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PUBLIC WORKS DESIGN MANUAL

AUGUST 21, 2023

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City of Denison
Public Works Design Manual

Record of Revisions

Date of Adoption	Comments
March 20, 2023	Public Works Design Manual Adopted by City Council
August 21, 2023	Stormwater Design Update Adopted by City Council

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City of Denison
Public Works Design Manual

Purpose

This following document contains the various construction criteria, techniques, and details which are the minimum requirements of the City of Denison for public facilities. This information is primarily intended for the use of the Developer and his Engineer to enable the applicant to provide the proper design for the public facilities associated with a proposed development. These criteria are not intended as an exhaustive list of the construction techniques available. In the event that the specific circumstances dictate additional requirements, it shall be the responsibility of the Developer's Engineer to provide the necessary details for construction to be approved by the Public Works Director.

These design criteria and details may be modified by administrative action of the city and subsequent City Ordinance at such times as may be appropriate in keeping with the most up-to-date construction techniques and specifications.

All water, sewer, street and drainage installations shall be in accordance with the current City Standards and Specifications (found herein and in the City Ordinances). As well as in the American Water Works Association (AWWA) design manuals. However, city standards, specifications, and local amendments take precedence over the AWWA manuals.

Section 1 Roadway Design

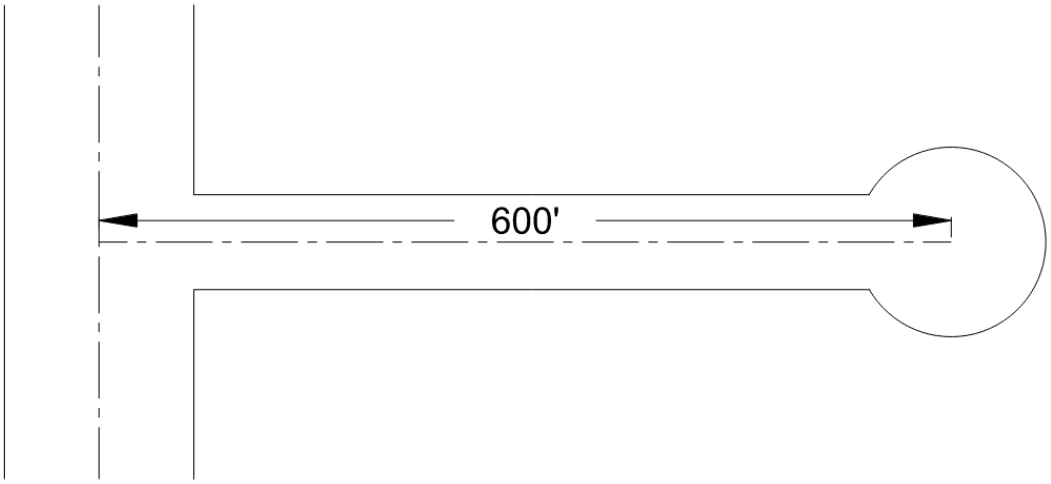
A. General Design Criteria

1. This section presents the basic criteria to be used in the design of roadways in the City of Denison. The design controls described in this section should be used in the design of all public roadways. Any variance required due to project specific constraints must be approved by the Public Works Director or their designee. At a minimum, all thoroughfare designs shall meet the guidelines in AASHTO's current edition of A Policy on Geometric Design of Highways and Streets.
2. All proposed streets shall be constructed of concrete with integral curb & gutter in accordance with the City's Standards and Specifications unless otherwise allowed by the Public Works Director or their designee. All proposed paving shall be placed following installation of City owned underground utilities.
3. Existing asphalt streets may be repaired as asphalt streets with either curb and gutter or bar ditches in accordance with the City's Standards and Specifications as allowed by the Public Works Director or their designee.

B. Horizontal Design

1. The minimum classified width of a proposed street shall be enlarged under the following conditions.
    a. Adjacent to commercial or multi-family land uses where, in the opinion of the Public Works Director or their designee and based on analysis of proposed width and expected traffic volume and flow, the standard required width is insufficient for proper access and circulation.
    b. Where, in the opinion of the City or in the opinion of the Developer, with the concurrence of the City, the aesthetic value achieved from extra width is dictated by special conditions.
2. The proposed streets shall be located in the center of the right-of-way to allow both parkways to be the same width unless otherwise allowed by the Public Works Director or their designee to be offset from the center of the right-of-way. The final grade of all parkways, existing and proposed, shall be one-quarter inch (1/4") per foot cross slope from the top of curb to the property line unless otherwise allowed by the Public Works Director or their designee. All parkways shall drain to the street. Exceptions may be allowed by the Public Works Director or their designee to preserve native trees.
3. Intersection Curb Returns:
    a. Minimum forty-foot (40') radius for arterial/arterial intersections.
    b. Minimum thirty-five-foot (35') radius for arterial/collector intersections
    c. Minimum thirty-foot (30') radius for industrial intersections
    d. Minimum twenty-five-foot (25') radius for local intersections

4. Roadway Centerlines:
    a. Minimum eight hundred and twenty-five-foot (825') radius for arterials
    b. Minimum three hundred and fifty-foot (350') radius for collectors and industrial
    c. Minimum two hundred and fifty-foot (250') radius for local
5. Reverse Curve Tangent Lengths:
    a. Minimum two hundred-foot (200') for arterials
    b. Minimum two hundred-foot (200') for collectors and industrial
    c. Minimum one hundred-foot (100') for local
6. Cul-de-sacs:
    a. Minimum forty-foot (40') radius to the back of curb
    b. Minimum fifty-foot (50') radius right-of-way
    c. Maximum 600 feet in length, measured from centerline of the cross street to the center point of the cul-de-sac, unless otherwise authorized by the Fire Marshal



7. Standard reinforced concrete curb height and width is six inches (6").
8. All street intersections shall be constructed to form a ninety-degree (90^{o}) angle +/- 10^{o} unless approved by the Public Works Director or their designee.

C. Vertical Design

1. Street grades shall be designed such that excessive soil depositions from too low a water velocity or pavement scouring from too high a velocity is avoided. The minimum street grade permitted shall be 0.60% and the maximum street grade permitted shall be 6.0%, unless otherwise approved by the Public Works Director or their designee. Any deviation from this range of permissible grades shall require written approval of the Public Works Director or their designee.
2. Vertical curves are not required for changes in grade with an algebraic difference of one percent (1%) or less.
3. Where vertical curves are required, the following shall be considered:

a. In order to maintain adequate sight distance, the minimum "K" values for the computation of vertical curves in the standard formula L=KA, where L is the length of the vertical curve in feet, and A is the algebraic difference of the street grades in percent (%) are listed below:

Table 1C-1 Minimum Vertical "K" Values and Length

Design Speed	Crest		Sag	
MPH	"K" Value	Length (ft)	"K" Value	Length (ft)
30	19	20	37	40
35	29	20	49	40
40	44	50	64	70
45	61	65	79	80
50	84	70	96	80

All vertical curves shall be designed following the guidelines in AASHTO's current edition of A Policy on Geometric Design of Highways and Streets

b. Minimum vertical curve values do not account for intersection sight distance for intersecting streets. Intersection sight distance for all intersecting streets shall be evaluated in accordance with AASHTO guideline and shall be considered when developing vertical curvature.

D. Medians

1. Median openings shall be spaced a minimum of six hundred feet (600') center-to-center and eight hundred feet (800') from an intersection on all divided streets and roadways.
2. Median opening widths shall be a minimum of sixty feet (60') wide and centered on driveways that they are across from.
3. The typical storage length is 150 feet with 150 feet of transition.
4. The maximum longitudinal grade break (algebraic difference) for median openings shall be 4%.
5. Median noses shall be designed based on the condition of the median at openings and intersections per the Median Nose details in the City of Denison's Standard Construction Details.
6. Median landscaping shall be designed in a manner that does not impact driver visibility. Factors that could limit driver visibility are roadway vertical and horizontal curvature, vegetation height and width, tree placement along with median height (berms). Typical areas of concern are median noses that located across from left-turn bays and placement of vegetation and trees around horizontal curves. All trees shall be trimmed to a minimum foliage height of 10 feet.

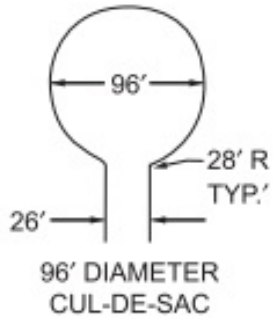
E. Sidewalks

1. Sidewalks shall be placed on both sides of the street within the right-of-way. No closer than one foot (1') from the right-of-way line

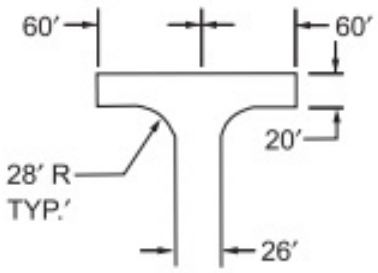
2. Sidewalks shall be designed and constructed to meet ADA and TAS requirements and have a cross slope of no greater than one two percent (2%) per foot.
3. Sidewalks shall not have a running grade (longitudinal slope) greater than 5%.
4. Sidewalks shall be constructed of four-inch (4") thick, three thousand (3,000) psi compressive strength concrete reinforced with #3 steel bars laid on maximum of eighteen-inch (18") centers per City of Denison Standard Details.
5. Sidewalks shall be a minimum of five feet (5') in width.
6. Sidewalks along TxDOT facilities shall be in accordance with TxDOT standards.
7. Sidewalks shall have accessible ramps at intersections of all streets and thoroughfares and at all driveways to conform with ADA guidelines.

F. Fire Lane

1. Fire lane shall be designed per the City of Denison adopted edition of the International Fire Code.
2. Minimum thickness for paving under fire lanes is 8".
3. All designated fire lanes shall always be maintained by the property owner.
4. Dead-end fire lanes shall not exceed 150 feet in length without approved turnaround provisions provided.



96′ DIAMETER
CUL-DE-SAC



120′ HAMMERHEAD

G. Driveway Standards

1. General Driveway Standards:
    a. Driveway permit applications are required for all new driveways and must be submitted to the City of Denison prior to approval.
    b. Sidewalk to be Removed: Where a driveway approach is to be built, the sidewalk shall be removed, redwood joints installed, and the entire area replaced as a driveway. The drive approach shall extend to the property line
    c. Driveway Approaches at Pedestrian Crossings: Driveway approaches shall not be located in street intersections or at established pedestrian crossings.
    d. Driveway Approaches at Obstructions: Driveway shall be kept at a minimum of five feet (5') away from obstructions such as streetlight posts, fire hydrants, traffic signals, etc.
    e. Driveway Approach not to be Obstructed: Driveway approaches shall not be constructed or designed for parking of vehicles or for use as angle parking.
    f. Accumulative Width of Approaches: Driveway approaches shall not occupy more than forty percent (40%) of the frontage of a lot or tract in each case.

g. Angle of Driveway Approach: The angle of the driveway approach with the curb line shall be ninety degrees (90°).

2. Residential Driveway Approaches
   a. Residential driveway approaches shall be hand poured and constructed of six-inch (6") thick thirty- six hundred (3,600) psi compressive strength concrete reinforced with #3 bars on eighteen-inch (18") centers both ways. The driveway shall begin 18" in front of the back-of-curb and extend to the property line or to a point ten feet (10') from the face of the curb whichever is greater. The drive approach shall be constructed such that the height of the drive approach at the property right-of-way line, with a normal ten-foot (10') parkway, shall be minimum eight and one-half inches (8 ½") higher than the gutter flowline. All driveways shall have a 5' sidewalk crossing graded at no more than two percent (2%) cross slope.
   b. Width of Driveway Approaches: Residential driveway approaches shall not be less than twelve feet (12') in width nor more than twenty feet (20') wide measured at the property line. Specific variance to this criterion may be requested by the property owner. Any variance granted based on a specific design submittal must have the approval of the Public Works Director or their designee.
   c. Radius: Residential driveways shall be constructed with the return curbs having a rolled face disappearing at the sidewalk and joining the street curb with a minimum five-foot (5') radius and a maximum ten-foot (10') radius.
   d. Provision for Joint Use Approaches: Drive approaches shall be located entirely within the frontage of the premises they serve except for joint-use, or cooperative driveways which may be permitted for use by adjoining property holders. When the joint drive approach is proposed, the request must be made by, and agreed to, by all the interested parties and all property owners involved. The design of the joint driveway facilities must be submitted with the request to be approved by the Public Works Director or their designee and Development Services and Planning Director.
   e. Residential Driveway Approaches at Street Intersections: The drive approach on corner lots must be located to approximately line up with the side of the house or garage that is farthest from the intersection. The drive approach edge farthest from the street intersection must be within three feet (3') of the far side of the house or garage, or otherwise approved by the Public Works Director or their designee and Planning Director.
   f. Only drive approaches in accordance with the above criteria will be allowed onto local or minor streets at a street intersection. If both streets are locally classified, a circular drive will be allowed on a corner lot if one of its two approaches meets the above location criteria. The other drive approach can have its near side no closer than fifteen feet (15') to the property corner closest to the intersection. If both streets have the same classification, other than local as contained in the City's current Thoroughfare Plan, the Public Works Director or their designee shall make the determination as to which street access will be allowed.

g. Future maintenance of the drive approach shall be the responsibility of the property owner.

3. Commercial Driveway Approaches
   a. Commercial driveway approaches shall be hand poured and constructed of eight-inch (8") to 10-inch (10") thick, per geotechnical engineer's recommendations, of thirty- six hundred (3,600) psi compressive strength concrete. The industrial driveway must be reinforced with #4 bars on eighteen-inch (18") centers both ways. The driveway shall begin 18" in front of the back-of-curb of the street and extend to the property line or to a point ten feet (10') from the face of the curb, whichever is greater. The drive approach shall be constructed such that the height of the drive approach at the property right-of-way line, with a normal ten-foot (10') parkway, shall be eight and one-half inches (8 ½") higher than the gutter flowline. All driveways shall have a 5' sidewalk crossing graded at no more than two percent (2%) cross slope.
   b. Width of Driveway Approach: The width of any commercial driveway approach shall not be less than thirty feet (30') measured along the property line. The Developer may request a specific variance to this criterion. Any variance granted based upon a specific design submittal must have the approval of the Public Works Director or their designee and the Development Services and Planning Director.
   c. Radius: Commercial driveways shall be constructed with the return curbs having a rolled face disappearing at the sidewalk and joining the street curb with a minimum ten-foot (10') radius and a maximum thirty-foot (30') radius.
   d. Allowable Spacing for Driveway Approaches: On streets classified as Collector Streets, the minimum centerline spacing between driveways shall be at least three hundred feet (300'). On streets classified as Arterials, minimum spacing shall be at least five hundred feet (500'). This spacing criterion shall be applied irrespective of the number of individual properties located within the intervening distance. The Developer may request a deviation from this criterion. Any deviation granted will be based on a specific design submittal and must have the approval of the Public Works Director or their designee and Development Services and Planning Director.
   e. Provision for Joint Approaches: Driveway approaches shall be located entirely within the frontage of the premises and shall be located no closer than ten feet (10') from each side property line except that joint, or cooperative, drive approaches with adjoining property holders may be permitted in order to conform with the provisions of paragraph (d) above. Any request for joint drive access must be by agreement of all parties involved and a specific plan submittal must be included for approval of the Development Services and Planning Director. Both property owners will be required to dedicate public ingress and egress easements to cover the approach and joint access area.

f. Approaches on Properties other than Residential: The driveway for the corner lot, if allowed, must be located a minimum of fifty feet (50') from the point of intersection of the curb lines of both streets.

4. Industrial Driveway Approaches
   a. Industrial driveway approaches shall be hand poured and constructed of eight-inch (8") to 10-inch (10") thick, per geotechnical engineer's recommendations, of thirty- six hundred (3,600) psi compressive strength concrete. The industrial driveway must be reinforced with #4 bars on eighteen-inch (12") centers both ways. The driveway shall begin at the curb of the street and extend to the property line or to a point ten feet (10') from the face of the curb, whichever is greater. The drive approach shall be constructed such that the height of the drive approach at the property right-of-way line, with a normal ten-foot (10') parkway, shall be eight and one-half inches (8 ½") higher than the gutter flowline. All driveways shall have a 5' sidewalk crossing graded at no more than two percent (2%) cross slope.
   b. Width of Driveway Approach: The width of any industrial driveway approach shall not be less than thirty feet (30') measured along the property line. The Developer may request a specific variance to this criterion. Any variance granted based upon a specific design submittal must have the approval of the Public Works Director or their designee and the Development Services and Planning Director.
   c. Radius: Industrial driveways shall be constructed with the return curbs having a rolled face disappearing at the sidewalk and joining the street curb with a thirty-foot (30') radius.
   d. Allowable Spacing for Driveway Approaches: On streets classified as Collector Streets, the minimum centerline spacing between driveways shall be at least three hundred feet (300'). On streets classified as Arterials, minimum spacing shall be at least five hundred feet (500'). This spacing criterion shall be applied irrespective of the number of individual properties located within the intervening distance. The Developer may request a deviation from this criterion. Any deviation granted will be based on a specific design submittal and must have the approval of the Public Works Director or their designee.
   e. Provision for Joint Approaches: Driveway approaches shall be located entirely within the frontage of the premises and shall be located no closer than ten feet (10') from each side property line except that joint, or cooperative, drive approaches with adjoining property holders may be permitted in order to conform with the provisions of paragraph (d) above. Any request for joint drive access must be by agreement of all parties involved and a specific plan submittal must be included for approval of the Public Works Director or their designee. Both property owners will be required to dedicate public ingress and egress easements to cover the approach and joint access area.
   f. Approaches on Properties other than Residential: The driveway for the corner lot, if allowed, must be located a minimum of fifty feet (50') from the point of intersection of the curb lines of both streets.

5. Driveways Crossing Bar Ditches
    a. The minimum culvert pipe size shall be eighteen-inch (18") diameter for reinforced concrete pipe (RCP). Corrugated galvanized metal and HDPE pipe may not be used. The ends of all culvert pipe shall be cut at a minimum 6:1 and maximum 3:1 slope with a headwall or precast TxDOT approved safety end treatment, unless otherwise approved by the Public Works Director or their designee.
    b. Radius: Driveways shall be constructed with the return curbs joining the edge of pavement at the street with a minimum five-foot (5') radius for residential and ten-foot radius (10') for commercial or industrial.
    c. The maximum slope from the edge of driveway to the top of the culvert pipe shall be 3:1 and minimum be 6:1. The sloped area around the end of the culvert pipe shall have a headwall or precast TxDOT approved safety end treatments. Riprap and/or other erosion control measures may also be required for slopes greater than 2:1 as per the Public Works Director or their designee.
    d. The minimum cross slope on the drive shall be one-eighth inch (1/8") per foot. The minimum longitudinal slope between the edge of pavement at the street and the valley over the culvert pipe shall be one-quarter inch (1/4") per foot.
    e. All driveways over bar ditches shall be constructed with a 4' wide valley at least three inches (3") lower than the edge of the road pavement to allow excess stormwater to exit from the drive before entering the roadway or as approved by the Public Works Director or their designee.
    f. Future maintenance of the drive approach and culvert pipe is the responsibility of the property owner.
    g. During the drive approach installation, all finish grading upstream and downstream of the proposed driveway culvert is the responsibility of the property owner. Final surveyed verification shots must be provided to the Public Works Director or their designee for a minimum of 200' upstream and downstream of the driveway to verify positive drainage. Variances may be granted by the Public Works Director or their designee.

H. Alleys

1. Alleys shall be composed of 8" concrete at edges with a minimum 6" thickness at the centerline. Minimum compressive strength of concrete shall be 3,600 psi and shall be reinforced with No. 3 steel bars on 18" centers or No. 4 bars on 24" centers.
2. Paving in alleys shall be at minimum 12' in width and maintain an invert of 2" at their centerline.
3. Refer to the City of Denison Encroachment Ordinance regarding rules and regulations for structures encroaching within city right-of-way and easements.
4. Standard alley sections with curbs shall be 12' in width from face-of-curb to face-of-curb. The curbs shall be 6" and poured monolithically with the paving. The centerline of the alley shall be 2" below the bottom face-of-curb elevation.
5. Driveways can only connect into alleys constructed or improved to current City of Denison standards.

Section 2 Stormwater Design

A. General

1. The City of Denison has adopted the North Central Texas Council of Governments Integrated Stormwater Management (iSWM) design criteria and regulations as the basis for the stormwater design. These criteria can be located on NCTCOG website, nctcog.org.
2. The criteria herein provided shall govern the design of storm drainage improvements within the City of Denison for all developments, public or private. Improvements shall include streets, alleys, storm sewers, channels, culverts, bridges, swales, and any other facilities through which stormwater flows.
3. The design factors, formulas, and procedures described are intended to serve as guidelines. When necessary, the Director of Public Works may request additional design and analysis beyond the requirements described herein.
4. Technical reviews and approvals from City staff are not an indication that the engineering design is without flaw. The Engineer of Record maintains sole responsibility for meeting the engineering standard of care and to ensure the design does not adversely impact the health, safety, and welfare of the public.
5. All drainage improvements shall be constructed in accordance with City specifications and be in dedicated right-of-way (ROW) or drainage easement. The Developer shall provide all the necessary easement and ROW for drainage improvements, including access ramps where required.
6. The Developer shall be required to install at his own expense all storm sewers and drainage structures both on and off site. This policy is applicable to all required drainage facilities including the channel improvements on the main channels and tributaries. The Developer shall be responsible for stormwater improvements based on the fully developed one hundred (100) year frequency discharge.

B. Basis of Design

1. Hydrologic Method (See **Table 2B-1**)
    a. The hydrologic method used to calculate runoff characteristics of a site or drainage area shall be determined by **Table 2B-1**. Calculations using the given hydrological method shall be performed per the latest edition of the iSWM Hydrology Technical Manual, Section 1.0 Hydrological Analysis. Rational, Modified Rational, SCS & Snyder's Unit Hydrograph methods are allowed hydrologic methods for the City of Denison.
2. Runoff Coefficient (See **Table 2B-2**)
    a. Storm drainage improvements shall be designed based on the drainage areas being fully developed. The zoning as shown on the current City Zoning maps or the City's Comprehensive Plan, whichever is more restrictive, shall determine the particular runoff coefficient value. **Table 2B-2** below indicates the runoff coefficients for different land uses.

3. Time of Concentration (See **Table 2B-3**)
    a. The time of concentration shall be defined as the time required for a drop of water to flow from the upper limits of a drainage area to the point of concentration.
    b. SCS methodology shall be used to determine the times of concentration.
    c. Times of concentration shall be calculated for all inlets, pipe junctions, and other critical design points in the proposed storm sewer systems. **Table 2B-3** shows minimum inlet times of concentrations which may be used in place of calculated times. Times of concentrations can be less than minimum inlet times if sufficient backup calculations are provided. When calculating inlet times, consider overland flow channelized at such time as the distance traveled exceeds fifty to one hundred feet (50'-100').

Table 2B-1: Constraints on Hydrologic Methods

Method	Size Limitation[1]
Rational	0-50 Acres
Modified Rational[2]	0-50 Acres
Unit Hydrograph (SCS)	Any Size
Unit Hydrograph (Snyder's)	1 Acre and larger

[1]Size limitation refers to the drainage basin for the stormwater management facility to be analyzed or designed (e.g., culvert, inlet, detention facility, etc.).
[2]The design engineer shall utilize the modified rational method as described in Section 1.5.2 of the iSWM Hydrology Manual dated 2020. If a newer version of the manual is available, use the methodology in the newer manual

Table 2B-2 Runoff Coefficient Values

Description of Area	Runoff Coefficients (C)
Lawns:	
Sandy soil, flat, 2%	0.10
Sandy soil, average, 2 - 7%	0.15
Sandy soil, steep, > 7%	0.20
Clay soil, flat, 2%	0.17
Clay soil, average, 2 - 7%	0.22
Clay soil, steep, > 7%	0.35
Agricultural	0.30
Forest	0.15
Streams, Lakes, Water Surfaces	1.00
Business:	
Downtown areas	0.95
Neighborhood areas	0.70
Residential:	
Single Family (1/8 acre lots)	0.65
Single Family (1/4 acre lots)	0.60
Single Family (1/2 acre lots)	0.55
Single Family (1+ acre lots)	0.45
Multi-Family Units, (Light)	0.65
Multi-Family, (Heavy)	0.85
Commercial/Industrial:	
Light areas	0.70
Heavy areas	0.80
Parks, cemeteries	0.25
Playgrounds	0.35
Railroad yard areas	0.40
Streets:	
Asphalt and Concrete	0.95
Brick	0.85
Drives, walks, and roofs	0.95
Gravel areas	0.50
Graded or no plant cover:	
Sandy soil, flat, 0 - 5%	0.30
Sandy soil, flat, 5 - 10%	0.40
Clayey soil, flat, 0 - 5%	0.50
Clayey soil, average, 5 - 10%	0.60

Table from iSWM Hydrology Technical Manual Rev. 4/2020, Table 1.6*

* If a newer version of this manual is available, utilize the methodology in the newer manual.

Table 2B-3 Minimum & Maximum Inlet Time of Concentration

Type of Area	Min. Inlet Time	Max. Inlet Time
Business and Commercial	10 Minutes	25 Minutes
Industrial	10 Minutes	25 Minutes
Multi-Family	10 Minutes	30 Minutes
Residential	15 Minutes	30 Minutes

4. Rainfall Intensity
    a. Rainfall intensities can be found in **Table 2B-4** and are based on the National Oceanic and Atmospheric Administration (NOAA) Atlas 14.
    b. Rainfall factors for the Modified Rational Method shall be from **Table 2B-5**.

Table 2B-4: Denison Rainfall Intensities and Modified Rational Rainfall Factors

	1-YR (in/hr)	5-YR (in/hr)	10-YR (in/hr)	25-YR (in/hr)	50-YR (in/hr)	100-YR (in/hr)	500-YR (in/hr)
5-min	5.14	7.22	8.3	9.78	10.9	12.1	14.8
10-min	4.11	5.79	6.65	7.85	8.79	9.71	11.8
15-min	3.41	4.8	5.51	6.48	7.23	7.98	9.77
30-min	2.37	3.32	3.81	4.47	4.98	5.49	6.75
60-min	1.55	2.17	2.5	2.95	3.29	3.64	4.52
2-hr	0.949	1.36	1.58	1.9	2.15	2.4	3.04
3-hr	0.702	1.02	1.20	1.45	1.65	1.87	2.38
6-hr	0.418	0.622	0.732	0.892	1.03	1.17	1.51
12-hr	0.247	0.371	0.438	0.533	0.611	0.694	0.902
24-hr	0.146	0.220	0.260	0.316	0.360	0.407	0.531
2-day	0.085	0.127	0.149	0.181	0.206	0.233	0.303
3-day	0.062	0.092	0.108	0.131	0.149	0.168	0.218
4-day	0.049	0.073	0.086	0.104	0.118	0.133	0.172
7-day	0.032	0.047	0.055	0.066	0.075	0.084	0.109
10-day	0.024	0.036	0.042	0.050	0.057	0.063	0.082
20-day	0.016	0.023	0.027	0.031	0.035	0.039	0.048
30-day	0.013	0.018	0.021	0.024	0.027	0.030	0.036
45-day	0.010	0.015	0.017	0.019	0.021	0.024	0.029
60-day	0.009	0.013	0.014	0.017	0.018	0.020	0.024

Table 2B-5: Rainfall Factors for Modified Rational Method

Table 1.18 Rainfall Factors "a" and "b" for the Modified Rational Method (1-year through 100-year return periods)

County		Return Interval						
		1	2	5	10	25	50	100
Collin	a	101.14	129.51	177.49	209.08	250.52	283.13	320.81
	b	14.214	16.634	20.174	21.668	22.821	23.455	24.502
Dallas	a	99.8	128.85	178.58	210.73	253.77	288.56	327.75
	b	14.114	16.624	20.352	21.785	23.03	23.866	24.893
Denton	a	97.258	124.47	173.1	205.74	248.54	283.99	325.18
	b	13.788	16.121	19.754	21.358	22.615	23.508	24.822
Ellis	a	101.94	129.3	181.43	214.61	259.34	295.76	336.3
	b	14.511	16.697	20.792	22.384	23.744	24.681	25.818
Erath	a	90.53	113.9	159.31	189.97	228.79	260.81	298.07
	b	13.32	14.99	18.439	19.981	20.955	21.65	22.712
Grayson	a	100.87	128.89	175.74	208.17	250.17	285.35	325.63
	b	14.086	16.567	20.006	21.751	22.993	24.027	25.322
Hood	a	93.351	117.38	163	194.75	235.56	269.71	309.25
	b	13.654	15.308	18.65	20.281	21.438	22.299	23.508
Hunt	a	107.65	131.48	178.92	209.36	249.71	282.05	318.9
	b	15.348	16.855	20.456	21.855	22.995	23.713	24.744
Johnson	a	94.751	120.21	168.39	198.98	240.45	275.19	313.38
	b	13.414	15.543	19.272	20.676	21.847	22.804	23.875
Kaufman	a	104.54	132.07	183.2	216.62	260.03	295.03	334.63
	b	14.637	16.912	20.837	22.424	23.65	24.42	25.496
Navarro	a	108.66	132.42	185.55	221.63	268.93	306.83	350.06
	b	15.326	16.758	20.945	22.903	24.437	25.402	26.665
Palo Pinto	a	91.031	115.97	164.22	196.59	242.51	281.03	326.0
	b	13.127	15.264	19.05	20.714	22.468	23.769	25.388
Parker	a	95.164	118.64	166.17	198.53	242.46	279.34	321.89
	b	13.848	15.396	18.999	20.608	22.048	23.123	24.527
Rockwall	a	107.9	131.23	179.89	212.63	254.36	287.68	325.96
	b	15.671	16.882	20.467	22.064	23.178	23.891	24.906
Somervell	a	92.245	116.25	162.12	193.36	232.22	265.8	303.15
	b	13.091	14.967	18.503	20.102	21.066	22.001	23.039
Tarrant	a	95.835	121.96	170.81	203.93	247.1	282.6	322.07
	b	13.425	15.704	19.435	21.09	22.366	23.302	24.388
Wise	a	93.326	118.05	165.95	200.22	247.21	287.89	334.11
	b	13.491	15.315	18.974	20.889	22.662	24.112	25.784

Table from iSWM Hydrology Technical Manual Rev. 4/2020, Table 1.18*

* If a newer version of this manual is available, utilize the methodology in the newer manual.

C. Design Storm Frequency

1. Each storm drainage facility, including street capacities, shall be designed to convey the runoff which results from the one hundred (100) year frequency storm.
2. The combined capacity of the street and ROW and/or drainage easements and the storm sewer pipe shall be adequate to safely convey the runoff from a one hundred (100) year frequency storm.
3. Storm sewer inlets shall be placed to pick up flow from the street when the runoff from a five (5) year frequency storm exceeds the capacity of the street to its top of curb, or the spread of water on a collector street does not leave at least one (1) traffic lane dry, or the spread of water on an arterial street does not leave at least two (2) traffic lanes dry, or every three hundred feet (300'), whichever is more restrictive.
4. The ponding of water within parking lots shall not exceed 6" and all fire lanes shall maintain a dry lane in the one hundred (100) year frequency storm.
5. The twenty-five (25) year frequency design flows shall not exceed the capacity of the paved alley sections and shall not exceed the capacity of the right-of-way for a one hundred (100) year frequency design flow.
6. Storm sewers shall have adequate capacity to convey the twenty-five (25) year frequency storm with a hydraulic gradient at an elevation no higher than the bottom of pavement or to convey the one hundred (100) year frequency flow with a hydraulic gradient at an elevation no higher than the gutter flowline.
7. Open channels shall be designed to carry the one hundred (100) year frequency storm runoff from a fully developed watershed with one foot of freeboard (1').

D. Off-Site Drainage

1. In respect to offsite drainage, the following provisions shall apply:
    a. The Developer shall be responsible for collection and disposal of all runoff from upstream of their proposed development and shall involve discharge design quantities calculated as though the upstream areas of runoff were fully developed. Runoff coefficients utilized to design drainage systems for the properties involved shall use the current zoning and/or the future use of the property as shown in the Denison Comprehensive Plan, whichever use is the most intensive.
    b. Effect of the development's drainage design on downstream properties and adjacent properties shall be given proper consideration. Water concentrated in streets, pipes, drains, culverts, and channels will be moved to a recognized watercourse without damage to intervening structures, offsite properties/facilities, or undue spreading across intervening land.
    c. The Stormwater must be carried to an "adequate or acceptable outfall" which is one which does not create or increase flooding or erosion conditions downstream. The Developer is responsible for constructing all offsite channelization or underground storm drain with overland relief required to discharge concentrated stormwater from the low end of their development to the recognized watercourse, and also to obtain all the necessary easements

from intervening landowners. Calculations will be required to show that connecting offsite drainage ways are capable of handling any increase in runoff due to development, concentration, or diversion for the 1-, 5-, and 100-year storm frequencies.

d. Any drainage easements necessary due to the Developer's alteration of existing drainage patterns shall be acquired by the Developer at no cost to the City.
e. Where the upstream/downstream assessment indicates that additional runoff from the developing property will overload downstream drainage facilities and result in hazardous conditions, the City may withhold approval of the development until appropriate provisions have been made to resolve the conflict. These provisions shall include any additional drainage studies or plans necessary to indicate that the offsite drainage problem will be corrected by onsite or offsite drainage improvements provided by the developer.
f. When required, the Developer will furnish to the City, a "hold harmless agreement" and a "release of liability" indemnifying the City of Denison from any liabilities due to damages caused to downstream property owner(s) by the discharge of storm drainage water from the said development.
g. The Developer should consider TxDOT's Policy regarding discharging stormwater runoff to TxDOT drainage facilities. In these cases, the Developer shall provide coordination and or approval from TxDOT.

2. Water Quality
    a. The removal of pollutants in stormwater runoff to protect water quality is not currently required by the City but is strongly encouraged. However, please note that although it may not be required by the City, other agencies may require water quality protection measures. The City also reserves the right to require water quality measures should it be deemed necessary due to the type of development proposed and its proximity to existing streams, tributaries, ponds etc.
3. Lot Grading
    a. Residential lot grading shall be conducted in a manner which will not allow runoff to cross any lots, besides the lot on which the drainage originates, before it enters a street or drainage easement. If this is not possible, then a drainage easement must be provided, and any necessary facilities shall be constructed and installed by the Developer.
    b. Commercial lot grading will be conducted in a manner which will take all runoff to the adjacent streets or drainage easements. No lot area will drain onto adjacent properties without approval of the Public Works Director or their designee.
    c. Finished floor elevations shall be set a minimum of one foot (1') above the top of curb at the centerline of the lot, two-foot (2') above the one hundred (100) year frequency stormwater surface elevation based on a fully developed watershed or two feet (2') above the effective FEMA base flood elevation, whichever is higher. Front yards must drain to adjacent street. The Public Works Director can allow deviations if justified.

E. Residential Single Lot Drainage Plan Requirements

1. Residential single lot developments shall submit the following as a part of a required drainage plan:
    a. An exhibit showing the current site plan, fencing, retaining walls, swales, driveway culverts, finished floor elevation, flow arrows, and proposed spot elevations to confirm proposed drainage patterns.
2. In cases where lot to lot drainage is present in existing conditions and these conditions are unaltered with the proposed drainage plan, appropriate offsite drainage easements shall be procured on the neighboring properties.
3. In no case shall an increase in drainage area be diverted artificially to adjacent properties or across roadways. Alterations to the hydrologic and hydraulic characteristics of lot-to-lot flow will require the necessary offsite drainage easements be procured on the affected properties.
4. Additional information may be required depending on size of the residential development and proximity to nearby open channels, floodplain, or floodway.

F. Upstream/Downstream Assessment

1. An Upstream/Downstream Assessment is required for any development which is not proposing storm water detention or where the contributing watershed at the outfall of the site is greater than fifty (50) acres.
2. An Upstream/Downstream Assessment shall be submitted in support of a Plat and shall be updated and resubmitted in support of the Final Plat and Construction Drawings. If the development does not require a plat, the Assessment should be submitted with the Site Plan.
    a. The Upstream/Downstream Assessment shall analyze the effect of the proposed development on existing downstream drainage facilities down to the Zone of Influence to ensure that the proposed development does not cause adverse impacts to adjacent, upstream, or downstream properties. Adverse impacts are defined in **Table 2F-1 below**. Refer to iSWM for a definition of the Zone of Influence.
3. If the subject development is part of a larger development, the Upstream/Downstream Assessment must include the larger development, and the Zone of Influence shall be determined based on the entire property. If the subject development is proposed to be constructed in phases, interim (phased) development and full-build development condition assessments will be required.
4. The study shall be sufficient to verify compliance with the applicable criteria contained within this manual and in the iSWM Criteria Manuals.
5. An upstream/downstream assessment must include the following:
    a. Written narrative supporting methodology and results of analysis.
    a. Hydrologic analysis of the one (1), five (5), and one hundred (100) year frequency storm events in pre- and post-development on-site conditions
    b. Pre- and post-development drainage area maps which includes the following:
        i. Topographic contours with contour labels
        ii. Drainage area boundaries
        iii. Time of concentration paths
        iv. Hydrologic modeling paths
        v. Flow direction arrows
        vi. Zone of Influence identified
    c. Land Use Maps
    d. Hydrologic Soils Maps
    e. Separate analysis for each major outfall from the proposed development
    f. Runoff discharges at critical downstream design points
    g. All applicable detailed calculations and results
    h. Digital copies of hydrologic and hydraulic models
    i. If increases in peak flows are proposed, hydraulic capacity analysis of all existing constraint points along the drainage path, such as existing floodplain developments, underground storm drainage systems, culverts, bridges, tributary confluences, or channels will be required. If a natural channel is located within the Zone of Influence, include an analysis as specified in Section G below.

6. Offsite areas shall be considered existing development conditions within the Zone of Influence's watershed.
7. The Upstream/Downstream Assessment shall be sealed by a Registered Professional Engineer licensed by the State of Texas. The following certification shall be included on the study and signed and sealed.

I,_____, a Professional Engineer registered in the State of Texas, have prepared this upstream/downstream assessment in compliance with the latest published requirements and criteria of the City of Denison, and have verified that the topographic information used in this study is in compliance with said requirements and is otherwise suitable for developing this workable Plan of Drainage which can be implemented through proper subsequent detailed construction planning.

Signature_____, P.E., Date_____(Seal)

Table 2F-1: Adverse Impact Criteria

Parameter	Requirements
Habitable Structures	No new or increased flooding greater than (0.00 feet) of existing insurable (FEMA) structures (habitable buildings).
Downstream Discharges	No increase in downstream discharges caused by the proposed development that, in combination with existing discharges, exceeds the existing capacity of the downstream storm drainage system or existing right-of-way.
Flood Elevations	No increase in 1-, 5-, and 100-year flood elevations unless contained in existing channel's top of banks, roadway, drainage easement and/or R.O.W. The only exception that will be considered is an increase confined within the limits of the on-site property that is proposed for reclamation.
Channel Velocities	Proposed channel velocities for 1-, 5-, and 100-year storms cannot exceed the applicable maximum permissible velocity shown in **Table 2L-1**. Exceptions to these criteria will require certified geotechnical /geomorphologic studies that provide documentation that the higher velocities will not create additional erosion. If existing channel velocities exceed maximum permissible velocities shown in **Table 2L-1**, no increase in velocities will be allowed.
Valley Storage	No reduction of total valley storage within natural channels will be allowed. Decreases in valley storage will require a downstream/upstream assessment with a Modified Puls analysis to support no adverse impact to downstream properties and structures.

G. Natural Channels and FEMA Floodplain

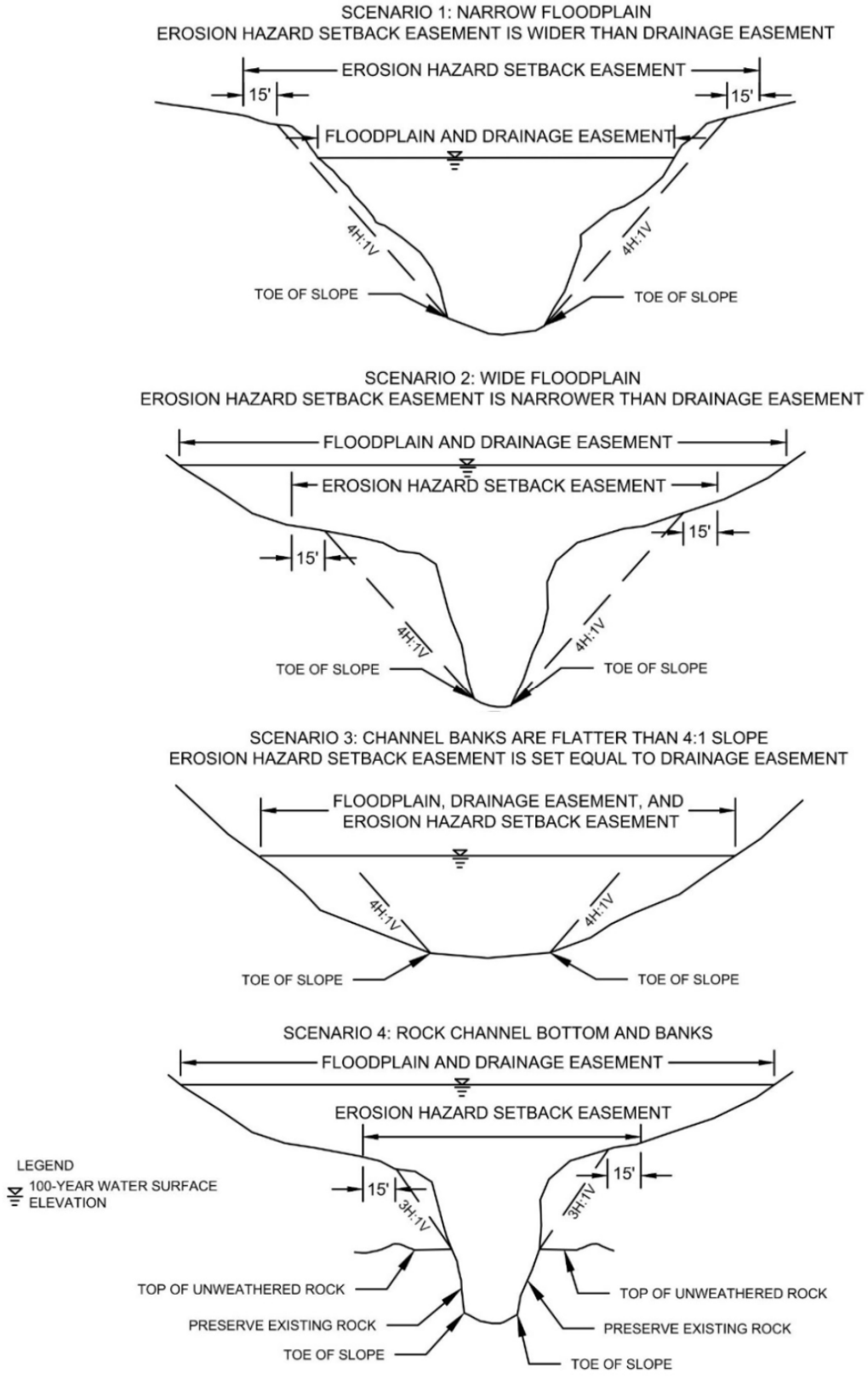
1. A flood study of a natural channel should be included as a part of an upstream/downstream assessment if any of the following are true:
    a. The contributing watershed to the natural channel is greater than fifty (50) acres.
    b. Floodplain reclamation is proposed.
    c. If requested by the Director of Public Works.
2. The United States Army Corps of Engineers HEC-RAS computer program shall be used.
3. Backwater calculations shall comply with normally accepted standards as required by FEMA applications for a Letter of Map Revision (LOMR) and Conditional Letter of Map Revision (CLOMR).
4. Studies of natural channels should include the following calculations, tables, exhibits, and models along with a narrative to describe the methodologies selected and analysis performed:
    a. Pre- and post-development hydraulic workmaps which include the following:
        i. Topographic contours with contour labels
        ii. Cross section alignments
        iii. Creek crossing structures shown and labeled with dimensions
        iv. FEMA floodplain and floodway limits (if applicable)
        v. Fully developed condition one hundred (100) year floodplain limits
    b. Record drawings for all structures included in the model if survey data of the structures is not available.
    c. A hydraulic analysis that includes FEMA peak flows and fully developed on- and offsite peak flows.
    d. One hundred (100) year water surface elevation table.
    a. One, five, and one hundred (1-, 5-, and 100-) year velocity table.
    b. If floodplain reclamation is proposed, comparison tables shall be prepared comparing the following:
        i. Pre- construction and post-construction one hundred (100) year water surface elevations (ft);
        ii. Pre- construction and post-construction one, five, and one hundred (1-, 5-, and 100-) year velocities (ft/s and %); and
        iii. Pre-construction and post-construction one hundred (100) year valley storage (ac-ft).
    c. Floodway Analysis (if applicable)
    d. Executable copy of the HEC-RAS model.
5. If any portion of the proposed site, subdivision or its offsite improvements (including pipes or ditches) fall within the limits of a FEMA floodplain, additional analysis in the form of a Conditional Letter of Map Revision (CLOMR) will be required if:
    a. Any portion of the proposed development is located within a FEMA Zone “A” floodplain; or
    b. Any portion of the proposed development is located within a FEMA Zone “AE” floodplain and the overall development (including all phases) is 5 acres or

larger; or

c. Any portion of the proposed improvements from a development includes dredging or filling within a FEMA designated floodway.
d. CLOMR approval from the City and submission of the application to FEMA will be required prior the allowance of grading improvements within floodplain areas.
e. In cases where a CLOMR would be required per FEMA requirements, acceptance of the CLOMR by FEMA will be required before the allowance of grading improvements within floodplain areas.

6. A LOMR will be required for improvements withing the FEMA effective floodplain prior to issuing building permits for lots in floodplain areas.
7. If an existing FEMA, County, City, or privately delineated floodplain or floodway are incorporated or extend to any portion of the proposed site, subdivision or its offsite improvements (including pipes or ditches), said floodplain and/or floodway model will be required to be extended through the entirety of the proposed development at the expense of the developer.
8. A floodplain and drainage easement and an erosion hazard setback easement shall be established for all natural channels per **Figure 2G-1**.
    a. Construction within an erosion hazard setback is not allowed unless a geotechnical and or structural analysis (signed and sealed by a registered professional engineer) supports that the proposed construction will be protected from channel erosion.
9. The Engineer is responsible for providing documentation of the relevant USACE approved permits prior to beginning modification to the floodplain or impacts to Waters of the United States. Alternatively, provide a signed and sealed statement detailing why such permits are unnecessary.

Figure 2G-1: Erosion Hazard Setback Establishment



H. Storm Drain Hydraulic Calculations

1. The hydraulic spreadsheet calculation table shall be included in the construction plans and shall include HGL calculations for each lateral, manhole, inlet, and outlet structure on the pipe.
2. The hydraulic grade line (HGL) must be calculated for all storm drain mains and laterals using appropriate head loss equations. Head losses shall be calculated per the following formulas:
   a. Head losses or gains for pipe size changes and other velocity changes will be calculated as follows:

$$H_L = \left[\frac{(V_2)^2}{2g}\right] - \left[\frac{(V_1)^2}{2g}\right]$$

H_L= Head loss or gain (ft)
V_1 = Upstream velocity (ft/s)
V_2 = Downstream velocity (ft/s)
g = Gravitational constant (32.2 ft/s^2)

   b. Head losses for pipe in full flow at manholes, bends, and inlets, where the flow quantity remains the same, shall be calculated as follows:

$$H_L = Kj\left[\frac{V^2}{2g}\right]$$

H_L= Head loss or gain (ft)
V = Velocity in the lateral (ft/s)
g = Gravitational constant (32.2 ft/s^2)
Kj = Coefficient of loss per **Table 2H-2**

   c. Head losses or gains at manholes, wyes, and junction boxes where there is an increase in flow quantity shall be calculated as follows:

$$H_L = \left[\frac{(V_2)^2}{2g}\right] - Kj\left[\frac{(V_1)^2}{2g}\right]$$

H_L= Head loss or gain (ft)
V_1 = Upstream velocity (ft/s)
V_2 = Downstream velocity (ft/s)
g = Gravitational constant (32.2 ft/s^2)
Kj = Coefficient of loss per **Table 2H-2**

3. Unless partial flow conditions exist, the beginning hydraulic gradient (Column 22 of the last downstream section) must begin at either the top of pipe or at the hydraulic gradient of the receiving stream at the coincident frequency provided in Table 1.10 of the iSWM Hydraulics Technical Manual, whichever is higher. It is also acceptable to perform a detailed hydrologic and hydraulic study of the watershed of the receiving stream to determine the connected outfall hydraulic gradient.
4. In partial flow conditions, the HGL represents the actual water surface within the pipe. Note that for partial flow conditions, the velocity of the flow should be calculated based on actual area of flow, not the full flow area of the pipe or box. Although the table is presented from upstream to downstream, the calculations are normally performed from the outfall upstream to each inlet.

5. No decreases in the calculated HGL shall be allowed as the HGL progresses upstream.
6. In all cases, head loss at all hydraulic structures shall be a minimum of 0.10'.
    a. EXCEPTION: In a supercritical flow regime with partial flow conditions, head losses are not generated at upstream junctions. These may be designated as "SUPERCRITICAL PARTIAL FLOW" in the head loss calculations but must be supported by Froude Number calculation within the Storm Drain Calculations Table.
7. The Engineer shall include a complete Storm Drain Calculations Table which includes all key design calculation columns listed below:

Table Column Description:

Column 1 Enter the downstream storm drain station number.

Column 2 Enter the upstream storm drain station number. This is the design point. Design should start at the farthest upstream point.

Column 3 Enter the distance (in feet) between the storm drain stations.

Column 4 Enter the designation of the drainage area(s) at the design point in Column 2 corresponding to the designations shown on the drainage area map.

Column 5 Enter the area in acres for the drainage area identified in Column 4.

Column 6 Enter the total drainage area in acres within the system corresponding to storm drain station shown in Column 2.

Column 7 Enter the runoff coefficient "C" for the drainage area shown in Column 5. Column 8 Multiply Column 5 by Column 7 for each area.

Column 9 Determine the total "CA" for the drainage system corresponding to the inlet or manhole shown in Column 2.

Column 10 Determine inlet time of concentration (See **Table 2B-4**).

Column 11 Determine flow time in the storm drain in minutes. The flow time is equal to the distance in Column 3 divided by 60 times the velocity of flow through the storm drain in ft/sec.

Column 12 Total time of concentration in minutes. Column 10 plus Column 11. Note that time of concentration only changes at a downstream junction with another drainage area(s). The junction of two paired inlets with each other is not a downstream junction.

Column 13 The intensity of rainfall in inches per hour for the twenty-five (25) year frequency storm from **Table 2B-4**.

Column 14 The intensity of rainfall in inches per hour for the one hundred (100) year frequency storm from **Table 2B-4**.

Column 15 The 25-year frequency storm runoff in cfs. Column 9 times Column 13.

Column 16 The 100-year frequency storm runoff in cfs. Column 9 times Column 14

Column 17 The proposed inlet bypass during the 100-year frequency storm. This should generally correspond to the carry-over from the Inlet Capacity Calculations (minor variances may occur due to travel time routing).

Column 18 Design Discharge for the storm drain system ("Qpipe") in cfs. This should be the greater of a substantial portion of Q25 (Column 15) or Q100-Qbypass (Column 16 minus Column 17)

Column 19 Enter the selected pipe size.

Column 20 Enter the appropriate Manning's roughness coefficient "n" from **Table 2H-1**

Column 21 Enter the required slope of the frictional gradient (hydraulic gradient) determined by Manning's equation. The pipe shall be designed on a grade such that the inside crown of the pipe coincides or is below the HGL when flowing full. In a partial flow condition, the friction slope is the slope of the water surface and should follow the slope of the pipe.

Column 22 This is the beginning hydraulic gradient of the line. It is equal to the Design HGL (Column 31) for the next downstream segment, or the beginning HGL of the system as described above.

Column 23 This is the upstream HGL before the structure and is calculated as Column 22 plus the friction loss (Column 3 times Column 21).

Column 24 Velocity of flow in incoming pipe (main line) at the junction, inlet or manhole at the design point identified in Column 2.

Column 25 Velocity of flow in outgoing pipe (i.e. the pipe segment being analyzed) at junction, inlet or manhole at design point identified in Column 2.

Column 26 Velocity head of the velocity in Column 24.

Column 27 Velocity head of the velocity in Column 25.

Column 28 Head loss coefficient "Kj", at junction, inlet or manhole at design point from Table 2H-2

Column 29 Multiply Column 26 by Column 28.

Column 30 Head Loss at Structure as calculated per the head loss equations above.

Column 31 Design HGL at the design point identified in Column 2. Column 23 plus Column 30. This is the beginning HGL (Column 22) for any upstream pipe discharging into that junction.

Column 32 Invert elevation for the pipe being analyzed at the downstream storm drain station in Column 1.

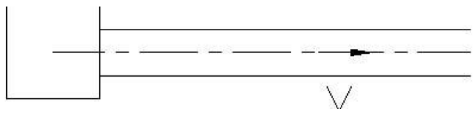
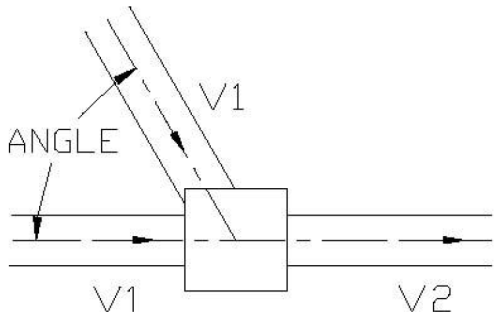
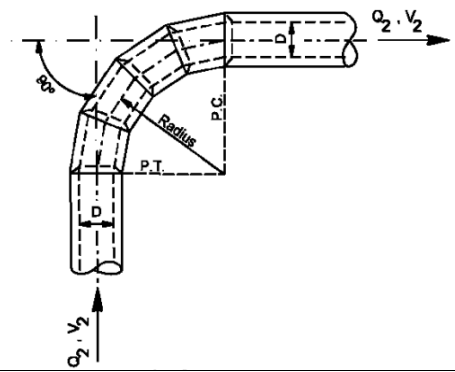
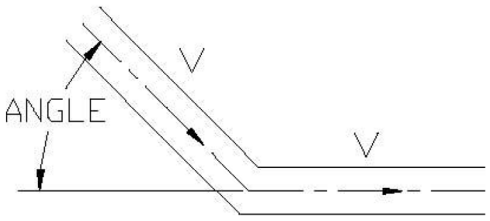
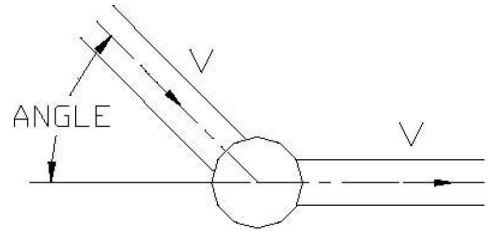
Column 33 Invert elevation for the pipe being analyzed at the design point (upstream storm drain station) in Column 2.

Column 34 Top of curb elevation at the design point in Column 2.

Table 2H-1: Manning's Coefficients for Storm Drain Conduits

Type of Storm Drain	Manning's n
Concrete Pipe (Design n = 0.013)	0.012 – 0.015
Concrete Boxes (Design n = 0.015)	0.012 – 0.015
Corrugated Metal Pipe, Pipe-Arch and Box (Annular or Helical Corrugations - see Table 1.8 in iSWM Hydraulics Technical Manual) **NOTE: City of Denison DOES NOT ALLOW CMP FOR NEW CONSTRUCTION**	0.022-0.037*
Profile Wall Thermoplastic High Density Polyethylene (HDPE) or Polyvinyl Chloride (PVC) **NOTE: USE OF HDPE OR PVC PIPE WILL REQUIRE PRE-APPROVAL FROM THE City of Denison**	0.010-0.013
NOTE: Actual field values for conduits may vary depending on the effect of abrasion, corrosion, deflection, and joint conditions. *NOTE: Analysis of existing conditions may require a different value than the stated design coefficients	

Table 2H-2: Junction & Structure Coefficient of Loss

Description of Condition	Coefficient Kj	Schematic
Inlet or Manhole at Beginning of Line	1.25	
Manhole and Wye 0º 22 1/2º 45º 60º 90º	 1.00 0.75 0.50 0.35 0.25	
Conduit on Curves for 90º* Curve radius = diameter Curve radius = 2 to 8 diameter Curve radius = 8 to 20 diameter	 0.50 0.25 0.10	
Bends where radius is equal to diameter 22.5º Bend 45º Bend 60º Bend 90º Bend	0.20 0.35 0.43 0.50	
Manhole at Change in Line Direction Line 0º 30º 45º 60º 90º	0.05 0.30 0.42 0.48 0.55	

I. Storm Sewer Systems

1. Storm sewers shall be designed as detailed in Section H above.
2. Easement width for storm sewer pipe shall be at least fifteen feet (15').
3. The one hundred (100) year and twenty-five (25) year hydraulic grades line shall be plotted for all storm drainage design profiles.
4. Storm sewer pipes shall be designed so that the mean velocity of flow is equal to or greater than two and one-half feet (2.5') per second and equal to or less than fifteen feet (15') per second in culverts and mains.
5. Inlet lateral pipes shall be designed so that the mean velocity of flow is equal to or less than thirty feet (30') per second.
6. All inlet laterals with a fifteen foot (15') per second or greater velocity or storm sewers with a twelve feet (12') per second or greater velocity shall be constructed with flowable fill or cement stabilized backfill.
7. Storm sewer pipes shall maintain a minimum slope of 0.5%
8. Pipes may be designed on a horizontal radius per pipe manufacturer standards.
9. Pipes shall not be designed with vertical curves.
10. The minimum pipe size is eighteen inches (18") for storm sewers.
11. Pipe sizes shall not be decreased in the downstream direction.
12. All storm sewer systems must be constructed with reinforced concrete pipe (RCP).
13. Energy dissipation such as riprap aprons is required at all storm sewer outfalls. Riprap design calculations shall be calculated in accordance with the iSWM Hydraulics Technical Manual.
14. Improvements shall be provided to route concentrated flow from storm sewer outfalls in a non-erosive matter to the flowline of the receiving channel.
15. A manhole or other entry point must be constructed at the start or top of the system. The maximum manhole or junction box spacing for storm drain systems is shown in **Table 2I-1**. Manholes and junction boxes must also be located at:
    a. Concentration points having three or more laterals
    b. Trunk line size changes for lines with a diameter difference greater than 24-inches
    c. Vertical alignment changes where the algebraic slope difference > 3%
    d. Future collection points are determined by the City

Table 2I-1 Maximum Spacing on Manholes and Junction Boxes

Pipe Diameter (in.)	Maximum Spacing (ft.)
≤24	300
27-36	400
>36	500

J. Flow in Streets

1. Street capacity shall be determined by utilizing Manning's equation:

$$Q = \left(\frac{1.486}{n}\right) AR^{\frac{2}{3}}\sqrt{s_0}$$

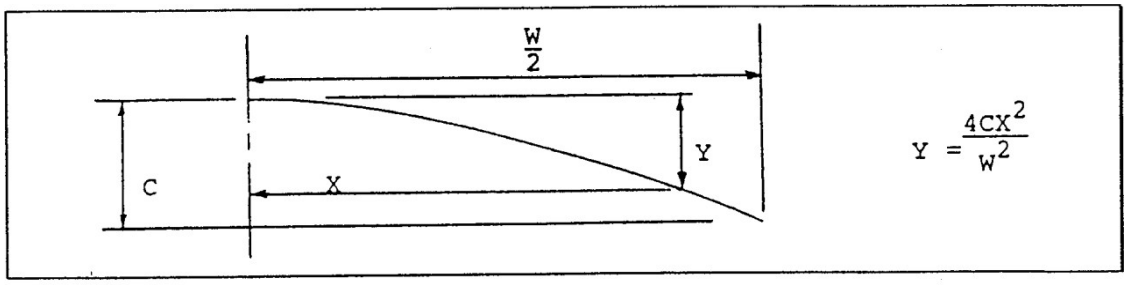
Q= discharge in cubic feet per second (cfs)
n = Manning's roughness coefficient, use Table H-6 below for pavement and gutters
A = cross-sectional area of flow in square feet (ft^2)
R = hydraulic radius in feet (ft)
S_0 = Street or gutter slope in feet per foot

Table 2J-1: Manning's Roughness Coefficient – Street and Gutter

Type of Gutter or Pavement	Manning's n
Concrete gutter, troweled finish	0.014
Asphalt pavement: Smooth texture Rough texture	 0.015 0.019
Concrete gutter with asphalt pavement: Smooth Rough	 0.015 0.018
Concrete pavement: Float finish Broom finish	 0.017 0.019
For gutters with small slopes, where sediment may accumulate, increase above values of n by	0.002

Table from iSWM Hydraulics Technical Manual Rev. 4/2020, Table 1.2*

For parabolic crown streets, the cross slope shall be represented by the following formula: (Note: All discharge of runoff from street to an open channel shall be in a flume or through an inlet with adjoining pipe and headwall.)



* If a newer version of this manual is available, utilize the methodology in the newer manual.

K. Storm Drain Inlets

Curb inlets shall be placed to ensure that the flow in a street does not exceed the design requirements set forth in Section C above.

Inlet design shall be based on the 25-year frequency design storm with no bypass allowed or based on the 100-year frequency design storm with no more than 10% bypass allowed.

1. Gutter Flow
   a. The following form of the Manning's equation should be used to evaluate gutter flow hydraulics:

$$Q = \left[\frac{0.56}{n}\right] Sx^{5/3} S^{1/2} T^{8/3}$$

Q= Gutter flow rate (cfs)
S_x = Pavement cross slope (ft/ft)
S = Longitudinal slope (ft/ft)
T = Width of flow in roadway (ft)
n = Manning's roughness coefficient

   b. Depth of flow in the gutter can be calculated using the following modified form of the equation above:

$$y_o = z\left(\frac{QnS_x}{S^{1/2}}\right)^{3/8}$$

y_o= depth of water in the curb and gutter cross section (ft or m)
Z = 1.24

   c. If the flow in the gutter is still excessive, the storm sewer shall be extended to a point where the gutter flow can be effectively intercepted by curb inlets.
   d. The flow in roadway gutters shall not exceed 20 cfs.

2. Capacity of Curb Inlet on Grade
   a. To determine the capacity of a curb inlet on grade, first determine the ratio of the flow in the locally depressed gutter section to the total flow in the road.

$$E_0 = 1/\left\{1 + \frac{S_w}{S_x}\left[\left(1 + \frac{S_w/S_x}{(T/W) - 1}\right)^{2.67} - 1\right]^{-1}\right\}$$

E_0= Ratio of flow in the depressed gutter to the total flow
S_x = Gutter cross slope (ft/ft)
S_y = Roadway cross slope (ft/ft)
T = Width of flow in roadway (ft)
W = Width of depressed gutter section (ft)

b. Then calculate the equivalent cross slope at the depressed curb inlet opening.

$$S_e = S_x + \frac{a}{w}E_0$$

S_e= Equivalent cross slope (ft/ft)
S_x = Roadway cross slope (ft/ft)
a = Gutter Depression Depth (ft)
W = Width of depressed gutter section (ft)
E_0 = Ratio of flow in the depressed gutter to the total flow

c. Then calculate the inlet length required to capture 100% of the gutter flow.

$$L_T = 0.60Q^{0.42}S^{0.3}\left(\frac{1}{nS_e}\right)^{0.6}$$

L_T= Required length of inlet (ft)
Q = Total flow in the roadway (cfs)
S = Roadway longitudinal slope (ft/ft)
n = Manning's roughness coefficient
S_e = Equivalent cross slope (ft/ft)

d. The efficiency of a curb inlet opening shorter than LT is:

$$E = 1 - \left(1 - \frac{L}{L_T}\right)^{1.8}$$

E = Inlet efficiency
L = Length of the curb inlet opening (ft)
L_T = Required length of inlet to capture 100% of the roadway flow (ft)

e. The total flow captured by the curb inlet is:

$$Q_i = EQ$$

Q_i = Flow capture by inlet (cfs)
E = Inlet efficiency
Q = Total flow in the roadway (cfs)

3. Capacity of Curb Inlets in Sag
   a. The capacity of a curb inlet in sag depends on the water depth at the curb opening and the height of the curb opening. The inlet operates as a weir to a depth equal to the curb opening height and as an orifice at depths greater than 1.4 times the opening height. At depths between 1.0 and 1.4 times the opening height, flow is in a transition stage and the capacity should be based on the lesser of the computed weir and orifice capacities.
   b. If the depth of flow in the gutter (d) is less than or equal to 1.4 times the inlet opening height (h), ($d \leq 1.4H$), determine the length of inlet required considering weir control. Calculate the capacity of the inlet when operating under weir conditions with the following equation:

$$Q = C_W(L + 1.8W)d^{1.5}$$

   c. Rearrange above equation to produce the following relation for curb inlet length required:

$$L = \left(\frac{Q}{C_w {y_o}^{1.5}}\right) - 1.8W$$

Q = total flow reaching inlet (cfs)
C_W = weir coefficient (3.0)
y_o = head at inlet opening (ft)
L = length of curb inlet opening (ft)
W = lateral width of depression (ft)

$$y_o = z\left(\frac{QnS_x}{S^{1/2}}\right)^{3/8}$$

y_o = depth of water in the curb and gutter cross section (ft or m)
Q = gutter flow rate (cfs)
n = Manning's roughness coefficient
S = longitudinal slope (ft/ft)
S_x = pavement cross slope (ft/ft)
Z = 1.24

d. If the depth of flow in the gutter is greater than the inlet opening height (d>h), determine the length of inlet required considering orifice control. The equation for interception capacity of a curb opening as an orifice follows:

$$Q = C_0 h L\sqrt{2gd_e}$$

Q = total flow reaching inlet (cfs)
C_0 = orifice coefficient = 0.70
h = depth of opening (ft) (this depth will vary slightly with the inlet detail used)
L = length of curb inlet opening (ft)
g = acceleration due to gravity = 32.2 ft/s^2
d_e = effective head at the centroid of the orifice (ft) d_e=d - h/2

Rearranging the equation allows a direct solution for required length:

$$L = \frac{Q}{C_0 h\sqrt{2gd_e}}$$

e. If both steps 1 and 2 were performed (i.e., h<d≤1.4h), choose the larger of the two computed lengths as being the required length.
f. Select a standard inlet length that is greater than the required length.

4. Capacity of Wye Inlets

$$\frac{Q}{P} = 3.1y^{3/2}$$

Q = flow (cfs)
P = perimeter of opening (ft)
y = head/depth (ft)

a. Wye (drop) inlets shall be located to collect water on non-paved areas where it is not practical to use a headwall.

5. Curb Inlet Placement
   a. Placing several curb inlets at a single location is only permitted in areas with steep grades (4% or greater) to prevent flooding and avoid exceeding street capacity in flatter reaches downstream.

b. No more than 20-ft of inlet shall be constructed at one location along one curb line.
c. Curb inlets shall be placed upstream from right angle turns and street intersections.
d. An emergency overflow path shall be provided on the plans for sag locations. An emergency overflow path is the path the storm water will take if the drainage facility becomes clogged or ceases to function as designed. The emergency overflow path must be located within public right-of-way or within a drainage easement and shown on the construction plans.
e. Curb inlet depth shall not be less than 4.5-ft from top of curb for all public improvements.
f. Inlets are required at the low point of a superelevation to prevent flow across the roadway.
g. On-grade curb inlets shall bypass to only one downstream inlet.
h. Grate inlets shall not be within a paved area or drain undeveloped areas.
i. Inlets shall not be connected in series.
j. Recessed curb inlets shall not be within a turn lane

6. Required Design Calculations
   a. The Engineer shall include a complete Inlet Calculations Table in the construction plans. All key design calculation columns shall be included. At a minimum this will include:
      - Inlet number or name
      - Location of inlet by storm drain station number
      - Drainage area designation
      - Drainage area size (acres)
      - Runoff coefficient (C)
      - Time of concentration (minutes)
      - 100-year intensity (in/hr)
      - 100-year runoff, Q=CIA (cfs)
      - 100-year carryover flow from upstream inlet (cfs)
      - 100-year total gutter flow (cfs)
      - Percentage of flow traveling from lower station side of sag inlet based on percentage of drainage area and carryover flow from that side (cfs)
      - Percentage of flow traveling from higher station side of sag inlet based on percentage of drainage area and carryover flow from that side (cfs)
      - 100-year total gutter flow reaching the lower station side of the sag inlet (cfs)
      - 100-year total gutter flow reaching the higher station side of the sag inlet (cfs)
      - Longitudinal slope of the approach gutter.
      - For sag inlets, half the longitudinal slope of the approach gutter on the lower station side of the inlet (ft/ft)
      - For sag inlets, half the longitudinal slope of the approach gutter on the higher station side of the inlet (ft/ft)
      - Street crown section type (straight crown [“rooftop”] or parabolic)
      - Roadway cross slope (%)

- Manning's roughness coefficient (n) for pavement (0.0175 for concrete pavement)
- Street capacity based on Manning's equation. For sag inlets calculate the street capacity for both the lower and higher station sides of the inlet and use the greater of the two. (cfs)
- Total right-of-way capacity as a function of the cross-sectional area of the right-of-way at the inlet. For sag inlets, the total right of way capacity on the lower station side of the inlet. (cfs)
- For sag inlets, the total right of way capacity on the higher station side of the inlet. (cfs)
- Depth of gutter flow "yo" in approach gutter from spread of water or from direct solution of Manning's equation for gutter capacity. For sag inlets, the depth of gutter flow on the lower station side of the inlet. (ft)
- Depth of gutter flow "yo" in approach gutter from spread of water or from direct solution of Manning's equation for gutter capacity. For sag inlets, the depth of gutter flow on the higher station side of the inlet. (ft)
- Spread of water (T) or width of ponding in the gutter measured from the face of curb.
- Gutter cross slope (%)
- Width of depressed gutter section (ft)
- 100-year ratio of flow in the depressed gutter to the total flow (E0)
- Gutter depression depth (ft)
- Equivalent cross slope (%)
- 100-year inlet length required to capture 100% of the gutter flow (ft)
- Actual length in feet of inlet which is to be provided. For wye inlets the length provided is equal to the perimeter of the opening intercepting flow. The length for wye inlets may be less than the total perimeter if the wye is not located in a sag location.
- Efficiency of a curb inlet where the length provided is shorter than the length required.
- Discharge in cubic feet per second which the inlet in question actually intercepts.
- Discharge capacity of the inlet (cfs)
- Bypass flow is the amount of water which passes the inlet in a 100-year storm. A substantial portion of the 100-year flow should be picked up by the inlet. The bypass flow should be accounted for in the next downstream inlet and should be reflected in the inlet bypass flow in the Storm Drain Hydraulics Calculations (minor variances may occur due to travel time routing in the Hydraulics Table).
- Downstream inlet receiving bypass flow
- Important comments relating to inlet

L. Unimproved Rural Roadside Ditches

1. Rural roadside ditches shall be designed to convey one hundred (100) year fully developed condition frequency storm runoff. The design storms must be contained within the right-of-way or the top of the roadside ditch, unless otherwise contained within a designated drainage easement.
2. Culverts within a roadside ditch or crossing under a roadway or driveway must be a minimum eighteen-inch (18") RCP with 6:1 precast TxDOT approved sloping headwall safety end treatments, unless otherwise approved by the Public Works Director or their designee. The culvert must convey the design storm without overtopping the roadway or driveway.

M. Drainage Swales and Open Channels

1. Drainage swale and open channels shall be designed to carry the one hundred (100) year frequency storm runoff from a fully developed watershed with one foot of freeboard (1').
2. Drainage ditches with a maximum depth less than or equal to 3-feet will be classified as a drainage swale. Drainage ditches with a maximum depth greater than 3-feet or conveying a flow greater than 100 cfs will be classified as an open channel.
3. Drainage swales will be subject to the following requirements:
    a. The minimum slope for an excavated drainage swale is one percent (1%).
    b. The side slopes should not be steeper than not steeper than four feet (4') horizontal to one foot (1') vertical (5 to 1 preferred).
    c. The drainage easement shall be established for all drainage swales as the width between the left and right banks plus ten feet (10') and rounded up to a five-foot (5') increment.
    d. The minimum easement width for drainage swales is fifteen feet (15').
4. Open channels will be subject the following requirements:
    a. All open channels shall have a minimum bottom width of six feet (6').
    b. Excavated Earthen Channels:
        i. The maximum allowable channel velocity shall depend on the natural channel lining and be determined by **Table 2M-1**.
        ii. Arrangements shall be made for perpetual maintenance of any proposed channels by the adjacent property owners or the earthen channel must be dedicated to and accepted by the City for public open space purposes.
    c. Partial Concrete Liner:
        i. Where, for reasons of downstream backwater flooding conditions, or where sufficient channel gradient and/or width cannot be provided to the extent that the one hundred (100) year fully developed water surface elevation is contained in the channel with appropriate freeboard, a concrete channel liner shall be extended to the natural ground line along each side of the channel. In no case shall the concrete lined capacity provided be less than that required to convey the twenty-five (25) year frequency discharge. Drainage easements shall

be provided along the sides of the concrete lined channel sufficient to encompass all areas beneath the water surface elevation resulting from a fully developed one hundred (100) year frequency storm discharge, plus such additional width easements as may be required to provide ingress and egress to allow maintenance and to protect adjacent property against erosion, caving-in of over- banks, etc., as determined and required by the Public Works Director or their designee. The Developer shall be responsible for furnishing complete cross-sections, grading plans, HEC-RAS, or the latest equivalent iSWM accepted computer modeling software, models and all other documentation requested by the Public Works Director or their designee which is required to justify less than full section concrete channel lining and to establish the limits of the one hundred (100) year overflow flood plain lines. Water surface profile calculations shall be based on backwater effects created by an existing bridge, culvert or other obstruction regardless of future downstream proposed improvements.

d. Full Concrete Lining:
    i. Lining of drainage ditch floors is to be a minimum of six feet (6') wide and minimum of six inches (6") thick, 3,000 psi compressive strength concrete. Concrete channel lining shall be designed by a geotechnical engineer and approved by the Public Works Director or their designee. Vertical concrete retaining wall sections shall be designed with adequate footing and reinforcing steel to support all anticipated soil and water pressure loads acting on each side of the structure. In addition, retaining walls shall be designed to support at least a "high surcharge" load unless otherwise approved by the Public Works Director or their designee.
e. Easements shall be dedicated for all open channels to encompass the area below the elevation of the water surface profile of a fully developed one hundred (100) year frequency storm, plus one foot (1') of freeboard and any additional area necessary to provide access for maintenance and an erosion hazard setback per Section G. This easement shall be at least fifteen feet (15') wider than the top of the channel width with a minimum of ten feet (10') on one side of the channel to serve as an access way for maintenance purposes.
f. Drainage easements for open channels shall not be cross-fenced.
g. The top of bank areas on either side of the channel shall remain open for maintenance purposes.
h. Unlined unvegetated excavated channels are not allowed.
i. The minimum slope for an excavated improved channel is one percent (1%). Open channels with slopes less than one percent (1%) shall have concrete pilot channels.
j. The water surface profile (hydraulic grade line) for the one hundred (100) year frequency storm shall be shown within the construction drawings.
k. Supercritical flow shall not be allowed in channels except at drop structures and other energy dissipators
l. Earthen channels, when approved, shall be constructed with a trapezoidal

shape and a minimum bottom width of six feet (6') and side slopes not steeper than four feet (4') horizontal to one foot (1') vertical (5 to 1 preferred). The side slopes shall be smooth, free of rocks, and contain a minimum of six inches (6") of topsoil.

m. After proposed earthen side slopes are cut, slopes shall be covered by grass according to the City's specifications but no less than one 2-inch high spring per half square inch of slope and bottom. The grass shall be planted to fifteen feet (15') outside the top of banks.
n. Maximum permissible velocities for the one hundred (100) year frequency storm discharge shall be maximum six feet (6') per second in earthen or partially lined concrete channels and fifteen feet (15') per second in fully lined concrete channels.
o. Special consideration should be given to outlet structures on channels where concrete linings meet earthen banks.
p. One reinforced concrete access ramp shall be provided at all intersections of every open channel with a public street. Access ramps shall be a minimum of twelve feet (12') wide with a maximum slope of sixteen percent (16%). "Authorized Personnel Only" sign must be placed at entrance.
q. Any channel modification must meet the applicable requirements of all Local, State and Federal Regulatory Agencies.

Table 2M-1: Roughness Coefficients and Maximum Velocity for Natural Channels

Channel Description	Manning's n	Max. Permissible Channel Velocity (ft/s)
MINOR NATURAL STREAMS		
Fairly regular section		
1. Some grass and weeds, little or no brush	0.030	3 to 6
2. Dense growth of weeds, depth of flow materially greater than weed height	0.035	3 to 6
3. Some weeds, light brush on banks	0.035	3 to 6
4. Some weeds, heavy brush on banks	0.050	3 to 6
5. Some weeds, dense willows on banks	0.060	3 to 6
For trees within channels with branches submerged at high stage, increase above values by	0.010	
Irregular section with pools, slight channel meander, increase above values by	0.010	
Floodplain – Pasture		
1. Short grass	0.030	3 to 6
2. Tall grass	0.035	3 to 6
Floodplain – Cultivated Areas		
1. No crop	0.030	3 to 6
2. Mature row crops	0.035	3 to 6
3. Mature field crops	0.040	3 to 6
Floodplain – Uncleared		
1. Heavy weeds scattered brush	0.050	3 to 6
2. Wooded	0.120	3 to 6
MAJOR NATURAL STREAMS		
Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of "n" for larger streams of mostly regular sections, with no boulders or brush	Range from 0.028 to 0.060	3 to 6
UNLINED VEGETATED CHANNELS		
Clays (Bermuda Grass)	0.035	5 to 6
Sandy and Silty Soils (Bermuda Grass)	0.035	3 to 5
UNLINED NON-VEGETATED CHANNELS		
Sandy Soils	0.030	1.5 to 2.5
Silts	0.030	0.7 to 1.5
Sandy Silts	0.030	2.5 to 3.0
Clays	0.030	3.0 to 5.0
Coarse Gravels	0.030	5.0 to 6.0
Shale	0.030	6.0 to 10.0
Rock	0.025	15
For natural channels with specific vegetation type, refer to Table 3.11 for more detailed velocity control.		

Table from iSWM Hydraulics Technical Manual Rev. 4/2020, Table 3.2*

* If a newer version of this manual is available, utilize the methodology in the newer manual.

N. Bridges and Culverts

1. All bridges and culverts shall be designed in accordance with the latest edition of the iSWM Technical Manual.
2. The fully developed one hundred (100) year frequency storm hydraulic grade line shall be plotted on the construction drawings.
3. All culverts shall have headwalls and wing walls upstream and downstream.
4. Culverts should always be aligned to follow the natural stream channel.
5. Energy dissipation such as riprap aprons is required at all storm sewer outfalls. Riprap design calculations shall be calculated in accordance with the iSWM Hydraulics Technical Manual.
6. All culverts shall pass the fully developed one hundred (100) year frequency storm runoff without allowing runoff to pass over the road.
7. Velocities in culverts should be limited to no more than fifteen feet (15') per second, but downstream conditions very likely will impose more stringent controls. Consideration must be given to the effect of high velocities and turbulence on the channel, adjoining property and embankment. Table 3.2 of the iSWM Hydraulics Manual lists maximum allowable velocities based on downstream channel conditions.
8. To ensure self-cleaning during partial depth flow, a minimum velocity of two and a half (2.5 fps) feet per second is required for the five (5) year frequency storm when the culvert is flowing partially full.
9. The low point on the bridge structure shall be at least two-foot (2') above the fully developed one hundred (100) year frequency stormwater surface.
10. Bridge hydraulic calculations should be performed using HEC-RAS. A scour analysis shall be submitted with the construction plans. The scour analysis shall be conducted in accordance with the following:
    a. TxDOT guidelines in "Evaluating Scour at Bridges" (HEC-18).
    b. Abutment scour does not need to be calculated. However, abutments shall be protected against potential scour through use of flexible revetment, where possible or hard armoring.
    c. Design bridge foundations to withstand the scour depths for either the one hundred (100) year flood or smaller flood if it will cause scour depths deeper than the one hundred (100) year flood.
    d. Check the bridge foundations against the scour depth associated with the five hundred (500) year flood. This flood event is considered an extreme event and the factor of safety on the bridge foundations shall be greater than or equal to 1.

O. Stormwater Detention Basin Design

The basic concept underlying the use of stormwater detention basins involves providing temporary storage of stormwater runoff so that peak rates of runoff can be reduced. Runoff is released from storage at a controlled rate which cannot exceed the capacities of the existing downstream drainage systems or the predevelopment peak runoff rate of the site, whichever is less.

Stormwater detention basins may be of two (2) basic types: On-site and Regional. In general, on-site basins are those which are located off-channel and provide stormwater detention for a particular project or development. Regional basins are designed to provide stormwater detention in conjunction with other improvements on a watershed-wide basis. The performance and safety criteria in this section apply to all basins which provide management of peak rates of stormwater runoff, regardless of type.

1. Performance criteria for On-site Stormwater Detention Basins
    a. On-site stormwater detention shall be provided for the one (1), five (5), and one hundred (100) year frequency storm events at each point of discharge from the project or development site unless the results of the upstream/downstream assessment determine that stormwater detention is not needed for the project.
    b. The City reserves the right to reduce peak rate discharge even further if existing discharge of the developing property is damaging adjacent properties. In addition, the capacity of the existing downstream systems must be considered in determining the need for managing the one hundred (100) year frequency storm event.
    c. If required by the City, the water quality (1.5") storm event should also be considered when designing stormwater detention basins.
2. Performance criteria for regional stormwater detention basins
    a. Performance criteria for regional detention basins shall be determined by the City on a project-by-project basis. The determination shall be based on an upstream/downstream assessment prepared by the project engineer.
3. Safety Criteria for stormwater detention basins
    a. All basins shall meet or exceed all specified safety criteria contained herein and all applicable state and federal regulations including the Dam Safety Rules of the Texas Commission on Environmental Quality (TCEQ).
    b. Use of these criteria shall in no way relieve the engineer of the responsibility for the adequacy and safety of all aspects of the design of the stormwater detention basins.
    c. If basins fall under the TCEQ dam safety criteria, the City will require review and approval from TCEQ prior to authorizing construction.
    d. Detention basins with vertical drops or walls greater than thirty inches (30") must install safety railing adjacent to all walls.
    e. On-site stormwater detention basins must include an emergency spillway with 6 inches of freeboard to convey the fully developed one hundred (100) year frequency storm assuming full outlet blockage.
    f. The spillway, embankment, and appurtenant structures shall be designed to

safely pass the design storm hydrograph with a freeboard of one-foot (1') for all on-site stormwater detention basins and two-foot (2') for regional stormwater detention basins less than one-hundred and fifty (150) acres. Freeboard for regional stormwater detention basins one-hundred and fifty (150) acres or more shall be determined in accordance with the Texas Administrative Code (Dam Safety Rules of the Texas Commission on Environmental Quality) and any other applicable state and federal regulations.

g. The minimum top width of earthen embankments shall be as follows:

Table 2O-1: Earthen Embankments Minimum Top Width

Total height of embankment (ft.)	**Minimum top width (ft.)**
0-6	4
6-10	6
10-15	8
15-20	10
20-25	12
25-35	15

h. The constructed height of an earthen embankment shall be equal to the design height plus the amount necessary to ensure that the design height will be maintained once all settlement has taken place. This amount shall in no case be less than five (5%) percent of the total fill height. All earthen embankments shall be compacted to ninety-five (95%) percent of maximum density. A note shall be included within the construction documents of the detention basin.

i. Earthen embankment side slopes shall be no steeper than four foot (4') horizontal to one foot (1') vertical. Slopes must be designed to resist erosion, to be stable in all conditions and to be easily maintained. Earthen side slopes for regional facilities shall be designed on the basis of appropriate geotechnical analyses.

j. Detailed hydraulic design calculation shall be provided for all stormwater detention basins. Stage-discharge rating data shall be presented in tabular form with all discharge components, such as orifice, weir, and outlet conduit flows, clearly indicated. A stage-storage table shall also be provided.

k. When designing stormwater detention basins in a series (i.e., when the discharge of one basin becomes the inflow to another), the design engineer must submit a hydrologic analysis which demonstrates the system's adequacy. This analysis must incorporate the development of hydrographs for all inflow and outflow components.

l. No outlet structures from stormwater detention basin's, parking detention, or other concentrating structures shall be designed to discharge concentrated flow directly onto public right-of-way or streets. Such discharges shall be conveyed by a closed conduit to the nearest existing storm sewer. If there is no existing storm sewer within three hundred (300) feet,

the outlet design shall provide for a change in the discharge pattern from concentrated flow back to sheet flow, following as near as possible the direction of the gutter.

m. Stormwater runoff may be detained within parking lots. However, the engineer should be aware of the inconvenience to both pedestrians and traffic. The location of ponding areas in a parking lot should be planned so that this condition is minimized. No required parking space or fire lane may be located within the ponding areas. Stormwater ponding depths (for the one hundred (100) year frequency storm) in parking lots are limited to a maximum of six (6") inches.
n. All pipes discharging into a public storm sewer system shall have a minimum diameter of eighteen (18") inches. In determining the actual size required, ease of maintenance and/or repair must be assured.
o. All concentrated flows into a stormwater detention basin shall be collected and conveyed into the basin in such a way as to prevent erosion of the side slopes. All outfalls into the basin shall be designed to be stable and non-erosive.
p. The bottom slope of stormwater detention basins shall be no less than 1%.
q. Swales within a stormwater detention basin may have minimum longitudinal grades of 0.5% and shall be provided with low flow concrete pilot channels.
r. Detention/retention facilities shall be designed with an emergency bypass/spillway in case the primary outfall ceases to function as designed. The emergency bypass/spillway shall be designed to pass a minimum of the one hundred (100) year pond inflow assuming a fully developed upstream contributing watershed.
s. The minimum finish floor elevation for any lot adjacent to a detention/retention facility shall be two feet (2') above the facility's one hundred (100) year fully developed water surface elevation.

4. Water Rights Considerations
    a. Retention and or wet detention facilities must obtain a TCEQ water rights permit if applicable. Refer to TCEQ for water rights regulations.
    b. For retention facilities and or wet detention facilities without a water rights permit, the Engineer shall provide a signed statement to the City stating the water rights permit is not required.
    c. Should the design engineer desire to utilize an existing facility from an agricultural use to another use, the existing facility may need to be brought into compliance with the TCEQ water rights regulations.
5. Outlet Structure Design
    a. The City has adopted the iSWM design process for outlet structures. Please refer to the iSWM Hydraulics Technical Manual dated 2014*, Section 2.2 Outlet Structures.
    b. Energy dissipation is required at outlet structure outfalls. Riprap design calculations shall be calculated in accordance with the iSWM Hydraulics Technical Manual.
    c. All detention pond designs should calculate a downstream tailwater as part of the outfall structure sizing.

6. Detention Basins Maintenance and Equipment Access Requirements
    a. For access to the pond bottom, provide a maintenance ramp of at least ten (10) feet wide with a maximum slope of fifteen (15%) percent. Twelve (12) feet width is required next to vertical walls. Gate access must be provided to the ramp with "Authorized Personnel Only" sign posted.
    b. Silt shall be removed by the owner or developer and the basin returned to original lines and grades when standing water conditions occur, the basin storage volume is reduced by more than ten (10%) percent, or the outfall structures are more than twenty (20%) percent blocked.
    c. To limit erosion, no unvegetated area shall exceed ten (10) sq. ft in extent.
    d. Accumulated paper, trash and debris shall be removed every six (6) months or as necessary to maintain proper operation.
    e. Ponds shall be mowed and sprayed with herbicide quarterly.
    f. Corrective maintenance is required any time a basin does not drain completely within sixty (60) hours of cessation of inflow (i.e., no standing water is allowed).
    g. Structural integrity of basin embankments shall be maintained at all times.
    h. Detention ponds in new subdivisions shall be located within an easement dedicated as a Homeowners Association lot.
    i. Detention basins in private subdivisions will be maintained by the required property owners' association, mandated by Section 17-326 of the Denison City Code. The developer shall provide an operations and maintenance plan for the detention/retention facility as part of the design. The operations and maintenance plan shall indicate the ingress and egress locations to enter and maintain the pond, required maintenance activities, a maintenance schedule, identification and contact information for the party responsible for the maintenance, and the community official responsible for the enforcement of maintenance activities.
    j. Maintenance of all detention facilities will be the sole responsibility of the developer, property owner, and/or Homeowners Association. Detention easements will be dedicated to the City of Denison.

P. Streambank Protection

1. The developer must meet at least one of the following conditions detailed in Section 2.1 of iSWM Hydrology Technical Manual dated 2020*:
    a. The developer must conduct an upstream/downstream assessment as described in Section E above. If downstream post development velocities exceed pre-development velocities the developer must improve/reinforce or stabilize the existing downstream conveyance system. It must also be shown that the proposed velocities do not exceed the allowable range of the improved downstream conveyance system.
    b. The developer must conduct an upstream/downstream assessment as described in Section E above. On site stormwater management controls must be installed to ensure that downstream post development discharges are at or below their pre-development discharges. Supporting documentation/ calculations must be provided.
    c. On site detention must be installed to provide 24 hours of extended detention generated by the 1-year 24-hour storm event to prevent erosive velocities downstream. Supporting documentation/calculations must be provided.

Q. Flood Mitigation

1. The developer must meet at least one of the following conditions detailed in Section 2.4 of iSWM Hydrology Technical Manual dated 2020*:
    a. The developer must conduct an upstream/downstream assessment as described in Section E above. If post development capacities exceed the capacity of the downstream conveyance system, the developer is required to improve the downstream conveyance system. The improvements/ modifications to the offsite downstream conveyance system must extend to a point at which the proposed development discharge no longer has a significant impact on the conveyance system. Supporting documentation/calculations must be provided that show peak discharges and water surface elevations are safely conveyed by the proposed downstream improvements.
    b. The developer must conduct an upstream/downstream assessment as described in Section E above. On site controls must be installed to ensure that the post development peak capacities can be adequately conveyed by the existing downstream conveyance system. Supporting documentation/ calculations must be provided that show peak discharges and water surface elevations are safely conveyed by the existing conveyance system.
    c. On site detention must be installed to ensure that existing run off conditions are maintained. Supporting documentation/calculations must be provided that show pre-development runoff conditions are maintained.

* If a newer version of this manual is available, utilize the methodology in the newer manual.

R. Erosion Control

1. A detailed erosion control plan will need to be supplied in the construction drawings. The plan must show the location of proposed erosion control measures including but not limited to sediment basins, construction entrances, concrete washouts, silt fences, inlet protection, rock check dams, etc.
2. All disturbed area within right-of-ways and drainage easements shall be revegetated with sod.
3. The developer will be required to acquire Stormwater Permits as mandated by the Texas Commission on Environmental Quality (TCEQ). The plan must be submitted and approved by the City of Denison before construction can commence. Additionally, the permit must be posted at the construction site per TCEQ requirements.
4. The developer will be required to install and maintain all erosion control measures stated in the approved construction drawings, the SWPPP manual, and/or as needed and/or required by the City of Denison to properly mitigate sediment wash off and maintain erosion control.
5. Erosion control measures must also stay in place until sod is installed or seeded grass is 90% established (if allowed). After meeting this requirement, the contractor must remove those controls. 90% of established growth of grass is required prior to acceptance. Final acceptance and payment will depend on meeting this requirement for City Projects.

Section 3 General Water and Wastewater Design

A. General

1. General Design Criteria – It is the responsibility of the engineer of record (engineer) to ensure that all water and wastewater plans are in conformance with the current edition of the City's various ordinances and master plans and the following.
   a. Rules and Regulations established by the Texas Commission on Environmental Quality (TCEQ)
   b. American Water Works Association Standards (AWWA)
2. The engineer shall obtain the available record drawings from the Public Works Department and conduct field investigations and verifications prior to construction.
3. Water and wastewater mains shall be sized and extended through the limits of a development to provide a connection for ultimate development of adjacent properties. All water systems must be looped to ensure water quality, reliability, and capacity.
4. Construction Standards and Specifications – All work and materials shall be in accordance with the current edition of the Standard Construction Details and Denison Public Works Design Manual. In the event that an item is not covered by the Standard Construction Details and Denison Public Works Design Manual, notification in writing by the contractor shall be made to the engineer, City inspector, and the Public Works Director of the issue. The Public Works Director or their designee shall make the final decision regarding all construction materials, methods, and procedures specified in construction plans. Reference to all documents contained in the project specifications shall refer to the current edition of each document.
5. All irrigation service lines must have a backflow prevention assembly on the customer side of the meter. No water may be returned to the City's potable water distribution system.
6. Open cut trench should have a full concrete panel replacement up to the sawcut/butt joint where open cut is allowed by the Public Works Director or their designee. For open cut on asphalt pavement, offset trench repair to a minimum of 1' on each side of the trench according to detail.

B. Separation of Water Mains from Wastewater Mains

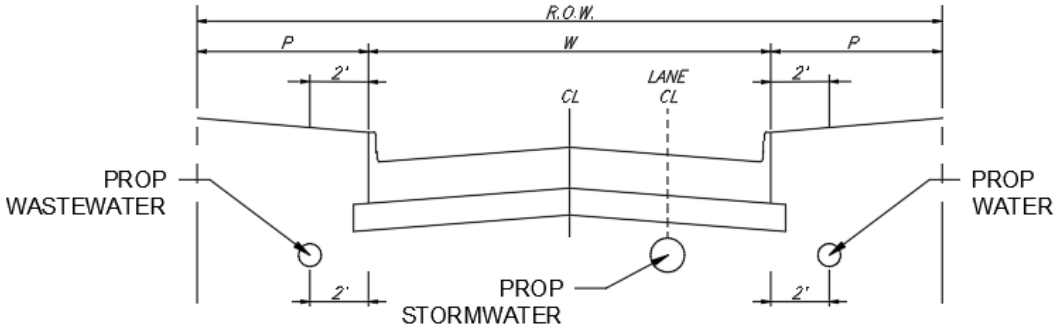
1 All water mains and wastewater mains shall be separated per TCEQ Rules and Regulations. Refer to the following:

a. Chapter 290 – Public Drinking Water Subchapter D: RULES AND REGULATIONS FOR PUBLIC WATER SYSTEMS §§290.38 – §§290.47

b. Chapter 217 – Design Criteria for Domestic Wastewater Systems Subchapter CC: CONVENTIONAL COLLECTION SYSTEMS §§217.51 – §§217.71

C. Typical Utility Layouts within Right of Way

1. Water Mains – Water mains shall be located on the north or east parkway 2 feet behind the curb. For arterial roadways, water lines shall be located outside of the ROW in a water easement.
2. Wastewater Mains – For arterial roadways, the wastewater lines shall be located outside of the ROW in a wastewater easement. For residential and collectors, wastewater shall be located south or west parkway behind the back of curb.
3. Stormwater Mains – Stormwater mains shall be located along the centerline of the lane downstream side of the roadway.



UTILITY LOCATIONS FOR LOCAL RESIDENTIAL STREETS
NTS

D. Tunneling, Jacking, and Boring

1. All water and wastewater mains to be installed under existing roadways shall be installed by a method other than open cut unless otherwise directed by the Public Works Director or their designee. Dry bores are only allowed within City right-of-way (ROW). Percussion Method (Impact Moling/Missiles) shall not be allowed within City ROW. Steel casing shall be a minimum of 1/2 inch thick and the inside diameter shall be appropriately sized for construction and maintenance of the carrier pipe. The design of the steel casing thickness shall be verified by the engineer. No bends and/or curves are permitted with casing pipes. Casings shall be required when crossing under existing and proposed arterials, highways, and railroads. Casings may also be required where deemed necessary by the Public Works Director or their designee.
2. The construction bore and receiving pit shall be located at a minimum distance of 4 feet behind the back of curb. The engineer shall provide a distance greater than

4 feet where there is no curb or barrier protection at the edge of pavement. Additional bore setback distances or shoring shall be required to maintain roadway integrity and the safety of construction personnel. When bore and receiving pits are located on private property, permanent water and wastewater easements for the pits will be required for the installation and future maintenance of the line.

3. The engineer shall design the pipe casing for the following loading conditions and/or applicable combinations thereof:
    a. Cooper's E-80 Railway loading or AASHTO HS20 loading, as applicable.
    b. Earth loading with the height of fill above the casing as shown on the plans as existing or finish grade whichever is greater.
    c. All other applicable loading conditions, including loads applied during transportation and handling.
6. The engineer shall consider the location, size, and depth of bore and receiving pits relative to existing utilities when establishing the beginning and ending stations.
7. Boring pits pen should have a full concrete panel replacement up to the sawcut/butt join or an asphalt patch of 20' by 20' where boring pits are allowed by the Public Works Director or their designee.

E. Crossings

1. Storm Drain Crossings – A steel encasement pipe shall be used to encase the carrier pipe when there is less than two-foot clearance between a water/sewer line and the storm drain. The encasement pipe shall be extended a minimum of 10 feet from the outside edge of a box culvert or the outside diameter edge of the storm drain for future maintenance of the carrier pipe.
2. Railroad Crossings – Railroad crossings should be in conformance with AREMA and other regulatory agency requirements.
3. Pipeline Crossings – Pipeline crossings should be in conformance with regulatory agency requirements.
4. Creek Crossings
    a. Water and wastewater mains constructed under any flowing stream or semi-permanent body of water, such as a marsh or pond, shall be installed inside a separate watertight encasement pipe. Water mains shall have isolation valves on each side of the crossing. Wastewater mains shall have bolt down manholes on each side of the crossing per detail.
    b. The engineer shall determine the type and limits of any special embedment and specify the limits for specialized backfills to prevent soil erosion at the areas of trench backfill and as approved by the Public Works Director or their designee.
    c. Mains with less than 4 feet of cover shall be protected by a concrete encasement with a minimum 10' into the bank on each side with concrete collars per detail or as required by the Public Works Director or their designee. Additional streambank stabilization practices needed such as gabions or concrete riprap or as required by the Public Works Director or their designee. Refer to **Section 2** for additional floodplain development

requirements.

d. Bank stabilization shall be provided for existing creek and ditch embankments disturbed by construction operations in accordance with the **Section 2** of this manual and as approved by the Public Works Director or their designee.

5. Aerial Creek Crossings
    a. Aerial crossings may be used when other alternatives have been evaluated and rejected. Any development within the fully developed 100-year floodplain must be approved by the Public Works Director. This may include, but is not limited to, a flood study and environmental permitting. The design of aerial creek crossings shall be performed by a structural Professional Engineer licensed in the State of Texas.
    b. The engineer shall use a minimum 1/2-inch-thick steel encasement pipe or ductile iron pipe around all aerial carrier pipes. The carrier pipe shall be restrained or be a monolithic pipe between a span section. Minimum 1/2 inch thick by 6-inch-wide stainless steel straps, bolts, and nuts or concrete collars shall be all around the steel encasement pipe at each pier/support structure, unless otherwise approved by the Public Works Director or their designee.
    c. A span section must withstand the hydraulic forces applied by the occurrence of a fully developed 100-year flood including buoyancy. Spans must be a minimum of 50 feet. Both the aerial crossing encasement pipe and the supporting structure shall be capable of withstanding impacts from debris and water. A scour analysis shall be performed and submitted to the Public Works Director or their designee for review and approval.
    d. Wastewater mains shall have manholes on each side of the crossing. The encasement pipe shall extend a minimum of 10’ into the embankment, be concrete encased, and protected with gabion blankets, concrete riprap, or otherwise approved erosion protection method per the discretion of the Public Works Director or their designee. Pier spacing for the aerial crossing supports must maintain adequate grade and meet the requirements regarding development in the floodplain as approved by the Public Works Director or their designee.
    e. Aerial crossings that parallel an existing aerial crossing shall be provided with adequate separation (20 feet minimum) to allow for maintenance and repair operations for the crossings.
    f. Support structures/piers shall be provided within the erosion hazard setback easement for the channel. Sanitary sewer manholes shall be placed on each side of the crossing outside of the erosion hazard setback easement.

F. Easements

All proposed water or wastewater facilities that are outside of ROW or existing easements, shall be provided with permanent water or wastewater easements. The following are the minimum requirements for the easements:

1. Water and wastewater easements shall have a minimum width of 15 feet. Additional easement width shall be provided based on depth and diameter of utilities. The minimum easement width for water and wastewater mains deeper than 10 feet to the bottom of pipe, shall be equal to 2.5 times the depth of the line rounded up to the nearest 5 feet. For example, a wastewater main 13 feet deep. The wastewater easement would be 2.5 x 13 feet = 32.5 feet, rounded up to the nearest 5 feet = 35 feet. In addition, the minimum easement width shall increase for pipe sizes larger than 36 inch such that there is still 7.5 feet minimum beyond the outer edge of pipe, rounded up to the nearest 5 feet. (i.e. 36 inch pipe requires min 20 foot easement). Larger easement widths may be required by the Public Works Director or their designee.
2. Single water or wastewater mains shall be located in the center of the easements. For 2 or more parallel water and wastewater mains in an easement, maintain the centerline of the utility a minimum of 7.5 feet from the edge of the easement for mains less than or equal to 10 feet deep. For mains greater than 10 feet deep, the easement width shall be 2.5 times the depth.
3. In residential developments, water and wastewater mains shall not cross residential lots. Water and wastewater easements shall be located completely on one side of a fence or property line.
4. Fire hydrants located outside of ROW or adjacent to water main easements shall be in a 15 feet wide easement along fire hydrant lead. Easement shall extend 5 feet beyond fire hydrant.
5. Two inch and smaller water meters serving multi-family residential and non-residential developments shall be in a minimum 5 feet x 5 feet water easement. Meters larger than 2 inches shall be in a minimum 15 feet x 20 feet water easement and shall not be within the ROW.
6. Temporary construction easements shall be provided to allow for installation, repair, and replacement.
7. Non-residential 3 inch and larger water meters shall be located in a water easement and clear of high traffic areas. The water easement shall be centered on the vault. The easement shall measure the outside dimensions of the vault and offset an additional 5 feet each side and rounded to the nearest 5-foot interval. Water meter vaults shall be sized according to the size of the water meter. Refer to the City of Denison Standard Construction Details for minimum water meter vault sizes.
8. Permanent water or wastewater easements are required when boring and receiving pits are located on private property. The boring and receiving pit areas are necessary for future maintenance of the line.
9. Access easements shall be provided to all water and wastewater easements including sections of water and wastewater mains that are not accessible or cutoff by tributaries, creeks or other obstructions along the permanent water or

wastewater easement. Additional access points shall be provided so that the distance between access points does not exceed 1,500 feet as measured along the maintenance access path.

10. Permanent water and wastewater easements shall have a 12 feet wide maintenance access path provided with a maximum running slope of 6H:1V and a cross slope of 10H:1V for maintenance equipment and vehicular travel. This maintenance access path shall be adjacent to any at grade utility features or appurtenances.
11. A 16 feet wide gate (locks provided by City) shall be provided at all fence locations that cross access easements and permanent easement ingress and egress locations.

G. Water and Wastewater Studies

1. Water studies, when deemed necessary by the Public Works Director or their designee, will be required based on flow rates, water line distance to site, water quality issues, pressure issues, etc. for the protection of public health, safety, and welfare.
2. A sanitary sewer basin map, when deemed necessary by the Public Works Director or their designee, will be required to ensure sufficient system capacity downstream of a proposed development.

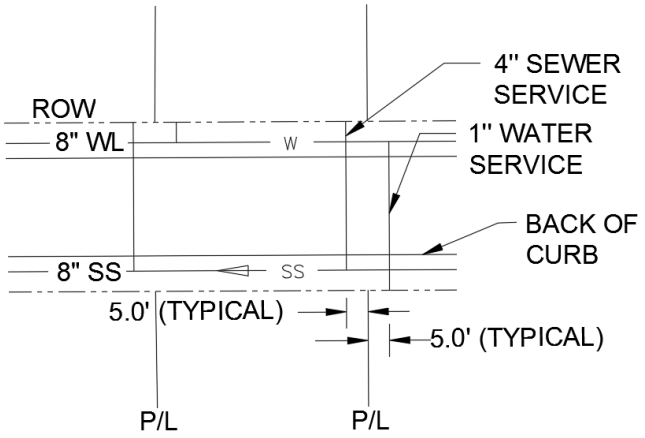
Section 4 Water System Design Criteria

A. General

1. The intent of the water system design requirements is to list minimum requirements for public water distribution and transmission system facilities and appurtenances.
2. Water services and stubouts need to be stamped in blue color at the top of curb.
3. Design criteria for all water systems shall comply with Texas Commission on Environmental Quality (TCEQ) current edition of Chapter 290, Subchapter D (Rules and Regulations for Public Water Systems), which is included in Part I of Title 30 of the Texas Administrative Code.
4. Water mains shall be sized and extended through the limits of a development to serve adjacent properties.
5. If a water loop serves only one property, the system shall be private and metered at each connection point to the public water system.
6. Connections to substandard mains shall not be allowed. Substandard mains shall be determined by the Public Works Director or their designee based on criteria including, but not limited to size, material, condition, pressure, flow rate, and/or camara inspection, etc. Offsite improvements may be necessary to provide adequate water service to the site.
7. Twelve-inch water lines and larger are required along specific proposed or future roadways in accordance with the Water Master Plan.
8. Only 12 inch or larger connections are permitted on 24-inch diameter and larger transmission mains. Smaller diameter connections less than 12-inch diameter shall be made on internal or parallel development lines.
9. If allowed by the Public Works Director or their designee to connect to the water system outside of the property's respective pressure plane, the minimum static pressure shall be 50 psi. A temporary booster system or pressure reducing valve may be required.

B. Water Services

1. All water services from the main to the meter shall be a 1-inch minimum size. All water services from the meter to the structure shall be size on size including the meter size. All water services shall be located 5 feet to the upstream side of the wastewater main from the lot lines or adjacent property line. Water services and meters shall be sized in accordance with Appendix E of the International Plumbing Code.



WATER & WASTEWATER SERVICE LOCATIONS
NTS

2. A domestic service connection shall not be allowed on fire hydrant leads.
3. Service saddle shall be double strap bronze with brass body or stainless steel double bolt wide straps with stainless steel body. Minimum size tap shall be 1 inch diameter using a stainless steel single strap with a minimum 2 inch band width. Tap locations, for taps 2 inches or greater, need to be a minimum of 5 feet from end of pipe section or other pipe connection.
4. Each meter box shall be located adjacent to the curb and installed after street pavement has been completed and curbs backfilled. Bullhead meter boxes shall be spaced 2 feet apart centered. A 2-inch minimum meter locator plate shall be placed in the recess of the meter boxes.
5. All meters supplied by the city will be at contractor's expense. Concrete meter vaults are required for meter sizes 3 inches and larger and shall be provided by the contractor.
6. In single family residential developments, the nearest edge of the water meter box shall be a minimum of 6 inches behind the back of curb, and the water service shall be no more than 12 inches deep, covered with a meter box in place at grade. If no curb is present, the water service shall be located at the property line, no more than 12 inches deep, covered with a meter box in place at grade. Along roadways without a curb, the water service line shall be constructed at a minimum of 18 inches below the ditch flowline.
7. Commercial water meters will be located in a water easement and clear of high traffic areas. Water meter vaults shall be sized according to the size of the water meter and to allow for a minimum of a 12-inch clear working area for maintenance and operation. A shut off valve should be placed outside vault box on the customer side. Minimum water meter vault sizes are shown in the City of Denison Standard Construction Details.
8. Installation of commercial meters will include two mainline valves, one bypass valve with chain and lock, a strainer, and bypass line, all located inside the vault. Clearances between fasteners on valves, strainers, and meters to interior surfaces shall provide adequate room for maintenance.

9. Water meter boxes shall be provided for each service per City Standard Construction Details. Requests for meters larger than those indicated above should be submitted with an installation detail specifying dimensions, materials, and location of the water meter vault for review and approval by the Public Works Director or their designee.

C. Water Demand and Supply

1. Residential development submittals shall include the total number of units and the total acres of the proposed development. Non-residential development submittals shall include estimated water use records showing the minimum hourly demand, maximum hourly demand, maximum daily demand, total building square footage, and the total acres for the proposed development. The projected maximum daily demand and maximum hourly demand shall be calculated and shown in MGD in accordance with the current edition of the Water Master Plan. A water basin map and sizing analysis shall be provided for water mains that serve more than 300 single family units, 400 multi-family units, or an equivalent combination of those uses or other uses.

D. Sizing Water Distribution Mains

1. Land uses shall be classified by the land use they most nearly resemble calculated by the engineer in accordance with the anticipated use. The engineer shall submit the Maximum Daily Demand and the Maximum Hourly Demand to the Public Works Director or their designee for review and approval.
2. For all developments, re-developments, and any type of facility tying into the City's water distribution system, the developer and their engineer shall provide the Public Works Department with the proposed developments full build-out daily demand, peak demand, size, capacity, population, etc. or otherwise necessary or requested information. In providing this information, the following guidelines shall be used:
    a. The engineer shall obtain the available record drawings. When record drawings are not available, field investigations and verifications shall be required prior to construction.
    b. The standard water main sizes that shall be used are noted in the **Table 4D-1**.
    c. Fire flows for all districts shall be calculated with a minimum residual pressure of 30 psi under combined fire and domestic (Maximum Daily Demand) water flow conditions and/or the latest requirement by the TCEQ. Fire flows shall be as determined by Appendix B of the International Fire Code. For single-family residential areas, a minimum fire flow of 1,000 gpm shall be provided. For retail and commercial a minimum fire flow of 1,500, multi- family and industrial areas, a minimum fire flow of 3,000 gpm shall be provided. Buildings larger than 75,000 square feet may require greater fire flows per the Fire Department.
    d. Mains are to be sized to ensure less than 7 feet of head loss per 1000 feet of water main using a Hazen Williams coefficient of C = 110 for the Maximum

Hourly Demand flow rates within the subdivision internal distribution system.

e. Mains shall be sized to provide service to adjacent properties.

Table 4D-1: Standard Water Main Sizes

8 inch	12 inch	16 inch	18 inch
20 inch	24 inch	30 inch	36 inch
42 inch	48 inch	54 inch	60 inch
66 inch	72 inch	----	----

3. Single Family Residential – 12-inch mains shall be required along all collector streets and other areas as determined by the Public Works Director or their designee. Eight-inch mains are required along smaller local streets.
4. Multi-Family Residential – Minimum size main in any multi-family project shall be 8 inches. Mains over 600 feet in length between intersecting mains or mains supplying more than one fire hydrant/fire service line shall be 12-inch diameter unless an 8-inch diameter size has been verified by the City's modeling. The City will provide the results of the modeling efforts within a brief letter report. The scope for the modeling efforts will be reviewed by the developer and the Public Works Director or their designee for approval prior to performing the modeling. The expense of the modeling efforts and letter report is the responsibility of the developer.
5. Non-Residential – Mains over 1,000 feet in length between intersecting mains or mains supplying more than two fire hydrants/fire service lines shall be 12-inch diameter unless an 8 inch diameter size has been verified by the City's modeling. The City will provide the results of the modeling efforts within a brief letter report. The scope for the modeling efforts will be reviewed by the developer and Public Works Director or their designee for approval prior to performing the modeling efforts. The expense of the modeling efforts and letter report is the responsibility of the developer.

E. Horizontal Alignment and Vertical Alignment

1. The following guidelines shall be used for the placement of water mains:
   a. Sixteen inch and larger water mains shall be designed in straight alignments if possible. Avoid excessive number of high points and low points between cross street connections.
   b. Minimum radius of curve and maximum deflection angle of pipe joints will be restricted to 75 percent of manufacturer's recommendation, after which the use of horizontal or vertical bends will be required.
   c. Restrained joints and concrete thrust blocks shall be provided for each dead end, valve, bend, tee-connection, fire hydrant, reducer, and where changes in pipe diameters or directions occur. The size and shape of concrete thrust

blocks shall be specified by the Engineer. The length of restrained-joint piping and details of joint-restraint glands, clamps, friction slabs, or other anchors shall be specified by the Engineer. Restraining mechanisms for PVC pipe and fittings shall be tested and shall meet the requirements of ASTM F1674.

d. All bends shall be 45 degrees or less where practical. Two 45 degree bends in a series shall be separated by a distance of five pipe diameters instead of a 90 degree bend.

F. Depth of Cover

1. The minimum depth of cover for water mains are indicated in **Table 4F-1.**

Table 4F-1: Depth of Cover to Top of Pipe

Pipe Size	**Minimum Depth of Cover**
8 inch	4.0 feet
12 inch and larger	5.0 feet

2. The engineer shall consider the ultimate roadway elevations in determining the depth of cover. Additional, minimum 5 feet depth of cover shall be required for unimproved bar-ditch roads and future development as directed by the Public Works. Director. Depths of cover greater than 8 feet shall be approved by the Public Works Director or their designee.

G. Pipe Material

1. The selected pipe material used in construction shall be noted on all plan and profile sheets in the Record Drawings.
2. The specification of pipe material is the responsibility of the engineer based on the analysis of specific site, soil conditions, loading conditions, and pressure requirements. The guidelines in Table **4G-1** are based on pipe size only and in no way relieve the engineer of the responsibility of pipe material specifications applicable to the particular project and restrictions due to special construction methods.
3. Additional specifications for the pipes referenced in **Table 4G-1** are as follows:
   a. Corrosion Protection System.
      i. All Bar Wrapped Concrete Cylinder and Ductile Iron Pipe will require a Corrosion Protection System (CPS). The CPS must be designed by a NACE certified Professional Engineer with considerable experience in corrosion engineering.
      ii. A detailed corrosion survey shall be conducted along the alignment to identify potential corrosion problems and recommend a corrosion protection system.
      iii. Based on the corrosion survey, a CPS shall be designed to include a Galvanic Protection System. The CPS shall be submitted for review and approval by the Public Works Director or their designee. The final anode

bed and test station locations need to be shown on the plans and record drawings.

iv. Dissimilar metals shall be isolated using insulating kits or other means to prevent galvanic corrosion.

b. PVC Pipe

i. PVC pipes shall be marked on the spigot ends with dual insert marks. The first mark, if visible, means the pipe needs to be inserted more. The second mark always needs to be visible.

ii. If the second mark is not visible, then the pipe was over-inserted and the joint needs to be disassembled and correctly installed.

Table 4G-1: Pipe Materials for Mains

Internal Diameter Pipe Size	**Pipe Material**
4 inch through 12 inch	• PVC, AWWA C900, minimum DR 18 (DR 14 for fire service lines). • Ductile Iron, AWWA C151, working pressure of 150 psi with 100 psi surge pressure, cement mortar lined, polyethylene liner.
12 inch And larger	• Ductile Iron, AWWA C151 Class 50, working pressure of 150 psi with 100 psi surge pressure, cement mortar lined, polyethylene liner. • PVC up to 18 inches, AWWA C905- 235 psi rated pipe

H. Fittings

1. All valves and fittings shall be restrained per the Standard Construction Details and the Public Works Design Manual.
2. Fittings shall be ductile iron in accordance with AWWA C110 or AWWA C153. All buried metal shall be wrapped in polyethylene tube wrap.

I. Pipe Embedment

1. For pipe sizes 16 inches and greater, the embedment class shall be a function of the pipe material selected including dead and live load considerations provided by the engineer. The engineer shall submit calculations on the embedment selected for the particular pipe type.
2. Trench dams may be required by the Public Works Director or their designee depending on the ground water potential, pipe slope and length of sloped line segments.

J. Dead-End Mains

1. Dead-end mains are not allowed unless approved by the Public Works Director or their designee. The design of all water distribution systems should include the opportunity for future looping or interconnect of any approved or proposed dead-end line.
2. All dead-end lines shall be 8 inch minimum and only be installed upon approval from the Public Works Director or their designee at a maximum length of 100 feet.
3. Where dead-end mains are approved, the engineer shall provide a fire hydrant at the end of the dead-end main for flushing and/or auto flusher approved by the Public Works Director or their designee.

K. Fire Hydrants

1. Fire Departments and Fire Sprinkler Systems
    a. At least one fire hydrant shall be within 50 feet of any Fire Department Connection (FDC). The FDC shall face and front a fire lane. FDC's shall be located in accordance with the International Fire Code. Stand-alone FDCs located adjacent to parking lots shall be properly protected.
    b. Fire lines exceeding 100 feet in length from the riser room to the circulating water main shall install a backflow preventer in a vault adjacent to the public water easement. The Fire Marshal shall approve the construction plans for the vault, fittings, valves, and double detector check and shall issue a separate permit for fire sprinkler systems.
    c. 20% of fire hydrants within a development project should be clow ihydrants. All hydrants shall be ordered powder coated silver in color. Tnemec series 43-38H diffused aluminum, silver or equivalent.

2. Fire Hydrant Spacing
    a. Single Family Residential – Fire hydrants shall be located at all intersecting streets and at intermediate locations between intersections as necessary to provide a maximum spacing of 500 feet between fire hydrants as measured along the route. The route shall be clear of permanent barriers and adjacent private property.
    b. Multi-Family Residential
        i. Fire hydrants shall be located at all intersecting streets and at intermediate locations between intersections as necessary to provide a maximum spacing of 300 feet as measured along the length of the centerline of the fire lane or roadway. Any structure at grade shall be no further than 500 feet from at least two fire hydrants as measured along the route. The route shall be clear of permanent barriers and adjacent private property.
        ii. At least one fire hydrant shall be within 50 feet of any Fire Department Connection as described in **Section 4.K.**
        iii. Fire hydrants shall be at least 35 feet from all buildings.

c. Non-Residential
    i. Non-Residential Property – As the property is developed, fire hydrants shall be located at all intersecting streets and at intermediate locations between intersections as necessary to provide a maximum spacing of 300 feet as measured along the length of the centerline of the fire lane or roadway. The front of any building at grade shall be no further than 300 feet from a minimum of two fire hydrants as measured along the route. The route shall be clear of permanent barriers and adjacent private property.
    ii. Fire Sprinkler System Stub-out – The Fire Marshal shall approve the vault, fittings, valves, and double detector check and will issue a separate permit for fire suppression systems.
    iii. Fire hydrant spacing shall be in accordance with Appendix C of the current edition of the International Fire Code.
    iv. At least one fire hydrant shall be within 50 feet of any Fire Department Connection as described in **Section 4.K.**
    v. Location of fire hydrants shall be installed outside of the PCs and PTs of curve radii of fire lanes (no fire hydrants shall be located within the radius delta angle between the PC and PT of the curve). Fire hydrants shall be at least 35 feet from all buildings.
    vi. Where access could be blocked due to a barrier between the fire hydrant and the building which it is intended to serve, additional fire hydrants shall be provided to improve the fire protection.

d. Spacing along Arterials – Where new water mains are extended along streets where hydrants are not needed for protection of structures or similar fire problems, fire hydrants shall be provided at spacing not to exceed 1,000 feet to provide for transportation hazards. For divided roadways, fire hydrants shall be provided at a spacing not to exceed 1,000 feet for each side of the roadway with 500 feet spacing on an alternating basis between the fire hydrants.

3. Fire Hydrant Installation
    a. Fire hydrants shall be located at a maximum of 5 feet 6 inches from the fire lane or roadway as measured from the centerline of the fire hydrant to back of curb, edge of pavement, or fire lane.
    b. A 3 feet clear radius shall be maintained for access and operation of the fire hydrant.
    c. Fire hydrants placed on private property shall be located in water easements and adequately protected behind a curb or curb stop, pipe bollards, or other methods as approved by the Public Works Director, or their designee, and the Fire Department. Curb or curb stop, pipe bollards, or other methods shall be the responsibility of the owner.
    d. Fire hydrants located on public or private property shall be accessible to the Fire Department at all times.
    e. Standard fire hydrant barrel shoe depth where ever practical shall be 5 feet. The fire hydrant lead line shall be adjusted to meet the standard fire hydrant depth.

4. Fire Hydrant Leads
    a. Fire hydrant leads shall be a minimum of 6 inches and have a bury depth of 4 feet.
    b. Valves shall be placed on all fire hydrant leads. The connection to the main line shall include a flanged tee connected to a flange by mechanical joint gate valve. The mechanical joint shall be restrained so that the valve is anchored to the main.
    c. Eight inch mains shall be connected so as to serve not more than two fire hydrants located between intersecting mains. Every development shall provide adequate water capacity for fire protection purposes. The procedure for determining fire flow requirements for building or portions of buildings shall be in accordance with the International Fire Code. The minimum required fire flow shall be 1,500 gpm at 22 psi.
    d. Fire hydrant leads shall not exceed 50 feet unless approved by the Public Works Director or their designee. If a variance is granted to exceed 50 feet, fire hydrant leads exceeding 100 feet in length from the circulating water main shall install a backflow preventer in a vault adjacent to the public water easement.
    e. Existing 4 inch mains used for hydrant supply shall be replaced and dead-ends eliminated where practical. Existing 6-inch lines shall be connected so that no more than one fire hydrant shall be between intersecting lines. New fire hydrants shall not be connected to substandard main.
    f. For main replacement projects in established neighborhoods, fire hydrants should be designed as close as possible to the old fire hydrant location, provided coverage is adequate. Fire hydrants shall not be installed closer than 9 feet to any wastewater main or any wastewater appurtenance.
5. Specifications – Fire hydrants shall be three-way breakaway type no less than 5- ¼ inch size. Mechanical joint connection is required.
6. Public and Private Fire Mains – Public and private fire protection water mains shall be installed according to the National Fire Protection Association (NFPA) 24 and the current City adopted International Fire Code.

L. Valves

1. General – The following guidelines should aid the engineer in placement of valves on proposed water mains.
    a. Valves are to be located at street intersections at or near side property lines, unless a specific construction issue requires the placement of the valve at a nonstandard point of connection. Valves shall be installed on each branch and mainline segment at tees and crosses for 12 inch or larger water mains. Site specific approval may be given to use a fire hydrant isolation valve within 100 linear feet of the connection point.
    b. Valves 12 inches and under shall be Resilient Wedge Gate Valves (RWGV). Valves shall be spaced 600 feet or less in a single family residential district and 500 feet or less in all other districts. Valves shall be placed in such a manner as to require two, but not more than three valves, to shut down each

main segment without shutting off more than one fire hydrant.

c. Twelve inch and larger valves may be butterfly type and shall be spaced at a maximum of 1,000 foot intervals. All valves shall have horizontal mounted actuators with a manhole for access to the actuators.
d. Valves shall be placed at or near the ends of mains in such a manner that a shutdown can be made for a future main extension without causing loss of service on the existing main. A minimum of 20 feet of main shall be installed past the valve and mechanical pipe thrust restraints shall be used to anchor it.
e. Main line water valves shall be provided on each side of the domestic service line connection serving Care Facilities, Emergency Rooms, Hospitals, Clinics, Schools, Montessori Schools, and Day Cares.
f. Where fire lines are connected to the water main, valves shall be installed on one side of the connection to provide the ability to isolate the main line and continue to provide water to the fire line. The fire line shall be provided with a valve at the connection with the main line.
g. Valve boxes shall be provided for buried valves. They shall be three-piece screw-type cast iron boxes of the extension type. The three pieces shall consist of the top section, bottom section, and cover.
h. Two inch square nuts that would be over 4 feet deep shall have valve stem extensions. In these cases, the 2 inch square valve operating nut shall be no greater than 2 feet from the finish grade.
i. Mechanical joint restraints are required for all valves.
j. The location of isolation valves shall be placed to anticipate system flushing and disinfection.
k. All valves shall be located outside of barrier free ramps.
l. All valves shall be stationed along water mains including profiles and reference roadway centerline stationing.

2. Air Release, Air/Vacuum, and Combination Air Valves
    a. Air release valves, air/vacuum, and combination air valves shall be required on 16 inch and larger water mains and as necessary for proper system operation. There are three primary functions of the valves that the engineer shall consider as follows.
        i. To vent large volumes of air during filling of the line,
        ii. To allow air into the pipe during emptying for maintenance and/or repairs; and,
        iii. To vent small volumes of air that come out of solution during service.
    b. Typically these are installed at high points where the pipeline has a vertical change in gradient. Additional installation locations may be requested by the Public Works Director or their designee.
    c. A fire hydrant shall be required at high points on 12 inch water mains for air relief and flushing maintenance operations. When a fire hydrant cannot be used, an air release valve may be approved by the Public Works Director or their designee.

M. Connections to Existing Water Mains

1. Tapping Sleeves and Valves
    a. Size on size tapping sleeves are not allowed. The largest allowable tapping sleeve shall be the main line size less one standard pipe size (Example: 16 inch x 12 inch, 8 inch x 6 inch, etc.). If a size on size connection is required, then a cut-in connection shall be used.
    b. Connections to an existing line shall be made with full body stainless steel tapping sleeve and valve. A resilient wedge gate valve shall be flanged to the tapping sleeve.
    c. The tap location needs to be a minimum of 5 feet from an existing bell and spigot connection or other type of pipe connection.
2. Cut-In Connection – When connecting to an existing main, it may be required to provide a cut-in connection with a tee and valve being installed into the existing main in lieu of a tapping sleeve and valve where there is not an existing main line valve between proposed water connection locations as directed by the Public Works Director or their designee. A test shut down of the existing water main(s) shall be conducted by the Public Works Department. The requirement for a test shutdown may be waived with approvals of the Public Works Director or their designee.
3. Four-Way Connections – The installation of a cross fitting shall not be allowed. Four-way connections shall be made via offset tees or a ring connection. Valves shall be provided on all legs of offset tees and ring connections except that a single valve may be placed between the offset tees or within the ring segment. Through legs of tees shall be equal to the largest pipe size. The ring segment shall be equal to or greater than the smaller pipe size. Where pipe size changes occur at a four-way connection, the largest size on each leg shall govern.
4. Blow-off valves shall be required at low points on mains 16 inches or greater.
5. Requirements for Abandoning Water Mains
    a. The engineer is to note the limits and appropriate conditions for abandoning existing water mains that are being replaced.
    b. The engineer shall make allowances to permit the existing and proposed mains to remain in service simultaneously thereby providing a means for transferring customer's services from the old main to the new main with minimum interruption. If the construction of a proposed main necessitates the abandoning of the existing main prior to the new main's placement into service, then provisions for a temporary water main with services must be addressed with the design.
    c. Abandoned lines to remain in place shall have the interior completely filled with grout. Valves to be abandoned in place shall have any extensions and the valve box removed and shall be capped in concrete.
    d. Existing fire hydrants and valves located on mains being abandoned are to be removed and delivered to the Public Works Department.
6. Replacement Lines – To replace an existing line, the new line should be designed parallel to the line being replaced. The engineer shall perform a field investigation to determine pavement condition over the existing main. Based on this field

investigation, the engineer shall include additional quantities for pavement replacement, if needed. Also, locate the proposed main at least 5 feet away from the existing curb to avoid damaging the curb or undercutting the pavement during installation of the proposed line. On lines being abandoned, the engineer should note and locate points of cut and plug at the junction with the line that remains in service.

7. Flushing and pressure testing should be performed when connecting to existing water mains.

N. Flushing and Disinfection

1. General
    a. All flushing and disinfection shall comply with AWWA C-651.
    b. All work shall be coordinated in advance (minimum 72 hours) with the designated construction inspector.
    c. The contractor is responsible for the cost of all water used in the filling, flushing, and disinfection of the new potable water system. Contractor will set up account with utility billing for construction meter.
    d. The contractor shall submit a Flushing and Disinfection Plan for review prior to beginning any water main installation. This plan shall show all the information needed to commission the public water mains and appurtenances in accordance with all applicable requirements. The Flushing and Disinfection Plan shall indicate how the contractor will ensure appropriate minimum velocities and flows to ensure proper flushing. Special attention should be paid to the larger diameter, long water mains. Alternative methods as identified in AWWA 651 may be more appropriate.
    e. Sample points shall be provided on each 1,000 feet intervals of new water main, at the end of line, and at each branch on the main line.
2. Initial Fill – The contractor shall utilize a jumper connection with backflow preventer and temporary meter assembly connected to an existing fire hydrant to fill the new system.
3. Debris Flush (Segment Flush)
    a. Segmented Debris Flush – The new water distribution system shall be flushed one segment at a time, using the in-line isolation valves and fire hydrants to ensure a full flow through each hydrant. The contractor shall provide all assistance necessary to operate valves and hydrants under the direction of the construction inspector.
    b. The contractor may utilize the jumper or the main isolation valve to perform the debris flush. When the jumper is used, the contractor may perform all necessary activities as described below without requesting the assistance of the Public Works Department.
    c. When the main isolation valve is used, the construction inspector must be given 72 hour notice to coordinate with the Public Works Department valve crew. The Public Works Department valve operator is the only one on-site authorized to operate the isolation valve on the “live” City system.

d. When using the jumper system to complete the debris flush, the contractor shall ensure there is an adequate supply to maintain appropriate flush velocities and flows.
e. When the main isolation valve is used to complete the debris flush, the Public Works Department valve operator will utilize the main in-line valve as long as the new valves and fire hydrants are open to prevent backflow into the water system.
f. When using this method, the City valve operator will use a flow rate meter to estimate the amount of water used. The Public Works Department will report these readings to the billing office. The contractor is responsible for the cost of the water used.

4. Disinfection
   a. The contractor shall provide the equipment and material needed for the disinfection process. Chlorine shall be loaded into all portions of the new water distribution system. Chlorination to include the main lines, fire hydrant leads, and all water services.
   b. The construction inspector will verify the chlorine residual at the beginning of the process (minimum 100 mg/L).
5. Disinfection Flush
   a. After a minimum of 24 hours, the construction inspector will verify a minimum chlorine residual of 10 mg/L.
   b. The contractor shall flush the new distribution system and appurtenances to reduce the residual to a maximum of 4 mg/L. This includes all fire hydrants and water services. The contractor may utilize the jumper system or the main isolation valve to perform this flush. Any operation of the main isolation valve will require coordination with the Public Works Department. The contractor is responsible for the cost of all water used. Once the residual has been dissipated and the water has remained in the pipe for a minimum of 16 hours with no use or flushing during the minimum of 16 hours, then the system is ready for the bacteriological testing.
   c. All flush water (potable water and super chlorinated water) shall be diverted to the nearest wastewater manhole by hose including all fittings and appurtenances. A strainer shall be used on the hose discharge into the wastewater manhole. Maintain a minimum 1-foot vertical air gap between end of discharge hose and manhole frame. If a sanitary sewer manhole is not available, then the contractor shall provide a de-chlorination diffuser at the flush outlet point(s) including all fittings and appurtenances. Detention may be allowed on-site dependent on weather conditions and approval from the Public Works Director or their designee. The detained water cannot be released until the chlorine residual is less than 0.01 ppm (mg/L).
6. Operation – The process delineated above will be reiterated until passing water sample test results are received. Upon receipt of the passing water sample tests, the City construction inspector will work with the Public Works Department to place the new system into operation.

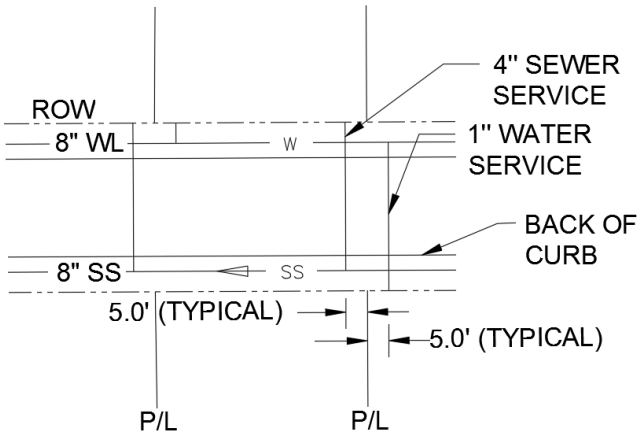
Section 5 Wastewater Design Criteria

A. General

1. Design criteria for all wastewater systems shall comply with the current edition of the TCEQ Chapter 217 (Design Criteria for Domestic Wastewater Systems).
2. Manhole vacuum testing, mandrel, and camara video inspection required per TCEQ.
3. Wastewater services need to be stamped in green color at the top of curb.
4. Wastewater main sizes shall comply with the Wastewater Collection System Master Plan
5. Wastewater mains shall be sized and extended through the limits of a development to serve adjacent properties.
6. Larger lines shall not flow into smaller lines.
7. Wastewater systems shall be designed so that all wastewater mains will be gravity flowlines. If the use of a wastewater lift station is approved by the Public Works Director or their designee, it shall be designed in accordance with **Section 5.6**.
8. Connections to substandard mains and manholes shall not be allowed. Substandard mains shall be determined by the Public Works Director or their designee based on criteria including, but not limited to size, material, condition, flow rate, capacity, etc. Offsite improvements may be necessary to provide adequate wastewater service to the site.

B. Sewer Services

1. General – The sizes and locations of service laterals shall be designated as follows:
    a. All sewer services shall be extended to a point 10 feet beyond the property line at a maximum depth of 5 feet.
    b. Cleanouts shall be placed at the ROW/property line for all new services and be outside of sidewalks and driveways.
    c. For rehabilitation of existing mains and services, new cleanouts shall be installed at the property line, with the wye directed towards the main.
    d. The service shall then be extended at a 45 degree angle and extend riser to finish grade.
    e. When the service lateral is extended, the extension will start at the street side of the 45 degree angle and extended to the structure.
2. Single Family Residential
    a. Service lateral size shall be 4 inch minimum at a 2 percent minimum grade for each lot or unit from the cleanout near ROW/property line to main.
    b. One service lateral per lot or each unit. Duplexes and/or townhomes shall have two 4 inch service laterals that shall be independently attached to the main.
    c. Service laterals shall be installed 5’ downstream of the lot line and shall have a minimum horizontal separation of 10 feet from the water service.
    d. The engineer shall review the finish pad elevations, depth of service lateral lines, slopes from pad to street to verify the sanitary sewer system can serve all properties within the sanitary sewer basin.



WATER & WASTEWATER SERVICE LOCATIONS
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3. Multi-Family Residential
    a. A minimum of 1 service lateral per building shall be required.
    b. Service laterals shall have a minimum horizontal separation of 10 feet from the water service.
    c. Service lateral size shall be 6 inch minimum at a 2 percent minimum grade. Concrete pads shall be installed around the cleanout.
4. Industrial and commercial
    a. A minimum of 1 service lateral per building shall be required.
    b. Service laterals shall have a minimum horizontal separation of 10 feet from the water service.
    c. Service lateral size shall be 6 inch minimum at a 2 percent minimum grade. Concrete pads shall be installed around the cleanout.

C. Design Flow

1. All wastewater collection systems shall be designed in accordance with the current Wastewater Collection System Master Plan.
2. Where possible, all collection systems will be laid out so that all lines will be gravity flow unless approved by the Public Works Director or their designee.
3. Residential development submittals shall include the total number of units and the total acres for the proposed development. Non-residential development submittals shall include total building square footage, the planned use for the building, and total acres for the proposed development. The projected wastewater flows shall be calculated and shown in MGD in accordance with the Wastewater Master Plan and per TCEQ Chapter 217 (Design Criteria for Domestic Wastewater Systems). A sanitary sewer basin map and sizing analysis shall be provided for sewer mains that serve more than 300 single family units, 400 multi-family units, or an equivalent combination of those uses or other uses.
4. All wastewater collection systems must be designed to convey the peak wet weather flow from the entire service area including offsite areas throughout the

system. Basin delineation shall be provided using LIDAR or surveyed contours. Contours shall be provided on 2 foot or less intervals. USGS topo is not permissible.

5. Flow calculations must include the specifics of the average dry weather flow and the dry weather flow peaking factor.

D. Sizing Wastewater Collection Mains

1. General
    a. For all developments, re-developments, and any type of facility tying into the City's wastewater distribution system, the developer and their engineer shall provide the Public Works Department with the proposed developments full build-out average daily flow, peak flow, size, capacity, population, etc. or otherwise necessary or requested information.
    b. The standard wastewater main sizes that shall be used are noted in the **Table 5D-1**.

Table 5D-1: Standard Wastewater Main Sizes

8 inch	10 inch	12 inch
15 inch	18 inch	21 inch
24 inch	27 inch	30 inch
33 inch	36 inch	39 inch
42 inch	48 inch	54 inch
60 inch	----	----

2. Average Daily Flow
    a. Table 5D-2 shall be used to calculate the average daily wastewater flow. The collection system shall be designed based on the peak flow calculations.
    b. For replacement of existing sewer and construction of parallel sewers for additional capacity, wastewater flow data will be provided by the Developer and their Engineer to the Public Works Department with the proposed developments full build-out average daily flow, peak flow, size, capacity, population, etc. or otherwise necessary or requested information.
    c. Wastewaters with direct connections to service lines shall be designed to be no more than 70% full and interceptors shall be designed for 100% full.
    d. Proposed parallel wastewater mains adjacent to existing wastewater mains shall be sized to eliminate surcharge in the existing lines.
    e. **Table 5D-2** summarizes multiple land use demand rates. Land uses not listed shall be classified by the land use they most nearly resemble in **Table 5D-2** or calculated by the engineer in accordance with the anticipated use. The engineer shall submit the average daily demand and peak flow calculations including off-site flows within the drainage basin to the Public Works Director or their designee for review and approval.

3. Peak Flow Factor – Peak flow factors are as follows:
    a. For average daily flow less than 0.05 MGD – Peak Flow Factor = 5.
    b. For average daily flow between 0.05 MGD and 1.0 MGD – Peak Flow Factor = 4.
    c. For average daily flow between 1.0 MGD and 2.0 MGD – Peak Flow Factor = 3.5.
    d. For average daily flow greater than 2.0 MGD – Peak Flow Factor = 3.

Table 5D-2 – Design Organic Loadings and Flows for a New Wastewater Treatment Facility TCEQ (TAC §217.32(a)(3))

Source	Remarks	Daily Wastewater Flow (gallons/person)	Wastewater Strength (mg/l BOD_5)	Wastewater Strength (mg/l NH_3-N)
Municipality	Residential	75-100	250-400	15-75
Subdivision	Residential	75-100	250-400	15-75
Trailer Park (Transient)	2½ Individuals per Trailer	50-60	250-350	15-75
Mobile Home Park	3 Individuals per Trailer	50-75	300	15-75
School	Cafeteria &	20	300	15-75
	Showers Cafeteria/No Showers	15	300	15-75
Recreational Parks	Overnight User	30	200	15-75
	Day User	5	100	15-75
Office Building or Factory	A facility must be designed for the largest shift	20	300	15-75
Hotel/Motel	Per Bed	50-75	300	15-75
Restaurant	Per Meal	7-10	1000*	15-75
Restaurant with bar or cocktail lounge	Per Meal	9-12	1000*	15-75
Hospital	Per Bed	200	300	15-75
Nursing Home	Per Bed	75-100	300	15-75
Alternative Collection Systems (Subchapter D of this chapter)	Per Capita	75	N/A	N/A
*Based on a restaurant with a grease trap				

E. Inflow and Infiltration

1. After determining the peak flow amount, the engineer shall add an average daily inflow and infiltration rate of 1,500 gpad.

F. Horizontal Alignment and Vertical Alignment

1. The following guidelines shall be used for the placement of wastewater mains:
2. Horizontal curves are not allowed.
3. Vertical curves are not allowed.
4. For new construction in open space areas, sewer mains shall be laid straight between manholes.
5. When the locations are known, services for future lots shall be installed.
6. Alignment should be located south or west parkway 2 feet behind the back of curb for residential and collector roadways.
7. Wastewater main shall be placed outside ROW following the centerline of a wastewater easement on arterial roadways.
8. For main replacement projects, when flow permits, 8 and 10 inch mains should be replaced in the same alignment.
9. Public wastewater mains shall not be located nearer than 8 feet from any tree.
10. No wastewater mains shall be located in alleys.
11. Wastewater mains deeper than 12 feet with service connections will require a second shallower parallel main to convey wastewater to the nearest downstream manhole.
12. The minimum acceptable Manning's "n" value for use in wastewater design shall be 0.013. Pipes shall be placed on such a grade that the velocity complies with current City's desired minimum and maximum criteria summarized in **Table 5F-1**

Table 5F-1: Grades for Wastewater Mains

Pipe Diameter (inches)	Minimum Slope (percent)	Maximum Slope (percent)
8	0.76	8.40
10	0.56	6.23
12	0.44	4.88
15	0.33	3.62
18	0.26	2.83
21	0.21	2.30
24	0.17	1.93
27	0.15	1.65
30	0.13	1.43
33	0.11	1.26
36	0.10	1.12
39	0.09	1.01
>39	**	**

** For pipes larger than 39 inch diameter, the slope can be determined by Manning's formula to maintain a flow velocity greater than 2.0 feet per second and less than 10.0 feet per second when the pipe is flowing full. Manning's formula is as follows:

$$V = \frac{1.486}{n}(R)^{2/3}(S)^{1/2}$$

Where:

V = flow velocity (feet per second)
n = Manning's roughness coefficient (dimensionless)
R = hydraulic radius, which is the area of the flow divided by the wetted perimeter (R = A/P) (feet)
A = flow area (square feet)
P = wetted perimeter (feet)
S = pipe slope (feet per foot)

G. Depth of Cover

1. The minimum depth for 8" mains should be 4 feet. Unimproved roads should have a minimum depth of 5.5 feet to ensure enough cover for future curb and gutter road construction.
2. When establishing depth for proposed wastewater mains, engineer shall evaluate proposed street grades and anticipate the size of proposed storm sewers in unimproved areas. Future storm sewers should be at least 3 feet below the top of pavement. The proposed wastewater main shall be at least 2 feet below the bottom of the future storm sewer. Minimum cover shall be 4 feet. Any main with less than minimum cover shall be encased in Class "G" embedment and is subject to approval by the Public Works Director or their designee. Refer to Section 3.E.4 for additional requirements for shallow cover at creek crossings.
3. The service lateral within the ROW must have at least 3 feet of cover at its shallowest point. The engineer is responsible for ensuring that sufficient depth and grade is maintained to serve all proposed and future building sites in the sewer shed.
4. The engineer shall consider the ultimate roadway elevations in determining the depth of cover. Additional depth of cover shall be required for future development and as directed by the Public Works Director or their designee.
5. Depth of cover greater than 20 feet must be approved by the Public Works Director or their designee

H. Manhole Locations and Manhole Sizes

1. Manholes shall be designed based on the following requirements and in the following locations:

    a. A manhole shall not be located in the flow path of a watercourse, or in an area where ponding of surface water is probable. Additional manholes may be required as determined by the Public Works Director or their designee.
    b. At each end of lines that are installed for aerial crossings and siphons with bolt down lids.
    c. At the location of service lateral connections that are 6 inch diameter or greater.
    d. Spacing shall be limited to 500 feet. TCEQ mains with horizontal curvature shall have a maximum spacing of 300 feet per TAC Title 30, Part 1, Chapter 217, Subchapter C, Rule 217.53.
    e. At all locations where diameter of the pipe changes.
    f. At all locations where pipe material changes.
    g. At all locations where the horizontal or vertical alignment of the sewer main changes.
    h. At the end of a wastewater collection system pipe that may be extended in the future. Provide pipe stub outs with plugs for future connections.
    i. Spacing between a manhole and an upstream cleanout shall be limited to 300 feet.
    j. Vacuum manhole testing shall be in accordance with ASTM 1244.

k. Existing brick tile manholes shall be replaced.

2. Floodplains
    a. Bolt down sanitary sewer manhole lids with gaskets shall be used to prevent the entrance of stormwater when manholes are placed within the limits of the fully developed 100-year floodplain. Where more than three manholes in sequence are to be bolt down sanitary sewer manhole lids with gaskets, every third manhole shall be vented 2 feet above the fully developed 100-year floodplain elevation or 6 feet above the adjacent ground line, whichever is higher. The engineer shall obtain and provide the elevation of the fully developed 100-year floodplain. Sealed manholes shall also be used in all areas subject to carrying drainage flow or in drainage ways. Refer to Section 2 of this manual for methodologies to determine the limits of the fully development 100-year floodplain.
3. Manhole Lids and Rims
    a. Reference the City of Denison Standard Construction Details for additional requirements for standard lids.
4. Manhole Sizes
    a. Manholes to be constructed on existing or proposed sewer lines shall be sized as shown in **Table 5H-1**.
    b. Manholes deeper than 8 feet shall be a minimum of 5 feet diameter and require structural design. Manholes deeper than 20 feet require approval from the Public Works Director or their designee. Manhole diameter may increase due to pipe geometry, excessive depths, and multiple pipes connected to the manhole. Twelve inch or larger mains shall use fiberglass manholes according to details. Special manholes shall be designed for mains larger than 36 inch diameter pipe and for mains greater than 12 feet deep. 18 inch minimum measured outside diameter to outside diameter of pipe along the outside surface of the wastewater manhole shall be maintained between pipes to manhole connections. If the 18 inch separation cannot be achieved a larger diameter manhole shall be selected to meet these requirements.
    c. Where pipes enter a manhole there shall be a minimum of 0.10 foot of drop between flowlines. Where unequal size pipes enter a manhole, crown of pipes shall match elevations.
    d. The manhole invert channels and benches shall be manufactured in the precast plant with the manhole bottom section. The invert channels shall be sloped to maintain a smooth transition through the manhole connecting all inlets and outlets without the need of further field modifications.

Table 5H-1: Manhole Diameter Requirements

Pipe Diameter	Manhole Minimum Diameter
8 inch through 10 inch	4.0 feet
12 inch through 36 inch	5.0 feet

5. Drop Manholes – Drop manholes shall be required when the inflow elevation is more than 24 inches above the outflow elevation. All drop manholes will have drops outside manhole per standard detail.
6. Corrosion Protection for Manholes
   a. Apply one of the following corrosion protective agents for all concrete manholes: Chesterton Arc 791, Raven 405, Warren Epoxy 301-14, or Spectra Shield. New manholes and wet wells shall be lined with Warren Environmental 3301-14 Epoxy Coating on interior surfaces. Apply corrosion protection to all exposed interior surfaces in existing/rehabbed sanitary sewer manholes and wet wells. Surface preparation and protective coating material (PCM) shall follow manufacturer's recommendations.
   b. Mains 12" and larger shall use fiberglass manholes.

I. Pipe Material

1. The specification of pipe material is the responsibility of the engineer based on the analysis of specific site, soil conditions, loading conditions, and pressure requirements. The following guidelines are based on pipe size only and in no way relieve the engineer of the responsibility of pipe material specifications applicable to the particular project and restrictions due to special construction methods.
2. Allowable pipe materials for gravity mains are shown in **Table 5I-1**.
3. Additional specifications for the pipes referenced in **Table 5I-1** are as follows:
   i. For water and wastewater separation deficiencies, wastewater pipe shall be:
      - (8 inch-15 inch) PVC Pressure Pipe Class 160 SDR 26 (ASTM D2241) or Ductile Iron AWWA C151 Pressure Class 350, internal ceramic liner and green polyethylene encased. Ceramic liner to be manufactured by Protecto 401 or HDPE, AWWA C901/C906, DIPS minimum DR13.5 (160 psi), ASTM D2239, ASTM D2737, ASTM D3035, ASTM F714 and ANSI/NSF 14/61 listed.
      - (18 inches and larger) – Green PVC Pressure Pipe Class 160 SDR 26 (ASTM D2241) or Ductile Iron AWWA C151 Pressure Class 350 (internal ceramic liner and green polyethylene encased). Ceramic liner to be manufactured by Protecto 401 or HDPE, AWWA C901/C906, DIPS minimum DR13.5 (160 psi), ASTM D2239, ASTM D2737, ASTM D3035, ASTM F714 and ANSI/NSF 14/61 listed.
      - For water and wastewater TCEQ separation deficiencies (larger than 18 inches) – FRP with recommended Structural Number (SN) and Pressure Class Number (PN) (150 psi minimum) or HDPE, AWWA C901/C906,

DIPS minimum DR13.5 (160 psi), ASTM D2239, ASTM D2737, ASTM D3035, ASTM F714 and ANSI/NSF 14/61 listed.

Table 5I-1: Pipe Materials for Gravity Mains

Internal Diameter Pipe Size	**Pipe Material**
6 inch through 24 inch	• Green PVC, SDR 26 (Pipe Class 160 psi) (ASTM D3034). Fittings shall be equivalent to pipe class. • 4 and 6 inch pipe for sanitary sewer services shall be green, PVC, SDR 26 (Pipe Class 160 psi).
24 inches and above	• CCFRPM, Centrifugally Cast Fiber Reinforced Polymer Mortar Pipe(HOBAS or approved equivalent) or as directed by the Public Works Director or their designee (ASTM D3262, D4161, D2412, D3681, D638) • Solid wall green PVC (ASTM F679, F794, F949 and D3350/DE345434C)

Notes: For piping that does not have the green material for wastewater applications, the pipe shall be spiral wrapped with appropriate detectable or non-detectable caution tape. The spiral wrapping shall be on 2 feet centers measured along the pipe. The selected pipe material used in construction shall be noted on all plan and profile sheets in the Record Drawings.

4. For trench depths greater than 10 feet or other dead and/or live loading considerations, the engineer shall provide a pipe with the appropriate SDR rating which shall meet or exceed SDR 26 pipe specifications. The Public Works Director may issue written approval for use of Ductile Iron AWWA C151 Pressure Class 350 (internal ceramic liner and polyethylene encased). Ceramic liner to be manufactured by Protecto 401 or approved equal.
5. Additional specifications for the above referenced pipes are as follows:
    a. Ductile Iron Pipe – All buried metal shall be wrapped per AWWA C105/A21.5ASTM 674 polyethylene tube wrap.
    a. Different pipe materials are not allowed between manholes.
    b. The material used for the wastewater shall be designed for a minimum structural life cycle of 50 years. If the pipe material will deteriorate when subjected to corrosive conditions, the engineer shall provide for an acceptable corrosion resistant liner or provide calculation and data that demonstrates that the design and operational characteristics will provide for the minimum life cycle.
    c. All gravity sewer pipes shall be green in color. PVC fittings may be either green or white in color.

d. All pipes with encasings shall be restrained joint pipes for all applications.

J. Pipe Embedment

1. The type of embedment and backfill for sewer mains shall in accordance with the City of Denison Standard Construction Details.
2. Trench Dams may be required by the Public Works Director or their designee depending on the ground water potential, pipe slope and length of sloped line segments.

K. Cleanouts

1. Cleanouts located on service laterals shall be 4 inch diameter for residential and 6 inch for commercial and should be located on the property line/ROW line.
2. Cleanouts on residential sewer services are to be located and installed as per approved drawings, building code requirements, and City of Denison Standard Construction Details.
3. A clean-out with watertight plugs may be installed in lieu of a manhole at the end of a wastewater collection system pipe if no extensions are anticipated, if the cleanout is 300 feet or less from the downstream manhole. Cleanout installations must pass all applicable testing requirements outlined for gravity collection pipes in TCEQ Chapter 217.57 (Testing Requirements for Installation of Gravity Collection System Pipes).
4. Cleanouts may be used on main lines within single family development at the end of lines only.
5. Cleanouts shall not be used on City maintained collection systems for multifamily, commercial and industrial development.
6. Cleanouts shall be provided on service laterals with locator pad and tape to surface at the property line.
7. Connections to Existing Wastewater Mains
    a. When connecting a 6 inch or larger new line to an existing wastewater main the engineer shall provide a new manhole at the point of connection. Prior to breaking into the existing line the new manhole and upstream pipe segment shall pass inspection by the Public Works Director or their designee.
8. Abandonment of Wastewater Mains
    a. The engineer shall specify on the plans the limits and appropriate conditions for abandoning existing wastewater mains that are to be replaced by the construction of proposed wastewater mains.
    b. The engineer shall ensure that the service laterals tying into the existing sewer line to be abandoned are transferred to the new main so a live sewer main is not abandoned. If a manhole on the sewer main being abandoned is to remain in service because other sewer mains are entering this manhole, then the sewer main to be abandoned shall be plugged inside the manhole. A note on the plans showing which sewer main is to be plugged inside the manhole is required.
    c. All abandoned wastewater and force main lines shall be cut and plugged and all void spaces within the abandoned line shall be filled with grout, flowable fill or an expandable permanent foam product.

d. Abandonment of all utilities within TxDOT ROW shall comply with TxDOT standards.
e. Place above ground markers every 500’ if wastewater main is located within an easement.

Section 6 Wastewater Lift Station Design Criteria

A. General Design Criteria

1. This section presents the basic criteria to be used in the design of lift stations in the City of Denison. At a minimum, lift station design and force main shall meet the guidelines in Title 30, Part 1, Chapter 217 of the Texas Commission on Environmental Quality (TCEQ), Subchapter C, Conventional Collection Systems. Public Works Director or their designee may require additional specifications.
2. All above ground features of the lift station will be installed a minimum 2-feet above the FEMA 100-year flood elevation.
3. Lift Station site size requirements:
    i. Firm pumping capacity of 200 GPM or less – minimum site size: 100 foot X 100 foot
    ii. Firm pumping capacity of 201 GPM to 1000 GPM – minimum site size: ½ Acre
    iii. Firm pumping capacity greater than 1000 GPM – minimum site size: 1 Acre
4. A diesel generator for backup electrical power shall be provided to operate the lift station at firm capacity. Provide automatic transfer switch with SCADA connection for monitoring status.
5. The lift station will be equipped with a magnetic flow meter to measure flow leaving the lift station. The flow meter will be installed in a concrete vault with a double-leaf access hatch manufactured by BILCO or approved equal.
6. The lift station will be equipped with level monitoring and control using a radar type level transducer. The radar level transducer will utilize backup floats for hi and hi-low level alarming.
7. Pump discharge shall be below ground level and pass through a concrete valve vault where a check valve, an isolation valve, and air release valve will be installed for each pump discharge. The valve vault shall be equipped with removable aluminum checker plate with panel sections not exceeding fifty pounds in weight. Valve vault should also have ladders for accessibility.
8. The lift station shall be equipped with an emergency quick-connect assembly connected to the force main for bypass pumping. The size of the quick-connect assembly will be appropriate for the required rate of flow. The quick-connect assembly will include an isolation valve and check valve for use of a portable engine driven pump. The quick-connect assembly will be located at ground level on a concrete pad near the wetwell.
9. The lift station will be equipped with SCADA to monitor wetwell level, pump operation, flow meter, and security camera, with integration into the City's SCADA system at the wastewater treatment plant. Full automation PLC control box with manual pump control backup required.
10. Lift station with pumps weighing greater than 400 pounds shall be equipped with a fixed monorail and electric hoist for the installation and removal of the pumps.
11. Lift stations sized for a peak flow of 1000 GPM or greater shall be equipped with an odor control biofilter.

12. A minimum 15-foot-wide, 6-inch thick concrete access road to the lift station wetwell with hammerhead turnaround shall be provided meeting the city standards of road design. The lift station property will be fenced per TCEQ requirements with a masonry panel fence and provided with an electric gate for maintenance vehicle access.

B. Wetwell Design Criteria

1. The wetwell capacity shall be designed for buildout, wet weather flow conditions.
2. Wetwell storage capacity shall be sized for pumps to not exceed four starts per hour.
3. The wetwell shall be configured for submersible pumps.
4. The wetwell may be designed as a single wetwell chamber for peak flows of 250 GPM or less. (three pump configuration with redundant pump)
5. For design of peak flows greater than 250 GPM, the wetwell shall be equipped with two separate chambers of equal capacity such that one-half of the wetwell can be taken out of service for cleaning while the other half remains in service. A junction structure with electrically actuated slide gates is required to direct flow to each wetwell chamber.

C. Submersible Pumps

1. Submersible pumps shall be equipped with twin guide bars on a discharge connection.
2. Submersible pumps shall be Flygt N-Pump Series or approved equivalent.