CITY OF DICKINSON

DRAINAGE CRITERIA MANUAL

(Adopted August 23, 2011)

I. INTRODUCTION

<u>Purpose</u>

This DRAINAGE CRITERIA MANUAL (the "Manual") provides design guidance for use by developers and engineers in preparation of drainage plans for development within the City of Dickinson (the "City"). It establishes rules and regulations that must be consistently followed and will be enforced throughout the City's jurisdiction including the portions of the Dickinson Bayou watershed lying within the City's boundaries. The design methods presented in this manual are intended to provide guidance for determination of runoff rates; methods of storm water collection, conveyance, and detention; and design standards for facilities (ditches, ponds, detention basins, etc.).

Methods of design and analysis other than those included in this Manual may be considered in certain cases where there may be inherent problems with the traditional methods. However, any deviation from this Manual will require consideration and acceptance by the City before approval will be granted for any work based on these alternatives.

<u>Policy</u>

Due to the nature of the watershed hydraulics within the City's boundaries and the prevalent existence of flood plains that exceed the banks of the creeks, it shall be the policy of the City to maintain zero net increase in storm water runoff rates and to insure no negative impacts attributable to new development and redevelopment that increases impervious cover by at least five percent (5%). Although it is the City's long-term goal to construct and maintain facilities (i.e., channels and regional detention facilities) that will contain 100-year storm flows within drainage rights-of-way, it is recognized that further impacts to the existing system cannot be tolerated. Therefore, the current City policy is based upon an "on-site detention" storm water management policy. Strict adherence to this policy will insure that existing runoff rates will not increase as a by-product of development, and therefore no off-site impacts will be developed. It is further recognized that impacts to other land owners and jurisdictions outside of the City's boundaries are unacceptable, and the City believes that this policy will effectively eliminate any such out-of-district impacts.

It is the goal of the City to support channel improvements of the major Creeks within its jurisdiction in general conformance with the adopted regional Master Plan. The City will also support and cooperate with the other governmental entities including the City of League City, City of Santa Fe, City of Texas City, Galveston County, Galveston County Consolidated Drainage District, Galveston County Drainage District No. 1, Galveston County Drainage District No. 2 and Brazoria County Conservation and Reclamation District No. 3 to improve local drainage.

Individual developers must provide infrastructure required to meet the City's stated objective of zero net increase in runoff rates and no negative impacts. Practically, this will mean that developers will provide adequate on-site detention volume to off-set increased runoff rates and must provide compensating storage volume for all fill placed in the floodplain. The City will require separate “off-line” detention facilities, and no “in-line” detention scenarios will be approved. Additionally, development in the delineated floodway will be restricted by the City.

This Manual also establishes minimum right-of-way requirements for certain ditches, channels and bayous within the City’s jurisdiction. These minimum right-of-way requirements are based upon past engineering studies, and generally allow for conveyance of the projected 100-year flow in a ditch section that can readily be accessed and maintained by the City.

Jurisdiction

The area within the City of Dickinson boundary is drained entirely by the Dickinson Bayou. Subdivisions and other developments in the area that are not located directly on this major drainage artery generally drain by man-improved or man-made ditches and storm sewers which convey the rainfall runoff to the major drainage artery. The City of Dickinson is responsible for the maintenance of those drainage ways that drain City road rights-of-way (within rights of way and identified in the Master Plan) within its City Limits.

Watersheds

The City’s service area covers approximately 12 square miles and lies in north central Galveston County. Historically, this service area was primarily rural agricultural, but recent growth in the area is changing the land use to urban development at an increasing rate. The City’s boundaries include a portion of one major watershed: Dickinson Bayou.

Dickinson Bayou

Dickinson Bayou watershed covers the entire City service area. Dickinson Bayou drains surface water from Alvin, Friendswood, League City, Santa Fe, Dickinson and unincorporated Galveston County as it flows from its upstream end in Brazoria County to its outfall in Galveston Bay (approximately 22 miles in length).

The topography of the Dickinson Bayou basin is relatively flat, soils are typically low permeable clays, and land use includes agricultural, some light industrial/commercial and residential development. The main channel of Dickinson Bayou is generally unimproved, and while some individual land owners have cleared underbrush along the banks, there has been no major effort by any jurisdictional entity to realign, widen or otherwise change the natural channel.

Definitions

Administrative Official: The individual charged with the administration and enforcement of this manual, or their duly authorized representative

City: City of Dickinson

Conduit: Any open channel or closed pipe system for conveying flowing water.

Developer: An individual or entity that makes improvements to real property for the purpose of reselling that property as a course of business, or for personal, non-residential use, and subdivision development greater than two adjoining lots shall be considered a Developer by the City. An individual engaging in construction of a single homestead to be used by that individual and his/her immediate family, including all reasonable associated improvements (i.e., driveways, garages, personal storage buildings and swimming pools) or infill development where public infrastructure including roadways and utilities exist adjacent to the parcel for lots less than one-half (1/2) acre in size shall not be considered a Developer by the City. Additionally, an individual who is subdividing a lot without improvements and only for subdivision purposes shall not be considered a Developer by the City.

Development: The term includes New Development, Redevelopment and In-fill Development.

1. In-fill Development: Development of open tracts of land in areas where the storm drainage infrastructure is already in place and takes advantage of the existing infrastructure as a drainage outlet.

2. New Development: Development of open tracts of land in areas where the storm drainage infrastructure has not been constructed and a drainage outlet must be extended to a conduit system under the jurisdiction of the City and/or Galveston County.

3. Redevelopment: A change in land use that alters the impervious cover from one type of Development to either the same type or another type, and takes advantage of the existing storm drainage infrastructure in place as a drainage outlet.

Drainage Plan: All Developers shall provide the City with a drainage plan prepared by a Professional Engineer licensed to practice in the State of Texas3 showing the overall approach for the collection, conveyance and storm water detention required by the City's "Drainage Criteria Manual" to assure a "no impact" development. Individuals constructing a homestead for their personal use shall be required to provide a grading and/or drainage plan that will eliminate negative impacts to the adjacent properties but that may not need to be prepared by a licensed engineer as determined by the City Council or the Administrative Official.

Floodplain Administrator: The individual charged with enforcing the City's floodplain management ordinance.

Infiltration Trenches: Trenches or basins that temporarily detain a design water quality volum while allowing infiltration to occur over a prescribed period of time.

Green Roof: A roof that is partially or completely covered with vegetation and growing medium with a drainage and irrigation system.

Hard Roof: Horizontal roof surfaces used to attenuate peak runoff associated with rainfall and effectively detain flow resulting from smaller rain events.

Porous Pavement: Permeable surface course that allows for infiltration of storm water runoff into a permeable layer of uniformly graded stone bed.

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II. ADMINISTRATION

Submittal

The City has authority for review and approval of plats and development plans for projects within its jurisdiction. Prior to commencing construction on proposed improvements, two (2) copies of plans, plats, reports, and calculations shall be submitted for review at least thirty (30) days prior to the meeting at which the item will be considered. Proposed plats and plans shall be submitted for each development unless an overall master drainage plan for the development has been previously approved, in which case the applicant must demonstrate compliance with the approved master plan. For projects of 25 acres or more or out of tracts of 25 acres or more, approval of a preliminary engineering report and conceptual master plan shall be required, detailing design methodology and concepts for drainage of the project prior to preliminary plat approval. All plans and reports must be prepared and sealed by a Professional Engineer licensed to practice in the State of Texas.

Fees

Drainage plans submitted to the City for approval must be accompanied by a check made payable to City of Dickinson for an amount specified in the Master Fee Schedule as determined by the City Council from time to time and on file at City Hall. A schedule of fees will be provided upon request to the City.

Site Visit

The City may require a representative of the property owner or developer to meet with City staff at the project site prior to plat or drainage plan approval. This meeting shall be for the City's benefit and allow the City to understand the developer's intentions.

Datum

All topographic information shown on plats and plans must be on the same vertical datum as the current FEMA FIRM Map showing the project area. In the event GPS surveying is used to establish bench marks, at least two references to bench marks relating to the Flood Insurance Rate Maps shall be identified. Adjustments between datum elevations must be completed and certified by a Texas Registered Professional Land Surveyor.

Plat Review and Approval

The plat review and approval process is detailed in the Subdivision Ordinance.

Drainage Plan Review

All construction plan sets shall include a Drainage Plan for review and approval by the City. The drainage plan shall present the applicant's overall approach to collecting and conveying rainfall runoff to the appropriate drainage artery. It is recommended that prior to preparation of the plan a meeting be arranged between the applicant and City Staff to discuss the proposed concept for drainage of the project. The design submittal shall contain the following items:

1. Name, address, and phone number of engineer that prepared the plan including contact person.
2. Scale of drawing with a minimum scale of 1"=100'.
3. Benchmark and reference benchmark with datum and year of adjustment.
4. A detailed location or vicinity map drawn to a scale. The project site shall be accurately located on the map.
5. Date on all submittals with date of all revisions with month, day, and year.
6. Signature lines for City Officials in accordance with ATTACHMENT D.
7. City notes in accordance with ATTACHMENT E.
8. Contour lines at 0.5 foot where slopes do not exceed 1.0% and 1 foot intervals for slopes exceeding 1.0% intervals covering the entire development and extended beyond the development boundaries at least 200 feet on all sides for developments over 5 acres and 50 feet on developments under 5 acres. At least two contours are required for each project.
9. Preliminary scheme for the passage of sheet flow from adjacent properties.
10. Drainage area divides for project area, with peak run-off rates and calculations for each drainage area.
11. Plan and profile drawings of all storm sewers and roadways at a minimum scale of 1”=50’horozontally and 1”=5’ vertically.
12. Locations of all planned drainage improvements proposed for moving run-off water from the development to the principle drainage artery, i.e., creek, stream, bayou, ditch etc., and their point(s) of entry into the drainage artery.
13. Points at which structures or pipelines will cross drainage ditches, streams etc., within the development.
14. Locations of structures or other physical features on the development area to provide orientation as required during field inspection of the site.
15. Location of all existing drainage structures, utility lines, pipelines, and other underground features on the property and adjacent rights-of-way.
16. Location and dimensions of all proposed drainage easements and rights-of-way.
17. Location of major drainage arteries adjacent to or crossing the development as determined through actual ground survey by the developer's surveyor. Survey shall have been completed within the past year and shall show stream alignment 200 feet upstream and downstream of development.
18. Cross-section of detention facility.
19. Detention calculations in accordance with Section VI including volumetric calculations of detention provided.

20. Drainage area map of receiving system, if discharging to existing storm sewer system. Drainage area of receiving channel if discharging to open ditch or stream. Include calculations to prove capacity is available.
21. Copy of approved permit from TxDOT if draining to or impacting their system.
22. Copies of documents and letters of request for permission to cross privately held easements or rights-of-way and their approvals to do so.
23. Limits of 100-year flood plain by a vertically controlled survey (not scaled from FEMA FIRM Maps).
24. A Floodplain Statement that specifies the site's position in relationship to the floodplain zones described on the appropriate FEMA FIRM map. This statement will specify the FIRM panel number, revision date, applicable zone(s), and the elevation of the 100-year floodplain (if applicable).
25. A statement that specifies that the development shall not impede, impound or block the existing flow of drainage on or from the adjacent properties.

<u>Certification</u>

Calculations and design drawings must be prepared under the supervision of a Professional Engineer licensed to practice in the State of Texas trained and licensed under the disciplines required by the project scope. All construction documents and design calculations must be sealed, signed and dated by the Professional Engineer licensed to practice in the State of Texas responsible for the development of the drawings.

<u>Design Analysis</u>

(1) Projects shall be tied to the National Geodetic Survey (NGS) datum adjustment Federal Emergency Management Agency (FEMA) rate maps or the most current NGS datum that match the FEMA rate maps. In the event GPS surveying is used to establish bench marks, at least two references to bench marks relating to the rate maps shall be identified. Equations may be used to translate other datum adjustments to the required adjustment.

(2) Drawing sets shall include a Drainage Area Map that will contain calculations of flow by the rational method.

Development and Roadway Outfalls
Drainage systems for curb-and-gutter pavements shall be underground closed Conduits. Individual residential lot drainage is exempt. Drainage systems for pavements without curb-and-gutter shall be roadside open-ditch sections.

<u>Low Impact Development</u>

Design requirements for Low Impact Development (LID) techniques are included in below. Only four techniques may be considered to have impact on detention rates: Infiltration Trenches, Hard Roof, Green Roof, and Porous Pavement. The overall detention mitigation volume and outflow rates determined in Section VI may be provided through a combination of LID measures and a detention facility. Maintenance and inspection of all LID measures shall be completed at the property owner's expense and shall not be the responsibility of the City. Documentation of all periodic inspections and maintenance shall be kept onsite by the property owner.

Infiltration Trenches

a. Overview

Infiltration Trenches are applicable for both water quality and water quantity control practices.

b. Design Criteria

(1) In-situ subsoil will have a minimum infiltration rate of 0.5 inches per hour. Geotechnical testing including one boring per 5000 square feet or two per project is required to confirm infiltration rate.
(2) Subsurface drainage systems are required where the in-situ subsoil rate is less than 0.5 inches per hour or where the project is constructed on fill soils.
(3) Avoid placement on slopes greater than 15% in fill areas.
(4) Trench area must be designed to empty with 48 hours.
(5) Backfill using clean aggregate larger than 1.5" and smaller than 3" surrounded by engineered filter fabric.
(6) Provide overflow structure or channel to accommodate larger runoff events.
(7) Provide 4" PVC observation well into subgrade.
(8) Runoff from commercial areas and parking lots require pretreatment; grass buffer strip or vegetated swabs, prior to draining into infiltration trench.
(9) Locate bottom of facility at least 4 ft. above seasonal high water table elevation.
(10) Locate at least 100 ft. from any water supply well.
(11) Maximum contributing drainage area is 5 acres or less.
(12) Mitigating detention volume can be reduced by the amount of infiltration into the subsoil and the volume of voids within the trench area.

c. Inspection and Maintenance Requirements

Inspect observation well for water level and drainage times. Conduct landscaping, mowing, and desilting of facility.

Hard Roof

a. Overview

Horizontal roof surfaces can be used to attenuate peak runoff associated with rainfall and effectively detain flow resulting from smaller rain events. The detention volume can be controlled in several ways, but typically a simple drain ring is placed around the roof drains. As storm water begins to pond on the roof, flow into the roof drains is controlled by orifices or slits in the drain ring. Extreme flows can be designed to overflow the ring and drain directly to the roof drains or be directed to openings in the parapet walls to prevent structural and flood damage to the roof. The roof deck must be designed to withstand the live load and be properly waterproofed.

b. Design Criteria

(1) The structural capability of the roof system must be considered when designing a temporary rooftop storage system and must comply with applicable building codes. For example, a three inch water depth is equivalent to a load of 15.6 lbs/sq.ft., which is less than most current building code requirements for live loads.

(2) Consideration must be given to the placement of electrical devices on the roof, such as air conditioning or ventilation systems and lights, and proper measures must be taken to protect the electrical devices from the collected water.

(3) Overflow mechanisms will be provided so that there is no danger of overloading the roof storage system during major storms. Additionally, roof slopes must be designed to drain positively toward the roof drains to help minimize localized roof ponding or 'bird bath' formation after the detained water volume is released.

(4) The adopted building codes used by the City of Dickinson will be used for additional structural criteria along with ASCE Standard Reference Number 7, Minimum Design Loads for Buildings and Other Structures.

(5) The amount of credit given for detention volume for rooftop storage must take into account that many flat roofs already pond significant amounts of water although not by design. Therefore, when measuring credit given for hard roof detention volume, it is recommended that credit only be given for the total rooftop storage volume less the rooftop storage volume associated with the first inch of rain. Typically, rooftop storage volumes are only effective during the smaller, more frequent rainfall events as the larger, less frequent storms typically exceed the rooftop storage capacity.

c. Inspection and Maintenance Requirements

(1) Each hard roof installation will be inspected by the City Inspector and/or City Engineer to check compliance with the approved drawings before final acceptance is issued. At a minimum, the following items will be checked during the inspection:

(a) Roof penetrations for ventilation, electrical or plumbing connections to verify proper sealing against leaks.

(b) The overflow system that drains excessive rainfall off of the hard roof once the maximum storage volume is captured.

(c) Certification from a Professional Engineer licensed to practice in the State of Texas or Architect registered to practice in the State of Texas that the hard roof, drain system and appurtenances have been installed and operate as designed.

(d) Drawings of the hard roof installation.

(2) Once the hard roof is installed, additional inspections will be required in order to properly maintain the drainage system and roof membrane. Routine inspections must be conducted and associated maintenance activities performed by the property owner on the following:

(a) Designated drainage paths and drainage system components must be inspected to ensure proper surface drainage is maintained and that the roof is draining properly after the collected storm water volume is released from a rainfall event.

(b) Routine inspections to collect and remove any trash or debris from the roof must be conducted to prevent clogging of the roof drains and overflow drainage system.

(c) Visible cracks in the roof surface must be identified and repaired in accordance with the roof manufacturer's recommendations in order to maintain roof integrity.

Green Roof

a. Overview

A green roof, in simplest terms, is a vegetated roof. The vegetation varies, but must be suitable to the local climate and be drought tolerant, unless a method of irrigation is also installed. Installation generally consists of a waterproof membrane installed over a suitably constructed roof deck. For in-situ installations, an under-drain drainage system is installed over the membrane. A lightweight engineered soil is installed on top of the under-drain, as fill dirt or topsoil is typically too heavy to use in rooftop applications. The engineered soil is then planted with select vegetation. If a modular system is selected, the drainage system may already be incorporated into the design, along with the soil and vegetation, depending on the manufacturer. The substrate material and depth are also factors that influence the efficiency of the green roof to store and/ or treat storm water. Roofs consisting of relatively thin soil layers, called extensive roofs, are not as heavy as the intensive roofs, which are covered with thicker soil layers.

b. Design Criteria

(1) Vegetation suitable to the climate and preferably a species that is drought tolerant, unless a method of irrigation is provided, must be installed. The effect of wind on the vegetation must also be considered when selecting the roof foliage, as wind velocities are typically higher at rooftop elevations.

(2) The amount of credit given for the rainfall amount stored will be as prescribed by the manufacturer for a modular system.

(3) The amount of credit given for the rainfall amount stored for non-modular systems will be calculated for the engineered soil. The rate will be derived by in-situ porosity testing. The porosity test will be

performed four times with the first time results being discarded and the three remaining results averaged. The test will require the first sample remain wet a minimum of 1 hour. The subsequent porosity tests will be performed the same day. In no case will the storage volume be credited more than 33% of total volume, as that is the assumed volume of clean graded washed gravel.

(4) The roof membrane must be sufficiently designed and installed to pond a minimum of 1-inch of water at the most shallow point on the roof for 24 hours without leaks. This must be tested in the same manner as shower pans are tested under the building code. Additionally, special consideration must be given for the plant root structure and prevention of soil migration during membrane selection. A root barrier may also be required to protect the waterproof membrane integrity.

(5) The under-drain drainage system must be designed for the selected plant's tolerance for drought and varying soil moisture contents by maintaining the proper balance of moisture and aerobic conditions within the soil media for optimum vegetation sustainability. Design provisions must address higher volume rainfall events to keep excessive amounts of water from ponding on top of the soil, to prevent erosion, and to prevent soil media saturation for extended periods. Structural calculations will be submitted that demonstrate the structure's ability to sustain the additional loading of the green roof appurtenances plus the maximum water weight that could be stored.

c. Inspection and Maintenance Requirements

(1) A maintenance plan for the green roof system must be developed in accordance with the membrane manufacturer's instructions and plant species selected. At a minimum, maintenance inspections must be performed at least four times per year. The maintenance plan must include provisions for vegetation maintenance and replacement as needed to maintain a minimum 80% coverage/survival rate in order to sustain storm water quality and/or detention credits. Irrigation may be required initially in order to establish the roof vegetation and to supply water under severe drought conditions. Any requirements for initial or intermittent use of fertilizer and pesticides for disease or insect control must be identified in the plan. Plant species must be carefully selected to minimize intermittent fertilizer and pesticide applications.

(2) Each green roof installation will be inspected by the agency responsible for issuing the storm water quality or detention credits to check compliance with the approved drawings before final acceptance is issued and the proper credits are approved. At a minimum, the following items must be checked during the inspection:

(a) Results from porosity testing (for non-modular installations).
(b) Certification from a Professional Engineer licensed to practice in the State of Texas or Architect registered to practice in the State of Texas that the green roof, including membrane, drain system and engineered soil system, was installed per the approved (permitted) drawings and operates as designed.
(c) Drawings of the green roof installation.

(3) Once the green roof is installed and established, additional inspections will be required in order to properly maintain the vegetation, drainage system and roof membrane. Routine inspections must be conducted and associated maintenance activities performed by the property owner on the following:
(a) Joints at adjoining walls, roof penetrations for vents, electrical and air conditioning conduits must be inspected regularly for leaks. The ceilings located directly below the green roof installation must also be visually inspected for signs of water staining or leaking.
(b) Designated drainage paths and drainage system components must be inspected to ensure proper surface drainage is maintained and that the soil layer is drained to prevent excessively saturated soils. Vegetation selected to tolerate drought conditions may rot or die if the soil is allowed to become saturated for extended periods.
(c) Vegetation must be visually inspected to identify weeds, accumulated trash or debris, dead or dying vegetation, disease or other infestation problems requiring maintenance attention. Weeds and dead vegetation must be removed on a regular basis, especially right after the roof is planted. If a certain plant or grass species continues to die, that plant or grass must be removed and replaced with a more tolerant species. Certified professionals will be used to apply chemical applications for the control of disease or insects at trouble spot locations.
(d) Trimming and pruning will be done in accordance with horticulture practices to keep vegetation aesthetically groomed.

<u>Porous Pavement</u>

a. Overview

Porous Pavement consists of a permeable surface course that allows infiltration of storm water runoff into a permeable layer of uniformly graded stone bed. The pavement surface may either be soft (grass) or hard (concrete, asphalt or advance gravel systems). The underlying permeable layer serves as a storage reservoir for runoff and/or infiltration. Porous Pavement is applicable for both water quality and water quantity control practices.

b. Design Criteria

(1) In-situ subsoil will have a minimum infiltration rate of 0.5 inches per hour. Geotechnical testing including one boring per 5000 square feet or two per project is required to confirm infiltration rate.

(2) Subsurface drainage systems are required where the in-situ subsoil rate is less than 0.5 inches per hour or where the project is constructed on fill soils.

(3) Will be limited to lightly traveled surfaces such as parking pads in parking lots, trails and sidewalks. Porous pavement is not permitted for residential driveways (area of pavement likely to be coated or paved over because of a lack of awareness) and commercial areas designed for heavy traffic volume and/or vehicles.

(4) Typical section of porous pavement and underlying permeable stone bed is shown on Figure 1 followed by a description of each layer of material.

(5) Subsurface drainage systems are required to be drained in 48 hours.

(6) If the volume of storage within the voids of the subsurface drainage system's stone bed meets the detention volume rate of 0.5 acre-feet per acre of development or 0.2 acre-feet per acre for tracts less than one acre, the area of the porous pavement is considered undeveloped. Otherwise, the total voids storage volume will be credited toward the required detention volume.

(7) If the time of concentration (Tc) from a project site that includes porous pavement and subsurface drainage system, is equal to the undeveloped time of concentration, the development of the project site is considered undeveloped.

(8) Soft porous pavement area will be considered undeveloped.

(9) The cross-section typically consists of four layers. The aggregate reservoir can sometimes be avoided or minimized if the sub-grade is sandy and there is adequate time to infiltrate the necessary runoff volume into the sandy soil without by-passing the water quality volume. A description of each of the layers is presented below:

<u>Porous Concrete Layer</u> – The porous concrete layer consists of an open-graded concrete mixture usually ranging from depths of 2 to 4 inches depending on required bearing strength and pavement design requirements. Porous concrete can be assumed to contain 18 percent voids (porosity = 0.18) for design purposes. Thus, for example, a 4 inch thick porous concrete layer would hold 0.72 inches of rainfall. The omission of the fine aggregate provides the porosity of the porous pavement. To provide a smooth riding surface and to enhance handling and placement a coarse aggregate of 3/8 inch maximum size is normally used.

Top Filter Layer – Consists of a 0.5 inch diameter crushed stone to a depth of 1 to 2 inches. This layer serves to stabilize the porous concrete layer. Top filter layer can be combined with reservoir layer using suitable stone.

Reservoir Layer – The reservoir gravel base course consists of washed, bank-run gravel, 1.5 to 2.5 inches in diameter with a void space of about 40 %. The depth of this layer depends on the desired storage volume, which is a function of the soil infiltration rate and void spaces, but typically ranges from two to four feet. The layer must have a minimum depth of nine inches. The layer will be designed to drain completely in 48 hours. The layer will be designed to store at a minimum the water quality volume (WQv). Aggregate contaminated with soil must not be used. A porosity value (void space/total volume) of 0.32 must be used in calculations unless aggregate specific data exist.

Bottom Filter Layer – The surface of the subgrade must be a 6 inch layer of sand (ASTM C-33 concrete sand) or a 2 inch thick layer of 0.5 inch crushed stone, and be completely flat to promote infiltration across the entire surface. This layer serves to stabilize the reservoir layer, to protect the underlying soil from compaction, and act as the interface between the reservoir layer and the filter fabric covering the underlying soil.

Filter Fabric – It is very important to line the entire trench area, including the sides, with filter fabric prior to placement of the aggregate. The filter fabric serves a very important function by inhibiting soil from migrating into the reservoir layer and reducing storage capacity. Fabric used must be MIRFI # 14 N or equivalent.

Underlying Soil – The underlying soil must have an infiltration capacity of at least 0.5 in/hr, but preferably greater than 0.50 in/hr. as initially determined from NRCS soil textural classification, and subsequently confirmed by field geotechnical tests. The minimum geotechnical testing is one test hole per 5000 square feet, with a minimum of two borings per facility (taken within the proposed limits of the facility). Infiltration trenches cannot be used in fill soils. Soils at the lower end of this range may not be suited for a full infiltration system. Test borings are recommended to determine the soil classification, seasonal high ground water table elevation, and impervious substrata, and an initial estimate of permeability. Often a double-ring infiltrometer test is done at subgrade elevation to determine the impermeable layer, and for safety, one-half the measured value is allowed for infiltration calculations.

c. Inspection and Maintenance Requirements

(1) Initial inspection of porous pavement to be conducted by the property owner shall be monthly for the first three months post construction.

(2) Property owner shall be required to conduct semi-annual inspections to ensure pavement surface is free of sediment.

(3) Property owner must vacuum sweep hard porous pavement followed by high pressure hosing to keep voids free of sediment quarterly.

(4) Property owner must annually inspect pavement surface and subsurface drainage system (if any) for deterioration, spalling or malfunctioning.

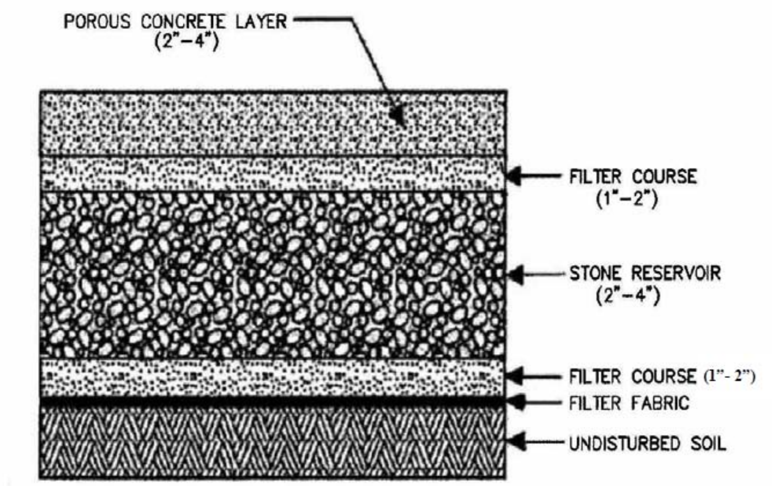

FIGURE 1
POROUS CONCRETE TYPICAL SECTION

Drainage Plan Approval

The City shall provide comments to the applicant as soon as possible after submittal. Once all comments have been addressed and the Drainage Plan has been approved by the City, the related plat will be placed on a Planning and Zoning Commission agenda. The Drainage Plan must be approved before the P&Z will take final action on the related plat.

Project Acceptance

Upon completion of all construction improvements, the applicant shall contact the City for an inspection of the project. Upon successful final inspection, the applicant must submit one copy of the as-built plans to the City.

The City will require the developer to provide a one year maintenance period upon completion of the improvements. Correction of any deficiencies discovered on the final inspection will begin the maintenance period. After one year the City will re-inspect the facility. A letter of final acceptance will be issued after correction of any deficiencies which will promptly be corrected by the developer before City release.

Maintenance of Storm Water Storage Facilities (Detention Ponds)

For the purpose of this section, a storm water storage facility shall mean an engineered system serving as a storm runoff collection and storage facility.

In each case where an on-site storm water storage facility is provided pursuant to this Manual, the Developer shall furnish evidence of acceptance for maintenance of such storage facility from the entity having authority to perform such service. All facilities are to be maintained privately. Evidence of dedication and provision of maintenance of such facilities must be provided to the City before final acceptance will be issued.

Revisions to Drainage Plans

All revisions to the approved drainage plan must be approved by the City. The City may require a re-submittal of a drainage plan or plat dependent upon the character and extent of the changes made as determined by the City.

III. PRIVATE AND PUBLIC UTILITY CROSSINGS

Utility, Pipeline, and Cable Crossing

All utilities, pipelines, and cable crossings, either publicly or privately owned, shall obtain a permit from the City prior to any construction to cross any drainage facility within the City boundaries.

All utilities, pipelines, and cables shall cross City facility within 20 degrees of perpendicular to that facility. No utility, pipeline, or cable shall be located within and parallel to a creek right-of-way without specific approval of the City Council.

Submittal Procedures shall be the same as required for plats and plans. Application fees are as stated in the Master Fee Schedule located on file in the City's office.

Review Procedure

Three copies of plans, plats, reports, and calculations shall be submitted for review.

The City Engineer and the Administrative Official shall review the submitted materials and either approve, disapprove or specify changes to be made to comply with this rule for approval.

Submittal

Top of utility, pipeline, or cable shall be a minimum of five (5) feet below the existing flowline of the channel being crossed, or five (5) feet below the projected flowline of the channel as provided by the City Engineer. Proposed utility, pipeline, or cable must stay at this depth for the entire width of existing easement, and then may be sloped towards the ground surface at a slope not to exceed 3:1.

All pipelines with a working pressure exceeding 200 pounds per square inch shall be constructed with a concrete pad over the line. Pads shall extend a minimum of one (1) foot on either side of edge of pipeline for the total length of the City's easement, and shall be six (6) inches thick. Top surface of pad shall be a minimum of five (5) feet below the existing flowline of the channel being crossed, or five (5) feet below the projected flowline of the channel as provided by the most recent available information. The City may release the requirement for a concrete pad if the pipeline is directionally drilled under easement and is at least ten (10) feet below the existing flowline of the channel being crossed, or ten (10) feet below the projected flowline of the channel as provided by the most recently available information.

Benchmark and survey requirements will comply with those listed for drainage plans. The drawings shall have the City's signature block as shown in ATTACHMENT D and shall contain the City design notes contained in ATTACHMENT E.

Notices

The Applicant shall provide the City with written notice of intent to begin construction at least forty-eight (48) hours notice prior to the start of construction.

Upon completion of crossing, the Applicant shall install markers on either end of crossing, at the right-of-way limits of the City easement. It shall be the Applicant’s responsibility to maintain the condition of all markers.

IV. HYDROLOGY

Hydrology is the study of precipitation. Policy makers and engineers must study and understand hydrology because they are interested in designing and building structures and systems to safely convey and discharge precipitation runoff while minimizing the potential of flooding. They must determine how much water should be collected and conveyed or stored, how fast this process must take place, how much can be safely discharged without adversely impacting surrounding properties, and what are other effects of the development being considered. The following sections discuss specific parameters and methods to be used in analyzing proposed developments in the City's service area.

Storm Frequency

All drainage improvements shall, at the minimum, be designed for the following storm frequencies. The return intervals listed here are minimums, and the individual design engineer or the City may choose to exceed these minimums given site specific requirements or constraints.

Type of Facility	Return Interval Storm
Closed Conduit Storm Sewers (for new developments)	3-year
Ditch Culverts (serving less than 50 acres)	5-year
Ditch Culverts (serving 50 to 100 acres)	25-year
Ditch Culverts (serving 100 acres or more)	50-year
Bridges crossing City Ditches	100-year
Major Ditches and City Channels	100-year
Detention Facilities	100-year

Peak Storm Runoff Rates

The Rational Method can be used for determining peak runoff flow rate for both existing and proposed conditions. These peak runoff rates are used to estimate the impact of development and the conveyance requirements for drainage improvements. This method is applicable for small to medium drainage areas (generally less than 200 acres) where the flow domain is typically overland sheet flow or shallow surface ditch flow. Other methods should be used to estimate peak runoff rates for larger areas or those served by well defined channels where flow routing in defined channels may be significant. The Rational Method takes the following form:

$$Q = C_f * (C * I * A)$$

Where:

Q = Peak Runoff Flow Rate (cfs)
C = Runoff Coefficient, See ATTACHMENT A
C_f = Frequency factor (the product of C_f and C should not exceed 1.0)
A = Area of drainage basin being studied (acres)
I = Rainfall Intensity of the design storm (inches/hour)

Frequency Factor (C_f)

The Frequency Factor is used in the Rational Method to scale the magnitude of the peak runoff in relationship to the return interval of the storm consistent with observed runoff data. This adjustment factor is used to account for the effects of antecedent moisture conditions that are generally associated with the less frequent storms. Appropriate values of C_f are presented in the following table.

Storm Frequency	Frequency Factor (C_f)
10	1.00
25	1.10
100	1.25

The product of C_f and C used in the Rational Method should not exceed 1.0.

Basin Time of Concentration (T_c)

The storm rainfall Intensity used in Rational Method will be selected based upon the return interval of the storm to be used (specified in the Storm Frequency Table above), and the duration of the storm to be used (based on the study basin's time of concentration). Time of Concentration (T_c) is defined as the length of time it takes a drop of water to travel from the most hydraulically remote portion of the drainage basin to its outlet. T_c is a property of the drainage basin reflective of its area, shape, surface gradient, land use, land cover, and soil type. T_c (in minutes) may be estimated from the following equation:

$$T_c = \text{Length}/(\text{Velocity} * 60) + 10$$

Where:

Length = Flow distance (feet)
Velocity = Flow velocity (fps) [see following table]

Flow Condition	Representative Velocities
Shallow overland flow in undefined channels	0.25 to 0.50 fps
Flow in street curb & gutter or road ditches	0.75 to 1.25 fps
Flow in shallow ditches	1.5 to 3.0 fps
Flow in defined channels	2.0 to 4.0 fps
Flow in closed conduit storm sewers	3.0 to 5.0 fps

The constant value of 60 in this equation is used to convert seconds to minutes and 10 is used as an estimate of initial delay between the start of rainfall and development of actual surface runoff. This method can be applied fairly accurately to large and small basins with either undeveloped or developed surfaces. However, the designer must specify the flow condition and estimated flow velocities for each flow domain on the site (i.e., the first 100' is overland flow followed by 250' in a gutter followed by 400' in closed conduit, etc.) and estimate time of concentration as the sum of all these individual flow conditions. The flow path used as the basis of this calculation should be clearly denoted on the plans with the associated design calculations.

Another method that can be used to estimate time of concentration for developed areas (i.e., storm sewer projects) is in the following form:

$$T_c = 10*(A)^{0.1761} + 15$$

Where:

A = Drainage Basin area (acres)

This method accurately estimates T_c for sewered projects; however it tends to underestimate actual T_c for basins with significant overland flow or open ditch flow, and therefore may overestimate peak runoff flow rates for these basins.

Alternative methods for estimating the basin's time of concentration will be accepted for reviewed by the City, and may be allowed for use if the method's applicability to a specific situation warrants its use over the methods presented.

Storm Intensity (I)

For small watersheds and individual developments, the storm intensity should be based upon the time of concentration of the basin being analyzed. For example, in the design of a detention facility serving a basin with a 2-hour time of concentration, an Intensity for a 100-year, 2-hour storm should be selected for use in the analysis.

For large watersheds and regional studies, use a 24-hour duration storm for the analysis and design. Appropriate design storm intensities are shown in ATTACHMENT C for various return interval storms.

V. HYDRAULICS

Hydraulics is the study of fluid flow behavior. Policy makers and engineers must study and understand hydraulics because they are responsible for designing and constructing conveyance and storage facilities capable of managing storm water runoff in a safe and effective manner while reducing the potential for flooding. The following sections discuss specific methods and parameters to be used in analyzing proposed developments in the City's service area.

Open Channel Flow

The vast majority of conveyance capacity within the City's service area is located in the network of open channels that the City builds and maintains. The Chezy-Manning equation will be used to estimate a ditch's conveyance capacity. This equation is in the following form:

$$Q = 1.486/n * A * R^{2/3} * S^{1/2}$$

Where:

n = Manning's Roughness Coefficient (unitless)
A = Flow Cross-sectional area (sf)
R = Hydraulic Radius (ft)
S = Slope of the Hydraulic Grade Line (ft/ft)

Typical values for Manning's 'n' are included in ATTACHMENT B. The flow area (A) is estimated from the ditch cross-section, and is the area that will be conveying water (also called the wet area). The hydraulic radius is calculated as the wetted area divided by the wetted perimeter. The wetted perimeter is defined as the length of water/surface interface around the perimeter of the wetted area (does not include the water/air interface length). For open channels, the slope of the hydraulic grade line is estimated to be the same as the ditch slope.

Closed Conduit (Pipe) Flow

The Chezy-Manning equation presented earlier is also applicable for estimating flow capacity for closed conduits (i.e., pipes). There are some important distinctions to remember, including:

- Manning's 'n' for pipe materials are significantly different (i.e., smaller) than those for bare earth or vegetative surfaces. See ATTACHMENT B for appropriate 'n' values.
- The assumption of hydraulic grade line slope being approximately equal to the pipe slope is only valid under free flow conditions. Once the pipe is full and experiences surcharge conditions, the hydraulic grade line slope will increase as flow increases.

VI. DETENTION FACILITIES

The intention of storm water detention is to mitigate increases in peak flow rates resulting from new development, redevelopment or in-fill development on an existing drainage system. Storm water detention volume is based on increased impervious cover and is calculated at the minimum rates set forth herein. Additional mitigation may also be required at the discretion of the City Engineer if upgrades to the storm conveyance system (i.e. larger storm sewers or channels) are anticipated to have a significant impact on downstream facilities.

To meet the City's requirements for zero net increase in runoff rates and no negative impacts to an existing drainage system or the immediately adjacent properties due to new development, redevelopment or in-fill development, projects will need to provide one or a combination of on-site detention facilities, Low Impact Development measures, or off-site improvements to outfall systems. If Redevelopment occurs without increasing the overall impervious character of the site, then no detention will be required by the City.

Each detention facility should be designed based upon site specific parameters and constraints using accepted engineering methods. The City will not allow in-line storage within City ditches or channels. No approvals will be given by the City for any proposed development until staff has been satisfied that the proposed design meets the City's requirements. The following paragraphs describe general design requirements and allowable methods for generating appropriate designs.

<u>General Requirements</u>

(1) As shown in the storm frequency table earlier, detention facilities must be designed to provide enough storage to accommodate a 100-year event for the sub-area it is intended to serve.

(2) Detention facilities may be designed to be wet (constant level ponds) or may be designed to drain completely. A wet detention facility must provide for aeration or pumping and must achieve an acceptable design that will prevent the breeding of mosquitoes and other insects. Engineer to provide the manufacturer's specifications and data for the proposed aeration system and calculations to support the adequacy of the number and size of aerators provided to support the size and depth of the proposed wet detention basin.

(3) Detention facilities must:
   - (a) Be designed and constructed with stable slopes (no greater than 4:1)
   - (b) Provide adequate access and maintenance berms around the entire perimeter (10' minimum for ponds less than 1 acre and 20' minimum for ponds larger than 1 acre);
   - (c) Have erosion control elements (i.e., backslope swales, drop pipes, slope pavement, etc.) as necessary to ensure a stable, low maintenance facility.

(4) All detention facilities less than 2 acres in size must provide for 6 inches of freeboard between the projected 100-year water surface elevation and the top of the berm. All detention facilities over 2 acres must provide 1 foot of freeboard. Outfall structures must be designed to restrict outflow from the detention facility at a rate not to exceed the pre-developed conditions, and must include a controlled release mechanism to safely discharge runoff from storm events in excess of the 100-year design storm.

(5) Detention storage may not be placed in road-side ditches or in curb-and-gutter streets in public or private easements and rights-of-way.

(6) Private parking areas and private access drives may be used for detention provided the maximum depth of ponding does not exceed 9 inches directly over the inlet, and paved parking areas are provided with signage stating that the area is subject to flooding during rainfall events. Detention within high traffic areas and fire/emergency access lanes shall not be permitted.

(7) Any detention pond with a pumped outfall must meet the following criteria:
   (a) The maximum volume of the pumped flow shall be limited to 75% of the total basin volume.
   (b) The maximum drain time is seven days.

(8) Private transport truck only parking may be used for detention provided the maximum depth of flooding does not exceed 15 inches directly above the inlet and signage is provided stating that the area is subject to flooding during rainfall events.

Ownership and Easements

(1) Private Facilities:

   (a) Pump discharges into a roadside ditch requires the submittal of pump specifications on the design drawings.
   (b) The City reserves the right to prohibit the use of pump discharges where their use may aggravate flooding in the public right-of-way.
   (c) Responsibility for maintenance of detention facilities must be indicated by letter submitted to the City as part of the design review.
   (d) All private properties being served must have drainage access to the pond or other detention facilities and adequate maintenance access. Dedicated easements may be required.
   (e) No public properties may drain into the detention area.
   (f) A private maintenance agreement must be provided when multiple tracts are being served.

(2) Public Facilities:

(a) Facilities will only be accepted for maintenance by the City within the City limits in cases where public drainage is being provided.
(b) The City requires a maintenance work area of 30-foot width surrounding the extent of the detention area. Public rights-of-way or permanent access easements may be included as a portion of this 30-foot width.
(c) A dedication of easement shall be provided by plat or by separate instrument.
(d) Proper dedication of public access to the detention facility must be shown on the plat or by separate instrument. This includes permanent access easements with overlapping public utility easements. Such easements shall have a minimum 20-foot width surrounding the perimeter of the detention basin as measured from the top of bank unless adjacent to a street right of way.
(e) Backslope drainage systems are required where the natural ground slopes towards the drainage basin. A basin that is within 30 feet of a parking lot or roadway with berms that drain away from the basin does not require a backslope swale. Compliance with the criteria provided in Galveston County Drainage Subdivision Rules and Regulations is required.

Variances

Based on a recommendation from the City Engineer and Administrative Official, Council may approve variances to the detention facilities requirements.

Waiver of Detention Requirements

A waiver of detention requirements may be requested if the following conditions are satisfied:

(1) Development is located in an area determined by the City not to need detention due to the geographic location in the watershed, the Development's proximity to regional facilities, or the capacity of the receiving outfall facilities. Such conclusion by the City shall be supported by submittal of a Hydraulic Report as described in Subsection (2).

(2) Hydraulic Report: Submit a hydraulic analysis prepared, signed, and sealed by a Professional Engineer licensed to practice in the State of Texas to demonstrate compliance with the conditions stated in this Drainage Criteria Manual. The hydraulic analysis shall consider (1) the current developed condition of the watershed of the storm water conveyance system, and (2) the fully developed condition of the watershed. The probable land use for the fully developed condition will be determined by the design engineer for review and approval by the City. The hydraulic analysis shall

demonstrate no negative impact to upstream or downstream conditions and shall demonstrate that a positive impact will be achieved (reduced flood crest) due to the exemption.

Calculation of Detention Volume

Detention volume for Development, Redevelopment, and In-fill Development areas is calculated on the basis of the amount of area of increased impervious cover. Impervious cover includes all structures, driveways, patios, sidewalks, etc. The following paragraphs describe allowable methods for use in determining storage volume requirements. This is not an exhaustive discussion of all methods, but will provide developers and engineers with a variety of tools for use in the City's service area.

Coefficient Method

For small developments (less than 5 acres for commercial or 10 acres for residential), the developer may chose to use this simplified method for detention volume estimation. Using this method, the developer would provide detention storage using the following equation:

$$\text{Storage} = 0.65 * A_{dev}$$

Where:

Storage = Detention volume required (ac-ft),
A_{dev} = The area of the site that will have modified cover (acres).

Using this method, storage is provided for the portion of the site that is being developed. For example, on a 4 acre commercial tract with 2.5 acres of building, parking, detention and landscape areas, the developer would be required to provide (2.5 acres)*(0.65 ac-ft/ac) = 1.63 ac-ft of detention storage. This method will not be allowed where the total developed area (either proposed or in the future) will exceed 5 acres for commercial or 10 acres for residential developments. The outfall structures will be designed separately as discussed in later paragraphs.

Triangular Hydrograph Method

The Dickinson Bayou Watershed Regional Drainage Plan uses this method to estimate detention volume requirements for all sizes of basins. This method uses simplified hydrographs of a triangular shape to estimate the detention storage requirements. The volume of storage required is computed as follows:

$$B = 43{,}560 * V / (0.5 * I)$$

and

$$S = 0.5 * B * (I - O) / 43{,}560$$

Where:

B = Duration of Inflow (seconds),
V = Total inflow volume (ac-ft),
I = Peak inflow rate (cfs),
O = Peak allowable outfall rate (cfs),
S = Required storage volume (ac-ft),

Small Watershed Method

The storage requirements for detention ponds can be determined using the Small Watershed Method (also called Malcom's Method). This method, like the Triangular Hydrograph Method, is a hydrograph based method that compares an expected inflow hydrograph to an allowable outflow hydrograph to determine required storage volume. Using this method, the required volume of storage is equal to the maximum cumulative difference between the inflow and outflow runoff curves.

DETENTION FACILITY INFLOW HYDROGRAPH

The inflow hydrograph is constructed by calculating instantaneous flow rates using the following equations:

$$Q_i = Q_p/2(1-\cos(\Pi * t_i/T_p)) \qquad \text{for } t_i \leq 1.25\ T_p$$

And

$$Q_i = 4.34 * Q_p * \exp(-1.3 * t_i/T_p) \qquad \text{for } t_i > 1.25\ T_p$$

Where: Q_i = instantaneous flow rate at time "i" [cfs]
Q_p = peak flow rate (Rational Method) [cfs]
t_i = time interval "i" [minutes]
T_p = time to peak [minutes]

In the equations listed above, the time to peak (T_p) is calculated by:

$$\text{Time to peak } (T_p \text{ in minutes}) = V/(1.39 * 60 * Q_p)$$

Where: V = volume of runoff [ft^3]

The total volume of runoff generated by the design storm event is the amount of rain that falls upon the watershed minus loses attributable to surface storage, soil infiltration, evaporation & transpiration, etc. For the purposes of projects within City jurisdiction, designers shall use a cumulative depth of excess rainfall of 9.7 inches when considering a 100-year event. Therefore, the total runoff volume is calculated by multiplying the cumulative depth of excess rainfall for the design storm event (9.7") by the watershed area.

DETENTION FACILITY OUTFLOW HYDROGRAPHS

Outflow hydrographs are constructed by determining the capacity of the outfall structure under incremental surcharge conditions. A table is generated that contains the estimated outfall rate for the proposed structure given increasing depths of ponding in the detention facility. To determine appropriate detention design, the engineer will provide a mass-balance for water in the detention facility (i.e. change in storage of the system equals the volume of water flowing in minus the volume of water flowing out) for several incremental time steps covering the duration of the storm event. The minimum storage requirement will equal the maximum cumulative storage determined in the time step analysis.

The Small Watershed Method is dependent upon the Rational Method for estimation of the peak flow rate, so it should only be used for basins of less than 200 acres where there is no well defined channel and any flow routing can be considered negligible.

HEC-HMS Computer Modeling

For basins over 200 acres in size, the City will require a HEC-HMS hydrograph analysis covering the site and the adjacent parts of the watershed. This analysis should verify that the proposed improvements will not increase runoff rates anywhere in the system and therefore will have no negative impacts on adjacent properties. The engineer must submit a complete design report with sufficient detail (program input parameters, program output and discussion of methods and assumptions used) for the City staff to review. Before beginning this type of analysis, please check with the City to receive the most current baseline HEC-HMS model of the area for development (if one is available).

<u>Outfall Restrictor Design</u>

The outfall structure is an important design component of the detention facility. The design of the outfall structure can be as simple as a single pipe segment, and can be as complex as multiple pipes with differing diameters at staggered elevations with overflow weirs and flow orifices. The following paragraphs describe ways to estimate flow conveyance of several flow control structures.

Orifice

One of the most simple flow control structures is an orifice. An orifice is a two-dimensional flow structure (i.e., a drilled hole in a concrete wall, a hole in plate steel or a very short section of pipe) with an estimated conveyance capacity dependent upon the difference in water elevations from one side of the orifice to the other and the orifice opening area. The general equation for estimating flow through an orifice is as follows:

$$Q = C * A * (2 * g * H)^{1/2}$$

Where:

Q = Orifice flow capacity (cfs)
C = Orifice coefficient (unitless) [use 0.8]
A = Orifice opening area (sf)
g = Gravitational acceleration constant (32.2 ft/s^2)
H = Differential head across the orifice (ft)

For the design head differential (H) use 2 feet or the 100-year water surface elevation in the detention facility minus the 25-year water surface elevation in the receiving ditch (if known). If discharging directly into a roadside ditch or a storm sewer, use 1 foot. The orifice should generally be greater than 6" diameter to reduce problems with clogging and blockage.

Outfall Pipe

The engineer may use one or more a pipe sections as flow control devices. The conveyance capacity of the pipe(s) can be estimated using the Chezy-Manning equation discussed earlier. In using this method, the slope of the hydraulic grade line is equal to the head differential across the structure divided by the length of the pipe section. For the design head differential use 2 feet or the 100-year water surface elevation in the detention facility minus the 25-year water surface elevation in the receiving ditch (if known). If discharging directly into a roadside ditch or a storm sewer, use 1 foot. The restrictor pipe shall not be less than 6" in diameter.

Overflow Weir

An overflow weir can be used on an outfall structure to restrict and regulate outflow. One of the biggest advantages of this outfall structure is that they do not have a finite conveyance capacity, and can therefore be used for emergency overflows to control larger than 100-year flows.

There are many types of weir designs to chose from when designing an outfall structure, and each has a slightly different equation for estimating flow capacity. One of the simplest to design and construct is a Cipoletti weir consisting of a horizontal weir (of width B) with triangular weirs on either side (at 4:1 slopes) and a depth of flow of H feet. Capacity of a Cipoletti weir can be estimate by the following equation:

$$Q = 3.367 * B * H^{3/2}$$

Where:

Q = Weir capacity (cfs)
B = Weir length (ft)
H = Depth of flow across weir (ft)

<u>Site Grading</u>

The building pads shall be built-up so that slab elevations for all occupied structures shall be placed at an elevation that meets or exceeds that prescribed in the adopted building code and the flood ordinance of the City of Dickinson.

All public and private access/egress roads shall be place at an elevation no lower than 12 inches below the 100-year floodplain elevation at the gutter (curb and gutter) or one inch above the 100-year floodplain elevation for open ditch unless a variance is obtained. The volume of fill material placed in the 100-year floodplain must have a corresponding cut somewhere in the immediate vicinity of the fill (within the same watershed and preferably on-site). Fill shall be placed and lots graded so that there is no negative impact to adjacent properties.

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VII. CITY FACILITIES (Major ditches)

The proper hydraulic design of channels is of primary importance to insuring that nuisance drainage conditions, flooding, sedimentation and erosion problems do not occur or the frequency of their occurrence is at an acceptably low rate. For facilities to be operated or maintained as City facilities, the following minimum design standards shall be applied to construction of new or reconstruction of existing facilities.

Design Frequency

New City facilities shall be designed and constructed to contain and safely convey runoff from the 100-year frequency storm when at all feasible to do so. Consideration must be made for the capacity of existing channels downstream, and no improvement shall be made that increase the frequency of downstream flooding.

Design Flow Velocities

Excessive flow velocity can cause erosion problems, may pose a threat to bank stability and may create safety problems. Additionally, velocities that are too low may allow sediment deposition resulting in loss of channel capacity. Generally, design flow velocities in unlined open channels (for 100-year flows) should be between 3 and 5 fps. Flow velocities in concrete lined channels may increase to be between 5 and 8 fps.

City Ditch Width and Ditch Depth

The minimum width shall be adequate to provide maintenance areas, maintainable side slopes, and minimum bottom widths in accordance with City criteria for the ultimate channel section. Ditch depth shall be what is required to provide the required capacity at a minimum.

City Ditch Channel Slope

City ditches shall have a minimum constructed channel slope of 0.05% to provide for the minimum velocities noted earlier. Excessive slopes may unnecessarily increase the potential for erosion of banks and undermining of bridge and culvert structures, therefore maximum slopes should generally not exceed 0.50%. In areas of steep topography, channel drop structures may be required to limit channel invert slopes.

City Ditch Side Slopes

In grass lined channels, maximum side slopes shall be 4:1 (horizontal:vertical). Variance from this criterion may be granted by the City to accommodate site specific issues, but 3:1 slopes should be the steepest unlined slope proposed. Side slopes for concrete lined channels shall be based on field conditions and shall be site specific.

City Ditch Bottom Width

The bottom width for City ditches should generally be no less than six feet. A larger bottom width may be required to meet other issues including ditch capacity, design velocity, etc.

City Ditch Horizontal Curves

In general, centerline curves for grass channels should be as gradual as possible and should have a radius greater than three times the ultimate ditch top width. Smaller curvature radii can be allowed with adequate slope paving as approved by the City.

City Ditch Confluences

The angle of intersection between the tributary and main channel should be between 15º and 45º (with an optimal value of 30º). Angles in excess of 90º will not be permitted.

City Ditch Transitions

Expansions and contractions should be designed to create minimal flow disturbance and thus minimal energy loss. Design consideration must be given to reducing erosion potential and turbulent flow characteristics at ditch transitions.

City Ditch Drop Structures

When introducing flow into ditch main channel from shallow surface swales, the designer must include drop pipes to reduce the erosion potential at the confluence. Drop pipes shall be appropriately sized for the area being served. Drop pipe structures shall be HDPE pipe (or approved equal), properly bedded with a discharge elevation of 12" above the main channel flowline. These drop pipes shall provide for a continuous maintenance berm along the main channel and shall include erosion protection at upstream and downstream ends.

City Concrete Lined Channels

As field conditions necessitate, concrete lined channels may be required to provide adequate capacity or erosion protection for less than optimum drainage easement widths. Design of concrete lined channels will be considered by the City on a case-by-case basis.

VIII. DESIGN OF STORM SEWERS

(1) Design Frequency

(a) New Development: The Design Storm Event for sizing storm sewers in newly developed areas shall be a 3-year rainfall. System shall be designed to convey extreme event (100 year rainfall) by overland sheet flow path that will not impact infrastructure or buildings.

(b) Redevelopment or In-fill Development: The existing storm drain (sewer, ditch) shall be evaluated using a 3-year design storm, assuming not development takes place. The storm drain will then be evaluated for the 3-year design event with the Development in place.

(i) If the proposed Redevelopment has a lower or equal impervious cover, no modifications to the existing storm drain area required.

(ii) If the proposed Development results in the hydraulic gradient of the existing storm drain below the gutter line, no improvements to the existing storm drain area required. Detention shall comply with Section VI above. Flow discharged to the storm drain shall comply with Section VI above.

(iii) If the analysis of the existing conditions finds that the existing storm drain is deficient (ie., the hydraulic grade line is above the gutter line), Applicant should check with the City to see if a Capital Improvement Project is proposed that will require a capital contribution. If a Capital Improvement Project is not proposed for the subject system, then on-site detention will be required in accordance with Section VI above. Flow discharged to the storm drain shall be in compliance with Section VI above.

(c) City Projects (CIP): Proposed City capital improvements may indicate a larger diameter storm sewer is planned in the area proposed for drainage improvements. The Public Works Department has information on proposed improvements and should be consulted for impact on New Development.

(d) Private Drainage Systems: Storm sewers for private drainage systems shall conform to the City of Dickinson's Building Code for development within the City limits.

(2) Velocity Considerations.

(a) Storm sewers should be constructed to flow in subcritical hydraulic conditions if possible.

(b) Minimum velocities should not be less than 3 feet per second with the pipe flowing full, under the design conditions.

(c) Maximum velocities should not exceed 8 feet per second without use of energy dissipation downstream.

(d) Maximum velocities should not exceed 12 feet per second.

(3) Pipe Sizes and Placement.

(a) Use culverts, storm sewer and inlet leads with at least 18-inch inside diameter or equivalent cross section. Box culverts shall be at least 2 feet by 2 feet. Closed Conduits; circular, elliptical, or box shall be selected based on hydraulic principals and economy of size and shape.

(b) Larger pipes upstream should not flow into smaller pipes downstream unless construction constraints prohibit the use of a larger pipe downstream, or the improvements are outfalling into an existing system, or the upstream system is intended for use in detention.

(c) Match crowns of pipes at any size change unless severe depth constraints prohibit and the City has approved an alternative.

(d) Locate storm sewers in public street rights-of-way or in approved easements. Back lot easements are discouraged and will require a variance from the City design standards.

(e) Follow the alignment of the right-of-way or easement when designing case in place concrete storm sewers.

(f) A straight line shall be used for inlet leads and storm sewers.

(g) Center culverts in side lot storm sewer easements.

(4) Starting Water Surface and Hydraulic Gradient.

(a) The hydraulic gradient shall be calculated assuming the top of the outfall pipe as the starting water surface.

(b) At drops in pipe invert, should the upstream pipe be higher than the Hydraulic Grade Line, then the Hydraulic Grade Line shall be recalculated assuming the starting water surface to be at the top of pipe at that point.

(c) For the Design Storm, the hydraulic gradient shall at all times be below the gutter line for all New Development.

(5) Manhole Locations.

(a) Use manholes at the following locations:
(i) Size or cross section changes
(ii) Inlet lead and Conduit intersections
(iii) Changes in pipe grade
(iv) Street intersections
(v) A maximum spacing of 700 feet measured along the Conduit run.

(b) Use manholes for existing monolithic-concrete storm sewers at the same locations as above except for intersections of inlet leads unless a manhole is needed to provide maintenance access at those intersections.

(c) Do not place manholes in driveways or in the street in front of or immediately adjacent to a driveway.

(6) Inlets

(a) Locate inlets at low points in the gutter.

(b) Valley gutters across intersections are not permitted.

(c) Inlet spacing is a function of gutter slope. The minimum gutter slope shall be 0.30 percent. For minimum gutter slopes, the maximum spacing of inlets shall result from a gutter run of 500 feet from high point in pavement or the adjacent inlet on a continuously graded street section, with a maximum of 1000 feet of pavement draining towards any one inlet location.

(i) Residential Development: Maximum spacing of inlets shall result from a gutter run of 500 feet from high point in pavement to the adjacent inlet on a continuously graded street section, with a maximum of 1000 feet of pavement draining towards any one inlet location.

(ii) Commercial Development: Maximum spacing of inlets shall result from a gutter run of 400 feet from high point in pavement to the adjacent inlet on a continuously graded street section with a maximum of 600 feet of pavement draining towards any one inlet location.

(d) Use only City of Dickinson standard inlets.

STANDARD STORM SEWER INLETS

INLET	APPLICATION	CAPACITY
Type A	Parking Lots/Small Areas	2.5 cfs
Type B-B	Residential/Commercial	5.0 cfs
Type C	Residential/Commercial	5.0 cfs
Type C-1	Commercial	10.0 cfs
Type C-2	Commercial	15.0 cfs
Type C-2A	Commercial	20.0 cfs
Type E	Roadside Ditches	20.0 cfs

(e) Do not use beehive grate inlets or other specialty inlets.

(f) Do not use grate top inlets in unlined roadside ditches.

(g) Do not place inlets in the circular portion of cul-de-sac streets unless justification based on special conditions can be provided and the City has approved such placement.

(h) Place inlets at the end of proposed pavement, if drainage will enter or leave pavement.

(i) Do not locate inlets adjacent to esplanade openings.

(j) For new residential development, locate inlets at the center of lots and drainage system with lot site layout such that inlets are not located within the driveway between the radius end points as defined by the driveway radius intersection with the curb or edge of pavement.

(k) Place inlets on side streets intersecting major streets, unless justification based on special conditions can be provided and the City has approved such placement.

(l) For private development with internal site drainage, only one connection is permitted to any one inlet, and that connection (lead) shall be made to the back of the inlet. Connection shall not be made to the front face and to the short sides of the inlet unless approved by the City. Design the connection not to exceed the pipe capacity minus either the capacity listed in the Standard Storm Sewer Inlets Table above, or calculated inlet inflow.

(m) For all new construction, convey public or private alleyway drainage to an inlet prior to entering the public street drainage system.

ATTACHMENT A

Rational Method 'C' Values

Land Use or Land Cover	Rational Coefficient 'C'
Raw, undeveloped acreage	**0.20**
Improved, undeveloped acreage (i.e., mowed, filled, graded, etc.)	**0.30**
Park Land	**0.40**
Residential – 1 acre lots or larger	**0.40**
Residential – ½ to 1 acre lots	**0.45**
Residential – less than ½ acre lots	**0.55**
Multi-Family	**0.75**
Commercial/Industrial	**0.90**

ATTACHMENT B

Manning's 'n' Values

Channel/Pipe Material	Manning's 'n'
Plastic Pipe (PVC & HDPE)	**0.010**
Clean Cast Iron	**0.014**
Concrete	**0.013**
Corrugated Metal	**0.025**
Smooth Bare Earth	**0.018**
Natural Channels (good condition)	**0.025**
Natural Channels (stones & weeds)	**0.035**
Natural Channels (poor condition)	**0.060**
Rip-rap	**0.035**

ATTACHMENT C

Design Intensity Values for Use in City of Dickinson
(Values calculated from TxDOT Intensity equations for Galveston County)

3-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	5.87
30 min	4.15
45 min	3.27
1 hour	2.72
3 hour	1.26
6 hour	0.75
12 hour	0.44
24 hour	0.26

5-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	**6.59**
30 min	**4.52**
45 min	**3.53**
1 hour	**2.93**
3 hour	**1.38**
6 hour	**0.84**
12 hour	**0.51**
24 hour	**0.30**

25-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	**8.81**
30 min	**6.08**
45 min	**4.77**
1 hour	**3.97**
3 hour	**1.89**
6 hour	**1.16**
12 hour	**0.71**
24 hour	**0.43**

50-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	**9.80**
30 min	**6.85**
45 min	**5.41**
1 hour	**4.53**
3 hour	**2.21**
6 hour	**1.38**
12 hour	**0.85**
24 hour	**0.52**

100-Year Frequency Storm

Storm Duration	Average Storm Intensity (in/hr)
15 min	**9.83**
30 min	**6.93**
45 min	**5.51**
1 hour	**4.63**
3 hour	**2.29**
6 hour	**1.44**
12 hour	**0.90**
24 hour	**0.56**

These values were calculated using the TxDOT Intensity equation in the form:

$$I = b/(T_c + d)^e$$

The intensity values for durations not shown in the tables above can be calculated directly using the following coefficients:

Storm Frequency	b	d	e
3-year	77	11.9	**0.782**
5-year	66	7.6	**0.739**
25-year	85	7.6	**0.727**
50-year	88	7.6	**0.704**
100-year	**85**	**7.8**	**0.690**

ATTACHMENT D

City of Dickinson Signature Block

Approved by the City of Dickinson on the ___________ day of _______________, 20 __.

____
Chief Building Official or His or Her Designee

ATTACHMENT E

City of Dickinson Notes

Required Notes for Plats

Refer to Subdivision Ordinance.

Required Notes for Drainage Plans

1. City must be notified in writing of intent to begin construction at least 48 hours prior to commencing construction and upon completion of improvements for the final inspection.

2. Buildings, fences or other structures shall not be erected in City rights-of-way or drainage easements.

3. The detention and drainage facilities are to be maintained by the property owner(s). *(Use this note for private systems only)*

4. All drainage facilities shall have erosion control established upon completion. Contractor to provide the City with proposed grass type, application rate, and application method for approval prior to commencing work.

5. Plantings, flower beds, other landscaping, or fill materials are not permitted in side lot drainage or detention easements.

ATTACHMENT F