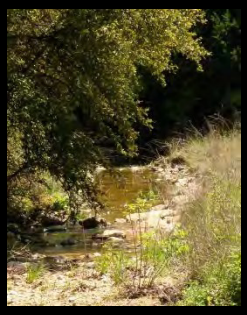
Storm Drainage Design Criteria Manual



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STORM DRAINAGE DESIGN CRITERIA
CITY OF BULVERDE, TEXAS

1. PURPOSE

The purpose of this manual is to provide the minimum standards to be used for the analysis and design of storm drainage systems for private development projects and City contracted projects within the City of Bulverde and its Extraterritorial Jurisdiction (ETJ). These standards apply both to new development as well as to improvements within existing developments. Design criteria and methods other than those described in these design standards shall be applied only after requesting and receiving approval from the Public Works Department. Development within Federal Emergency Management Agency (FEMA) designated floodplains shall comply with the requirements set forth in Chapter 9 of this manual and in the City of Bulverde Flood Damage Prevention Ordinance (Article 3.07). The Public Works Director for the City of Bulverde serves as the Floodplain Administrator for the City.

The design criteria presented in this manual are based on national engineering practice for stormwater management, modified to suit the needs of Bulverde, Texas. Depending on specific site conditions, the design of storm drainage systems may need to exceed the minimum standards presented here in order to provide adequate protection from flooding. Criteria not specifically detailed herein shall be determined in accordance with sound engineering practices with the City's approval.

This manual is written for use by engineers who are familiar with generally accepted hydrologic and hydraulic design practices. A detailed presentation of hydrologic and hydraulic design methods and procedures is not included, as this information is readily available through industry-accepted publications. This manual relies, in part, on methods and procedures published in several technical manuals, including the Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) *Urban Hydrology for Small Watersheds* dated June 1986, the Texas Commission on Environmental Quality (TCEQ) *Hydrologic and Hydraulic Guidelines for Dams in Texas* dated January 2007, the TCEQ *Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices* dated July 2005, the Texas Department of

Transportation (TxDOT) *Hydraulic Design Manual* dated October 2011, and the Federal Highway Administration (FHWA) Hydraulic Engineering Circular No. 22 (HEC-22) *Urban Drainage Design Manual* (Publication No. FHWA-NHI-01-021) dated September 2009.

The guidelines in this manual will be periodically updated to reflect changes in City practices. It is the responsibility of the user to determine that they are utilizing the most current version of this manual. The guidelines in this manual do not replace any applicable requirements by the Texas Commission on Environmental Quality (TCEQ). Additional processes and technology that may be approved and detailed by TCEQ in the future may be accepted by the City, with the approval of the City Department of Public Works.

Compliance with these standards does not relieve the applicant of the responsibility to use sound professional judgment. These standards are intended to assist, but not substitute for competent work by design professionals.

2. DRAINAGE REPORT SUBMITTAL REQUIREMENTS

In an effort to facilitate development while applying drainage rules, a tier system is established requiring different submittals depending on the probable impact on the drainage basin. In all cases, properly sized easements shall be granted across all contiguous property owned by the applicant; and a comprehensive Drainage Plan and Drainage Report shall be provided for all property on the subject plat whether developed by this application or not. Best Management Practices (BMPs) shall be exercised in the design process.

2.1. TIER 1 SUBMITTALS

A Tier 1 application will apply to any development or redevelopment meeting all of the following criteria.

- Total disturbance area of less than 1 acre.
- Total increase in impervious cover of less than 2,000 square feet.
- Not part of an overall project affecting 1 acre or more, or resulting in an increase in impervious area of 2,000 square feet or more.

Tier 1 Applications do not require a complete Stormwater Management Plan, but do require proof that the development is adequately protected from flooding. Submittals for a Tier 1 application shall incorporate the following:

- Provide a brief project summary including the location, description of the existing property and the proposed development.
- Show proof that the development adheres to the requirements set forth in Chapter 9 of this manual and in the City of Bulverde Flood Damage Prevention Ordinance.
- Provide an exhibit showing the site boundary, existing structures, proposed improvements, and temporary erosion control structures. Also show locations where runoff will leave the site during a rainstorm event. If applicable, show the 1 % Annual Chance (100-yr) floodplain on the site exhibit.

Upon review of a Tier 1 Submittal, the Director of Public Works may require a Tier 2 submittal if the proposed improvements are located in an area with known flooding problems, or if they are adjacent to a street or drainage structure with known flooding problems.

2.2. TIER 2 SUBMITTALS

A Tier 2 application is required for any development or redevelopment that does not qualify as a Tier 1 Application. Submittals for Tier 2 Applications require a complete Stormwater Management Plan completed and sealed by a licensed engineer, consisting of the following:

- Provide a brief project summary including the location, description of the existing property and the proposed development, a discussion of surrounding developments, and the proximity to floodplains.
- Provide a detailed figure for the existing site conditions and a detailed figure for the proposed site conditions that show site boundary, topographic contours, basin/sub-basin area boundaries, drainage structures, wetlands, sensitive area buffers and setbacks, easements, etc. State on each figure the total area and the amount of pervious and impervious area in each basin/subbasin area. Show flow paths with slope, flow type, surface type, and run length.
- Describe existing conditions including structures, drainage basins, flow paths, pervious/impervious areas, slopes, vegetation/land use, soil type, runoff curve numbers (CN), time of concentration and other runoff characteristics as well as upstream offsite flow contributions, downstream offsite capacity analysis, and existing drainage problems.
- Describe proposed developed conditions including, drainage basins, flow type and flow paths, pervious/impervious areas, slopes, vegetation/land use, CNs, time of concentration and other runoff characteristics as well as upstream offsite flow routing, detention or retention storage volume, release rates, overflow route capacity, and proposed storm drainage system.
- Describe applicable State or Federal regulations, design standards, design storm frequencies, as well as hydrologic and hydraulic methods of analysis.
- State runoff control design assumptions and describe method of analysis.

- Include a Stormwater Pollution Prevention Plan (SWPPP) to mitigate onsite erosion during construction. The SWPPP is required with the Final Plat submittal and should include the location of proposed best management practices (see Chapter 10 for details).
- Appendix: Provide any models, calculations, and figures necessary to support the proposed design, including basin characteristics, time of concentration, weighted Curve Numbers (CN), percent impervious area, runoff hydrograph generation, stage-discharge and stage-storage tables for detention routing, conveyance system capacity calculations, floodplain maps, applicable excerpts from previous reports, correspondence with adjacent property owners, utility companies, or regulatory agencies, or other information necessary to fully document the drainage plan.

Two copies of the Preliminary Drainage Report shall be submitted to the City of Bulverde for review. The City Public Works Department will return one copy with comments and suggested revisions to the applicant. The applicant shall revise the Stormwater Management Plan and submit two copies, one hard copy and one electronic copy in Word format, of the Final Drainage Report along with the Storm Drainage Construction Plans and Details for final review. Storm Drainage Construction Plans and Details shall also be submitted in electronic PDF format.

3. RAINFALL

3.1. MINOR AND MAJOR STORM EVENTS

The Minor Drainage System is designed to transport the runoff from storm events with recurrence intervals between 5-year and 25-year with a minimum of disruption to the urban environment. Minor storm drainage can be conveyed in the curb and gutter area of the street (subject to street classification and capacity as defined herein), a roadside ditch, by the underground storm drain, open channels, or other conveyance facilities.

The Major Drainage System is designed to convey runoff from the 100-year recurrence interval storm to minimize health and life hazards, damage to structures, and interruption to traffic and services. Major storm flows can be carried in the urban street system (within acceptable depth criteria), open channels, storm sewers, natural drainage ways, and other facilities.

Drainage planning and design shall include consideration for both the Minor and Major Drainage Systems.

Table 3.1
Design Storm Frequency by Facility Type

Facility Type	Design Storm Frequency (Recurrence Interval, Year)	
	Minor	Major
Open Channel (drainage area less than 100 acres)[+]	25	100
Open Channel (drainage area 100 acres or greater)	-	100
Storm Drain	5	100
Bridge	-	100
Culvert (Level A)	-	100
Culvert (Level B)	25	100
Culvert (Level C)	10	100
Culvert (Level D)	5	100

[+] Does not apply to bar ditches adjacent to rural street sections (see Section 5.1.3).

3.2. DESIGN STORM FREQUENCY

The design storm frequency for the Minor Storm varies depending on facility type, as shown in Table 3.1. Design criteria will differ between the Minor and Major Storm event for each facility type. Chapter 5 contains the design criteria for the separate facilities.

1.1. DESIGN STORM DEPTH AND INTENSITY

For drainage areas greater than 20 acres, the Snyder Synthetic Hydrograph Method for calculating runoff shall be used in accordance with Section 4.2 of this manual. Rainfall depths to be used with the Snyder Synthetic Hydrograph Method for the City of Bulverde, for durations from 5 minutes up to 24 hours, and for recurrence intervals from 1-year up to 500-year are provided in Table 3.2. This information was derived from the National Oceanic and Atmospheric Administration (NOAA) publication *Atlas 14, Volume 11 precipitation frequency estimates* (Atlas 14, Volume 11).

Table 3.2

Duration	Total Rainfall for Frequency (Inches)							
Minutes	**1-Year**	**2-Year**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**	**500-Year**
5 minute	0.45	0.53	0.66	0.78	0.94	1.06	1.19	1.52
15 minute	0.90	1.06	1.33	1.55	1.86	2.11	2.36	3.00
30 minute	1.27	1.50	1.87	2.17	2.60	2.93	3.27	4.19
1 hour	1.65	1.96	2.46	2.88	3.47	3.93	4.41	5.76
2 hour	1.98	2.42	3.09	3.69	4.57	5.28	6.07	8.26
3 hour	2.15	2.69	3.48	4.21	5.30	6.21	7.24	10.10
6 hour	2.46	3.16	4.15	5.09	6.54	7.80	9.23	13.26
12 hour	2.77	3.62	4.80	5.95	7.71	9.25	11.03	16.23
24 hour	3.12	4.12	5.51	6.86	8.93	10.75	12.87	19.14

For drainage areas less than 20 acres and having a lag time less than 20 minutes, the Rational Method for calculating runoff may be used in accordance with Section 4.3 of this manual. Rainfall intensities to be used with the Rational Method for the City of Bulverde, for durations from 5 minutes up to 20 minutes, and for recurrence intervals from 2-year up to 500-year are

provided in Table 3.3. This information was also obtained from Atlas 14, Volume 11 and converted to IDF tables by the Bexar Regional Watershed Management (BRWM) partners.

Table 3.3							
Duration	**Rainfall Intensity for Frequency (Inches/Hour)**						
Minutes	**2-Year**	**5-Year**	**10-Year**	**25-Year**	**50-Year**	**100-Year**	**500-Year**
5	6.34	7.96	9.31	11.22	12.72	14.26	18.19
6	5.98	7.53	8.81	10.64	12.06	13.53	17.14
7	5.70	7.17	8.40	10.16	11.52	12.91	16.30
8	5.45	6.87	8.05	9.74	11.04	12.37	15.58
9	5.24	6.61	7.73	9.36	10.60	11.88	14.95
10	5.05	6.36	7.44	9.00	10.20	11.43	14.38
11	4.87	6.13	7.17	8.66	9.82	11.00	13.85
12	4.70	5.92	6.91	8.34	9.46	10.59	13.35
13	4.54	5.71	6.67	8.03	9.11	10.19	12.88
14	4.39	5.51	6.43	7.73	8.77	9.81	12.43
15	4.24	5.32	6.20	7.44	8.44	9.43	11.99
16	4.10	5.14	5.99	7.18	8.14	9.10	11.57
17	3.98	4.98	5.80	6.95	7.88	8.80	11.20
18	3.86	4.84	5.63	6.75	7.64	8.53	10.86
19	3.76	4.71	5.47	6.56	7.42	8.29	10.56
20	3.66	4.58	5.33	6.39	7.22	8.07	10.28

3.4 PROBABLE MAXIMUM PRECIPITATION (PMP)

Detention and retention ponds meeting TCEQ dam criteria will be required to pass a certain percentage of the probable maximum flood (PMF). The PMF is the estimated runoff resulting from the probable maximum precipitation (PMP). PMP values for the Bulverde area can be found in the US Army Corps of Engineers *Hydrometeorological Report No. 51.*

4. RUNOFF

4.1. DRAINAGE BASIN AREA

The total area, including upstream offsite area, contributing to the point of interest shall be included in the delineation of drainage basins. Runoff from upstream undeveloped land, not part of the proposed project, shall be based on historic conditions assuming that detention storage will be provided if the upstream land is developed. Runoff from developed upstream land must be determined based on existing conditions or approved drainage plans.

Where appropriate, drainage basins tributary to existing streams can be based on the effective Digital Flood Insurance Rate Map (DFIRM) data for Comal County. The basin boundaries of the DFIRM may be modified as appropriate based on additional data and as approved by the City.

4.1.1 RIPARIAN BUFFERS

Riparian buffer zones shall be defined as 60 feet on either side of the centerline of any watercourse that drains greater than 25 acres. Follow requirements per Section 4.07 of the Bulverde Subdivision Ordinance. The SWMP shall call out these buffer zones and erosion control plans shall include BMP protection for these zones within the SWPPP.

4.2. SCS CURVE NUMBER METHOD

For drainage areas greater than 20 acres or with time of concentration calculations greater than 20 minutes, the SCS Curve Number Method shall be the method employed using the process detailed in the NRCS Technical Release 55 (TR-55) *Urban Hydrology for Small Watersheds*. The design storm duration shall be 24-hour for both the minor and major storm events.

4.2.1. Types

Use site-specific soils information for the project site when available, or the NRCS *Soil Survey of Comal and Hays Counties Texas* to identify the soils and corresponding hydrologic soil groups for drainage basins. This data is available through the NRCS website https://websoilsurvey.sc.egov.usda.gov.

4.2.2. Curve Numbers

Curve numbers (CNs) to be used shall be as set forth in Table 4.1.

Table 4.1
Runoff Curve Numbers for Urban Areas
(Average Watershed Condition, $I_a = 0.2\ S_R$)

Land Use Description		Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Undeveloped areas (pre-developed conditions)					
Open space (lawns, parks, golf courses, good grass cover)		39	61	74	80
Meadow (continuous grass, protected from grazing)		30	58	71	78
Brush (brush-weed-grass mixture w/brush the major element)		30	48	65	73
Woods		30	55	70	77
Fully developed urban areas (vegetation established)					
Lawns, open spaces, parks, golf courses, cemeteries, etc.					
Good condition; grass cover on 75% or more of the area		39	61	74	80
Fair condition; grass cover on 50 to 75% of the area		49	69	79	84
Poor condition, grass cover on 50% or less of the area		68	79	86	89
Paved parking lots, roofs, driveways, etc.		98	98	98	98
Streets and roads					
Paved with curbs and storm sewers		98	98	98	98
Gravel		76	85	89	91
Dirt		72	82	87	89
Paved with open ditches		83	89	92	93
	Average % impervious				
Commercial and business areas	85	89	92	94	95
Industrial districts	72	81	88	91	93
Row houses, town houses, and residential with lot sizes 1/8 acre or less	65	77	85	90	92
Residential: average lot size	Average % impervious				
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acre	12	46	65	77	82
Developing urban areas (no vegetation established)					
Newly graded area		77	86	91	94

4.2.3. Transform Method

The transform method to be used may be the Snyder Synthetic unit hydrograph (peaking coefficient of 0.71), or the SCS dimensionless unity hydrograph (Type III).

4.2.4. Lag Time

Either the Snyder lag time method or TR-55 methodology may be used to determine the time of concentration and /or lag time (typically 0.6*Tc).

The Snyder lag time (T_{lag}) is calculated using the following equation:

$$T_{lag} = C_t*(LL_{ca}/\sqrt{S})^N$$

Where: T_{lag} = Snyder lag time (hours)

C_t = basin lag coefficient (0.15)

L = the main stream distance from the outlet to the divide (miles)

L_{ca} = the main stream distance from the outlet to a point opposite the basin centroid (miles)

S = average watershed slope (ft/ft)

N = basin exponent coefficient (0.34)

The TR-55 methodology separates the movement of water through the drainage basin into the following three components:

1. Overland (sheet) flow - flow over plane surfaces
    a. Use Manning's kinematic solution (TR-55 Equation 3-3)
    b. Maximum length = 100 feet (Merkel 2001)
    c. Maximum time of 20 minutes
2. Shallow Concentrated Flow – assumed flow depths of 0.1 to 0.5 feet
    a. Use Manning's equation for defined swales and bar ditches
    b. Use Figure 3-1 from TR-55 where the geometric section is not defined
3. Channel Flow – based on bankfull elevation
    a. Existing computer model where available
    b. Manning's equation otherwise. Develop discharge based on bankfull elevation and calculate velocity based on channel geometry/slope.

4.3. RATIONAL METHOD

One of the most widely used equations for the calculation of peak runoff from small basins is the Rational Formula, given as follows:

$$Q = CIA$$

Where: Q = flow in cfs,

C = a dimensionless runoff coefficient,

I = rainfall intensity in inches per hour, and

A = drainage area in acres

The Rational Method shall be employed using the procedures detailed in Section 3.2.2 of the HEC-22 Manual.

4.3.1. Limitations

The Rational Method may be used with some specific limitations:

- Only for use in predicting conservative peak runoff rates to determine the required capacity for conveyance facilities.
- Drainage basin area (A) shall not exceed 20 acres.
- Time of Concentration minimum is 5 minutes, maximum is 20 minutes.
- Not to be used for determining storage requirements for detention or retention ponds.

4.3.2. Runoff Coefficients

Runoff Coefficients to be used shall be as set forth in Table 4.2.

Table 4.2				
	Runoff Coefficients			
Character of Surface	**Up to 1%**	**Over 1% & up to 3%**	**Over 3% & up to 5%**	**Over 5%**
Concrete paved or roof	0.97	0.97	0.97	0.97
Asphalt paved	0.95	0.95	0.96	0.97
Grassed areas - well maintained, greater than 75% covered	0.36	0.42	0.46	0.51
Grassed areas - fair condition, 50% to 75% covered	0.41	0.46	0.49	0.53
Grassed areas - poor condition, less than 50% covered	0.47	0.50	0.53	0.55
Cultivated Land	0.47	0.49	0.51	0 54
Pasture or Range Land	0.41	0.46	0.49	0.53
Forest or wooded Land	0.39	0.42	0.47	0.52
Low Density Development	0.50	0.54	0.58	0.60
Medium Density Development	0.55	0.57	0.62	0.64
High Density Development - less than 40% impervious	0.68	0.70	0.72	0.75
High Density Development - 40% to 60% impervious	0.75	0.77	0.80	0.84
High Density Development - greater than 60% impervious	0.85	0.88	0.91	0.97
Undeveloped Areas	0.39	0.42	0.47	0.52

4.4. COMPUTER MODELS

Acceptable storm drainage computer modeling packages are listed as follows: XPStorm™, StormCAD™, EPA SWMM, HYDRA (TR-20 & TR-55), and HEC-HMS.

The hydrologic results from computer models shall be verified through comparison to the results of other accepted methods including USGS Regional Regression Equations, the Snyder Unit Hydrograph Method, SCS Unit Hydrograph Method and/or the Rational Method. To the extent possible, the results shall also be verified against observed runoff during historic rainfall events in Bulverde to ensure reasonableness.

5. HYDRAULIC ANALYSIS AND DESIGN

5.1. STREETS

Streets are an integral part of the urban drainage system and may be used for transporting a limited amount of storm runoff. The primary purpose of streets however, is for traffic and the use of streets for storm runoff must therefore be restricted.

5.1.1. Urban Streets

The City allows the use of streets for drainage within the limitations specified in Tables 5.1 and 5.2. Section 2.04 of the Bulverde Subdivision Ordinance (Article 10.02) contains explanations of the street classifications.

Table 5.1
Allowable Use Of Urban Streets For Storm Runoff

Street Classification	Storm Collection Requirement
Local	Flow spread must leave at least one ten-foot lane free of water in a five-year storm. The 100-year storm must be contained within the street right-of-way with a maximum depth of one foot on street pavement.
Collectors	Flow spread must leave at least two ten-foot lanes free of water in a 5-year storm, and one twelve-foot lane free of water in a 100-year storm. Stormwater runoff will not be allowed to cross collector streets.
Thoroughfares	Flow spread must leave at least two ten-foot lanes free of water in each direction in a 10-year storm, and one ten-foot lane in each direction in a 100-year storm. The 100-year storm must be contained within at least one, ten-foot lane in each direction. Stormwater runoff will not be allowed to cross thoroughfares.

Gutter flow encroachment and hydraulics shall be evaluated using the methods presented in Chapter 10, Section 4 of the TxDOT *Hydraulic Design Manual*.

Gutters shall be constructed at slopes no flatter than 0.3 percent.

5.1.2. Inlet Spacing and Location

The interception capacity of inlets and required spacing shall be determined in accordance with the procedures described in Sections 4.3 and 4.4 of the HEC-22 Manual. Minimum design standards for storm inlets are as follows:

- In general, inlets shall be placed at the following locations:
  - Prior to pedestrian crossings
  - At all traffic intersections
  - At low points in the gutter grade
  - Where significant flows from off the right-of-way are expected
  - On horizontal curves where a change from normal crown to super-elevation may cause water to sheet-flow across the road
  - Where lay-down curb (e.g., at approaches) may allow the flow to escape and cause flooding
  - Where necessary to maintain street flow spread within the allowable limits set forth in Table 5.1.
- Inlet types – allowed storm inlet types include grated and combination (grated with curb opening or grated with curb opening plus slotted drain) inlets. Standard storm drain inlets should conform to the "Drainage Construction Structural Standards" from the City of San Antonio Standard Details for Construction. The standards can be found at the following location: http://www.sanantonio.gov/TCI/Current-Vendor-Resources/Standard-Specifications-and-Details#285914-drainage-standards
- Inlets in sag locations – inlet capacity in sump locations shall reflect 50 percent plugging by debris (design capacity equals 50 percent of the theoretical capacity).
- Lateral pipe connections – no more than two inlets shall be connected by each lateral pipe entering trunk line manholes.

5.1.3. Rural Streets

Drainage channels must be provided parallel to rural streets. Rural Streets shall conform to the following:

- Roadside channels shall be designed to carry the five-year storm with six inches of freeboard from pavement edge and to carry the 100-year storm within the street right-of-way and adjacent drainage easements.
- Rural collector streets shall be designed with one ten-foot lane open down the middle of the street during the 100-year storm.

5.1.4. Driveway Design

Section 3.10.069 of the City of Bulverde Flood Prevention Ordinance states that the grade of driveways shall be constructed as to conform to the slope of the roadway shoulder and not impede the natural flow of the drainage adjacent to the roadway. If swells or dip type driveways are used, the lowest point of the swell shall be a minimum of eight inches below the shoulder elevation and a swell of at least four feet in width maintained. Drives shall intersect the roadway at not less than 45 degrees. The permit holder is responsible for insuring positive drainage away from the road surface.

If a culvert is proposed under the driveway, the culvert shall be sized according to the following criteria:

- The inundation at the culvert inlet does not back flow onto adjacent properties.
- The drainage design criteria for the adjacent street must be maintained.
- The culvert drainage cannot be analyzed by normal depth only. All culverts must be analyzed using entrance and exit losses using one of the following methodologies:
  - The Federal Highway Administration (FHWA) *Hydraulic Design Series 5* (contained in the FHWA HY-8 software, as well as other design software).
  - Chapter 6 US Army Corps of Engineers HEC-RAS River Analysis System (when analyzed as part of a HEC-RAS model).
  - Other software as approved by the Director of Public Works.

5.2. STORM DRAIN

5.2.1. Hydraulics

Storm drains will be analyzed using the methods set forth in Chapter 7 of the HEC-22 Manual for the hydraulic design of storm drains, except as modified herein. The following is a list of acceptable modeling software:

- Hydroflow Hydrographs
- WinStorm
- StormCAD
- XPStorm
- Other software as approved by the Director of Public Works or City Engineer.

The Standard Hydraulics Form has been developed for the City of Bulverde for general use in storm drain analysis and design. This spreadsheet includes equations for the losses specified in the HEC-22 Manual. An example calculation has been included in Appendix B. An electronic copy of the spreadsheet can be obtained from the Public Works Department.

- Freeboard Requirements

  The following are freeboard requirements for underground storm drains.

  a) Underground storm drains shall be designed to flow by gravity carrying the 5-year storm and sized to contain the 5-year storm to the top of pipe.
  b) The design of underground storm drains shall be checked with 100-year storm flows and sizes increased as necessary to contain the 100-year storm to the top of manhole lid or inlet grate.

- Manning "n" values

  The Manning's "n" value used for the design of storm drains shall be as shown in Table 5.2.

Table 5.2 Manning's Coefficients (n) for Storm Drain Conduits	
Pipe Material	Manning's "n" Coefficient
Concrete pipe	0.013
Concrete Boxes	0.015
Polyvinyl chloride (PVC)	0.011

- Diameter, Slope, and Velocity Limits

  Minimum slopes for storm drain pipes shall be designed to maintain a full-flow velocity of at least 2.5 feet per second for the 5-year storm event. Maximum full-flow velocity shall be limited to 15 feet per second.

  Minimum diameter for storm drain main lines that will be part of the public storm drainage system shall be 18 inches. Pipe sizes shall normally increase in the downstream direction, and transitions from smaller pipes to larger pipes shall occur by matching the inside top (crown) of the pipes where practicable. Where flow lines are placed at the same level, the smaller pipe often must discharge against a head. It may not be feasible to follow this guideline in every instance, but it should be followed wherever practicable.

- Maintenance Access

  All stormwater facilities shall be accessible for operation and maintenance. When vehicle access is necessary, for facilities constructed outside of the street section, access roads shall be provided in dedicated access easements. The minimum clear driving lane width is 12 feet. Access roads shall have a maximum grade of nine percent and shall be constructed with gravel surfacing.

  Gates and/or bollards are required when necessary to restrict access to stormwater facilities. Cables and/or chains stretched across access roads are not acceptable.

5.2.2. Materials

Reinforced concrete pipe (RCP) or SDR-35 Polyvinyl Chloride (PVC) shall be used for public storm drain systems. A minimum of Class-II RCP shall be used for storm drain main lines. HDPE pipe or Corrugated Metal Pipe (CMP) may be used for storm drains on private property.

The minimum cover depends upon the pipe size, material type and class, and soil bedding condition, but shall not be less than 18 inches for RCP and 24 inches for PVC or HDPE at any point along the pipe. Where the minimum cover criteria cannot be achieved, the designer shall provide documentation that the proposed installation can withstand the design loading condition.

Pipe wall strengths and coatings shall be suitable for the soil conditions, design depths, and trench details. Pipe strength shall be designed assuming HS-20 live load capacity unless unique conditions of the site warrant a higher load capacity (i.e., HS-25 or E-80).

A typical design strength calculation shall be submitted using pre-approved software (SAMMM or Pipe Pac). Supporting documentation shall include pipe strength calculations, loading conditions, soil conditions, trench cross sections, bedding materials and any other information necessary to determine the suitability of the proposed design.

Corrosion, abrasion and other appropriate observations of field conditions shall also be considered in determining appropriate pipe materials and joint types. Corrosion resistance shall be evaluated based on minimum resistivity, pH, sulfate content and chlorine content of the soil and groundwater. Tests shall be conducted along the proposed alignment of the drainage system.

Storm drains within the City of Bulverde shall be constructed in accordance with TxDOT Standard Specifications.

5.2.3. Access Manholes

- General

Access manholes are required when joining pipes of different sizes, at horizontal or vertical bends in the alignment, at lateral connections, and at the upstream terminus of storm drain mains. Standard manhole details should conform to the "Drainage Construction Structural Standards" from the City of San Antonio Standard Details for Construction, except that the lid diameter shall be 36-inches. The standards can be found at the following location:

http://www.sanantonio.gov/TCI/Current-Vendor-Resources/Standard-Specifications-and-Details#285914-drainage-standards

- Required Size

  Larger manhole diameters or a junction box may be required when storm drain alignments are not straight through or when lateral pipes enter the manhole. The number and size of pipes that may be connected to any one manhole is limited in order to maintain the integrity of the structure. For structural integrity, minimum undisturbed wall (edge of pipe opening to edge of pipe opening) shall be 8 inches. Each manhole shall contract to fit a standard, 36-inch manhole lid.

- Required Spacing

  The maximum manhole spacing along storm drains is as set forth in Table 5.3.

Table 5.3
Maximum Allowable Manhole Spacing

Storm Drain Diameter	Maximum Spacing
18" to 24"	300'
30" to 36"	375'
42" to 54"	450'
60" and Larger	900'

- Maximum manhole depth – manhole depths shall not exceed 20 feet without special safety provisions such as intermediate platforms and minimum diameter risers of 48 inches.

- Drop manholes – the difference between the highest pipe invert entering a manhole and the invert leaving shall not exceed 24 inches. Manholes exceeding 24 inches of fall shall be designed as drop manholes. Drop manholes with drop heights exceeding six feet require structural design.

5.2.4. Clearance from Other Utilities

The following clearances shall be maintained between storm drains and other utilities. If minimum clearance cannot be obtained, then concrete encasement shall be used as an alternative to minimum clearance. All clearances listed below are from edge-to-edge of each pipe.

- Horizontal clearances from storm main:

Cable TV	5 feet
Gas	5 feet
Power	5 feet
Sewer	5 feet
Telephone, Fiber Optics	5 feet
Water	10 feet

- Vertical clearances from storm main:

Cable TV	1 feet
Gas	1 feet
Power	1 feet
Sewer	1 feet
Telephone, Fiber Optics	1 feet
Water	1.5 feet

- Where storm sewer pipes cross over or below a water main, one full length of pipe shall be used, with the pipes centered for maximum joint separation.

Avoid crossing other utilities at highly acute angles. Whenever possible, the angle measure between utilities shall be between 45 and 90 degrees.

5.2.5. Private Drainage System Connections

Private drainage systems connections to the public storm drain system shall be approved by the City of Bulverde and shall comply with the following criteria.

- Connections from stormwater outfalls from private parking lots, driveways, and roadway drainage shall be made by the following (in order of preference):
  - Connecting the conveyance pipeline to an existing manhole or catch basin; or
  - Constructing a new manhole or catch basin on the existing storm drain pipeline and connecting the conveyance pipeline to this new structure.

5.2.6. Outfalls

- General

  Use the methods set forth in Chapter 7.1.5 of the HEC-22 Manual as modified herein.

  Outfalls shall discharge no lower than the bank-full water surface elevation (2-yr storm) in open channels or streams, where practicable.

  Outfalls downstream of detention facilities shall be designed to prevent backwater into those facilities.

- Erosion Protection and Energy Dissipation

  When flow velocities exceed 5 feet-per-second at the outfall point, during the Minor Storm (when the outfall conduit is running at design capacity), energy dissipation, in addition to erosion protection may be required to minimize erosion. Design energy dissipation measures in accordance with FHWA HEC-14, *Hydraulic Design of Energy Dissipaters for Culverts and Channels*. This manual is available as a PDF document from the FHWA Website:

  https://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf

- Maintenance Access

  Provide maintenance access for inspection and debris removal at all outfalls

5.3. OPEN CHANNEL CONVEYANCES

5.3.1. General

Use the methods in Chapter 5 of the HEC-22 Manual except as modified herein. The following is a list of acceptable modeling software:

- Flowmaster (only where backwater is not an issue)
- HEC-RAS
- XPStorm
- Other models as approved by the City

5.3.2. Clearance

Channels shall be located no closer than ten feet from any structure foundation as measured horizontally from the edge of the channel at the freeboard elevation. The maximum water surface elevation during the 100-year storm event shall be no less than two feet below the finished floor elevation of adjacent residential dwellings and public, commercial, and industrial buildings. The 2-foot requirement does not apply to "storage only" structures that meet all requirements specified in the City of Bulverde Flood Damage Prevention Ordinance.

5.3.3. Erosion Control

Use the criteria set forth in Section 5.1.7 of the HEC-22 Manual for stable channel design. Erosion control shall be used to protect all riparian buffers in addition to offsite project areas.

Erosion control structures, such as check drops or check dams, may be required to control flow velocities. However, Natural Channel Design procedures as described in the National Engineering Handbook Part 654 Chapter 11 are recommended to provide a stable channel design and reduce erosion.

5.3.4. Freeboard Requirements

Channels shall be designed with the following freeboard requirements:

- Channels with a drainage area less than 100 acres: 25-year peak runoff with two feet of freeboard and containing 100-year peak runoff within easement or right-of-way

- Channels with a drainage area 100 acres or larger: 100-year peak runoff with one foot of freeboard

5.3.5. Low-Flow Channels

Low flow channels shall be included in the channel cross section to carry sustained low flows and frequent storm events in a confined sub-section of proposed channels. The low flow channel shall be based on bankfull flows, as detailed in the National Engineering Handbook Part 654 Chapter 11.

5.3.6. Friction Factors (n)

Use Manning's roughness factors (n) set forth in the Table 5.4 (below). The design shall consider the channel roughness both immediately after construction and when vegetation is well established. Roughness factors (n), which are representative of unmaintained channel conditions, shall be used for the analysis of water surface profiles. Roughness factors (n), which are representative of maintained channel conditions, shall be used to determine velocity limitations.

Table 5.4
Manning's Coefficients (n) for Open Channels

Type of Channel and Description	Manning's "n" Coefficient
Concrete-lined	0.015
Grass-lined channels (maintained)	0.035
Grass-lined channels (unmaintained)	0.055
Rock Rubble Riprap (6-inch)	0.035
Rock Rubble Riprap (12-inch)	0.040
Rock Rubble Riprap (12-inch)	0.042
Natural Channel with Trees, Little or no Underbrush	0.055
Natural Channel with Trees, Moderate Underbrush	0.075
Natural Channel with Trees, Dense Underbrush	0.090
Natural Channel with Dense Trees, Dense Underbrush	0.100

5.3.7. Slopes

Side slopes shall be no steeper than 4:1 for publicly maintained channels. For privately maintained channels, a 4:1 slope is suggested; however, a 3:1 slope is allowed.

5.3.8. Maintenance Access

Provide maintenance access for inspection, mowing operations, and debris removal by conventional equipment along the length of the conveyance channel. The type of equipment needing access is dependent on the size of the channel. Large channels will need access for dump trucks and loaders. For small ditches, foot or pick-up truck access may suffice. Access easements for earth channels shall extend a minimum of two feet on one side and fifteen (15) feet for an access road on the opposite side of the extreme limits of the channels when such channels do not parallel and adjoin an alley or roadway. When such channels do parallel and adjoin an alley or roadway, the easement shall extend a minimum of two feet on both sides of the extreme limits of the channel. This distance will provide an access way along the channel with a maximum cross slope of ½ inch per foot toward the channel.

5.4. BRIDGES

Hydraulic sizing for bridges within TxDOT right-of-way shall conform to the requirements of the TxDOT *Hydraulic Design Manual,* and must be submitted to TxDOT for review and approval. Bridges outside of TxDOT jurisdiction shall conform to the requirements detailed in this section. Proposed bridges within Jurisdictional Waters of the U.S. will be required to comply with Section 404 permitting from the U.S. Army Corp of Engineers.

5.4.1. Freeboard Requirements

The water surface elevation during the 100-year storm event shall be a least one foot below the lowest bridge girder, where practicable, to allow for the passage of floating debris.

5.4.2. Allowable Rise

The water surface elevation during the Major Storm event upstream of bridges shall not increase due to channel constrictions and hydraulic losses caused by the bridge.

5.4.3. Scour

Estimates of local and long term scour shall be calculated according to methods detailed in Chapter 9, Section 6 of the TxDOT *Hydraulic Design Manual* to determine the required abutment protection and establish the required depth of the bridge support structures.

5.5. CULVERTS

Culverts are used to convey irrigation ditches and natural drainage-ways under City Streets and other travel ways. Culverts shall be designed using the methods set forth in the Federal Highway Administration (FHWA) Hydraulic Design Series No. 5 (HDS-5), *Hydraulic Design of Highway Culverts*, Publication No. FHWA-NHI-01-020 except as modified herein. HDS-5 is available as a PDF document from the FHWA Website:

https://www.fhwa.dot.gov/engineering/hydraulics/pubs/12026/hif12026.pdf

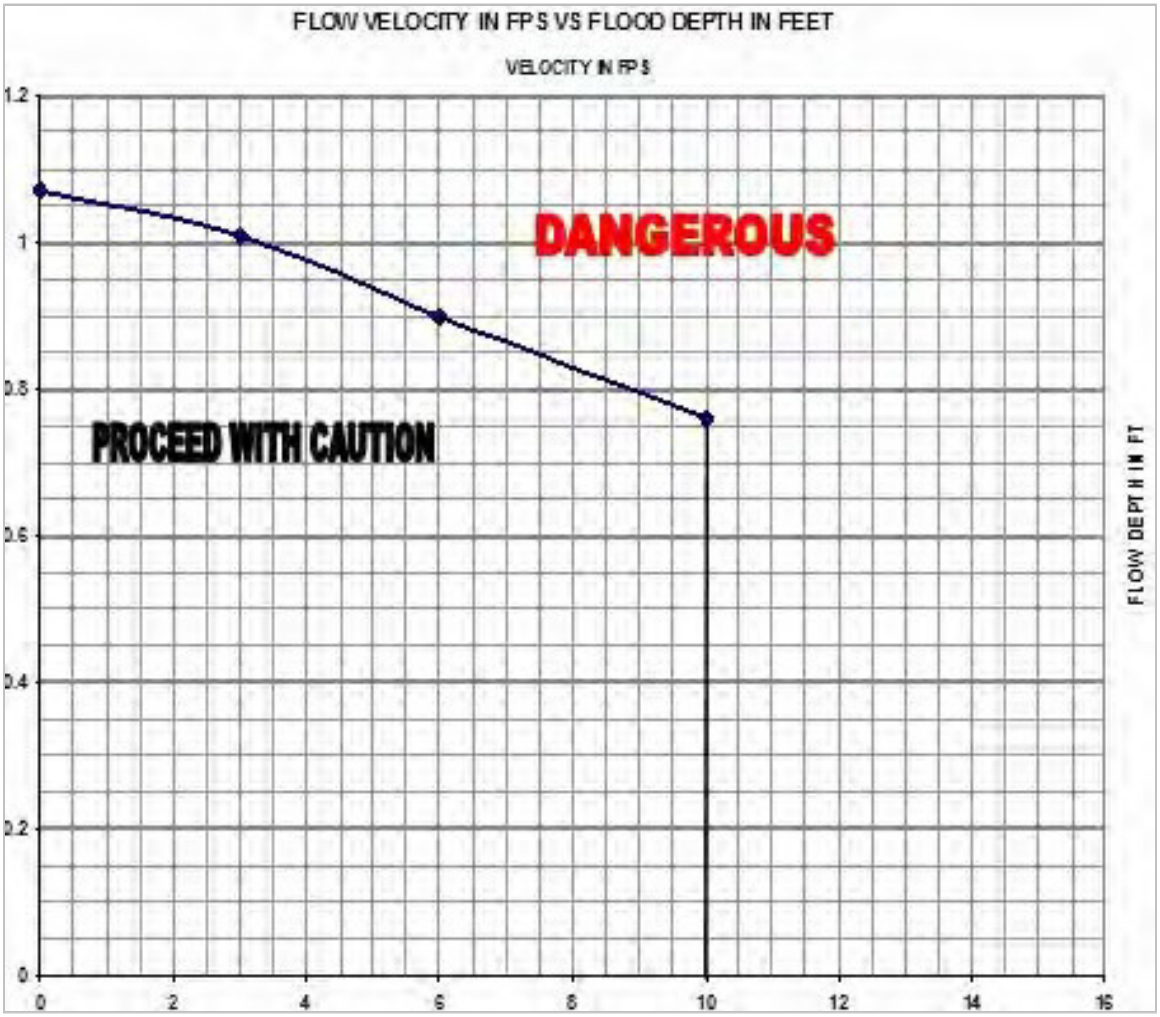
5.5.1. Street overtopping

Culverts shall be sized such that the depth of street overtopping is limited as set forth in Table 5.5.

Table 5.5
Culvert Sizing By Level

Culvert Type	Description	Minor Storm Design	100-Year Design
Level A	Thoroughfares, Collector Streets, Primary Access	-	No Overtopping
Level B	Local Streets with drainage areas greater than ½ sq. mi.	25-year design storm with maximum headwater depth as described in Section 5.5.2	Dangerous conditions no more than 15 minutes
Level C	Local Streets with drainage areas between 100 acres and ½ sq. mi.	10-year design storm with maximum headwater depth as described in Section 5.5.2	Dangerous conditions no more than 25 minutes
Level D	Local Streets with drainage areas less than 100 acres.	5-year design storm with maximum headwater depth as described in Section 5.5.2	Dangerous conditions no more than 30 minutes

Dangerous conditions for overtopping will be determined using the following chart:



5.5.2. Headwater depth

The headwater (HW) depth shall be limited according to the following ratios to diameter (D):

- For drainage facilities with a cross sectional area less than or equal to 30 square feet: HW/D ≤ 1.5
- For drainage facilities with a cross sectional area greater than 30 square feet: HW/D ≤ 1.2

Culverts must also be sized without creating significant flow constriction, such that existing channels upstream are not overtopped during the design flow event.

5.5.3. Allowable Velocities

Culverts shall be designed to maintain a minimum velocity of 2.5 feet-per-second during the design storm event to prevent sediment accumulation and shall be designed with a minimum slope of 0.5 percent where practicable.

Culverts shall be sized to limit velocities in order to minimize erosion potential during major storm events unless adequate erosion control or energy dissipation is provided.

5.5.4. Minimum size

Culverts shall have a minimum diameter or height of 18 inches unless a smaller size is approved by the City of Bulverde.

5.5.5. Materials

A minimum of Class-II reinforced concrete pipe (RCP) or SDR-35 Polyvinyl chloride (PVC) shall be used for culverts under public streets. Polyvinyl chloride (PVC), RCP, or Corrugated Metal Pipe (CMP) may be used in culverts under private driveways.

Culvert wall strengths and coatings shall be suitable for the soil conditions, design depths, and trench details. Culvert strength shall be designed assuming HS-20 live load capacity unless unique conditions of the crossing warrant a higher load capacity (i.e., HS-25 or E-80).

When an abrasive bed load is anticipated or when velocities exceed 10 feet per second, protective measures shall be implemented to limit pipe damage. Corrosion, abrasion and other appropriate observations of field conditions shall also be considered in determining appropriate culvert materials and joint types. Corrosion resistance shall be evaluated based on minimum resistivity, pH, sulfate content and chlorine content of the soil and groundwater.

5.5.6. End Treatments

Culverts shall be designed with appropriate end treatments at their inlets and outlets such as flared end sections, headwalls, or wing walls to provide smooth transitions to/from the drainage channel or ditch and to conform to the embankment slopes. Erosion protection or energy dissipaters shall be provided as necessary to limit erosion due to turbulent flow and high velocities.

For exit velocities in excess of 5 feet-per-second during the 100-year storm, energy dissipation, in addition to erosion protection may be required to minimize erosion. Design energy dissipation measures in accordance with FHWA HEC-14, *Hydraulic Design of Energy Dissipaters for Culverts and Channels*. This manual is available as a PDF document from the FHWA Website:

https://www.fhwa.dot.gov/engineering/hydraulics/pubs/06086/hec14.pdf

5.5.7. Safety Racks

Safety racks are generally needed on culverts if one cannot see clearly through the culvert, if the culvert is more than 150 feet long, if a 48-inch diameter object cannot pass through or if the outlet may trap or injure a person being carried through. The open area of safety racks shall be at least four times the open area of the culvert. Safety racks shall be constructed of smooth steel pipe, with a corrosion protection finish and capable of withstanding the full hydraulic load when completely blocked under maximum submergence. Bar clear spacing shall not exceed six inches and bars shall be generally perpendicular to flow. The longitudinal slope of the safety rack shall not exceed 3.0 H to 1.0 V. There shall be a minimum clear area under the front edge of 9 to 12 inches. Safety racks shall be attached by removable devices such as bolts or hinges to allow access for maintenance, prevent undesirable access and prevent vandalism. Safety racks shall only be installed at inlets to culverts. Safety racks at outlets to culverts can create safety issues and trap debris reducing capacity and causing maintenance problems. The rack must not cause water to rise higher than the maximum allowable flood elevation.

5.5.8. Maintenance Access

Provide maintenance access to the upstream and downstream ends of culverts for inspection and debris removal.

6. OFF-SITE DISCHARGE

Proposed development shall be responsible for mitigating the impact of increased impervious cover on drainage facilities on property upstream and downstream of the subdivision. Mitigation measures shall be based on 2-year, 5-year, 10-year, 25-year and 100-year storms. Mitigation measures shall be designed in accordance with the criteria herein and sealed by a Professional Engineer.

7. DETENTION AND RETENTION FACILITIES

On-site detention shall be provided for runoff control from new development, expansion, and redevelopment. Detention facilities shall be designed to limit the runoff from the site to pre-development rates for the full range of potential storms including the 2-year, 5-year, 10-year, 25-year, and 100-year events. All detention structures shall be designed in accordance with the requirements herein and sealed by a Professional Engineer.

Retention facilities are used to fully retain the site runoff volume where no viable outfall exists. Retained runoff is then evacuated through infiltration and evaporation. Retention facilities shall be designed to store the post-development site runoff from the 100-year, 24-hour storm. The water surface in the retention facility shall return to the pre-storm level within 72-hours after cessation of the 100-year storm, 24-hour storm.

Design criteria for detention and retention facilities shall be as detailed in Chapter 8 of the HEC-22 Manual as modified herein.

Detention or retention storage is not required if the total area to be developed or redeveloped results is less than 2,000 square feet of additional or new impervious area.

Street and parking overlays are considered to be routine maintenance and are not considered to be redevelopment.

The 100-year water surface elevation in the storage areas shall be at least two feet below the lowest finished floor elevation in the areas tributary to the stormwater detention or retention facility. Detention storage in parking lots shall have a maximum depth of 5 inches. Rooftop detention shall be allowed only if part of a properly design green roof (with waterproof membrane, adequate structural design, etc.).

7.1. SAFETY

Fencing shall be required when vertical walls are used or when more than 25 percent of the perimeter side slopes are steeper than 3 H: 1V.

7.2. MULTI-PURPOSE USE

Detention facilities designed for multi-purpose use (sport courts, neighborhood parks, play areas, picnic areas, etc.) are allowed.

Runoff from more frequent storms shall be stored separately from the multiple use areas. At a minimum, the detained volume for the 2-year, 24-hour design storm shall be used to size the separate facilities.

Multi-use amenities shall be anchored to prevent floatation. The developer shall make arrangement for maintenance of such amenities unless such responsibility is accepted by the City of Bulverde.

7.3. WATER QUALITY TREATMENT

Developers are encouraged to design detention ponds to serve the incidental benefit of water quality treatment as required by TCEQ for the Edwards Aquifer contributing and recharge zones. Water quality treatment guidelines can be found in TCEQ's *Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices.*

Sediment accumulation should be taken into account in detention design. All detention ponds shall have 20 percent more volume than the calculated required volume for detention to account for sediment accumulations. This additional volume may be reduced by a detailed sediment analysis approved by the City Public Works Department. If other potential pollutants such as oils, grease, or fuel (gasoline and diesel) could be present in the site runoff, it may also be necessary to provide measures to remove these contaminants.

Developer shall include approved permit from TCEQ for water quality treatment prior to acceptance of Final Plat.

7.4. LOW-FLOW CHANNELS

Dry detention ponds shall be constructed with Low-flow channels that have a capacity of 1 to 3 percent of the peak 100-year design storm inflow and a minimum slope of 0.5 percent. Pond bottoms shall be sloped at a 1 percent minimum grade towards the low-flow channel to facilitate drainage.

7.5. OUTLET CONTROL STRUCTURES

- General

  Use the criteria and methods set forth in Chapter 8 of the HEC-22 Manual except as modified herein.

- Orifices

  Minimum orifice diameter without screening is six inches. Screening shall be provided to prevent blockage for orifices of smaller diameter.

- Provide debris barriers or trash racks on the detention pond outlet to protect the outlet from blockage or plugging. Regular removal of floatables shall be considered in the maintenance plan for detention ponds servicing commercial sites.

- Maintenance Access

  All stormwater detention system outlet control structures shall be accessible for maintenance and operation.

  Outlet control structures, which are not abutting a roadway, shall be provided with easements at least 15 feet wide to accommodate maintenance vehicles. The minimum clear driving width shall be 12 feet and the minimum turn-around radius shall be 25 feet or hammerhead. The maximum grade of access roads shall be nine percent and gravel surfacing shall be provided.

  Gates and/or removable bollards are required to restrict access, as necessary, to detention or retention facilities.

7.6. EMBANKMENTS

The maximum embankment height is measured from the downslope toe to the crest of the embankment. Embankments six feet and higher shall be designed and inspected by a

licensed civil/geotechnical engineer with expertise in embankment design and shall follow TCEQ design requirements as outlined in the *Design and Construction Guidelines for Dams in Texas*.

TCEQ regulations may be updated or revised periodically. It is the responsibility of the owner and the designer to comply with all State requirements for design and permitting.

7.7. OUTLET CONDUITS

The minimum diameter for outlet conduits shall be 18 inches. Anti-seep collars shall be placed on all outlet conduits through embankments.

7.8. SET BACKS

- Detention or Retention ponds shall not be located:
  - within 1: 1 plane from the pond bottom to the finished grade at an adjacent building;
  - within the 1: 1 plane from the pond bottom to the property line when an easement is not provided on the adjacent property; and
  - where such facilities interfere with other underground utilities,

The top of a cut embankment and the toe of a fill embankment shall be setback at least 5 feet from property lines.

7.9. EMERGENCY OVERFLOW & SPILLWAYS

Use the criteria set forth in Chapter 8.4.4.4 of the HEC-22 Manual as modified herein. All detention storage facilities shall include a provision for non-erosive control of overflows. Overflows from the Major Storm event shall be directed to a safe discharge path to protect adjacent and downstream properties from damage.

Surface detention ponds shall be provided with a minimum of two controlled overflows - the primary overflow in the control structure and the emergency overflow in the engineered embankment.

7.10. VEGETATION & LANDSCAPING

Ponds shall be landscaped to provide for slope stability, erosion control, and low maintenance. Landscape materials shall be fully compatible with use as a stormwater detention facility, including runoff treatment. Utilize plant species native to the Bulverde area to the maximum extent practicable.

Floatable or erodible material (i.e., wood chips, beauty bark, straw mulch, etc.) shall not be allowed in the pond interiors unless multi-use facilities are designed with park amenities

Vegetation on pond embankments shall be limited to shallow rooted varieties.

Points of inflow to the pond shall be armored to prevent erosion.

7.11. MAINTENANCE ACCESS

A vehicle access ramp shall be provided to the bottom of the detention or retention pond when the bottom width is 15 feet or greater and/or when the height of the interior pond embankment and/or wall is greater than four feet. The grade of the access ramp shall be no steeper than 20 percent.

Gates and/or removable bollards are required to restrict access to detention or retention facilities. Cables and chains stretched across access roads are not acceptable.

7.12. UNDERGROUND DETENTION FACILITIES

Underground detention facilities shall be designed with consideration given to the environmental sensitivity of the Edwards Aquifer. Underground detention shall not be designed to infiltrate stormwater. Impermeable liners shall be provided where necessary to prevent the infiltration of stormwater. Impermeable liners approved by TCEQ can be found in the *Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices* (TCEQ, 2005), which may be downloaded as a PDF document from the following website:

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg348/rg-348.pdf

8. EASEMENT REQUIREMENTS

Easements shall be located to provide access to the utilities within the easement by the lots adjacent to the easement. Easements shall be parallel to streets when possible. Easements shall be widened when necessary to allow for service vehicle access and cornering within the easement. No easement shall be longer than 1,000 feet in length without access to a street. Drainage facilities that are constructed to serve predominantly public property or public right-of-way shall be publicly owned and shall be dedicated to the City.

The access easement conditions shall prohibit the property owner from installing any landscaping, improvements, retaining walls, etc., which would hinder access to the drainage facility or necessitate restoration of access easement area.

8.1. EASEMENT WIDTH REQUIREMENTS

The required utility easement width within public right-of-way shall be as follows:

Channels: Easements for drainage channels, swales, and ditches shall have a width as specified in the following table unless the City determines that terrain, size and depth of adjacent utilities, or access requires a wider easement.

Easement Contains:	Minimum width:
Channel less than four feet deep and less than 20 feet wide	Channel width plus two feet on both sides.
Channel four feet deep or greater, or 20 feet wide or greater	Channel width plus two feet on one side and 15 feet on the other side.
Channel with adjacent utilities on one side	Channel width plus two feet on side opposite utilities and 20 feet on side with utilities.

Storm Sewers: Easement for underground storm sewer facilities shall have a minimum width equal to 20 feet or as calculated by the following, whichever is greater:

$$W = 16 + 2H + D$$

Where:

W = easement width,
H = depth of soil cover over pipe or box,
D = diameter or width of pipe or box, respectively.

8.2. EASEMENT DOCUMENTATION REQUIREMENTS

All easements shall be shown on the project plans and shall be designated "exclusively for storm drainage use".

All utility easements shall be properly executed. Easement documents shall include a map, property legal description, and owners' names.

Easements shall be dedicated to, and approved by, the City prior to acceptance of a public drainage system and shall be filed along with the Plat with Comal County. Grantee shall be the "the City of Bulverde, a municipal corporation, its heirs, successors, or assignees."

Indemnification and hold-harmless agreements to hold the City harmless shall be included in recorded documents where maintenance access across private property and /or pumping of storm drainage is deemed necessary by the City.

Transfer of ownership for all drainage facilities appurtenant to public easements shall be given to the City with the executed real property documents that transfer property rights to the City. Grantor shall pay all title policy and recording fees necessary to transfer rights to the City.

9. FLOODPLAINS

Development activity within floodplains shall be restricted in accordance with the City of Bulverde Flood Damage Prevention Ordinance (Article 3.07). Areas denoted as a Special Flood Hazard Area (SFHA) on the FEMA Flood Insurance Rate Maps shall be dedicated as easements or rights-of-way. The subdivider shall obtain US Army Corps of Engineers Section 404 and/or Section 10 permits for all construction within US waters.

FEMA designated floodplains should be maintained in natural condition whenever feasible. Flood storage must be maintained to prevent downstream or upstream impacts. Volume lost within FEMA designated floodplains due to fill activities must be offset by compensating excavation.

In areas where the City has a detailed hydrologic and hydraulic study (Developer shall check with City staff prior to submitting Stormwater Management Plan) or in areas designated as FEMA Flood Zone AE, the water surface elevations based on the FIS or detailed study shall be shown on the plat based on surveyed topography.

10. EROSION AND SEDIMENT CONTROL

The objective of the Erosion and Sediment Control Standards is to minimize erosion of disturbed areas during the construction of a project. Erosion and subsequent sediment transport can have a significant impact on the water quality of receiving surface waters. Sediment loads to surface waters increase turbidity, increase water temperatures, degrade fish habitat and spawning areas, and depress dissolved oxygen concentrations. Moreover, toxic substances, trace metals and nutrients which are absorbed to soil particles can be transported into surface waters as well. The addition of these substances to surface waters degrades the existing water quality.

The Best Management Practices include the management, techniques, and methods for control of accelerated erosion and sediment damage resulting from construction activities that result in a land disturbance that demonstrates an increase of pollutants in stormwater discharges off site.

10.1. PURPOSE

It is the purpose of these Standards to enact a comprehensive and coordinated erosion and sediment control program for the conservation and protection of land, water, and other resources of the City of Bulverde and thereby

- Encourage the use of land in accordance with its capabilities and treat it according to its needs;
- Prevent degradation of lands, streams, reservoirs, and lakes;
- Protect and promote the health, safety, and general welfare of the people.

10.2. EMERGENCY LAND MANAGEMENT PRACTICES

No prior notification is required for emergency land management practices necessitated by and initiated during or immediately after fire, flood, windstorm, earthquake, structural failure or other catastrophic events. Within five days after commencement of such activity, the land occupier shall notify the City Engineer of the action, with an explanation of why emergency action was

necessary. Reasonable care must be taken to minimize soil disturbance and erosion during the conduct of emergency land management practices.

10.3. COMPLAINTS

Land occupiers and City and County officials responsible for the maintenance of water quality may file a complaint against any person alleging that accelerated erosion or sediment damage has occurred or is occurring.

The complaint shall:

- include the name and address of the complainant;
- be in writing, signed, notarized, and delivered to the City Public Works Department;
- include the date and location of the alleged violation; and
- describe the source, nature and extent of the accelerated erosion or sediment damage alleged to have occurred or which is occurring.

The complaint shall become public record on file at the City Public Works Department.

The City shall, at the earliest possible date, discuss alternative solutions with the contractor or owner of the development to achieve an acceptable solution.

10.4. LIABILITY

Neither the approval of a plan or any other action of the City of Bulverde under the provisions of these Standards, shall relieve any person from the responsibility for damage to any person or property otherwise imposed by law, nor impose any liability upon the City of Bulverde for damage to any person or property.

10.5. BEST MANAGEMENT PRACTICES

Refer to *Complying with the Edwards Aquifer Rules: Technical Guidance on Best Management Practices* by TCEQ and any subsequent addenda for guidance on the selection and implementation of Erosion and Sediment Control measures. This reference provides specific

guidance and design details on accepted BMPs to reduce erosion and sediment during construction activities and is available as a PDF document from the following website:

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg348/rg-348.pdf

Erosion control BMPs should be selected based on terrain, soil type, and the type of proposed construction activity. In addition to implementing adequate erosion control BMPs, no development shall occur within areas with a slope exceeding 15 percent over an area larger than 0.5 acres unless approved by the Director of Public Works. The removal of natural vegetation and alteration of soil cohesion can significantly jeopardize slope stability within these areas.

Construction Site BMPs inspection checklists are provided in Appendix A and should be used as directed in Section 10.9.

10.6. MINIMUM REQUIREMENTS DURING LAND DISTURBING ACTIVITY

Land-disturbing activities shall require as a minimum that:

- Stripping of vegetation, regrading and other development activities shall be conducted in such a manner so as to minimize erosion. No clearing or stripping may occur without installation of SWPPP BMPs and approved permit from TCEQ.
- Cut and fill operations must be kept to a minimum.
- Development plans must conform to topography and soil type so as to create the lowest practical erosion potential.
- Whenever feasible, natural vegetation shall be retained, protected, and supplemented.
- The disturbed area and the duration of exposure to erosive elements shall be kept to a practicable minimum.
- Disturbed soil shall be stabilized as quickly as practicable.
- Temporary vegetation or mulching shall be employed to protect exposed critical areas during development.
- Permanent vegetation and structural erosion control measures must be installed as soon as practicable.

- To the extent necessary, sediment in run-off water must be trapped by the use of sediment basins, sediment traps, or similar measures until the disturbed area is stabilized.
- Adequate provisions must be provided to minimize damage from surface water to the cut face of excavations or the sloping surfaces of fills.
- Cuts and fills may not endanger adjoining property.
- Developments shall not disturb more than that percentage of the surface area indicated in Section 4.04 of the Bulverde Subdivision Ordinance.
- Cuts and fills associated with the preparation of land for development of lots and public improvements may not exceed four (4) feet in depth, with exceptions as described in Section 4.05 of the Bulverde Subdivision Ordinance.
- Fills may not encroach upon natural water courses or constructed channels in a manner so as to adversely affect the conveyance capacity of the channel or other property owners.
- Construction equipment must cross flowing streams by means of bridges or culverts except when such methods are not feasible and provided, in any case, that such crossings are kept to a minimum.
- The contractor must maintain a sweeper on site during earthwork and immediately remove soil that has been tracked onto paved areas as a result of construction.
- Visible or measurable erosion which leaves the construction site shall be prohibited. Visible or measurable erosion is defined as:
  - Deposits of mud, dirt, sediment or similar material exceeding ½ cubic foot in volume in any area of 100 square feet or less on public or private streets, adjacent property, or into the storm and surface water system, either by direct deposit, dropping, discharge, or as a result of the action of erosion; or
  - Evidence of concentrated flows of water over bare soils; turbid or sediment laden flows; or evidence of on-site erosion such as rivulets on bare soil slopes, where the flow of water is not filtered or captured on the site using the techniques in the approved erosion control plan; or
  - Earth slides, mud flows, earth sloughing, or other earth movement which leaves the property.
- Under no condition shall sediment be discharged to surface waters or natural wetlands. Under no condition shall the sediment be washed into the storm sewers or drainage ways.

10.7. MINIMUM REQUIREMENTS OF A TEMPORARY EROSION AND SEDIMENT CONTROL PLAN

Any person planning to engage in construction activities, falling within the requirements in this Manual, shall submit an erosion and sediment control plan to the City Public Works Department for approval prior to any disturbance of land within the Bulverde City Limits. The plan shall be submitted using the format described in Section 2 and shall include the required attachments.

The City Public Works Department will review all plans submitted and approve any such plans that meet these standards. When the plan submitted for approval is found to be inadequate, the City will notify the person in writing of any necessary modifications, terms, and conditions as will permit approval of the plan.

The erosion and sediment control plan shall contain, as a minimum, the following information:

- Name, address, and telephone number of the applicant.
- Location of the property development.
- Description of land disturbing activities.
- A site map indicating areas of total development and all areas of soil disturbance, areas of cut and fill, drainage patterns and approximate slopes anticipated after major grading activities, areas used for the storage of soils or wastes, location of all erosion and sediment control measures or structures and areas where vegetative practice are to be implemented, the location of impervious structures (including buildings, roads, parking lots, outdoor storage areas, and etc.) after construction is completed, springs, wetlands and other surface waters, and the boundary of 100 year flood plains, if determined.
- The nature of fill material to be used, the existing soils located at the site, and the characteristics of such soils. Soil surveys are good sources of soil characteristics. Use site-specific soils information for the project site when available, or the NRCS *Soil Survey of Comal and Hays Counties* to identify the soils. If possible, include information on the soil series and/or mapping units found at the site.
- Estimates of the total area of the site, and all other sites if the project is a phased development, which is expected to undergo clearing, excavation, and/or grading.

- The nature of the construction activity, including a proposed time table for major activities.
- The names of the receiving water(s) and the size, type and location of each outfall and the location of any connections to public storm sewers.

The temporary erosion and sediment control plan should contain a description of best management practices (BMPs) appropriate for the site which shall be implemented to control erosion and sediment. The following minimum components shall be addressed:

- A description, including a schedule of implementation, of Temporary Soil Stabilization practices designed to preserve existing vegetation where practicable and revegetate open areas as soon as possible after grading or construction.
- A description, including a schedule of implementation of Temporary Sediment Control practices which indicates how the permittee will control sediment from the construction site. Temporary control measures shall not be removed until permanent vegetation and site stabilization has taken place.
- Graveled access entrance and exit drives and parking areas to reduce the tracking of sediment onto public or private roads may be required during wet working conditions. All unpaved roads on the site carrying more than 25 vehicle trips per day should be graveled. When trucking saturated soils from the site, loads shall be required to drain until drippage has been reduced to less than one gallon per hour before leaving the site.

Measures for controlling potential pollutants at their source shall also be addressed.

10.8. APPROVAL TO BEGIN WORK

The following minimum requirements must be completed prior to beginning construction:

- A copy of the approved erosion and sediment control plan must be on-site during construction. The applicant is responsible for obtaining any other required or related permits prior to beginning construction.

- The area to be cleared and graded must be approved by the City Public Works Department prior to beginning any work on the site. Clearing shall be limited to the areas within the approved disturbance limits.
- All BMPs indicated in the approved erosion and sediment control plan shall be installed as shown and in accordance with the schedule for implementation or per the direction of the City Public Works Department.
- A public information sign listing 24-hour emergency phone numbers for the City and the contractor must be posted at the project site, in full view of the public and the contractors, and it must remain posted until final sign-off by the City.

10.9. INSPECTIONS AND RECORDKEEPING

Inspections and record keeping of construction activities should be in compliance with the applicable local, state and federal permits.

- Person(s) Responsible for Inspecting Site **-** The person(s) inspecting the site should be a person on staff or a third party hired to conduct such inspections. The person inspecting the site should be a "qualified person."
- Frequency of Inspections - At a minimum, a site inspection must be conducted in accordance with one of the two schedules listed below, unless located in Drought-Stricken Areas.
  - At least once every 7 calendar days; or
  - Once every 14 calendar days and within 24 hours of the occurrence of a storm event of 0.25 inches or greater. To determine if a storm event of 0.25 inches or greater has occurred on the site, a properly maintained rain gauge on the site must be kept, or obtain the storm event information from a weather station that is representative of the location. For any day of rainfall during normal business hours that measures 0.25 inches or greater, the total rainfall measured must be recorded for that day in accordance with the Inspection Report guidelines.
- Reductions in Inspection Frequency - The inspection frequency may be reduced for stabilized areas, drought-stricken areas, and frozen conditions.
- Areas that Need to Be Inspected. During the site inspection, at a minimum the following areas of the site should be inspected:

- All areas that have been cleared, graded, or excavated and that have not yet completed stabilization;
- All stormwater controls (including pollution prevention measures) installed at the site;
- Material, waste, borrow, or equipment storage and maintenance areas;
- All areas where stormwater typically flows within the site, including drainageways designed to divert, convey, and/or treat stormwater;
- All points of discharge from the site; and
- All locations where stabilization measures have been implemented.

- Requirements for Inspections - During the site inspection, at a minimum the following must be done:
  - Check whether all erosion and sediment controls and pollution prevention controls are installed, appear to be operational, and are working as intended to minimize pollutant discharges.
  - Check for the presence of conditions that could lead to spills, leaks, or other accumulations of pollutants on the site.
  - Identify any locations where new or modified stormwater controls are necessary.
  - At points of discharge and, if applicable, the banks of any surface waters flowing within the property boundaries or immediately adjacent to the property, check for signs of visible erosion and sedimentation *(i.e., sediment deposits)* that have occurred and are attributable to the site discharge; and
  - Identify any and all incidents of noncompliance observed.
  - If a discharge is occurring during the inspection, it is required to:
    a. Identify all points of the property from which there is a discharge;
    b. Observe and document the visual quality of the discharge, and take note of the characteristics of the stormwater discharge, including color, odor, floating, settled, or suspended solids, foam, oil sheen, and other obvious indicators of stormwater pollutants; and
    c. Document whether the stormwater controls are operating effectively, and describe any such controls that are clearly not operating as intended or are in need of maintenance.

Based on the results of the inspection, initiate corrective action utilizing the Construction Inspection Checklist, located in Appendix A.

Inspection Report.

- Requirement to Complete the Construction Inspection Checklist -An inspection checklist must be completed within 24 hours of completing any site inspection. Each inspection report must include the following:
  a. The inspection date;
  b. Names and titles of personnel making the inspection;
  c. A summary of the inspection findings;
  d. If an inspection is performed because of rainfall measuring 0.25 inches or greater, the applicable rain gauge or weather station readings that triggered the inspection must be included; and
  e. If it is determined that it is unsafe to inspect a portion of the site, describe the reason it was unsafe and specify the locations that this condition applied to.

- Signature Requirements. Each inspection checklist must be signed.

- Recordkeeping Requirements - It is required to keep a current, copy of all inspection checklists at the site or at an easily accessible location, so that it can be made available at the time of an onsite inspection or upon request by EPA. For purposes of the stormwater permit, the inspection reports may be kept electronically if the records are:
  a. In a format that can be read in a similar manner as a paper record;
  b. Legally dependable with no less evidentiary value than their paper equivalent; and
  c. Accessible to the inspector during an inspection to the same extent as a paper copy stored at the site would be, if the records were stored in paper form.

All inspection reports completed for this Part must be retained for at least 3 years from the date that the permit coverage expires or is terminated.

10.10. MONITORING

If required, a monitoring plan will be prepared noting the location of the proposed sampling points. The plan will also note what pollutants and nutrients are being monitored and at what frequency the samples will be collected. The plan will detail what actions are to be taken if pollutants exceed specified levels noted in the plan and at what increased frequency and for what period of time monitoring may be required.

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APPENDIX A – CONSTRUCTION INSPECTION CHECKLIST

CONSTRUCTION BMP COMPLIANCE INSPECTION CHECKLIST

Project Name:				
Project Number:				
Contractor:				
Inspector's Name:				
Inspector's Title				
Signature				
Date of Inspection:				
Inspection Type: (Check Applicable)	☐ Prior to forecast rain ☐ 24-hr intervals during extended rain		☐ After a rain event ☐ Other_____	
Season:	☐ Rainy		☐ Non-Rainy	
Storm Data:	Storm Start Date and Time:		Storm Duration (hrs):	
	Time elapsed since last storm: (Minutes, Hours or Days)		Approx. Rainfall Amount: (cm)	

Identify existing erosion control practices employed:
(Check all that apply and describe conditions – see further explanation below)

BMP Used on Project		**General Design and Installation Requirements** (NOTE: for in depth requirements, refer to TCEQ Manual)	**BMP Adheres to Design/Installation Requirements?**	**Describe Condition of BMP**
	Interceptor Swale	- V-shaped or Trapezoidal Shaped - With flat bottom and side slopes of 3:1 or flatter - Stone stabilization should be used if grade exceeds 2% - Stone should be three inches thick		
	Diversion Dike	- Top width should be 2 feet - Minimum height of compacted fill – 18 inches - Side slopes of 2:1 or flatter		
	Pipe Slope Drain	- Flexible pipe capable of conveying runoff - Riprap should be used in outlet apron - Riprap should be either crushed stone or PCC		
	Polyacrylamide (PAM)	- Environmentally safe PAM product - Water soluble. linear or non-crosslinked PAM - Applied to dry soil, uniformly distributed		
	Outlet Stabilization Level Spreader	- Well graded mixture of stone, no larger than 1.5 times the d_{50} size - Select stone from field stone or quarry stone - Geotextile fabric - Able to accommodate 10-yr, 3-hr peak runoff or design discharge of water conveyance structure, whichever is greater - Riprap and fabric conforms to grading limits shown on plans		
	Subsurface Drain	Perforated pipe in various materials that meet requirements of manufacturer's specifications		

		Trench installed on a continuous grade No warped or deformed pipe		
	Temporary Vegetation	- Installed according to season and availability of water for irrigation - Erosion or other damage should be repaired as soon as possible - If vegetative cover is < 80%, the area should be reseeded		
	Blankets/Matting	- Biodegradable rolled erosion control products (i.e., jute, curled wood fibers, etc.) Installed according to TCEQ requirements (with proper soil preparation, anchors and erosion stops) - Apply new material if damaged		
	Hydraulic Mulch	- Shredded wood fiber or hydraulic matrix with a stabilizer - Installed according to TCEQ requirements (with proper soil preparation) - Repaired as soon as possible after rain or damage occurs		
	Sod	- Sod machine cut at uniform thickness, cut to supplier's standard width and length - Installed within 36 hours after harvested Sod installed and maintained according to TCEQ requirements - On slopes > 3:1 sod laid with staggered joints and secured by stapling - Sod should be properly irrigated		
	Dust Control	- Utilize one of the methods mentioned in TCEQ Manual and reapply BMPs when dust is evident		

Note areas where repairs or maintenance is needed:

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Identify existing sediment control practices employed:
(Check all that apply and describe conditions – see further explanation below)

BMP Used on Project		Design and Installation Requirements	BMP Adheres to Design/Installation Requirements?	Describe Condition of BMP
	Construction Exit	- Project runoff < 5 acres - V-shaped or Trapezoidal Shaped - With flat bottom and side slopes of 3:1 or flatter - Stone stabilization should be used if grade exceeds 2% - Stone should be three inches thick		
	Silt Fence (interior)	- Project runoff < 10 acres - Top width should be 2 feet - Minimum height of compacted fill – 18 inches - Side slopes of 2:1 or flatter		
	Silt Fence (exterior)	- Silt fence material should be polypropylene, polyethylene or polyamide woven or nonwoven fabric - Fabric width = 36 inches		
	Triangular Filter Dike	- 6”x6”, 6 gauge wire mesh, wrapped with the same geotextile fabric used for silt fences - Dike should be positioned parallel to the contours and overlap		
	Rock Berm	- Rock berm should be secured with a woven wire sheathing (20 gauge) - 3 to 5 inch diameter rock - Berm at least 18” in height - Stone should not be misshapen or contain more than 6 inches of sediment		
	High Service Rock Berm	High service rock berms should only be used in areas of important environmental significance as stated in TCEQ’s Manual		
	Brush Berm	- The maximum slope length < 100 feet; - The maximum slope gradient behind the barrier < 50 % (2:1) - Brush should consist of woody brush and branches, preferably juniper < 2 in. diameter - Rope should be ¼ inch polypropylene or nylon - Anchors should be 3/8- inch diameter rebar stakes that are 18- inches long		
	Sand Bag Berm	- Sand bag material should be polypropylene, polyethylene, polyamide or cotton burlap woven fabric, - Minimum unit weight 4 oz/yd2 - Mullen burst strength > 300 psi - UV stability >70% - Bag length = 24 to 30 inches - Width = 16 to 18 inches - Thickness = 6 to 8 inches - Sand should pass through a No. 10 sieve. - When silt reaches 6 inches, the accumulated silt should be removed and disposed of at an approved site		
	Vegetative	Minimum width of a vegetative buffer used for		

	Buffer Strips	sediment control should be 50 feet		
	Inlet Protection	Filter fabric should be a nylon reinforced polypropylene fabric which meets the following minimum criteria: - Tensile Strength = 90 lbs. - Puncture Rating = 60 lbs.; - Mullen Burst Rating = 280 psi - Apparent Opening Size = U.S. Sieve No. 70 - Posts for fabric should be 2" x 4" pressure treated wood stakes or galvanized steel - Concrete blocks should be standard 8" x 8" x 16" concrete masonry units - Wire mesh should be standard hardware cloth or comparable wire mesh with an opening size not to exceed 1/2 inch		
	Sediment Trap	- Preferable to be used instead of sediment basins, if meets treatment requirements - All aggregate should be ≥ 3 inches in diameter - Volume should not be > 0.5 cubic foot - Side slopes for the embankment = 3:1. - Width of the embankment = 3 feet - A core of filter stone having a min. height of 1.5 feet - Min. width at the base of 3 feet should be placed across the opening of the earth embankment and covered by geotextile fabric which should extend a minimum distance of 2 feet in either direction from the base of the filter stone core		
	Sediment Basin	- Sediment basin appropriately sized (2-year, 24-hour storm per acre) - Sediment basin riser outlet designed so that the dewatering zone will drain in no less time than 48 hours - Riser pipe watertight and have a trash rack and anti-vortex device - Outlet pipe stabilized in concrete encasement length-to-width ratio between inlet(s) and outlet at least 2:1 - Emergency spillway sized to carry the 10 year, 3 hour storm with 1 foot of freeboard - Emergency spillway lined with rip rap the basin have a permanent stake to indicate the sediment levels		
	Fiber Rolls	- Consists of straw, coconut fibers or similar, tied into a tight, tubular roll - See TCEQ requirements for limitations and installation		
	Dewatering Operations	- Ensure that activity based BMPs are in place prior to dewatering operation - Use dewatering applications as shown in TCEQ Manual (i.e., weir tanks, filter bags, etc.)		
	Spill Prevention	- Avoid spills through employee education - Clean up spills immediately after occurrence and dispose of materials properly		

	Utility Line Crossings	- Made perpendicular to flow line - Discharge should not cause scouring or erosion - High service rock berms should be installed downstream of the proposed trench		
	Concrete Washout	- Located at least 50 feet from sensitive features, storm drains, ditches or water bodies - Wash out should be located where concrete can be disposed of properly		

Note areas where repairs or maintenance is needed:

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Condition of BMP Key: (1) Installed incorrectly (2) Wrong location (3) Lack of Maintenance (4) Wrong BMP Application used (5) Indeterminate

APPENDIX B – STANDARD HYDRAULICS FORM

City of Bulverde, TX
Standard Hydraulic Form

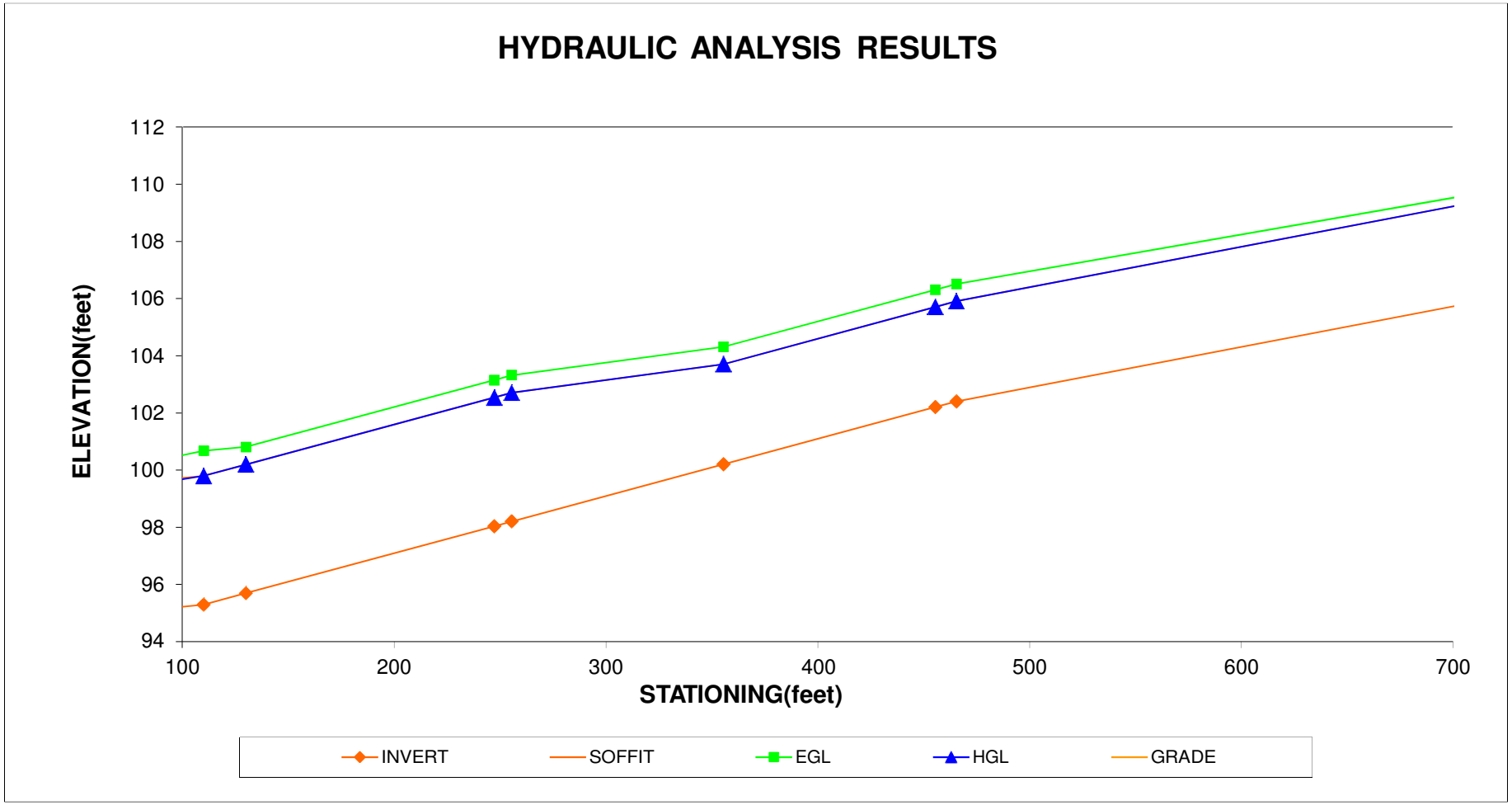
Drainage Manual Example Project

Storm Drain Manning's n (typ=0.013)= 0.013 | Outlet Velocity V_d (fps)= 5.4 | Inlet Structure Type or K_i= a = Headwall: Grooved Edge

	STORM DRAIN DATA								FLOW DATA							ENERGY LOSS DATA																								RESULTS		
	STATION		PIPE	BOX		#	INVERT ELEV		Pipe Length L	Pipe Slope S	A	Q	V	$V^2/2g$	S_f	Pipe Friction Loss	Exit Loss	Bends (Curves)			Transition Losses						Junction Losses (No Access Manhole)						Inlet and Manhole Losses			Misc	Entrance Loss		Total Loss	EGL/HGL		Pressure/ Partial Flow
																					Contraction Loss			Expansion Loss																			
	FROM (ft)	TO (ft)	D (in)	SPAN (ft)	RISE (ft)		D/S (ft)	U/S (ft)	(ft)	(%)	(ft^2)	(cfs)	(ft/s)	(ft)	(ft/ft)	H_f (ft)	H_o (ft)	Θ (deg)	K_b	H_b (ft)	Θ (deg)	K_c	H_c (ft)	Θ (deg)	K_e	H_o (ft)	Θ (deg)	D_l (in)	Q_l (ft^3/s)	A_l (ft^2)	V_l (ft/s)	H_i (ft)	H_{e+e} (ft)	H_o (ft)	H_t (ft)	H_m (ft)	K_e	H_o (ft)	(ft)	U/S EGL	U/S HGL	
1		0.00	54					94.50									0.43																								98.93	98.50	
2	0.00	110.00	54			1	94.50	95.30	110.0	0.73%	15.90	120	7.55	0.88	0.0037	0.41		14	0.05	0.04							30	36	20	7.07	2.83	0.17							0.63	100.68	99.80	PARTIAL
3	110.00	130.00	54			1	95.30	95.70	20.0	2.00%	15.90	100	6.29	0.61	0.0026	0.05																							0.05	100.81	100.20	PRESSURE
4	130.00	247.25	54			1	95.70	98.04	117.3	2.00%	15.90	100	6.29	0.61	0.0026	0.30																							0.30	103.15	102.54	PARTIAL
5	247.25	255.50	54			1	98.04	98.21	8.3	2.06%	15.90	100	6.29	0.61	0.0026	0.02											30	36	40	7.07	5.66	0.13							0.15	103.32	102.71	PRESSURE
6	255.50	355.50	42			1	98.21	100.21	100.0	2.00%	9.62	60	6.24	0.60	0.0036	0.36																							0.36	104.31	103.71	PARTIAL
7	355.50	455.50	42			1	100.21	102.21	100.0	2.00%	9.62	60	6.24	0.60	0.0036	0.36																							0.36	106.31	105.71	PARTIAL
8	455.50	465.50	42			1	102.21	102.41	10.0	2.00%	9.62	60	6.24	0.60	0.0036	0.04											30	30	20	4.91	4.07	0.11							0.14	106.51	105.91	PRESSURE
9	465.50	719.00	42			1	102.41	106.00	253.5	1.42%	9.62	40	4.16	0.27	0.0016	0.40																					0.20	0.05	0.46	109.77	109.50	PARTIAL
10	719.00	719.00	42			1	106.00	106.00	0.0		9.62	40	4.16	0.27	0.0016	0.00																							0.00			

Summary of Results

					(Optional)			100-Yr Check	5-Yr Check
STATION	INVERT	SOFFIT	EGL	HGL	GRADE	LOCATION	DESCRIPTION	Grade - HGL	Soffit - HGL
0.00	94.50	99.00	98.93	98.50					OK
110.00	95.30	99.80	100.68	99.80					OK
130.00	95.70	100.20	100.81	100.20					OK
247.25	98.04	102.54	103.15	102.54					OK
255.50	98.21	102.71	103.32	102.71					OK
355.50	100.21	103.71	104.31	103.71					OK
455.50	102.21	105.71	106.31	105.71					OK
465.50	102.41	105.91	106.51	105.91					OK
719.00	106.00	109.50	109.77	109.50					OK
719.00	106.00	109.50							


HYDRAULIC ANALYSIS RESULTS
ELEVATION(feet)
112
110
108
106
104
102
100
98
96
94
100
200
300
400
500
600
700
STATIONING(feet)
INVERT
SOFFIT
EGL
HGL
GRADE