
S_f = Friction slope of flow in closed conduit, ft/ft;
V = Velocity of flow in closed conduit, fps;
n = Manning's coefficient;
R = Hydraulic radius, ft;
A = Cross-sectional area of closed conduit, square feet (sq ft); and
P = Wetted perimeter inside closed conduit, ft.

Changes in the hydraulic grade caused by junctions, structures, enlargements, and contractions are to be computed with the following formula using the appropriate k_j. Values for k_j shall be obtained from Table 8.6. Note that the change in hydraulic grade at junctions and structures shall be computed independently for the main and each branch conduit.

$$\Delta HG = (V_2^2 - k_j\ V_1^2) / 2g$$

where:

ΔHG = Change in hydraulic grade, ft;
V_1 = Velocity of flow in upstream conduit, fps;
V_2 = Velocity of flow in downstream conduit, fps;
k_j = Loss coefficient; and
g = 32.2 = Acceleration of gravity, ft/sec/sec.

Changes in the hydraulic grade caused by bends and obstructions shall be computed with the following formula using the appropriate k_j. Values for k_j shall be obtained from Table 8.6.

$\Delta HG = k_j\ V^2 / 2g$ where: $V = V_1 = V_2$; or

$\Delta HG = [\ V_2^2 - (\ 1 - k_j\ )\ V_1^2\ ]\ / 2g$ where $V_1 \neq V_2$.

The hydraulic grade in inlets shall be the higher grade computed by inlet or pressure control. For pipe inlet control, compute the headwater (HW) per the attached Chart 1B: Appendix G Inlet Control. This chart is taken from *Hydraulic Design of Highway Culverts* (FHWA, 2001). Note that the computed headwater per Chart 1B is the depth of flow in the inlet based on the flowline of the storm drain conduit. Pressure control is computed with the following formula.

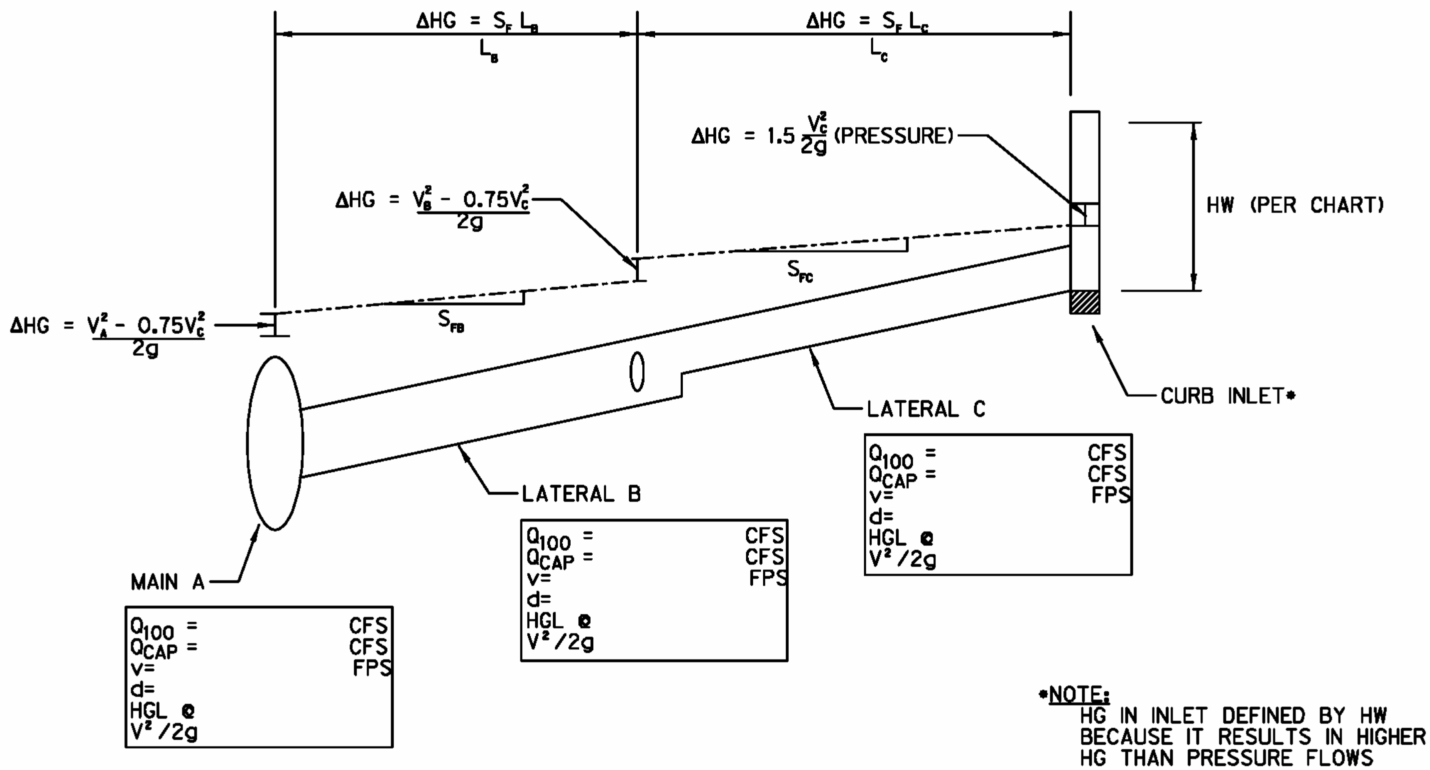
$$\Delta HG = 1.5\,V^2 / 2g;$$

where:

V = Velocity of pressure flow in the downstream conduit, fps.

The greater hydraulic grade obtained from pipe inlet and pressure control is the hydraulic grade in the inlet.

FIGURE III-12
HYDRAULIC GRADELINE COMPUTATION



HYDRAULIC GRADELINE COMPUTATION

f. <u>Minor Losses</u>

TABLE III-15

LOSS COEFFICIENTS

	Loss Coefficient (k_j)
JUNCTIONS	
45° to 60° branch [1]	0.75
90° branch [1]	0.50
2- 45° to 60° branches [1]	0.50
True Y	0.60
JUNCTION BOXES[2]	
Straight run	0.75
Straight run w/45° branch [3]	0.50
Straight run w/90° branch [3]	0.25
90° bend	0.00
ENLARGEMENTS	
A_2 / A_1 = 1.4	0.90
A_2 / A_1 = 2.6	0.65
A_2 / A_1 = 4.0	0.48
CONTRACTIONS	
A_2 / A_1 = 0.7	0.92
A_2 / A_1 = 0.4	0.75
A_2 / A_1 = 0.3	0.64
BENDS	
Conduit on curve for 90° bend [4]	
Curve radius = 1.0 diameter	0.50
Curve radius = 4.0 diameters	0.40
Curve radius = 14.0 diameters	0.25
Curve radius ≥ 20.0 diameters	0.00
Bends where the curve radius equals the	
diameter	0.50
90° bend	0.43
60° bend	0.35
45° bend	0.20
22½° bend	
OBSTRUCTIONS	0.25
$A_{Obstruction} / A_{Conduit}$ = 0.1	0.66
$A_{Obstruction} / A_{Conduit}$ = 0.2	1.28
$A_{Obstruction} / A_{Conduit}$ = 0.3	2.94
$A_{Obstruction} / A_{Conduit}$ = 0.4	5.55
$A_{Obstruction} / A_{Conduit}$ = 0.5	
INLETS	1.50
At upstream end of conduit [5]	

[1] When $Q_{Branch} < 0.05\ Q_{Main}$, then $k_j = 1.00$ may be used for calculation of hydraulic grade on main.

[2] Specified values for k_j for manholes may also be used for analysis of existing inlets.

[3] When $Q_{Branch} < 0.05\ Q_{Main}$, then $k_j = 0.75$ may be used for calculation of hydraulic grade on main.

[4] For bends other than 90°, adjust k_j values as $k_j = c\ k_j'$ (k_j' is from the table) where c = 0.85 for a 60° bend, c = 0.70 for a 45° bend, and c = 0.40 for a 22½° bend.

[5] Specified k_j is for pressure control calculation. Use the higher hydraulic grade based on pressure or inlet control.

g. Partial Flow in Conduits

The following data shall be shown on the plans: Q, V, $V^2 / 2g$, S_f, V_p, and d_p, where V_p = velocity of open channel flow and d_p = depth of open channel flow.

Depth and velocity of open channel flow shall be based on the uniform flow assumption using Manning's formula for all storm drain pipe or box systems, except near outfalls. The friction slope (S_f) of the flow in the closed conduit shall be assumed to be equal to the slope of the conduit.

When open channel flow exists in a conduit downstream of junctions, structures, enlargements, contractions, obstructions, inlets, or changes in slope, it is necessary to evaluate the change in the hydraulic grade to determine if the flow is changing to pressure in the upstream conduit. Downstream open channel flow in a closed conduit transitions to pressure flow in the upstream conduit when the computed change in hydraulic grade (ΔHG) causes the upstream hydraulic grade to be equal to or greater than the top of the upstream conduit.

If open channel flow is supercritical in the downstream conduit and the pressure flow friction slope (S_f) in the upstream conduit is equal to or greater than the slope of the conduit (S_o), the starting hydraulic grade for the upstream conduit shall be at the top of the conduit.

If open channel flow is subcritical in the downstream conduit and the flow transitions to pressure flow in the upstream conduit, then conservation of energy shall be maintained in the hydraulic grade. Many times it is acceptable to calculate the change in the hydraulic grade with the following formula.

$$\Delta HG = (V_2^2 - k_j V_1^2) / 2g$$

where:

ΔHG = Change in hydraulic grade, ft;
V_1 = Velocity of pressure flow in upstream conduit, fps;
V_2 = Velocity of open channel flow in downstream conduit, fps;
k_j = Loss coefficient per Table 6; and
g = 32.2 = Acceleration of gravity, ft/sec/sec.

When subcritical flow exists in a closed conduit with junctions, structures, enlargements, contractions, obstructions, inlets, or changes in slope, it may be necessary to conduct a backwater analysis to evaluate the hydraulic grade line.

The hydraulic grade in all inlets where the downstream conduit is in open channel flow, shall be computed as inlet control (i.e., headwater) per the procedure specified in Chart 1B of Appendix G.

Computations for possible transitions from open channel to pressure flow shall be presented on the construction plans.

2.08 VELOCITY IN CLOSED CONDUITS

Storm drain grades shall be set to produce a velocity of not less than 3 feet per second (fps) when flowing full. Grades producing velocities of less than 3 fps will not be allowed. All storm drain mains shall be a minimum of 24 inches in diameter. The minimum size of laterals is 18 inches. Discharge velocity shall be calculated with a tailwater depth not greater than the lesser of the top of the pipe at the pipe outlet or the actual 100-year water surface elevation in the channel.

Table III-16 shows the maximum allowable velocities in closed conduits:

TABLE III-16

RECOMMENDED MAXIMUM VELOCITY

Type of Conduit	Maximum Velocity
Culverts	15 fps
Inlet Laterals	15 fps
Storm Drains	15 fps

Discharge velocities cannot exceed the permitted velocity of the channel or conduit at the outfall.

2.09 ROUGHNESS COEFFICIENTS FOR CONDUITS

Recommended values for the roughness coefficient "n" for concrete conduits with smooth joints and good alignment is 0.013. Where engineering judgment indicates a value other than 0.013 be used, the appropriate adjustments should be made in the calculations and a justification presented subject to the City Engineer's approval.

2.10 OPEN CHANNELS

When storm water runoff cannot be carried in a pipe of 72" in diameter or smaller, or it is not necessary for the protection of adjacent facilities that the storm water be carried in an enclosed facility, open channels should be used. Open channels may be used in lieu of a closed conduit when it is mutually agreeable to both the City and the owner.

Earthen Channels

Earthen channels are encouraged throughout the City, particularly for channels draining areas of greater than 4,000 acres, and shall meet all state and federal regulations. When earthen channels are to be preserved, improved or constructed, an application for an earthen channel shall be submitted to the City Engineer prior to approval of the preliminary plat, final plat, or building permit. This application shall contain topographic, hydrologic, and hydraulic information sufficient to properly evaluate the proposal and showing that:

a. All land having an elevation at or below the fully developed one hundred (100) year flood elevation plus 2 feet of freeboard shall be is contained within an easement dedicated to the public for the purpose of providing drainage. This easement shall include a minimum 10 foot strip along the limits of the floodplain on each side where maintenance access is required. These access areas shall have a maximum slope of 10 percent and shall be vegetated with native grasses. The channel easement shall have a minimum hydraulic capacity to accommodate a one hundred (100) year flood based on a fully developed watershed plus (1) foot of freeboard, and shall be a minimum of 20’ wider than the top width of the channel.

b. All channel improvements, such as reshaping, realignment, etc., are protected with sodding, backsloping, cribbing, or other bank protection that is designed and constructed to control erosion from the fully developed two (2) year, ten (10) year and one hundred (100) year fully developed floods by allowing a maximum earthen channel and downstream discharge velocity not to exceed those values shown in Table III-17 Improved or constructed earthen channels shall have the following minimum specifications:

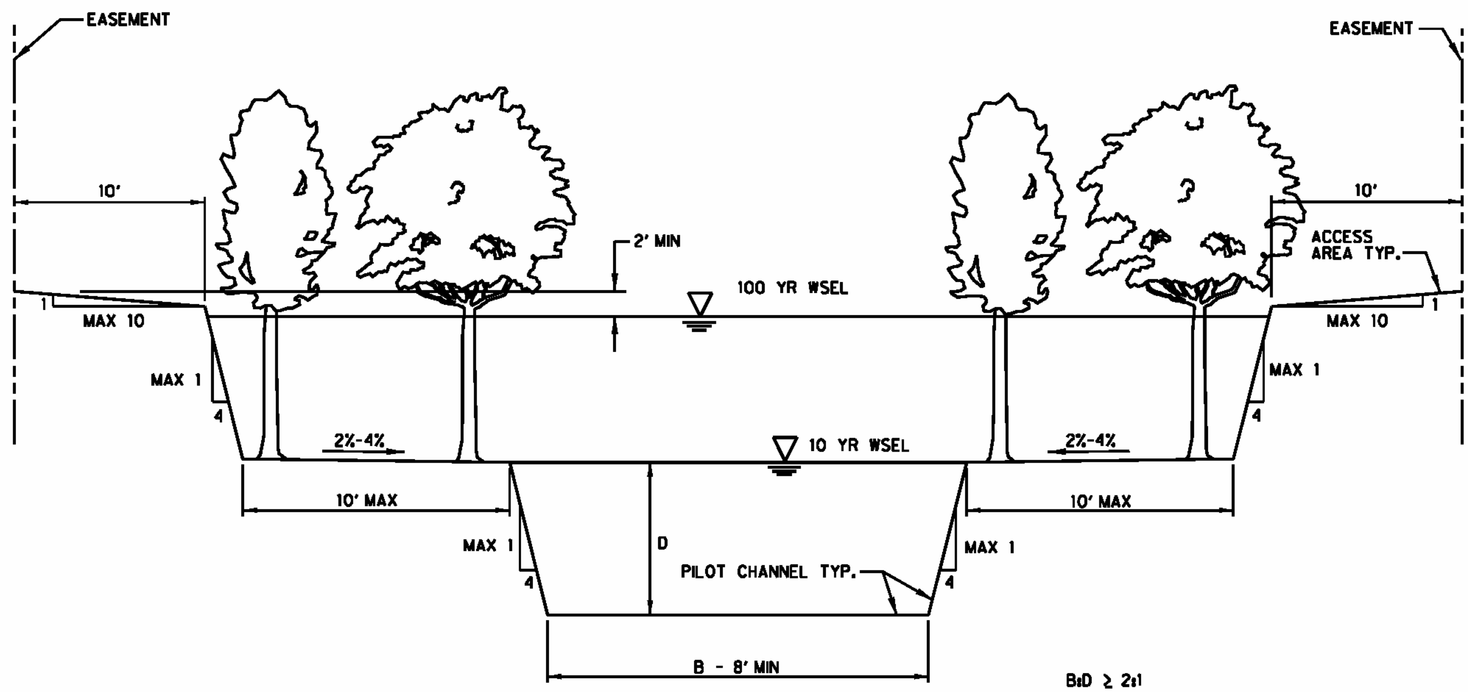
   1. Constructed or improved earthen channels shall consist of a pilot channel that conveys the 10 year fully developed flood with a floodplain area consisting of overbank and sideslopes that will convey the 100 year fully developed flood plus (1) foot of freeboard;

   2. The pilot channel shall be trapezoidal with maximum 4:1 sideslopes, minimum bottom width of 6 feet, and a bottom width to depth of flow ratio of not less than 2:1 (for the fully developed 10-year flood);

   3. The floodplain shall have maximum 4:1 sideslopes and minimum 10’ width of overbank (i.e., area from pilot channel top-of-bank to toe of floodplain sideslope) on each side of pilot channel with 2- to 4-percent cross-slopes, see Figure III-13. Access to channel bottom may require flatter side slopes in floodplain at point locations where required by the City Engineer.

c. Interim check dams shall be provided to control erosion.

FIGURE III-13
EARTHEN CHANNEL CROSS SECTION



EARTHEN CHANNEL CROSS-SECTION
N.T.S.

Concrete-Lined Channels

Concrete lined channels are not permitted in areas zoned single-family, multi-family, or townhouse residential developments. All lined channels must be screened by continuous adjacent landscaping of at least 4 feet in height. Low flow pilot channel lining of earthen channels shall be required for earthen channels carrying more than 100 cfs.

Any concrete-lined open channel that conveys less than 20 cfs is considered a flume. Flumes that convey less than 5 cfs do not require freeboard. All other flumes with a Froude Number less than or equal to 0.8 must have a minimum of 6" of freeboard or with a Froude Number greater than 0.8 must have 1' of freeboard.

a. Design Parameters

1. Channels shall be designed for subcritical flow with a minimum depth of 1.1 x critical depth.

2. Channels shall include engineered inlet structures, outlet structures, and, if applicable, drop structures with erosion control. All inlets, outlets, and drops with velocities that exceed those allowable for project soil conditions shown in Table III-17 shall have downstream erosion control. If the velocity is less than those shown in Table III-17 and flow is supercritical at outlets and drops, a hydraulic jump will occur downstream and erosion control should be provided the full length of the jump and as needed downstream for oscillating jumps (i.e., jumps that occur at $2.5 < Fr < 4.5$). Channel outlets and drops with velocities exceeding 9 fps shall have energy dissipaters designed per *HEC-14 Hydraulic Design of Energy Dissipaters for Culverts and Channels* (FHWA, 2000), *Design of Small Dams* (USBR, 1973), or *Open Channel Hydraulics* (Chow, 1959). Calculations for energy dissipaters shall be included on the construction plans.

3. All inlet structures, outlet structures, drop structures, energy dissipaters, and erosion control shall have minimum 3' toe walls at the upstream and downstream ends and engineered toe walls on the side slopes.

4. Design depth at bends shall include run-up on the outside channel bank. This will typically require hand calculation.

5. Erosion control mats shall be placed after seeding all earthen portions of channels and disturbed areas around channels and streams.

6. Construction plans for channels shall include a plan, profile, sections, and details for the channel and appurtenances. The plan should include the channel, existing and proposed contours, and limits of the existing and proposed floodplain and floodway. The profile should include the existing profile at the centerline and banks extending upstream and downstream of the proposed improvements, proposed centerline and banks to where they tie into the existing ground, and hydraulic grade line. The profile should be annotated with Q, V, $V^2/2g$, d, Fr (Froude Number), and Manning's *n*.

7. According to the Corps of Engineers Manual EM1110-2-1601 *Hydraulic Design of Flood Control Channels* the following table lists the maximum permissible velocity for average channel velocities.

8. Channels with supercritical flow will require special design and approved by the City Engineer.

Concrete-Lined Pilot Channels

Concrete-lined pilot channels will be required in all earthen channels draining less than 4,000 acres, unless preempted by US Army Corps of Engineers requirements. Concrete-lined pilot channels shall be constructed in accordance with the Standard Details. Erosion at the concrete/earth interface has been a major problem with concrete-lined pilot channels in the past. For this reason the engineer must perform a depth/velocity analysis for a full range of discharges including 2-, 5-, 10-, 25-, 50- and 100-year frequencies. For this analysis the Engineer must compute a composite “n” based on the ratio of paved wetted perimeter to unpaved and using “n” = 0.015 for paved concrete, “n” = 0.040 for grouted riprap, and “n” = 0.030 for mowed grass. For depths with velocities exceeding 6 fps, grouted riprap must be provided.

TABLE III-17

MAXIMUM PERMISSIBLE VELOCITIES
AND ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

CHANNEL DESCRIPTION	MAXIMUM ROUGHNESS COEFFICIENT	MAXIMUM VELOCITY
NATURAL STREAMS		
Moderately Well Defined Channel		
Grass & Weeds, Little Brush	0.035	6
Dense Weeds, Little Brush	0.040	6
Weeds, Light Brush on Banks	0.045	6
Weeds, Heavy Brush on Banks	0.060	6
Weeds, Dense Willows on Banks	0.080	6
Irregular Channel With Pools and Meanders		
Grass & Weeds, Little Brush	0.045	6
Dense Weeds, Little Brush	0.050	6
Weeds, Light Brush on Banks	0.060	6
Weeds, Heavy Brush on Banks	0.070	6
Weeds, Dense Willows on Banks	0.100	6
Flood Plain, Pasture		
Short Grass, No Brush	0.035	6
Tall Grass, No Brush	0.050	6
Flood Plain, Cultivated		
No Grass	0.035	6
Mature Crops	0.050	6
Flood Plain, Uncleared		
Heavy Weeds, Light Brush	0.070	6
Medium to Dense Brush	0.160	6
Trees With Flood Stage Below Branches	0.120	6
UNLINED VEGETATED CHANNELS		
Mowed Grass, Clay Soil	0.030	6
Mowed Grass, Sandy Soil	0.030	6
LINED CHANNELS		
Smooth Finished Concrete	0.015	15
Rip-Rap, Rubble or Gabions	0.040	10

b. Model Development

1. All conveyance models shall conform to FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners.*

2. The modeling of channels, streams and rivers, bridges, and culverts should follow the procedures and employ the methodologies specified in the *HEC-RAS Technical Manual*, *EM No. 1110-2-1601 Hydraulic Design of Flood Control Channels* (COE, 1994), *HEC-22 Urban Drainage Design Manual* (FHWA, 2001), and *Open Channel Hydraulics* (Chow, 1959).

3. Sections shall be taken downstream, upstream and through the study area to fully analyze the impacts of the project. The post project flood profile should be computed to within 0.01' of the pre-project profile both upstream and downstream of the project.

4. The downstream starting water surface shall be at a control (i.e., critical depth), known water surface elevation, or using uniform flow assuming that the slope of the channel is equal to the slope of the energy gradeline (S_o). At stream confluences, the starting water surface elevation for the tributary should be the coincident flood elevation on the main stream (the floodplain should be delineated using the backwater from the main stream for the same frequency storm as the channel design until the flood elevation in the tributary controls). If uniform flow is used, the model must start at a distance far enough downstream that an error from ½ S_o to 2 S_o does not effect the water surface elevation through the project or downstream areas that may be impacted by the project.

5. All sections shall be taken perpendicular to the flowlines. This requirement causes some sections, particularly in meandering streams, to be a set of broken lines, not one straight line. In no case shall a section be parallel to the flow at any point on the section.

6. Interpolated sections may not be used. However, to limit field surveying, overbank sections may be taken from a topographic map and the channel may be interpolated between surveyed sections for data that are not ascertainable from the topographic map. City topographic maps may be used for off-site data.

7. Sections should be spaced to account for backwater effects and to properly simulate stream flow conditions. Sections with critical flow will not be accepted, unless it can be demonstrated that the sections are controls within the stream. On streams with steep sloped streambeds the sections should have maximum spacing of about 100', on streams with moderately sloped streambeds sections should have maximum spacing of about 300', and on streams with flat sloped streambeds sections should have maximum spacing of about 500'.

8. Care should be taken to determine where ineffective flow areas are within the stream. Typically such areas are located outside levees or berms, just upstream and downstream of culverts and bridges or other constrictions, and at tributaries or side areas that drain in to the stream being modeled. Ineffective flow areas should be blocked out of the appropriate sections and the section labeled to clarify why it does not match topography.

9. Stream banks should be determined based on stream geomorphology. Generally, field observation is required to complete this task. The top-of-bank is typically where vegetation begins, although this is not always the case. Examples of where

this rule does not apply are on the outside bank of meanders (where the elevations of the bank should be similar on each side of the stream) and for severely incised channels (where the banks may be only a few feet up the eroded slopes for a small stream).

10. The Floodplain Administrator should be contacted for information on approved floodplain hydraulic models for fully developed watershed conditions available at the City Engineer's office. If a hydraulic model is not available from the City, then the engineer must develop it. Current effective FEMA models shall be obtained from the FEMA library for use with CLOMR and LOMR submittals. Modeling should be conducted with the current effective FEMA model format, or HEC-RAS computer programs (latest version). For prismatic channels with flows less than 100 cfs and no backwater conditions, uniform flow calculations may be used.

11. Floodplains shall be delineated based on the 100-year flood elevation, considering downstream backwater conditions and no maintenance of the floodplain or channels. Modeling shall be through reaches using the downstream discharge. All frequency floods shall represent fully developed watershed conditions. Discharges for FEMA models shall be obtained from the FEMA library.

12. For channelizations, the channel banks in the model typically should extend to the top of the channel and, if necessary, *n* values should vary spatially across the channel.

c. <u>Channel Velocities And Stream Bank Erosion</u>

1. The maximum flow velocity in earthen streams shall be as shown in Table III-17 for soil conditions. If velocities already exist above those shown in Table III-17, the proposed project cannot increase velocities above the existing velocities. Check dams shall be provided to help control erosive velocities.

    (a) This requirement applies to within, upstream, and downstream of the project and is evaluated for the 100-year flood by comparing pre- and post-project velocities. Pre-project velocities are evaluated using pre-project topography and pre-project development conditions. Post-project velocities are evaluated using post-project topography and adjusting the pre-project runoff to account for fully developed conditions at the project site.

    (b) This requirement includes the analysis of reduced flood storage within floodplain areas.

    (c) The effect on backwater caused by coincident flow within the main stream may not be considered for velocity calculations on a tributary.

    (d) For projects where work will be conducted within the drainage way, an additional model shall be developed for post project conditions with *n* values that reflect post construction conditions prior to re-establishment of vegetation. This post construction model shall be analyzed for the 10- and 100-year floods. The maximum velocities resulting from this post construction model shall be used for engineering design of erosion control measures.

(e) The maximum velocity requirement for downstream channels should not be changed by the project; however, if it can be mitigated by demonstrating no loss of valley storage through the project site for the 2-year and 100-year floods

2. For all earthen streams and channels (including natural channels), the engineer as a minimum shall submit a letter report with supporting information demonstrating the stability of stream meandering, erosion, and slopes. The report will certify that the *proposed drainage easement is of sufficient size to take into account any additional width to accommodate future bank erosion as determined by engineering slope stability calculation.* A future stable 4:1 earthen bank may be assumed in establishing the limits of the drainage easement.

3. If engineering design measures are proposed to mitigate future erosion and a detailed geomorphologic study is not presented, the letter report should, as a minimum, address stabilizing meanders and erosion areas, the streambed eroding to the flowline of the nearest downstream stabilized streambed (i.e., to the nearest culvert, lined channel, etc.) and stable slopes to property lines based on the reduced flowline.

4. Constructed and natural earthen banks shall have engineered 4:1 slopes. Typically maximum slopes of 4:1 are stable in clay soils and reduced slopes in sandy soils.

5. Design of erosion control measures at meanders and bends shall consider the increased velocity on the outside of the bend. This will typically require hand calculation.

2.11 HYDRAULIC DESIGN OF BRIDGES AND CULVERTS

Culverts and bridges and storm drains that are used to convey flood waters under roadways, pedestrian bridges and rights-of-way shall be designed to convey the fully developed 100-year flood. Headwater and tailwater velocities shall be used for the design of erosion control measures.

Where there are junctions in a culvert, where there are bends in a culvert, or there are obstructions or junction boxes in a culvert, it may be necessary to conduct hand-calculations and adjust the appropriate model parameters to obtain the correct results. Such culverts and bridges should be labeled to identify why the model parameters have been adjusted.

a. Bridge

Bridge design shall be in accordance with the Texas Department of Transportation Hydraulic Design Manual, current edition. The hydraulic grade for the fully developed 100-year flood shall be a minimum of 2.0 feet below the lowest obstruction on a bridge. A waiver may be issued with written authorization from the Floodplain Administrator. Headwater and tailwater velocities shall be used for the design of erosion control measures.

b. Culverts

Culverts shall be designed to convey the 100 year fully developed flood. The headwater hydraulic grade shall be a minimum of 1’ below the top of curb for culverts. All culverts shall have headwalls on the upstream and downstream ends with 3’ toe walls. Culvert control may oscillate from inlet to outlet control, however for this manual the concept of minimum performance applies. This will ensure that the culvert will not operate at a lower level of performance than calculated, but that it may operate more efficiently at times. The culvert design method is based on the use of design charts and nomographs taken from *HEC-5 Hydraulic Design of Highway Culverts* (FHWA, 2001).

Types of Control

A culvert flowing in inlet control has shallow, high velocity flow categorized as ”supercritical” flow. For supercritical flow, the control section is at the upstream end of the barrel (the inlet). Conversely, a culvert flowing in outlet control will have relatively deep, lower velocity flow termed “subcritical” flow. For subcritical flow the control is at the downstream end of the culvert (the outlet). The tailwater depth is either critical depth at the culvert outlet or the downstream channel depth, whichever is higher. In a given culvert, the type of flow is dependant on all of the factors listed in Table III-18.

1. Inlet Control

Examples of Inlet control

Figure III-14 depicts several different examples of inlet control flow. The type of flow depends on the submergence of the inlet and outlet ends of the culvert. In all of the examples, the control section is at the inlet end of the culvert. Depending on the tailwater, a hydraulic jump may occur downstream on the inlet.

TABLE III-18

CULVERT CONTROL FACTORS

Factor	Inlet Control	Outlet Control
Headwater Elevation	X	X
Inlet Area	X	X
Inlet Edge Configuration	X	X
Inlet Shape	X	X
Barrel Roughness		X
Barrel Area		X
Barrel Shape		X
Barrel Length		X
Barrel Slope	*	X
Tailwater Elevation		X

* Barrel slope affects inlet control performance to a small degree, but may be neglected.

Figure III-14 A depicts a condition where neither the inlet nor the outlet end of the culvert are submerged. The flow passes through the critical depth just downstream of the culvert entrance and the flow in the barrel is supercritical. The barrel flows partly full over it’s entire length, and the flow approaches normal depth in the culvert barrel.

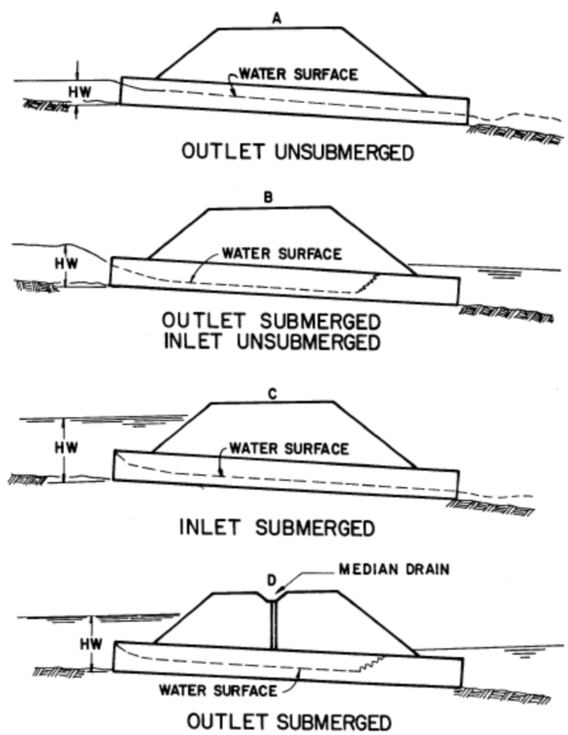
Figure III-14 B shows that submergence of the outlet end of the culvert does not assure outlet control. In this case, the flow just downstream of the inlet is supercritical and a hydraulic jump forms in the culvert barrel.

Figure III-14 C is a more typical design situation. The inlet end is submerged and the outlet end flows freely. Again, the flow is supercritical and the barrel flows partly full over it's entire length. Critical depth is located just downstream of the culvert entrance, and the flow is approaching normal depth at the downstream end of the culvert.

Figure III-14an unusual condition illustrating the fact that even submergence of both the inlet and outlet ends of the culvert does not assure full flow. In this case, a hydraulic jump will form in the barrel. The median inlet provides ventilation of the culvert barrel. If the barrel were not ventilated, sub atmospheric pressure could develop which might create an unstable condition during which the barrel would alternate between full flow and partly full flow.

FIGURE III-14

TYPES OF INLET CONTROL



Hydraulics

Inlet control performance is defined by the three regions of flow shown in Figure III-15: unsubmerged, transition, and submergence. For low headwater conditions, as shown in Figure III-14 A and B, the entrance of the culvert operates as a weir. A weir is an unsubmerged flow control section where the upstream water surface elevation can be predicted for a given flow rate. The relationship between flow and water surface elevation can be predicted for a given flow rate. The relationship between flow and water surface elevation must be determined by model tests of the weir geometry or by measuring prototype discharges. These test or measurements are then used to develop equations for unsubmerged inlet control flow. The equations developed are as follows:

Form (1) $HW_i/D = H_C/D + K[K_uQ/AD^{0.5}]^M - 0.5S$ (26)

Form (2) $HW_i/D = K[K_uQ/AD^{0.5}]^M$ (27)

Equations (26) and (27) apply up to about $Q/AD^{0.5} = 3.5$

For headwaters submerging the culvert entrance, as shown in Figure III-14 C and D, the entrance of the culvert operates as an orifice. An orifice is an opening, submerged on the upstream side and flowing free on the downstream side, which functions as a control section. The relationship between flow and headwater for submerged conditions can be defined as follows:

$$HW_i/D = c[K_uQ/AD^{0.5}]^2 + Y - 0.5S \quad (28)$$

HW_i is the headwater depth above the inlet control section invert (ft)
D is interior height of culvert barrel 9ft)
H_C is the specific head at critical depth ($d_c + V_c2/2g$) (ft)
Q is the discharge (ft^3/s)
A is the full cross sectional area of culvert barrel (ft^2)
S is the culvert barrel slope (ft/ft)
K, M, c, Y are constants from Table III-19
K_u is 1.0 for English Units

For mitered inlets use +0.7S instead of -0.5S as the slope correction factor.
Equation (28) applies above about $Q/AD^{0.5} = 4.0$

The flow transition zone between the low headwater and the high headwater flow conditions is poorly defined. This zone is approximated by plotting the submerged and unsubmerged flow equations and connecting them with a line tangent to both curves, as shown in Figure III-15.

FIGURE III-15

INLET CONTROL PERFORMANCE CURVES

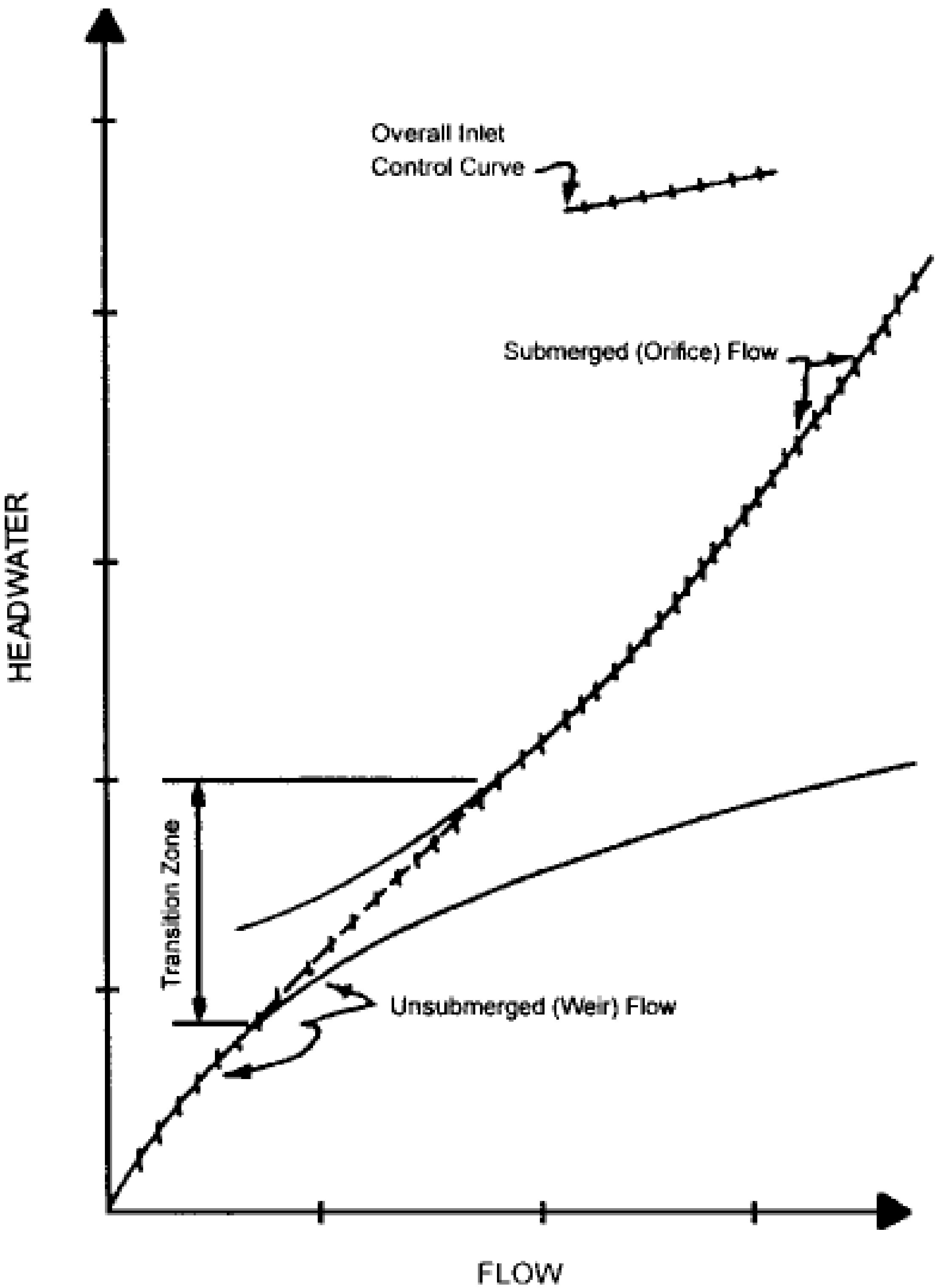


TABLE III-19

CONSTANTS FOR INLET CONTROL CULVERTS [E]

Chart No.	Shape and Material	Nomograph Scale	Inlet Edge Description	Equation Form	Unsubmerged		Submerged		References
					K	M	c	Y	
1	Circular Concrete	1	Square edge w/headwall	1	.0098	2.0	.0398	.67	56/57
		2	Groove end w/headwall		.0018	2.0	.0292	.74	
		3	Groove end projecting		.0045	2.0	.0317	.69	
2	Circular CMP	1	Headwall	1	.0078	2.0	.0379	.69	56/57
		2	Mitered to slope		.0210	1.33	.0463	.75	
		3	Projecting		.0340	1.50	.0553	.54	
3	Circular	A	Beveled ring. 45° bevels	1	.0018	2.50	.0300	.74	57
		B	Beveled ring. 33.7° bevels*		.0018	2.50	.0243	.83	
8	Rectangular Box	1	30° to 75° wingwall flares	1	.026	1.0	.0347	.81	56
		2	90° and 15° wingwall flares		.061	.75	.0400	.80	56
		3	0° wingwall flares		.061	.75	.0423	.82	8
9	Rectangular Box	1	45° wingwall flare d = .043D	2	.510	.667	.0309	.80	8
		2	18° to 33.7° wingwall flare d = .083D		.486	.667	.0249	.83	
10	Rectangular Box	1	90° headwall w/3/4° chamfers	2	.515	.667	.0375	.79	8
		2	90° headwall w/45° bevels		.495	.667	.0314	.82	
		3	90° headwall w/33.7° bevels		.486	.667	.0252	.865	
11	Rectangular Box	1	3/4° chamfers; 45° skewed headwall	2	.545	.667	.04505	.73	8
		2	3/4° chamfers; 30° skewed headwall		.533	.667	.0425	.705	
		3	3/4° chamfers; 15° skewed headwall		.522	.667	.0402	.68	
		4	45° chamfers; 10°-45° skewed headwall		.498	.667	.0327	.75	
12	Rectangular Box	1	45° non-offset wingwall flares	2	.497	.667	.0339	.803	8
	3/4° chamfers	2	18.4° non-offset wingwall flares		.493	.667	.0361	.806	
		3	18.4° non-offset wingwall flares 30° skewed barrel		.495	.667	.0386	.71	
13	Rectangular Box	1	45° wingwall flares - offset	2	.497	.667	.0302	.835	8
	Top Bevels	2	33.7° wingwall flares - offset		.495	.667	.0252	.881	
		3	18.4° wingwall flares - offset		.493	.667	.0227	.887	
16 – 19	C M Boxes	2	90° headwall	1	.0083	2.0	.0379	.69	57
		3	Thick wall projecting		.0145	1.75	.0419	.64	
		5	Thin wall projecting		.0340	1.5	.0496	.57	

Chart No.	Shape and Material	Nomograph Scale	Inlet Edge Description	Equation Form	Unsubmerged		Submerged		References
					K	M	c	Y	
29	Horizontal	1	Square edge w/headwall	1	.0100	2.0	.0398	.67	57
	Ellipse	2	Groove end w/headwall		.0018	2.5	.0292	.74	
	Concrete	3	Groove end projecting		.0045	2.0	.0317	.69	
30	Vertical	1	Square edge w/headwall	1	.0100	2.0	.0398	.67	57
	Ellipse	2	Groove end w/headwall		.0018	2.5	.0292	.74	
	Concrete	3	Groove end projecting		.0095	2.0	.0317	.69	
34	Pipe Arch	1	90° headwall	1	.0083	2.0	0.379	.69	57
	18” Corner	2	Mitered to slope		.0300	1.0	.0463	.75	
	Radius CM	3	Projecting		.0340	1.5	.0496	.57	
35	Pipe Arch	1	Projecting	1	.0300	1.5	.0496	.57	56
	18” Corner	2	No Bevels		.0088	2.0	.0368	.68	
	Radius CM	3	33.7° Bevels		.0030	2.0	.0269	.77	
36	Pipe Arch	1	Projecting	1	.0300	1.5	.0496	.57	56
	31” Corner		No Bevels		.0088	2.0	.0368	.68	
	Radius CM		33.7° Bevels		.0030	2.0	.0269	.77	
41-43	Arch CM	1	90° headwall	1	.0083	2.0	.0379	.69	57
		2	Mitered to slope		.0300	1.0	.0463	.75	
		3	Thin wall projecting		.0340	1.5	.0496	.57	
55	Circular	1	Smooth tapered inlet throat	2	.534	.555	.0496	.90	3
		2	Rough tapered inlet throat		.519	.64	.0210	.90	
56	Elliptical	1	Tapered inlet-beveled edges	2	.536	.622	.0368	.83	3
	Inlet Face	2	Tapered inlet-square edges		.5035	.719	.0478	.80	
		3	Tapered inlet-thin edge projecting		.547	.80	.0598	.75	
57	Rectangular	1	Tapered inlet throat	2	.475	.667	.0179	.97	3
58	Rectangular	1	Side tapered-less favorable edges	2	.56	.667	.0446	.85	3
	Concrete	2	Side tapered-more favorable edges		.56	.667	.0378	.87	
59	Rectangular	1	Slope tapered-less favorable edges	2	.50	.667	.0446	.65	3
	Concrete		Slope tapered-more favorable edges		.50	.667	.0378	.71	

Inlet control performance curves are developed using either the inlet control equations shown or the nomographs found in Appendix G. If the design equations are used, both submerged and unsubmerged flow headwaters should be calculated for a series of flow rates bracketing the design flow. The resultant curves are then connected with a line tangent to both curves. Using the combined culvert performance curves, it is easy to determine the headwater elevation for any flow rate, or to visualize the performance of the culvert installation over a range of flow rates.

The inlet control calculations determine the headwater elevation required to pass the design flow through the selected culvert configuration in inlet control. The approach velocity head may be included as part of the headwater, if desired. The inlet control nomographs of Appendix G are used in the design process

2. Outlet Control

Examples of Outlet Control

Figure III-16 illustrates various outlet control flow conditions. In all cases, the control section is at the outlet end of the culvert or further downstream. For the partly full flow situations the flow in the barrel is subcritical.

Figure III-16 A represents the classic full flow condition, with both inlet and outlet submerged. The barrel is in pressure flow throughout its length. This condition is often assumed in calculations, but seldom actually exists.

Figure III-16 B depicts the outlet submerged with the inlet unsubmerged. For this case, the headwater is shallow so that the inlet crown is exposed as the flow contracts into the culvert.

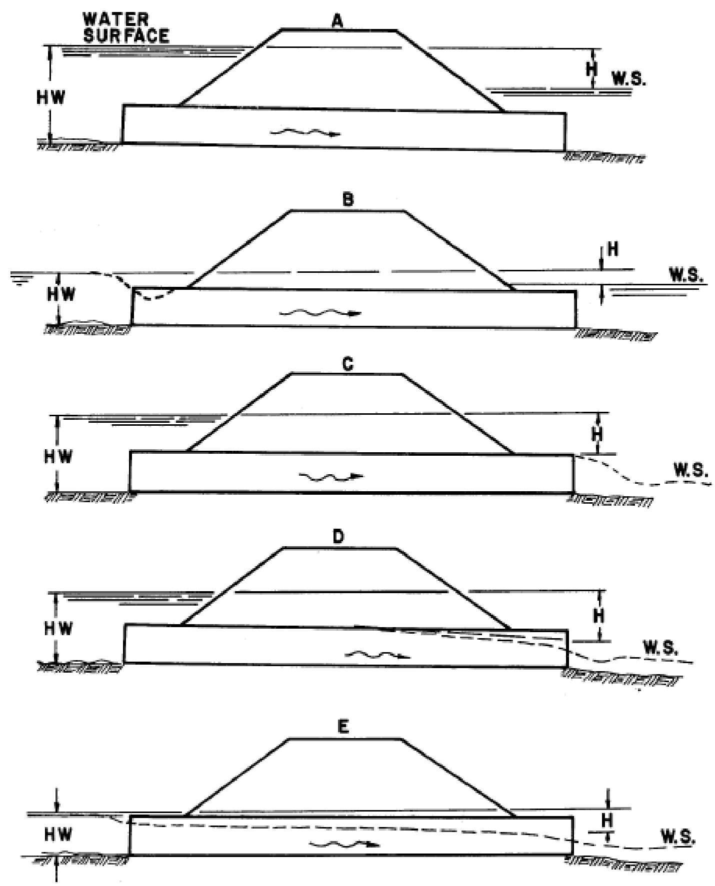
Figure III-16 C shows the entrance submerged to such a degree that the culvert flows full throughout its entire length while the exit is unsubmerged. This is a rare condition. It requires an extremely high headwater to maintain full barrel flow with no tailwater. The outlet velocities are usually high under this condition.

Figure III-16 D is more typical. The culvert entrance is submerged by the headwater and the outlet end flows freely with a low tailwater. For this condition, the barrel flows partly full over at least part of its length and the flow passes through critical depth just upstream of the outlet.

Figure III-16 E is also very typical, with neither the inlet nor the outlet end of the culvert submerged. The barrel flows partly full over its entire length, and the flow profile is subcritical.

FIGURE III-16

TYPES OF OUTLET CONTROL



Hydraulics of Outlet Control

Full flow in the culvert barrel as depicted in Figure III-16 A is the best type of flow for describing the outlet control hydraulics. Outlet control flow conditions can be calculated based on energy balance. The total energy (H_L) required to pass the flow through the culvert barrel is made up of the entrance loss (H_e), the friction Loss (H_f), and the exit Loss (H_o). Other losses, including band losses (H_b), losses at junctions (H_j), and losses at grates (H_g) should be included as appropriate.

$$H_L = H_e + H_f + H_o + H_b + H_j + H \quad (1)$$

The barrel velocity is calculated as follows:

$$V = Q/A \quad \textbf{(2)}$$

V is the average velocity in the culvert barrel, (ft/s)
Q is the flow rate (ft/s)

A is the full cross sectional area of the flow (ft^2)

The Velocity Head is:

$$H_V=V^2/2g \quad (3)$$

g is the acceleration due to gravity, 32.2 (ft/s/s)

The entrance loss is a function of the velocity head in the barrel, and can be expressed as a coefficient times the velocity head.

$$H_e=k_e(V^2/2g) \quad (4a)$$

Values of k_e based on various inlet configurations are given in Table III-20 below.

The friction loss in the barrel is also a function of the velocity head. Based on the Manning equation, the friction loss is:

$$H_f=[29n^2L/R^{1.33}](V^2/2g) \quad (4b)$$

n is the Manning roughness coefficient
L is the length of the culvert barrel (ft)
R is the hydraulic radius of the full culvert barrel=A/p (ft)
A is the cross sectional area of the barrel (ft^2)
p is the perimeter of the barrel (ft)
V is the velocity in the barrel (ft/s)

The exit loss is a function of the change in velocity at the outlet of the culvert barrel. For a sudden expansion such as an endwall, the exit loss is:

$$Ho=[V^2/2g- V_d^2/2g] \quad (4c)$$

V_d is the channel velocity downstream of the culvert (ft/s)

The downstream velocity is usually neglected, in which case the exit loss is equal to the full flow velocity head in the barrel and the equation reduces to:

$$Ho=H_V=V^2/2g \quad (4d)$$

TABLE III-20

ENTRANCE LOSS COEFFICIENTS[E]

Outlet Control, Full or Partly Full Entrance Head Loss

$H_e = k_e(V^2/2g)$

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 = D/12)	0.2
Mitered to conform to fill slope	0.7
*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
Rounded on 3 edges to radius of B/12 or B/12 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 D/12 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: “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. These latter sections can be designed using the information given for the beveled inlet.

Bend losses, junction losses, grate losses and other losses are discussed in HDC-5 *Hydraulic Design of Highway Culvert.*

Inserting the above relationships for entrance loss, friction loss, and exit loss into Equation (1), the following equation for loss is obtained:

$$H=[1+k_e+(29n^2L/R^{1.33})]*V^2/2g \quad (5)$$

FIGURE III-17

FULL FLOW ENERGY AND HYDRAULIC GRADE LINES [E]

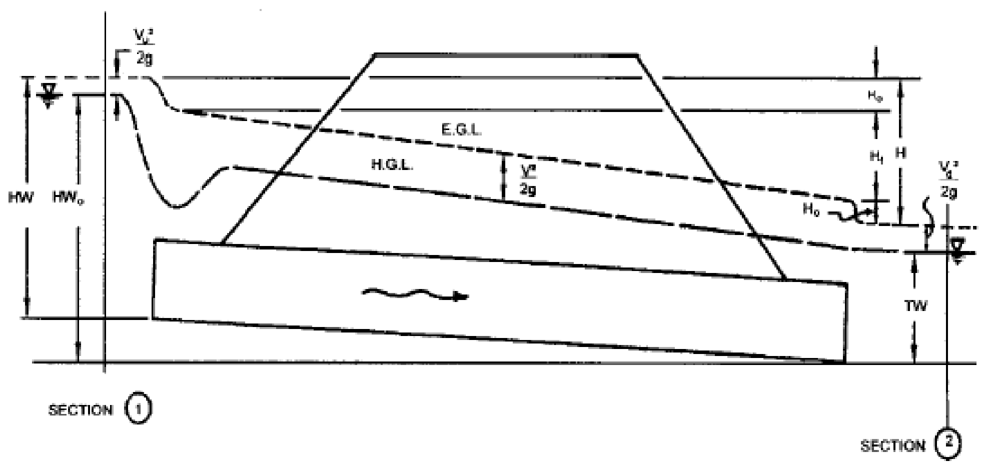


Figure III-17 depicts the energy grade line and the hydraulic grade line for full flow in a culvert barrel. The energy grade line represents the total energy at any point along the culvert barrel. HW is the depth from the inlet invert to the energy grade line. The hydraulic grade line is the depth to which water would rise in vertical tubes connected to the side of the culvert barrel. In full flow, the energy grade line and the hydraulic grade line are parallel straight lines separated by the velocity head lines except in the vicinity of the inlet where the flow passes through a contraction.

The headwater and tailwater conditions as well as the entrance, friction, and exit losses are also shown in Figure III-17. Equaling the total energy at sections 1 and 2, upstream and downstream of the culvert barrel in Figure III-17, the following relationship results:

$$HW_O + V_U^2/2g = TW + V_d^2/2g + H_L \quad (6)$$

HW_O is the headwater depth above the outlet invert (ft)
V_U is the approach velocity (ft/s)
TW is the tailwater depth above the outlet invert (ft)
V_d is the downstream velocity (ft/s)
H_L is the sum of all losses

Note: the total available upstream energy (*HW*) includes the depth of the upstream water surface above the outlet invert and the approach velocity head. In most instances, the approach velocity is low, and the approach velocity is neglected. However, it can be considered to be a part of the available headwater and used to convey the flow through the culvert.

Likewise, the velocity downstream of the culvert (V_d) is usually neglected. When both approach and downstream velocities are neglected, Equation 6 becomes:

$$HW_O = TW + H_L \quad (7)$$

In this case, H_L is the difference in elevation between the water surface elevation at the outlet and the water surface elevation at the inlet. If it is desired to include the approach and/or downstream velocities, use Equation (4c) for exit losses and Equation (6) instead of Equation (7) to calculate the headwater.

Equations (1) through (7) were developed for full barrel flow. They also apply to the flow situations shown in Figure III-16 B and C, which are effectively full flow conditions. Backwater calculations may be required for the partly full flow conditions shown in Figure III-16 D and E. These calculations begin at the water surface at the downstream end of the culvert and proceed upstream to the entrance of the culvert. The downstream water surface is based on critical depth at the culvert outlet or on the tailwater depth whichever is higher. If the calculated backwater profile intersects the top of the barrel, as shown in Figure III-16 D, a straight full flow hydraulic grade line extends from that point upstream to the culvert entrance. From Equation (4b), the full flow friction slope is:

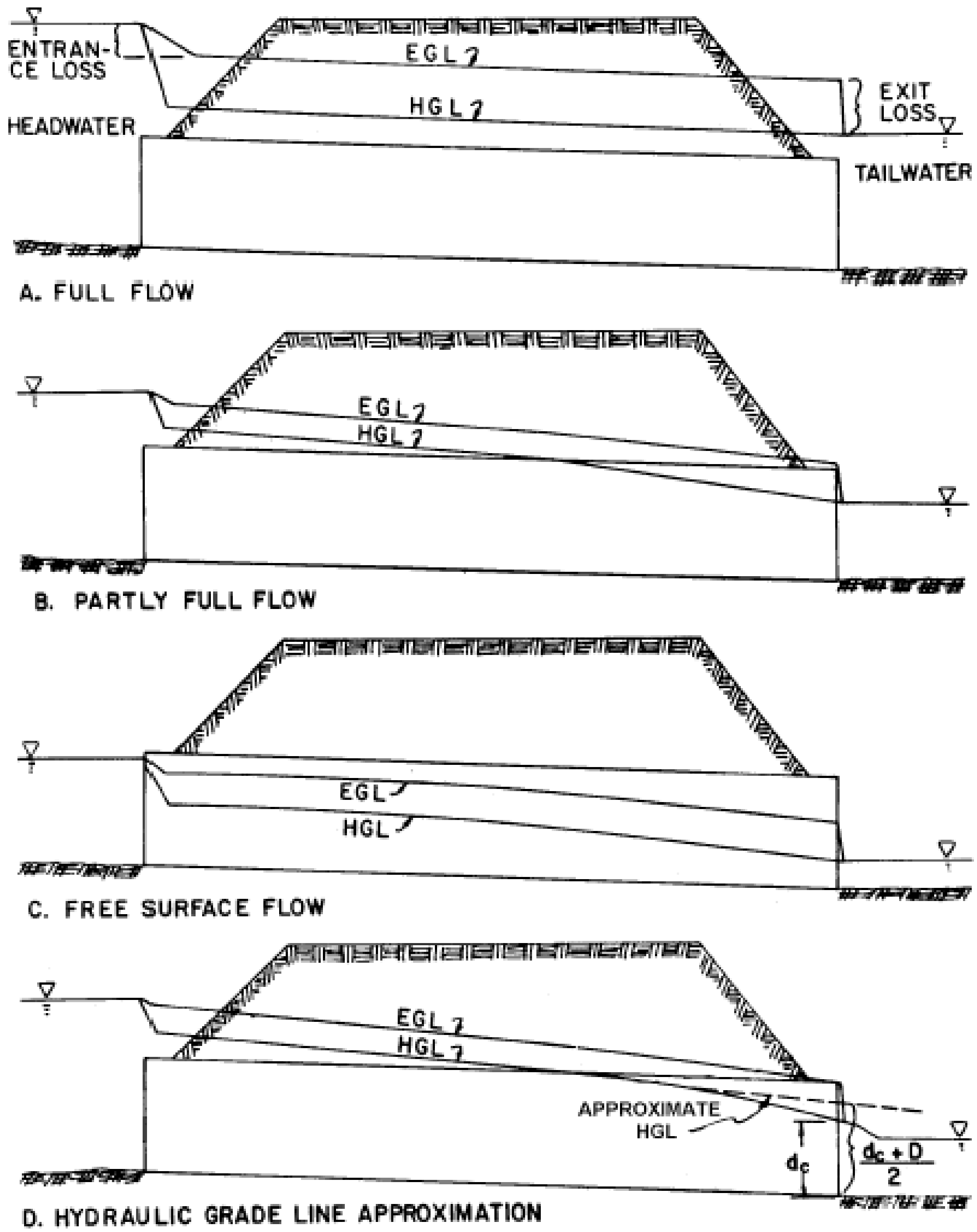
$$S_n = H_f/L = (29\ n^2/R^{1.33})*(V^2/2g)$$

In order to avoid tedious backwater calculations, approximate methods have been developed to analyze partly full flow conditions. Based on numerous backwater calculations performed by the FHWA staff, it was found that a downstream extension of the full flow hydraulic grade line for the flow condition shown in Figure III-18 pierces the plane of the culvert outlet at a point half-way between the critical depth and the top of the barrel. Therefore, it is possible to begin the hydraulic grade line at a depth of $(d_c+D)/2$ above the outlet invert and extend the straight, full flow hydraulic grade line. The inlet losses and the velocity head are added to the elevation of the hydraulic grade line at the inlet to obtain the headwater elevation

This approximate method works best when the barrel flows full over at least part of its length. When the barrel is partly full over it's entire length, the method becomes increasingly inaccurate as the headwater falls further below the top of the barrel at the inlet. Adequate results are obtained down to a headwater of 0.75D. For lower headwaters, backwater calculations are required to obtain accurate headwater elevations.

FIGURE III-18

OUTLET CONTROL ENERGY AND HYDRAULIC GRADE LINES



The outlet control nomographs in Appendix G provide solutions for Equation (5) for entrance, friction, and exit losses in full barrel flow. Using the approximate backwater method, the losses (*H*) obtained from the nomographs can be applied for partly full flow conditions. The losses are added to the elevation of the extended full flow hydraulic grade line at the barrel outlet in order to obtain the headwater elevation. The extended hydraulic grade line is set at the higher of $(d_c+D)/2$ or the tailwater elevation at the culvert outlet. Again, the approximation works best when the barrel flows full over at least part of its length.

Outlet control performance curves can be developed using Equations (1) through (7), or the nomographs in Appendix G. Flows bracketing the design flow are selected. For these flows, the total losses through the barrel are calculated or read from the outlet control nomographs. The losses are added to the elevation of the hydraulic grade line at the culvert outlet to obtain the headwater.

Design Process

Compare the headwater elevations calculated for the inlet and outlet control. The higher of the two is designated the controlling headwater elevation. The culvert can be expected to operate with that higher headwater for at least part of the time.

If outlet control governs and the headwater depth is less than 1.2D, it is possible that the barrel flows partly full through its entire length. In this case, caution should be used in applying the approximate method of setting the downstream elevation based on the greater of tailwater or $(d_c + D)/2$. If an accurate headwater is necessary, backwater calculations should be used to check the result from the approximate method. If the headwater depth falls below 0.75D, the approximate method should not be used.

2.12 STORM DRAIN INLET VELOCITY

Velocities (Vi) shall be calculated at all storm drain inlets (both closed conduits and open channels) to determine the need for erosion protection, except at inlets in a street. Storm drains frequently have velocities at the inlets that are higher than the velocities in the discharging stream or channel. These inlet velocities may require flow adjustment or erosion control to prevent upstream erosion.

The following is a summary of an approximate procedure to calculate the design velocity at a storm drain inlet. The greater inlet velocity resulting from the 2-year flood and design flow for the discharging stream or channel is to be used for design of erosion control at the inlet.

Compute the headwater (HW) at the inlet as pressure control (for culverts this is referred to as outlet control) and as inlet control (using Chart 1B) for both the 2-year flood and the design flow. The controlling headwater and inlet velocity is determined by the following procedure when the upstream channel/stream flow is subcritical.

- If it is a closed conduit and both headwaters are greater than 1.2 times the height of the inlet (h), then the lower of the two headwaters is the controlling headwater and the inlet velocity is the full flow velocity of the closed conduit.
- If it is a closed conduit and one headwater is greater than 1.2h and the other is lower than 1.2h, then the higher of the two headwaters is the controlling headwater and the inlet velocity is the full flow velocity of the closed conduit.
- For all other cases the critical flow velocity in the storm drain may be assumed as the inlet velocity or a backwater analysis may be performed.

Note that the inlet velocity to be used for design of the upstream erosion control shall be the greater of the velocities resulting from the 2-year flood and the design flow through the storm drain. Erosion control is required for velocities that exceed 6 fps and the limits of the erosion control must be determined with water surface profiles if the velocity exceeds 8 fps.

In all cases where the flow in the upstream channel/stream at or near the inlet is supercritical, then the velocity in the channel/stream corresponding to the supercritical flow is used as the inlet velocity. In this case it must be determined if a hydraulic jump occurs at the inlet. Such cases require special analysis and design as required by the City Engineer.

2.13 STORM DRAIN OUTLET VELOCITY

Velocities (Vo) shall be calculated at all storm drain outlets (both closed conduits and open channels) to determine the need for erosion protection. Storm drains usually have velocities at the outlets that are higher than the velocities in the receiving stream or channel. These outlet velocities may require flow adjustment or energy dissipation to prevent downstream erosion.

The following is a summary of an approximate procedure to calculate the velocity at a storm drain outlet. The design flow for the storm drain is to be used to calculate the velocities and depths of flow at the outlet (do, Vo), in the storm drain near the outlet (d1, V1) and in the receiving stream or channel near the outlet (d2, V2).

a. Channel/Stream Velocity

The velocity downstream (also referred to as tailwater) of the outlet in the stream or channel shall be the velocity corresponding to the uniform flow depth for prismatic channels with subcritical flow (i.e., when du2>dc2, then d2=du2 and V2=Vu2) and non-prismatic channels or streams with subcritical flow when flow conditions do not result in a decreasing depth of flow downstream of the outlet (i.e., d2=du2 and V2=Vu2). For all supercritical flows and for non-prismatic channels and streams with subcritical flow with flow conditions in the channel or stream that result in a decreasing depth of flow downstream of the outlet, no tailwater shall be assumed (i.e., d2=0 and V2=N/A).

b. Storm Drain Velocity

If a supercritical flow exists within a storm drain anywhere upstream of the outlet, then the highest uniform velocity within the storm drain may be used (V1=Vmax and d1=d corresponding to Vmax) or a drawdown analysis may be conducted to determine the velocity at the outlet. A drawdown analysis should begin at the upstream control where critical depth can be used to approximate the depth of flow in the storm drain and then proceed downstream to the outlet.

Subcritical flow cannot be assumed near the outlet in storm drains with upstream supercritical flows just because uniform depth is greater than critical depth near the outlet. In such cases, an analysis must be conducted to demonstrate that a hydraulic jump occurs within the storm drain if subcritical flow is to be used to determine the velocity in the storm drain near the outlet. When a hydraulic jump occurs in a storm drain the length of the jump and turbulence must also be considered downstream.

If flow within the storm drain is subcritical at all locations upstream, then the velocity at uniform depth is the velocity in the storm drain near the outlet. For closed conduit storm drains and culverts, if uniform depth exceeds the top of the conduit then full flow shall be assumed near the outlet (i.e., pressure flow).

c. Outlet Velocity

When the flow near the outlet in the storm drain is subcritical, then the outlet velocity shall be determined as follows. The critical velocity in the upstream storm drain is used as the outlet velocity when the tailwater in the downstream channel or stream is less than critical depth. If the tailwater is greater than critical depth and less than the depth of flow in the storm drain near the outlet, then the tailwater depth is used to compute the outlet velocity in the storm drain except when the tailwater is above the top of a closed conduit. The full flow velocity (i.e., pressure flow velocity) of the closed conduit shall be used when the tailwater is greater than the top of a closed conduit.

In all cases where the flow in the upstream storm drain near the outlet is supercritical, then the velocity in the storm drain corresponding to the supercritical flow is used as the oulet velocity.

Velocities at the outlets shall be shown on the plans with calculations. If there is a hydraulic jump at the outlet, the Froude Number and location of the jump must be on the plans with calculations. Erosion control is required for velocities that exceed 6 fps and the limits of the erosion control must be determined with water surface profiles if the velocity exceeds 8 fps. Outlets with velocities exceeding 9 fps shall have energy dissipators designed per HEC-14 *Hydraulic Design of Energy Dissipators for Culverts and Channels* (FHWA, 2000), *Design of Small Dams* (USBR, 1973), or *Open Channel Hydraulics* (Chow, 1959). Calculations for energy dissipators shall be included on the construction plans.

FIGURE III-19

OUTLET VELOCITY – INLET CONTROL [E]

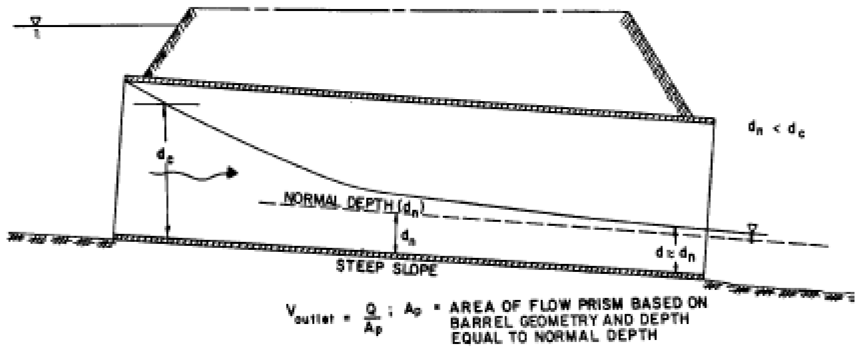
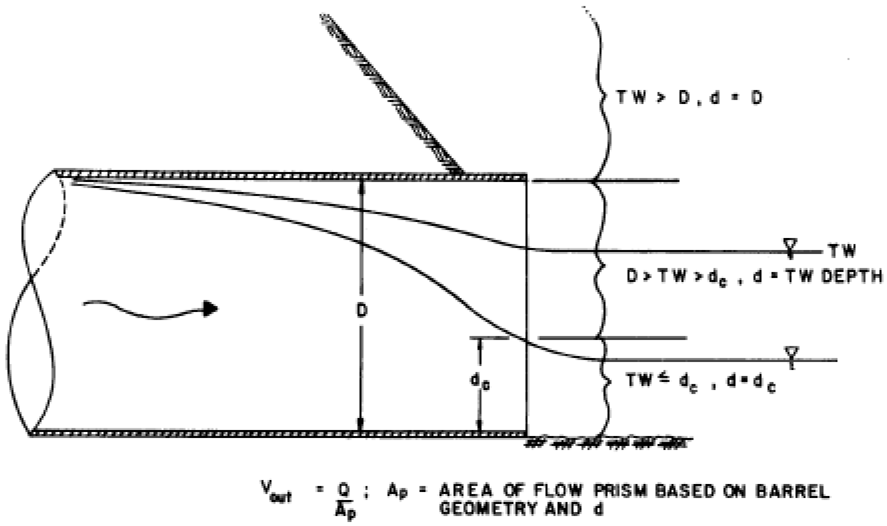


FIGURE III-20

OUTLET VELOCITY – OUTLET CONTROL [E]



In outlet control, the cross sectional area of the flow is defined by the geometry of the outlet and either critical depth, tailwater depth, or the height of the conduit (Figure III-20).

2.14 HEADWALLS AND ENTRANCE CONDITIONS

Standard sloped headwalls are to be used to protect the embankment from erosion and the storm drain from displacement. Sloped headwalls conforming to the minimum slope specified in this Design Manual shall be constructed at the entrance of all storm drainage facilities.

Special headwalls and wingwalls may be required at the entrance of all hydraulic structures where approach velocities are in excess of 8 feet per second. Storm drain entrance and headwall shall be designed such as the flow line of the storm drain is coincident with the flow line of the upgradient stream or channelfrom which the flow is entering the storm drain.

2.15 HEADWALLS AND EXIT CONDITIONS

Headwalls are used to protect the embankment from erosion and the storm drain from displacement. Sloped headwalls conforming to the minimum slope specified in this manual shall be constructed at the entrance and/or outfall of all storm drainage facilities.

Storm drain exits and headwall shall be designed such that the flow line of the storm drain is coincident with the flow line of the stream or channel into which the storm drain discharges. The maximum exit velocity from the storm drain is limited to the maximum velocity allowed in the stream or channel.

Due to the geometry of the storm drain-stream intersection, turbulence or other conditions may tend to produce erosion. Erosion control will be used to protect the stream bed from scour and erosion. The erosion control shall be reinforced and have toe walls on all sides to prevent undermining.

2.16 DRAINAGE AREA MAP

A map having a scale of one inch (1") equals two-hundred feet (200') (showing the street right-of-way) is suitable unless dealing with a large drainage area. For large drainage areas a map having a scale of one inch (1") equals two-thousand feet (2,000') is acceptable. When calculating runoff, the drainage area map shall show the boundary of the drainage area contributing runoff into the proposed system. The area shall be further divided into sub-areas to determine flow concentration points or inlet locations. Drainage area maps should show streets, zoning, zoning boundaries, existing ground on 2-foot contours, and a hydraulic summary table. Summary table may be omitted on subdivision plans.

Direction of flow within streets, alleys, natural and man-made drainage ways, and at all system intersections shall be clearly shown on the drainage area map. This includes sags, crests and corners. Existing and proposed drainage inlets, storm drainage systems and drainage channels shall be clearly shown and differentiated on the drainage area map.

2.17 DRAINAGE EASEMENTS

All drainage being conveyed across a platted lot shall be in a drainage easement. Drainage easements shall be granted on plats or by separate instrument if the property has not been platted. This ordinance shall apply to all areas within the jurisdiction of the city and drainage easements shall be conveyed to the city for plat approval, issuance of a building permit, issuance of an earthwork permit, approval of construction plans by the Engineering Department, and/or for site plan approval subject to Sect. 245 of the Texas Local Government Code.

No building, wall, pool, or other structure shall be located or constructed within a Drainage Easement (DE). Only the following facilities may be allowed in a DE (outside the erosion clear zone) with written approval of the Public Works Director.

a. A fence may be placed in a drainage easement when the construction plans are approved prior to construction. A fence shall not impede the flow and have a minimum 3-inch vertical clearance above the water surface for design flows less than 5 cubic feet per second (cfs) and a minimum 8-inch clearance for design flows exceeding 5 cfs. Wrought iron fences may be within the drainage when they can convey the flow 50-percent clogged with debris and maintaining the specified clearances above the water surface. Fences within the floodplain at and near Lake Lewisville shall also be approved by the US Army Corps of Engineers.

b. Facilities transverse to the DE such as railroads, streets, bridges, and utilities.

c. Park amenities, such as trails, playgrounds, and benches.

d. Parking lots and driveways may be placed within drainage easements when they are constructed above the 100-year floodplain or the drainage is in a closed conduit and the overflow does not exceed 6-inches in depth within the parking lot.

DE's shall be shown, labeled, and described by metes and bounds on the plat or when provided as a separate instrument.

Overland flow shall be maintained as sheet flow within a drainage easement where possible. Concentrated flows shall be controlled with drainage structures.
Channels are all swales, ditches, floodplain areas with fill, once natural channels that have been disturbed including realignment and/or the placement of fill within the floodplain, and lined and unlined drainageways where the flow has a free surface and is not in a closed conduit. Natural channels are undisturbed streams where no fill has been placed in the floodplain and includes the mainstream channel and associated floodplain.

DE's shall have the following minimum widths unless otherwise approved in writing by the Public Works Director.

a. Channels shall have as a minimum 1-foot of freeboard in the DE.

b. Earthen channels conveying greater than 10-cfs shall have 4-feet each side of the top of bank at a maximum 10-percent cross-slope in the DE.

c. Lined channels 3-feet deep or less shall have 6-feet each side of the top of bank at a maximum 10-percent cross-slope in the DE.

d. Lined channels greater than 3-feet deep shall have 15-feet each side of the top of bank at a maximum 10-percent cross-slope in the DE.

e. DEs shall not be less than 15-feet for storm drain pipes 36-inches in diameter or less.

f. DEs shall not be less than 20-feet for storm drain pipes greater than 36-inches in diameter.

g. DEs for storm drain boxes shall include a minimum of 8-feet clear on each of the box.

h. Natural channels shall have 10-feet each side outside the 100-year floodplain at a maximum 10-percent cross-slope and contain the Erosion Clear Zone.

The Erosion Clear Zone (ECZ) shall be fully contained within a drainage easement and one of the following shall apply.

a. When a line is projected from the toe of the slope of the bank of the natural creek on a four horizontal to one vertical slope to the natural ground surface.

   1. If the resulting intersecting line is greater than 50 feet horizontally from the toe of the natural bank, the ECZ shall be located at the inter-section point. This is illustrated in Figure III-4, *Deep Depth Creeks.*

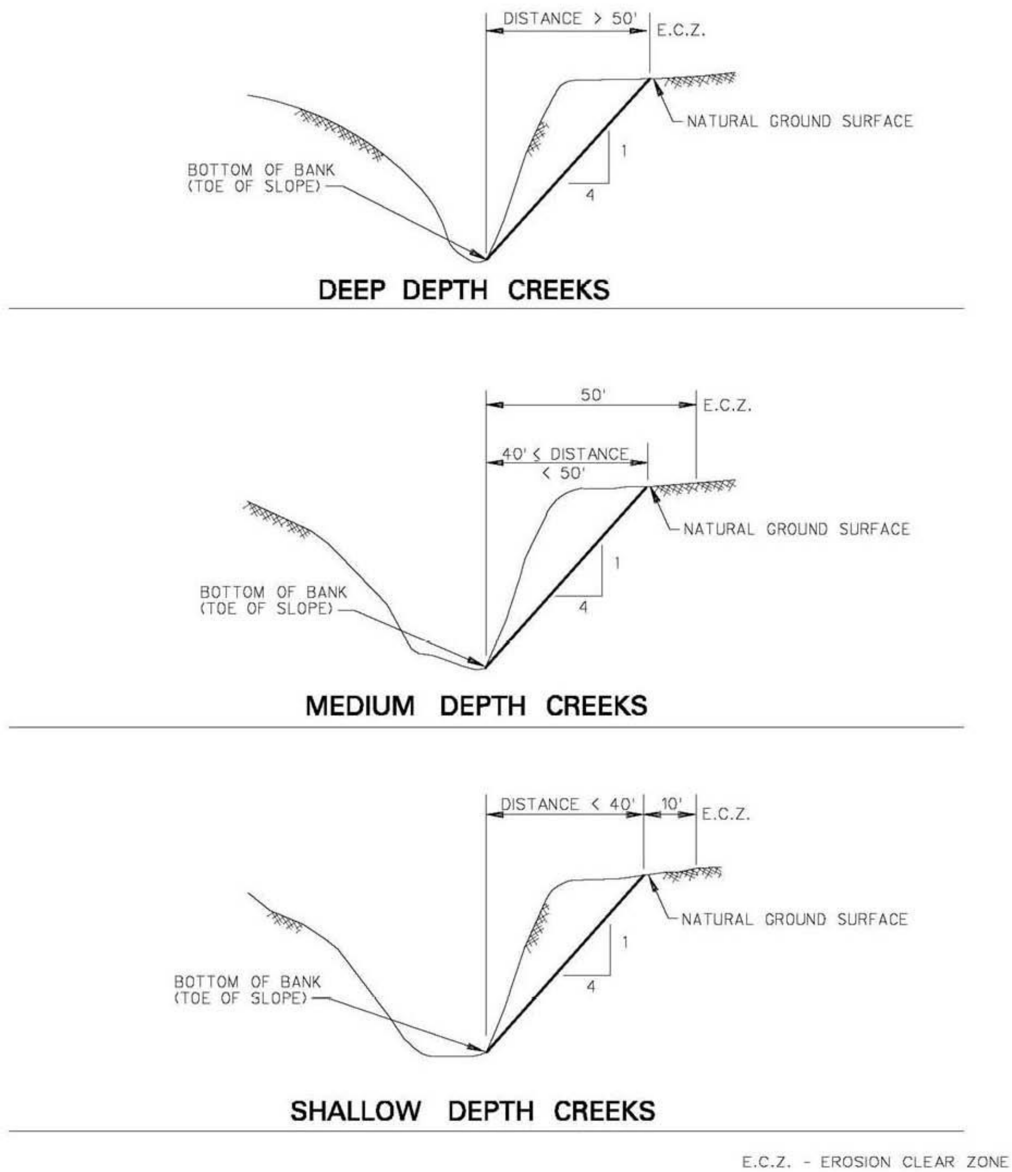
   2. If the resulting intersecting line is at least 40 feet, but less than 50 feet horizontally from the toe of the natural bank, additional footage shall be added to the requirements, so that a total of 50 feet measured horizontally from the toe of the bank is in the setback. This is illustrated in Figure III-4, *Medium Depth Creeks*.

   3. If the resulting intersecting line is less than 40 feet horizontally from the toe of the natural bank, additional 10 feet shall be added to the requirements. This is illustrated in Figure III-4, *Shallow Depth Creeks.*

b. In lieu of an ECZ, a plan to stabilize and protect the banks of the creek with design calculations shall be approved by the Engineering Department prior to construction.

FIGURE III-21

EROSION CLEAR ZONE



CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

PART IV - WATER AND WASTEWATER LINES

PART IV - WATER AND WASTEWATER LINES

I WATER MAINS

1.01 GENERAL

Water mains shall be placed on the north and east sides of a street, in accordance with the utility assignments in Appendix A. Where applicable, line sizes shall comply with the City's Water Distribution System Master Plan or subsequent revisions.

a. Water lines in the City of The Colony are categorized as:

   1. Distribution Lines – sizes 12-inch and less.

   2. Transmission Mains – sizes greater than 12-inches.

b. Mains shall be a minimum size of 8-inch diameter pipe. For mains in commercial and manufacturing districts, a minimum of 12-inch diameter pipe will be required if the main is over 600 feet in length.

c. Dead end lines are not allowed.

d. Fire hydrant lead lines shall be 6-inch diameter pipe no greater than 50 feet in length.

e. Water lines 12-inches and greater shall be profiled. P.I.s shall be stationed and elevations to 0.01 feet provided for all water lines.

1.02 WATER MAIN MATERIAL

a. Water mains 12-inches in diameter and smaller shall be AWWA C900 or C909 DR18 (Class 150) or DR 14 (Class 200) PVC, mechanical joint, or a bell and spigot joint. A recession in the bell shall have a single rubber gasket. Ductile iron fittings shall be used.

b. Water mains greater than 12 inches in diameter and larger shall be one of the following:

   1. Reinforced Concrete, Pretensioned Cylinder Pipe (RCCP), complying with AWWA C-303 (Pressure Class 150 or greater). RCCP pipe shall be provided with Cathodic protection. The Cathodic Protection System shall be designed by a Texas licensed professional engineer.

   2. PVC pipe with a minimum pressure Class of 165 PVC pipe shall not be used for mains greater than 24” diameter.

c. Water lines shall be minimum pressure Class 150.

d. All water mains outside utility easements which supply fire sprinkler systems shall be minimum 200 PSI working pressure and U.L. listed.

e. Water mains shall be standard sizes that are readily available, such as 6-inch, 8-inch, 12-inch, 16-inch, 18-inch, 20-inch, 24-inch, 30-inch, and 36-inch.

1.03 WATER VALVES

Valves 12-inches and smaller shall be placed on or near street property lines and shall be spaced at a maximum of 800 feet apart in residential and 500 feet in all other districts. They shall be placed in such a manner as to require preferably two, but not more than three valves to shut down each City block, or as may be required to prevent shutting off more than one fire hydrant. On cross-feed mains without services, a maximum of four valves shall be used to shut down each block. Also, valves shall be placed at or near the ends of mains in such manner that a shut down can be made for a future main extension without causing loss of service on the existing main. If valves cannot be located for such a shut-down, restrained joints shall be used. The location of valves larger than 12-inches will be as approved by the Director of Engineering and Utilities. Valves 12-inches and under shall be Resilient Seat Gate Valves (RSGV). Valves larger than 12 inches shall be Butterfly Valves.

1.04 FIRE HYDRANTS

a. Number and Locations

A sufficient number of fire hydrants shall be installed to provide hose stream protection for every point on the exterior wall of the building. There shall be sufficient hydrants to concentrate the required fire flow, as recommended by the publication "GUIDE FOR DETERMINATION OF REQUIRED FIRE FLOW" published by the Insurance Service Office, around any building with an adequate flow available from the water system to meet this required flow. In addition, the following guidelines shall be met or exceeded:

1. SINGLE FAMILY AND DUPLEX RESIDENTIAL - As the property is developed, fire hydrants shall be located at all intersecting streets and at intermediate locations between intersections at a maximum spacing of 500 feet between fire hydrants as measured along the route that fire hose is laid by a fire vehicle. All buildings shall be within a 500 foot radius of a fire hydrant.

2. MULTIFAMILY RESIDENTIAL - As the property is developed, fire hydrants shall be located at all intersecting streets and at intermediate locations between intersections at a maximum spacing of 400 feet as measured along the length of the center line of the roadway, and the front of any structure at grade and shall be no further than 400 feet from a minimum of two fire hydrants as measured along the route that a fire hose is laid by a fire vehicle. All buildings shall be within a 400 foot radius of a fire hydrant.

3. OTHER DISTRICTS - As the property is developed, fire hydrants shall be located at all intersecting streets and at intermediate locations between intersections at a maximum spacing of 300 feet as measured along the length of the center line of the roadway, and the front of any structure at grade and shall be no further than 400 feet from a minimum of two fire

hydrants as measured along the route that a fire hose is laid by a fire vehicle. All buildings shall be within a 300 foot radius of a fire hydrant.

4. PROTECTED PROPERTIES - Fire hydrants required to provide a supplemental water supply for automatic fire protection systems shall be within 100 feet of the fire department connection for such system.

5. Fire hydrants shall be installed along all fire lane areas as follows:

   (a) <u>Non-Residential Property or Use</u>

      (1). Within 150 feet of the main entrance.

      (2). Within 100 feet of any fire department connection.

      (3). At a maximum intermediate spacing of 300 feet as measured along the length of the fire lane.

   (b) <u>Apartment, Townhouse, or Cluster Residential Property or Use</u>

      (1). Within 100 feet of any fire department connection.

      (2). At maximum intermediate spacing of 400 feet as measured along the length of the fire lane.

6. Generally, no fire hydrant shall be located closer than fifty (50') feet to a non-residential building or structure unless approved by the Utility Director and Fire Department.

7. In instances where access between the fire hydrant and the building which it is intended to serve may be blocked, extra fire hydrants shall be provided to improve the fire protection. Railroads, expressways, major thoroughfares and other man-made or natural obstacles are considered as barriers.

8. Along divided arteries fire hydrants shall be installed on both sides of the roadway so as to preclude the need for laying hose across the roadway.

b. Restrictions

1. All required fire hydrants shall be as required by the North Central Texas Council of Governments Specifications, Fourth Edition and Addenda and shall be placed on water mains of no less that six (6") inches in size.

2. Valves shall be placed on all fire hydrant leads.

3. Required fire hydrants shall be installed so the break away point will be no less than three (3") inches, and no greater than five (5") inches above the grade surface.

4. Fire hydrants shall be located a minimum of two (2') feet and a maximum of six (6') feet behind the curb line, depending on the location of the sidewalk. The fire hydrant shall not be in the sidewalk.

5. All required fire hydrants placed on private property shall be adequately protected by either curb stops or concrete filled steel posts or other methods as approved by the Utility Director and Fire Department and shall be in easements. Such stops or posts to be the responsibility of the landowner on which the said fire hydrant is placed.

6. All required fire hydrants shall be installed so that the steamer connection will face the fire lane or street, or as directed by the Fire Department.

7. Fire hydrants, when placed at intersections or access drives to parking lots, when practical, shall be placed so that no part of the fire truck will block the intersection or parking lot access when connections to the fire hydrant are made.

8. Fire hydrants, required by this article, and located on private property, shall be accessible to the Fire Department at all times.

9. Fire hydrants shall be located at street or fire lane intersections, when feasible.

10. Fire hydrant bonnet shall be painted according to Standard Details.

1.05 FIRE LINE METERING

Generally, the City of the Colony will own, operate and maintain all fire lines serving fire hydrants. Such fire lines shall be designed and constructed in accordance with the City's standards and shall be placed in an easement dedicated to the City for this purpose. Sprinkler service lines, fire line connections and other fire lines which are not maintained by the City shall be equipped with either a water meter or a detector check assembly having a capacity equal to the required fire flow. Water meters and detector check assemblies shall be constructed in accordance with City standards.

1.06 MINIMUM COVER

The minimum cover to the top of the pipe must vary with the valve stem. In general, the minimum cover below the street grade should be as follows: 12-inch and smaller, 4.0 feet. Lines larger than 12-inch shall have 5.0 to 6.0 feet of cover. Water lines with more than 6.0 feet of cover shall be approved by the Utility Director. For water lines to be constructed along county type roads, which are commonly built with a high crown about the surrounding property, increase the cover as required to allow for future paving grade changes.

1.07 CLEARANCES BETWEEN WATER AND WASTEWATER LINES:

Clearances between water and wastewater lines shall meet State requirements. Minimum clearances for water and wastewater lines crossing storm drains shall be two (2) feet or one-half (0.5) feet when the water or wastewater line is encased.

1.08 METER BOX AND SERVICE

A service with a meter box is constructed from the main to a point just behind the curb line, usually in advance of paving. The location of the meter box is as shown on the Utility Assignments detail sheets and as shown on the City of The Colony Details. On multiple apartments and business properties, the desired size and location is usually specified by the owners. Minimum requirements for water service sizes are:

a. One-inch single water services are required to serve all single-family residential lots including townhouse lots and patio homes. Separate meter connections shall be provided for each of the family units.

b. The size of apartment, condominium, or multi-family services will depend on the number of units served with a minimum of one meter per building.

1.09 SERVICE CONNECTIONS

a. Service connections shall not be allowed to fire hydrant leads.

b. Service connections shall not be allowed to transmission mains.

II. WASTEWATER

2.01 MINIMUM SIZE

The minimum size of wastewater mains in the City of The Colony shall be 8-inch. 6-inch lines may be used to connect to existing 6-inch mains and then only when approved by the Utility Director. Line sizes shall convey peak flows as shown on the City's Wastewater Master Plan or subsequent revisions. All wastewater lines shall be standard sizes such as 6-inch, 8-inch, 12-inch, 15-inch, 18-inch, 21-inch, 24-inch, 30-inch, and 36-inch.

2.02 LOCATION

Sewers shall be constructed with extensions to the development boundary to allow for direct connection by future developments. If feasible, sewers shall be placed in streets. Sewers shall generally be located in the center of the street.

2.03 MINIMUM COVER

Minimum cover over all wastewater mains shall be 4.0 feet unless approved by the City Engineer. Approved mains with less than 3.5 feet of cover shall be capped as per the "Cap Detail" on the Wastewater Standard Details.

2.04 WASTEWATER FLOWS, SIZE AND GRADES

Wastewater lines shall be designed to convey flows from all upstream areas based on ultimate development of the sewershed. Wastewater flows shall be obtained from the City's Wastewater Master Plan. Subbasin flow shall be computed in accordance with the following formula:

$$Q = \frac{C^{0.89}}{295}$$

Where:

Q = Peak wastewater flow (million gallons per day)
C = Equivalent single family connections

This equation is graphically displayed in Figure IV-1. Equivalent single family connections are based on a density of 3.1 persons per dwelling unit. Densities for other residential uses shall be determined by the City Engineer. Wastewater flow for non- residential uses shall be evaluated by the design engineer and submitted to the City Engineer for approval.

Pipes should be placed on such a grade that the velocity when flowing full is not less than two feet or more than ten feet per second. Minimum grades shall be as follows:

6" - 0.50%	8" - 0.33%	10" - 0.26%	12 - 0.20%
15" - 0.14%	18" - 0.12%	21" - 0.10%	24" - 0.08%

All grades shall be shown to the nearest 0.01 foot with P.I. stationing. When the slope of a wastewater line changes, a manhole will be required. No vertical curves will be allowed. Horizontal curves (meeting pipe manufacturer recommendations) to match change in street direction will be allowed as approved by the Utility Director.

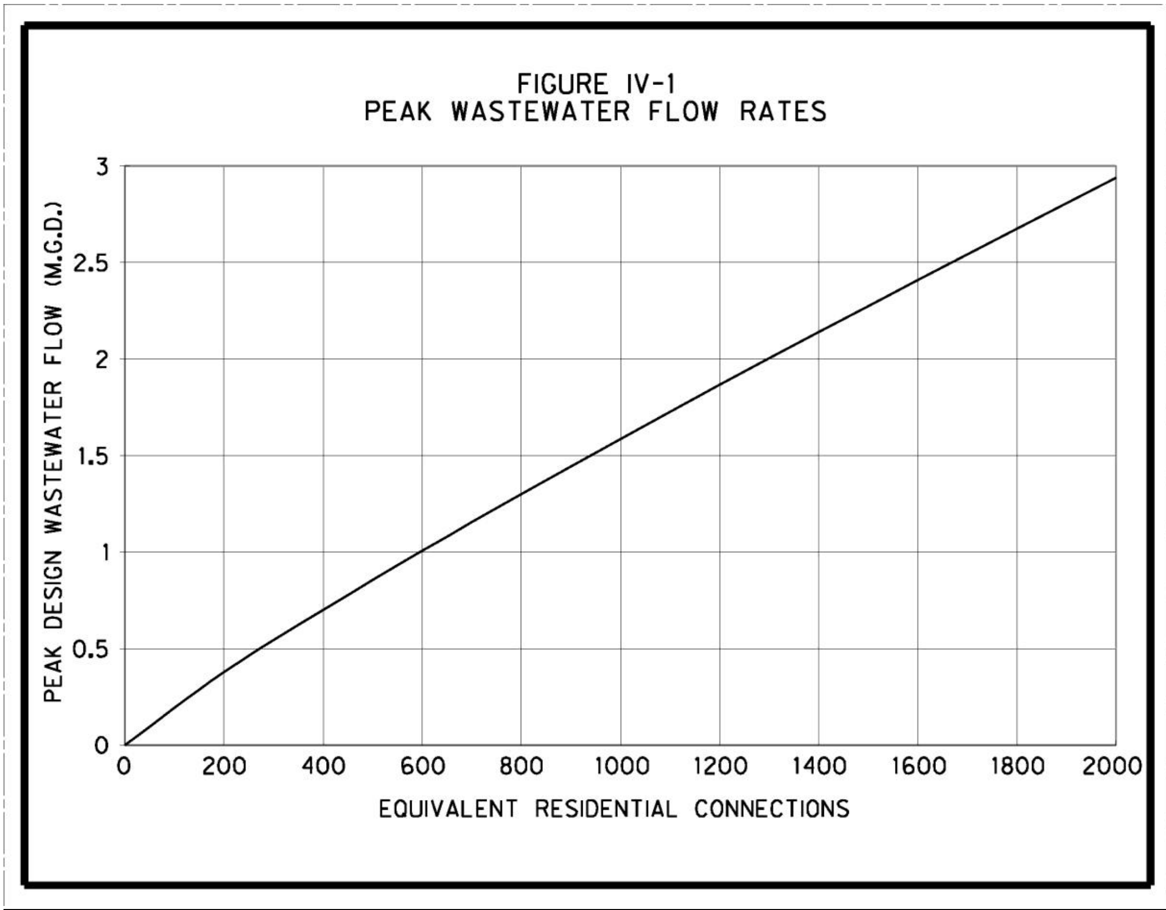


FIGURE IV-1
PEAK WASTEWATER FLOW RATES
PEAK DESIGN WASTEWATER FLOW (M.G.D.)
3
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
1200
1400
1600
1800
2000
EQUIVALENT RESIDENTIAL CONNECTIONS

2.05 MANHOLES

The sizes shall be as designated on the Wastewater Standard Details. In general, manholes shall be placed at all four-way connections and three-way connections. The diameter of a manhole constructed over the center of a sewer should vary with the size of the wastewater line. In floodplains, sealed manhole covers shall be used. Drop manholes shall be required when the inflow elevation exceeds the outflow elevation by more than 24 inches.

TABLE IV-1

MINIMUM MANHOLE SIZES

Largest Main Size of Manhole	Manhole Diameter
6" – 8"	4' 0"
12" – 24"	5' 0"
Greater than 24"	6' 0"

Manholes more than 8 feet deep shall be a minimum of 5 foot diameter.

2.06 LATERALS

For single family dwellings, the lateral size shall be 4" minimum; for multiple units, apartments, local retail and commercial - 6" minimum; for manufacturing and industrial, the size should be determined by the Engineer. House laterals shall be located 10 feet downstream from the center of the lot, and shall have a 10-foot lateral separation from the water service. Manholes will be required on 6-inch and larger laterals where they connect to the main line. Laterals will not be connected to sewer mains that are deeper than 12 feet. A minimum of one lateral per building shall be required. Also, a minimum of one lateral per residential lot shall be required. Duplexes shall have a lateral to each unit.

A cleanout shall be installed in each lateral and located at the right-of-way or easement line.

2.07 WASTEWATER LINE MATERIALS

a. All wastewater lines shall be PVC SDR 35 for depths less than 14 feet and SDR 26 for deeper installation.

b. For wastewater lines crossing creeks with a minimum cover of 5 feet or more to the flowline, wastewater lines shall be PVC with concrete encasement and shall extend 50 feet beyond the streambanks.

c. For wastewater lines crossing creeks with a minimum cover of 5 feet or less to the creek flowline, wastewater lines shall be cement lined ductile iron pipe with polywrap. Each joint shall be strapped to a concrete pier drilled to a depth at least 10 feet below the flowline of the pipe.

2.08 UTILITY EASEMENTS

All public utilities shall be in a utility easement. Utility easements shall be granted on plats or by separate instrument if the property is not platted.

No building, wall, or pool shall be located or constructed within a Utility Easement (UE). Only the following facilities may be allowed in a UE with written approval of the Utility Director.

a. A fence constructed of steel or wood may be placed in a UE;

b. Facilities transverse to the easement such as roads, streets and private utilites; and

c. Parking lots and driveways subject to written approval of the City Engineer.

UEs shall be shown, labeled and described by metes and bounds on the plat or when provided by separate instrument.

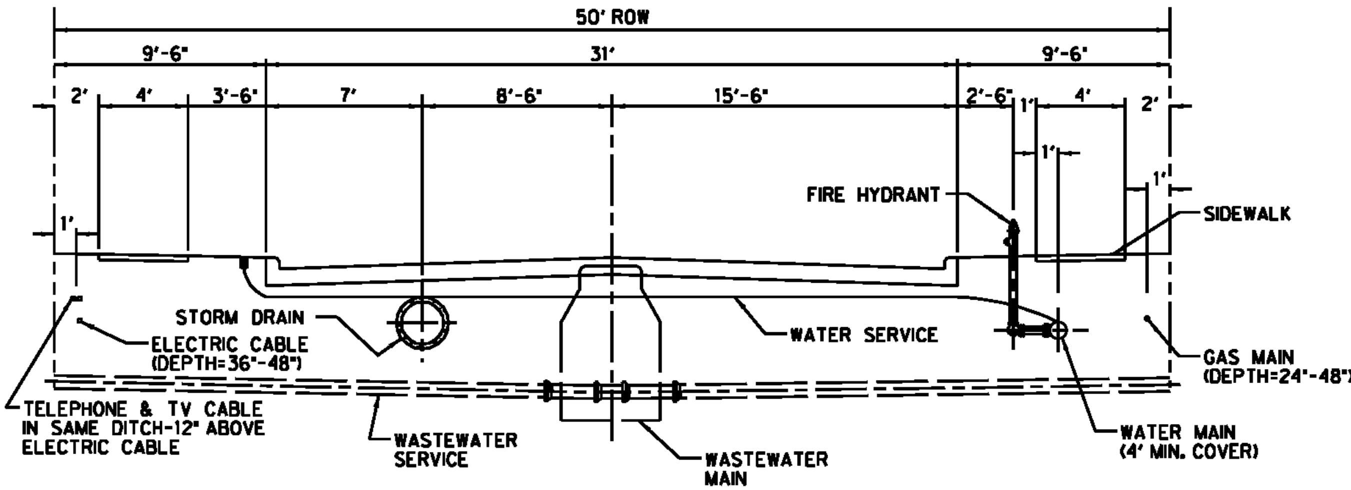
UEs shall have the following minimum widths unless approved in writing by the Utility Director.

a. No UE shall be less than 15' width.

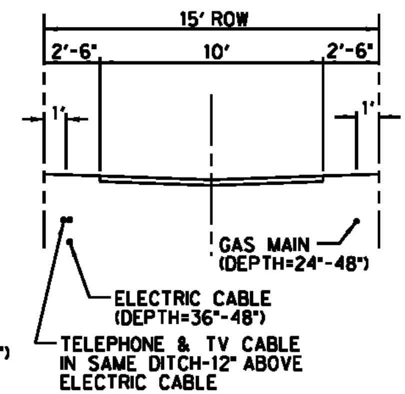
b. UEs with a water and wastewater line shall have a minimum width of 25'.

c. When there are more than two utility lines or a line is greater than 12" diameter, then the width of the UE will be determined by the Utility Director. Typical easement width with a single line are: 16" to 20" diameter 20' easement; 24" to 27" 25' easement; and 30" and greater 30' easement.

Appendix “A”



RESIDENTIAL TYPE "A"
SECTION LOOKING NORTH OR WEST
N.T.S.

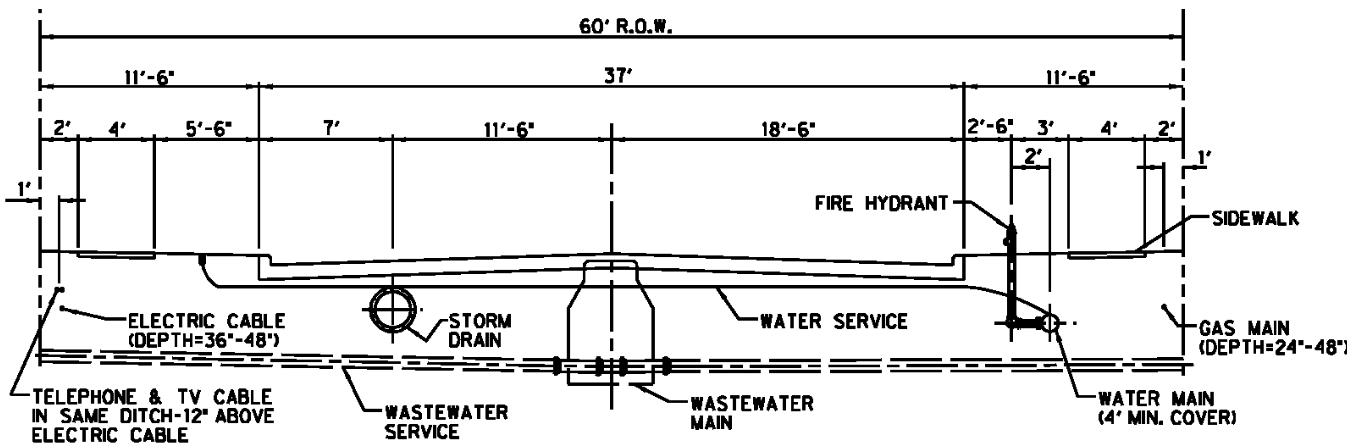


ALLEY SECTION
LOOKING NORTH OR WEST
N.T.S.

NOTE:
GAS, ELECTRIC AND TV CABLE UTILITIES ARE TO BE LOCATED IN ALLEYS WHERE POSSIBLE.

UTILITY ASSIGNMENTS

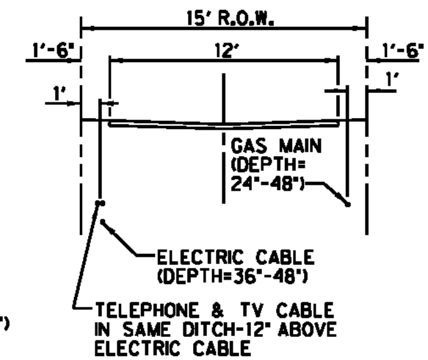
A-1



NOTE:
IF A SCREENING WALL IS REQUIRED, ALL FRANCHISED UTILITIES MUST BE LOCATED IN A 5' WIDE EASEMENT ADJACENT TO STREET ROW. EASEMENTS ARE REQUIRED ON BOTH SIDES OF THE STREET IF BOTH GAS AND ELECTRIC UTILITIES ARE PRESENT IN THE SAME STREET.

COLLECTOR TYPE "2U-C"
SECTION LOOKING NORTH OR WEST

N.T.S.



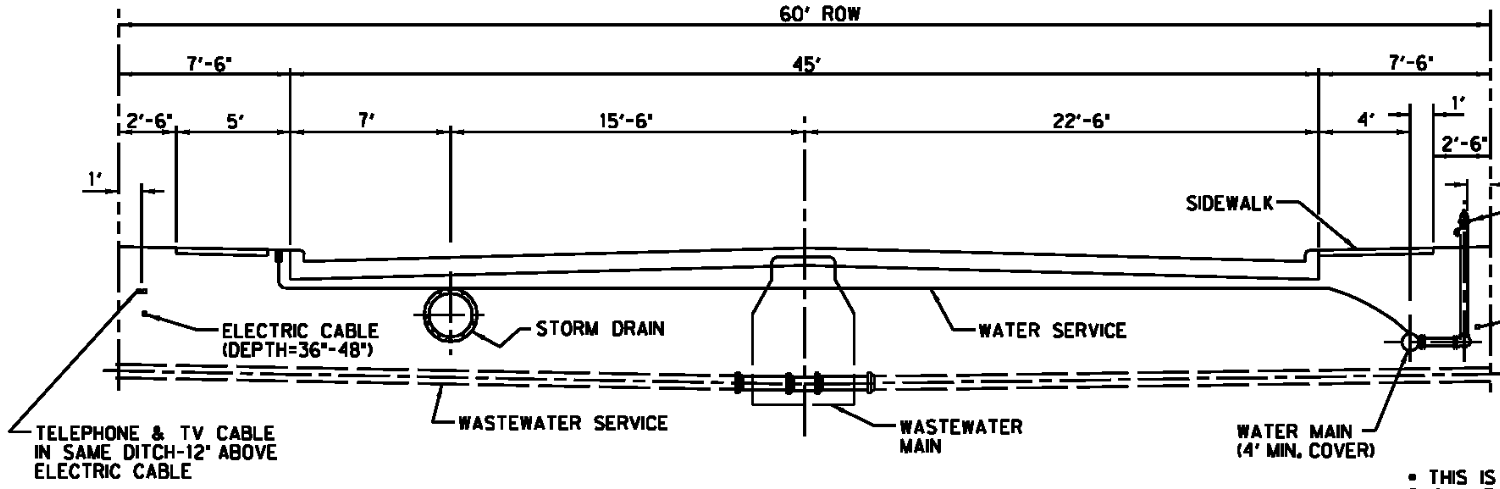
ALLEY AT FLARES
SECTION LOOKING
NORTH OR WEST

N.T.S.

NOTE:
GAS, ELECTRIC AND TV CABLE UTILITIES ARE TO BE LOCATED IN ALLEYS WHERE POSSIBLE.

UTILITY ASSIGNMENTS

A-2



* THIS IS NORMAL LOCATION FOR GAS LINE EXCEPT NEAR FIRE HYDRANTS. NEAR HYDRANTS, GAS LINE TO BE LOCATED ON A 5 FT EASEMENT ADJACENT TO THE STREET ROW.

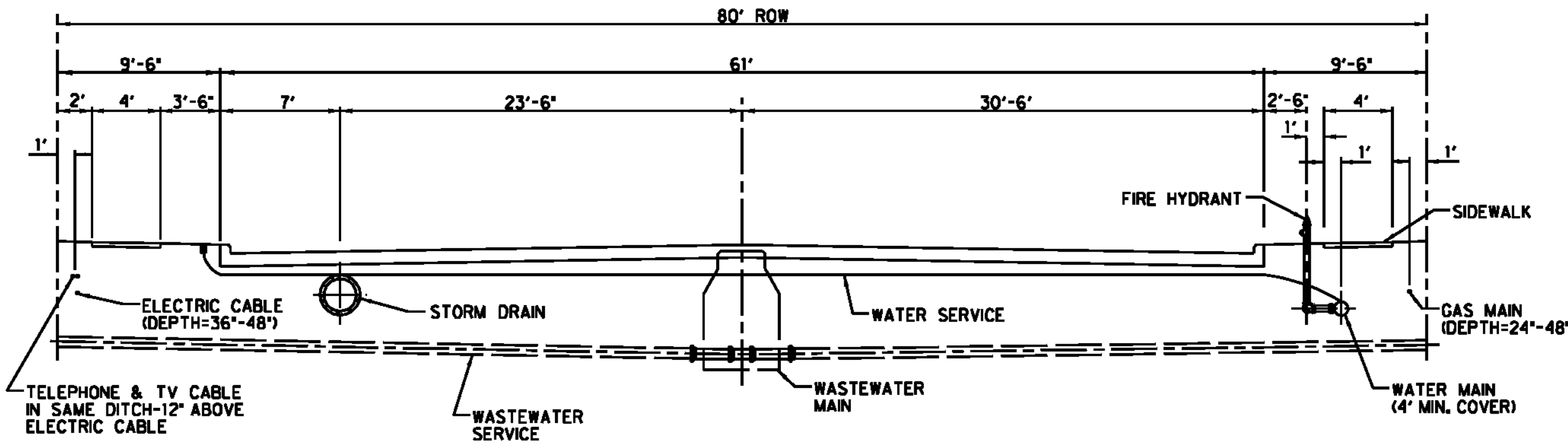
NOTE:
IF A SCREENING WALL IS REQUIRED, ALL FRANCHISED UTILITIES MUST BE LOCATED IN A 5' WIDE EASEMENT ADJACENT TO STREET ROW. EASEMENTS ARE REQUIRED ON BOTH SIDES OF THE STREET IF BOTH GAS AND ELECTRIC UTILITIES ARE PRESENT IN THE SAME STREET.

COLLECTOR TYPE "4U-B"
SECTION LOOKING NORTH OR WEST

N.T.S.

UTILITY ASSIGNMENTS

A-3

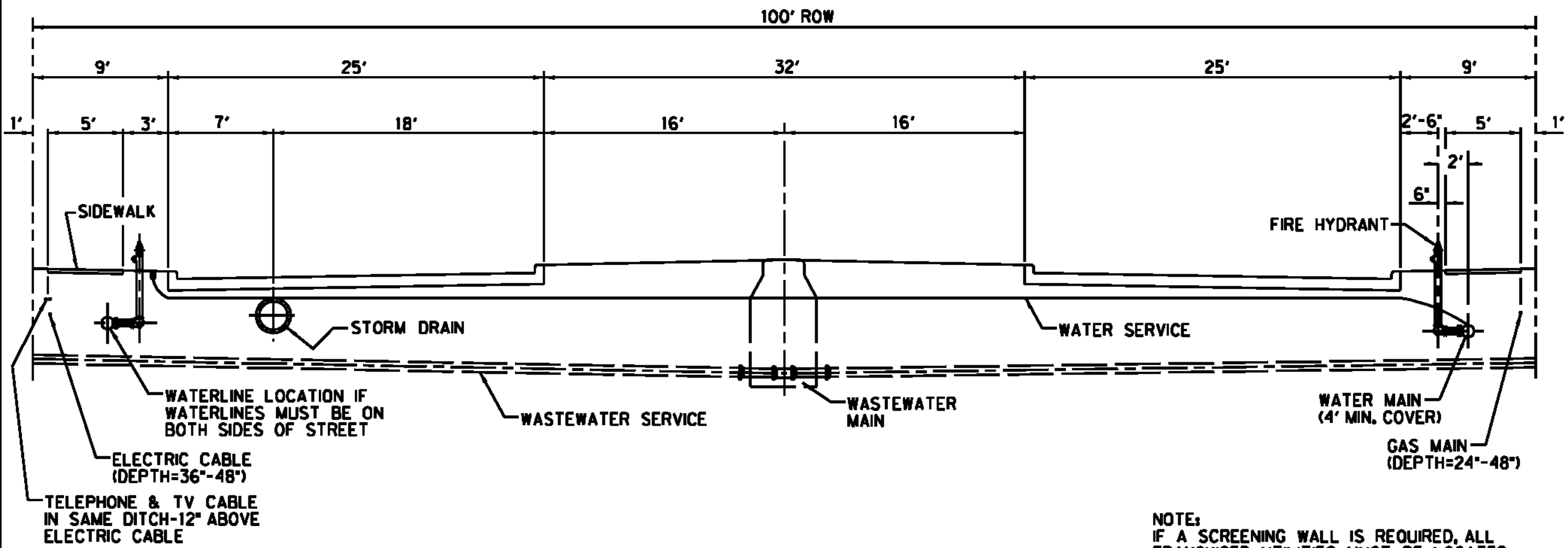


NOTE:
IF A SCREENING WALL IS REQUIRED, ALL FRANCHISED UTILITIES MUST BE LOCATED IN A 5' WIDE EASEMENT ADJACENT TO STREET ROW. EASEMENTS ARE REQUIRED ON BOTH SIDES OF THE STREET IF BOTH GAS AND ELECTRIC UTILITIES ARE PRESENT IN THE SAME STREET.

COLLECTOR TYPE "4U-A"
SECTION LOOKING NORTH OR WEST
N.T.S.

UTILITY ASSIGNMENTS

A-4

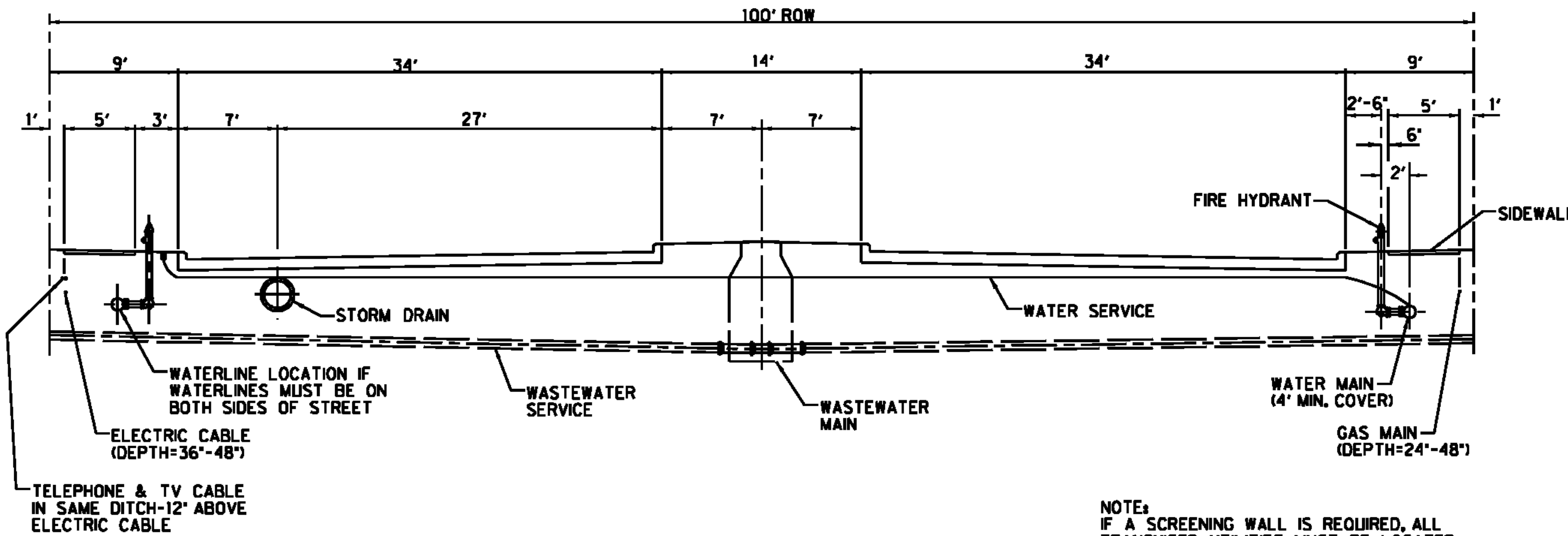


NOTE:
IF A SCREENING WALL IS REQUIRED, ALL FRANCHISED UTILITIES MUST BE LOCATED IN A 5' WIDE EASEMENT ADJACENT TO STREET ROW. EASEMENTS ARE REQUIRED ON BOTH SIDES OF THE STREET IF BOTH GAS AND ELECTRIC UTILITIES ARE PRESENT IN THE SAME STREET.

MAJOR TYPE "4D-C"
SECTION LOOKING NORTH OR WEST
N.T.S.

UTILITY ASSIGNMENTS

A-5

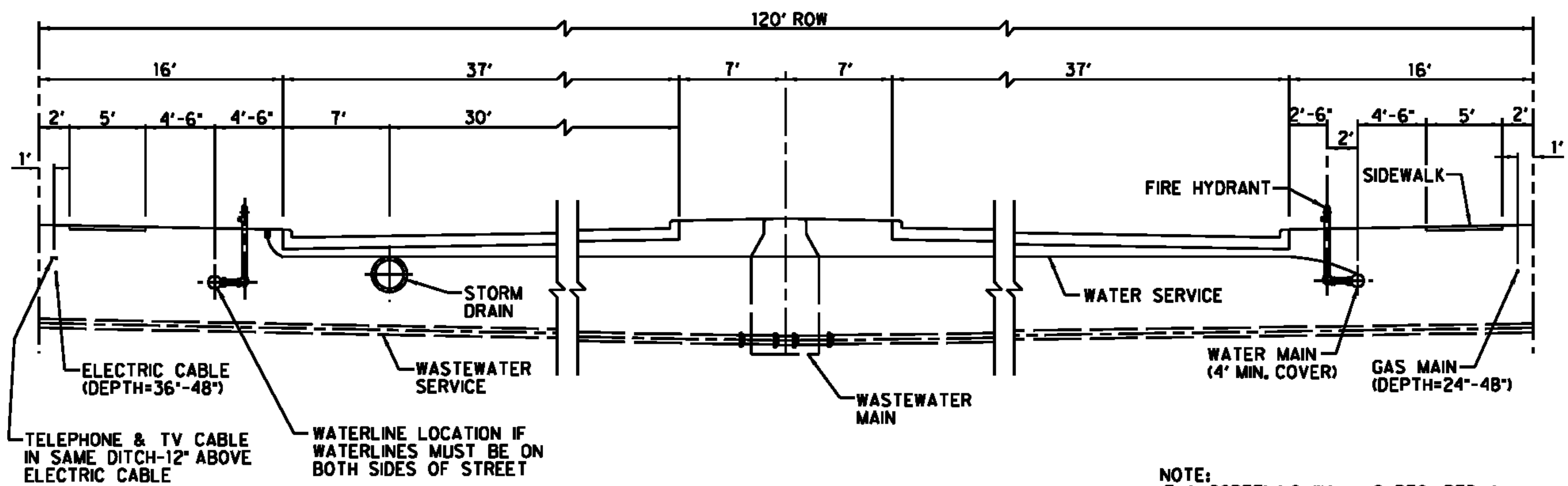


NOTE:
IF A SCREENING WALL IS REQUIRED, ALL FRANCHISED UTILITIES MUST BE LOCATED IN A 5' WIDE EASEMENT ADJACENT TO STREET ROW. EASEMENTS ARE REQUIRED ON BOTH SIDES OF THE STREET IF BOTH GAS AND ELECTRIC UTILITIES ARE PRESENT IN THE SAME STREET.

MAJOR TYPE "6D-B"
SECTION LOOKING NORTH OR WEST
N.T.S.

UTILITY ASSIGNMENTS

A-6

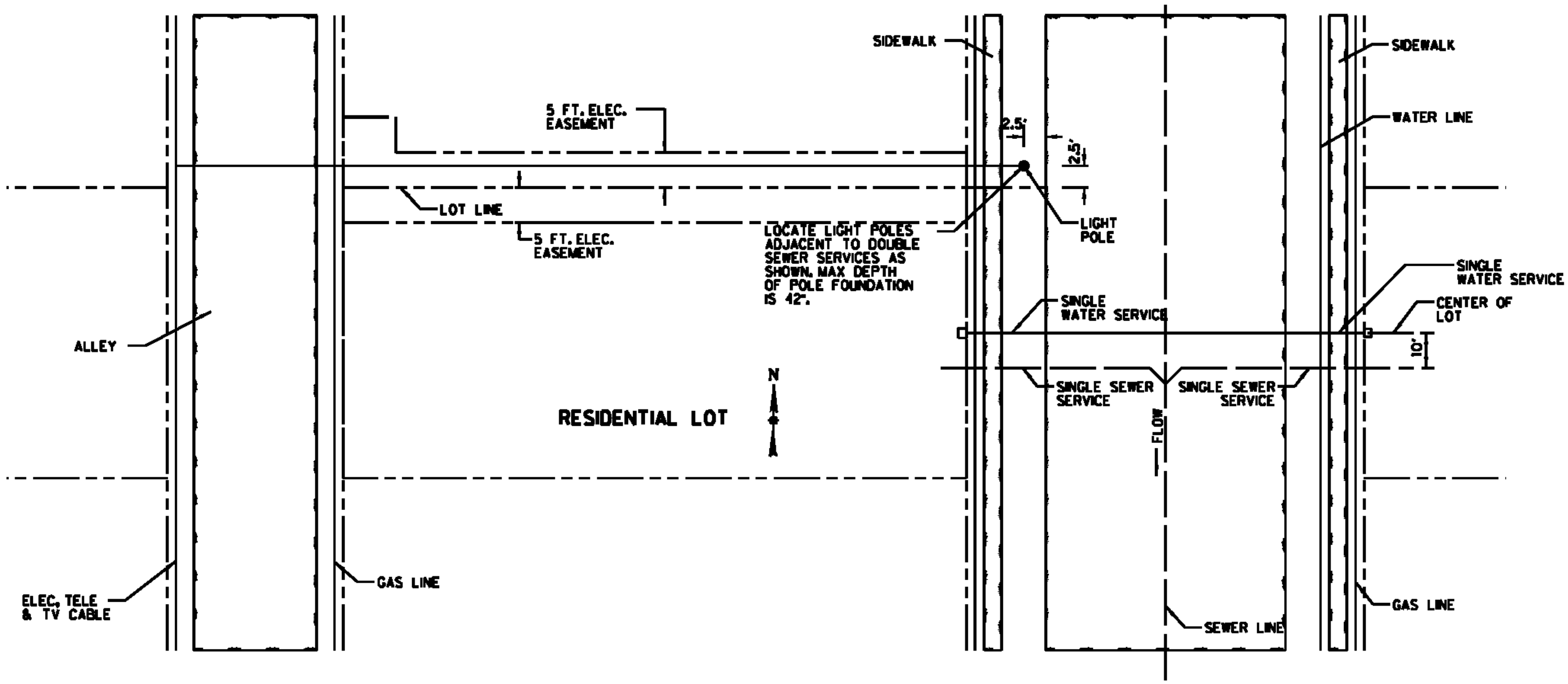


NOTE:
IF A SCREENING WALL IS REQUIRED, ALL FRANCHISED UTILITIES MUST BE LOCATED IN A 5' WIDE EASEMENT ADJACENT TO STREET ROW. EASEMENTS ARE REQUIRED ON BOTH SIDES OF THE STREET IF BOTH GAS AND ELECTRIC UTILITIES ARE PRESENT IN THE SAME STREET.

MAJOR TYPE "6D-A"
SECTION LOOKING NORTH OR WEST
N.T.S.

UTILITY ASSIGNMENTS

A-7



NOTE:
TELEPHONE AND TV CABLE PEDESTALS WHEN LOCATED IN THE STREET, SHALL BE PLACED AT THE SAME LOT LINE AS THE DOUBLE SEWER SERVICES.

TYPICAL UTILITY PLAN

N.T.S.

UTILITY ASSIGNMENTS

A-8

Appendix “B”

CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

APPENDIX "B"

PRIVATE DEVELOPMENT GENERAL NOTES

1. All work shall be done in accordance with the City of The Colony standard details and specifications which has adopted the North Central Texas Council of Governments (N.C.T.C.O.G.) "STANDARD SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION", Fourth Edition and Addenda. Copies may be obtained from the "NORTH CENTRAL COUNCIL OF GOVERNMENTS", PO Drawer 5888, Arlington, Texas, 76005-5888, Phone (817) 640-3300; also available at www.publicworks.dfwinfo.com A copy of the contract documents, plans and specifications shall be available on-site at all times by the Contractor.

2. The location and depth of all utilities shown on the plans are approximate and there may be other unknown existing utilities not shown on the plans. All existing utilities shall be field verified and protected by the Contractor prior to the start of construction. Also see **General Note No. 3(D)**. The contractor shall contact the following utility companies 72 hours prior to doing any work in the area:

a.	Texas One Call	1 (800) 245-4545
b.	City of The Colony Water Department	(972) 624-3113
c.	TXU Electric	(972) 985-2075
d.	Atmos Energy	(972) 881-4161
e.	AT&T	(972) 569-3010
f.	Time Warner Cable	(214) 320-5435
g.	Coserv Electric	(940) 321-7800
h.	Coserv Gas	(940) 321-7800

3. It shall be the responsibility of the Contractor to perform the following:

   a. Prevent any property damage to property owner's poles, fences, shrubs, mailboxes, etc.
   b. Provide access to all drives during construction.
   c. Protect all underground and overhead utilities and repair any damages. Also see **General Note No. 2.**
   d. Notify all Utility Companies and verify location of all utilities prior to the start of construction.
   e. Cooperate with the Utility Companies where utilities are required or specified to be relocated.
   f. Work in close proximity to and protect existing Utility Mains, traffic lights and poles.
   g. Any item not specifically called out to be removed shall be brought to the attention of the Engineer prior to removing that item or it shall be replaced at the Contractor's own expense.
   h. Any tree, shrub, or grassed areas damaged by the Contractor's work shall be repaired at the Contractor's expense

4. In the preparation of the plans and specifications, the Engineer has endeavored to indicate the location of existing underground utilities. It is not guaranteed that all lines or structures have been shown on the plans

5. The Contractor shall verify, locate, and protect existing water, sanitary sewer, storm sewer, gas, electric and telephone mains and services and restore service in case of any damage.

6. The Contractor shall provide proper barricades and maintain traffic flow as per Manual on Uniform Traffic Control Devices (MUTCD) at all times.

7. The location for the disposal of construction material shall be approved by the City of The Colony Engineering division prior to the start of construction.

8. All phases of construction must be coordinated with the Engineer. Also, the Contractor is required to coordinate with the property owners in order to minimize conflicts

9. Field adjustments may be necessary and will be carried out as directed by the Engineer

10. The Contractor shall contact the City of The Colony Engineering Department prior to any sign removal. Please See General Note No. 3. Sign removal and reinstallation/relocation shall be in good condition equal to or better than existing condition, and as per the Engineer's specifications.

11. All fences, signs, and property corner monuments removed for, or damaged during construction shall be replaced with new material as per the Engineer's specifications.

12. The Contractor shall relocate existing mailboxes in conflict with the proposed improvements and as specified on the plans, in good condition equal to or better than existing condition, complete in place. The mailboxes shall be accessible at all times for mail delivery.

13. The Contractor shall be responsible for taking all precautions to protect existing trees outside the scope of this Project.

14. The Contractor shall be responsible for repairing any damage caused by the Contractor outside of the designated work area with new quality material at the Contractor's expense.

15. The Contractor shall locate, verify working condition and protect all existing sprinkler systems lines and heads (if any). Remove, adjust and reinstall in good condition equal to or better than existing condition; replace, if in direct conflict, with the same or better quality material and appurtenances.

16. All existing grades shown on the plans are approximate and shown based on the best information available.

17. All backfill for ditch lines are to be mechanically tamped to 95% STD Proctor density (ASTM D698), at a moisture content near optimum (-1% to +3%).

18. Contractor to fill all voids under existing pavement when installing new line. Also all ditch lines must be filled at the end of each day’s work.

19. All pipe shall be kept free of trash and dirt at all time. At the end of each day, the pipe shall be temporarily connected/sealed.

20. The Contractor shall keep the existing fire hydrants in service at all times.

21. The Contractor shall maintain the existing water mains in service during all phases of construction. Leaks caused by the Contractor shall be repaired immediately at the Contractor's expense. Leaks along the existing water main close to the working area, caused by vibration, etc. (during working hours) shall be repaired by the Contractor with the City only providing the required parts. The City will repair all leaks if the Contractor is not on the job-site (primarily after working hours); if the leak is directly caused by the Contractor and not repaired, all charges incurred shall be billed to the Contractor.

22. All cutting and plugging of the existing water main where specified on the plans, shall include all labor, fittings and appurtenances required to perform this work, with the cost incidental to the project.

23. The Contractor shall maintain the existing sanitary sewer mains and services in operation when installing the proposed sanitary sewer main. This shall include any temporary connections, if required.

24. Clearances on water and wastewater lines shall meet State requirements. Minimum clearances for water and wastewater lines crossing storm drains shall be two (2) feet or one-half (0.5) feet when the water or wastewater line is concrete encased.

25. Street closing requests shall be submitted to the City of The Colony Engineering Department in writing, a minimum of two weeks in advance of any street closing for notifications to Police, Fire, Mail, Garbage and School. There are no guarantees that street closings will be approved by the City.

26. Seed/sod shall be furnished to establish ground cover over all disturbed areas as an erosion control measure. The Contractor shall not wait until the Completion of the entire project before doing this work. The project shall not be accepted by the City Engineer prior to the establishment of ground cover.

27. Sheeting, shoring, and bracing: The contractor will abide by all applicable federal, state, and local laws governing excavation, Trench's side slopes shall meet Occupational Safety and Health Administration (OSHA) standards that are in effect at the time of construction. Sheeting shoring and bracing shall be required if side slope standards are not met. A pull box, meeting OSHA standards, will be acceptable. The Contractor will submit detailed plans and specifications for trench safety systems that meet OSHA standards that are in effect at the time of development of project when trench excavation will exceed a depth of five (5) feet. These plans will be sealed by an Engineer registered by the State of Texas and submitted to the City before obtaining a construction permit.

28. Contractor shall conform activities to the SWPPP as specified, including installing, maintaining, and removing pollution controls, conducting and documenting inspections of pollution controls, sprinkling for dust control, maintaining spill response equipment on-site, and "good housekeeping". Pollution controls include silt fences (or straw bales), stabilized construction entrance, establishing grass, sprinkling for dust control. The Contractor shall also be responsible for submitting Notice of Intent (NOI) and Notice of Termination (NOT) to the Texas Commission on Environmental Quality (TCEQ).

29. The Contractor shall maintain the existing water mains and services in operation when installing the proposed water main. This shall include any temporary connections, if required in areas of conflict

30. Contractor must notify each property owner 24 hours prior to shutting off water for connection to new main.

31. The Contractor shall contact the City of The Colony at (972) 625-4471 for the operation of all water valves.

32. The cost of replacing all pavement markers, traffic buttons, striping, etc., disturbed during the construction shall be Contractor's responsibility to maintain, repair or replace.

33. The Contractor shall maintain the flow of traffic at all times and provide access to all drives.

34. The maximum deflection of pipe joints shall not exceed that recommended by the pipe manufacturer. If it is necessary to deflect the pipe (greater that the recommended amount) the Contractor shall provide fittings or specials.

35. The Contractor shall notify Engineering Inspection 48 hours in advance for all water or wastewater locates or turnoffs of water.

36. Prior to the start of construction, Inspection, Water/Wastewater and the Contractor shall make a dry run to the system to insure, to the extent possible, that the utility can be found and secured.

37. Work may not be backfilled until it has been inspected by the City.

38. For the development of any subdivision, the developer shall pay an inspection fee of four (4) percent of the total contract amount of work involving the installation or improvement of any of the following items intended for dedication to the City, located on City-owned property, and/or within a public easement: street, alley ways, water lines, wastewater lines, drainage or storm sewer systems, non-single family sidewalks and driveways, screening and/or retaining wall, and/or fences.

    One hundred percent of the fees must be paid at the time of the pre-construction meeting. Construction or developers must provide the City with copies of contracts for all infrastructure. These copies must include total linear feet of water lines, wastewater lines, streets, alleys and sidewalks.

    An additional fee of forty-dollars ($40.00) per hour with a two (2) hour minimum, shall be assessed for any inspection scheduled after regular engineering inspection hours (Monday through Friday from 7:00 a.m. to 6:00 p.m.), or on holidays.

    After-hours and holiday inspection requests must be scheduled at least twenty-four 924) hours in advance, and the fee paid at the time of the inspection request.

Appendix “C”

CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

APPENDIX "C"

ADDENDUM TO THE
NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS
STANDARD SPECIFICATIONS FOR PUBLIC WORKS CONSTRUCTION

This addendum to the North Central Texas Council of Governments Standard Specifications for Public Works Construction – Fourth Edition, sets forth (by reference number) exceptions or requirements of the City of The Colony, Texas and thereby takes precedence over any conditions or requirements of the Standard Specifications with which it is in conflict.

101.1 The term "OWNER" shall refer to the City of The Colony, Texas. The term "OWNER'S Representative" shall refer to the City's Engineer or other duly authorized assistant, agent, Engineer, inspector, or superintendent acting within the scope of the particular duties instructed to him or her.

Add new paragraph 103.3.1.5

103.3.1.5 MAINTENANCE BONDS

The Contractor shall furnish the City of The Colony with a Maintenance Bond from an approved surety company which protects the City against defective workmanship and materials for a period of two (2) years from the date of the final acceptance by the City. Where defective workmanship and/or materials are discovered requiring repairs to be made under this guarantee, all such repair work shall be done by the Contractor at his own expense within five (5) days after written notice of such defect has been given to him by the City. Should the Contractor fail to repair leaks or correct such defective workmanship and/or materials within five (5) days after being notified, the City may make the necessary repairs and charge the Contractor with the actual cost of all labor and materials required.

The Maintenance Bond shall be in the amount of $50,000.00 or 10 percent (10%) of the amount of the Contract, whichever is greater, but not to exceed 100 percent (100%) of the Contract amount. The Contractor shall execute the Maintenance Bond on the forms furnished by the City.

106.5 This item shall be revised to require that testing of all materials be performed by an independent testing laboratory acceptable to the City. The Contractor shall pay the cost of all material testing including the retesting of all materials which fail the required tests. Test reports of all materials tested shall be sent to the City.

Add a new paragraph 107.27:

107.27 RECORD DRAWINGS

The Contractor shall furnish two (2) sets of prints and one mylar reproducible set of drawings marked with the location of all water and sewer services, electrical cables and any changes in the plans. All record drawings to be delivered to the City of The Colony.

Add a new paragraph 109.7:

109.7 SUBSIDIARY ITEMS

Only those items in the Proposal will be measured and paid for. All other items of work required to complete the project shall be considered subsidiary to the pay items in the proposal and no claims whatsoever for extra work for such subsidiary items will be considered.

202.1 Where pipelines and conduits are placed in existing lawns or landscaped areas, remove and replace topsoil sod and other plants and guarantee the survival of all plants so replaced.

203.2 Delete: "the Contractor shall have 24 hours in which to comply with the instruction of the Owner" and replace with: "the City shall have the right to remedy without notice".

203.4.5 Removal and separation of topsoil is required unless otherwise noted. Finished grade shall be ± 0.1 feet of original grade unless otherwise noted. The Contractor is responsible for removing and disposing of all excess excavated materials. Such materials may not be left on public right-of-way or adjacent property without written permission to do so.

203.7.3 Density tests shall be performed by an independent testing laboratory and paid for by the Contractor. One Density test shall be performed for each 1000 C.Y. of embankment at a location selected by the City. The City may perform additional density tests at his expense. Density tests which fail shall be retested at the Contractor's expense. The minimum density for embankments subjected to vehicular traffic is 95% at 0 to 2% above optimum moisture in accordance with method Tex 113 E.

301.2 Unless otherwise noted, lime treatment applied to pavement subgrade shall be at a rate of not less than 6% of the subgrade dry weight.

301.2.3.4 Dry placing of lime is allowed only with special permission of the City.

301.2.3.5.1 One gradation test shall be performed for each 300 linear feet of pavement which receives lime treatment. The City shall select the location of each test. The gradation test shall be performed by an independent testing laboratory. The cost of testing shall be borne by the Contractor.

301.2.3.6 One density test shall be performed for each 300 linear feet of pavement. The density test shall be performed by an independent testing laboratory. The City shall select the location of each test. The cost of testing shall be borne by the Contractor.

301.3 Portland cement treatment of base and subgrade may be used only with special permission of the City.

302.9.2 Add to the second paragraph, substitute the following:

If measurement for pavement is in tons of material in place and accepted, weight shall be computed at 110 lb./in – S.Y.

Add the following in place of the last sentence in the first paragraph; before “MAXIMUM SIZE AGGREGATE”:

303.2.1.3.2 No more than 40% difference shall be retained between any two consecutive sieves.

303.5.4.2 Expansion joints shall be spaced at not greater than 300 feet centers. Expansion joints are required across the entire pavement width on all side of an intersection.

303.5.4.4 Sawed dummy joints shall be spaced both transversely and longitudinally at spacing’s of 15 feet, 17 feet 6 inches and 20 feet; for 6 inches, 7 inch and 8 inch pavement respectively.

303.5.6.1 A stamp or die shall be used to mark on the face of the curb or edge of pavement, the location of all of the following facilities:

Facility	Marking
Water Valve	V
Water Service	W
Sanitary Sewer Service	S

For water valves, the bottom of the “V” shall point in the direction of the valve. The stamp or die shall be approved by the City.

303.8 Testing of concrete pavement shall be performed by an independent testing laboratory acceptable to the City and paid for by the Contractor. The Contractor shall furnish all materials, equipment and labor required to perform all concrete tests including but not limited to slump, air content, concrete thickness and concrete strength. One concrete air content and slump test shall be performed on each load of concrete batched or delivered to the job site.

303.8.2 One concrete thickness tests shall be performed for each 500 L.F. of concrete pavement placed. The City shall select the location of each test.

303.8.3 Minimum pavement compressive strength shall be 4000 p.s.i. at 28 days for all streets, curbs, gutters and alleys unless otherwise noted. Air content shall be 3-5%. The Contractor shall prepare test cylinders in the number specified for “test cylinders.”

305.2.1 All concrete for sidewalks and driveway approaches shall be 4,000 psi @ 28 days.

305.2.2.2 Reinforcement is required in all driveways and walks.

305.3.1 All concrete for medians shall be 4,000 psi @ 28 days.

305.4.1 All concrete for headers shall be 4,000 psi @ 28 days.

402.4.4.1 "(c)(1) Measurement of Reinforced Concrete Pavement."

Remove/Replace of reinforced concrete pavement shall be measured at the specified trench width plus 2 feet, thickness in inches and length in linear feet.

Additional reinforced concrete pavement ordered by the City to be placed will be measured as the thickness in inches; and length and width in linear feet.

402.4.9 Add Replacing Gravel Pavement on a Dirt Base.

The existing gravel pavement shall be replaced with compacted flexible base, as specified in Item 301.5. The minimum thickness of flexible base shall be eight inches.

The flexible base shall be measured at specific trench width only, eight inches thick, and the length measured in linear feet.

402.4.10 Add: "If the limiting ditch width occurs within 3 feet of an expansion joint, construction joint or dummy joint, the City may order the pavement removed and replaced to the existing joint.

Replacement of the reinforced concrete pavement shall be the thickness measured in inches, specified ditch width plus two feet, and the length measured in linear feet.

Additional reinforced concrete pavement ordered by the City to be placed will be measured as the thickness in inches, and the length and width in linear feet.

501.4.3 Bolts for flanges shall be Type 316 stainless steel.

Add the following paragraph:

501.4.4.4 Mortar for Joints

a) Inside of joint – one part Portland cement and two parts washed sand. Add only enough water to form a zero slump mixture. Mix in a mechanical mixer to a uniform consistency.

b) Outside of joint – one part Portland cement and two parts washed sand. Add enough water to make the mixture flowable Mix in a mechanical mixer to a uniform consistency.

Add the following paragraph:

501.4.4.5 Dielectric Bushings, Sleeves and Washers

a) The dielectric bushings and sleeves shall be made from a nylon-molding compound or a nylon-base, Grade N-1, laminated thermosetting material. Washers shall be made from linen or fiber reinforced thermosetting plastics.

b) The insulation for each bolt in the bolt circle shall be 1/32” thick and shall be in length equal to the thickness of the two steel flanges and the 1/8” thick insulating gasket. They shall fit the bolts snugly.

c) The insulating fiber reinforced plastic washer shall be of the same diameter as the steel washers furnished with the bolt set and shall be 3/32” thick.

Add the following paragraph:

501.4.4.6 For Concrete Pressure Pipe installed in casing, apply mortar support rings on at least ten (10’) foot centers on all placed pipe to be placed in encasement pipe to prevent the pipe from resting on the bells.

501.4.5.2 Design Criteria – Prestressed Concrete Cylinder Pressure Pipe AWWA C-301.

The pipe manufacturer shall design the pipe to withstand the design pressure and support the trench loads with the embedment type (including the bedding angle) shown on the plans. All design shall be performed according to the Applicable Standards and according to generally accepted engineering procedures. Submit design calculations to the Engineer for review before manufacturing pipe. The following values shall be used in designing the pipe:

(a) Unit weight of soil (w) = 125 lb. per cu. ft.

(b) Coefficient of friction between backfill and trench wall (K u’ = 0.110)

(c) Bedding angle – a = 30º

Unless otherwise noted, pipe shall be designed for a pressure of 150 p.s.i.

501.4.6.2 Design Criteria – Ber-Wrapped Concrete Cylinder Pressure Pipe AWWA C-303.

a) The pipe manufacturer shall design the pipe to withstand the design pressure and support the trench loads with the embedment type (including the E’) shown on the plans. All design shall be performed according to the Applicable Standards and according to generally accepted engineering procedures. Submit design calculations to the Engineer for review before manufacturing pipe. The following values shall be used in designing the pipe:

1) Unit weight of soil (w) = 125 lb. Per cu. Ft.

2) Coefficient of friction between backfill and trench wall (K u’ = 0.110)

3) Modulus of soil reaction – E’ = 100

Unless otherwise noted, pipe shall be designed for a pressure of 150 p.s.i.

b) The manufacturer may use only 25% of the calculated composite moment of inertia of the pipe wall for C-303 pipe. The pipe shall be capable of supporting the trench loads with superimposed H-20 wheel load.

Add the following paragraph:

501.5 Repair or replace pipe or fittings with the following imperfections as directed by the Engineer:

(1) A piece broken out of the pipe.

(2) Any crack extending entirely through the barrel of the pipe or to the steel cylinder or rods.

(3) Any shattering or flaking of concrete at a crack.

(4) Any excessive surface cracking due to temperature conditions. The pipe supplier shall control these cracks by adequate concrete mix, curing or preservation of moisture in pipe interior during yard storage and shipment to jobsite.

501.7.4 Change the following ASTM A325 (Type 3) to: (A 325M) (Type B). Bolts for buried flanged ends shall be Type 316 stainless steel.

501.10 Copper Water Service Tubing

(a) Copper water service tubing shall be Type K Copper.

(b) Service fittings for copper water service tubing shall be as follows:

(1) Corporation Stops – Mueller H15000 flared fitting or Mueller H15405 compression fitting or approved equal.

(2) Branch Valve Assemblies for Double Water Services – Mueller H15362 with two H14265 angle stops or approved equal. Branch valve assemblies shall have 7 ½” centers.

(3) Angle Stops for Single Water Services – Mueller H14255, or approved equal.

501.13.5 Change “one-half” to “one-third of the total number”.

501.13.7 Plates may be spray coated in the field with a minimum dry film thickness of 0.05 in. (20 mils) prior to installation.

502(see also 502.8) Polyethylene encasement meeting 502.8 is required for all cast iron and ductile iron pipe, fittings and valves.

502.1.1
(see also 502.1.1.2) Fiberglass manholes may be used only with special permission of the City. Brick manholes shall not be used.

502.1.1.1 (2) The gradation shall conform to ASTM C-14.

502.1.1.1.1 Joints shall have trapped O-ring rubber gaskets in accordance with Item 2.12.4 (c).

502.1.1.2 Fiberglass manholes may be used only with special permission of the City.

502.1.4.1.2 Tongue and groove pipe with pre-molded joint sealing compound will not be allowed for manholes.

502.3 Fire hydrants shall be Mueller Centurion or approved equal.

502.3
(see also 502.3.2) Fire hydrants shall be braced and blocked on concrete slab or stone slab not less than 4" thick unless in sound rock trench.

Above grade, fire hydrants shall be painted as follows:

a) Clean all surfaces to receive paint to remove all dirt, oil and other contaminants.

b) Apply one 5 mil dry film thickness coating of epoxy mastic equal to Carboline 801 or Sherwin Williams B58.

c) Apply two 1.5 mil dry film thickness coasts of aliphatic urethane equal to Carboline 134 or Sherwin Williams B65.

d) Color of the urethane coatings for the barrel of the hydrant shall be ANSI 70 grey.

e) Color of the urethane coatings for the bonnet of the hydrant shall be based on the largest size line within 75 feet horizontally from the hydrant according to the following table:

Line Size	Color
6"	ANSI 70 Grey
8"	Blue
12"	Yellow

f) All colors except grey shall be safety colors per ANSI Z53.1. Grey color shall be per ANSI Z755.1.

A blue Stimsonite, Fire-Lite reflector (or approved equal) shall be placed in the center of the street opposite fire hydrants.

502.3.1.1 Scissor type main valves are not acceptable.

502.3.1.1 All accessories for mechanical joint hub shall be attached to foot when shipped. All mechanical joint gland bolts, shall be high strength, low alloy, corrosion resistant steel, and shall conform to ASTM Designation A 323, Type B.

502.3.1.1 All hydrants shall be equipped with:

Two hose outlets 2 ½-inches in (6.4 cm) nominal I.D. National Standard Fire-Hose Coupling Screw Thread. One 4 ½-inch nominal I.D. National Standard Thread.

502.3.1.1 Two or more non-corrosive outlets for drainage shall be provided in the base or barrel or between the base and barrel of the hydrant. The outlet shall be an integral part of the drain valve. Drain rods independent of the main stem shall not be accepted.

502.3.1.1 Direction to open shall be counter-clockwise.

502.3.1.1 The operation nozzle cap nuts shall be 1 ½ in. point to face at base and 1 ¼ in. point to face at top. A weathercap or shield shall be furnished to protect the opening between the operating nut and the top of the bonnet.

502.3.1.3 Main valve seats shall be of such design that incorrect positioning is impossible and that the threads will be adequately guided into position. Arrangements shall also be made to hold the main valve gasket in place during assembly. The main valve shall be made of bronze and threaded into a bronze retainer ring or it may be threaded into a heavy bronze bushing in the hydrant base.

502.3.1.5 Any flanges shall have a minimum thickness of 7/8 in. (2.2 cm). Bolt hole edge distance shall be sufficient to provide full support for the bold head and nut.

502.3.1.6 Operating stems whose threads are located in the barrel or waterway shall be of Manganese bronze, Everdur or other high quality non-corrodible metal, and all working parts in water way shall be bronze to bronze.

Operating stems whose threads are not located in the barrel or water way may be made of high grade bronze or steel, and stem nuts shall be bronze. Steel stems shall have bronze, stainless steel, or other non-corrodible metal sleeve where passing through O-rings. Operating threads must be sealed against contact with the water at all times regardless of open or closed position of the main valve.

502.3.1.12 A copy of an independent certified testing laboratory test results shall be submitted regarding the flow data from hydraulic tests for head loss through the hydrant.

502.3.3 Blocking shall be included in payment for fire hydrants and shall not be paid separately.

502.5.1.3 Add the following at the end of the second paragraph: "Valve must have a positive stop to prevent damage to brass ball over opening."

In the sixth paragraph add "and 1 inch" after ¾" in the first sentence and change "streamline" to "solder."

In the seventh paragraph change "streamline" to "solder."

502.6 The following valves types shall be used unless special permission is given to do otherwise:

502.6.6.1 Gate Valves (AWWA C 500) 12” and smaller

502.6.3 Air Valves

502.6.4 Brass Wheel Valves 3” and smaller

502.6.5 Butterfly Valves 16” and larger

502.6.2 Resilient Seat Gate Valves (AWWA C 509) 4” through 12”

502.6.1.8 Stuffing box bolts and nuts shall be Type 316 Stainless Steel.

502.6.1.14 Add: “Valves shall be sheathed in polyethylene film and tape per section 2.9.5”.

502.6.2.2 Bonnet Bolts and Nuts shall conform to AWWA Standard C509 with the following exception. All Bonnet bolts and nuts shall be Type 316 Stainless Steel.

502.6.2.3 Valves shall have flanged, push-on, or mechanical-joint ends, or any combination of these as may be specified. Bolts for mechanical joint ends shall meet ASTM A-325M (Type B). Bolts for direct buried flanges shall be Type 316 Stainless Steel.

502.6.2.5 Stuffing Box Bolting and Nuts shall conform to AWWA Standard C509 with the following exceptions: Stuffing box bolts and nuts shall be Type 316 Stainless Steel.

502.6.2.6 Hand Wheels and Operating Nuts – All valves shall be nut operated unless otherwise shown or specified. All operating nuts shall be ductile ion or cast iron. Handwheels shall be furnished only when called for on plans or in the contract specifications.

All valves shall open by turning counterclockwise.

502.6.2.16 Tests – All valves shall be tested by the manufacturer in accordance with AWWA Standard C500. Any leaking at the test pressure through any casting or between the bronze ring and the iron body shall cause the said casting to be rejected. No plugging or patching to stop any leakage shall be allowed.

Add paragraph 502.6.2.17

502.6.2.17 Drawings – The manufacturer shall have on file with the City for approval a detail drawing of each type and size of valve to be furnished under these specifications. Offerings having exceptions or modifications to these specifications must be accompanied by new detailed drawings and statement of changes effected. Failure to meet these requirements shall be sufficient cause for rejection.

502.6.5.1 (7) Delete split – V packing.

502.6.5.1 (8) Discs shall be epoxy coated.

502.6.5.1 (10) Add new line: The interior of the valve shall be epoxy coated.

502.6.5.1 (11) Add new line: Valves shall be Class 150-B unless otherwise noted.

502.6.5.3 Revise to read: Valves for direct burial service shall have mechanical joint ends and exposed valves shall have flanged ends.

502.6.5.6

a) Operator shall be located on the side of the valve, suitable for buried service.

b) Manufacturing Experience – Five (5) years minimum manufacturing experience is required.

502.6.6.1

Add: All valve stacks shall be of cast iron pipe or PVC pressure pipe and of one continuous piece to the finished grade. Furnish and install stainless steel valve operator extensions when operating nut is more than four (4") feet below furnished grade.

502.6.7 Inspection and Rejection – When requested by the City, the Contractor shall furnish test coupons on each heat of ferrous or nonferrous metal going into the valves. Such specimen shall be furnished upon sworn affidavit by the manufacture.

When requested at any time, notarized reports of physical tests performed on material used in the manufacture of valves furnished hereunder shall be provided.

Such reports or coupons furnished shall be identified by purchase order or contract. The material shall also be identified as to location within the valve and specification or composition.

Valves may be rejected for failure to comply with all of the requirements of the specifications.

502.6.12 Bonnet bolts shall be Type 316 Stainless Steel.

502.10.3 Special Requirements for Water Service Taps on PVC Water Pipe

(a) Direct tapping of PVC pipe will not be permitted.

(b) Taps may be made on PVC pipe using the following devices at the Contractor's option.

    (1) Service Saddles – Brass or Stainless Steel saddles – Clow Vega 3407 and 3408, Romac 101-N and 102-N. Any other service saddle must be submitted to the Engineer for approval before installing.

    (2) Main Line Fitting – Taps may be made in a mechanical joint plug installed in the branch of a tee.

(c) All Water Services shall be marked on the end of services with a blue plastic tape with the word "Water" stamped thereon.

(d) After the completion of paving, all water deadheads shall have a meter box installed by the Contractor. The type of meter box shall be as shown on the Standard Details.

Add the following:

502.10.3.1.1(2)
The two sections or halves type saddle may only be used on PVC pipe. Single strap clamps will not be permitted on any type pipe.

502.10.3.1.2 Only soft copper (Type K) tubing will be allowed and a curb stop will be required in lieu of a brass gate valve.

502.10.3.1.4 Direct tapping of cast iron and ductile iron pipe will be ¾" and 1" only.

502.10.3.1.5 Flanged outlets will be required for taps greater than 2".

502.10.3.1.7 Taps must be made with a shell cutter assembly and the coupon removed.

502.10.3.2 Tape shall also project out of the ground for one foot at a point one foot back of the curb.

Services 1" and smaller in diameter up to fifty (50') feet (15 meters) in length shall be installed with one continuous piece of water service tubing with no splices, couplings, etc.

Add the following:

502.10.4 Laterals to property shall be marked under the ground surface by placing red plastic tape. The word "SEWER" shall be printed at intervals. One end shall be placed at end of lateral, the other just under the ground surface projecting at least one foot (30 cm) back of proposed or existing curb and extending out of ground for one foot.

503.3.3.2 The maximum vertical deviation from the plan grade for sanitary sewer lines shall be ½" inch per 10 feet.

503.3.3.5 In the first sentence of the sixth paragraph – after "tunnel lining shall be" add "backfilled with Class B concrete or grouted per ASTM C476. No concrete or grout shall be."

Add the following:

504.4.2.1 All construction water shall be furnished at standard commercial rates by the City from the nearest convenient City main. A water meter shall be used to determine the amount of water used. The Contractor may obtain water meters from the City after payment of a deposit. If City water is unavailable, Contractor shall be responsible for purchasing water from a local supplier or another city. The City reserves the right to designate the time of day in which water can be withdrawn from City mains.

504.5.3.2.1 Add: Excavations within five (5') of pavement shall be considered to be influenced by vehicular traffic.

The moisture content shall be 2-4% above optimum moisture.

No water jetting is allowed.

504.5.3.2.1 &
504.5.3.2.2 Density tests shall be performed by an independent testing laboratory and paid for by the Contractor. One density test shall be performed for each 500 L.F. of backfill placed at a location selected by the City. The City may perform additional density tests at their expense. Density tests which fail shall be retested at the Contractor's expense.

505.1.6 Pipe must be swabbed clean prior to placing in the ditch.

506.3 Add: Installation of Concrete Pressure Pipe

(1) Pipe Laying

b) Install pipe and fittings at the locations shown on the plans. Lay pipe to the grade shown on the shop drawings which have been reviewed by the Engineer and released for construction. The Contractor shall establish the grade in the trench from grade stakes set by the Engineer. Use a string line or laser set on the centerline of the ditch to establish trench and pipe grades.

c) Minor deflections in the line may be made by unsymmetrical closure of pipe joints; however, the maximum pull shall be ¾" for sizes twelve (12") inch through twenty-one (21") inch and one (1") inch for sizes twenty-four (24") inch through forty-eight (48") inch. Beyond these limits use short pipe sections, beveled joints or angle adaptor to make necessary line and grade changes.

d) Lay pipe and fittings on specified bedding so as to be uniformly supported along its entire length. No "blocking up" of pipe or joints will be permitted. Provide bell holes to allow making the exterior joint.

e) Keep the pipe clean during the laying operation and free of all sticks, dirt and trash, and at the close of each working day, seal the open end of the pipe against the entrance of all objects, especially water.

506.4 Pipe Jointing

After the subgrade and embedment materials have been placed and the length of pipe has been placed in the trench, true to line and grade, thoroughly clean the bell and spigot by brushing and wiping.

506.4.1 Lubricate the rubber gasket and the inside surface of the bell with a lubricant approved by the pipe manufacturer. Snap the rubber gasket into the spigot ring groove to equalize circumferential distribution of the gasket. For pipe 18" and smaller, butter the end bell with mortar such that when the joint is made up, the mortar will completely fill the recess in the inside surface of the pipe at the joint. After the joint is engaged, clean the inside of the joint with a swab. Mortar the inside of joints of pipe eighteen (18") inches and larger by applying mortar to the annular space by hand after the joint is made up and hand troweling the mortar smooth.

Force the spigot in the bell by use of a choke chain or chain and ratcheting hoist. Do not use a backhoe or other excavating machinery to force the spigot into the bell. After the spigot is forced into the bell of the adjacent pipe, the inside recess between the ends of the pipe shall have a maximum opening of 1” and a minimum opening of ¼”.

Mortar the exterior surface of the joint by placing a joint wrapper around the pipe, using a band crimping tool. The joint wrapper shall be seven (7”) inches minimum width and be hemmed on each side with steel bands. It shall encircle the pipe, leaving an opening at the top to allow placing mortar. Joint wrappers shall be the type and quality recommended by the pipe manufacturer.

Pour liquid grout in the top of the joint wrapper in a continuous operation until the grout is completely around the pipe. During the filling of the wrapper, rod the mortar to eliminate voids.

Apply a one (1”) inch coating of Portland cement mortar on all exposed steel on fittings or specials. Allow the coating to take an initial set. Wrap the mortar coating in steel wire mesh and apply a second one (1”) coating of mortar. Immediately after the mortar has set, cover the mortar with damp earth or burlap to prevent rapid moisture loss.

(2) Cutting of Pipe

Field cutting of pipe will not be permitted except with special permission of the Engineer.

(3) Reaction Blocking and Anchorage

a) Block, anchor or harness all piping subject to internal pressure to preclude separation of joints. Provide suitable reaction blocking, anchors, harnesses or other acceptable means for preventing movement of pipe caused by internal pressure for all unplugged bell and spigot or all-bell tees, Y-branches, bends deflecting 11- ¼” degrees or more, and plugs.

b) Extend 2000 p.s.i. concrete blocking from the fitting to solid undisturbed earth and install so that all joints are accessible for repair. The bearing area shall be as shown on the plans.

c) If adequate support against undisturbed ground cannot be obtained, install metal harness, anchorages consisting of stainless steel rods, bolts and washers across the joint and securely anchor to pipe and fitting or install other adequate anchorage facilities to provide necessary support. Should the lack of a solid vertical excavation face be due to improper trench excavation, the entire cost of furnishing and installing metal harness anchorages shall be borne by the Contractor. Welding of joints will not be permitted without special permission by the Engineer.

d) Protect from corrosion all steel clamps, rods, bolts and other metal accessories used in reaction anchorages or joint harnesses subject to submergence or in direct contact with earth and not encased in concrete with two inches of wire reinforced field applied mortar cured with wet burlap bags.

(5) Insulation of Dissimilar Metals

Furnish and install dielectric bushings, sleeves and washers between concrete steel cylinder pipe and cast iron pip, ductile iron pipe or any dissimilar metal. Also furnish dielectric bushings, sleeves and washers on all blind flanges.

Add the following:

506.6 Taps and blow-offs for testing and disinfection purposes of all contracts will be installed by the Contractor, at locations specified by the City, and shall not be paid for separately but shall be included in the appropriate bid item.

Upon completion of the testing and purification the Contractor shall return to the job site and remove the blow-off down to the corporation stop. He shall leave the corporation stop and backfill, replacing all pavement. Removal of blow-off shall include all labor, materials, tools, equipment and incidentals necessary to complete the work, including excavation, disposal of surplus materials and backfill and shall not be paid for separately but shall be included in the appropriate bid item.

506.7 The Contractor shall furnish all labor, materials and equipment to purge, disinfect and test the completed waterline. Bacteriological test samples shall be collected and tested by an independent testing laboratory approved by the City. The cost of testing shall be borne by the Contractor.

506.9 A commercially available magnetic tape shall be installed 12" above the top of all PVC water pipe. Magnetic tape shall be blue in color and have the wording "Caution Water Line Buried Below" displayed prominently and continuously along the tape. The ends of the magnetic tape shall be brought up inside each main line valve box.

507.5 Visual inspection of sanitary sewers is required. The contractor shall furnish one copy of the videotape of the sewer inspection in VHS format to the City.

Add the following:

507.5.1.1 The rate of infiltration or exfiltration for manhole testing shall not exceed one tenth of a gallon per hour per foot of height.

507.5.1.4.1 Deflection testing shall be performed not sooner than 30 days from date the backfill is completed unless the entire backfill is compacted to 95% Standard Proctor density or better.

702.2.4.1 All structural concrete shall be Class C.

702.2.4.1(7) Testing of structural concrete strength shall be performed by an independent testing laboratory acceptable to the City and paid for by the Contractor. The Contractor shall furnish all materials, equipment and labor required to perform all concrete tests including but not limited to slump, air content and concrete test beams or cylinders.

Add the following to the first paragraph:

702.4.13 No water or dry cement shall be added to surface of concrete for finishing.

702.5 Add the following sentence to the end of 702.5:

All concrete to be used in precast products for drainage structures shall come from plans certified by the National Precast Concrete Association.

702.6.1 Pneumatically Placed Concrete may be used only where specifically called for on the plans or where special permission has been obtained from the City.

801.4.3.1 Delete the last sentence in the paragraph and replace with:

The Contractor shall locate the position of work according to plans.

802.1.1 All concrete for concrete steps shall be 4,000 psi @ 28 days.

802.2.1 All concrete for retaining walls shall be 4,000 psi @ 28 days.

Add the following:

802.4.3.2 2000 p.s.i. concrete will be used in inaccessible locations when a mechanical device cannot compact to required densities and as directed by the City, i.e.: under pipes, road washouts, under paving, etc.

Backfill shall be placed and compacted in not greater than 6” layers. The minimum backfill density shall be 95% at 0 to 2% above optimum moisture for all backfill subject to vehicular traffic. All other backfill shall be placed at a density equal to adjacent, undisturbed soil. Backfill density tests shall be determined in accordance with ASTM D698 by an independent testing laboratory selected by the Contractor and acceptable to the City. The Contractor shall pay for all costs of testing backfill densities. One density test shall be performed at each location for each 500 C.Y. of backfill placed. The location of the backfill test shall be selected by the City. The City may perform additional backfill density tests at his expense. The Density tests which fail shall be retested at the Contractor’s expense.

803.3.4 Measurement of rip-rap will be based on specified trench width plus 2 feet. In the event of excessive excavation, the Contractor will be required to rip-rap the entire excavation plus 1 foot on both sides at his expense.

Add the following:

805.2.2 All supplied extra material to make systems operational must be shown on "As-built" drawings with copies provided to the City.

805.4 Delete the entire fifth paragraph beginning with "Unless otherwise specified….

"

Appendix “D”

CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

APPENDIX “D”

PLANS REVIEW CHECKLIST

Please make sure the plans you are submitting are in accordance with this checklist. The following checklist will be used during the Plan Review.

PRELIMINARY PLAT CHECKLIST:

1. Drawn to a scale of 1” = 400’ or larger (1” = 200 or larger preferable). Yes ____ No ____ N/A ____
2. Show name of the proposed development and the lot and block if applicable. Yes ____ No ____ N/A ____
3. Other descriptions of tract such as survey abstract and other Denton County Deed Records recording information. Yes ____ No ____ N/A ____
4. Name and address of the subdivider. Yes ____ No ____ N/A ____
5. Name and address of the engineer or surveyor for the project. Yes ____ No ____ N/A ____
6. Show North arrow, scale, and date prepared. Yes ____ No ____ N/A ____
7. The boundary line of the tract shall be drawn accurately to scale. Yes ____ No ____ N/A ____
8. Show the subdivision names and/or property owners of record for all of the adjacent properties. Yes ____ No ____ N/A ____
9. Show the location, right-of-way width and names of all existing/platted streets on or adjacent to the property being developed. Yes ____ No ____ N/A ____
10. Show the size, location and recording information for all existing easements or other public ways on or adjacent to the property being developed. Yes ____ No ____ N/A ____
11. Show any railroad right-of-ways on or adjacent to the property being developed. Yes ____ No ____ N/A ____
12. Show all size and location of any easements being dedicated on or adjacent to the property being developed. Yes ____ No ____ N/A ____

13. Show the layout of all proposed streets, alleys, and sidewalk with right-of-way width. Yes ____ No ____ N/A ____

14. Show the layout, numbers and dimensions of all proposed lots. Yes ____ No ____ N/A ____

15. Show the building set back lines. Yes ____ No ____ N/A ____

16. Show the existing two (2) foot contours referenced to NAD. Yes ____ No ____ N/A ____

17. Show all existing water, wastewater, fire hydrants, culverts, and storm drains on or adjacent to the property being developed. Yes ____ No ____ N/A ____

18. Show preliminary layout of water, wastewater, fire hydrants, culverts, and storm drains on or adjacent to the property being developed. Yes ____ No ____ N/A ____

19. Show proposed retention/detention ponds. Yes ____ No ____ N/A ____

20. Show and label all existing and proposed mutual access easements with adjacent properties. Yes ____ No ____ N/A ____

FINAL PLAT – A separate plat shall be filed and shall include:

1. Scale. Yes ____ No ____ N/A ____

2. Property Lines:

    a. Bearings and distances. Yes ____ No ____ N/A ____

    b. Point of commencing. Yes ____ No ____ N/A ____

    c. Point of beginning. Yes ____ No ____ N/A ____

    d. Property corners (labeled found or set). Yes ____ No ____ N/A ____

    e. Basis of Bearing. Yes ____ No ____ N/A ____

3. Street dedication within plat limits. Yes ____ No ____ N/A ____

4. Corner clips at street intersections where required. Yes ____ No ____ N/A ____

5. Alley dedication within plat limits. Yes ____ No ____ N/A ____

6. Sight distance easements for alley intersection with streets. Yes ____ No ____ N/A ____

7. Dashed lines showing labeled easements. Yes ____ No ____ N/A ____

8. Floodways / Floodplains (FEMA):

    a. Show the ultimate 100-year water surface elevation. Yes ____ No ____ N/A ____

    b. Show floodplain and floodway boundaries. Yes ____ No ____ N/A ____

    c. Drainage Floodway easement limits (drainage easement 10 feet outside of floodplain).

    d. Minimum fill and floor elevations specified. Yes ____ No ____ N/A ____

9. Curve data. Yes ____ No ____ N/A ____

10. Building set-back lines and lot lines. Yes ____ No ____ N/A ____

11. Lot and block numbers. Yes ____ No ____ N/A ____

12. Abutting property owner names and recording information. Yes ____ No ____ N/A ____

13. Street names and right-of-way width. Yes ____ No ____ N/A ____

14. Utility company easement dedications. Yes ____ No ____ N/A ____

15. Utility and drainage information for water, wastewater and storm sewer. Yes ____ No ____ N/A ____

16. Abstract lines and names. Yes ____ No ____ N/A ____

17. City limit line. Yes ____ No ____ N/A ____

18. County line. Yes ____ No ____ N/A ____

19. Owners certificate and dedication. Yes ____ No ____ N/A ____

20. North to top or right of sheet. Yes ____ No ____ N/A ____

21. Metes and bounds (dedication statement):

    a. Owner’s signature on final mylar. Yes ____ No ____ N/A ____

    b. Notarization on final mylar. Yes ____ No ____ N/A ____

22. Surveyor’s certification on final mylar:

    a. Signature on final mylar. Yes ____ No ____ N/A ____

    b. Seal on final mylar. Yes ____ No ____ N/A ____

23. Acceptable subdivision name (assigned by planning commission). Yes ____ No ____ N/A ____

24. Show owner's name, address and phone number. Yes ____ No ____ N/A ____

25. Show surveyor's name, address and telephone number. Yes ____ No ____ N/A ____

SITE PLAN – Each site plan shall include:

1. Scale – notation of scale and bar or graphic scale. Yes ____ No ____ N/A ____

2. Legend Yes ____ No ____ N/A ____

3. Date Yes ____ No ____ N/A ____

4. Title Block:

   a. Name and project number of proposed project. Yes ____ No ____ N/A ____

   b. The words "Site Plan", "Landscape Plan" and "Building Elevations." Yes ____ No ____ N/A ____

   c. The County and Abstract in which the project is located. Yes ____ No ____ N/A ____

   d. The name, address, and telephone number of property owner. Yes ____ No ____ N/A ____

   e. The name, address, and telephone number of the engineer and/or architect who prepared the applicable plan. Yes ____ No ____ N/A ____

5. Location Map Yes ____ No ____ N/A ____

6. Easements Yes ____ No ____ N/A ____

7. Water and Wastewater Lines Yes ____ No ____ N/A ____

8. Building setback lines Yes ____ No ____ N/A ____

9. Zoning Yes ____ No ____ N/A ____

10. Lot size and density Yes ____ No ____ N/A ____

11. Floor to Area Ratio Yes ____ No ____ N/A ____

12. Parking Standard and Layout including parking calculations Yes ____ No ____ N/A ____

13. Dumpster location and screening — Yes ____ No ____ N/A ____

14. Gateway Overlay District Requirements — Yes ____ No ____ N/A ____

15. Signage — Yes ____ No ____ N/A ____

16. Building Proximity — Yes ____ No ____ N/A ____

17. Fire Sprinklers (a note indicating if the building is to be sprinklered) — Yes ____ No ____ N/A ____

18. Fire Hydrants — Yes ____ No ____ N/A ____

19. Fire Lanes — Yes ____ No ____ N/A ____

20. Right-of-Way widths — Yes ____ No ____ N/A ____

21. Signature Block — Yes ____ No ____ N/A ____

22. Landscaping Plans — Yes ____ No ____ N/A ____

23. Building Elevations — Yes ____ No ____ N/A ____

24. Construction Materials in Façade. — Yes ____ No ____ N/A ____

A more detailed checklist is contained in the Development Service Department Application Manual.

GENERAL

1. North arrow clearly shown on each plan sheet. — Yes ____ No ____ N/A ____

2. Bench marks shown on each sheet; located on permanent structure outside of construction limits and conveniently spaced (500' +). — Yes ____ No ____ N/A ____

3. Title blocks; title; sheet number and scales shown. — Yes ____ No ____ N/A ____

4. Each sheet must bear the seal of a Licensed Professional Engineer, signature, and date. — Yes ____ No ____ N/A ____

5. Street names on each sheet. — Yes ____ No ____ N/A ____

6. Property owners and property lines shown. — Yes ____ No ____ N/A ____

7. Submit six (6) sets of plans for review. — Yes ____ No ____ N/A ____

8. Place standard general notes (Appendix "B") on plans. — Yes ____ No ____ N/A ____

9. Existing, proposed and future facilities must clearly be defined. Yes ____ No ____ N/A ____

COVER SHEET * - The cover sheet shall include:

1. Project title and type of project. Yes ____ No ____ N/A ____
2. Location map. Yes ____ No ____ N/A ____
3. Disposal site for excess excavation. Yes ____ No ____ N/A ____
4. Index of Sheets. Yes ____ No ____ N/A ____
5. Approval blocks for City. Yes ____ No ____ N/A ____
6. Professional Engineer's seal, signature and date. Yes ____ No ____ N/A ____
7. "Release for Construction" note. Yes ____ No ____ N/A ____

* NOTE: If the Cover Sheet is not furnished, information should appear on other sheets.

GRADING * – Each grading plan shall include:

1. Existing one-foot contours based on an on-the-ground survey or controlled aerial topographic map (dashed lines and labeled) to extend 20 feet from property line onto adjacent property. Yes ____ No ____ N/A ____
2. Proposed one-foot contours – solid lines and labeled. Yes ____ No ____ N/A ____
3. Show top of curb elevation every 50 feet on streets, alleys, existing and proposed parking lots. Yes ____ No ____ N/A ____
4. Slope:
    a. Back of street curb to property line: ¼" per foot. Yes ____ No ____ N/A ____
    b. Parking lot top of curb to property line: Maximum 4 (horizontal) to 1 (vertical). Yes ____ No ____ N/A ____
    c. Any unpaved area to property line: Maximum slope of 4:1. Yes ____ No ____ N/A ____
    d. Show driveways with ¼" per foot + 6" from street gutter up to property line. Yes ____ No ____ N/A ____
5. Letter of approval if grading is proposed on adjacent property. Yes ____ No ____ N/A ____

6. Utility easement from abutting property owners. Yes ____ No ____ N/A ____
7. Proposed inlets, label and size. Yes ____ No ____ N/A ____
8. Proposed pipes, label and size. Yes ____ No ____ N/A ____
9. Existing inlets and pipes. Yes ____ No ____ N/A ____

   * NOTE: Add statement that grading <u>only</u> is being submitted with these plans.

<u>DRAINAGE</u> – Design of Drainage Systems shall include:

1. Runoff calculations for all areas showing:
   a. Acreage. Yes ____ No ____ N/A ____
   b. Runoff Coefficient. Yes ____ No ____ N/A ____
   c. Inlet Time. Yes ____ No ____ N/A ____
   d. 10-year and 100-year intensities. Yes ____ No ____ N/A ____
2. Rational Method calculation for area less than 200 acres. Yes ____ No ____ N/A ____
3. Unit Hydrograph Method for areas greater than 200 acres. Yes ____ No ____ N/A ____
4. Statement that drainage from the abutting property will not be impaired by the proposed grading. Yes ____ No ____ N/A ____
5. Emergency overflow for 100-year storm at low points or design for 100-year storm. Yes ____ No ____ N/A ____
6. No diversion of drainage. Yes ____ No ____ N/A ____
7. Drainage Area Map:
   a. 1” = 200’ or less with match lines between any two or more maps. Yes ____ No ____ N/A ____
   b. Show existing and proposed storm drains and inlets. Yes ____ No ____ N/A ____
   c. Calculate sub areas for each inlet and point of analysis. Yes ____ No ____ N/A ____
   d. Provide existing and proposed two foot contours on map for on and offsite. Yes ____ No ____ N/A ____
   e. Indicate zoning on drainage area. Yes ____ No ____ N/A ____

f. Calculate discharge at all inlets, dead-end streets and alleys or to adjacent additions or acreage. Yes ____ No ____ N/A ____

g. Calculations of:

1) Spread of water Yes ____ No ____ N/A ____

2) Inlets Yes ____ No ____ N/A ____

3) Street capacity Yes ____ No ____ N/A ____

4) ROW capacity Yes ____ No ____ N/A ____

5) Hydraulic grade line for conduits Yes ____ No ____ N/A ____

h. For cumulative runoff, show calculations. Yes ____ No ____ N/A ____

i. Define all crests, sags and streets and alley intersections with flow arrows. Yes ____ No ____ N/A ____

8. Curbs for alleys where capacity is exceeded. Yes ____ No ____ N/A ____

9. Storm water from streets does not flow into alleys or drives. Yes ____ No ____ N/A ____

10. Offsite drainage or discharge to downstream property will require a letter of permission and/or easements. Yes ____ No ____ N/A ____

11. Discharge does not adversely affect downstream property. Yes ____ No ____ N/A ____

PAVING PLAN – Each Paving Plan shall include:

1. Right-of-way, street, alley, drives and sidewalks dimensioned. Yes ____ No ____ N/A ____

2. Centerline stations shown. Yes ____ No ____ N/A ____

3. Limits of work defined. Yes ____ No ____ N/A ____

4. Barrier free ramps at all intersections. Yes ____ No ____ N/A ____

5. Pavement transitions. Yes ____ No ____ N/A ____

6. Traffic control items; striping, traffic buttons, sign. Yes ____ No ____ N/A ____

7. Street lighting. Yes ____ No ____ N/A ____

8. Concrete pavement thickness. Yes ____ No ____ N/A ____

9. 4,000 psi in 28 days concrete compressive strength. Yes ____ No ____ N/A ____

10. 6” curbs. Yes ____ No ____ N/A ____

11. Reinforcement with No. 4 bars 24” o.c. both ways. Yes ____ No ____ N/A ____

12. Sidewalks to be 4” thick, 4,000 psi in 28 days, reinforced with No. 4 bars 24” O.C.E.W. Yes ____ No ____ N/A ____

13. Expansion joints at intersection and at minimum 600 foot intervals for pavement. Yes ____ No ____ N/A ____

14. Saw cut at 15-, 17.5- and 20-foot intervals for 6-inch, 7-inch and 8-inch pavements respectively. Yes ____ No ____ N/A ____

15. Radius at corners conform to Table II-2. Yes ____ No ____ N/A ____

16. Gutter flow arrows. Yes ____ No ____ N/A ____

17. Roadways comply with master thoroughfare plan. Yes ____ No ____ N/A ____

18. Geometrics meet design speed criteria. Yes ____ No ____ N/A ____

19. Is Superelevation required? Yes ____ No ____ N/A ____

20. Retaining Walls:

    a. Type, beginning and ending locations and wall elevations. Yes ____ No ____ N/A ____

    b. Provide design if non-standard or modified. Yes ____ No ____ N/A ____

    c. Drainage behind walls shown. Yes ____ No ____ N/A ____

21. Driveway grades shown. Yes ____ No ____ N/A ____

PAVING PROFILES AND GRADES – Plans shall include:

1. Profiles plotted showing ground at proposed property line. Yes ____ No ____ N/A ____

2. Top of curb profiles must meet minimum and maximum grade requirements. Yes ____ No ____ N/A ____

3. Driveway profile grades. Yes ____ No ____ N/A ____

4. Vertical curves must be designed in accordance with Table II-5. Yes ____ No ____ N/A ____

5. Contour grading plans for major intersections. Yes ____ No ____ N/A ____

6. Spot top of curb elevations in plan view on proposed left turn lanes. Yes ____ No ____ N/A ____

7. Check carefully for any place water might pond. Are inlets located at sag points or vertical curves? Yes ____ No ____ N/A ____

8. Are grades, crossfall, slopes, etc., consistent with information shown on typical section? Yes ____ No ____ N/A ____

9. Check ends of project for drainage. If gutters drain to ditches or field type inlets, are grades and profiles shown? Yes ____ No ____ N/A ____

10. Minimum grades maintained to assure complete drainage. Yes ____ No ____ N/A ____

CLOSED CONDUIT STORM DRAINS – All storm drain plans shall include:

1. Plan and profile of all proposed storm drains drains. Yes ____ No ____ N/A ____

2. Station of laterals on trunk profile. Yes ____ No ____ N/A ____

3. Plan view of each area showing

   a. Size of inlet. Yes ____ No ____ N/A ____

   b. Lateral size. Yes ____ No ____ N/A ____

   c. Flow line. Yes ____ No ____ N/A ____

   d. Paving station. Yes ____ No ____ N/A ____

   e. Top of curb elevation. Yes ____ No ____ N/A ____

4. Details of all non-standard items. Yes ____ No ____ N/A ____

5. Curve data for storm drains. Yes ____ No ____ N/A ____

6. Property lines and easements with dimensions. Yes ____ No ____ N/A ____

7. Class III RCP unless otherwise noted. Yes ____ No ____ N/A ____

8. Concrete cushion. Yes ____ No ____ N/A ____

9. Plot hydraulic grade line (HGL). Yes ____ No ____ N/A ____

10. Storm drain discharge at flow line of creek or channel and use rip-rap. Show coincident water surface of outfall. Yes ____ No ____ N/A ____

11. Headwalls and erosion control at outfall of storm drains. Yes ____ No ____ N/A ____

12. Laterals connected at 60 degree angle. Yes ____ No ____ N/A ____

13. Matching pipe centerline at connection. Yes ____ No ____ N/A ____

14. 3600 psi in 28 days for structural concrete strength. Yes ____ No ____ N/A ____

15. Existing and proposed utilities in plan and profile. Yes ____ No ____ N/A ____

16. On profile indicate:

    a. Grade. Yes ____ No ____ N/A ____

    b. Flow line elevations every station. Yes ____ No ____ N/A ____

    c. Existing and proposed ground line. Yes ____ No ____ N/A ____

    d. Hydraulic grade line and data. Yes ____ No ____ N/A ____

17. Show sizes in plan and profile. Yes ____ No ____ N/A ____

18. Show computations for existing system when connecting to existing storm drain. Yes ____ No ____ N/A ____

19. Velocities and hydraulic gradients conform to Design Manual. Yes ____ No ____ N/A ____

20. Inlets and conduits properly sized. Yes ____ No ____ N/A ____

21. Storm drain inlet and outlet velocity calculations. Yes ____ No ____ N/A ____

CREEKS AND CHANNELS – Plans of creeks and channels shall include:

1. Stationing in plan and profile. Yes ____ No ____ N/A ____

2. Profiles indicating:

    a. Existing flow line. Yes ____ No ____ N/A ____

    b. High banks. Yes ____ No ____ N/A ____

    c. Hydraulic profile and data. Yes ____ No ____ N/A ____

    d. Rock line. Yes ____ No ____ N/A ____

3. Hydraulic Computations.

    a. 100-year discharge — Yes ____ No ____ N/A ____

    b. Velocity — Yes ____ No ____ N/A ____

    c. Critical depth — Yes ____ No ____ N/A ____

    d. Manning’s “n” — Yes ____ No ____ N/A ____

    e. Design grade for improved channels — Yes ____ No ____ N/A ____

4. Cross sections as relative to property line. — Yes ____ No ____ N/A ____

5. Erosion control. — Yes ____ No ____ N/A ____

6. Compacted fill where fill required. — Yes ____ No ____ N/A ____

7. Design velocities not greater than original stream velocities or greater than stated in Design Manual. — Yes ____ No ____ N/A ____

8. Maximum side slope on earthen channels not greater than 4:1. — Yes ____ No ____ N/A ___

BRIDGES – Plans of bridges shall include:

1. Lowest member of bridge 2 feet above design water surface elevation. — Yes ____ No ____ N/A ____

2. Soil Borings on plans. — Yes ____ No ____ N/A ____

3. Soils report. — Yes ____ No ____ N/A ____

4. Channel sections upstream and downstream. — Yes ____ No ____ N/A ____

5. Structural details and calculations with dead load deflection diagram. — Yes ____ No ____ N/A ____

6. Vertical and horizontal alignment. — Yes ____ No ____ N/A ____

7. Bridge cross section. — Yes ____ No ____ N/A ____

8. Hydraulic calculations on all sections. — Yes ____ No ____ N/A ____

WATER – All water distribution and transmission facilities shall include:

1. Minimum 8” for main lines — Yes ____ No ____ N/A ____

2. DR 18 Class 150 PVC all water mains less than or equal to 12-inch diameter. — Yes ____ No ____ N/A ____

3. Loop water mains. Yes ____ No ____ N/A ____

4. Valves on fire hydrant leads. Yes ____ No ____ N/A ____

5. Valves on main lines between each fire hydrant. Yes ____ No ____ N/A ____

6. Maximum distance between each fire hydrant.

   a. Residential – 500' c-c on street. Yes ____ No ____ N/A ____

   b. Apartments – 400' c-c on street. Yes ____ No ____ N/A ____

   c. Office, retail, commercial, industrial 300' c-c on street. Yes ____ No ____ N/A ____

7. All portions of building within 300' radius of a fire hydrant in commercial. Yes ____ No ____ N/A ____

8. All portions of building within 400' radius of a fire hydrant in apartment. Yes ____ No ____ N/A ____

9. All portions of buildings within 500' radius of a fire hydrant in residential and duplex. Yes ____ No ____ N/A ____

10. Maximum length non-looped line serving a fire hydrant is 150 feet. Yes ____ No ____ N/A ____

11. Lateral service (min. 1" copper) from main line to two feet from back of curb at center of lot in residential subdivisions. Yes ____ No ____ N/A ____

12. Water main extended to opposite property line or tied to existing main. Yes ____ No ____ N/A ____

13. Profiles mains 12" and larger. Yes ____ No ____ N/A ____

14. Consult master water plan. Yes ____ No ____ N/A ____

15. Show location of water meters: 15.

   a. Domestic. Yes ____ No ____ N/A ____

   b. Irrigation. Yes ____ No ____ N/A ____

   c. Fire line. Yes ____ No ____ N/A ____

16. Show size of water meters. Yes ____ No ____ N/A ____

17. Note minimum pipe covers (attach water and sewer standard notes). Yes ____ No ____ N/A ____

18. Dedicate water line easements up to and including fire hydrants and water meters for lines off ROW. Yes ____ No ____ N/A ____

WASTEWATER – All wastewater plans shall include:

1. 8" minimum, PVC SDR-35 (unless 6-inch approved by City Engineer). Yes ____ No ____ N/A ____
2. Manhole at end of all lines. Yes ____ No ____ N/A ____
3. Manholes at change of pipe size and tees. Yes ____ No ____ N/A ____
4. 500' maximum distance between manholes. Yes ____ No ____ N/A ____
5. Minimum slopes:
   a. 6" – 0.50%. Yes ____ No ____ N/A ____
   b. 8" – 0.33%. Yes ____ No ____ N/A ____
   c. 10" – 0.25%. Yes ____ No ____ N/A ____
   d. 12" – 0.20%. Yes ____ No ____ N/A ____
   e. 15" – 0.14%. Yes ____ No ____ N/A ____
   f. 18" – 0.12%. Yes ____ No ____ N/A ____
6. Maximum slope such that velocity is less than 10 fps. Yes ____ No ____ N/A ____
7. Sewer laterals 10' downstream from water service or to center of lot. Yes ____ No ____ N/A ____
8. Minimum lateral size:
   a. Residential, 4". Yes ____ No ____ N/A ____
   b. Apartment, retail or commercial – 6". Yes ____ No ____ N/A ____
   c. Manufacturing or industrial – 8". Yes ____ No ____ N/A ____
9. Profile all sewer lines except laterals. Yes ____ No ____ N/A ____
10. Show other utility lines crossing wastewater lines. Yes ____ No ____ N/A ____
11. Label lines to correspond to profile. Yes ____ No ____ N/A ____
12. Concrete encasement at creek crossing. Yes ____ No ____ N/A ____
13. Provide stubouts to adjacent property. Yes ____ No ____ N/A ____

14. Note benchmark on all sheets. Yes ____ No ____ N/A ____

15. 15’ utility easement provided for lines not in ROW. Yes ____ No ____ N/A ____

UTILITIES – All plans shall show the following:

1. Existing and proposed facilities shown in plan and profiles views. Yes ____ No ____ N/A ____

2. Underground facilities close to or in conflict with proposed construction located by actual ties and elevations. Yes ____ No ____ N/A ____

3. Caution notes shown when construction operations come close to existing utilities. Telephone number of utility contact shall be shown. Yes ____ No ____ N/A ____

EROSION CONTROL – All plans shall show the following:

1. Existing and Proposed Grading Yes ____ No ____ N/A ____

2. Existing and Proposed Drainage Features Yes ____ No ____ N/A ____

3. Erosion features including temporary construction entrance, silt fence, inlet protection, rock berms, seeding, etc. Yes ____ No ____ N/A ____

4. Erosion control standard details Yes ____ No ____ N/A ____

PAVEMENT MARKINGS AND SIGNAGE

1. Pavement Markings and Signage Plan in accordance with MUTCD. Yes ____ No ____ N/A ____
2. Pavement Markings Standard Details. Yes ____ No ____ N/A ____

LANDSCAPE AND IRRIGATION PLANS

1. Landscape Plan showing rights-of-way and proposed back of curbs, sidewalk, existing; and proposed utilities and other features pertinent to the plan. Yes ____ No ____ N/A ____

2. Planting details. Yes ____ No ____ N/A ____

3. Irrigation Plans including metering, back flow prevention, and provision for electrical service and controllers. Yes ____ No ____ N/A ____

4. Irrigation details. Yes ____ No ____ N/A ____

STREET LIGHTING

1. Lighting and Conduit Layout Plan Yes ____ No ____ N/A ____
2. Lighting Standard Details Yes ____ No ____ N/A ____

Appendix “E”

APPENDIX “E”

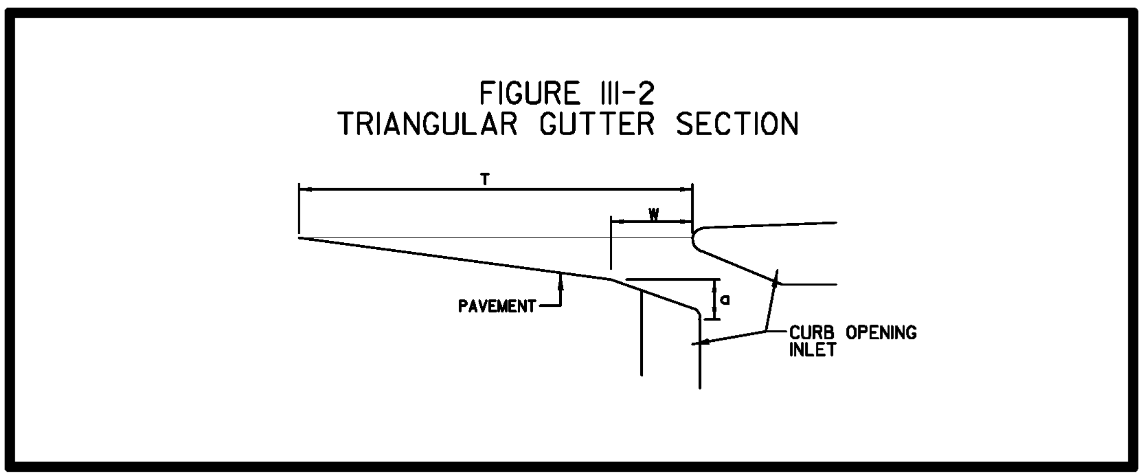
INLET DESIGN

Two types of inlets are approved for use: a recessed curb inlet for streets and a Y-inlet for open areas or channels. Recessed curb inlets shall be 5-, 10-, 15-, or 20-feet in length. No more than 20 linear feet - of inlets shall be placed along one gutter at any given location. At sags, at least one curb inlet shall be a minimum of 10 feet in length. Computations for flow in to inlets shall be shown on the construction plans. Inlets shall be placed at intersecting property lines when possible.

7.1 Flow In To Inlets on Grade

Flow from triangular street gutters in to curb inlets on grade shall be computed with the following formulas.

Figure 7.1A Triangular Gutter Section



A. Compute depth of flow and ponded width (T) in the gutter section at the inlet.

1. The ponded width can be determined by:

$$T = \frac{d}{S_X} \quad or \quad T = \left(\frac{Qn}{K_U S_X^{1.67} S_L^{0.5}}\right)^{0.375}$$

where:

T = ponded width (ft or m)
K_U = 0.56 (0.376 for metric)

2. $$d = z\left[\frac{QnS_x}{S^{0.5}}\right]^{0.375}$$

where:

d = depth of water in the curb and gutter cross section (ft or m)
Q = gutter flow rate (cfs or m^3/s)
n = Manning's roughness coefficient (0.016)
S_L = longitudinal slope (ft/ft or m/m)
S_X = pavement cross slope (ft/ft or m/m)
z = 1.24 for English units (1.443 for metric)

3. Determine the ratio of the width of flow in the depressed section (*W*) to the width of total gutter flow (*T*) by:

$$E_O = \frac{K_W}{K_W + K_O}$$

where:

E_O = ratio of depressed flow of total flow
K_W = conveyance of the depressed gutter section (cfs or m^3/s)
K_O = conveyance of the gutter section beyond the depression (cfs or m^3/s)

The conveyance of a cross section can be computed by:

$$K = \frac{zA^{2/3}}{nP^{2/3}}$$

where:

z = 1.486 for English units (1.0 metric)
A = area of cross section (ft^2 or m^2)
n = Manning's roughness coefficient (0.016)
P = wetted perimeter (ft or m)

4. Determine the area of the cross section in the depressed gutter section by:

$$A_W = WS_X\left(T - {}^{W}/_{2}\right) + \tfrac{1}{2}aW$$

where:

A_W = area of depressed gutter section (ft^2 or m^2)
W = depression width for an on-grade curb inlet (ft or m)
S_X = cross slope (ft/ft or m/m)
T = calculated ponded width (ft or m)
a = curb opening depression (ft or m)

5. Determine the wetted perimeter in the depressed gutter section by:

$$PW = \sqrt{(WS_X + a)^2 + W^2}$$

where:

P_W = wetted perimeter of depressed gutter section (ft^2 or m^2)
W = depression width for an on-grade curb inlet (ft or m)
S_X = cross slope (ft/ft or m/m)
a = curb opening depression (ft or m)

6. Determine the area of cross section of the gutter section beyond the depression by:

$$A_O = \frac{S_X}{2}(T - W)^2$$

where:

A_O = area of gutter/road section beyond the depression width (ft^2 or m^2)
S_X = cross slope (ft/ft or m/m)
W = depression width for an on-grade curb inlet (ft or m)
T = calculated ponded width (ft or m)

7. Determine the wetted perimeter of the gutter section beyond the depression by:

$$P_O = T - W$$

Where:

P_O = wetted perimeter of the depressed gutter section (ft or m)
T = calculated ponded width (ft or m)
W = depression width for an on-grade curb inlet (ft or m)

B. Flow from gutter sections to recessed curb inlets on grade shall be computed with the following formulas:

$$E_O = 1 / \left\{ 1 + \frac{S_W / S_X}{\left(1 + \frac{S_W / S_X}{\frac{T}{W} - 1}\right)^{2.67} - 1} \right\}$$

$$Q_W = Q - Q_S$$

$$Q_S = \frac{K_U}{n} S_X^{\,1.67} S_L^{\,0.5} T^{\,2.67}$$

$$Q = \frac{Q_S}{1 - E_O}$$

where:

K_U = 0.53 (0.376 for metric)
n = Manning's roughness coefficient (0.016)
S_L = longitudinal slope (ft/ft or m/m)
S_X = pavement cross slope (ft/ft or m/m)
Q_W = flow rate in the depressed section of the gutter, m^3/s (ft^3/s)
Q = gutter flow rate, m^3/s (ft^3/s)
Q_S = flow capacity of the gutter section above the depressed section, m^3/s (ft^3/s)
E_O = ratio of flow in a chosen width (usually the width of a grate) to total gutter flow Q_W/Q)

$S_W = S_X + a/W$

C. Flow from parabolic gutter sections to curb inlets on grade shall be computed with the following formulas:

A parabolic cross section can be described by the equation:

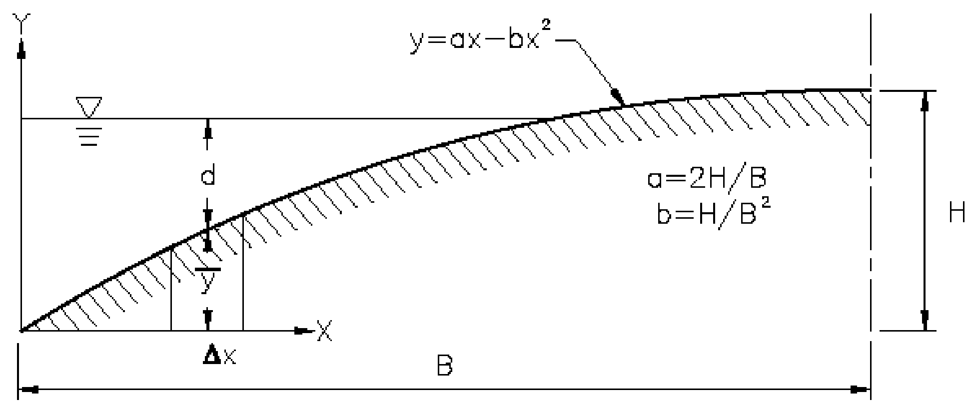
$y = ax - bx^2$

where:

a = 2H/B
b = H/B^2
H = crown height
B = street half width

The relationships between a, b, crown height, H, and street half width, B, are shown in Figure 7.1A.

Figure 7.1A
Properties of a Parabolic Curve



To determine depth of flow in a gutter in a parabolic street, first determine conveyance (K).

$K = Q/S^{1/2}$

where:

Q = single gutter discharge (cfs)
S = gutter slope (ft/ft)

Depth of flow in a gutter (y) shall be determined by the following formula:

$y = mK^p$

m and p are coefficients that vary depending on street width and crown height. Table 6.1C provides coefficients for calculating depth in parabolic streets.

Table 7.1A
Conveyance Coefficients

Street Width	m	p	H (ft)	Conveyance (K) for y = crown height	Conveyance (K) for y = 0.5 ft. (full depth
27 feet	0.1005	0.3692	0.42	44.1	96.2
31 feet	0.0952	0.3692	0.42	51.0	111.0
37 feet	0.0954	0.3693	0.5	83.0	83.0
45 feet	0.0884	0.3696	0.5	103.0	103.0

Note: Values of K are for a single gutter.

Spread of water can be calculated according to the following formula:

Spread of Water (T) = $B - ((H-y)/b)^{0.5}$

where:
H, B, & y are all in feet

D. Determine the equivalent cross slope (S_E) for a depressed curb opening inlet by:

$$S_E = S_X + \frac{a}{W} E_O$$

where:
- S_E = equivalent cross slope (ft/ft or m/m)
- S_X = cross slope of road (ft/ft or m/m)
- a = gutter depression (ft or m)
- W = gutter depression width (ft or m)
- E_O = ration of depressed flow to total flow

E. Calculate the length of curb inlet required for total interception by:

$$L_R = zQ^{0.42} S^{0.3} \left[\frac{1}{nS_E}\right]^{0.6}$$

where:
- L_R = length of curb inlet required (ft or m)
- z = 0.6 for English units (0.82 metric)
- Q = flow rate in gutter (cfs or m^3/s)
- S = longitudinal slope (ft/ft or m/m)
- n = Manning's roughness coefficient
- S_E = equivalent cross slope (ft/ft or m/m)

If no carryover is allowed, the inlet length is assigned a dimension of at least L_r. Use a nominal length available for standard curb opening inlets. If carryover is considered, round the curb opening inlet length down to the next available standard curb opening length and compute the carryover flow.

F. Determine carryover flow by:

$$Q_{CO} = Q \left[1- \frac{L_A}{L_R} \right]^{1.8}$$

where:

Q_{CO} = carryover flow (cfs or m^3/s)
Q = total flow in gutter (cfs or m^3/s)
L_A = design length of proposed the curb opening inlet required to intercept the total flow (ft or m)

Carryover rates usually should not exceed about 0.5 cfs (0.03 m^3/s) or about 30 percent (30%) of the total flow in gutter. Greater rates can be troublesome and cause a significant departure from the principles of the Rational Method Application. In all cases, you must accommodate any carryover rate at some other specified point in the storm drain system.

G. Calculate the intercepted flow as the original discharge in the approach curb and gutter minus the amount of carryover flow.

$$Q_I = Q - Q_{CO}$$

where:

Q_I = intercepted flow (cfs or m^3/s)
Q = total flow in gutter (cfs or m^3/s)
Q_{CO} = carryover flow (cfs or m^3/s)

H. If the curb opening inlet is not depressed and recessed, the intercepted flow shall be reduced by 20 percent (20%), and the carry overflow shall be increased by the same amount.

7.2 Curb Inlets at Sags

The flow into a curb inlet in sag can be estimated as 2.0 cfs/ft. provided the flow is confined to the street right-of-way for the 100-year flood. The wier and orifice equations provided in Item 7.3 “Y-Inlets” assuming no cloggage, should be used to confirm flows are confined to the available right-of-way in the sag.

7.3 Y-Inlets

Flow into Y inlets shall be calculated using either the weir flow formula for an unsubmerged inlet or the orifice flow formula for a submerged inlet. First, weir flow will be considered. Weir flow occurs when an inlet is unsubmerged, which occurs at depths of flow, d, less than 0.70 feet above the inlet invert for Y inlets. Beginning with the general weir flow equation, we have the following:

$$Q = C_d L d^{1.5}$$

where:

Q = Flow, cfs;
C_d = Discharge coefficient;
L = Length of notch crest perpendicular to the flow, ft; and
d = Head measured above weir crest, ft.

The weir flow equation can now be applied to Y inlets to obtain the following:

For $d < 0.70'$: $Q_I = 2.25\ L\ d^{\ 1.5}$

where:

Q_I = Flow in to inlet, cfs;
2.25 = Weir coefficient adjusted for 25% clogged inlet throat;
L = Length of throat opening, ft; and
d = Depth of flow at inlet throat, ft.

When the depth of flow above the inlet invert, d, rises to 0.70 feet or higher, the inlet opening becomes submerged, causing orifice flow to govern the head-discharge relationship. The general orifice flow equation is as follows:

$$Q_I = C_d A_0 (2gHW)^{0.5}$$

where:

Q_I = Flow in to inlet, cfs;
C_d = Discharge coefficient;
A_0 = Area of inlet opening, ft^2;
g = Gravity acceleration constant, 32.2 ft/s^2; and
HW = Headwater above centerline of inlet opening height, ft.

Rewriting headwater, HW, as the depth of flow above the inlet opening height centerline, which is 0.25 feet for an opening height of 0.5 feet, we have

$$Q_I = C_d A_0 ((2g)(d-0.25))^{0.5}$$

where:

d = Depth of flow above inlet invert, ft.

Substituting the area of inlet opening, A_0, as the length of inlet opening, L, measured in feet, multiplied by the height of inlet opening, 0.5 feet, we have

$$Q_I = C_d (0.5L)((2g)(d-0.25))^{0.5}$$

By substituting 32.2 ft/s^2 for g, obtaining a C_d of 0.60 from an orifice discharge coefficient table, and assuming that 25% of the inlet throat is clogged, leaving only 75% of the inlet throat open to flow, we have

$$Q_I = (0.60)(0.75)(0.5L)((2)(32.2)(d-0.25))^{0.5}$$

Finally, simplifying produces the following orifice flow equation for Y inlets:

For $d \,/\, 0.70'$: $Q_I = 1.8\ L\ (d - 0.25)^{\ 0.5}$

where:

1.8 = Constant for English units to account for orifice coefficient adjusted for 25% clogged inlet throat.

7.4 Grate Inlets

The use of grate inlets shall require written approval from the City Engineer.

Grate inlets generally loose capacity with increase in grade, but to a lesser degree than curb opening inlets. The principal advantage of grate inlets is they are installed along the roadway where the water is flowing. The disadvantage is that they may be clogged by floating trash or debris. For safety reasons, preference should be given to grate inlets where out-of control vehicles might be involved. Additionally, where bicycle traffic occurs, grates should be bicycle safe. Grate inlets shall only be used with the approval of the City Engineer for thoroughfare construction. Private systems may construct grate inlets as outlined in this manual.

The allowable types of grates for use in the City depend on the inlet condition. For inlets in sag condition parallel bar grates are required Figures 7.4 A-B. For inlets on grade curved vane grates Figure 7.4 C are preferred, however 85 tilt bar grates (30 or 45 degree) are allowed as well Figure 7.4 D-E.

<u>Figure 7.4A - P-50 and P-50x100 Grate</u>
(P-50 is the grate without 3/8” transverse rods)

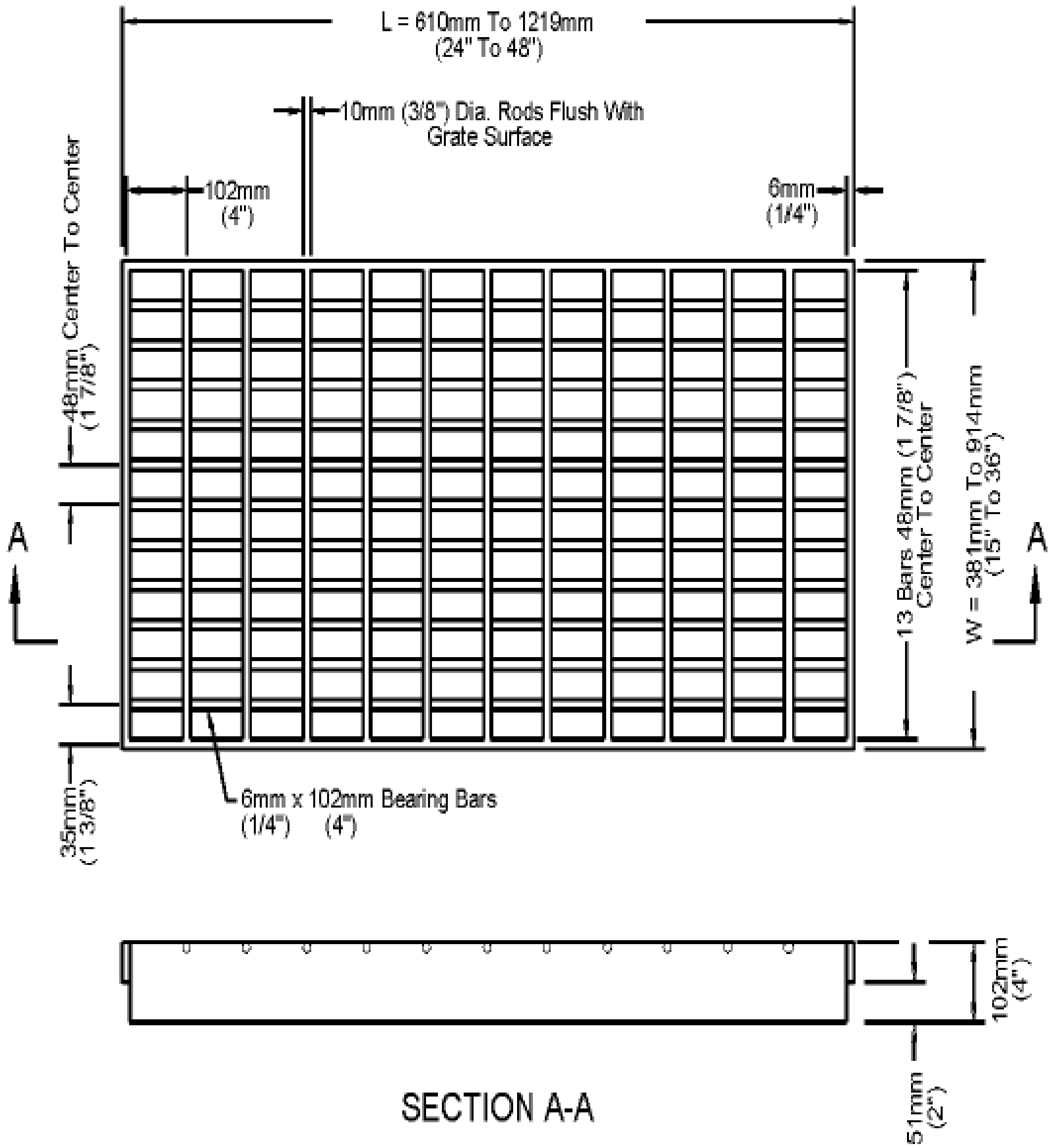


Figure 7.4B - P-30 Grate

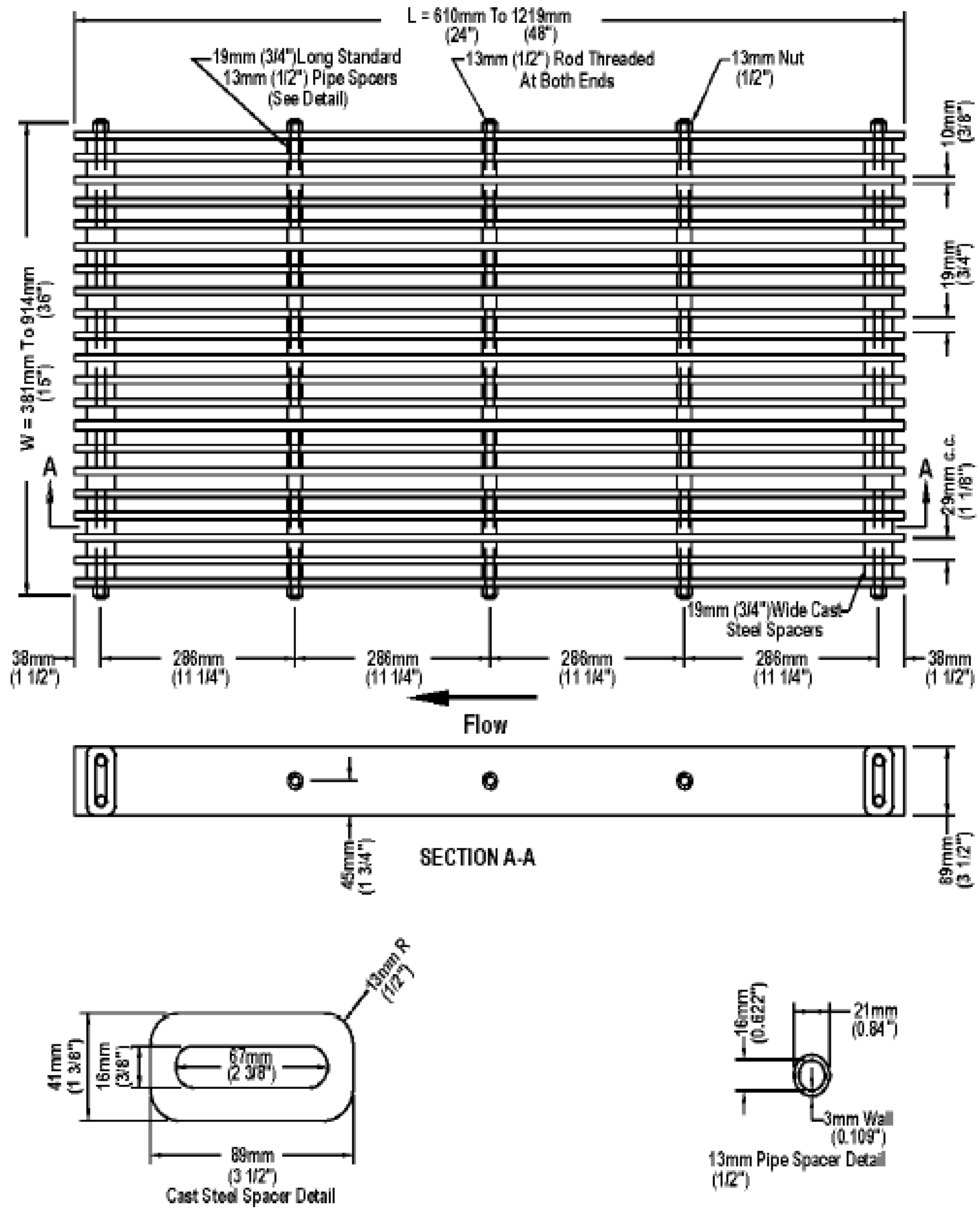


Figure 7.4C - Curved Vane Grate

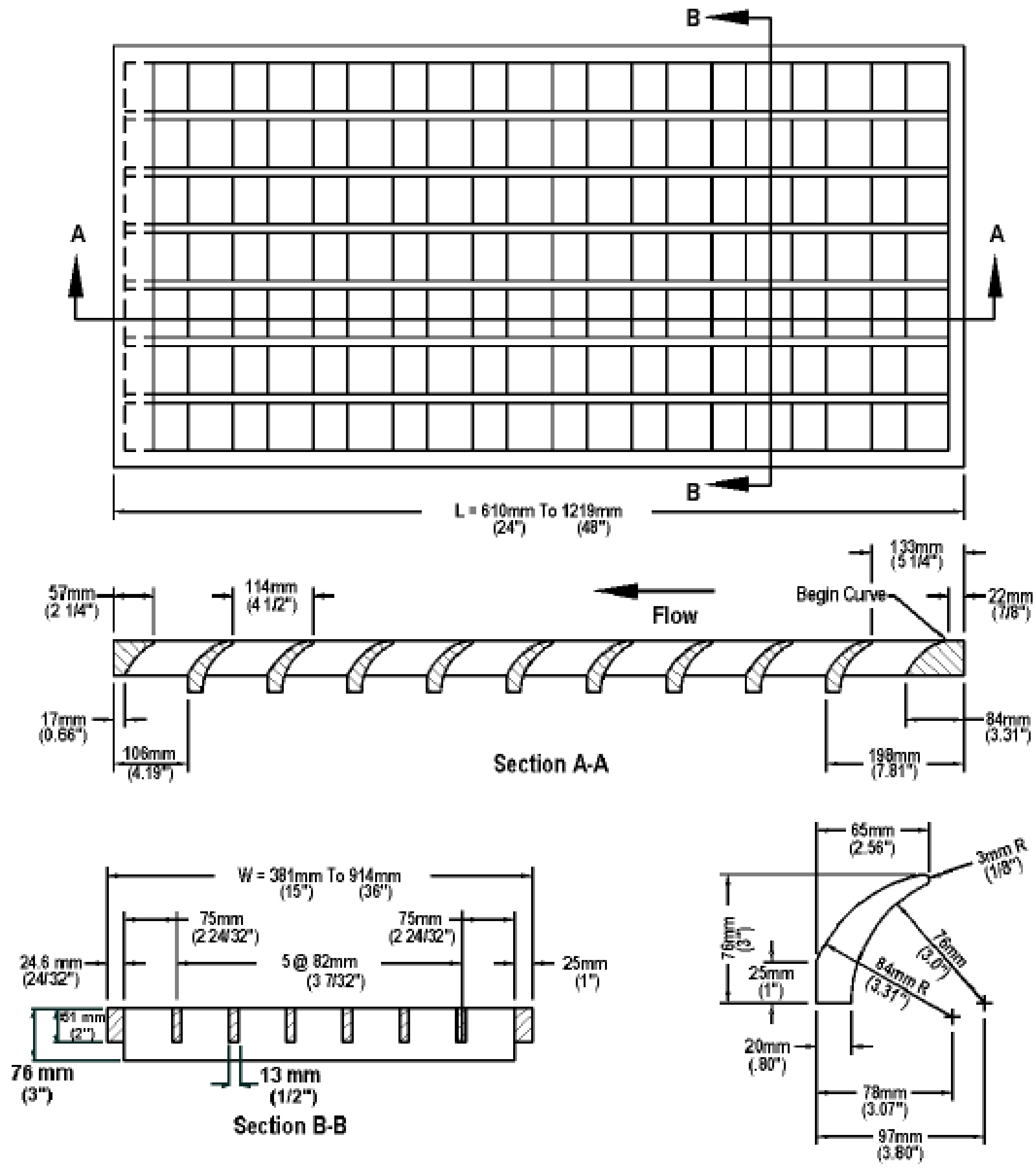


Figure 7.4D - 45˚ - 85 (3.25") Tilt-Bar Grate

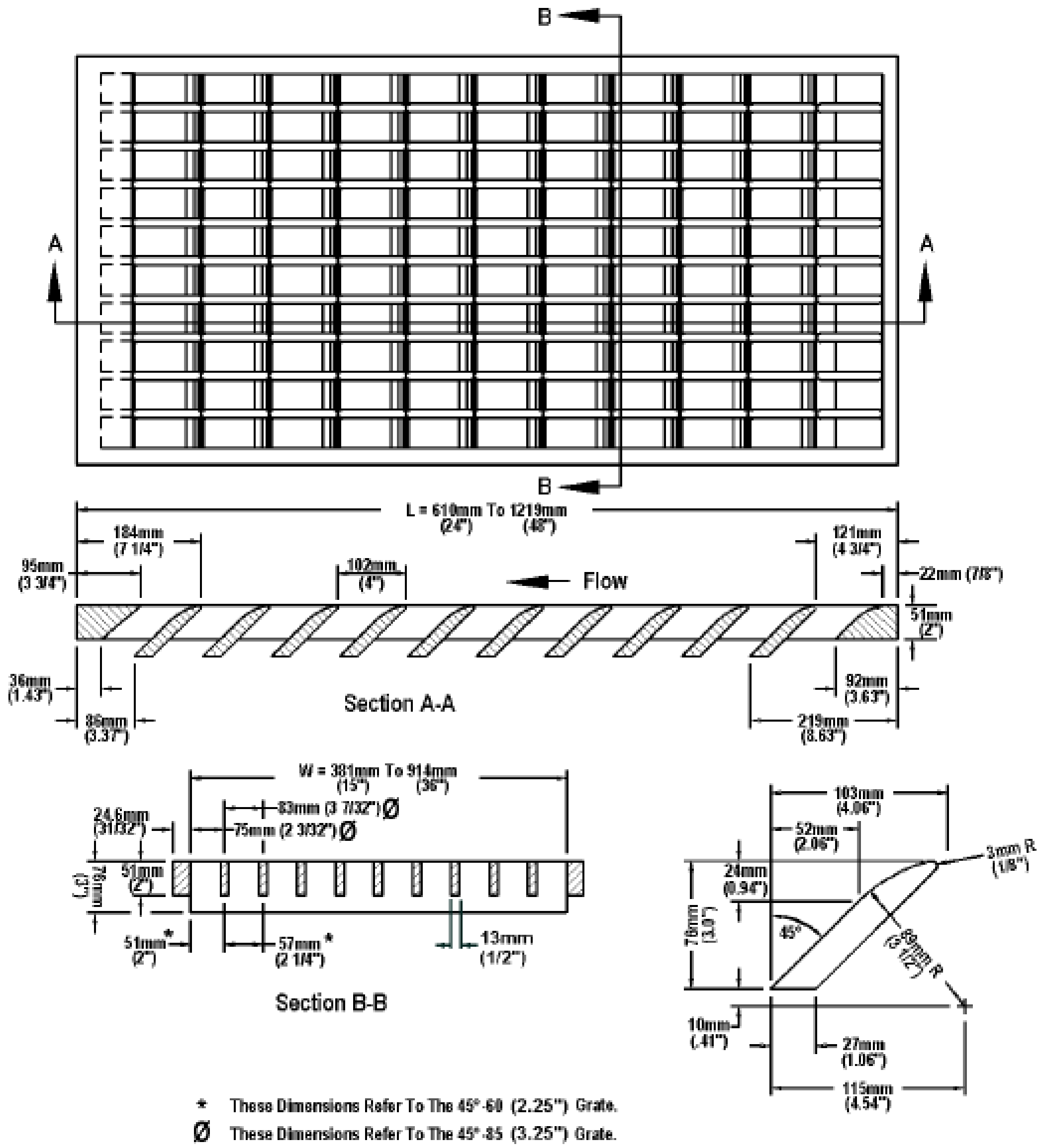
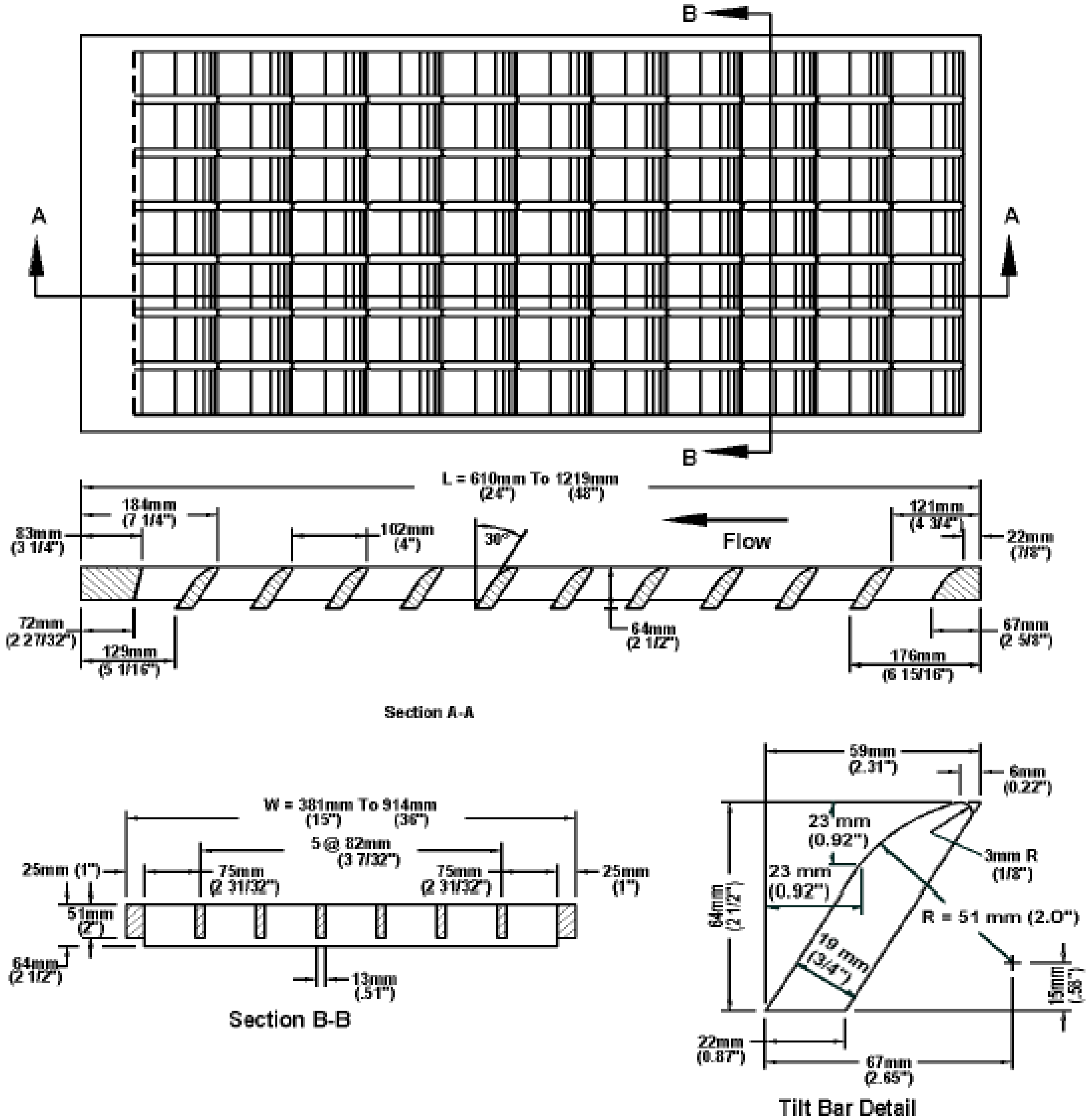


Figure 7.4E - 30˚ - 85(3.25") Tilt-Bar Grate



Grate Inlets on Grade

The capacity and efficiency of grate inlets increase with increased slop and velocity if splash-over does not occur. This is because frontal flow increases with increased velocity, and all frontal flow will be intercepted if splash-over does not occur. Design charts for inlets on grade and procedures for using the charts are presented for the various inlet configurations. For locally depressed inlets the quantity of flow reaching the inlet would be dependant on the upstream gutter section geometry and not the depressed section geometry.

When the velocity approaching the grate is less than the 'splash-over' velocity, the grate will intercept essentially all of the frontal flow. Conversely, when the gutter flow velocity exceeds the 'splash-over' velocity for the grate, only a part of the flow will be intercepted. A part of the flow along the side of the grate will be intercepted, dependent on the cross slope of the pavement, the length of the grate, and flow velocity.

The ration of frontal flow to total gutter flow, E_O for a uniform cross slope is expressed by the equation:

$$E_O = Q_W/Q = 1 - (1- W/T)^{2.67}$$

where:

Q is the total gutter flow (ft^3/s)
Q_W is the flow in width W (ft^3/s)
W is the width of depressed gutter or grate (ft)
T is the total spread of water (ft)

Chart 2B in Appendix F provides solutions of E_O for either uniform cross slopes or composite gutter sections.

The ration of side flow, Q_S, to total gutter flow

$$Q_S/Q = 1 - Q_W/Q = 1- E_O$$

The ration of frontal flow intercepted to total frontal flow, R_f, is expressed by:

$$R_f = 1 - K_u(V-V_O)$$

where:

K_u is 0.09
V is the velocity of flow in the gutter (ft^3/s)
V_O is the gutter velocity where plash-over first occurs, (ft^3/s)
(Note: R_f cannot exceed 1.0)

This ratio is equivalent to frontal flow interception efficiency. Chart 5B in Appendix F provides a solution for the equation above which takes into account grate length, bar configuration, and gutter velocity at which splash-over occurs. The average gutter velocity (total gutter flow divided by the area of flow) is needed to use Chart 5B in Appendix F. This velocity can also be obtained from Chart 4B in Appendix F.

The ratio of side flow intercepted to total side flow, E_S, or side flow interception efficiency, is expressed in the equation below. Chart 6B in Appendix F provides a solution to the equation:

$$E_S = 1/(1 + K_u V^{1.6}/S_X L^{2.3})$$

where:

K_U is 0.15 for English Units

A deficiency in developing the empirical equations and charts from experimental data is evident in Chart 6B in Appendix F. The fact that a grate will intercept all or almost all of the side flow where the velocity is low and the spread only slightly exceeds the grate width is not reflected in the chart. Error due to this deficiency is very small. Where velocities are high, side flow interception may be neglected without significant error.

The efficiency, E, of a grate is expressed as:

$$E = R_f E_O + R_S(1 - E_O)$$

The first term is the ration of intercepted frontal flow to total gutter flow, and the second is the ration of intercepted side flow to total side flow.

It is important to recognize that the frontal flow to total gutter flow ration, E_O, for composite gutter sections assumes by definition a frontal flow width equal to the depressed gutter section width. The use of this ration when determining a grate's efficiency requires that the grate width be equal to the width of the depressed gutter section, W. If a grate having a width less than W is specified, the gutter flow ratio, E_O must be modified to accurately evaluate the grate's efficiency. Because an average velocity has been assumed for the entire width of gutter flow, the grate's frontal flow ration E_O can be calculated by multiplying E_O by a flow area ratio. The area ratio is defined as the gutter flow area in a width equal to the grate width divided by the total flow area in the depressed gutter section. This adjustment is represented in the following equations:

$$E'_O = E_O(A'_W/A_W)$$

where:

E'_O is the adjusted frontal flow area ratio for grates in composite cross sections

A'_W is the gutter flow area in a width equal to the grate width (ft^2)

A_W is the flow area in depressed gutter width (ft^2)

The interception capacity of a grate inlet on grade is equal to the efficiency of the grate multiplied by the total gutter flow as represented below: (Note E'_O should be used in place of E_O)

$$Qi = EQ = Q[R_f E_O + R_S(1-E_O)]$$

Grate Inlets in Sag

Grate inlets in sag vertical curves operate as weirs for shallow ponding depths and as orifices at greater depths. Between weir and orifice flow depths, a transition from weir to orifice flow occurs. The perimeter and clear opening area of the grate and the depth of water at the curb affect inlet capacity. The capacity at a given depth can be severely affected if debris collects on the grate and reduces the effective perimeter or clear opening area. Grates of larger dimension will operate as weirs to greater depths than smaller grates.

The capacity of grate inlets operating as weirs is:

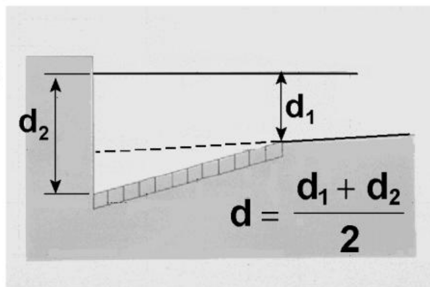
$$Q_i = C_W P d^{1.5}$$

where:

P is the perimeter of the grate in ft disregarding the side against the curb
C_W is 3.0 for English Units
d is the average depth across the grate:

$$d=0.5(d_1 + d_2)$$

Figure 7.4F - Average Depth Across Grate



The capacity of a grate inlet operating as an orifice is:

$$Q_i = C_o A_g (2gd)^{0.5}$$

where:

C_o is the orifice coefficient = 0.67
A_g is the clear opening area of the grate (ft^2)
g = 32.16 (ft/s^2)

This equation requires the clear opening area of the grate.

Chart 9B in Appendix F is a plot of the equations above for various grate sizes. The effects of grate size on the depth at which a grate operates as an orifice is apparent from the chart. Transition from weir to orifice flow results in interception capacity less than that computed by either the weir to the orifice equation. This capacity can be approximated by drawing in a curve between the lines representing the perimeter and net area of the grate to be used.

Some assumptions must be made regarding the nature of clogging in order to compute the capacity of a partly clogged grate. For grate inlet is sag conditions calculations should be performed with the assumed that 50 percent (50%) of the grate open area is clogged, and the perimeter of the grate (disregarding side adjacent to the curb) shall be reduced by 25 percent (25%).

Flow in to all other inlets shall be computed per the procedures specified in *HEC-22 Urban Drainage Design Manual* (FHWA, 2001). Copies of this manual are available free of change on the Internet under publications at *http://www.fhwa.dot.gov/.*

7.5 Non-Recessed Curb Inlets

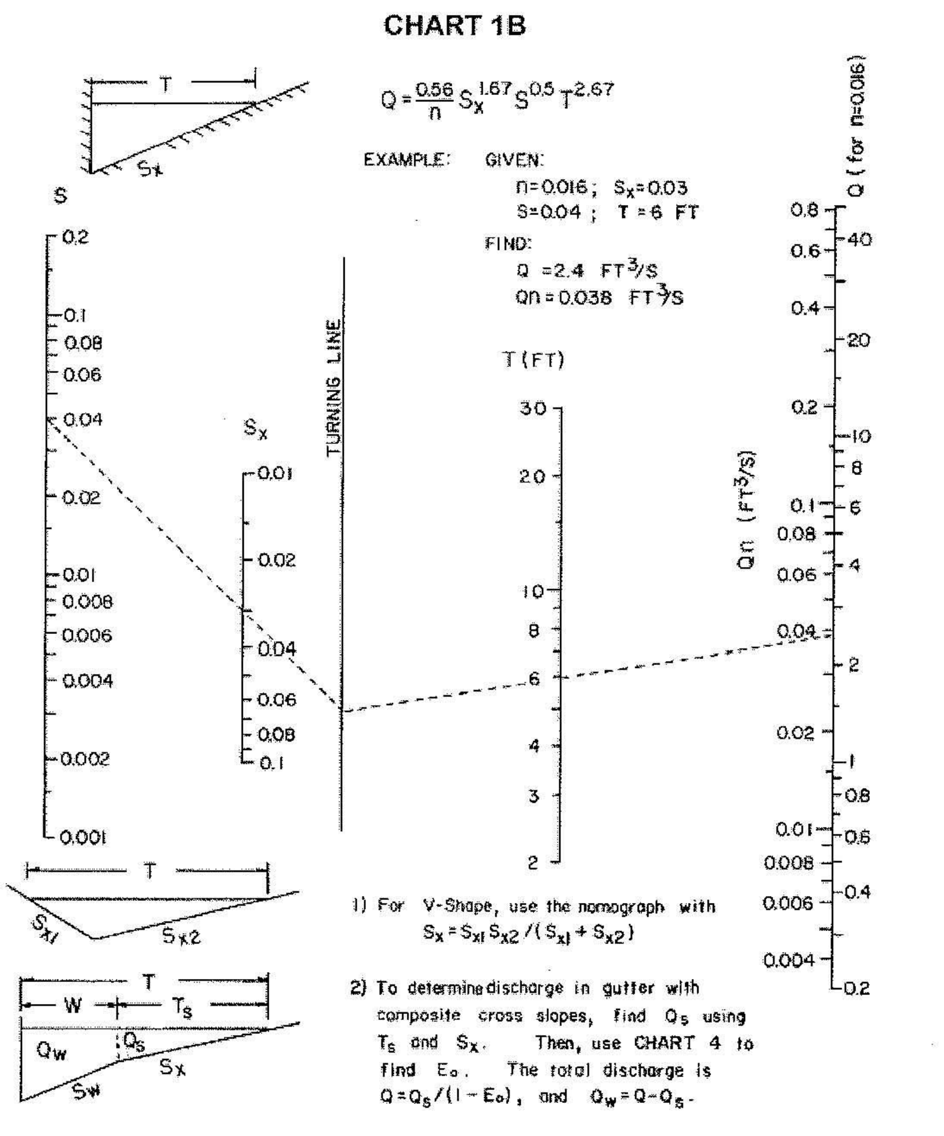
The use of non-recessed curb inlets shall require special approval from the City Engineer.

They shall only be allowed to avoid conflicts with existing utilities. Their design shall be computed per the procedures specified in *HEC-22 Urban Drainage Design Manual* (FHWA, 2001). Copies of this manual are available free of change on the Internet under publications at *http://www.fhwa.dot.gov/*

Appendix “F”

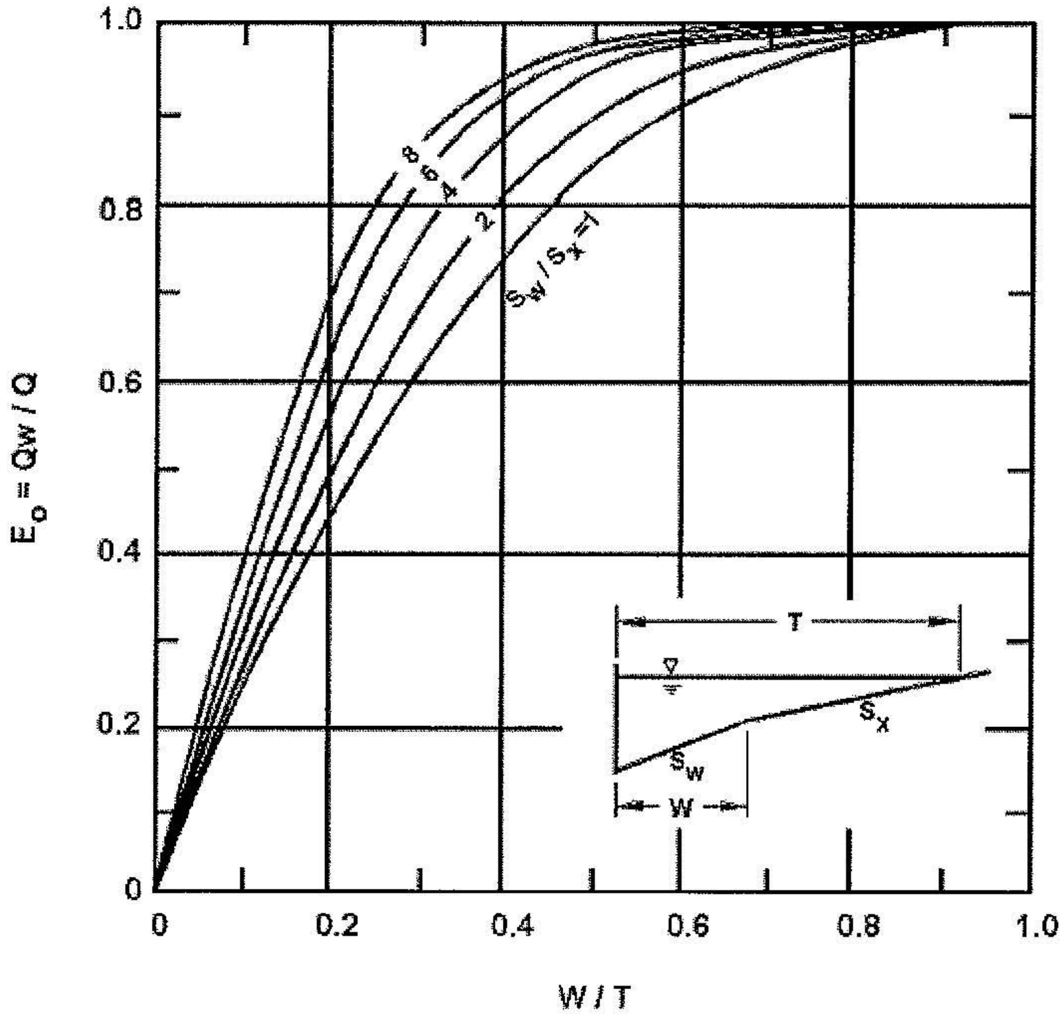
APPENDIX “F”

DESIGN CHARTS FOR GRATE INLETS



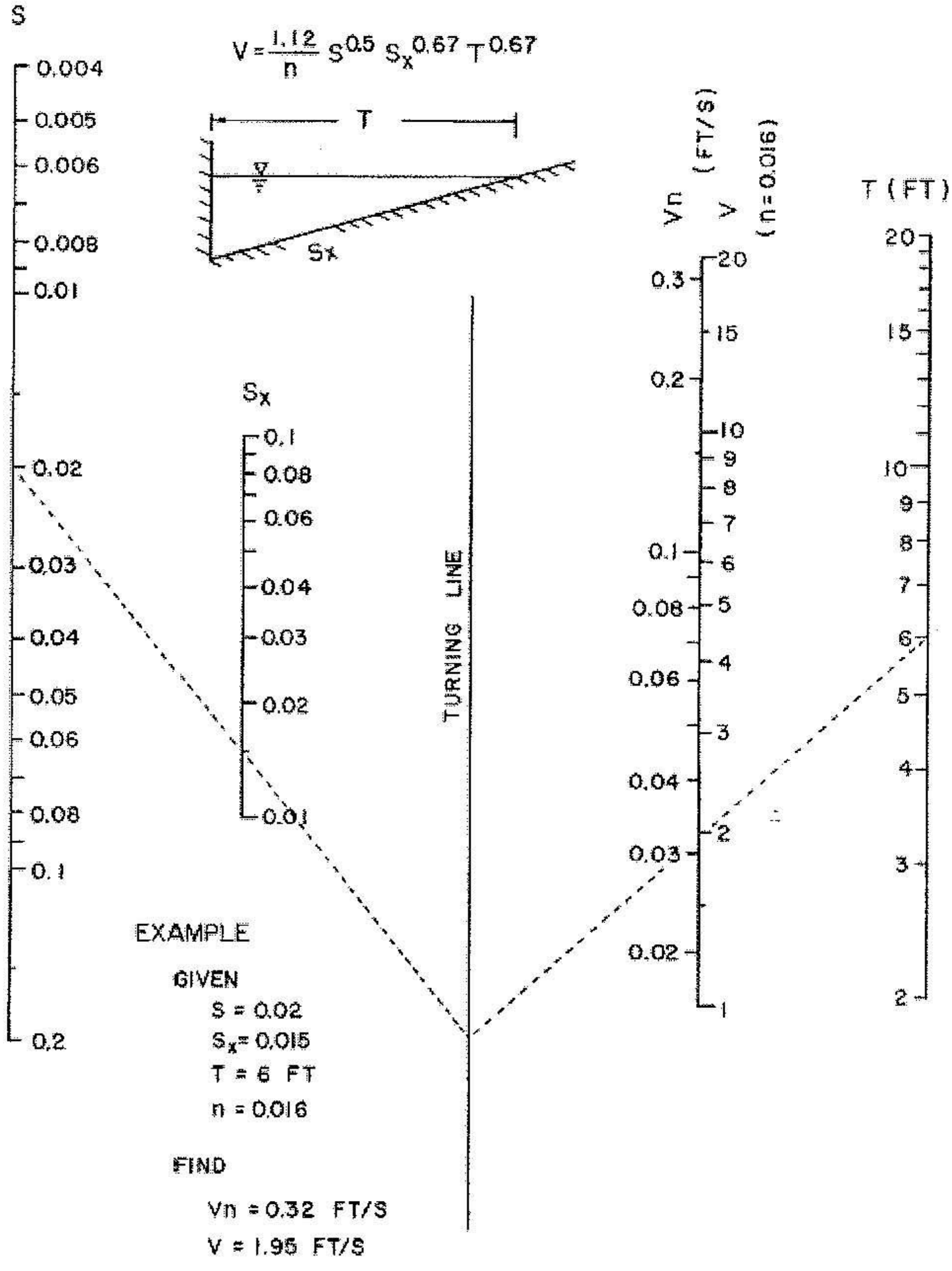
Flow in Triangular Gutter Sections - English Units

CHART 2B



Ratio of Frontal Flow to Total Gutter Flow

CHART 4B



Velocity in Triangular Gutter Sections - English Units

CHART 5B

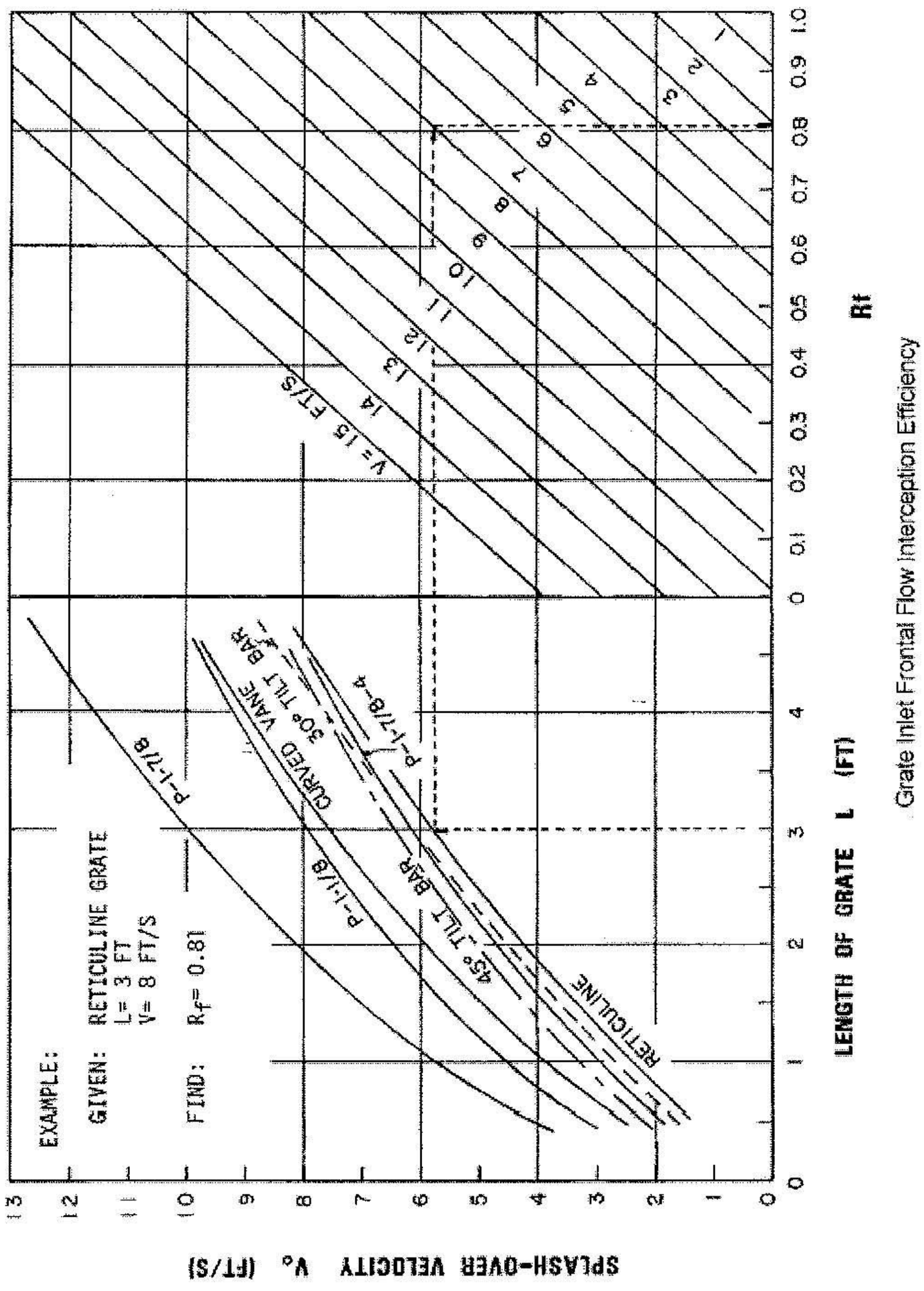


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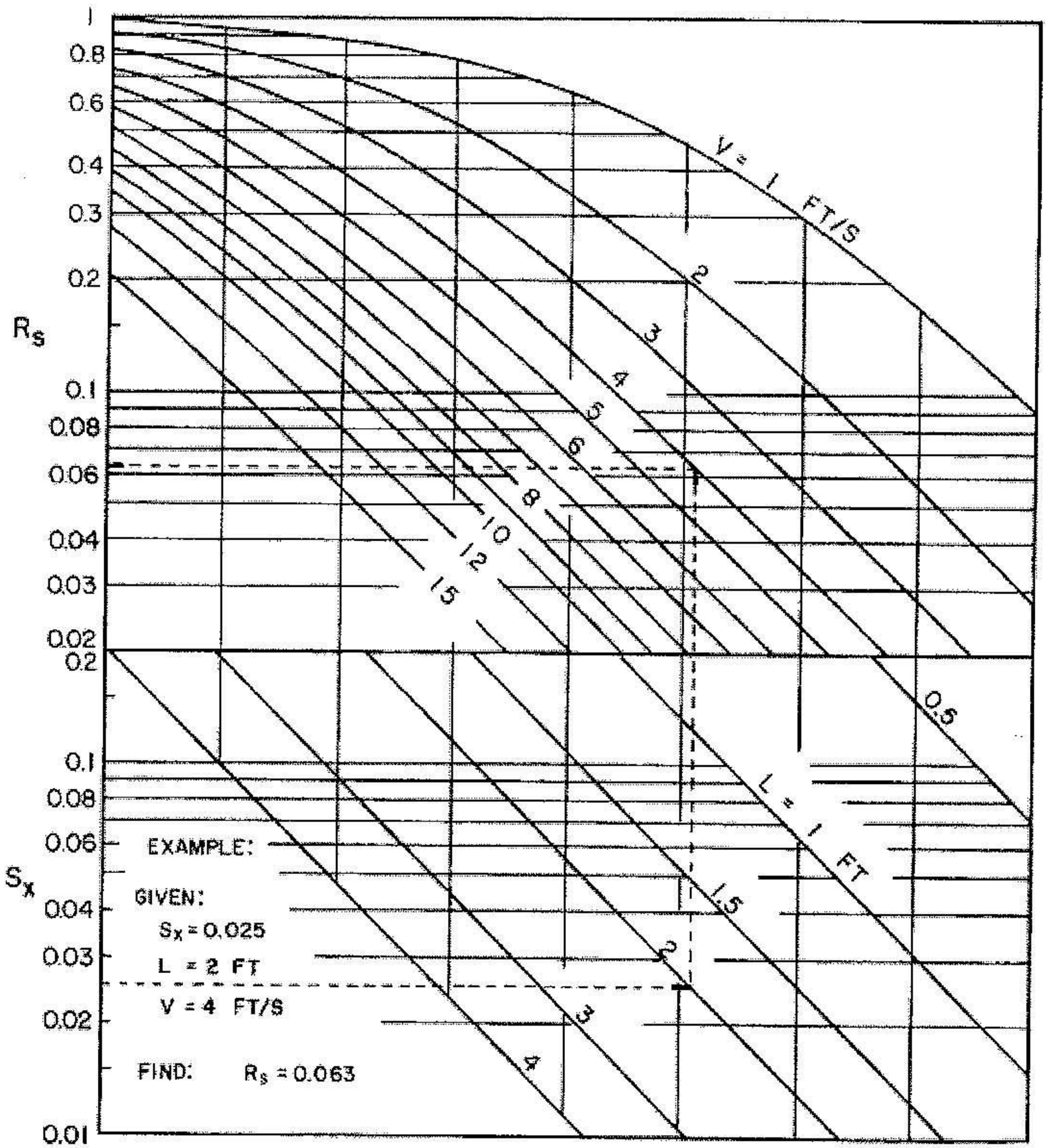
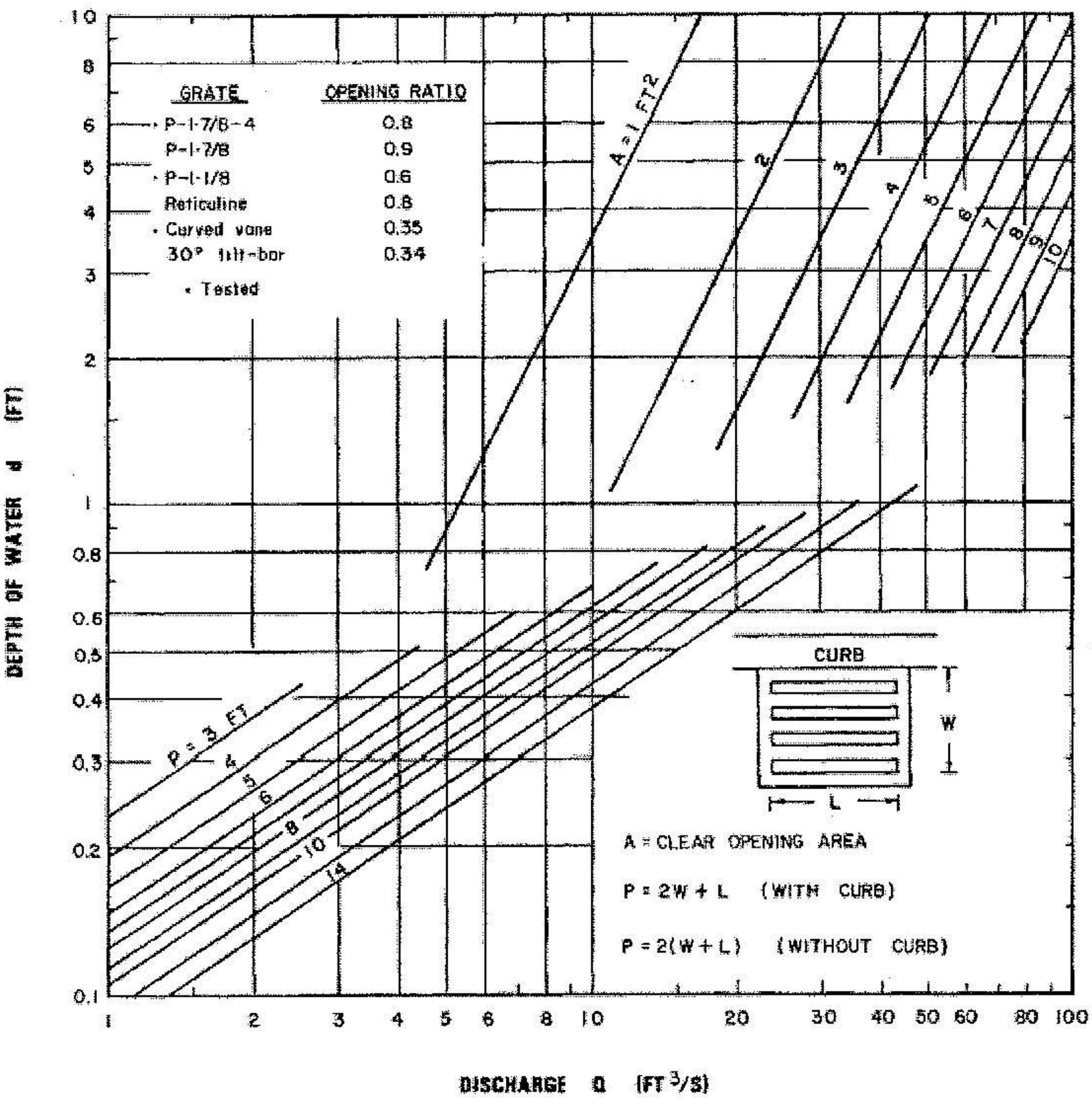
CHART 6B



Grate Inlet Side Flow Intercept Efficiency

CHART 9B



Grate Inlet Capacity in Sump Conditions - English Units

Appendix “G”

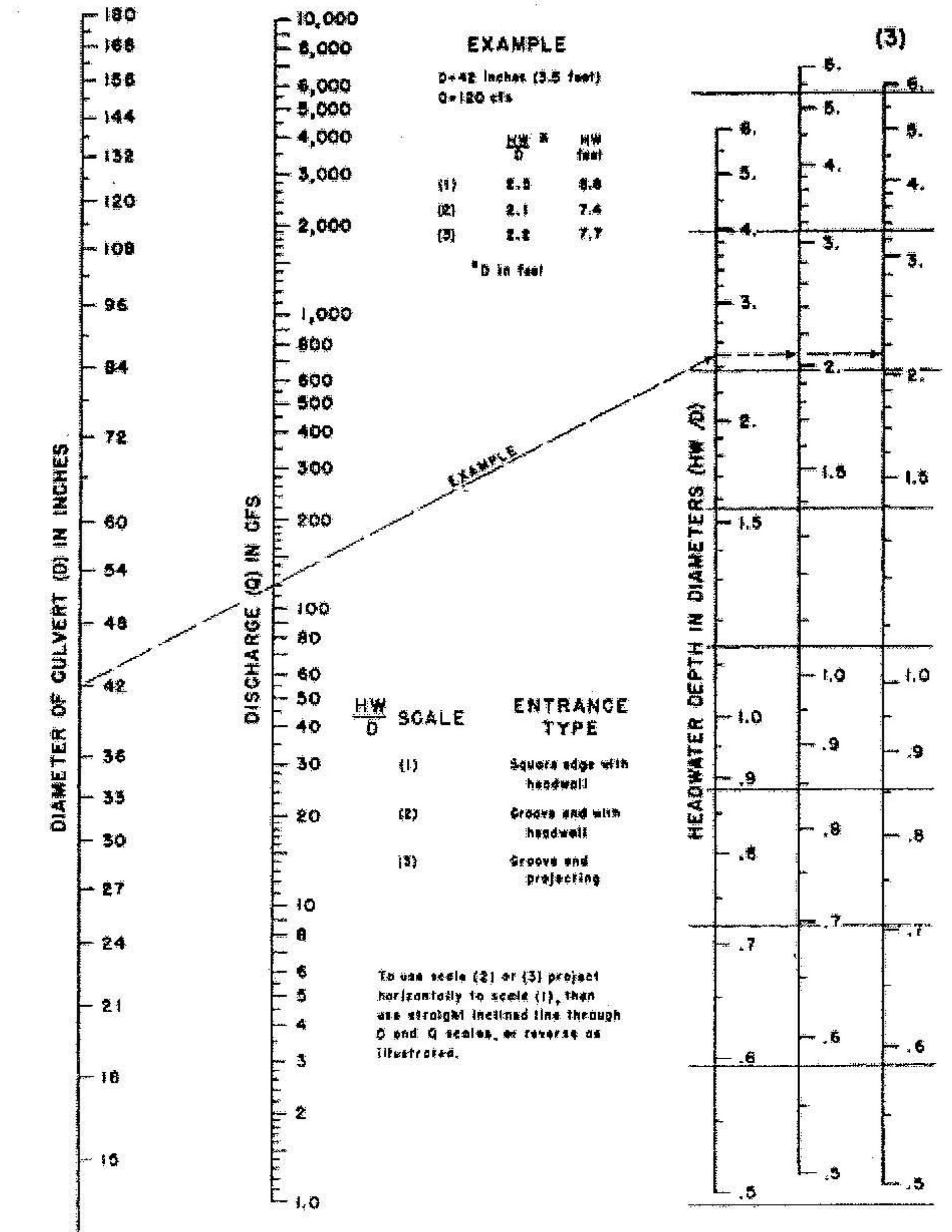
CITY OF THE COLONY

ENGINEERING DESIGN MANUAL

APPENDIX “G”

DESIGN CHARTS FOR CULVERTS

CHART 1B

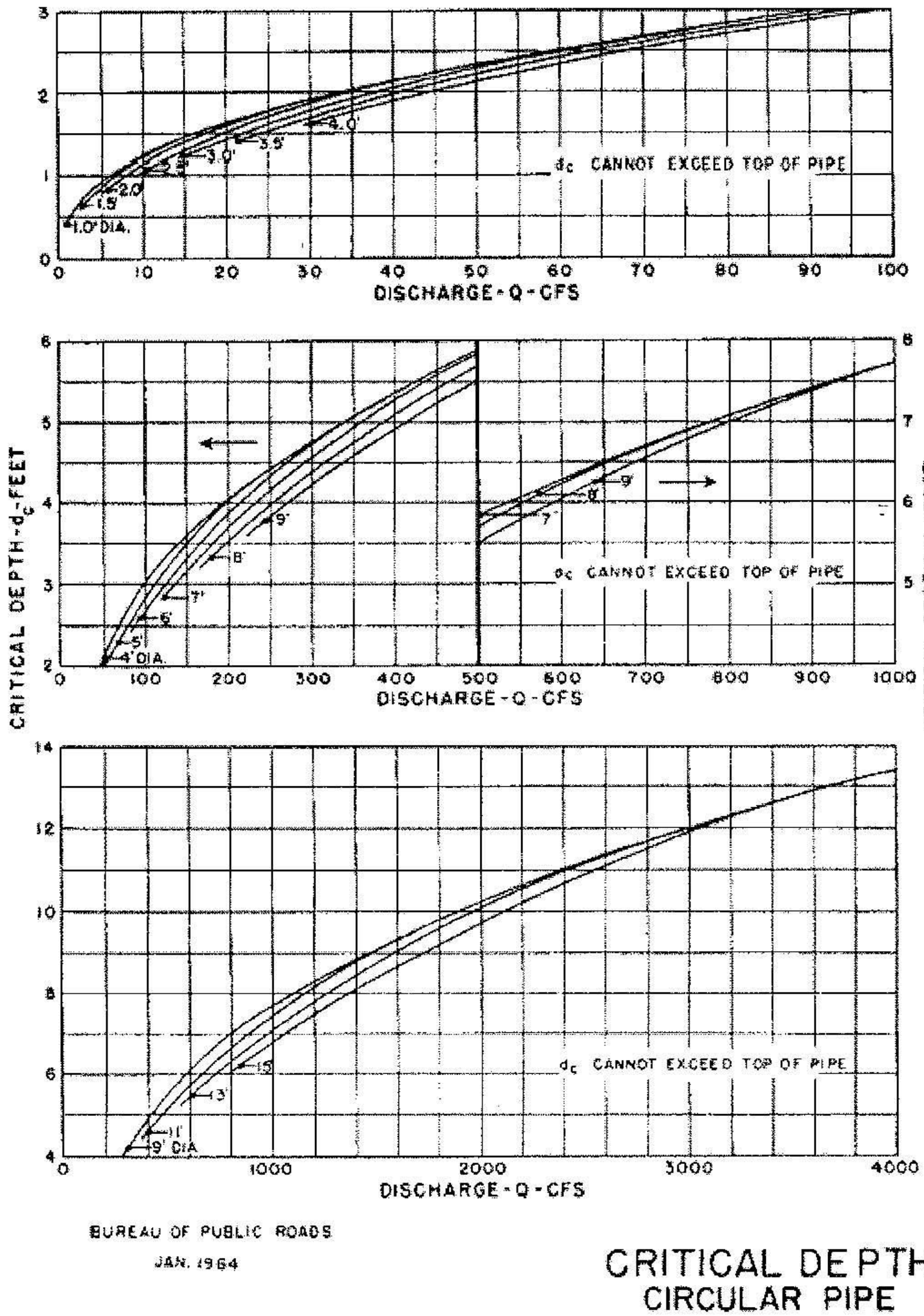


HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

HEADWATER SCALES 2&3 REVISED MAY 1964

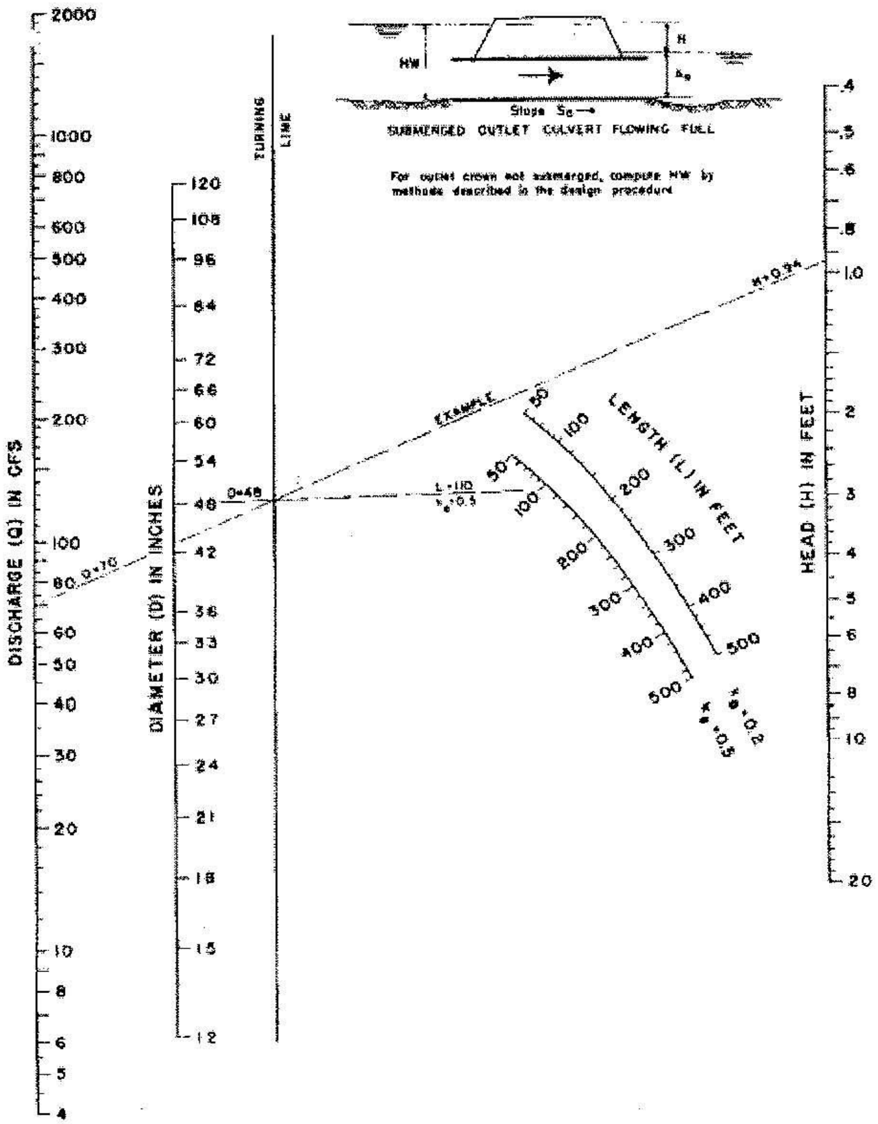
BUREAU OF PUBLIC ROADS JAN 1963

CHART 4B



CRITICAL DEPTH
CIRCULAR PIPE

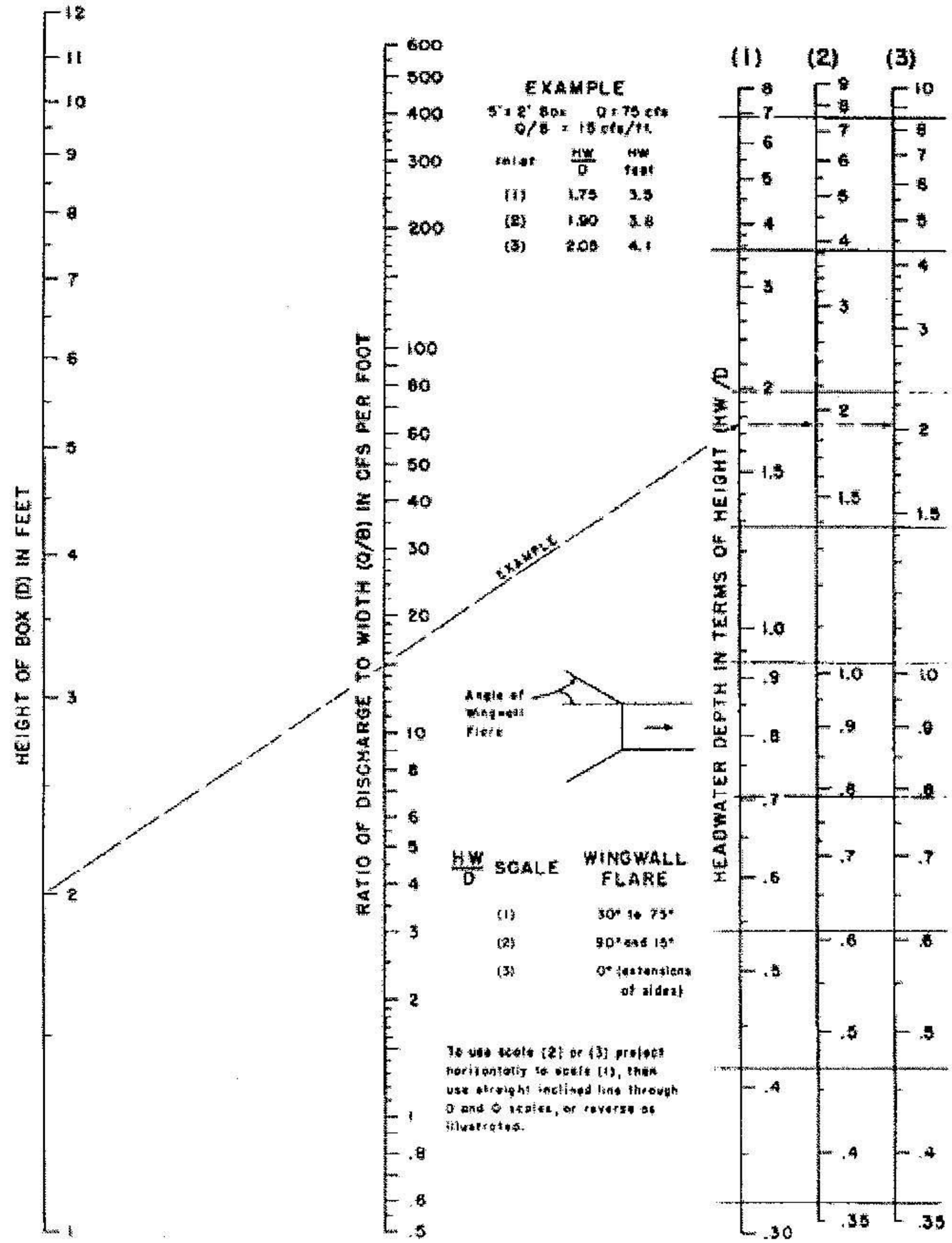
CHART 5B



HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

BUREAU OF PUBLIC ROADS JAN 1963

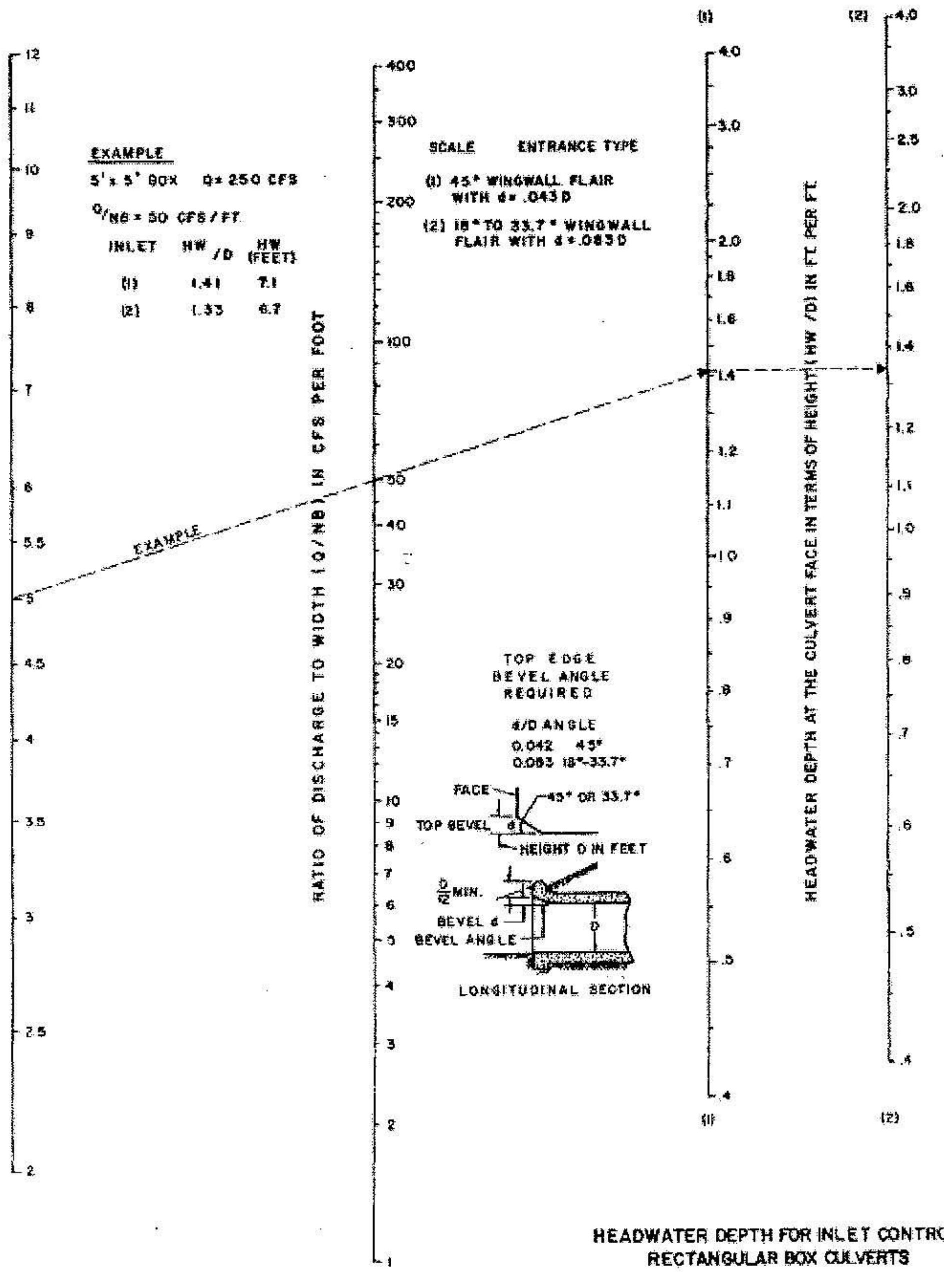
CHART 8B



HEADWATER DEPTH
FOR BOX CULVERTS
WITH INLET CONTROL

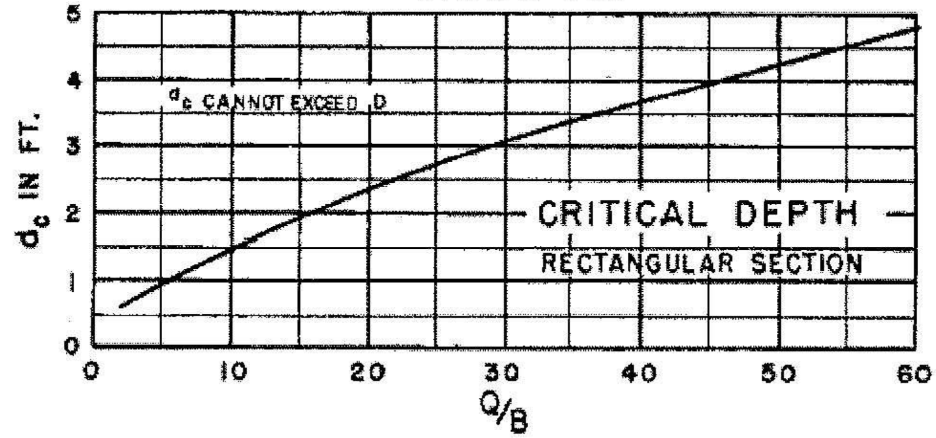
BUREAU OF PUBLIC ROADS JAN. 1963

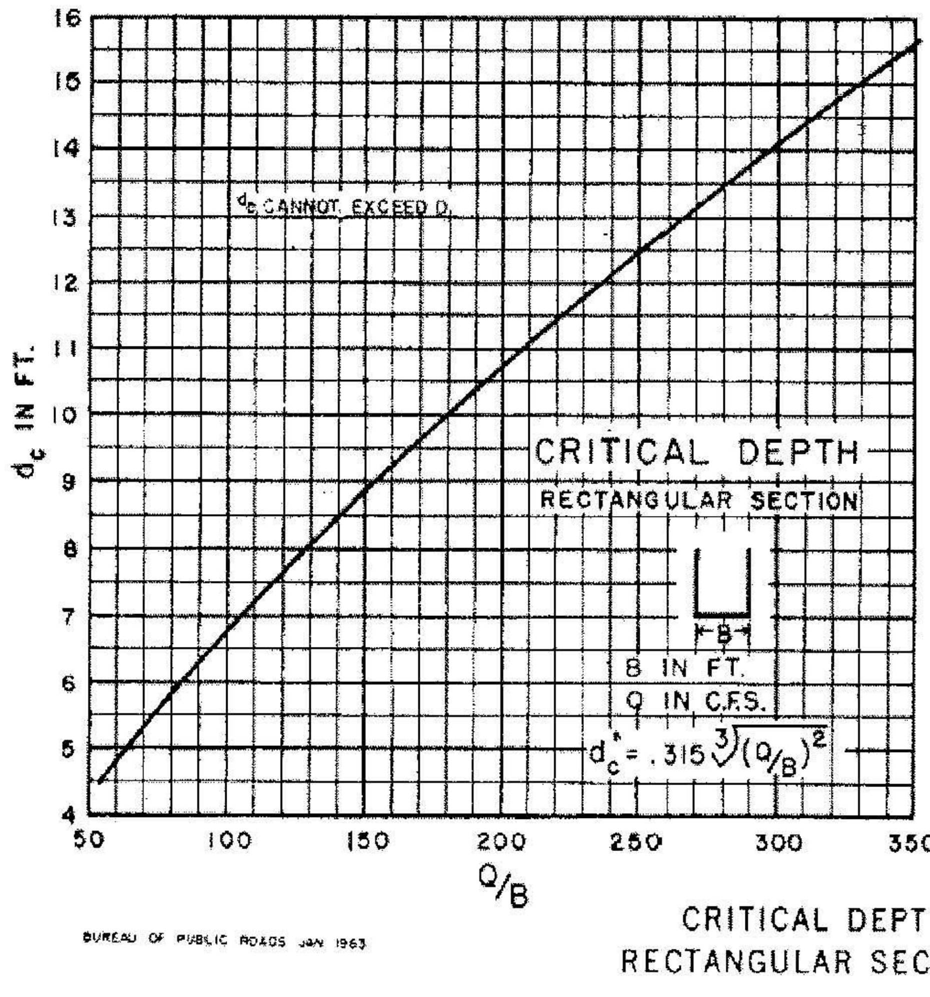
CHART 9B



HEADWATER DEPTH FOR INLET CONTROL
RECTANGULAR BOX CULVERTS
FLARED WINGWALLS 18° TO 33.7° & 45°
WITH BEVELED EDGE AT TOP OF INLET

CHART 14B

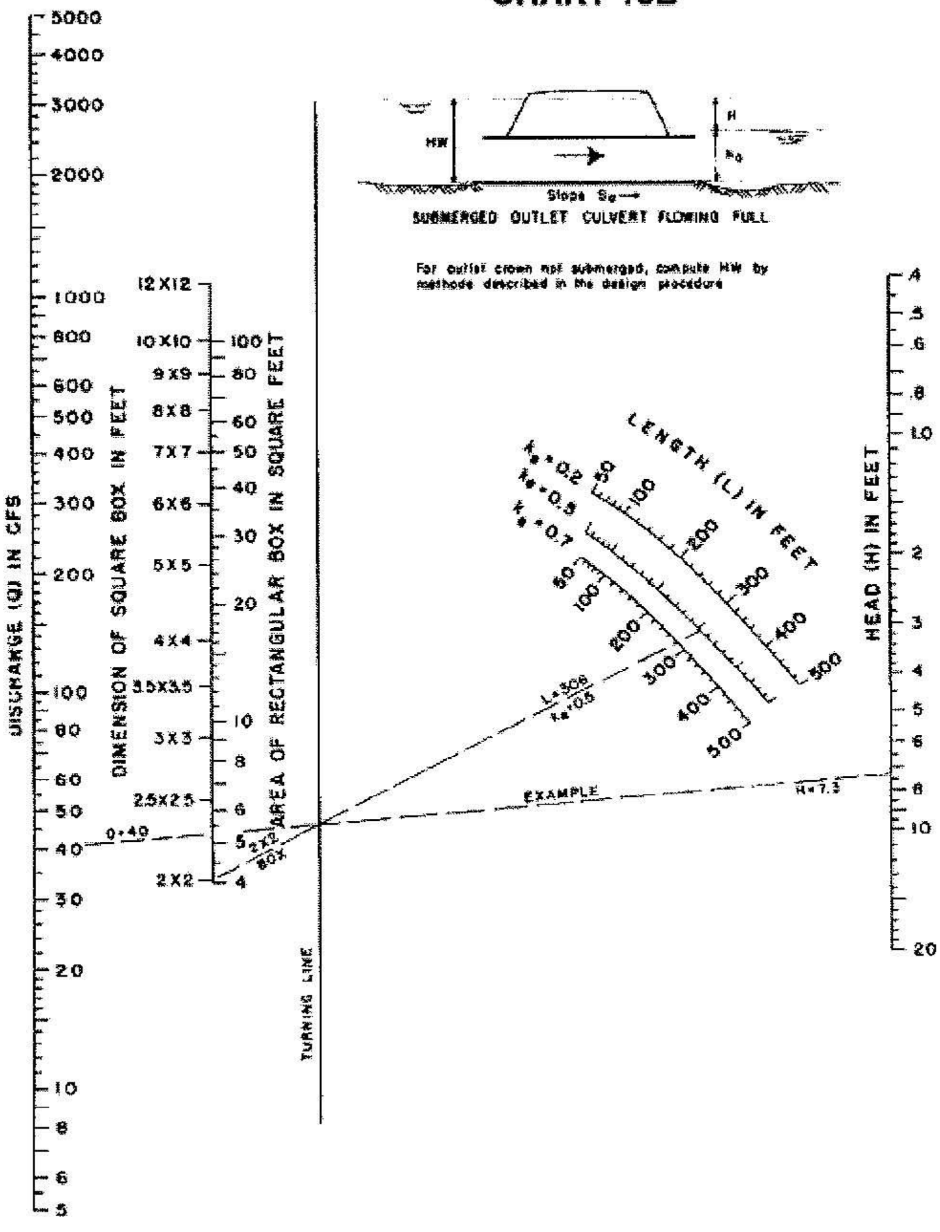




BUREAU OF PUBLIC ROADS JAN 1963

CRITICAL DEPTH
RECTANGULAR SECTION

CHART 15B



HEAD FOR
CONCRETE BOX CULVERTS
FLOWING FULL
n = 0.012

AU OF PUBLIC ROADS JAN. 1963