CITY OF BIXBY
STORMWATER DRAINAGE CRITERIA

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E.1 GENERAL REQUIREMENTS

E.1.1 Master Drainage Plans

If a Stormwater Master Drainage Plan is adopted for the area under consideration, proposed stormwater drainage systems shall comply with the provisions of the plan.

E.1.2 Storm Drainage System

E.1.2.1 All stormwater runoff shall be reviewed by the City Council with regard to analysis, design and construction of drainage facilities. The appropriate public authority shall have the right to cause to be maintained the drainage system for its intended purposes. Floodplain variances must be submitted to the City Council.

Review of plans by the City Engineer does not release the Consulting Engineer from his professional responsibility to meet the planning and design objectives of the project as required by good engineering practice and the City of Bixby. The City will exercise justifiable reliance based upon the consulting engineer's submitted design.

E.1.2.2 Drainage facilities, both public and private, shall consist of all elements necessary to convey stormwater runoff from its contact with the earth to its disposition in the Arkansas River.

The drainage system, both public and private, may consist of storm sewers (which are closed conduits); improved channels constructed in conformity with adopted City Standards; unimproved drainageways left in their natural condition; the areas covered by restricted drainage easements for the purpose of providing overland flow; and all appurtenances to the above including inlet, manholes, junction boxes, headwalls, dissipaters, culverts, etc. All portions of the drainage system that exist on dedicated drainage rights-of-way or restricted drainage easements shall be owned and maintained as provided by City of Bixby ordinance, agreement, or covenant.

E.1.2.3 The stormwater drainage system shall be designed to receive and pass the runoff from a 100-year frequency rainstorm within dedicated easements under full urbanization. Full urbanization is defined as the total development in an area that is anticipated. The entire flow shall be confined within the said stormwater drainage system.

Subject to requirements for Earth Change Permits and of the City Drainage Standards, improvement of downstream conveyance may be required if such improvements comply with the policies of this chapter, or if current flooding problems exist, subject to the review of the City Engineer.

E.1.2.4 The stormwater collection system shall be designed for either of the following conditions:

A. Convey:

1. A minimum of the runoff from a 5-year frequency rainstorm in a pipe network with overland flow capacities so that the combination of any two will pass the runoff from a 100-year frequency rainstorm under

fully urbanized conditions; or

2. The entire runoff from a 100-year frequency rainstorm may be contained in the pipe network. Should the entire runoff from a 100-year frequency rainstorm be conveyed in a pipe network, a bypass system shall be designed considering the pipe network to be 50% blocked. If it can be demonstrated that, in unique situations, property damage or flooding will not occur, a smaller by-pass system may be required by the City Council.

B. Where sump collection systems are used, an overflow route shall be established in the event of complete blockage of the sump.

C. Runoff from areas greater that one half (1/2) acre outside the roadway shall be collected before it reaches the roadway. Parking lots shall have internal drainage systems so as to reduce concentrated flows into streets. This item does not apply to single-family residential lots on local streets.

D. Inlets shall be located at intersections to prevent the flow from crossing the intersection. Inlets at intersections shall be located so they do not encroach upon the curb return. No drainage structure shall be permitted at a wheelchair ramp.

E. Drainage areas, runoff from 5-year and 100-year frequency rainstorms, time of concentration, and inlet design for each inlet shall be summarized and tabulated on the plans. This summary table shall also be a part of the drainage calculations.

E.1.3 Drainage Easements

E.1.3.1 Drainage easements will be required for all stormwater management facilities, not in public rights of way; including storm sewers, channels, storage areas and other hydraulic structures. Drainage easements need not be exclusive, but other uses shall not restrict the drainage purposes within the easement.

E.1.3.2 The easement dedication should clearly identify that the purpose includes operation and maintenance of stormwater management facilities. Widths and specific purposes (i.e.: storm sewer, maintenance access, channel, etc.) for drainage easements shall be shown on all plats.

E.1.3.3 For storm sewers, the widths of the easements are determined by the size of the sewer and equipment needed to remove, replace or repair the sewer. For channels, storage areas and other structures, the width of the easement is generally determined by the size of the facility and the equipment needed for maintenance. Typically, the easement will cover the entire facility, plus 20 feet for maintenance access.

E.1.3.4 The overland flow portion of the collector system shall be confined to dedicated rights-of-way, or restricted drainage easements to assure that stormwater can pass through the development without inundating the lowest level of any building, dwelling, or structure. Restricted drainage easements shall be shown on the plat. The stormwater runoff from no more than 3 lots, or ½ acre whichever is less,

shall be allowed onto another lot or between 2 lots. If more lots or area needs to be drained, then an underground storm sewer shall be required.

E.1.4 Maintenance

E.1.4.1 Owner's Maintenance Responsibility. It shall be the responsibility of all owners of property, whether undeveloped, developed, or undergoing development to:

A. Mow and provide minor maintenance of drainage channels and their slopes for that portion of the channel lying within their property line.

B. Keep clear all drainage channels within the boundaries of their properties in accordance with the requirements of this article.

C. Control all storm water runoff and drainage, erosion and sedimentation from points and surfaces on the property.

D. Prevent any and all drainage interferences, obstructions, blockages, or other adverse effects upon drainage, into, through, or out of the property.

E. Not take any action which will alter or otherwise change designed and installed storm water management control systems and not take any action on existing property that shall adversely affect stormwater runoff in any manner contrary to the provisions of this Section, whether temporary, permanent, or a combination thereof.

E.1.4.2 The City may require improvements, provision of drainage easements, and for provision of improvements, agreements, and/or easements beyond the boundaries of the subdivision, development, or property improvement to facilitate flow of stormwater from or through the property, to avoid damage from changed runoff conditions, to provide continuous improvement of the overall storm drainage system, and to accommodate all drainage conditions or requirements. Where stormwater runoff flows require the logical extension of any street or its associated drainage in order to prevent flooding, ponding, or uncontrolled runoff, the extension shall be provided by the developer.

E.1.4.3 During all construction activity and all other non-construction activity developers, property owners and contractors shall be required to keep streets, gutters, inlets, drainage pipes, swales, ditches, drainage channel, and all drainage devices and structures clean and free from debris, sedimentation, soil, and any materials. Any failure to meet this requirement shall, upon notice and failure to immediately correct the notified condition, constitute sufficient grounds for stopping all work until correction is completed.

E.1.4.4 Developers, property owners, or their legal agents, upon receipt of notice by the City of Bixby that repair or maintenance is required within a channel lying within their property, shall be responsible for effecting such repair or maintenance within the time specified, or the City shall have repair and maintenance performed at the expense of the property owner.

E.1.4.5 City's Maintenance Responsibility. It shall be the responsibility of the City to:

A. Repair and maintain drainage channels and their slopes when located within or upon rights-of-way dedicated and accepted by the City

Council.

B. Develop and implement standards and specifications required to clearly and accurately interpret the physical requirements of this section.

C. Design and implement a Drainage Master Plan for urban drainage, storm water management, and flood control.

D. Make such necessary improvements of primary and secondary drainage channels that cannot or will not be improved through private development.

E. Improve and maintain floodway and flood fringe areas that are dedicated public areas, rights-of-way, parklands, or public-owned buildings or developments.

F. Improve and maintain all public-owned drainage channels or systems outside the flood fringe area.

E.1.5 Drainage Reports

E.1.5.1 Report Contents. The Drainage Report shall contain the applicable information listed:

General location and description

Location

1. Township, range, section, ¼ section
2. Local streets within and adjacent to the subdivision
3. Major drainageways and facilities
4. Names of surrounding developments

Description of Property

1. Area in acres
2. Ground cover (type of trees, shrubs, vegetation)
3. Major drainageways

Drainage basins and sub-basins

Major Basin Description

1. Reference to major drainageway-planning studies such as Master Drainage Plans, flood hazard delineation reports, and flood insurance rate maps.
2. Major basin drainage characteristics
3. Identification of all drainage system components within 50-feet of the property boundary.

Sub-Basin Description

1. Historic drainage patterns of the property in question
2. Off-site drainage flow patterns and impact of development

Drainage design criteria.

Regulations: Discussion of the optional criteria selected or the deviation from this criteria, if any

Development Criteria Reference and Constraints

1. Previous drainage studies (i.e., Project master plans) for the site in questions that influence or are influenced by the drainage design and how the plan will affect drainage for the site.

2. Discussion of the drainage impact of site constraints such as streets, utilities, railways, existing structure, and development of site plan

Hydrological Criteria

1. Design rainfall
2. Runoff calculation method
3. Detention discharge and storage calculation method
4. Design storm recurrence intervals
5. Discussion and justification of any criteria or calculation methods used that are not presented in or referenced by this criteria.

Hydraulic Criteria

1. References for calculation of facility capacity
2. Detention outlet type
3. Grade control structure criteria used
4. Discussion of any drainage facility design criteria used that are not presented in this criteria.

Drainage facility design

General Discussion of

1. Proposed and typical drainage patterns
2. Compliance with off-site runoff considerations
3. The content of tables, charts, figures, plates, or drawings presented in the report.
4. Anticipated and proposed drainage patterns

Specific Discussion of

1. Drainage problems encountered and solutions at specific design points
2. Detention storage and outlet design
3. Maintenance access and aspects of the design
4. Actual maintenance agreement
5. Easements and/or RPW dedications required

Conclusions

Compliance with new Standards

1. Storm Water Criteria
2. Major Drainageway Planning Studies
3. 100-year floodplain after proposed project

Drainage Concept

1. Effectiveness of drainage design to control damage from storm runoff
2. Influence of proposed development on the Major Drainageway Planning Studies recommendation(s)

References

Reference all criteria and technical information used

Appendices

Hydrologic Computations

1. Land use assumptions regarding adjacent properties
2. Minor and major storm runoff at specific design points
3. Historic and fully developed runoff computations at specific design points
4. Hydrographs at critical design points

Hydraulic Computations

1. Culvert capacities
2. Storm sewer capacity
3. Street capacity

4. Storm inlet capacity including inlet control rating at connection to storm sewer
5. Open channel design
6. Check and/or channel drop design
7. Detention area/volume capacity and outlet capacity calculations

The report shall contain a certification sheet as follows:

"I hereby certify that this report (plan) for the preliminary drainage design of (Name of Development) was prepared by me (or under my direct supervision) in accordance with the provisions of City of Bixby Stormwater Criteria Manual for the owners thereof."

(SEAL)_____
Signature

E.1.5.2 Drawing contents

Sheet-1 – General Location Map: A map shall be provided in sufficient detail to identify drainage flows entering and leaving the development and general drainage patterns. The map should be at a scale of 1" = 200' to 1" = 2000' and show the path of all drainage from the upper end of any off-site basins to the defined major drainageways. The map shall identify any major construction (i.e., Developments, irrigation ditches, existing detention facilities, culverts, main storm sewers), along the entire path of drainage. The size of the drawings shall be a multiple of 8½" x 11".

Sheet-2 – Floodplain Information: A copy of the regulatory floodplain map showing the location of the subject property shall be included with the report. The size of drawings shall be multiple of 8½" x 11.

Sheet-3 – Drainage Plan: Map(s) of the proposed development at a scale of 1" = 20' to 1" = 200' on a 22" x 24" drawing shall be included. The plan shall show the following:

1. Existing and proposed contours at 2-foot maximum intervals. In terrain where the slope is relatively flat, spot elevations with drainage arrow may be substituted.
2. Property lines, and easements with purposes noted: Name, address and telephone number of legal owner of property; vicinity sketch.
3. Streets, roads and highways adjacent to the property.
4. Existing drainage facilities and structures, natural or man-made, including, roadside ditches, drainageways, gutter flow directions and culverts. All pertinent information such as material, size, shape, slope, and location shall also be included.
5. Overall drainage area boundary and drainage sub-area boundaries.
6. Proposed type of street flow (i.e., Vertical or combination curb and gutter), roadside ditch gutter flow directions, and cross-pans.
7. Proposed storm sewers and open drainageways, including inlets, manholes, culverts, retaining walls, erosion control measures, and other appurtenances.

8. Proposed outfall point for runoff from the developed area and facilities to convey flows to the final outfall point without damage to downstream properties.
9. Routing and accumulation of flows at various critical points for the minor storm runoff.
10. Path(s) chosen for computation of time-of-concentration.
11. Details of detention storage facilities and outlet works.
12. Location and elevations of all defined floodplains affecting the property.
13. Location and elevations of all existing and proposed utilities affected by or affecting the drainage design.
14. Routing of off-site drainage flow through the development.
15. Bar graph illustrating estimated timing of construction schedule.

E.1.6 Stormwater Detention Requirements

E.1.6.1 Depending upon ownership of the site and the area tributary to a stormwater detention site, two types of stormwater detention are defined: on-site and regional. On-site detention is defined as the privately owned and generally privately maintained facility, which serves the developing area in question. Regional detention is defined as privately or publicly owned and maintained facilities that are generally part of a planned open space park system or greenbelt area serving a larger portion of the watershed. The importance of regional detention is the assurance that the facility will be maintained and will function as designed. The City will determine whether detention facilities will be private or public.

E.1.6.2 The following requirements apply to all watersheds within the City:

A. In the absence of planned regional stormwater detention sites or planned channel improvements, on-site stormwater detention is required, unless the proposed system will connect to an existing system with 100-year flood capacity, subject to approval by the City.

B. Downstream conveyance may be improved to compensate for increased flows if the improvements convey the water to an existing system with 100-year flood capacity, subject to approval by the City.

C. Stormwater detention facilities will be owned and maintained by the private sector. Those facilities must meet the performance standards of the City's criteria. The facilities may be either wet or dry depending upon multiple-use and water quality considerations. Wet detention shall be reviewed by the City Council, and shall have adequate flow through to maintain water levels. Mosquito control shall be incorporated into the maintenance plan.

D. If required by the City, an owner will contribute to the cost of a regional detention site(s) or improvements to downstream conveyances in lieu of constructing on-site detention. The developer must adequately demonstrate that "in lieu of" downstream storage will mitigate the increased runoff from the development. In addition, there cannot be any direct identifiable adverse impacts on downstream properties. The fee in-lieu-of amount shall be established by an ordinance reviewed by the City.

E.1.6.3 Fees In Lieu of On-site Detention:

If the City requires fee in lieu of providing on-site detention, the fee shall be calculated as follows:

Commercial and Industrial Developments:

Fee = Rate x Impervious Area
Rate = Fee rate as set by ordinance (cents per square foot)
Impervious Area = Actual increase in impervious area (square feet)

NOTE: Fee must be paid before building permit will be released.

Multi-family Residential Developments:

Fee = Rate x Impervious Area
Rate = Fee rate as set by ordinance (cents per square foot)
Impervious Area = Actual increase in impervious area (square feet)

NOTE: Fee must be paid before building permit will be released.

Residential Developments:

Fee = Rate x Impervious Area
Rate = Fee rate as set by ordinance (cents per square foot)
Impervious Area = Area is calculated as follows:

1. Obtain the housing density (lots per acre) by dividing the platted acreage into the number of platted lots.

2. Obtain the percent of impervious area by using the calculated housing density and Figure E.1.1, "Residential Housing Density vs. Impervious Area," included in this Section.

3. Multiply the percent of impervious area by the platted acreage to obtain the impervious area.

4. Convert the results to square feet.

NOTE: Fee must be paid before the plat will be released for filing.

E.1.7 Variances

A variance is grant of relief from any of the requirements of the Engineering Criteria for the City of Bixby when specific enforcement would result in unnecessary hardship. A variance, therefore, permits development or construction in a manner otherwise prohibited by the drainage criteria and may only be granted by the City Council.

E.2 RAINFALL / RUNOFF / FLOODPLAIN REQUIREMENTS

E.2.1 Storm Frequency Rainfall

Two publications were used to develop the design rainfall. The US Department of Commerce, US Weather Bureau "Technical Paper No. 40, Rainfall Frequency Atlas of the United States" (Reference 17) was used for cumulative rainfall data of storm durations greater than 1-hour. The National Oceanic and Atmospheric Administration (NOAA) "Technical Memorandum NWS HYDRO-35" (Reference 18) was used for cumulative rainfall data of storm durations from 5- to 60-minutes.

The cumulative point rainfall data for the 2-, 5- and 10-year storms from the US Department of Commerce requires conversion from a partial-duration series to an annual series. The partial-duration series is a series so selected that their magnitude is greater than a certain base value. If the base value is selected so that the number of values in the series is equal to the number of the record, the series is called an annual exceedance series. This conversion is calculated using the factors listed in Reference 17 and repeated below:

FIGURE E.1.1

FACTORS FOR CONVERTING
PARTIAL DURATION SERIES TO ANNUAL SERIES

RETURN PERIOD	CONVERSION FACTOR
2-YEAR	0.88
5-YEAR	0.96
10-YEAR	0.99

The total rainfall depths for durations of five minutes to 24-hours and for return periods of 1-year to 500-years were developed and are presented in Table E.2.1. The data have been converted to an annual series.

TABLE E.2.1

	TOTAL RAINFALL DEPTHS (U.S. DEPARTMENT OF COMMERCE) Frequency (Return Period)							
Duration	1-year	2-year	5-year	10-year	25-year	50-year	100-year	500-year
5-minute	0.30	0.42	0.55	0.62	0.72	0.80	0.87	1.04
10-minute	0.65	0.77	0.94	1.07	1.24	1.36	1.49	1.70
15-minute	0.89	1.01	1.22	1.39	1.58	1.74	1.93	2.20
30-minute	1.15	1.32	1.73	2.00	2.28	2.58	2.85	3.40
1-hour	1.50	1.62	2.23	2.61	3.04	3.44	3.80	4.75
2-hour	1.76	1.94	2.75	3.25	3.80	4.40	4.75	6.00
3-hour	1.94	2.18	3.05	3.63	4.25	4.75	5.37	6.80
6-hour	2.25	2.44	3.70	4.36	5.20	5.78	6.40	8.25
12-hour	2.75	2.97	4.38	5.15	6.10	6.80	7.60	9.85
24-hour	3.18	3.43	4.98	6.04	7.00	7.78	8.75	11.50

E.2.2 RUNOFF

E.2.2.1 APPROVED METHODS

A. Table E.2.2 contains methods of runoff which analysis may be used for the design of components of the storm drainage system as applicable.

TABLE E.2.2

	Applicable for		Minimum. Drainage Area, AC	Maximum Drainage Area, AC
	Peak Q	Volume Calc.		
Rational Method	Yes	No	0	200
SCS Method	Yes	Yes	2	2000
Snyder Method	Yes	Yes	2	None
Unit Volume Relationship	No	Yes	0	2

E.2.2 RATIONAL METHOD

E.2.2.1 Formula: The Rational Method is based on the formula: $Q = CIA$

"Q" is defined as the maximum rate of runoff in cubic feet per second. "C" is a runoff coefficient of the area. "I" is the average intensity of rainfall in inches per hour for a duration equal to the time of concentration. The time of concentration is the time required for water to flow from the most remote point of the basin to the point being investigated and to reach a steady state condition. "A" is the contributing watershed area in acres.

E.2.2.2 Time of Concentration:

A. One of the basic assumptions underlying the Rational Method is that runoff is a function of the average rainfall rate during the time required for water to flow from the most remote part of the drainage area to the point under consideration.

B. The time of concentration consists of overland flow time, T_o plus the time of travel, T_f, in the storm sewer, paved gutter, roadside drainage ditch, or drainage channel. For non-urban areas, the time of concentration consists of an overland flow time, T_o, plus the time of travel in a combined form, such as a small swale, channel, or drainage. The latter portion, T_f, of the time of concentration can be estimated from the hydraulic properties of the storm sewer, gutter, swale, ditch, or drainage. Overland flow time, on the other hand, will vary with surface slope, surface cover and distance of surface flow. The infiltration rate of the soil, the presence of depression storage areas and the amount of

antecedent rainfall will also affect the inlet time, since the rainfall must first overcome these losses before a steady state runoff condition will be achieved. Thus, the time of concentration can be calculated using the following equation:

$T_c = T_o + T_f$

In which T_c = time of concentration (minutes)

T_o = initial, or overland flow time (minutes)

T_f = travel time in the ditch, channel, gutter, storm sewer, etc. (minutes)

Minimum time of concentration, T_c, shall be 5 minutes.

C. The overland flow time, T_o, in non-urbanized watersheds may be calculated as follows:

$T_o = 1.8\ (1.1\text{-}C)(L_o^{0.5})/(S_o^{0.333})$

Where C = runoff coefficient

L_o = length of overland flow, (feet, 500-feet maximum)

S_o = average basin slope (percent)

In lieu of the foregoing, formulas may be used as contained in the ODOT Roadway Design Manual, Section 15.3.2.1.

D. The equation for overland flow time, T_o, is generally adequate for distances up to 500 feet. For longer basin lengths, the runoff will combine and the sheet flow assumption is no longer valid. The time of concentration would then be overland flow in combination with the travel time, T_f, which is calculated using the hydraulic properties of the swale, ditch, or channel. The time of concentration is then the sum of the initial flow time, T_o, and the travel time, T_f.

E.2.2.3 Runoff Coefficient: The runoff coefficient, C, represents the integrated effects of infiltration, evaporation, retention, flow routing, and interception, all of which affect the time distribution and peak rate of runoff. Determination of the runoff coefficient requires judgment and understanding on the part of the engineer. Table E.2.3 presents the recommended range of C values for different surface characteristics as well as for different aggregate land uses. Coefficient values selected from the range available shall be consistent with the urbanized percent imperviousness (i.e. minimum percent imperviousness requires minimum runoff coefficient value). Also, for flat slopes and permeable soils, use the lower values. For steep slopes and impermeable soils use the higher values.

E.2.2.4 Intensity: The intensity, I, is the average rainfall rate in inches per hour for the period of maximum rainfall of a given frequency having a duration equal to the time of concentration. For a given time of concentration, T_c, and a given design storm frequency, the rainfall intensity, I, can be obtained using the following equation:

$$I = d / (c + e)^f$$

Where I = Rainfall Intensity, inches per hour

T_c = Time of Concentration, minutes

d, e, f = Parameters defined in Table E.2.4.

TABLE E.2.3

RUNOFF COEFFICIENTS AND PERCENT IMPERVIOUSNESS

Land Use or Surface Characteristics	Percent Imperviousness	Runoff Coefficients
BUSINESS:		
Commercial Areas	70 to 95	0.70 to 0.95
Neighborhood Areas	60 to 80	0.50 to 0.70
RESIDENTIAL:		
Single Family	35 to 60	0.30 to 0.65
Multi-unit (detached)	45 to 55	0.40 to 0.60
Multi-unit (attached)	65 to 75	0.60 to 0.75
1/2 acre lot or larger	30 to 45	0.25 to 0.40
Apartments	65 to 75	0.50 to 0.70
INDUSTRIAL		
Light uses	70 to 80	0.50 to 0.80
Heavy uses	80 to 90	0.60 to 0.90
PARKS, CEMETERIES	4 to 8	0.10 to 0.25
PLAYGROUNDS	40 to 60	0.50 to 0.60
RAILROAD YARDS	35 to 45	0.20 to 0.35
UNDEVELOPED AREAS		
Cultivated	30 to 70	0.35 to 0.60
Pasture	20 to 60	0.25 to 0.50
Woodland	5 to 40	0.10 to 0.40
Offsite flow analysis (land use not defined)	35 to 55	0.45 to 0.65
STREETS		
Paved	90 to 100	0.80 to 0.90
Gravel	50 to 70	0.55 to 0.65
DRIVES AND WALKS	90 to 100	0.80 to 0.90
ROOFS	85 to 95	0.80 to 0.90

LAWNS		
Sandy soils	5 to 10	0.10 to 0.20
Clayey soils	10 to 30	0.13 to 0.35

Source: Stormwater Criteria Manual, City of Tulsa

TABLE E.2.4
RAINFALL INTENSITY PARAMETERS

Design Storm	Parameter		
	d	e	f
2 Year	56.43	11.5	0.81
5 Year	72	15	0.80
10 Year	82	15	0.80
25 Year	95	15	0.80
50 Year	108	15	0.80
100 Year	120	15	0.80

Source: Drainage Design Manual, ODOT, February, 1988

E.2.3 UNIT HYDROGRAPH METHODS

E.2.3.1 Introduction: A hydrograph method must be used to determine peak runoff rates from watersheds larger than 200 acres, which is the upper limit of the Rational Method and for all detention pond analyses. A hydrograph method is required for all drainage areas larger than two acres. Table E.2.2 indicates methods applicable to various size watersheds. This section contains brief explanations of the various hydrograph methods; however, the design engineer is assumed to be familiar with the basic assumptions and limitations regarding the applicability of the method used.

E.2.3.2 Design Storm Precipitation:

A. The design storm shall have a duration a minimum of twice the time of concentration for peak flow calculations. For design of detention storage basins, a 24-hour storm shall be used.

B. A precipitation hyetograph shall be used as the input for all runoff calculations. The specified precipitation is assumed to be uniformly distributed over the watershed. The hyetograph represents average precipitation depths over a computation interval.

C. The unit duration incremented shall be in multiples of one, two or five minutes (e.g., 1-, 2-, 5-, 10-, or 15-minutes) with the maximum unit duration to be 15 minutes under most circumstances. An acceptable unit

storm duration should not exceed one-fifth of the time to peak of the watershed, t_p. As an example, if the watershed has a t_p of 35 minutes, then an appropriate unit storm duration would be five minutes.

E.2.3.3 SCS Unit Hydrograph Method: The Soil Conservation Service (SCS) method is presented in detail in Section 4 of the U.S. Department of Agriculture Soil Conservation Service Engineering Handbook and Model Drainage Manual, American Association of State Highway and Transportation Officials, 1991. The SCS computer program TR20 or the U.S. Army Corps of Engineers computer program HEC-1 are acceptable ways of utilizing the SCS methodology. The SCS publication TR55 may be used for areas up to 2,000 acres.

E.2.3.4 Snyder Unit Hydrograph Method: This unit hydrograph method is described in detail in Handbook of Applied Hydrology, V.T. Chow, McGraw-Hill Publishing Company, 1964. For this area, two regionalized equations for the lag time of the watershed in terms of time to peak, t_p and unit hydrograph, q_p, shall be used.

The equations are as follows:

The time to peak of the unit hydrograph from the midpoint of unit rainfall, t_p, is computed from the following formula:

$$t_p = 1.40\ (LxLca/S^{0.5})^{0.376}$$

where L = length along the stream from the study point to the upstream limit of the watershed, in miles;

L_{ca} = length along the stream to a point adjacent to the centroid of the watershed, in miles;

S = weighted average slope of the basin along the stream to the upstream limit of the watershed.

The time to peak, t_p , is further adjusted for the physical effects of urbanization based on the percentage of channel improvements within the basin. The following equation is used to make that adjustment:

$$adj.\ t_p = t_p\ x\ 10^{-(0.0034)x\%Ch}$$

where %Ch = percentage of channel improved.

The peak of the unit hydrograph, q_p, is calculated as:

$$q_p = 375\ x\ (adj.\ t_p)^{-0.906}$$

Finally, the basin shape factor is computed from the following formula:

$$C_p = \frac{(adj.t_p \times q_p)}{640}$$

The values obtained for adjusted t_p and C_p are input values in the HEC-1 program, used to calculated the unit hydrograph.

E.2.3.5 Unit Volume Relationship: For parcels of land up to two acres the simple curve relationship shown on Figure E.2.1 is satisfactory for sizing detention storage volume. The City may require a more detailed analysis where the more simplified methods are judged inadequate.

FIGURE E.2.1

E.3 STREET DRAINAGE, INLETS, STORM SEWERS AND CULVERTS

E.3.1 STREET DRAINAGE

E.3.1.1 Depth in Streets: Use of streets for conveyance of stormwater runoff shall be within the following limitations:

A. For the 50-year frequency rainstorm, two driving lanes of arterial streets and one driving lane for collector streets shall remain open. Depth of flow for arterial, collector and local streets shall not exceed 6". Where no curb exists stormwater encroachment shall not extend past the street right-of-way.

B. The 100-year flow shall be contained within the right-of-way.

C. At sump locations, the water depth shall not exceed 12" above the top of the grate for the 100-year frequency rainstorm.

D. Where sump collection systems are used, an overflow route shall be established in the event of complete blockage of the sump in accordance with Section E.1.2.

E.3.1.2 Location of Storm Sewers: Storm sewer shall not be placed within the wheel path of any driving lane of the pavement. The preferred location of the storm sewer is according to the following order of priority listed.

A. Behind the Curb

B. Down the Center of the Traffic Lane

C. On Centerline

The traffic lane is defined as the normal width provided for each lane and delineated by pavement stripes.

E.3.1.3 Drainage Impact On Streets

A. Sheet Flow To minimize the effects of hydroplaning and splashing of sheet flow, streets shall be designed with a 2% (1/4" per foot) minimum cross slope. In addition, for arterial streets, the amount of flow permitted in the street is limited to the outside lane before a storm sewer inlet is required.

B. Cross Flow: The depth of cross flow permitted in non-arterial streets, where it cannot be avoided, is limited to the top of curb. Cross flow in arterial streets is not permitted and is strongly discouraged for collectors and residential streets. The cross flow limitations for freeways are determined by the Oklahoma Department of Transportation.

Sump areas will be drained by inlets and a storm sewer system. Omission of the crown to allow water to cross the street and drain into a side street at an intersection shall not be allowed.

C. Valley Gutters: Concrete valley gutters are required in asphalt streets when the longitudinal grade is 1% or less. The width of the valley gutter will be determined by the depth required. The maximum slope of the lateral grade shall be 5%. If a birdbath exists on an asphalt valley greater than 1%, then a concrete valley gutter shall be constructed.

E.3.1.4 Hydraulic Evaluation

A. Curb and Gutter Capacity:

1. The allowable storm capacity of each street section with curb and gutter shall be calculated using the modified Manning's formula:

$$Q = 0.56(Z/n)S^{1/2}Y_T^{8/3}$$

Where Q = discharge in cfs

Z = reciprocal of the street cross slope (S_x, ft/ft)

Y_T = depth of flow at the gutter (feet)

S = longitudinal grade of street (ft/ft)

n = Manning's roughness coefficient

2. Manning's roughness coefficient, n, shall be used according to the applicable construction condition from Table E.3.1.

3. When the street cross section has different cross slopes, capacity computation shall take into account the various cross slopes.

B. Roadside Ditch Capacity: The capacity of a roadside ditch shall be computed using Manning's equation. The allowable flow over the paved portion of the street is computed according to Section E.1.2. This capacity of the roadside ditch and street capacity are combined to determine the entire street section capacity. The paved street portion contributes to the total capacity only when the depth of flow in the roadside ditch is exceeded for the design storm. As in streets with curb and gutter, the maximum allowable depth at the pavement edge shall not exceed the limits set in Section E.1.2.

TABLE E.3.1
MANNING'S N-VALUES FOR
STREET GUTTERS

Construction Type	n
Concrete gutter troweled finish	0.012
Asphalt Pavement Smooth texture Rough Texture	0.013 0.016
Concrete gutter with asphalt pavement Smooth Rough	0.013 0.015
Concrete pavement Float finish Broom finish	0.014 0.016
Brick	0.016

Note: For gutters on flat grade where sediment may accumulate, increase all above values of Manning's "n" by 0.002.

Source: Drainage Design Manual, ODOT, February, 1988

E.3.2 STORM SEWER INLETS

E.3.2.1 Maximum Time of Concentration: A maximum time of concentration to the first inlet of 10 minutes shall be used for single and multifamily residential areas, and 5 minutes for commercial and industrial areas.

E.3.2.2 Allowable Inlet Types:

A. ODOT, CICI-1-X

B. Inlet types shall be in accordance with the City's standard drawings.

C. On arterial streets, offset type inlet, ODOT Standard SSCD-1-15, shall be used.

E.3.2.3 Location of Inlets:

A. Inlets shall be located at all low points in the gutter grade, on side streets at intersections where runoff would flow onto an arterial street or highway and upgrade of bridges to prevent runoff from flowing onto the bridge deck. Inlets are also required when the 5-year depth of flow in the gutter is exceeded.

B. Inlets at intersections shall be located in such a manner that no part of the inlet will encroach upon the curb return. Inlets on a continuous grade in the interior of a block should be placed upstream of a nearby driveway, if possible. The flowline and top of curb elevations shall be shown on all inlets.

E.3.2.4 Spacing Between Inlets: The spacing between inlets shall be such that depths of flow and widths of spread requirements are not violated. The distance between inlets and the distance to the first inlet shall not exceed 600 feet.

E.3.2.5 Interception and Bypass:

A. Some portion of the runoff is allowed to bypass an inlet and combine with the runoff at the next inlet. As many of the inlets as possible should be sump inlets.

B. The type of inlet to be used and the percent of flow to be intercepted at a particular location is left to the judgment of the designer. The objective is to minimize the cost of the storm sewer system while satisfying all of the design criteria. In general, an interception rate of 70 to 80 percent will result in an economical design.

E.3.2.6 Inlets in Sump Condition: When inlets are placed in a sump, emergency overflow shall be provided as described in Section E.1.2.4.A.2. An easement will be provided where overflow occurs outside of public rights of way.

E.3.2.7 HYDRAULIC DESIGN

A. Methodology: Curb and grate inlet capacities shall be in accordance with FHWA HEC-12 methods.

B. Grate Inlets:

1. Grated inlets without a curb opening are not permitted.

2. The bicycle safe grates (in combination with a curb opening) are the only

grates approved within the street right-of-way. Refer to ODOT Standard CIG-1-X.

3. When a grate is used in conjunction with a curb opening directly behind the grate, only the hydraulic capacity of the grate shall be utilized to estimate the flow that is intercepted, since the curb opening portion is reserved to collect debris.

4. Grate interception capacities shall be determined for the specific grate to be used in the project. For example, if the grate inlet is manufactured by Neenah Foundry use Neenah's method of computing the capacity.

C. Curb Opening Inlets: Two types of curb opening inlets are approved. Cast in place concrete inlets, and manufactured metal inlets. Refer to ODOT Standards CICI-1-X or SSCD-1-15. The throats shall be open with no bar dividers.

E.3.3 STORM SEWER PIPE SYSTEM

E.3.3.1 Definitions.

A "storm sewer system" refers to a system of inlets, pipes, manholes, junctions, outlets, and other appurtenant structures designed to collect and convey storm runoff to a defined drainageway. A "drainage system" also includes curbs and gutters, roadside ditches, swales, channels, and detention systems for the control of overland runoff. In general, a storm sewer system is required when other parts of the drainage system no longer have the capacity for additional runoff without exceeding the design criteria.

E.3.3.2 Design Criteria

A. Design Storm Frequency:

1. The storm sewer system, beginning at the upstream end with inlets, is required when the allowable street capacity (see Section E.1.2) or overflow capacity is exceeded for the design storm. The "design storm" has three connotations in the City: The design storm for the piped storm sewer system is the 5 year storm, the street and piped storm sewer system combined is the 50 year storm and the piped storm sewer system, street, and ROW combined is the 100 year storm. Minor system and the design storm for the major system, the 5-year and 50/100-year storm respectively. Thus, the storm sewer system should be designed for the larger of the following events:

   a) The 5-year flow, less the allowable capacity of the gutter or roadside ditch; or

   b) The flow equal to the difference between the 50-year and the allowable street capacity; or

   c) The flow equal to the difference between the 100-year and the capacity within the ROW.

2. The intent is to intercept the 5-year flood and convey the flow in a storm sewer. However, it is impractical to intercept all the runoff in the street at the inlet and some "carry-over" flow will occur. The procedure simply puts a limit on the amount of carry-over flow that can occur in the street.

B. Construction Materials: Storm sewers may be constructed using reinforced concrete, corrugated metal, or plastic pipe. The materials, pipes, and appurtenances shall meet the requirements of ODOT.

C. Vertical Alignment:

1. The sewer grade shall be such that a minimum cover is maintained to withstand AASHTO HS-20 loading on the pipe. The minimum cover depends upon the pipe size, type and class, and soil bedding condition, but shall not be less than one foot from the top of pipe to the finished grade at any point along the pipe. If the pipe encroaches into the street sub-grade, a variance must be granted of the City.

   Pipe joints shall be tight fitting. All joints shall have an approved gasket system to prevent infiltration of bedding material and minimize ex-filtration.

2. Manholes will be required whenever there is a change in size, alignment, elevation grade and slope, or where there is a junction of two or more sewers. For sewers equal to or larger than 60" diameter, pre-formed smooth transitions shall be approved by the City Engineer. Pipes entering or leaving a manhole shall have matching soffits unless a variance is granted by the City Engineer. The interior of manholes shall provide smooth grouted fillets and rounded exit openings. The maximum spacing between manholes for various pipe sizes shall be in accordance with Table E.3.3.

3. The minimum clearance between storm sewer and water main (for new construction), either above or below shall be 12". Ductile iron pipe (with proper bedding) or concrete encasement of the water line will be required for clearances of 12" or less when the clearance between existing water mains cannot be maintained.

4. The minimum clearance between storm sewer and sanitary sewer (for new construction), either above or below, shall be 12". In addition, when an existing sanitary sewer main lies above a storm sewer, or within 18" below, the sanitary sewer shall have impervious encasement or be constructed of ductile iron pipe for a minimum of 10' on each side of the storm sewer crossing.

5. Siphons or inverted siphons are not allowed in the storm sewer system.

6. Pumped systems may be considered after all other possibilities have been exhausted, subject to approval by the City Engineer. The pumping plants shall be designed in accordance with the same criteria as gravity systems. Where storage and/or bypass of higher flows are used in conjunction with pumping, a detailed analysis of stage verses discharge shall be submitted for review.

   A. Wet well – Provide a wet well large enough to provide ideal flow conditions for the pump intake.

   B. Trash removal – Provide a bar grating covered opening sufficient to accommodate 60% blockage and can be cleaned during operation.

C. Power supply – 2 – independent sources or a back up generator.

D. Capacity – Minimum 5-year capacity with redundant capacity. Controls shall allow for

E. Sump drainage – Provide a sump capable of automatically maintaining a "dry" wet well.

F. Controls – Electronic emitence or other similar level controls are acceptable.

G. Pumps – Primary pumps shall be vertical lift single or multistage type. Pumps shall be placed so that they can be easily removed for repair. All pumps shall have intake screens adequate to protect the impeller from debris.

H. Discharge pipes shall be steel or ductile iron. All outlets shall have flap gates.

Table E.3.3
STORM SEWER ALIGNMENT AND SIZE CRITERIA

MANHOLE SPACING:

Pipe Size	Maximum Spacing for Manholes	Minimum Manhole Size
15" to 24"	300'	4'
27" to 42"	400'	5'
48"	500'	6'
54" to 66"	500'	8'
>66"	500'	junction structure

MINIMUM RADIUS FOR RADIUS PIPE:

Short radius bends shall not be used on sewers 48" or less in diameter for public systems.

MINIMUM PIPE DIAMETER:

Type	Minimum Equivalent Pipe Diameter	Minimum Cross-Sectional Area
Main Trunk	15"	1.23 SF
Lateral from inlet	15"	1.23 SF

Source: Stormwater Criteria Manual, City of Tulsa

D. Horizontal Alignment

1. Storm sewer alignment between manholes shall be straight except when accepted in writing by the City Engineer. Approved curvilinear storm sewers may be constructed using pipe bends or radius pipes.

2. A minimum horizontal clearance of ten feet is required between sanitary and water utilities and the storm sewer.

3. The permitted locations for storm sewer within a street right-of-way are: (a) behind the curb, (b) down the center of the driving lane, and (c) on centerline. Behind the curb is the preferred location.

E. Pipe Size: The minimum allowable pipe size for storm sewers is presented in Table E.3.3.

F. Storm Sewer Capacity and Velocity

1. Storm sewer shall be designed to convey the difference between the capacity of the street and the design storm (5-year) flood peaks without surcharging the storm sewer. The sewer may be surcharged during larger floods and under special conditions when approved by the City Engineer.

2. The capacity and velocity shall be based on the Manning's n-values presented in Table E.4.1. The maximum full flow velocity shall be less than 20 fps. Higher velocities may be accepted by the City Engineer if the design includes adequate provisions for uplift forces, dynamic impact forces and abrasion. The minimum velocity in a pipe based on full flow shall be 2.5 fps to avoid excessive accumulations of sediment.

3. The energy grade line (EGL) for the design flow shall be no more than one foot above the final grade at manholes, inlets, or other junctions. To insure that this objective is achieved, the hydraulic grade line (HGL) and the EGL shall be calculated by accounting for pipe friction losses and pipe form losses. Total hydraulic losses will include friction, expansion, contraction, bend, manhole, and junction losses.

C. Storm Sewer Inlets and Outlets

1. Before discharging the runoff from a parking lot of area larger than 0.5 acres, the runoff must first be collected in a storm sewer inlet and connected to the storm sewer within the street right-of-way, or roadway ditch or drainage conduit. Accordingly, the flow in the street shall be reduced by the amount intercepted by the inlet.

2. All storm sewer outlets into open channels shall be constructed with a headwall and wing walls or a flared-end-section. When the outlet velocity exceeds six feet per second, erosion control measures shall be taken. If required to prevent erosion, energy dissipaters shall be provided.

E.3.4 Culverts:

E.3.4.1 Definition: A culvert is defined as a closed conduit for the passage of water under an embankment, such as a road, railroad, or driveway. The distinction between a culvert and a sewer is the means by which flow enters the conduit. Flow normally enters a culvert by an open channel, generally at a similar elevation and a culvert usually crosses a street.

E.3.4.2 Construction Materials: Culverts shall be constructed of reinforced concrete or corrugated metal in accordance with Table E.5.2. Other materials may be used on a case-by-case basis on acceptance by the City Engineer.

E.3.4.3 Hydraulic Design: Culvert design shall follow the methodology presented in Hydraulic Design of Highway Culverts, Hydraulic Design Series HDS No. 5, FHWA, U.S. Department of Transportation and Drainage Manual, Oklahoma Department of Transportation, 1992.

E.3.4.4 Design Frequency: 100-year without overtopping, with one foot of freeboard below the minimum roadway overflow elevation, unless otherwise approved by the City Engineer.

E.3.4.5 Minimum Size:

a. Pipe Culverts - 15" equivalent

b. Box Culverts - no less than 3' in height

E.3.4.6 Outlet Velocity:

a. In design of culverts both the minimum and maximum velocities must be considered. A minimum velocity of 3- feet per second at the outlet is required to assure a self-cleaning condition of the culvert.

b. The outlet area shall include a headwall with wing walls or an end-section in addition to the riprap protection if required. Where outlet velocities exceed six feet per second, erosion control measures shall be taken. Energy dissipaters shall be provided as required.

E.3.4.7 Structural Design: Culverts shall be designed to withstand an HS-20 loading in accordance with the design procedures of AASHTO Standard Specifications for Highway Bridges and with the pipe manufacturers recommendations. In addition, the AASHTO maximum heights of cover for corrugated metal structures shall also be followed. The minimum cover over top of the pipe shall be 12" unless otherwise accepted by the City Engineer.

E.3.4.8 Driveway Crossings: Driveway culverts shall be sized to pass the 10-year ditch flow capacity without overtopping the driveway. The minimum size culvert shall be a 15" round pipe , or equivalent, for all streets. Sloped headwalls required per the city's Standard Details, not smaller than upstream culvert.

E.3.4.9 Pipe End: Provide prefabricated culvert end sections or other approved end treatment.

E.3.5 BRIDGES

E.3.5.1 Bridge: A bridge is constructed with abutments and superstructures, which are typically concrete, steel, or other materials. Since the superstructures are generally not an integral structural part of the abutments, and are therefore free

to move, the hydraulic criteria for bridges is different than for culverts. Bridges are also usually constructed with earth or rock inverts, whereas culverts are typically the same material throughout the waterway opening.

E.3.5.2 Hydraulic Design The sizing criteria set forth in Section E.3.4.5 for culverts shall apply with the exception that freeboard for bridges is defined as the vertical clearance of the lowest structural member of the bridge superstructure above the water surface elevation of the design frequency flood. The minimum freeboard shall be 1 foot for the 100-year frequency flood, unless approved by the City.

No rise in water surface is allowed off-site due to the restrictions created by the construction of the bridge.

E..3.5.3 Velocity: The velocity limitations through the bridge opening are controlled by the potential abutment scour and subsequent erosion protection provided. Using riprap for the channel lining and/or protection of the abutments and wing walls, the maximum channel velocity is limited to 15 fps.

E.3.5.4 Hydraulic Analysis: The hydraulic design of bridge crossings shall be in accordance with Drainage Manual, Oklahoma Department of Transportation, 1992.

E.3.5.5 Inlet and Outlet Configuration: The design of bridges shall include adequate wing walls of sufficient length to prevent abutment erosion and to provide slope stabilization from the embankment to the channel. Erosion protection on the inlet and outlet transition slopes shall be provided to protect from the erosive forces of eddy current.

E.3.5.6 Structure Design: Bridges shall be designed in accordance with AASHTO/ODOT criteria. Rails shall comply with ODOT TR-1 or TR-2 Standard Details.

E.4 OPEN CHANNELS

E.4.1 DESIGN

E.4.1.1 Channel Geometry: For trapezoidal channels, the minimum bottom width shall be 4' with side slopes of not steeper than 4 to 1 for sodded sections and a minimum bottom width of 3' with side slopes of not steeper than 1-1/2:1 for paved or rock-lined sections, unless approved by the City Engineer.

E.4.1.2 Manning's “n” - Value: Manning’s Equation in the calculations of hydraulic characteristics of channels will be acceptable. The "n" value used for channels shall be based on the individual channel characteristics, according to Table E.4.1. Designers should anticipate growth of trees as a natural maturation process of the channel. Values less than 0.05 shall be justified.

TABLE E.4.1

MANNING'S N-VALUE FOR OPEN CHANNELS

Channel Type	n-Value Range	Recommended Value
Grass lined - maintained	.029 to .100	
Grass lined - not maintained	.045 to .10	.035
Natural Streams	.025 to .100	Note (1)
Riprap Lined	.	
1. Ordinary riprap	.025 to .050	.035
2. Gabions	.025 to .050	.035
3. Grouted riprap	.023 to .030	.027
4. Stone mattress	.025 to .033	.028
Concrete Lined		
1. Float finished/wood forms	.013 to .016	Note (2)
2. Slip formed	.013 to .016	Note (2)
3. Gunite	.016 to .023	Note (2)

Notes:

1. Source: Chow, V.T., Open Channel Hydraulics, McGraw-Hill Book Company, 1959, and pictures
2. High value used for capacity determination and low value used for velocity consideration

E.4.1.3 Minimum Slope: Channels shall have minimum slopes of 0.15% for concrete-lined channels and 0.25% for grass-lined channels. The City Engineer's acceptance is required for channels with a flatter slope.

E.4.1.4 Minimum Velocity: Minimum velocity in a drainageway system shall be 2.5 fps to avoid sedimentation.

E.4.1.5 Maximum Velocities: Velocities shall not exceed 5 fps for sections grass sections depending on soil conditions. Velocities in concrete lined or paved sections shall not exceed 15 fps. The dissipation of energy shall be required at the confluence of improved channels with natural channels through the use of dissipaters, stilling basins and etc. which shall be designed in accordance with FHWA HEC #14 Hydraulic Design of Energy Dissipaters for Culverts and Channels Drainage Manual.

Velocities offsite shall not exceed those that existed prior to construction.

E.4.1.6 Freeboard: Where practical, the design water surface elevation shall be kept

below the level of natural ground. A 1' freeboard above the energy grade line should be added to calculated flow depths to determine minimum channel depths for subcritcal flow. For super-critical channels, the freeboard requirement shall be:

$H_{FB} = 2.0 + 0.25V(d)^{1/3}$

H_{FB} = freeboard height (feet)

V = Velocity in fps

d = depth (feet)

E.4.1.7 Trickle Channels: All channels altered or improved from the natural state will require a paved trickle channel unless a variance is granted by the City Engineer. Sodding, or other methods of erosion control shall be required adjacent to the paved channel.

E.4.1.8 Concrete Flumes: Concrete flumes in lieu of enclosed pipe shall be required on a case-by-case basis by the City Engineer, as overflow protection for storm sewer systems, and to drain areas not exceeding five (5) acres in size. All concrete flumes shall extend to the rear of adjacent lots and shall discharge into a dedicated drainage facility or channel.

E.4.1.9 Roadside Ditches: Roadside ditches shall conform with requirements of this section.

E.4.1.10 Base Flood Elevation (BFE) or floodplain boundary changes shall be approved by FEMA.

E.5 HYDRAULIC STRUCTURES

5.1 DEFINITIONS

TABLE E.5.2

CULVERT MATERIALS

PIPE MATERIAL	STANDARD
Reinforced Concrete Pipe	
Round	ASTM C-76 or AASHTO M-170
Elliptical	ASTM C-507 or AASHTO M-207
Arch	ASTM C-506 or AASHTO M-206
Pre-Cast Concrete Manholes	ASTM C-478 or AASHTO M-199
Pre-Cast Concrete Box	ASTM C-789/C-850, AASHTO M-259/273 or ODOT
Concrete Cast-in-Place Box	ODOT Standard
Corrugated Aluminum Alloy:	
Alloy Pipe and Under-drains	AASHTO M-196
Structural Plate	AASHTO M-219
Aluminized Type II Coated	AASHTO M-274
Corrugated Steel	
Metallic coated for sewer/drains	AASHTO M-196
Bituminous Coated pipe/arches	AASHTO M-190
Polymer Pre-coated	AASHTO M-245
Structural Plate	AASHTO M-167
*High Density Polyethylene (HDPE)	ASTM D2321-89

*No HDPE greater than 18-inch will be allowed. No HDPE will be allowed under any driving surfaces. No HDPE shall be allowed for any proposed public facilities.

E.6 STORAGE

E.6.1 GENERAL

a. The detention storage shall accommodate the excess runoff from a 100-year frequency storm. The excess runoff is that runoff generated due to urbanization which is greater than the runoff historically generated under existing conditions, for a given frequency storm. Detention facilities shall be designed so that the peak rate of discharge does not exceed that of the pre-development conditions for all storm events up to and including 100-year.

b. Peak release rates from developments shall not exceed the existing runoff that occurred before development for all storm frequencies up to and including the 100-year frequency storm. Releases for 1, 2, 5, 10, 25, 50, 100, 500-year storms shall not exceed the existing rate. A variance may be allowed for the 500-year storm if dam safety is otherwise compromised, with the approval of the City Engineer.

c. Generally, urbanization results in more impervious area and a reduction in floodplain storage, both of which contribute to increased flow rates. If improvements are made to any natural channel downstream from an area of 40 acres or more, current floodplain storage must be maintained.

d. Where available, detention facilities shall be designed using the City's hydrologic and hydraulic models for the watershed to assure that there is no adverse impact from water surface elevation or flow velocity. Otherwise, a hydrologic and hydraulic model will be prepared by the owner’s engineer for the analysis.

E.6.2 DESIGN CRITERIA

a. The design storm for detention shall be a 24-hour storm. Rainfall depths shall be in accordance with Section E.2.1.

b. The time increment used in developing the rainfall distribution and in reading off the ordinates of the unit hydrograph may be rounded off to the nearest whole time interval or to the nearest time increment.

c. Rainfall distributions shall be consistent with the modeling technique used.

d. All calculations for detention facilities shall be submitted for review by the City Engineer. The submittal shall include hydrographs for both existing and developed conditions, detention facility stage-area-volume relationships, outlet structure details, and a stage versus time analysis through the facility.

e. Floodplain areas and detention facility locations shall be identified at the preliminary plat stage to illustrate how these areas will be managed during and after construction.

f. If a tract of land under development has a floodplain area within its boundary, the information that must be furnished either with the preliminary plat or before the final plat is submitted, shall include:

   1. A backwater analysis on the existing drainage system.

   2. A backwater analysis on the proposed drainageway system

g. Detention facilities should be located in areas accepted by the City. Each

facility shall incorporate methods to minimize erosion and other maintenance reducing designs.

h. Additional detention storage, in excess of the required storage for a drainage area, can be provided to satisfy the detention requirements for a tract of land downstream of the detention facility, providing the detention facility is constructed prior to the development of the downstream tract, with the approval of the City Engineer.

i. A minimum number of detention facilities is encouraged for each development. Regional detention facilities are encouraged for phased or cooperative development in a drainage basin.

j. If runoff has a natural tendency to drain in several directions for a given development tract of land where detention is required, then detention storage shall be provided for the biggest drainage area. Additionally, a detention storage may be provided, at the same facility, to satisfy detention requirements for a separate drainage area on the same development, provided that:

   1. The whole developmental tract of land is in the same watershed.

   2. The smaller drainage area(s) that, has/have been compensated for does/do not, either singly or in combination, adversely impact the health, welfare and safety of the general public downstream.

k. If a tract of land being developed is located in more than one sub-watershed, of the same overall watershed, grading work to divert flows from one sub-watershed to another will be permitted if there is proper capacity in the receiving stream.

l. The detention area shall be identified as a separate platted area; as appropriate, it may consist of one or more platted lots, a separate block, or it may be identified as a reserve area.

m. Provision for the detention facility shall appear among the plat's restrictive covenants.

n. In the event the detention facility becomes unnecessary as a result of drainage improvements, the facility may be vacated, by action of the City Council, as provided for in the covenants or applicable law.

o. An access way at least 20 feet wide shall be provided to any required detention area. Access may be provided by frontage on a dedicated public street or by an access easement from a dedicated public street to the detention area.

p. If the detention facility is approved by the City to serve areas outside the subdivision in which it is located, such additional areas shall be specifically identified in the provision for detention.

q. Any dam or berm shall be designed in accordance with the dam safety criteria of the Oklahoma Water Resources Board.

r. The maintenance responsibility for on site detention facilities shall remain with the private sector and appropriate covenants shall be submitted to the City for approval to insure maintenance.

E.6.3 DESIGN DETAILS

a. Detention dams or dikes shall be constructed as earth filled and non-overflow type dams. Embankment slopes shall not be steeper than 4: 1. Spillways shall be constructed to pass the 500-year flood event with a minimum of one (1) foot of freeboard on the earth dam structure.

b. Side slopes on detention facilities shall not be steeper than 4:1.

c. Access road, with grade of 10% or less, shall be provided to the detention areas for maintenance purposes.

d. Detention facilities shall be provided with a low flow channel from the inlet to the outlet structure to transmit low flows, and with subsurface drainage as required to maintain a dry surface.

e. Storm sewer outlets in the slope of the detention pond shall be protected by a reinforced concrete slope wall.

f. All earth slopes and earth areas subject to erosion, such as, adjacent to low flow channels, inlet structures, and outlet structures shall be slab sodded with Bermuda sod or protected with other erosion control measures. All other earth surfaces, within the area designated for detention facility site, shall have an established growth of Bermuda grass. All covered areas shall be fertilized, watered and in an established growing condition prior to completion and acceptance of the detention facility.

g. Stormwater detention facilities shall be designed as "dry" facilities, with the outlet structure at the lowest elevation in the pond.

With the approval of the City Engineer, a "wet" facility may be allowed to maximize storage. Wet facilities shall have adequate flow through to maintain water levels. Mosquito control shall be incorporated into the maintenance plan.

E.7 SEDIMENTATION CONTROL AND WATER QUALITY

E.7.1 Regulation

A. This chapter includes standards and requirements for erosion and sedimentation control for construction areas less than 5-acres in size (City Earth Change Permit). For larger construction areas, discharges for stormwater are authorized under the Oklahoma Department of Environmental Quality (ODEQ) , Water Quality Division, General Permit (GP-005) for Storm Water Discharges from Construction Activities within the State of Oklahoma.

The control of erosion and sedimentation from construction activities shall be in accordance with this Section and NPDES General Permits for Storm Water Discharges from Construction Sites in the September 9 and September 25, 1992, Federal Register.

B. The ODEQ adopted a General Permit for Storm Water Discharges from construction activities, which includes discharges from construction with areas greater than 5 acres in size. The objective of the General Permit is to improve water quality by reducing pollutants in storm water discharges. Authorization to discharge under the General Permit is obtained by

submitting a Notice-of-Intent (NOI) along with supplemental information, which is briefly described in this Section and ODEQ General Permit for Storm Water Discharges from Construction Activities within the State of Oklahoma.

E.7.2 EXEMPTIONS

A. Exemptions from the erosion control submittal process are granted by the City for construction areas less than 5-acres or as stipulated in GP-005. A summary of these exemptions is presented below.

1. Bona fide agricultural and farming operations.
2. Customary and incidental routine grounds maintenance, landscaping, and home gardening.
3. Development or improvements on one and two family residential properties at residential single family or duplex density.
4. Emergency repairs of a temporary nature made on public or private property.
5. Temporary excavation for the purpose of repairing or maintaining any public street, public utility facility, or any service lines related thereto.
6. Routine maintenance of the stormwater drainage system.
7. Other exemptions as may be granted by the City in writing.

E.7.3 SUBMITTALS

E.7.3.1 Permit Applications

1. All new development disturbing less than 5 acres shall have prepared and implemented an erosion and sedimentation control plan. The plan shall be prepared and will be reviewed in accordance with the criteria presented in this section.
2. New development disturbing an area greater than 5 acres must obtain authorization to discharge under the ODEQ General Permit for Storm Water Discharges from Construction Activities. Notices of Intent must be submitted through the City Engineer to:

   Storm Water Notice of Intent
   Oklahoma Department of Environmental Quality
   Water Quality Division
   1000 NE Tenth Street
   Oklahoma City, OK 73117-1212

   The City requires that when a developer files an "NOI" for a development, it will remain in force for the duration of the development, including the development of smaller areas (for example: individual residential lots) that are a part of the larger common plan of the development.
3. Erosion Control Plans are an integral part of the Earth Change Permit. Erosion Control Plans are also related to drainage analysis and report requirements.

4. Erosion and Sedimentation Control Plan approval is required prior to issuance of an Earth Change permit. Since the drainage plan has considerable impact on site grading, erosion control planning and drainage planning should be a concurrent process. However, for some developments, site grading to an interim condition may be desired. To account for cases where site grading will precede final drainage planning, the erosion control plan may be submitted with a Preliminary Drainage Report. Subsequently, the plan will need to be modified to reflect grading changes necessitated by final drainage design.

E.7.3.1 Erosion and Sedimentation Control Report

Purpose: The purpose of the Erosion and Sedimentation Control Report is to identify and define conceptual solutions to the problems which may occur on site and off site as a result of the development. In addition, those problems anticipated on site and off site during development must be addressed in the report. All reports shall be typed on 8-1/2" x 11" paper and bound together. The drawings, figures, plates, tables, and site plan shall be bound with the report or included in a folder/pocket at the back of the report.

A. Report Contents: The narrative report shall contain the applicable information listed:

1. Name, address, and telephone number of the applicant, landowner, developer, and engineer.

2. Project description - Briefly describe the nature and purpose of the land disturbing activity, the amount of grading involved, and project location including section, range, and township.

3. Existing site conditions - A description of the existing topography, vegetation, and drainage.

4. Immediate adjacent areas - A description of neighboring areas such as streams, lakes, residential areas, roads, etc., which might be affected by the land disturbance.

5. Soils - A brief description of the soils on the site giving such information as soil names, mapping unit, erosion tendencies, permeability, hydrologic soil group, depth, texture, and soil structure. (This information may be obtained from the S.C.S. soil survey for Tulsa County.)

6. Erosion and sediment control measures - A description of the methods which will be used to control erosion and sedimentation on the site.

7. Permanent stabilization - A brief description, including specifications, of how the site will be stabilized after construction is completed. This information is optional for the initial report but may be required for the report addendum.

8. Stormwater management considerations - Explain how stormwater will be handled.

   Determine detention requirements. This information is optional for the initial report but may be required for the report addendum.

9. Maintenance - A schedule of regular inspections and repair of erosion

and control structures should be set forth. This information is optional for the initial report but may be required for the report addendum.

B. Drawing Contents

1. General Location Map: A map shall be provided in sufficient detail to indicate the location of the project site. The map should be at a scale of 1" = 1000' to 1" = 2000' and should indicate the project site in relation to existing topographic, and transportation, features and land boundaries. The map shall show the drainage area of land tributary to the site. The drawing shall be a multiple of 8-1/2" x 11".

2. Sediment and Erosion Control Plan: Map(s) of the proposed development at a scale of 1" = 20' to 1" = 200' on 22" x 34" drawing sheets shall be included. The plan shall show the following:

A boundary line survey of the site on which the work is to be performed.

Existing topography at a maximum of one (1) foot contour intervals with supplemental spot elevations as required to clearly describe the existing conditions. The contours shall extend a minimum of 100-feet beyond the property line (if available).

Proposed topography at a maximum of one (1) foot contour intervals with supplemental spot elevations as required to clearly describe the proposed changes.

Location of any existing structure or natural feature on the site.

Location of any structure or natural feature on the land adjacent to the site and within a minimum of 100 feet of the site boundary line. The map shall show the location of the storm sewer, channel, or creek receiving storm runoff from the site.

Location of any proposed additional structures or development on the site, if known.

Limits of clearing and grading - Areas which are to be cleared and graded.

Detailed Drawings: Detailed drawings and structural practices used that are not referenced in this Manual and other information or detail as may be reasonably required by the City. The size of drawings shall be a multiple of 8-1/2” x 11”.

E.7 .4 STRUCTURE PRACTICES

E.7.4.1 TEMPORARY STRUCTURAL PRACTICES

A. Dikes:

1. Types
   a. Diversion dike.
   b. Interceptor dike.
   c. Perimeter dike.
2. The design drainage area for dikes shall not exceed 5 acres.

3. The minimum dimensions shall be:
    a. Top Width - 2'
    b. Height - 1.5'
    c. Side Slopes - 2:1 or flatter

B. Swales:

1. Types:
    a. Interceptor swale.
    b. Perimeter swale.
2. The design drainage area for swales shall not exceed 5 acres.
3. The minimum dimensions shall be
    a. Bottom width - 4'
    b. Depth - 1' min,
    c. Grade - 1% min.
    d. Slopes - 2:1 or flatter

C. Straw Bale Dike: No straw bales will be allowed except in unusual circumstances when no other erosion control method would be effective. Use of straw bales must be approved by the City Engineer on a case-by-case basis.

D. Silt Fence: Silt fences can be constructed near the perimeter of a disturbed area to intercept sediment while allowing water to percolate through. Silt fences may not be used where there is a concentration of water in a channel or other drainage. The following criteria are applicable:

1. Drainage area - 2 acre maximum
2. Height - 30" minimum
3. Material - burlap, polypropylene fabric or nylon reinforced polyester netting.
4. Support - Steel fence posts at 8' maximum spacing.

E. Entrances: A stabilized construction entrance shall be built to reduce or eliminate the tracking or flowing of sediment onto public rights of way.

F. Stone Outlets: A stone outlet structure shall be constructed in areas where the entire drainage area to the structure is not stabilized or where there is a need to dispose runoff at a protected outlet or where concentrated flow for the duration of the period of construction needs to be diffused.

G. Paved Chute: A grade stabilization structure in the form of a paved chute or flume shall be constructed to prevent erosion, where concentrated flow of surface runoff is to be conveyed down a slope. The maximum allowable drainage area upstream of such a structure shall not exceed 36 acres.

H. Pipe Slope Drain: A grade stabilization structure in the form of a pipe slope drain shall be constructed to prevent erosion, where concentrated flow of surface runoff is to be conveyed down a slope. The maximum allowable drainage area upstream of such a structure shall not exceed 5 acres.

I. Temporary Sedimentation Basin: Storm water detention facilities may be used temporarily as sediment basins.

1. A temporary outlet structure for the storm water detention facility to work as a sediment pond shall be constructed.
2. At the end of the construction activity, the developer shall make sure that the outlet structure shall meet the design requirements of a storm water detention facility.
3. Condition of the detention facility that is used as a sediment pond during construction, shall meet the following requirements at the time of acceptance.
   a. It shall be completely cleaned by the developer and be rid of any immediate maintenance.
   b. It shall meet all design standards.

J. Sediment Trap: A sediment trap, a small temporary basin usually installed in a drainageway at a storm drain inlet shall conform to the following criteria:

1. Drainage area - 5 acres maximum.
2. Trap size - at least 1800 cubic feet per acre of drainage.
3. Embankment:
   a. Height - 5' maximum
   b. Top width - 3' minimum
   c. Slopes - 2:1 or flatter

E.7.4.2 PERMANENT STRUCTURAL PRACTICES

A. Depending on the project layout, a diversion shall be constructed across a slope less than 15% to:

1. Prevent runoff from higher areas having a potential for causing erosion and thereby interfere with the establishment of vegetation on lower areas.
2. Reduce the length of slopes to minimize soil loss.

B. Diversions need be constructed only below stabilized or protected areas.

C. Outlets from diversions shall be constructed to discharge in such a manner as not to cause erosion.

D. Outlets shall be constructed and stabilized prior to the operation of diversion.

E. Storm drain outlet protection shall be provided when converting pipe flow to channel flow. The reduction in velocity shall be consistent with the roughness coefficient of the receiving waterway. The reduction in velocity may be accomplished by:

1. Providing grouted riprap stabilization;
2. Providing energy dissipaters;
3. Providing permanent vegetation; depending on the site-specific needs.

E.7.5 VEGETATIVE PRACTICES

E.7.5.1 Temporary Vegetative Practices

1. Small grains like oats, rye and wheat, and sudans and sorghums are feasible temporary vegetation to control erosion. This practice is effective for areas where soil is left exposed for a period of 6 to 12 months. The time period may be shorter during periods of erosion rainfall.

    a. Prior to seeding, needed erosion control practices such as diversions, grade stabilization structures, berms, dikes, etc. shall be installed.

    b. Temporary vegetative practice is usually applied prior to the completion of final grading of the site.

    c. If the area to be seeded has been recently loosened to the extent that an adequate seedbed exists, no additional treatment is required. However, if the area to be seeded is packed, crusted and hard, the top layer of soil shall be loosened by other suitable means.

    d. Fertilizer shall be applied at a rate of 600 pounds per acre or 15 pounds per 1000 square foot using 10-20-10 or equivalent.

    e. Soils known to be highly acidic shall be lime treated.

    f. Seeding requirements shall be as specified in Table E.7.5.1.

    g. Seeds shall be drilled or broadcast uniformly.

    h. Seeding implements should be used at right angles to the general slope to minimize erosion.

    i. After 2 to 3 months of planting the seeded site shall be top dressed with 8 pounds per 1000 square feet or 350 pounds per acre of 33-0-0.

    j. Areas that are not well covered shall be replanted.

    k. The seeded area shall be watered when feasible and needed.

Table E.7.5.1
Planting Rates - Temporary Practice

Plant	Per Acre	Per 1000 SF	Planting Date
Annual Ryegrass	40 lbs.	0.9 lbs.	9/15 - 11/30
Elbon Rye	2 bu.	3.0 lbs.	8/15 - 11/30
Wheat	2 bu.	3.0 lbs.	8/15 - 11/30
Oats	3 bu.	2.5 lbs.	8/15 - 11/30
Sorghum	60 lbs.	1.4 lbs.	3/1 - 9/15
Sudan Grass	40 lbs.	0.9 lbs.	4/1 - 9/15

E.7.5.2 Permanent Vegetative Practices:

Bermuda grass, Kentucky 31 Tall Fescue, and Old World Blue Stem are some of the permanent vegetation that could be effectively used to control erosion.

1. Prior to seeding, needed erosion control practices such as dikes, swales, diversions, etc. shall be installed.
2. The sub-grade shall be loosened evenly to a depth of 2 to 3 inches and 10-20-10 fertilizer

(10 pounds per 1000 square feet or 450 pounds per acre) shall be mixed with the loosened surface soil by disking or other suitable means.

3. Soils known to be highly acidic shall be lime treated.
4. Planting rate requirements shall be as specified in Table E.7.5.2.

Table E.7.5.2
Planting Rates - Permanent Practice

Plant	Per Acre	Per 1000 SF	Planting Date
Bermuda Grass	22 lbs.	0.5 lbs.	4/1 - 8/15
Fescue	44 lbs.	1.0 lbs.	9/1 - 11/1
Old World Blue Stem	6.1 lbs.	0.14 lbs.	4/1 - 6/30

5. Seeds shall be drilled or broadcast uniformly.
6. Seeding implements should be used at right angles to the general slope to minimize erosion.
7. Mulch will be used where needed.
8. The area shall be watered daily or as often as necessary to maintain adequate soil moisture until the plants grow about 1/2 - 1 inch.
9. Sodding solid slab Bermuda sod may be used from 4/1 through 10/1.