IV Storm Water System Improvements

A. General

This section pertains to the standard principles and practices for the design and construction of storm drainage facilities within the City of Roanoke. The design criteria and procedures described in the following pages are intended to serve as guidelines for the design of the storm drainage facilities provided for developments within the City. Responsibility for the actual design remains with the design engineer. Deviations from the City of Roanoke Texas requirements, standards and criteria must be approved by the City of Roanoke's Director of Public Works or his/her representative.

The City of Roanoke has joined a regional effort to adopt and implement a consistent and intentional storm water management program. The City of Roanoke has adopted the technical portions of the regional integrated Storm Management (iSWM) Manual. The digital versions of the iSWM manual can be downloaded from the following website: http://iswm.nctcog.org/Documents/Development.asp.

Not all design situations will be addressed by these Criteria. Variances will need to be submitted and approved to deviate from the requirements of these Criteria. The Public Works Director reserves the right to require development to be designed by additional or different criteria not presented in this document if it is in the best interest of public safety, health, and welfare.

Materials, construction, and testing shall be in conformance with the City of Roanoke Design Standards and the NCTCOG Standard Specifications for Public Works Construction.

B. Requirements for Construction Plan Submittals

The City of Roanoke encourages developers to discuss the existing and proposed drainage conditions for every development before planning or design efforts begin. Properly identifying and analyzing drainage needs and concerns early will help in the construction plan approval process.

The construction Plans shall generally include, but not be limited to, the following information:

1. A topographic drainage area map of the entire contributing watershed (no greater than a 1"=200' scale). The drainage area map shall include on-site and off-site drainage areas that are delineated appropriately;

2. Plan and profiles of all closed and open drainage systems. Existing and proposed ground elevations, rim and invert elevations gradient, type of pipe and utility crossings shall be shown in the profile;

3. Calculations for all proposed closed and open drainage systems showing the runoff coefficients, time of concentrations, intensities, and runoff discharges for the appropriate design storm events.

The City of Fort Worth's calculations and spreadsheets shall be used for design and construction plan submittal;

4. Detention basin plan sheet, if required, including plan views, profiles views, section views, appropriate details, storage-volume-discharge calculations, outlet design and calculations, freeboard calculations, emergency spillway calculations, easements if necessary, and grading plan near the pond.

5. FEMA floodplain boundaries and fully-developed floodplain boundaries;

6. Preparation and submission of a Conditional Letter of Map Revision (CLOMR) and a Letter of Map Revision (LOMR), when applicable.

7. Location of existing and proposed drainage easements

8. Any required permitting or regulatory requirements from the United States Army Corps of Engineers (USACE), the Texas Commission on Environmental Quality (TCEQ), Environmental Protection Agency (EPA), or other Local, State, or Federal agencies.

9. Description and calculations for existing drainage facilities within and downstream of the development;

10. A detailed drainage study may be required for any development. The information required for a drainage study can be provided in the construction plans or as a separate document. The Drainage Study shall include a hydrologic and hydraulic evaluation. The hydrologic evaluation shall determine the amount of storm water runoff that is generated during pre-development, post-development, and ultimate conditions. The hydraulic evaluation will determine the capacity of the existing, proposed, and ultimate drainage facilities which include closed pipe, culvert systems and open channel systems. An adequate outfall must be identified in the drainage study. An adequate outfall is defined as "one that does not create adverse flooding or erosion conditions downstream and is in all cases subject to the approval of the Director of Public Works."

11. A Downstream Assessment (Adopted from the City of Fort Worth's current version of the *integrated* Storm Water Management Manual-iSWM)

12. The engineer is responsible for performing a downstream assessment to determine the Zone of Influence, capacity of the downstream facilities, and detention basin requirements. A "zone of influence" from a proposed development extends to a point downstream where the discharge from a proposed development no longer has a significant impact upon the receiving stream or storm drainage system. Downstream impacts due to a development must be analyzed and mitigated for the 2-, 25-, and 100-year floods for the entire zone of influence, as determined by the development engineer's analysis. The Zone of Influence for any proposed development must be defined by the development engineer, based on a drainage study that determines the specific locations along the drainage route where "no adverse impacts" from the new development exist.

A drainage study will include the necessary hydrologic and hydraulic analyses to clearly demonstrate that the limits of the Zone of Influence have been identified, and that along the drainage route to that location, these parameters are met:

a. No new or increased flooding of existing insurable (FEMA) structures (habitable buildings),

b. No more than 0.1' increases in flood elevations over existing roadways for the 2-, 10- and 100-year floods.

c. No significant rise (0.1' or less) in 100-year flood elevations, unless contained in existing channel, roadway, drainage easement and/or R.O.W.

d. No significant increases (maximum of 5%) in channel velocities for the 2-, 10- and 100- year floods. Post-development channel velocities cannot be increased by more than 5% above pre-development velocities, nor exceed the applicable maximum permissible velocity shown in iSWM. Exceptions to these criteria will require certified geotechnical/geomorphologic studies that provide documentation that higher velocity will not create additional erosion. If existing channel velocities exceed six (6) feet per second, no additional increase in velocities will be allowed.

e. No increases in downstream discharges caused by the proposed development that, in combination with existing discharges, exceeds the existing capacity of the downstream storm drainage system.

f. For any proposed outfall with a watershed of 100 acres or less, the downstream assessment may use the ten percent rule of thumb (as delineated in Section 2.0 of the Hydrology Technical Manual) or a detailed study in order to determine the Zone of Influence. For all other watersheds, the Zone of Influence will be defined by a detailed hydrologic and hydraulic analysis.

Storm drainage from a development must be carried to an "adequate outfall" or "acceptable outfall." An adequate outfall is one that does not create adverse flooding or erosion conditions downstream and is in all cases subject to the approval of the Director of Public Works. See Zone of Influence definition for the required conditions or criteria to determine the adequacy of an outfall from a proposed development.

Studies of the proposed development and drainage areas, including a downstream assessment of properties that could be impacted by the development, will accompany the drainage study. The "zone of influence" and "adequate outfall point" for the proposed development will be identified in the study and construction plans. These studies will include adequate hydrologic analysis to determine the existing, proposed, and fully-developed runoff for the drainage area that is affected

by the proposed development. They will also include hydraulic studies that help define the "Zone of Influence" and any upstream or downstream offsite effects. The study, as part of the development site plan, shall address existing downstream, off-site drainage conveyance system(s) and define the drainage path from the outfall of the on-site storm water facilities, to the off-site drainage system(s) and/or appropriate receiving waters. It will include a capacity analysis of all existing constraint points such as existing floodplain developments, underground storm drainage systems, culverts/bridges, or channels from the point of storm water discharge of the development downstream to the limits of the "Zone of Influence". Storms to be analyzed will include the 2-, 25-, and 100-year events.

C. Hydrologic Criteria

The City of Roanoke has adopted the hydrologic methods and calculations presented in the City of Fort Worth's version of the *integrated* Storm Water Management Manual (Chapter 2), with the following modifications:

1. The Rational Method can be used for developments smaller than or equal to 100 acres in size. Drainage areas in excess of 100 acres shall use a hydrograph method such as HEC-HMS.

2. USGS and TxDOT equations will not be allowed to be used in the design, unless otherwise approved by the Director of Public Works.

3. The Modified Rational Method for detention basin design can be used for developments less than 25 acres in size and for conceptual and preliminary design purposes only. A hydrograph method must be used for final design purposes for development greater than 25 acres.

4. Runoff computations shall be based upon fully developed conditions in accordance with the ultimate land use assumption in the current Comprehensive Land Use Plan for the City of Roanoke. The drainage facilities shall be designed by disregarding the detention effects of upstream properties and calculating runoff as if the off-site property was developed without any detention. If an approved regional detention/retention facility is in operation, the design engineer may size downstream drainage facilities based on consideration of the detention effects of the regional facility.

5. The intensity-duration Table for the City of Roanoke is included in NCTCOG Appendix A of the iSWM Technical Manual. http://iswm.nctcog.org/technical_manual.asp . Also attached herein.

6. The runoff coefficients for the City of Roanoke are shown in the following table:

Ground Cover	Runoff Coefficient, c
Lawns	0.30
Forest	0.25
Cultivated land	0.41
Meadow	0.40
Parks, cemeteries	0.25
Unimproved areas	0.30
Pasture	0.50
Paved Streets/ Sidewalks	0.90
Brick streets	0.85
Building/Roofs	0.95
Play Grounds	0.40
Paved Parking Lots	0.90
Gravel Parking/Roads	0.80
Railroad Yards	0.45

7. The City of Roanoke will not allow the Simplified SCS Peak Runoff Rate Estimation to be used in design.

8. The design engineer shall provide the City of Roanoke with an exhibit (workmap) and calculations used to develop the unit hydrograph. The exhibit and calculations shall include the drainage area name, size, lag time, curve number, and discharge rates.

D. Hydraulic Design of Streets and Closed Conduits

The City of Roanoke requires closed storm sewer systems to be designed to convey the 25-year storm event with 100-year positive overflow for inlets on grade in streets such that the depth of flow in the street does not exceed the top of curb. The 25-year storm event must be contained within the permissible spread limits. Sag inlets shall be designed to capture the 100-year storm event.

Culverts and bridges shall be designed to convey the 100-year storm event. Emergency overflow paths for all sag and culvert locations shall be identified.

The closed storm sewer system's Hydraulic Grade Line (HGL) must be one (1) foot below the curb line at inlet locations.

1. Spread Criteria
   The spread of water on the roadway shall be limited to prevent the street from losing its effectiveness as a traffic carrier, which is an important concern in the case of emergency vehicles which may not be able to traverse an inundated roadway. The following table lists the allowable flow spread limits based upon the classification of the street.

Table 2: Spread Criteria

Street Classification	Allowable Spread Limits
Local	The 25-year storm event must be contained within the top of curb
Collector	The 25-year storm event spread limit must be contained within one twelve (12) foot lane
Thoroughfare	The 25-year storm event spread limit must be contained within one twelve (12) foot lane in each direction

a. The 100-year storm event must be contained within the right-of-way. Calculations shall be submitted to City staff showing the right-of-way capacity, gutter capacity, and spread limits. Gutter flow shall be based upon a maximum inlet time of 15 minutes. Most situations will use an inlet time of 10 minutes.

b. Inlets shall be installed upstream of intersections, at sag locations or where the allowable spread limits are exceeded.

c. A maximum of five (5) cfs will be allowed to cross intersections of residential streets in the 100-year event. However, only one street shall be crossed with surface drainage at any one intersection, and this street shall be the lower classified street. No surface drainage will be permitted to cross a Collector or Arterial roadway.

d. Inlets shall be located at the appropriate locations on super-elevated cross sectional roadways to prevent the gutter flow from crossing the roadway.

e. When a driveway (residential or commercial) intersects a street, a maximum of five (5) cfs will be allowed to be discharged into the street. If the five (5) cfs is exceeded, an inlet shall be installed upstream to capture the runoff before it enters the street.

f. Spread limits shall be identified on the plans at all sag locations. Emergency overflow paths shall be indicated on the plans.

2. Inlet Design Criteria
   a. Calculations for all inlets shall be in accordance with the City of Fort Worth's adopter version of the integrated Storm Water Management Manual (Chapter 3).

   b. See the TxDOT Hydraulic Design Manual for additional calculations to determine the capacity and size of various types of inlets including depressed inlets.

   c. The minimum inlet size shall be ten (10) feet in width. Curb inlets sizes shall be ten (10), fifteen (15), and twenty (20) feet in width. No more than twenty (20) feet of inlet shall be placed along a gutter at any one location. Inlets shall be located away from areas where pedestrians may frequent (e,g., near mailbox locations).

   d. Curb inlets shall not be used as junction boxes.

   e. Inlet spacing shall meet the spread criteria.

   f. Slotted or combination inlets shall not be allowed unless approved by the Director of Public Works.

3. Closed Conduit System Design Criteria
   a. Calculations for all storm sewer systems shall be in accordance with the City of Fort Worth's version of the integrated Storm Water Management Manual (Chapter 3).

   b. Only public storm sewer pipe shall be reinforced concrete pipe (Class III) and the minimum size of 18".

   c. Storm sewer grades shall not be less than 0.4% unless otherwise approved by the Director of Public Works.

   d. The minimum allowable velocity in a full flow storm sewer conduit shall be 2.5 feet per second.

   e. The maximum allowable velocity in a full flow storm sewer conduit is 12.5 feet per second.

   f. The appropriate full flow or partial flow calculations shall be submitted to City staff for review.

   g. The Hydraulic Grade Line (HGL) shall be established for all storm drainage designs and be included in the profiles of the storm sewer. The 10-year and 100-year HGLs must be shown on the profiles of public storm sewer systems. The HGL shall be shown from the outfall to the upstream system. Allowance of head must also be provided to allow for future extensions of the storm sewer system.

h. The HGL shall be shown whether the storm sewer system is under partial or full flow conditions. If the storm sewer system is under partial flow conditions, the calculations provided shall reflect those conditions.

i. When performing hydraulic analyses for storm drainage system design, the HGL elevation shall begin at the tailwater pool water level or depth of flow in the pipe at the downstream end, whichever is higher. The tailwater elevation shall be based on the ratio of the drainage area of the receiving body of water (at the confluence location) to the drainage area of the system. If the ratio is 15:1 or greater, the 10-year water surface of the receiving body of water shall be used as the starting 100-year HGL elevation. If the ratio is less than 15:1, the 100-year elevation of the receiving body of water shall be used as the starting water surface for design.

j. If a system is discharging into an existing downstream storm drain, the HGL shall be tied into the HGL for the 10-year or 100-year event (as applicable) in the downstream storm drain. It is the design engineer's responsibility to evaluate all data employed in the analysis, including any data used from existing plans or provided by the City. If the existing downstream system is undersized, downstream flooding cannot be increased (this may require additional detention than that required by these guidelines) and the proposed system should be designed to accommodate future downstream drainage improvements.

k. Friction head loss throughout the system during pressure flow shall be determined by direct application of Manning's Equation. A Manning's 'n' value of 0.013 is to be used for these calculations when concrete storm sewer is used.

l. Appropriate headlosses shall be considered in the design of the storm sewer system and hydraulic grade line determination. These headlosses include those losses generated from entrance, expansion, contraction, manhole, bend, and junction losses.

m. The minimum public storm sewer pipe size shall be twenty-one (21) inches for use with ten (10) foot and fifteen (15) foot inlets and twenty-four (24) inches for use with twenty (20) foot inlets.

n. Headloss calculations shall be in accordance with the City of Fort Worth's adopted version of the integrated Storm Water Management Manual (Chapter 3), unless otherwise indicated below:

    a. The minimum headloss shall be 0.1 feet.

    b. The following 'K' values shall be used in the head loss calculations.

Table 3: Headloss Coefficients for Junctions and Inlets

Description of Conditions	Coefficient K
Inlet on main line	0.50
Inlet on main line with branch lateral	0.25
Manhole on main line with 45 degree branch lateral	0.50
Manhole on main line with 60 degree branch lateral	0.35
Manhole on main line with 90 degree branch lateral	0.25
45 degree wye connection or cut-in	0.75
60 degree wye connection or cut-in	0.70
Inlet or manhole at beginning of line	1.25

Table 4: Headloss Coefficient Due to Pipe Curvature

	Kb		
Conduit on Curves	**Degree of Pipe Bend**		
	90 degree	**60 degree**	**45 degree**
Pipe Radius=Diameter	0.50	0.43	0.35
Pipe Radius=2x to 8x Diameter	0.25	0.21	0.18
Pipe Radius =8x to 20x Diameter	0.40	0.34	0.28

Table 5: Headloss Coefficient Due to Sudden Enlargements and Contractions

D2/D1*	Sudden Contractions-Kj
1.2	0.08
1.4	0.18
1.6	0.25
1.8	0.33
2.0	0.36
2.5	0.40
3.0	0.42
4.0	0.44
5.0	0.45
10.0	0.46

* D_2/D_1-Ratio of larger to smaller diameter

4. Easements for Closed Conduit Systems

   a. Refer to Part B Technical Standards for minimum easements widths for storm sewer systems.

   b. Drainage easements for box culverts shall include the width of the box culvert plus ten (10) feet on each side of the box culvert.

   c. Drainage easements shall be provided for all public water crossing private property. The easements shall extend to an acceptable outfall location.

E. Hydraulic Design of Open Channels, Culverts, Bridges, and Detention Structures

1. Design Storm Recommendations

a. Storm Sewer Systems: Storm drainage systems shall be designed for the 10-year storm event with the 100-year storm event being contained within the right-of-way. If the right-of-way does not have the capacity to contain the 100-year storm event, or the 10-year hydraulic grade line is less than one (1) foot below the gutter line, the storm sewer system shall be designed for a 100-year storm event.

b. Roadway Culvert Designs: Culverts shall be designed for a 100-year storm event. Emergency overflow paths shall be shown on the plans. One (1) foot of freeboard is required, unless the freeboard requirement adversely affects adjacent development.

c. Open Channel Design: Open channels shall be designed for the fully developed, 100-year storm event.

d. Energy Dissipation Design: Energy dissipation shall be designed for the fully developed, 100-year storm event. The City discourages the use of energy dissipaters except where hydraulically constrained (subcritical flow throughout the drainage system is preferred).

e. Storage: Detention shall be designed to contain the 2-year, 10-year and 100-year storm events. All detention facilities shall be designed with a one (1) foot freeboard requirement.

f. A minimum of two (2) feet of vertical separation is required (outside of pipe to outside of pipe) between the storm sewer and other public utilities, except as required by TCEQ regulations. Separation closer than two (2) feet requires concrete or steel encasement of the utility lines, unless otherwise approved by the Director of Public Works.

2. Culvert Design

Calculations for the culvert design shall be provided to City staff for review. The calculations shall include upstream and downstream headwater and tailwater conditions, existing, proposed, and ultimate flows and velocities, hydraulic grade lines and appropriate erosion control calculations and designs. A backwater analysis using HEC-RAS is required.

3. Bridge Design

Calculations for the bridge design shall be provided to City staff for review. The calculations shall include upstream and downstream headwater and tailwater conditions, existing, proposed, and ultimate flows and velocities, hydraulic grade lines and appropriate erosion control calculations and designs. A backwater analysis using HEC-RAS is required. The HEC-RAS model may be required to be submitted to City Staff for review. Should the bridge be FEMA regulated, the effective FEMA HEC-2 or HEC-RAS model must be used. One (1) foot of freeboard from the water surface elevation to the low chord is required for bridge structures, unless the freeboard requirement adversely affects adjacent development.

4. Open Channel Design

a. Calculations for open channel designs and shall be provided to City staff for review. Open channels shall be designed for the fully developed, 100-year storm event. The calculations

shall include upstream and downstream headwater and tailwater conditions, existing, proposed, and ultimate flows and velocities, hydraulic grade lines and appropriate erosion control calculations and designs. A backwater analysis using HEC-RAS is required.

b. Open channels shall have earthen side slopes no steeper than four (4) to one (1) vertical and concrete lined side slopes no steeper than 1.5 to one (1).

c. All unpaved channels shall have a minimum longitudinal slope of 0.6%, unless otherwise approved by the Director of Public Works. A pilot channel shall be included in all improved major earthen channels.

d. Velocities within improved channels shall not exceed pre-improved channel velocities by more than 5% and shall not exceed six (6) feet per second. If velocities exceed six (6) feet per second, appropriate erosion control and channel lining consideration shall be incorporated into the design.

e. At the discretion of the Director of Public Works, fencing and/or guardrails shall be provided for the benefit of public safety along open channels, and detention ponds.

f. Maintenance ramps shall be included in the open channel designs and shall be at least ten (10) feet wide with a maximum grade of 15%.

g. Roadside ditches and other smaller swales shall be designed in accordance with the open channel design criteria presented above, unless otherwise directed by the Director of Public Works.

h. Riprap shall be designed by Method #2 (The Gregory Method) as described in Section 3.2.7 of the iSWM Hydraulics Technical Manual. A properly designed geotextile material is required under the granular bedding. The City of Fort Worth standard specifications give guidance on the type of geotextile to be used. Regardless of the minimum allowable riprap thickness, the minimum riprap thickness is 12 inches. Surface runoff from residential lots shall cross no more than one additional lot before being directed toward the street or a dedicated drainage system. When the flow reaches the second lot, side lot swales shall be in place to direct the flows to the street or to a dedicated City drainage system within an easement in the rear yard. Where lot to lot drainage occurs, the lot lines shall be aligned and a dedicated private drainage easement shall be provided.

5. Storage Design
   a. Detention basins will be required if the downstream facilities within the "Zone of Influence" are not adequately sized to convey the appropriate design storm. Detention facilities shall be designed to detain the difference between pre-developed and developed runoff conditions.

   b. Detention basins shall be designed using a unit hydrograph method if the contributing drainage area is greater than one hundred (100) acres.

c. The detention basin will be designed for the 2-year, 10-year and 100-year storm events. A multistage outfall structure will be required. Detailed design calculations including outfall structure design and detention pond storage-elevation-discharge tables will be required to be submitted to City staff.

d. Earthen side slopes shall not exceed four (4) to one (1).

e. A pilot channel shall be used within detention basins with a minimum bottom width of five (5) feet.

f. The design of detention facilities shall include provisions for collecting and removing sediment deposited after collecting and releasing storm water.

g. The City does not assume maintenance for private detention ponds. All detention ponds must be placed in a private drainage easement dedicated on the final plat. Public storm sewer infrastructure draining to or away from a private detention facility must be placed in a public drainage easement. In cases where a private detention pond will be used by owners platting separate lots, a Joint Detention Agreement must be in place between the property owners and must be accepted by the City prior to the property being final platted.

h. Detention is allowed in parking lots. Detention in parking lots may not be deeper than six (6) inches in depth at any location, except in truck only parking areas where a maximum of nine (9) inches of may be stored. Parking spaces inundated by detained storm water may not be counted toward required parking ratios for the development. Warning signs must be placed on the site designating that the area may be inundated in an extreme storm event.

i. Detention facilities shall be designed to empty in less than 24 hours, unless it is also serving as a sediment control facility.

j. Detention facilities shall not be counted as an erosion control measure unless:

    a. The basins are designed to empty a minimum of 24 hours from the storm event, and

    b. Adequate sediment storage areas in the basin are set aside and maintained.

k. The property owner shall maintain all detention facilities. A maintenance plan must be included on the final construction plans outlining these minimum measures:

    a. Facilities shall be mowed at least twice a year to control weeds and discourage woody growth.

b. Debris, litter, and accumulated sediment shall be removed from detention facilities at least twice a year. Particular attention should be given to removal of debris, litter, and sediment around outlet structures.

l. Conformance with the maintenance plan as approved by the City Engineer is the responsibility of the owner of the detention facility.

m. An emergency spillway shall be designed one (1) foot above the 100-year water surface elevation. The emergency overflow path shall be indicated on the plans.

n. State rules and regulations regarding dam design and safety requirements shall be observed including 30 TAC Chapter 299, Dams and Reservoirs (TCEQ). Water rights permitting, rules, and regulations shall also be considered.

o. A maintenance plan shall be submitted to City staff for review.

6. Energy Dissipation
A backwater analysis is required to design energy dissipaters. The analysis shall be submitted to City staff for review. If the current effective FEMA model is available, the engineer shall use this model for design purposes.

7. Easements for Open Channel and Detention Basins
   a. Drainage easements are required for both on-site and off-site public storm sewer and open channel systems.

   b. The floodplain, both FEMA and fully developed, shall be dedicated to the City as a drainage easement. For all channelization, the easement shall be at least twenty (20) feet wider than the top of the channel banks, with fifteen (15) feet on one side and five (5) feet on the other side with dedicated vehicular access available to public right-of-way.

   c. Temporary drainage easements may be allowed for temporary channels and swales. These easements will not be dedicated and maintained by the City.

   d. Drainage easement for channels must remain as a separate easement from other proposed or existing easements (e.g. water, sewer, etc.).

   e. Easements for detention basins shall be negotiated between the City and the Property Owner.

8. Development within the Floodplain
   a. All development within the Federal Emergency Management Agency (FEMA) floodplain or 100-year fully developed floodplain shall require the approval of the City Engineer.

   b. The City Engineer should be contacted for information on approved floodplain hydraulic models for fully developed watershed conditions for the channels in the City. If a hydraulic

model is not available from the City, then it must be provided by the developer of the property.

c. Prior to the approval for preliminary grading for proposed development within the 100-year fully developed floodplain, a floodplain study must be submitted to and approved by the City. The floodplain study must show that the proposed alterations to the floodplain will not increase the 100-year fully developed floodplain elevation at any location along the channel. This report must contain the following items:

   i. A written report describing the project and summarizing the effects of the floodplain study. This narrative should contain tables comparing the pre-and post-project flood elevations.

   ii. A hydraulic model of the floodplain's existing condition. This model should be produced using the United States Army Corps of Engineers HEC-RAS modeling program. The City will accept any version of HEC-RAS that is accepted by the (FEMA). HEC-2 models are permitted if the effective 100-year fully developed hydraulic model was previously developed using HEC-2 software. The cross sections within the model~~ing~~ must be based on the FEMA datum (NGVD 29).

   iii. A hydraulic model of the proposed condition of the floodplain. This model shall account for any changes proposed within the floodplain.

   iv. Stream profiles and cross sections generated by the hydraulic modeling software.

   v. Floodplain maps of the existing and proposed conditions. These maps shall be based on a minimum of 2-foot topographic contours that are based on the FEMA vertical datum. The proposed condition floodplain ~~work~~ map must include the proposed grading and the limits of the proposed development within the floodplain.

   vi. If the 100-year fully developed flow is not available from the City, or if the Developer wishes to update the 100-year fully developed flow for the channel, the report must document the generation of the fully developed peak flow value. The methodology required to determine these flows is the same as that describe in the "Hydrology" section of this Ordinance.

d. The FEMA floodplains and floodways include all areas ~~so~~ depicted on FEMA's Flood Insurance Rate Maps (FIRMs).

e. A LOMR submittal to FEMA must be submitted to the City upon completion of the fill within the floodplain. This submittal must follow the criteria set forth by FEMA. The

National Flood Insurance Program (NFIP) guidelines 65.3 and associated references are hereby incorporated by reference.

f. If the proposed development encroaches on the FEMA floodway or includes on-line bridge or culvert construction or modifications, then a CLOMR submittal must be produced and accepted by both the City and FEMA.

g. A CLOMR may be required for developments that do not encroach on the FEMA floodway at the City Engineer's discretion.

h. If a CLOMR is required by the City, a building permit will not be granted for the subject tract until (at a minimum) the CLOMR has been approved by the City.

i. The CLOMR and LOMR must have properly completed FEMA forms that specify that the City will not conduct ~~no~~ maintenance for the improvements (except for public streets, bridges, and culverts).

j. The finished floor (FF) elevation of commercial buildings shall be a minimum of 1 foot above the 100-year fully-developed water surface elevation (WSEL) of the adjacent floodplain. The FF elevation of residential buildings shall be a minimum of 2 feet above the 100-year fully-developed WSEL of the adjacent floodplain.

Table 5.3 Denton County Rainfall Data

		Return Period (Years)						
	Coefficients	1	2	5	10	25	50	100
	e	0.82089	0.80553	0.79891	0.78388	0.76912	0.76817	0.75660
	b	43.381	50.455	65.467	70.683	78.538	89.853	95.776
	d	T8	9	11	11	11	12	12
Hours	Minutes	Rainfall Intensity (inches per hour)						
0.083	5	5.28	6.02	7.15	8.04	9.31	10.19	11.23
	6	4.97	5.70	6.81	7.67	8.89	9.76	10.75
	7	4.70	5.41	6.50	7.33	8.50	9.36	10.32
	8	4.46	5.15	6.23	7.03	8.16	9.00	9.93
	9	4.24	4.92	5.98	6.75	7.84	8.67	9.57
	10	4.04	4.71	5.75	6.50	7.55	8.36	9.24
	11	3.87	4.52	5.54	6.27	7.29	8.08	8.93
	12	3.71	4.34	5.35	6.05	7.04	7.82	8.65
	13	3.56	4.18	5.17	5.85	6.82	7.58	8.39
	14	3.43	4.04	5.00	5.67	6.61	7.36	8.14
0.250	15	3.31	3.90	4.85	5.50	6.41	7.14	7.91
	16	3.19	3.77	4.70	5.34	6.23	6.95	7.70
	17	3.09	3.66	4.57	5.19	6.05	6.76	7.50
	18	2.99	3.55	4.44	5.05	5.89	6.59	7.31
	19	2.90	3.44	4.32	4.91	5.74	6.43	7.13
	20	2.81	3.35	4.21	4.79	5.60	6.27	6.96
	21	2.73	3.26	4.11	4.67	5.46	6.12	6.80
	22	2.66	3.17	4.01	4.56	5.34	5.99	6.65
	23	2.59	3.09	3.91	4.45	5.21	5.85	6.50
	24	2.52	3.02	3.82	4.35	5.10	5.73	6.36
	25	2.46	2.95	3.74	4.26	4.99	5.61	6.23
	26	2.40	2.88	3.66	4.17	4.89	5.50	6.11
	27	2.34	2.81	3.58	4.08	4.79	5.39	5.99
	28	2.29	2.75	3.51	4.00	4.69	5.28	5.88
	29	2.24	2.69	3.44	3.92	4.60	5.18	5.77
0.500	30	2.19	2.64	3.37	3.85	4.51	5.09	5.66
	31	2.14	2.58	3.31	3.77	4.43	5.00	5.56
	32	2.10	2.53	3.24	3.71	4.35	4.91	5.47
	33	2.06	2.49	3.18	3.64	4.28	4.83	5.38
	34	2.02	2.44	3.13	3.58	4.20	4.75	5.29
	35	1.98	2.39	3.07	3.51	4.13	4.67	5.20
	36	1.94	2.35	3.02	3.46	4.06	4.59	5.12
	37	1.91	2.31	2.97	3.40	4.00	4.52	5.04
	38	1.87	2.27	2.92	3.35	3.94	4.45	4.96
	39	1.84	2.23	2.88	3.29	3.88	4.38	4.89
	40	1.81	2.19	2.83	3.24	3.82	4.32	4.82
	41	1.78	2.16	2.79	3.19	3.76	4.26	4.75
	42	1.75	2.13	2.74	3.15	3.71	4.20	4.68
	43	1.72	2.09	2.70	3.10	3.65	4.14	4.62
	44	1.69	2.06	2.66	3.06	3.60	4.08	4.56
0.750	45	1.67	2.03	2.63	3.01	3.55	4.02	4.50
	46	1.64	2.00	2.59	2.97	3.50	3.97	4.44
	47	1.62	1.97	2.55	2.93	3.46	3.92	4.38
	48	1.59	1.94	2.52	2.89	3.41	3.87	4.32
	49	1.57	1.92	2.49	2.85	3.37	3.82	4.27
	50	1.55	1.89	2.45	2.82	3.33	3.77	4.22
	51	1.53	1.86	2.42	2.78	3.28	3.73	4.17
	52	1.51	1.84	2.39	2.75	3.24	3.68	4.12
	53	1.49	1.82	2.36	2.71	3.21	3.64	4.07
	54	1.47	1.79	2.33	2.68	3.17	3.60	4.02
	55	1.45	1.77	2.30	2.65	3.13	3.55	3.98
	56	1.43	1.75	2.28	2.62	3.09	3.51	3.93
	57	1.41	1.73	2.25	2.59	3.06	3.48	3.89
	58	1.39	1.71	2.22	2.56	3.03	3.44	3.85
	59	1.37	1.69	2.20	2.53	2.99	3.40	3.81
1	60	1.36	1.67	2.17	2.50	2.96	3.36	3.77
2	120	0.81	1.01	1.33	1.55	1.85	2.11	2.38
3	180	0.59	0.74	0.99	1.15	1.38	1.58	1.79
6	360	0.34	0.43	0.58	0.68	0.83	0.95	1.09
12	720	0.19	0.25	0.34	0.40	0.49	0.57	0.65
24	1440	0.11	0.14	0.20	0.23	0.29	0.33	0.39