# City of Hempstead, Texas

## Stormwater Management Regulations

Prepared by:

STRAND ASSOCIATES, INC.®
TBPE No. F-8405
TBPLS No. 10030000
1906 Niebuhr Street
Brenham, TX 77833
www.strand.com

April 2023

STRAND
ASSOCIATES®
Excellence in Engineering
Since 1946

## GENERAL PROVISIONS

Drainage facilities shall be designed and constructed in accordance with these Stormwater Management Regulations (Regulations) and the City of Hempstead, Texas' (City) Standard Details. Project specifications for specific developments shall be reviewed and approved by the City Engineer. The following design criteria are the City's minimum methods and standards. Other hydrologic and hydraulic design methods may be used to satisfy drainage requirements with previous approval of the City.

A. Upstream Conditions

All drainage facilities shall be designed based on potential and fully developed upstream conditions. A minimum runoff coefficient of 0.75 shall be used for all undeveloped upstream property.

B. Downstream Conditions

Downstream water surface elevations shall be determined for a 100-year design frequency storm in order to define the downstream flood hazards created by the proposed development.

C. Protection of Downstream Properties

A downstream drainage improvement or retention system shall be designed and constructed to protect downstream properties from any increase in stormwater runoff level.

D. Discharge Points

All drainage improvements shall be terminated at a discharge point approved by the City. Such discharge point, or outlet, shall be designed and constructed to prevent damage to or overflowing into the adjacent property. The City may require creek improvement, channel lining, energy dissipaters, or other improvements for such outlet to prevent erosion or increase the flow capacity.

E. Public Streets as Drainage Facilities

1. Maximum spread of water to be allowed in local streets at a 10-year design flow shall allow for one clear lane of traffic (12 feet wide).

2. Maximum spread of water in collector streets at a 10-year design flow shall allow for one clear lane of traffic each way (12 feet wide each).

3. Maximum spread of water in arterial streets at a 10-year design flow shall allow for two clear lanes of traffic (24 feet wide).

F. Drainage Channels and Structures

1. An underground storm drain on curb and gutter streets shall be installed beginning at the point where the calculated stormwater runoff is of such a quantity that it exceeds the height specified previously. The storm drain system from this point shall be constructed to an approved outlet.

2. For noncurb and gutter streets, open channel (channel or ditch) methods may be used to dispose of stormwater runoff of such a quantity that it exceeds the height specified previously. Such channels may be in dedicated drainage easements outside the standard street right-of-way (ROW) upon City approval of the location and alignment of such easements. Alternatively, the street ROW may be widened to accommodate an open channel of greater capacity than the standard street or ditch section.

3. If the channel is located in a widened street ROW, the City shall approve the ROW width and channel configuration.

4. All channels shall be designed and constructed to terminate at an approved outlet.

G. Habitable Structures

Adequate means for stormwater runoff in excess of the street's "design storm" capacity (i.e., 10-year storm) shall be provided to flow around habitable structures for areas not in the floodplain. Any area in a Federal Emergency Management Agency (FEMA) floodplain needs to comply with FEMA guidelines.

1. A grading or drainage plan shall be provided that shows all building sites can provide a finished floor elevation to be a minimum of 1 foot above the adjacent roadway centerline at its highest point along the property frontage. Corner lots shall be subject to being a minimum of 1 foot above the highest point in the centerline of both abutting streets.

2. Provisions shall be made in the subdivision grading plan that will contain stormwater on each lot and discharge it to either the street or a drainageway at the rear of the lot. If necessary, drainage swales shall be constructed on the low side of each lot, which will prevent stormwater migration to adjacent lots.

3. All streets shall be designed and constructed to minimize any fill required to bring building pads into compliance with this document.

4. Alternative methods of building protection of those previously noted may be accepted by the City upon submittal of detailed, engineered drawings.

H. Drainage System Criteria

If an underground drainage system is required, and a 60-inch or smaller pipe will handle the design flow, reinforced concrete pipe shall be used. If a 60-inch pipe is not adequate, reinforced concrete pipe or natural and/or a lined open drainage channel may be used. If reinforced concrete pipe is selected, the maximum allowable velocity shall be 12 feet per second in the pipe. Lining materials, if used, shall be approved by the City.

I. Line of Flow

Water courses shall be allowed to follow their natural lines of flow. Rechanneling or rerouting of water courses may be permitted where approved by the City provided that the point at which the water course enters the lot and the point at which it leaves the lot are not changed.

J. Bridges and Box Culverts

Bridges or box culverts shall be designed and constructed at all street crossings over all drainageways and floodways in accordance with Table 2 “Design Storm Frequency.”

K. Valley Gutters

Concrete valley gutters shall be provided if the gutter flow must be carried across intersections of curbed streets.

L. Public Easements Required

All public drainage facilities shall be placed in public easements.

## DESIGN CRITERIA

A. Basis for Discharge

For sizing of stormwater conveyance systems with drainage areas less than 100 acres and situations where reflecting storage volume routing effects is not necessary, the Rational Method is acceptable. The Rational Formula for calculating storm flows is shown in Figure 1. The United States Soil Conservation Service (now called National Resources Conservation Service) unit hydrograph methods are acceptable for any size drainage area and are required for the design of stormwater conveyance measures that have drainage areas larger than 100 acres. Unit hydrograph methods shall be used for the design of all stormwater storage measures (detention basins). When unit hydrograph methods for computing runoff are proposed, appropriate National Oceanic Atmospheric Administration (NOAA) Atlas 14 rainfall depths shall be used, applying the appropriate NOAA Atlas 14 temporal rainfall distributions. The engineer can propose to use other hydrologic methods but must have their use approved by the City.

For street or gutter flow, the velocity shall be based on the grade of the street. In the absence of detailed calculation by Manning’s Formula for the specific street section, the average velocities shown in Table 1 may be used.

| Slope of Gutter | Assumed Velocity (feet per second) |
|---|---|
| 0.5% | 1.5 |
| 1.0% | 2.2 |
| 2.0% | 3.1 |
| 3.0% | 3.8 |
| 4.0% | 4.3 |
| 5.0% | 4.9 |
| 6.0% | 5.3 |
| 8.0% | 6.1 |
| 10.0% | 6.9 |

**Table 1 Average Velocities of Runoff**

| **The Rational Formula** | |
|---|---|
| **Q = CIA** | |
| Q = The maximum storm flow rate at a given point (in cubic feet per second). | |
| C = A runoff coefficient that varies with the topography, land use, and moisture content of the soil at the time. The runoff coefficient shall be based on the ultimate use of the land. The runoff coefficient can be selected from the major use classification shown in the following. | |
| | |
| Shopping Centers | 0.95 |
| Business Areas | 0.80 |
| Industrial Areas | 0.70 |
| Residential Areas: | |
| Less than 2 lots per acre | 0.40 |
| Greater than 2 lots per acre but less than 4 lots per acre | 0.50 |
| Greater than 4 lots per acre but less than 8 lots per acre | 0.60 |
| Greater than 8 lots per acre | 0.75 |
| Apartments | 0.75 |
| Park and Open Space | 0.30 |
| | |
| I = The average intensity of rainfall in inches per hour for a period equal to the time of concentration of flow from the farthest point of the drainage area to the point under consideration. | |

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

Where

| | **5-year** | **10-year** | **25-year** | **50-year** | **100-year** |
|---|---|---|---|---|---|
| e = | 0.805 | 0.801 | 0.806 | 0.810 | 0.813 |
| b = | 72.59 | 84.44 | 108.19 | 131.31 | 156.54 |
| d = | 11.01 | 11.12 | 12.35 | 13.54 | 14.48 |

t = Time of concentration in minutes

A = The drainage area, in acres, tributary to the point under design calculated from the drainage map of the area. This drainage map shall be submitted with any drainage map of the area. This drainage map shall be submitted with any drainage plans submitted for consideration by the City Manager.

**Figure 1 The Rational Formula**

Using the average velocities in Table 1, the time of concentration shall be calculated by the formula shown in Figure 1, or by other recognized methods (such as the Texas Department of Transportation [TxDOT] formulas), unless more data is shown on the drawings for calculating time of concentration.

B. Storm Frequency

Design storm frequencies for storm drainage improvements are shown in Table 2.

| Type of Facility | Description of Area to be Drained | Minimum Design Frequency (years) |
|---|---|---|
| Streets and Storm Sewers or Side Ditches, Combined* | Residential, Commercial, and Industrial | Local–10 years<br>Collector–10 years<br>Arterial–10 years |
| Culverts, Bridges, Channels, and Creeks | Any Type of Area Greater Than 100 Acres | 100 years |

*If a storm drain (an inlet) is located at a low point so that flow in excess of the storm drain capacity would be directed onto private property, and such overflow could cause damage or serious inconvenience in the opinion of the City Manager, the design frequency shall be 25 years.

**Table 2 Design Storm Frequency**

C. Underground Drainage Facility Design

The underground drainage facility (storm drain) capacity shall be calculated by Manning's Formula as follows:

$$Q = \frac{1.486}{n} AR^{2/3}S^{1/2}$$

Where

Q = The discharge in cubic feet per second
A = The cross-sectional area of flow in square feet
R = The hydraulic radius in feet equals area or wetted perimeter
S = The slope of the hydraulic gradient in feet per foot
n = The coefficient of roughness

The elevation of the hydraulic gradient of the storm sewer shall be a minimum of 1.0 feet below the elevation of the adjacent street gutter. The stormwater pipe shall be sized so that the average velocity in the pipe will not exceed 12 feet per second.

$$T = \frac{D}{V \times 60}$$

Where

T = Time of concentration in minutes for use in Figure 1
D = Distance in feet from point of concentration to the most hydraulically distant part of the drainage basing under construction.
V = Velocity calculated by an engineer for streets and/or storm sewers.

D. Open Channel Design

Open channel facilities shall be designed and constructed based on frequencies shown in Table 2 and calculated by Manning's Formula with roughness coefficients and velocities as shown in Table 3. Side slopes of channels shall be no steeper than 3 to 1 in earth and 1 to 1 when lined with concrete.

| Open Channels | Maximum Permissible Velocity in feet per second | Coefficient* "n" |
|---|---|---|
| Paved | | |
| Concrete | 8 | 0.011 to 0.020 |
| Asphalt | 8 | 0.013 to 0.017 |
| Rubble or Riprap | 8 | 0.017 to 0.030 |
| Earth | | |
| Bare, Sandy Silt, Weathered | 2.0 | 0.020 |
| Silt Clay or Soft Shale | 3.5 | 0.020 |
| Clay | 6.0 | 0.020 |
| Soft Sandstone | 8.0 | 0.020 |
| Clean Gravelly Soil | 6.0 | 0.030 to 0.150 |
| Turf | | |
| Shallow Flow | 6.0 | 0.060 to 0.08 |
| Depth of Flow over 1 Foot | 6.0 | 0.040 to 0.06 |

*Will vary slightly with straightness of alignment, smoothness of bed and side slopes, and whether the channel has light vegetation or is choked with weed and brush.

**Table 3 Coefficient of Roughness**

Unless otherwise approved, all open channels shall be designed for the 100-year design flow and have a minimum channel bottom width of 6 feet. A 20-foot maintenance easement shall be provided on both sides of the channel.

E. Culvert Design

Enclosed culverts shall be installed if a creek or ditch crosses proposed roadway improvements. The quantity of flow to be carried by the culvert shall be determined by the Rational Formula. The size of the culvert required shall be the larger size, checking both inlet and outlet flow control.

Design of culverts shall include the determination of upstream and downstream backwater conditions, velocities, and flooding conditions. Culverts with discharge velocities that exceed those provided in Table 4 shall not be designed or installed.

All culverts shall be provided with safety end treatments or other appropriate termination structures.

| Culvert Discharging onto Surface | Maximum Allowable Velocity (fps) |
|---|---|
| Earth | 6 |
| Sod Earth | 8 |
| Paved or Riprap Apron | 8 |
| Shale | 8 |
| Rock | 8 |

fps = feet per second

**Table 4 Culvert Discharge–Velocity Limitations**

## MINIMUM DESIGN STANDARDS

The design requirements set forth within these Regulations are minimum design standards. The City reserves the right to require additional precautions or treatments consistent with sound engineering practice to provide for conditions not specifically covered within these Regulations.

## STORMWATER DETENTION

A. General

Stormwater detention facilities shall be required where deemed appropriate by the City when it is determined that adverse downstream flooding would occur because of a proposed development. Runoff detention storage shall be used, wherein the storm volume is held back in the watershed and released at an acceptable rate. This section presents information on storage techniques, including guidance for the design of appropriate storm runoff storage facilities.

B. Downstream Impacts

If it is anticipated that additional runoff caused by the development will overload any existing downstream drainage facility, whether natural or improved, and result in hazardous conditions, approval of the improvements for the proposed subdivision may be withheld until appropriate provisions have been made to resolve the problem. If existing capacity is not available downstream and property damage could occur, the applicant or developer shall provide a drainage system or detention facility to mitigate the deficiency.

C. Funding of Improvements

The developer shall pay for the cost of all drainage improvements required, including any necessary off-site channels or storm sewers and acquisition of the required easements.

D. Floodplain Preservation

Preservation of major floodplains is strongly encouraged, and detention or retention may be required if a proposed drainage improvement is found to create actual or potential upstream, adjacent, or downstream property damage because of the creation of excessive flood velocities or heights.

E. Design Procedures

The following design procedures are intended to ensure new development (with detention) will not cause any adverse impacts on existing flooding conditions downstream. Stormwater detention shall be used to reduce the net increase in stormwater runoff because of development of the property at the 2-, 10-, 25-, and 100-year events, unless a downstream assessment shows that none is required. Multi-stage outlet structures may be required. (Note: The design engineer should contact the City for any specific requirements for the watershed in which the proposed facility is to be located). For small watersheds less than 5 acres that require detention, the developer has the option of providing the 0.55 acre-feet of detention per acre developed instead of developing a model.

F. Hydrology Methods

All storage facilities shall be designed and analyzed using reservoir routing of an inflow unit hydrograph. The software program or computational method must be approved by the City. The analysis should consist of comparing the design flows at a point or points downstream of the proposed storage site with and without storage. Design calculations shall show the effects of the detention facility in each of the 2-, 10-, 25-, and 100-year storm events. This may require the use of multi-stage control structures. The detention facility shall be designed to provide the required detention for all the above-listed frequencies.

Rainfall estimates should be based on published values in the NOAA Atlas 14, Volume 11–Precipitation-Frequency Atlas of the United States.

A calculation summary shall be provided on construction drawings. For detailed calculations of unit hydrograph studies, a separate report shall be provided to the City for review and referenced on the construction drawings. Stage-storage-discharge values shall be tabulated and flow calculations for discharge structures shall be shown on the construction drawings.

G. Design Tailwater Depth

In order to route the inflow hydrograph through the detention facility, a relationship must be established between the volume of storage in the pond and the corresponding amount of discharge through the outflow structure. In most cases, this relationship is directly dependent on the elevation of the tailwater at the outlet of the outflow structure.

For the purpose of establishing an outflow rating curve, the tailwater in the receiving channel shall be assumed to be (at all times) at the level of the same frequency storm being analyzed. In certain situations where this assumption may be shown not to be reasonable, an alternative tailwater condition can be presented for approval to the City.

H. Final Sizing of Pond Storage and Outflow Structure

Detention facilities shall be sized such that at least 1 foot of freeboard shall be maintained during the 100-year storm event, as measured from the top of the detention or retention facility berm.

The minimum recommended outflow pipe for a detention facility is 12 inches. When further flow restriction is necessary, the restriction should be located at a separate manhole outside of the receiving channel.

I. Storm Sewer Hydraulic Gradients

The hydraulic gradients in storm sewers shall be determined using procedures outlined in previous sections of these guidelines. The starting water surface elevation for these calculations shall be the 25-year maximum pond elevation.

J. Allowances for Extreme Storm Events

Design consideration must be given to storm events in excess of the 100-year flood. An emergency spillway, overflow structure, or swale must be provided, as necessary, to effectively handle the extreme storm event. In places where a dam has been used to provide detention directly in a channel, due consideration must be given to the consequences of a failure and, if a significant hazard exists, the dam must be adequately designed to prevent such hazards.

In addition, detention facilities that measure greater than 6 feet in height are subject to Title 31 Texas Administrative Code (TAC) Chapter 299 (Subchapters A through E), which went into effect May 13, 1986, and all subsequent changes. The height of a detention facility or dam is defined as the distance from the lowest point on the crest of the dam (or embankment), excluding spillways, to the lowest elevation on the centerline or downstream toe of the dam (or embankment), including the natural stream channel. Subchapters A through E of TAC Chapter 299 classify dam sizes and hazard potential and specify required failure analyses and spillway design flood criteria.

K. Erosion Controls

The erosional tendencies associated with a detention pond are similar to those found in an open channel. For this reason, the same types of erosion protection are necessary, including the use of backslope swales and drainage systems, proper revegetation, and pond surface lining where necessary. Proper protection must especially be provided at pipe outfalls into the facility, pond outlet structures, and overflow spillways where excessive turbulence and velocities will cause erosion.

L. Multipurpose Land Use

The amount of land required for a stormwater detention facility is generally quite substantial. For this reason, it is logical that storage facilities could serve a secondary role as parks or recreational areas whenever possible. Such dual use areas will be allowed only after proper review of the design scenario and approval of the specific project by the City.

When a dual-use facility is proposed, a joint use agreement is required between the City and the entity sponsoring the secondary use. This agreement must specify the maintenance responsibilities of each party.

M. Approval of Private and Dual-Use Facilities

For privately maintained or dual-use systems, each stormwater detention facility will be reviewed and approved only if the following are met:

1. The facility has been designed to meet or exceed the requirements contained within this document.

2. Provisions are made for the facility to be adequately maintained.

N. Maintenance

In general, the City will only be responsible for maintenance of stormwater detention basins that serve public facilities such as dedicated public streets or parks and recreational areas. Responsibility for the maintenance of any portion of a facility not designed for flood control will not rest with the City, nor will the City be responsible for any damage that may occur resulting from flooding of the facility. The maintenance of new and existing stormwater detention or retention basins shall be the responsibility of the owner. The owner of the basin(s) shall maintain them in such a manner as to provide a neat and aesthetically appealing area. Vegetation shall be controlled and mowed periodically. The City will inspect each pond annually and identify any deficiencies that exist in the pond maintenance. The owner will be notified of these deficiencies and required to make corrections. Corrections may include vegetation control, erosion repairs, silt removal, seeding of bare of disturbed areas, and repairs to outfall structures, orifices, and pumping units. Aboveground pumps and piping shall be kept in a neat appearance with well-maintained protective coatings. It is the intent of this ordinance to require that each detention pond be annually restored to its original design dimensions and function as a minimum.

A 30-foot-wide access and maintenance easement shall be provided around the entire detention pond. This is in addition to the dedication required for the pond itself. All owners must prepare and submit a Stormwater Management Maintenance Plan for the proposed detention basin and a long-term Stormwater Management Maintenance Agreement.

O. Pump Detention

Pumped detention systems will not be maintained by the City under any circumstances and will be approved for use only under the following conditions:

1. A gravity system is not feasible from an engineering and economic standpoint.

2. At least two pumps are provided, each of which is sized to pump the design flow rate. If a triplex system is used, any two of the three pumps must be capable of pumping the design flow rate.

3. The selected design outflow rate must not aggravate downstream flooding. (Example: A pumping system designed to discharge at the existing 100-year flow rate each time the system comes online could aggravate flooding for more frequent storm events).

4. Fencing of the control panel is provided to prevent unauthorized operation and vandalism.

5. Adequate assurance is provided that the system will be operated and maintained on a continuous basis.

6. Emergency backup source of power is provided.

It is recommended that if a pumping system is desired, review of the preliminary conceptual design be obtained by the City before any detailed engineering is performed.

P. General Requirements for Detention Pond Construction

The City encourages the use of innovative and aesthetically appealing construction techniques for detention storage. Any detention storage that is not underground or in a parking lot shall be landscaped to ensure the facility is an aesthetic asset to the City. An approved landscaping plan prepared by a registered landscape architect shall be required for all detention areas except those designed underground or in parking areas. The depth of water in parking areas shall not exceed 9 inches. For large regional detention ponds, a landscaping plan may not be required if it will have a multipurpose land use. Detention methods not specifically mentioned previously shall be submitted for prior approval of the City.

The structural design of detention facilities is very similar to the design of open channels. For this reason, all requirements pertaining to the design of lined or unlined channels shall also apply to lined or unlined detention facilities.

In addition, the following guidelines are applicable:

1. Pond Bottom Design–A pilot channel shall be provided in detention facilities to ensure that proper and complete drainage of the storage facility will occur. Concrete pilot channels shall have a minimum depth of 2 inches, minimum width of 4 feet, and a minimum flowline slope of 0.001 feet per foot. Unlined pilot channels shall have a minimum depth of 1 foot, a minimum flowline slope of 0.005 feet per foot, and maximum side slopes of 4 to 1. A geotechnical report shall be prepared and submitted addressing slope stability for all proposed side slopes exceeding 4 to 1.

   The bottom slopes of the detention basin should be graded toward the pilot channel at a minimum slope of 0.005 feet per foot and a recommended slope of 0.01 feet per foot.

   Detention basins that make use of a channel section for detention storage may not be required to have a pilot channel but should be built in accordance with the requirements for open channels.

   Vegetated slopes shall be less than 10 feet in height and shall have side slopes no steeper than 4 to 1.

2. Outlet Structure–The outlet structure for a detention pond is subject to higher than normal head water conditions and erosive velocities for prolonged periods of time. For this reason, the erosion protective measures are very important.

   Reinforced concrete pipe used in the outlet structure should conform to American Society for Testing and Materials (ASTM) C-76 Class III with compression-type rubber gasket joints conforming to ASTM C-443. Pipes, culverts, and conduits used in the outlet structures should be carefully constructed with sufficient compaction of the backfill material around the pipe structure. Generally, compaction density should be the same as the rest of the structure. The use of cement stabilized sand backfill around the outlet conduit should be considered where soil types or conditions may prevent satisfactory backfill compaction. Cement stabilized sand backfill should also be used where headwater depths could cause backfill to wash out around the pipe.

   Where possible, the location and orientation of the flow discharged from a detention pond shall duplicate the predevelopment conditions and minimize increased concentration of discharges.

Q. Abandonment of Existing Facilities

Abandonment of existing detention ponds may be approved by the City if development schemes in a particular area have changed such that they are no longer required, or an acceptable alternative to the detention pond is used as provided by this chapter. Any abandonment will require that the current detention pond be completely filled with material approved by the City. Any alternatives to filling the detention pond must be approved by the City. Abandonment plans are subject to review and approval by the City.