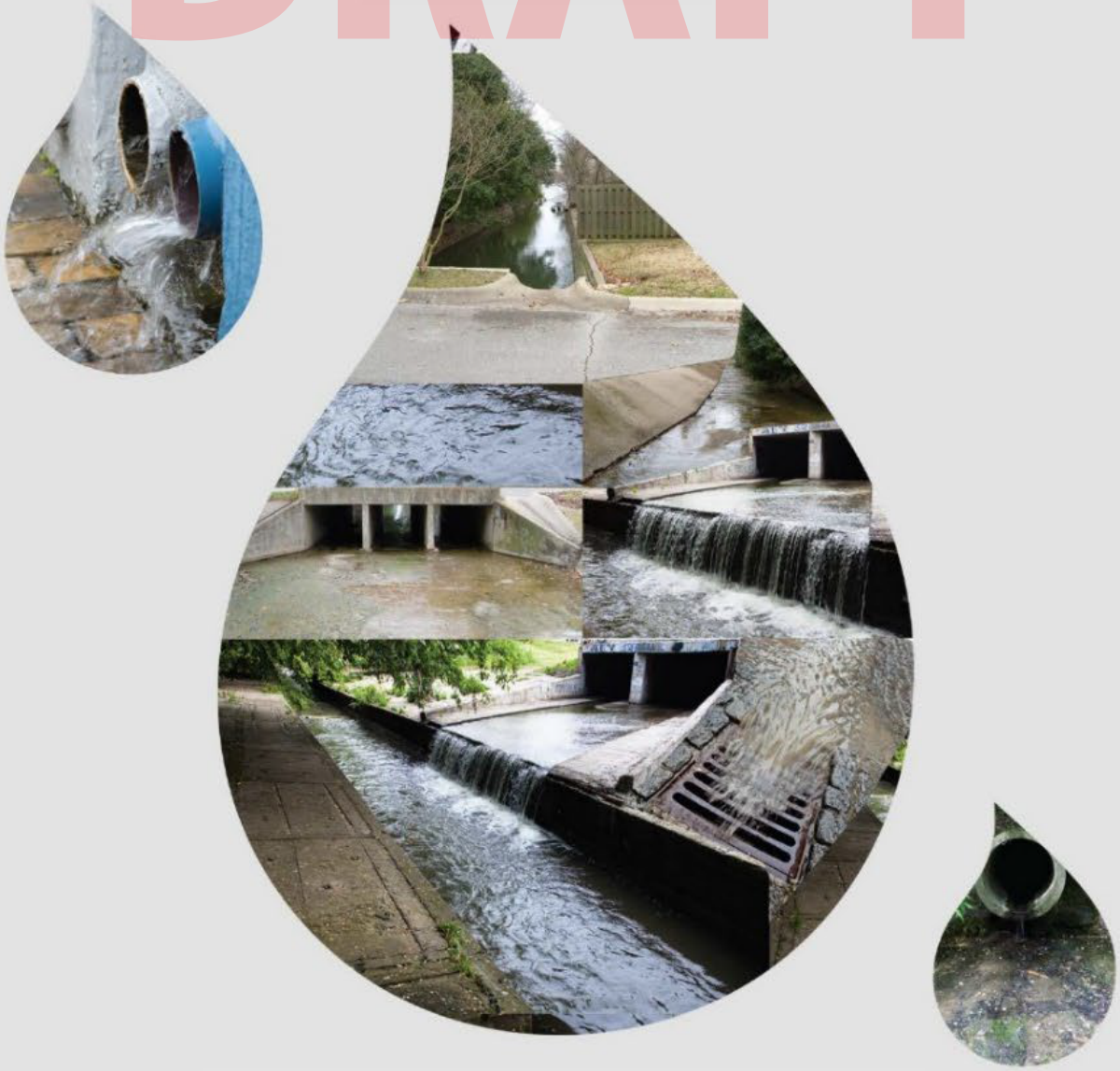
CITY OF FORT WORTH

AN iSWM COMMUNITY

STORMWATER CRITERIA MANUAL



June, 2024

FORT WORTH®

Stormwater Management

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Foreword

Adoption of Manual by City of Fort Worth

This Stormwater Criteria Manual ("Manual") is adopted and becomes effective on June 1, 2024. The North Central Texas Council of Government ("NCTCOG") iSWM Technical Manuals are adopted and incorporated herein by reference. To the extent a conflict exists between this Manual and the NCTCOG iSWM Technical Manuals, this Manual shall control.

City staff shall develop and implement administrative processes, procedures and documents in order to administer and manage the requirements outlined in this Manual.

Relationship to Previous Manuals

The original City of Fort Worth (City) Storm Drainage Criteria and Design Manual was developed in 1967 and amended in 1975, 1986, and 1994. In 2006, updated design criteria were developed in conjunction with the first version of the NCTCOG's iSWM Manual™. In 2012, the manual was revised to incorporate the City's Grading Permit requirements and revised values for impervious cover in hydrologic calculations. The City criteria presented in the 2015 manual are generally consistent with those in the 2012 version. The 2015 revision incorporates local provisions into the document and reflects the development process changes implemented by the City of Fort Worth in 2013 – 2015.

This 2024 Manual revision is primarily to adjust the stormwater development review process and clarify criteria and design requirements. This is in response to Texas House Bill 3167 that was passed by the 86th Legislature and became effective September 1, 2019. As in 2012 and 2015 versions, the over-arching motivation for this Manual is to provide efficient guidance for effective mitigation of the impacts of new development and construction on the character of stormwater runoff.

Purpose and Limitations of Manual; Waivers

This Manual provides requirements for the most commonly encountered stormwater or flood control designs in the City. It shall be used for watershed master plans and for design of remedial measures for existing facilities. This Manual was developed for users with knowledge and experience in the applications of standard engineering principles and practices of stormwater design and management. There will be specific situations not completely addressed or covered by this Manual. Other methods of design or waivers to the criteria shall be requested using the Stormwater Waiver Request Form CFW-7. Any waivers from the requirements of this Manual must have the express approval of the Director of the Department of Transportation and Public Works (TPW) or the Director's designee (Director). For construction plans submitted to the City's Infrastructure Plan Review Center, any waivers from the requirements of this Manual must have the approval of the Director of the Development Services Department, or their designee, who will consult with the Director of TPW before making a determination. Close coordination with the staff of the City is recommended and encouraged during the planning, design and construction of all stormwater facilities.

The design procedures as presented herein are based on the historical rainfall records of duration, intensity, and frequency of storms that have occurred in the past in the Fort Worth area. This is the customary and accepted basis for the design of drainage facilities. There is no assurance, however, that rainfall will not occur in the future that will temporarily overload the drainage facilities. The degree of protection afforded by the requirements included herein is considered consistent with good municipal practice in this region. The requirements in this Manual are the minimum standards for stormwater management in the City of Fort Worth and shall be applied to all studies, plans and plats. In addition to the City's requirements, all studies, plans, and plats must comply with all applicable state, federal, and local laws.

Please note that all references to iSWM Technical Manuals refer to the ***2014*** *NCTCOG iSWM Technical Manuals*, such as *Planning, Hydrology, Hydraulics, and Site Development Controls*.

Goals and Objectives for Stormwater Management

A proper understanding of the City's adopted goals and objectives for stormwater management, as summarized in Chapter 1 is essential for the proper application of this Manual.

Contact Information

Additional information on the City of Fort Worth's Stormwater Management program and policies can be obtained at www.fortworthtexas.gov/stormwater/ or by contacting the Stormwater Development Services (SDS) Team at SDS@fortworthtexas.gov. For information on the iSWM regional manual and program, contact the NCTCOG at 817-695-9220 or at the website http://iSWM.nctcog.org/.

Acknowledgements

The City of Fort Worth acknowledges the extensive efforts of the North Central Council of Governments and their consultants in the development of the iSWM regional program and manuals. The City also wishes to acknowledge the significant contribution by consulting engineers, planners, developers, and community leaders in the Fort Worth area who dedicated many hours of meetings, review of policy and criteria, and development of specific recommendations that were incorporated in the previous editions and in the 2024 version:

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Halff Associates, Inc. coordinated the development of the 2012 Fort Worth local criteria. Freese and Nichols, Inc. coordinated the revisions to the 2012 criteria that were incorporated into the 2015 manual. City Staff have prepared these 2024 revisions to the Manual.

Errata Sheet

Overview of the NCTCOG iSWM Program

The iSWM Program for Construction and Development is a cooperative initiative that assists municipalities and counties to achieve their goals of water quality protection, streambank protection, and flood mitigation, while also helping communities meet their construction and post-construction obligations under state stormwater permits.

Development and redevelopment by their nature increase the amount of imperviousness in our surrounding environment. This increased imperviousness translates into loss of natural areas, more sources for pollution in runoff, and heightened flooding risks. To help mitigate these impacts, more than 60 local governments are cooperating to proactively create sound stormwater management guidance for the region through the “integrated” Stormwater Management (iSWM) Program.

The iSWM Program is comprised of four types of documentation and tools as shown in Figure 1. These are used to complement each other and to support the development process.

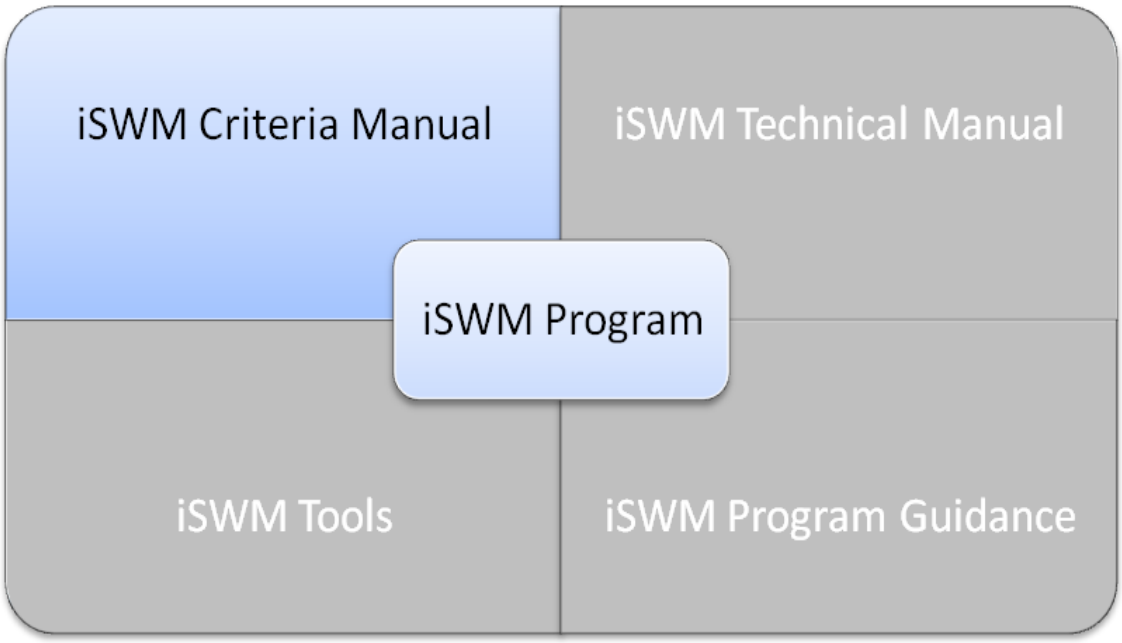

Figure 1 iSWM Program Support Documents and Tools

The four parts of iSWM are:

Stormwater Criteria Manual (this Manual) – This Manual provides a description of the development process, utilizing the design concepts and regional criteria adopted as part of the iSWM focus areas. This Manual incorporates locally adopted design criteria as required by the City in conjunction with the iSWM criteria.

iSWM Technical Manual – This set of documents provides technical guidance including equations, descriptions of methods, fact sheets, etc. necessary for design. The iSWM Technical Manual includes categories for Planning, Water Quality, Hydrology, Hydraulics, Site Development Controls, Construction Controls and Landscape. The iSWM Technical Manual is referenced in this document.

iSWM Tools – This includes web-served training guides, examples, design tools, etc. that could be useful during design.

iSWM Program Guidance – This includes reference documents that guide programmatic planning rather than technical design.

The *iSWM Technical Manual*, Tools, and Program Guidance provide references and additional information that will be helpful in the development of a Drainage Study and Construction Plans which will comply with the City criteria.

1 Stormwater Goals and Objectives

1.1 Introduction

The purpose of this Manual is to provide design criteria and a framework for incorporating effective and environmentally sustainable stormwater management into the site development and construction processes.

The City's primary goal is to manage stormwater so that drainage conditions do not get worse as new areas are developed – while making improvements in the areas of the City that are already developed.

This goal can be accomplished by:

1. Developing detailed watershed plans that promote orderly growth and result in an integrated system of public and private stormwater infrastructure.
2. Adopting development policies and standards that prevent flooding, preserve streams and channels, and minimize water pollution without discouraging either new or infill development.
3. Fully complying with regulatory permit requirements.
4. Operating the stormwater system in a more efficient and effective manner.
5. Informing the public about stormwater issues in the community.
6. Securing funding that is adequate for meeting these needs and is recognized by the public as fair and equitable.

The City's planning and design objectives described in this manual are to:

1. Regulate the drainage policy and criteria for new development and redevelopment so property development does not increase flooding problems, cause erosion, or pollute downstream water bodies.
2. Facilitate the development of comprehensive watershed planning that promotes orderly growth and results in an integrated system of public and private stormwater infrastructure.
3. Minimize flood risks to citizens and properties, and stabilize or decrease streambank and channel erosion on creeks, channels, and streams.
4. Improve stormwater quality in creeks, rivers, and other water bodies, remove pollutants, enhance the environment and mimic the natural drainage system, to the extent practicable, in conformance with the Texas Pollutant Discharge Elimination System (TPDES) permit requirements.
5. Support multi-use functions of stormwater facilities for trails, green space, parks, greenways or corridors, stormwater quality treatment, and other recreational and natural features, provided they are compatible with the primary functions of the stormwater facility.
6. Encourage a more standardized, integrated land development process.

The criteria provided in this manual will help to meet sustainable development goals and objectives. There are many ways that sustainable development may be achieved while following these criteria.

Chapter Summary

The Stormwater Criteria Manual consists of five chapters:

Chapter 1 – Stormwater Goals and Objectives

Chapter 2 – Stormwater Development Process

Chapter 3 – Stormwater Design Criteria

Chapter 4 – Stormwater Construction Criteria

Chapter 5 – References

1.2 Abbreviations and Definitions

For convenience, two terms which are used frequently throughout this manual are abbreviated:

- City – City of Fort Worth
- TPW – Department of Transportation and Public Works

Several stormwater and development terms are used in this manual which have unique or special meanings. They are defined below:

Adequate Outfall – Outfall that does not create adverse flooding or erosion conditions downstream (No Adverse Impact) from the development through the downstream end of the Zone of Influence. In all cases shall be subject to the approval of the Director of the Transportation and Public Works Department. Refer to Section 3.1, Table 3.1.

Adverse Impact Assessment – A determination of the downstream and upstream limit of properties that could be impacted by a development (also see Zone of Influence).

BMP or Best Management Practice – A physical, chemical, structural, or managerial practice or device that prevents, reduces, or treats the pollution of stormwater, or reduces or treats erosion, or minimizes runoff.

Common Plan of Development (also Common Plan) – Any development or construction activity completed in stages, separate phases, or in combination with other construction activities on land consisting of 1.0 acres or more as determined by the City based upon its evaluation of development plans, applications, or activities.

Developer – A person or entity that owns, manages, controls or influences a development or Common Plan of development. A Developer may manage, control, or influence development owned by multiple persons or entities.

Development – A contiguous tract of land, regardless of whether easements such as right-of-way, public access easements, drainage easements, or utility easements are located on the land, that is proposed to or has been improved by making a different use of the land or by making alterations or improvements to the land.

Drainage Study – Studies of a proposed Development and drainage areas, drainage facilities, and flood risk. A Drainage Study for a Development or Common Plan of Development shall include an Adverse Impact Assessment throughout the Zone of Influence.

Early Grading Permit –A permit issued by the City for a land disturbance that involves only earthwork in conformance with the Grading Permit Ordinance and this Manual.

Engineer or Engineer of Record – The person authorized to practice engineering in Texas who is responsible for preparing engineering plans for a Development.

Erosion and Sediment Control (ESC) Plan – A plan and notes indicating the installation and maintenance of BMPs and application of pollution prevention procedures used to control erosion, sediment, construction materials, and waste during the construction phase of improvements in conformance with the criteria contained in this Manual. This plan shall be included within the construction plan set required for Development within the City. The ESC Plan was previously referred to as an iSWM Construction Plan.

Flood Study – A hydrologic and hydraulic analysis that complies with all local, state, and federal requirements, guidance, and criteria for FEMA SFHA Flood Study submissions, and complies with all hydrologic and hydraulic modelling best practices as defined by the relevant FEMA, USACE, FHWA and NCTCOG technical publications, guidance and manuals.

Floodplain Development Permit – A permit required before any Development activity shall begin within a floodplain or FEMA designated Special Flood Hazard Area (SFHA). This shall require a separate submittal to the City Floodplain Administrator.

Fully Developed Conditions – For watershed hydrology, fully developed conditions include all existing developed areas which shall reflect current land use or current zoning, whichever yields the greatest runoff, and all existing undeveloped areas which shall reflect anticipated future land use designated by zoning classification, by the City's Comprehensive Plan, or by an accepted concept plan, or in the ETJ, NCTCOG future land use maps.

Grading Permit – A permit issued by the City for a land disturbance in conformance with the Grading Permit Ordinance and this Manual.

Maintenance Plan or Operations and Maintenance Plan – A plan prepared in accordance with this Manual for the purpose of describing maintenance and operational requirements of a structural BMP and interchangeably used with the "City Stormwater Facility Maintenance Plan."

Master Drainage Study – A "Drainage Study" that is submitted in support of a concept plan or other multi-phased Development. The Master Drainage Study shall establish baseline hydrologic and hydraulic conditions from which impacts are measured. It shall provide a framework, including hydrologic and hydraulic models, to support future Development phases.

Natural Creeks – Those drainageways that are generally unimproved, that often exhibit a meandering course, and which are not proposed to be improved to City standards for earthen channels. Natural creeks are generally not dredged, mowed or otherwise maintained by the City and shall be contained within floodplain easements rather than drainage easements.

Offsite Drainage Area – An area which drains to the proposed Development.

Private Water – Runoff water which is generated on private property and flowing within the property or from one property to another. Drainage easements and drainage facilities which contain only private water shall not be maintained by the City.

Public Water – The concentration of surface water flowing through or from public land or right-of-way. Public water must be contained within a dedicated right-of-way, floodplain or drainage easement.

Redevelopment – See Development.

Stormwater Fee Credits – An incentive provided by the City to encourage the voluntary use of BMPs which improve stormwater management. See Appendix F.

Stormwater Facility Maintenance Agreement or Maintenance Agreement (SWFMA) – A legal agreement between the City and a property owner, including HOAs and POAs, for perpetual maintenance of a structural BMP.

Stormwater Management Plan (SWMP) – A stormwater management plan (SWMP) that conforms to the criteria contained in this Manual (also see Drainage Study). The previous terminology for a SWMP was an integrated Stormwater Management Plan, or iSWM Plan.

Stormwater Pollution Prevention Plan or SWPPP – The site design, operations, and inspections plan required by the Environmental Protection Agency (EPA) and the Texas Council on Environmental Quality (TCEQ) for the control of erosion and sediment during construction.

Stormwater Pre-Construction Check – A verification that applicable items and permits were completed and provided before beginning construction, issuing a Grading Permit, or scheduling an IPRC Pre-Construction meeting.

Zone of Influence – A "Zone of Influence" from a proposed Development extends to a point downstream where the discharge from a proposed Development no longer has a significant impact, as defined in Chapter 3, upon the receiving stream or storm drainage system, and downstream properties. The Zone of Influence for any proposed Development must be defined by the development engineer by a Drainage Study that: (1) determines the extent of the downstream drainage route subject to impacts from a proposed Development, and (2) delineates what existing conditions are in place or what proposed mitigation is planned so that "no adverse impacts" from the new Development will occur.

1.3 Application of Stormwater Criteria

1.3.1 Adverse Impact Assessment Threshold

The requirement to submit a downstream assessment and no adverse impact analysis to the City for review applies under the following conditions for Development and Redevelopment as illustrated below and in Table 1.1. Note that Developments that fall below this threshold should still follow the downstream assessment and no adverse criteria; however, that information would not be reviewed by the City.

Table 1.1 One Acre Threshold
Land disturbing activity or platting of 1.0 acre or more OR Land disturbing activity or platting of less than 1.0 acre where the activity is part of a Common Plan of Development that is 1.0 acre or more.

A Common Plan of Development consists of construction activity that is completed in separate stages, separate phases, or in combination with other construction activities. To be considered as a Common Plan of Development for purposes of this policy, a tract must meet one or more of the following characteristics:

- Included in a single concept plan submitted to the City,
- Included in a single preliminary plat submitted to the City,
- Included in a single final plat submitted to the City,
- Is comprised of contiguous land (or land separated only by roadway and/or drainage rights-of-way or easements) under the same root ownership or control,
- Is encumbered by a single Master Drainage Study, Drainage Study, Flood Study or Plan,
- Is encumbered by a single Developer's Agreement, TIF, 380 Agreement or other public/private partnership agreement,
- Is overlaid by a common Homeowner's or Property Owner's Association (HOA, POA), or
- Is owned or managed by a common Developer.

The City requires a Grading Permit prior to any land disturbance of 1.0 acre or more, and less than 1.0 acre of disturbance when the construction is a part of a Common Plan. After construction and grading activities are completed and disturbed areas are stabilized, a Grading Certificate must be provided by the Contractor or Engineer which affirms that construction has been completed in substantial compliance with plans accepted by the City and all temporary BMP's have been removed.

This manual does not consider Development and Redevelopment separately; rather criteria are applied based on land disturbance and platting activities.

If an existing site has been cleared and/or graded within the prior five years of the date of the Developer's initial application submittal, the Developer may consider the land conditions prior to the clearing and grading to be the existing site conditions.

New Development or Redevelopment, subject to the applicability requirements shown in Table 1.1, which are located in critical, sensitive, or potentially flood-prone areas, or as identified through a watershed study or plan, are subject to additional performance and regulatory criteria. Furthermore, these sites shall utilize certain structural controls in order to protect a special resource or address certain water quality or drainage problems identified for a drainage area or watershed.

1.3.2 Site Design below One Acre

Although a plat or construction plan application might not meet the land distance or platting thresholds in Table 1.1; plat and construction plan applications shall require a Drainage Study to determine the size and type of drainage improvements, easements, and assess and mitigate flood risk. Furthermore, all Developments within the city limits and ETJ shall comply with the City of Fort Worth Subdivision Ordinance and Development permitting requirements, including but not limited to building permits, Floodplain Development Permits, SWPPP, Grading Permits, and urban forestry permits.

If Development or Redevelopment activity that is comprised of pieces less than one acre is later shown to be part of a Common Plan, then all pieces shall be required to come into compliance with this Manual. For example, a Common Plan might consist of individual land disturbing activities and plats of less one acre. However, if these pieces were all owned, managed or controlled by a common Developer then the work shall be considered a Common Plan.

Refer to Section 2.2.2 for the conditions under which no Drainage Study is needed.

1.3.3 Adoption of Standards

For projects which have an accepted Drainage Study and/or iSWM plan, including phased Developments which have some existing constructed phases after the adoption of the iSWM criteria in June 2006, findings in accepted studies will remain valid. The applicability of the current drainage criteria is presented below in the Applicability of the iSWM Standards Adoption Language.

> *Concept, Preliminary and Final iSWM Plans, as well as drainage design calculations accepted by the City of Fort Worth after the adoption of the City's drainage design standards and criteria on June 1, 2006 shall be considered valid when:*
>
> - *The proposed project is a phase of a multi-phase Development that has a valid preliminary plat*
> - *The drainage infrastructure of the proposed phase will connect directly to drainage infrastructure of a phase of the same Development with drainage infrastructure designed and constructed based on the standards in previous versions of the City's iSWM manual.*
>
> *All iSWM plans and stormwater design projects submitted after the September 29, 2015 adoption date not meeting the criteria above shall use the current Stormwater Criteria and iSWM standards and will be valid for a period of time that is concurrent with the accepted preliminary or final plat for the project.*

If a proposed Development maintains or decreases the percent imperviousness onsite, a Drainage Study, Construction Plans and landscape plans shall be required to provide confirmation of maintained or decreased percent imperviousness and show no additional impacts.

For Developments for which stormwater criteria is applicable as set forth in Table 1.1, the building permit process shall require a drainage review of the Grading Permit and Construction Plans to ensure that the site runoff is consistent with the accepted Drainage Study, existing runoff patterns and stormwater management has been appropriately addressed.

2 Stormwater Development Process

This chapter discusses the submittal process, development paths and subsequent stormwater submissions that are required for a Development or Redevelopment project.

2.1 Stormwater and Floodplain Submissions

2.1.1 Document Management

Drainage Studies and Flood Studies shall be submitted to the Stormwater Development Services (SDS) team of the Development Service Department at the City of Fort Worth. All documents shall be submitted in a digital format. Documents comprised of text or images should be provided as a portable document format *(.PDF) file. All model files shall be provided so that they are executable and the model can be recreated. Although revisions might only require portions of the submission to be updated; a complete submission of project documents shall be provided with each revision/response submission. For information on the procedure for digital submittals, visit the City's website or contact the Stormwater Development Services team at SDS@fortworthtexas.gov

2.1.2 Pre-Submittal Meetings

Before submitting a Drainage Study or Flood Study, the applicant shall meet with SDS and Floodplain Management staff to gather information, build consensus, and determine the scope of the studies. Contact staff at SDS@fortworthtexas.gov to schedule a Pre-Submittal meeting. The meeting request form shall be completed and returned with attachments to SDS before a meeting can be scheduled.

2.1.3 Application Fee

The City Council has adopted a fee structure for the review of stormwater and floodplain submissions. The City Council may amend the fee structure in the future. Fees are due at the time of application submission. The application shall be considered incomplete, and the review shall not proceed, until the fee is paid in full.

2.1.4 Completeness Checks

Upon receiving stormwater or floodplain submissions for review, the submittal package shall initially be reviewed for completeness.

Incomplete submissions, and incomplete revisions or responses, shall not be accepted for review and the applicant notified of the deficiencies and incomplete items. Review shall not proceed until a complete application, revision and response is received.

2.1.5 Checklists

Application checklists shall be furnished by the City and the applicant shall provide the applicable checklist with each application submission. Checklists shall be provided in a digital format and may be obtained from the City's website or by contacting the SDS team at SDS@fortworthtexas.gov

These checklists are intended as a guide, not an exhaustive list, to help the applicant include the most commonly required items in the submission. The checklists may be refined and updated by City staff. Applicants shall complete and provide the latest checklist available at the time of submitting an application.

2.1.6 Review and Acceptance

City staff, or a contractor, shall review application submissions for general compliance with this Manual. An acceptance (or approval) does not relieve the owner, Developer, engineer, or designer from responsibility for ensuring that the calculations, plans, specifications, construction and record drawings are in compliance with this Manual and all other applicable local, state and federal requirements, and will accomplish the necessary or desired drainage, floodplain or stormwater management outcomes.

An accepted Drainage Study is one that was submitted, reviewed, revised to correct all deficiencies, and was found to be in conformance with all applicable design criteria and standards. If errors or omissions are later identified in the Drainage Study, then they shall be corrected and subsequent Development applications revised to conform to the corrected study.

Information that is not required to be submitted for review shall not be reviewed by the City. If a Drainage Study for a Development less than one acre and not part of Common Plan of Development was submitted then it may be rejected for review; or only the relevant and required parts of the study would receive a review. For example, a Drainage Study for a 0.6 acre Development would be reviewed for easement and infrastructure requirements, but not reviewed for adverse impacts resulting from additional impervious cover.

2.1.7 Revisions and New Applications

If a Development is proposed or required to change or revise a previously accepted Drainage Study or Flood Study then the Drainage Study or Flood Study shall be submitted as a new application and the new application fee shall be paid by the applicant. Examples of when a Drainage Study would need to be changed include, but are not be limited to:

- The study was submitted in support of Preliminary Plat and later needs to be refined to support infrastructure plans or final plat.
- A plat or plan application was not consistent with the Drainage Study and the applicant chooses to submit a revised study instead of correcting the plat or plan.
- A drainage study is missing information necessary to support the review and approval of the Development application.
- The Developer chooses to change the site plan or land use, changes engineers/firms, or modifies other elements that may affect the accepted Drainage Study.
- There are changes to offsite land use or drainage facilities, or the Development is unable to obtain permits, easements or agreements, or encounters utility conflicts.

Substantial design or scope changes that occur after the first City review shall require a new application be submitted.

2.2 Stormwater Submission Requirements

2.2.1 Overview

The requirements of each Stormwater submission is dependent on the Development path underway, as shown in Figure 2.1 at the end of this chapter. The process diagram provided in Figure 2.1 is for Stormwater Development reviews only and does not include additional reviews required by other City of Fort Worth Departments. It shall be the applicant's responsibility to inquire regarding pertinent permitting and review submittals required for their project.

The scope of drainage analysis and review is dependent on the type of Development application and area of land disturbance. Stormwater reviews including Drainage Studies are required for Grading Permits, Construction Plans, Concept Plans, and all types of Plats. A Drainage Study Acceptance Letter (DSAL) form shall be provided with the Development application to confirm that a Drainage Study was submitted, reviewed and accepted as meeting City criteria for the specific type of Development application.

Drainage studies shall be submitted in support of concept plans, preliminary plats, public infrastructure plans, final plats, and Grading Permit applications. The necessary hydrologic and hydraulic analyses to clearly demonstrate that the limits of the Zone of Influence have been identified shall be included. Drainage studies shall include all required models, exhibits, analysis and supporting analysis and information. Refer to the relevant chapters of this Manual for more details.

A Drainage Study shall include an analysis of existing, proposed, and fully developed watershed conditions for each design storm. The Drainage Study is necessary to determine infrastructure and easement needs, and perform an Adverse Impact Assessment to determine the Zone of Influence and required mitigation. The Drainage Study shall provide an analysis to determine onsite controls and to establish adequate downstream capacity throughout the Zone of Influence to support future development of the project. A Drainage Study shall contain volume and location

information when detention is to be utilized. Detailed design calculations for detention requirements shall be required for submission of public infrastructure construction documents, Grading Permits, preliminary plats and final plats. The Drainage Study must include the necessary hydrologic and hydraulic analysis to clearly demonstrate that the limits of the Zone of Influence have been identified, and that along the drainage route to that location, the parameters listed in Table 3.1 and Section 3.7.3 of this Manual are met. Furthermore, drainage studies shall demonstrate that proposed public infrastructure conforms to the relevant design criteria in Section 3.8. Drainage studies shall be signed and sealed by the engineer, including the initial submission. All Drainage Study submissions, including revisions, shall be submitted as a combined report document.

2.2.2 Concept Plan

A concept plan is intended for multi-phase Developments and is required by the City Subdivision Ordinance when:

- Preliminary plats are proposed to be presented in phases; or
- Total land area of contiguous parcels under the same ownership and control is greater than one square mile (640 acres),

An acceptable Drainage Study is required before submitting a Concept Plan application. The limit of the Zone of Influence shall be based on the concept plan area. All subsequent Development applications and studies within the bounds of the concept plan shall conform to ensure that the Development of the concept plan as a whole does not cause an adverse impact. Additional information regarding the required Drainage Study in support of a concept plan is provided below and in Section 2.3, Step 2.

2.2.3 Platting

An accepted Drainage Study is required before applying for a preliminary plat. Drainage Studies are also required before making application for a final plat, minor plat, short form final plat, re-plat or any other type of plat.

A Drainage Study is not required when all of the following conditions are met:

1. The plat area and anticipated total onsite and offsite land disturbance are both less than 1 acre (a land disturbance plan or site plan shall be required to verify land disturbance area);
2. The Development is not a part of a Common Plan of Development;
3. There are no offsite drainage areas, or existing or proposed public or private drainage facilities, that drain to or through the project limits; and
4. There is no known, adjacent, suspected or regulated flood risks that potentially impact the project.

Note that a Drainage Study, Flood Study, Floodplain Development Permit, or other City requirements shall apply at later stages in the Development process as applicable.

2.2.4 Grading Permit Application

After acceptance of a Drainage Study, if a proposed Development of 1.0 acre or more, or a Common Plan of Development requires earthwork only, an Early Grading Permit application may be submitted. A Grading Permit shall be required for any other construction activities and shall be applied for by making a second Grading Permit application. During the Grading Permit application, staff will perform a detailed review of the construction plans for compliance with the Drainage Study, City standards and criteria. Additional information regarding the application for a Grading Permit is provided in Section 2.3, Step 4. Grading Permit applicants shall refer to the City of Fort Worth website for more information and detailed application and review checklists.. All items on the documents and checklists published on the City's website shall be required before a Grading Permit can be issued. These checklists may be updated by City staff in order to improve guidance for the applicant. The applicant shall use the latest checklist available at the time of application submission.

2.2.5 Stormwater Pre-Construction Check

Before issuance of a Grading Permit, scheduling an IPRC Pre-Construction Meeting, or otherwise proceeding to construction, other stormwater and floodplain approvals related to and applicable to the work shall be in place. These include:

- Accepted Drainage Study and Flood Study that meets all City criteria
- Issued Floodplain Development Permit, Grading Permit, Parkway Permit
- Recorded SWFMA, encroachment agreements, future improvement agreements, and easements
- Other Agency approvals, such as:
    - State permits from TxDOT and TCEQ
    - FEMA approved CLOMR,
    - Clean Water Act related permits and approvals (e.g. 404 (individual & NWP), 408, etc.)
    - Park conversion, and TRWD permits

2.2.6 Additional Development Information

Proposed Developments may require an urban forestry permit, SWPPP, and Water department review. Questions regarding external requirements shall be directed to the responsible City department.

Prior to a Certificate of Occupancy being issued, a Final Grading Certificate prepared by a licensed Professional Engineer or the contractor shall be submitted. The Final Grading Certificate shall state that the site grading and drainage improvements are constructed in substantial compliance with the accepted plans. If the improvements were not constructed in substantial compliance with the plans, appropriate documentation shall be provided to substantiate changes and compliance with Stormwater criteria and other applicable City requirements. If changes were made to public facilities, the City shall require an engineer to document field changes by submitting certified as-built plans and documenting changed calculations and proposed corrective actions. The final grading certificate, building permit, and certificate of occupancy are administered by the Development Services Department.

2.2.7 Construction Plans

Construction of public infrastructure shall require submittal of construction plans for review through the Infrastructure Plan Review Center (IPRC). These plans will be reviewed for conformance with the City stormwater criteria and consistency with the accepted Drainage Study.

2.3 Preparation of Stormwater Submittals

This Section describes the required contents and general procedure for preparing a Drainage Study, final construction plans, an Erosion and Sediment Control (ESC) Plan. The level of detail involved in each submittal will depend on the project size and the individual site and development characteristics. Detailed criteria for the calculations required in the Drainage Study and construction plans are covered in Chapter 3 of this Manual.

Stormwater master plans are an important tool used to assess and prioritize both existing and potential future stormwater problems and to consider alternative stormwater management solutions. The City may have individual watershed plans, or several Developers may choose to work cooperatively to develop a unified approach to watershed planning, development controls, permit compliance, multi-objective use of floodplain and other areas, and property protection. The City Stormwater staff shall be consulted on any regional approaches considered.

There are five steps defined in the preparation of Stormwater Development review submittals. In general, each of the following steps builds on the previous step to result in the Drainage Study, Construction Plans and ESC Plan.

Step 1 – Baseline Data Collection and Analysis

Step 2 –Conceptual Stormwater Design and Planning

Step 3 – Prepare Drainage Study

Step 4 – Prepare Drainage Study Updates, Construction Drawings, and Stormwater Facilities Maintenance Agreement (SWFMA)

Step 5 – Prepare Grading Permit Application

2.3.1 Preparation Overview

Step 1 –Baseline Data Collection and Analysis

The site Developer shall become familiar with the City stormwater management, Development requirements and design criteria that apply to the site. These requirements include:

- Stormwater Criteria Manual (this manual)
- Available online iSWM Program documents, which include:
- iSWM Technical Manual
- iSWM Tools
- iSWM Program Guidance
- State and Federal Regulatory Requirements
- Other City Ordinances and Criteria (Not regulated by the Stormwater Division)
  - Platting Procedures
  - Zoning Requirements
  - Development Codes and Procedures
  - Tree and Landscape Requirements
  - Special Use Permits
  - Drainage Master Plans and Watershed Plans
  - Erosion Control Plans
  - Floodplain Development Ordinance
  - Grading Plan Ordinance
  - Construction/Building Permit Notifications and Requirements
  - Urban Forestry Requirements

Information regarding the above items can be obtained from this Manual, at a pre- Development conference with the City, or from the relevant state and federal agencies.

A critical part of any project involves the proposed Developer working closely with various departments within the City. Integrating the stormwater management practices with other regulatory requirements will promote a sustainable Development.

Opportunities for special types of Development (e.g., clustering) or special land use opportunities (e.g., conservation easements or tax incentives) should be investigated. In addition, there may be an ability to partner with the local community for the development of greenways or other riparian corridor or open space developments.

All applicable state and federal regulatory requirements must also be met.

In addition to understanding all applicable regulations and ordinances, it is also necessary to collect and review information on the existing site conditions and map the following site features:

- Topography
- Drainage patterns and basins
- Intermittent and perennial streams on-site and off-site waters that will receive discharges from the proposed Development
- Soil types and their susceptibility to erosion
- Ground cover and vegetation, particularly unique or sensitive vegetation areas to be protected during Development.
- Existing Development
- Existing Stormwater facilities on-site and off-site facilities that will be receive discharges from the proposed Development Property lines, adjacent areas and easements
- Wetlands and critical habitat areas
- Boundaries of wooded areas and tree clusters
- Floodplain boundaries
- Steep slopes
- Required buffers and setbacks along water bodies
- Proposed stream crossing locations
- Other required protection areas

Upon completion of the baseline data collection and analysis, it is recommended and encouraged to schedule a Stormwater Pre-Development Conference with the Stormwater Development Services staff. This meeting will allow a dialogue to begin between the Developer and the City regarding the site conditions and potential areas of concern prior to work being done for the Development. To schedule a pre- Development conference with the Stormwater staff, please send an email to sds@fortworthtexas.gov.

The site analysis shall be summarized in the relevant Stormwater review submission along with any other supporting documents. The data collected and analyzed during this step of the Development process shall be used as the starting point for preparing the Drainage Study, Construction Plans and the ESC Plan.

Step 2 –Conceptual Stormwater Design and Planning

If a concept plan is not required or submitted, proceed to Step 3.

For larger master plan Developments with multiple phases of Development, a concept plan may be required. The concept plan allows the design engineer to propose a potential site layout and gives the Developer and City a "first look" at the stormwater management system for the proposed Development. Specific requirements for the concept plan shall be obtained through the City Development Services Department. If a concept plan is required, an accepted Drainage Study will be required before filing an application.

The following conceptual stormwater design and planning practices shall be followed in analyzing the drainage conditions, especially for concept plans:

1. Use integrated Site Design Practices. Note: integrated Site Design Practices are encouraged but not required within the City. Examples include:
   - Preserving the natural feature conservation areas defined in the site analysis
   - Fitting the Development to the terrain and minimizing land disturbance
   - Reducing impervious surface area through various techniques
   - Preserving and utilizing the natural drainage system wherever possible
2. Determine the credits for integrated Site Design (Appendix F) and water quality volume reduction (Appendix F) as applicable, to be accounted for in the design of structural and non-structural stormwater controls on the site.
3. Calculate conceptual estimates of the design requirements for streambank protection and flood mitigation based on the conceptual plan site layout.
4. Perform screening and conceptual selection of appropriate temporary and permanent structural stormwater controls and identification of potential site locations.

The stormwater planning and design concepts in this step become the foundation for developing the Drainage Study.

Step 3 – Prepare Drainage Study

The Drainage Study ensures that requirements and criteria are complied with and opportunities are taken to minimize adverse impacts from the Development. An accepted Drainage Study is a prerequisite of all preliminary plat, construction plan and final plat applications. This step builds on the data compiled in Step 1 by developing the existing and proposed runoff calculations and identifying proposed stormwater controls as well as the Zone of Influence associated with the Development. The Drainage Study Checklist outlines the data that shall be included in the Drainage Study.

At a minimum the information listed in this Manual and the Drainage Study Checklist shall be required. The study shall include an Adverse Impact Assessment of properties that could be impacted by the Development. These studies shall include the hydrologic analysis to determine the existing, proposed, and fully-developed runoff for the watershed and drainage areas that is affected by the proposed Development. Existing and proposed hydrologic conditions shall assume existing land use for offsite conditions. The study shall include a hydraulic analysis that defines the Adequate Outfall as defined in Table 3.1. It shall include a capacity analysis of all existing constraint points such as pipes, culverts/bridges, or channels from the point of stormwater discharge from the Development (edge condition) downstream through the Zone of Influence.

For Development projects involving properties 100 acres or less, the Adverse Impact Assessment may be limited to the Zone of Influence as determined by either the Drainage Study (analysis extends further downstream than 10% rule) or established as the point where the property being developed comprises less than 10% of the total drainage area (see the iSWM Hydrology Technical Manual, Section 2.4). Consideration of critical infrastructure and logical analysis end points (i.e. bridges, road crossings, and creek or river confluences) shall be required when using the 10% rule. The Adverse Impact Assessment shall extend beyond the 10% point and include critical downstream infrastructure. Also see Section 3.7 for more information.

For Development projects involving properties more than 100 acres in size, the limit of the Zone of Influence shall be defined by the hydrologic and hydraulic analyses. The limit of the Zone of Influence shall not be less than what would have been required by the 10% rule. If a Development proposes to detain to pre-developed flows at the Development property boundary, then hydrologic and hydraulic analysis shall extend downstream to a logical stopping point, typically the next major tributary confluence beyond the point defined by the 10% rule. If a project does not detain to pre-developed flows, then hydrologic and hydraulic analysis shall extend downstream, beyond the next tributary confluence after the 10% point, and extend to where the hydrologic analysis shows pre-Development and post- Development flows are the same.

It shall be noted that acceptance of the Drainage Study does not imply acceptance of any subsequent Development or stormwater applications. Those submissions will be required and reviewed as Development proceeds.

Step 4 – Prepare Drainage Study Updates, Construction Drawings, and Stormwater Facilities Maintenance Agreement

An updated Drainage Study (if applicable) and Construction Plans shall be prepared and submitted to the City for review and approval prior to final plat application or any construction activities on the Development site. An updated Drainage Study shall be required before Construction Plan or Grading Permit application to reflect changes that occurred as the detailed drainage and grading design progressed. When public infrastructure will be constructed, submittals also must conform to the Infrastructure Plan Review Center (IPRC) requirements. Changes identified during IPRC or Grading Permit Plan Review which result in changes to the Drainage Study shall require a resubmittal of the Drainage Study for review. The constructions plan submitted to IPRC or with a Grading Permit shall include an ESC Plan.

If applicable, an executed stormwater facility maintenance agreement (SWFMA) shall be required before a project is released for construction.

Step 5 – Prepare Grading Permit Application

If required by the Grading Permit Ordinance, then a Grading Permit must be obtained for grading a Development, of 1.0 acre or more, or for a Common Plan of Development. Early Grading Permits are available for only earthwork such as clearing, grubbing, and grading, with no construction allowed. A Grading Permit is required even if an Early Grading Permit is obtained. An approved Grading Permit is required prior to infrastructure and building construction. The Grading Permit application is provided on the City's website. All single-family residential grading plans must conform to Section 3.8.2 (Subdivision Drainage Site Grading) and Appendix E (Single Family Residential Lot Drainage Types). Proposed lot grading that does not comply shall submit an individual lot grading plan sheet for each lot that does not comply.

Changes in existing drainage divides shall be identified and data shall be required to document that capacity is available in the existing system to carry the additional flow to the system.

Grading permit applications shall be submitted through the City Permit Center or via the online Accela Citizen Access portal. A completed Grading Permit application form, administrative fee, signed/sealed plan sheet(s) and a digital copy of the executed SWPPP is required to be submitted with the application for a Grading Permit.

The Early Grading Permit is for earthwork only and will be at the risk of the owner/ Developer. A Drainage Study accepted by the City will be required for the issuance of an Early Grading Permit or a Grading Permit. An approved Floodplain Development Permit (FDP) is required before any Grading Permits will be issued for work within 50 feet of a SFHA (floodplain). For projects with stormwater detention facilities (or other facilities requiring a maintenance agreement), a recorded SWFMA shall be required before issuance of a Grading Permit. All applicable local, state, and federal permits shall be obtained before beginning site construction activity.

Please note:

1. Drainage calculations presented on the construction plans must conform to calculations and analysis submitted in the Drainage Study. Where City approval of construction plans is not required, the above information required for the Drainage Study and permit approval, as well as construction plans for any drainage improvements shall be submitted.
2. If a stormwater facility is provided which qualifies for a Stormwater Utility Fee Credit, the engineer must submit an application to the City along with supporting documentation which shows compliance with the Stormwater Utility Fee Credit Policy and iSWM standards for water quality treatment. Refer to Appendix F – Stormwater Utility Fee Credit Policy.
3. A Grading Permit and accepted Drainage Study will be required prior to the issuance of a commercial building permit associated with a project causing 1.0 acre or more land disturbance, or smaller sites that are part of a Common Plan of Development. See the Grading Permit Application Form for submittal information. A Grading Permit will be required, even if an Early Grading Permit was obtained at an earlier stage.
4. Construction phase requirements shall comply with IPRC requirements.

A Stormwater Facility Maintenance Agreement (SWFMA) is required for each stormwater control that will not be wholly maintained by the City. This agreement must outline both preventive maintenance tasks as well as major repairs, identify the schedule for each task, assign clear roles to effected parties, and provide a maintenance checklist to guide future owners including an annual self-inspection to be provided to the City. Please refer to the Stormwater Facility Maintenance Agreement Checklist.

A customized facility specific Operations and Maintenance Plan shall be developed in accordance with City Stormwater Criteria Manual and NCTCOG iSWM Technical Manuals, and shall be included with the SWFMA. It shall clearly state which entity has responsibility for operation and maintenance of temporary and permanent stormwater controls and drainage facilities to ensure they function properly from the time they are first installed.

The Operations and Maintenance Plan shall include:

- Responsible party for all tasks in the plan
- Inspection and maintenance requirements
- Maintenance of permanent stormwater controls and drainage facilities during construction
- Cleaning and repair of permanent stormwater controls and drainage facilities before transfer of ownership
- Frequency of inspections for the life of the permanent structures
- Description of maintenance tasks and frequency of maintenance
- Access and safety issues
- Maintenance easements
- Reviewed and accepted maintenance agreements

Guidance for development of Operation and Maintenance Plans has been provided with each temporary and permanent Best Management Practice (BMP) included in the iSWM Technical Manual.

2.3.2 Drainage Study

The Drainage Study shall demonstrate that the overall Development plan (e.g. concept plan) does not cause an adverse impact. Subsequent drainage studies shall demonstrate how the new phase (e.g. preliminary plat) ensures that the overall Development plan does not cause adverse impacts. Impacts shall be measured from the baseline pre- Development conditions at time of the original Drainage Study submitted in support of the overall Development plan (e.g. concept plan).

All maps and exhibits provided with the Drainage Study shall include, at a minimum, all of the features noted below. Features shall be delineated, labeled and described on the exhibit or map.

A Drainage Study submission shall include, but not be limited to, the following:

1. A completed copy of the latest Drainage Study checklist furnished by the City.

2. Project summary information (Name, location, description, land use, site/plat area, disturbance area, etc.)
3. Contact information for the owner and engineer:
    a. Owners name, company name, phone number, email, and address.
    b. Engineers name, firm name, phone number, email, and address.
4. The purpose of the Drainage Study, and specifically which type of Development application the study would support. Note that a Drainage Study that was reviewed and accepted for a concept plan or preliminary plat only, would not support an application for a final plat, Grading Permit or infrastructure (IPRC) application.
5. A report or technical memo that is signed and sealed by a professional engineer licensed in the State of Texas, that includes:
    a. Description of the design methods, key assumptions and unusual conditions or site constraints
    b. Description and results of the Adverse Impact Assessment and Zone of Influence
    c. Response to specific questions or issued raised during the pre-submittal meeting
    d. Summary of results and comparison of pre- Development and post- Development condition.
    e. Results based confirmation that Development impacts do not meet or exceed the no adverse impact thresholds.
    f. Description and summary results for the impact mitigation plan and provision of an Adequate Outfall. Note this would include detention pond sizing and proposed storm drain extensions.
    g. Response to review comments, clearly describing how the comments were addressed and what changes were made to plans and models.
    h. Detailed description and explanation of all model input parameter changes.
6. Document, include and describe specific planning concerns and data sources. These items include but are not limited to:
    a. List and reference previous drainage studies, iSWM Plans or watershed plans that considered the project area.
    b. Note the source and date of contour or topography information. *Note that LiDAR contours are freely available from the City GIS website.*
    c. Known or suspected flooding or erosion downstream of the project.
    d. Known or suspected downstream constrictions, such as undersized culverts or storm drains.
    e. FEMA floodplains that require a Flood Study, CLOMR, LOMR, etc. If yes, list and reference any existing studies.
    f. Known or suspected wetland areas, mitigation areas, waters of the US, or other natural habitat features that may require consideration, 404 permit, nationwide permit, or state or federal permit.
    g. Existing impoundments or dams that could be, or become, subject to TCEQ permitting.
    h. Environmental concerns that would require special treatment or design consideration (e.g. fuel station, vehicle maintenance, auto recycling, illegal dump sites, industrial facilities, etc.).
7. Description of how Low impact design (LID) principles were applied to the project, such as the following:
    a. Preserved floodplains, streams, drainage patterns, natural storage, or steep slopes?
    b. Preserved trees, natural vegetation, wetlands, or other natural features?
    c. Drained runoff to pervious or vegetated areas?
    d. Utilized natural drainage systems (without erosion) instead of storm drain systems.
    e. Reduced pavement, minimize impervious cover or use alternative materials such as porous pavement
8. Pre-Development conditions map to document baseline pre-Development conditions, including:
    a. Project boundaries
    b. Aerial photo representing pre-Development conditions (imagery captured within 5 years of submission and before land disturbance started)
    c. Label and identify perennial and intermittent streams
    d. Delineate effective FEMA floodplains and label with zone, panel number, and effective date
    e. Delineate and label wetlands and natural habitat areas

f. Label, delineate and identify location of dams and impoundments
g. Label and identify existing roads, buildings and other impervious features
h. Label and identify existing major utilities, pipelines and easements
i. Label, delineate and identify existing stormwater conveyance systems, including: overland flow, storm drains, inlets, catch basins, channels, swales, culverts, and bridges. Include plan number reference and facility size.

9. Post-Development map and site plan, including:
    a. Limits of clearing and grading
    b. Proposed street and lot layout
    c. Site plan elements (buildings, facilities, parking lot, etc.)
    d. Construction phasing plan
    e. Location and size of proposed storm drains and other stormwater controls (e.g. ponds)
    f. Location and size of existing storm drains, including plan reference number.
    g. Proposed dams or ponds subject to TCEQ requirements
    h. Proposed FEMA floodplain limits
10. Pre-Development Drainage Area Map
    a. Project boundaries
    b. Existing topography (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)
    c. USDA hydrologic soil types (or separate soils maps)
    d. Perennial or intermittent stream centerlines
    e. Delineate FEMA floodplains, studied floodplains, floodplain easements and open channels
    f. Location of wetlands, dams and impoundments
    g. Existing roads, buildings and other impervious areas
    h. Locations and size major utility lines and easements
    i. Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow
    j. Locations and dimensions of channels, bridges, or culvert crossings
    k. Delineation of watershed or drainage area boundaries, with correctly orientated flow arrows
    l. Delineate offsite drainage areas (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)
    m. Contours extend beyond project limits and offsite drainage areas to ensure the entire watershed has been delineated
    n. Delineate longest flow path each drainage area
    o. Provide time of concentration calculations for each area and lag time calculations for hydrograph methods.
    p. Computation table showing drainage areas, runoff coefficients or curve numbers, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100 year storms. Include a column to identify the collection point for each drainage area.
    q. Location of all site outfalls or where runoff leaves the site
    r. Delineate entire Zone of Influence and identify analysis points.
    s. Existing zoning and land use
    t. Composite calculations for runoff coefficients or curve numbers
    u. Drainage area and analysis point labels consistent with hydrologic and hydraulic calculations tables
11. Post-development Drainage Area Map
    a. Project boundaries
    b. Existing and proposed topography (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)
    c. USDA hydrologic soil types (or separate soils maps)

d. Perennial or intermittent stream centerlines
e. Delineate FEMA floodplains, studied floodplains, floodplain easements and open channels
f. Location of wetlands, dams and impoundments
g. Roads, buildings and other impervious areas
h. Locations and sizes of major utility lines and easements
i. Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow
j. Locations and dimensions of channels, bridges, or culvert crossings
k. Delineation of watershed or drainage area boundaries, with flow arrows
l. Delineate offsite drainage areas (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)
m. Contours extend beyond project limits and offsite drainage areas to ensure the entire watershed has been delineated
n. Delineate longest flow path for each drainage area
o. Provide time of concentration calculations for each area and lag time calculations for hydrograph methods.
p. Computation table showing drainage areas, runoff coefficients or curve numbers, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100 year storms, for existing, proposed and ultimate conditions. Include a column to identify the collection point for each drainage area.
q. Location of all site outfalls or where runoff leaves the site, including labels with pre/post/ultimate discharges.
r. Proposed and ultimate zoning and land use
s. Identify changes to watershed boundaries
t. Composite calculations for runoff coefficients or curve numbers
u. Delineate entire Zone of Influence and identify analysis points.
v. Show downstream constrictions with runoff controls
w. When the Development is a multi-phase project provide an overall drainage area map with all phases labeled.
x. Proposed stormwater facilities with private maintenance (includes private storm drains, if detention is proposed, provide volume required)
y. Drainage area and analysis point labels consistent with hydrologic and hydraulic calculations tables.

12. Ultimate Development Drainage Area Map shall illustrate the full build out and final condition of the overall Development that future phase shall adhere too. The map shall include all of the features noted above for a post Development drainage area map.
13. Hydrologic analysis and models shall adhere to all of the criteria listed throughout this Manual, as well as the following:
    a. Analysis methodology and inputs conform to Section 3.4 and relevant sections of the NCTCOG iSWM Technical Manuals.
    b. Selected hydrologic methods per Table 3.4
    c. Runoff coefficient and curve numbers per Table 3.5
    d. On site existing conditions per actual land use, not zoning
    e. Offsite conditions modelled as existing land use for comparison of pre- and post-development conditions
    f. Entire watershed (onsite and offsite areas) modelled per zoning or land use, which ever yields the highest peak discharge, for ultimate conditions hydrology.
    g. Ultimate conditions hydrology used for easement and stormwater facility sizing
    h. Unit hydrograph analysis performed using acceptable software package and model files provided.
    i. Modified Rational Method, if selected, was calculated using the equations described in the

NCTCOG Hydrology Technical Manual, and not using a software package.

j. The hydrologic analysis and Adverse Impact Assessment is carried to, or beyond, the Zone of Influence based on the 10% rule of thumb. This is required even when detention is provided (except for the specific small site waiver).
k. Hydrologic work map was provided and shows model basins and routing
l. Junctions or calculation nodes provided at critical analysis points (e.g. at outfalls, culvert crossings, ponds, etc.)
m. Reach modelling approaches applied per this Manual and standard modelling conventions
n. Pre- and post-development modelling include onsite storage (e.g. upstream of a road culvert) and floodplain storage to determine impacts of any watershed storage loss that result from the Development
o. Where a project discharges to more than one outfall, provide a corresponding analysis and Adverse Impact Assessment for each outfall
p. Include mitigation design and analysis.
q. Provide all applicable hydrologic condition analyses, including but not limited to: existing, proposed, proposed with mitigation if applicable, and ultimate. A multi-phased Development would include an additional condition for each phase.
r. Rainfall depths per NCTCOG iSWM Hydrology Technical Manual.
s. A summary results and comparison table was provided, and includes all junctions and design storms.
t. Analysis for a Zone A floodplain includes all applicable design storms and complies with FEMA guidelines.
u. Land use maps for existing pre-development condition, proposed condition and ultimate (greater intensity of zoning and comprehensive plan)
v. Soils maps provided
w. Adverse Impact Assessment – see Chapter 3

14. Hydraulic analysis and models
    a. Analysis methodology and inputs conform to Section 3.8 and other relevant sections of the Stormwater Criteria Manual, the NCTCOG iSWM Technical Manuals, and applicable references (e.g. HEC-RAS manual).
    b. Standard modelling conventions are adhered to (e.g. ineffective flow areas at culverts, cross-sections perpendicular to flow, bank stations contained well inside the floodplain, etc.)
    c. For 1D analysis, Manning's n per Table 3.15, Table 3.16 and other relevant technical references.
    d. Proposed multi-barrel culverts designed with one of the barrel flow lines at the stream centerline, and other barrels set higher to establish a single low flow drainage path
    e. Provide a hydraulic work map including, but not limited to: aerial imagery, cross sections, inundation limits, stream centerline, structures, flow change locations, labels, proposed easement limits, etc.
    f. Provide a summary table that correlates cross-sections to hydrologic nodes or add hydrologic nodes to RAS workmap
    g. Analysis considers appropriate tail water and effect of coincidental peaks
    h. Analysis sizes all driveway culverts and demonstrates that roadside ditch design meets design standards.
    i. Mixed flow regime analysis is included if Froude number(s) is 0.9 or above (supercritical flow check).
    j. Analysis shows compliance with all applicable design criteria in Section 3.8.
    k. Analysis shows compliance with all No Adverse Impact criteria throughout the entire Zone of Influence
    l. Results summaries for all design storms and watershed conditions are tabulated.
    m. Summary tables include a comparison of pre- and post-development conditions at all cross sections and critical locations.
    n. Culvert and bridge hydraulics checklists are completed and attached for all proposed hydraulic

structures.

o. Where a project discharges to more than one outfall, provide a corresponding analysis for each outfall.
p. A dam breach analysis was performed and the results, dam maintenance plan and EAP are attached
q. Drainage structure sizes and easement delineations (ultimate conditions 100-year flow)
r. Flood elevations and corresponding minimum finished floor elevations for all potentially affect and proposed lots (ultimate conditions 100-year flow) are shown.
s. Any other information pertinent to the preparation and review of project documents, including plat and construction plans are provided.

15. Detention pond checklist – attach a completed checklist for each stormwater detention facility
16. Culvert hydraulics checklist – attach a completed checklist (or equivalent) for each roadway culvert
17. Bridge hydraulics checklist – attach a completed checklist (or equivalent) for each bridge crossing
18. Dam Maintenance and Emergency Action Plan – attach a completed checklist and plan for each facility subject to the requirement
19. Record Drawings – List the referenced record drawings and provide a copy of all record drawings used in the design; include only the relevant sheets necessary to document compliance with past drainage design, capacity and existing drainage facilities. Highlight pertinent information on the sheets provided.
20. Previous Stormwater Management Plans – list the referenced plans and describe how the content was used. If a model was used then note the source of the model in the report / memo discussion. If the plans or models were prepared by another engineer but for the basis of your design then affirm that you have reviewed and agreed with the findings. Include relevant plan sheets to illustrate how the past studies support your project.
21. Identifies future permitting, regulatory and documentation needs:
    a. Maintenance
    b. Easements
    c. Grading Permit
    d. FDP, CDC, CLOMR and LOMR
    e. Public infrastructure and CFA
    f. Park Conversion
    g. USACE permits (nationwide, 404, etc.)
    h. TCEQ Water Rights
    i. TxDOT permit – required when project outfall includes connection to a TxDOT storm drain, inlet, open channel, ditch or other TxDOT drainage infrastructure
    j. Future improvements agreement
    k. TRWD Permit – required when connecting to a TRWD facility
    l. Adjacent property letters
    m. Encroachment Agreement
    n. Parkway Permit

2.3.3 Construction Plans

Construction plans shall incorporate and utilize the latest standard details that are promulgated by the City. Plans shall adhere to all requirements listed in this Manual and other criteria documents or ordinances.

Grading Permit Plans shall provide all items listed on the Grading Permit checklist furnished by the City.

Driveway Culvert plans shall adhere to all requirements of this Manual for constructions plans. Plan and profile sheets, stationing, and survey shall extend to the nearest upstream and downstream culvert. Minimum roadside ditch slopes shall be maintained between all driveway culverts and other drainage structures. If there are no nearby driveway culverts or drainage structures then the plan, profile and survey shall extend a minimum of 500 feet upstream and 500 feet downstream of the proposed driveway culvert.

Connection to the back of inlet of a private storm drain shall require review and acceptance of engineering plans that meet the requirements for constructions plans.

Sidewalk flumes shall meet the design described in this Manual and standards for construction plans.

2.4 Floodplain Development & Flood Study

2.4.1 Introduction

As an active participant in the National Flood Insurance Program (NFIP), the City maintains and enforces a floodplain management program consistent with Federal requirements (Title 44, Code of Federal Regulations) through implementation of standards outlined in Chapter 7, Article VIII of the Fort Worth City Code. Under these regulations, the City is responsible for the review and approval of all proposed floodplain Development projects and ensuring that permits required by Federal, State, and Local laws have been received. Approval of the Floodplain Development Permit is contingent upon approval of the Floodplain Development Study. The City is also responsible for submitting all revised flood hazard information and data to FEMA in order to update affected Flood Insurance Rate Map (FIRM) panels to reflect the present condition of flood risk in all FEMA basins within City limits.

The City has adopted some standards that are higher that the requirements in the NFIP. The City's specific higher standards include the following:

- A regulatory design storm defined as the 1.0% annual chance event occurring on ultimate development land use conditions within drainage basins shall be used.
- Finish floor elevations shall be 2.0 feet above the water surface resulting from the regulatory design storm. Critical facilities as defined by the floodplain ordinance shall have a minimum finished floor above the 0.2% annual chance event.
- Proposed Developments shall not increase flood elevations during the regulatory design storm unless contained within a dedicated floodplain easement, and all other applicable criteria are met.

The City also participates in the regional Corridor Development Certificate (CDC) program managed by the North Central Texas Council of Governments (NCTCOG), and reviewed by the U.S. Army Corps of Engineers (USACE). Projects located in or affecting the floodplains of the West Fork Trinity River and Clear Fork Trinity River are within the Trinity River Regulatory Zone and must meet CDC criteria in addition to City & FEMA floodplain development criteria.

2.4.2 Flood Study

The Flood Study is a key component to the City's review and approval process for any proposed Development project in a FEMA floodplain. This study allows the applicant to clearly document that all proposed floodplain Development activities comply with local, state, and federal (FEMA) floodplain regulations. The Flood Study is a stand-alone document that is different from the Drainage Study report for a proposed project or activity. More specifically, the Flood Study demonstrates compliance with federal requirements, not just municipal requirements. All Flood Study reports must be submitted for review through the SDS electronic submittal process.

- **Due to the complexity and frequently-changing nature of regulatory models available across the City, a pre-submittal meeting is required prior to submitting a floodplain study for review.**
- **The City reserves the right to reject any submittals delivered without a pre-submittal meeting.**
- **Based on the varying complexity of floodplain Development projects submitted annually, the City reserves the right to request additional information and/or technical analyses beyond that which is outlined in this Manual at any time during the review if determined necessary.**

A CLOMR, LOMR, or Flood Study shall be required by the City for any of the following activities within an effective FEMA- or other City-regulated floodplain:

- Proposed Development within a designated floodway;
- Proposed Development resulting in any change to the floodplain and/or floodway boundaries or base flood elevation;
- Proposed activities that alter a natural floodplain, stream channel, or natural protective barriers (e.g. riparian zones) or result in a waterway alteration or change of watercourse location;

- FEMA Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) submittals for areas previously studied under detailed and approximate methods, or;
- Other unique special hazard projects.

2.4.3 Floodplain Development Permits

A Floodplain Development Permit is required before performing any construction activity, or causing physical alterations to property, within the FEMA SFHA (Floodplain). Refer to the City's Floodplain Ordinance for more information. Floodplain Development Permit (FDP) application fees were categorized into three tiers and differentiated by the scope of work to be performed in the FEMA floodplain.

1. ***Basic***. Limited to: storm drain outfall(s), underground utility crossings, at grade improvements that have no effect on floodplain hydraulic conditions and do not require a Flood Study, single family improvements that do not require an Elevation Certificate (EC) and do not require a Substantial Damage / Substantial Improvement (SD/SI) evaluation.
2. ***Fill***. Includes: cut or fill in the FEMA floodplain, or any activity within the CDC area. Work that would typically cause a physical change to floodplain delineation or inundation limits.
3. ***Single Family Lot***. Includes one (1) single family lot that requires a pre-construction or post construction EC, or SD/SI evaluation. For example: pre-LOMR new construction or significant work performed on existing or damaged houses.

Note that FDP application fees are separate and in addition to Flood Study, CLOMR, and LOMR application fees.

2.5 Non-FEMA City Flood Risk Area Development Requirements

2.5.1 Introduction

Where it rains, it can flood. Between 2014 and 2018, more than 40 percent of flood insurance claims in the U.S. came from outside the FEMA floodplains.

The Floodplain Provisions Ordinance has proven to be very successful in reducing flood damages in or near the FEMA/City regulatory floodplains, but it does not address flood risks in areas outside of the FEMA regulatory floodplains. The City Flood Risk Area Policy has been created to build upon the successes of the Floodplain Provisions Ordinance to reduce the flood risk in areas outside the FEMA/City regulatory floodplains by establishing consistent Development guidelines managed with local resources. The three key components to reducing flood damages in City Flood Risk Areas (CFRA) are mapping the risk areas, communicating the risk to end users, and regulating how Development occurs in risk-prone areas.

This section explains the difference between the different flood risk areas within the city and outlines the requirements for developing within a designated CFRA. The City Floodplain Provisions Ordinance and the Stormwater Criteria Manual specify the requirements and prohibitions that apply to a particular property. The City ordinances can be found at https://www.amlegal.com/codes/client/fort-worth_tx/. Specific questions or comments about these CFRA Development requirements can be directed to Stormwater Development Services (SDS@fortworthtexas.gov).

2.5.2 Flood Risk Area Definitions

The City utilizes three different flood risk areas to determine the level of flood risk for properties. It is important to note that these flood risk areas do not overlap. See Figure 1 for examples.

FEMA Special Flood Hazard Area (SFHA)/City Regulatory Floodplain – Typically areas of riverine flooding that are flooded by a storm that has a 1% chance of equaling or exceeding that intensity in any given year. The FEMA floodplain is mapped using existing land use conditions, while the City has implemented higher standards and requires that fully-developed basin conditions be considered. Development in the basin is assumed to be the maximum allowable under the adopted zoning for the land. These floodplains are adopted and enforced in order to participate in the National Flood Insurance Program (NFIP). All Development within this area requires a Floodplain Development Permit (FDP).

City Flood Risk Area (CFRA) – Areas located generally upstream of the FEMA/City regulatory floodplains, where detailed engineering studies prepared for specific basins indicate where stormwater runoff accumulates. The CFRA is regulated by the City, but not FEMA.

Potential High Water Area (PHWA) – Areas located generally upstream of the FEMA/City regulatory floodplains and created for advisory purposes and planning efforts, which indicates that stormwater runoff accumulates to a depth of six (6) inches or greater due to concentration of flow and obstructions based on topography. The PHWA is also used to aid in the review of Drainage Studies submitted to Stormwater Development Services (SDS) for projects not in CFRA that will disturb greater than 1 acre of land as well as to inform Developers of projects under 1 acre of the flood risks.

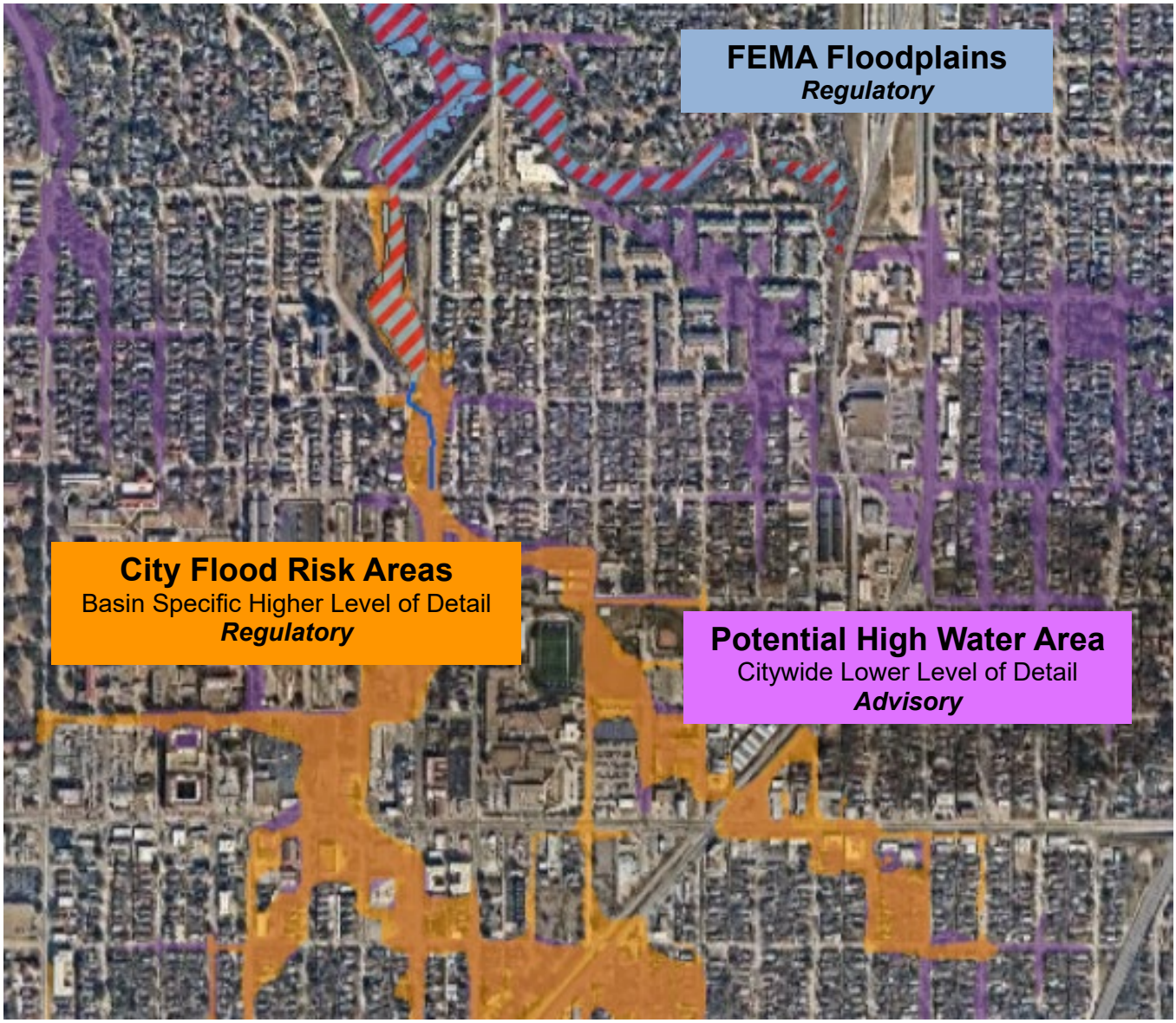

Figure 2.1 Example of CFRA, PHWA, and SFHA Mapping

2.5.3 Where to Find the Flood Risk Information

The City's Flood Risk Viewer website located at Flood Risk Viewer (fortworthtexas.gov) provides the location and extents of SFHAs, CFRAs and PHWAs. This information is also made available to residents, Developers, and engineers using the zoning map tool found on the Zoning Website located at https://www.fortworthtexas.gov/departments/development-services/zoning. Additionally, the One Address tool located at https://oneaddress.fortworthtexas.gov, includes basic information for both CFRAs and PHWAs along with to the FEMA flood risk areas. Property owners or Developers should use this information as a starting point to determine actual flood risks at a specific location. Future evaluations prepared for Stormwater Management Program planning purposes or in support of individual Development projects will be used to update the City Flood Risk Area and Potential High Water Area extents.

2.5.4 Comparison of NFIP and CFRA

Since CFRAs are regulated by the City and not by FEMA, the City with Stakeholder assistance created provisions to minimize public and private losses due to flood conditions within the identified CFRA that were not addressed by the NFIP regulations. The following table provides a comparison of notable differences between the two.

Table 2.1 Comparison of FEMA SFHA and Non-FEMA CFRA

SFHAs	CFRAs
Critical Facilities- Federally-funded facilities must be located outside the 500-year floodplain. (Hospitals, nursing homes, childcare facilities, emergency responder, etc.) State licensing requires location outside 100-year floodplain.	***Critical Facilities***- If outside the FEMA 500-year floodplain, could be located in CFRAs if adequately protected from flooding. (1)(3)
Renovations / Remodels- "Substantial Damage or Improvements" regulations require that the entire structure be brought into compliance with current codes if repairing damage or constructing improvements that cumulatively equal or exceed 50% of the existing structure's value.	***Renovations / Remodels***- "Substantial Damage or Improvements" regulations are not required outside the FEMA 100-year floodplain, so cumulative improvements would not need to be tracked.
Basements- New construction of residential basements not allowed in FEMA floodplains unless properly elevated above the flood elevation. Commercial basements must be properly floodproofed.	***Basements***- New construction of residential or commercial basements allowed in CFRAs if properly floodproofed. (2)
Waivers & Appeals- The waiver and appeals process for FEMA floodplain permitting may require action by the construction & fire prevention board of appeals and the City Plan Commission.	***Waivers and Appeals***- The waiver and appeals process for CFRAs may be handled administratively by Stormwater Development Services and Floodplain Management staff.
Flood Insurance- Flood insurance is required by Federal regulations for any Federally-backed loan or mortgage. Some Federal grant funds also require the purchase of flood insurance. Cash transactions do not require flood insurance, and the flood insurance requirement expires upon the full payment of a Federally-backed loan.	***Flood Insurance***- Since all CFRAs are located outside the FEMA floodplains, flood insurance is not a mandatory part of any loan or grant. However, flood insurance is available to anyone in the City, and any lender could require flood insurance as a condition of their loan.
Flood Protection- Lowest floor elevations for residential projects in FEMA floodplains must be elevated 2.0 feet above the 100-year fully developed flood elevation. Commercial projects may provide wet or dry floodproofing certification to the same elevation. (2)	***Flood Protection***- Because CFRAs are managed by the City, elevation is not mandatory for residential projects in CFRAs. A variety of flood protection options could be considered as long as the necessary flood protection is provided. Commercial projects may use wet or dry floodproofing techniques to achieve the necessary flood protection. (2)

Flood Map Revisions Due to Projects- Map changes are submitted to FEMA after project construction through the Letter Of Map Revision (LOMR) process. Approval time is typically 9-18 months depending on the project.	***Flood Map Revisions Due to Projects***- City-managed floodplain maps can be quickly and easily updated using digital files prepared for the project plat and plans. A compliance certificate can also be provided as needed to ensure finance needs are met on schedule.
FEMA Map Corrections Due to Inaccuracies- FEMA floodplain maps are corrected through the official LOMR/LOMA process. Certified existing conditions are submitted to FEMA for approval. This process averages 3-9 months and may take longer for significant errors.	***CFRA Map Corrections Due to Inaccuracies***- CFRA maps are easier to correct more quickly because the maps are maintained locally. Evidence of correct elevations (4) can be provided at any time to show accurate CFRA limits.

(1) Texas Health & Human Services Commission
(2) Floodproofing and Flood Protection – FEMA flood damage reduction and floodproofing guidelines
(3) Adequate Flood Protection – Lowest floor elevation or floodproofing to an elevation of at least 2.0 feet above the 100-year ultimate development flood elevation.
(4) Elevation Certificate or survey

2.5.5 CFRA Development Requirements

For the purposes of CFRA regulation, Development activities include but are not limited to the construction or alteration of buildings or other structures (i.e. residential structures, non-residential structures, fences, sheds, garages, and retaining walls), filling, grading, paving, excavation, drilling operations or storage of equipment or materials.

A ***CFRA Certificate of Compliance*** is required for proposed projects with less than one acre of disturbance to ensure compliance with the provisions of the Floodplain Provisions in Chapter 7 Article 8 Division 7 of the City Code. For Development activities with areas of disturbance one acre or more, the CFRA Certificate of Compliance will not be required but submission and approval Stormwater Drainage Study will be required. If the proposed Development is considered to be part of a Common Plan of Development then the criteria for sites with area of disturbance of one acre or more will apply.

For all ***structures mitigated via elevation***, a post-construction elevation certificate must be submitted to the city within 60 days of completion of construction. The certificate must be completed by a registered public land surveyor or licensed professional engineer and include the elevation in relation to mean sea level of the lowest floor including basement, finished garage and lowest elevation of machinery or equipment servicing the building.

For all ***structures mitigated via floodproofing***, the floodproofing method must be shown on the construction plans. The structure and attendant utility and sanitary facilities must be floodproofed to or above the DFE. All wet or dry floodproofing shall be completed in accordance to FEMA floodproofing guidance.

The City will not approve any Development activity in the CFRA until either the CFRA Certificate of Compliance or the Stormwater Drainage Study have been reviewed and approved by the City. This means no building permits or other permits will be issued for a property within the CFRA until either the CFRA Certificate of Compliance or Stormwater Drainage Study is approved. The only exceptions to this will be in the cases of either a minor project or waiver both of which require prior approval from the Floodplain Administrator or designee.

2.5.6 CFRA Development Procedures

1. Is the Proposed Development Located in a CFRA?

First, the owner or representative of any proposed public or private Development located in the vicinity of a CFRA shall determine if the proposed work is located within the CFRA using the City's websites before submitting a building permit. Continue to the next step only if the proposed Development is located within the CFRA.

2. How large is the Proposed Development?

Proposed Developments inside a CFRA with a land disturbance of one acre or greater will need to adhere to the established SDS Drainage Study submittal and review process and will not follow the steps for a CFRA Certificate

of Compliance. Models used to produce the CFRA can be utilized by Developers/engineers in the drainage studies for projects greater than one acre.

Proposed Development inside a CFRA with a land disturbance of less than one acre will require a CFRA Certificate of Compliance to ensure compliance with the City of Fort Worth Floodplain Provisions Ordinance. This certificate must be stamped by a licensed professional engineer registered with the State of Texas who certifies that the proposed structure is safe from flood risk and that the proposed project will not cause any adverse impacts to flood risk on adjacent properties. A Flood Study and/or Drainage Study will not be required to be submitted to the City for review. Continue to next step.

3. Complete CFRA Certificate of Compliance

For proposed Development requiring submittal of a CFRA Certificate of Compliance, the form may be requested from the Stormwater Development Services group at sds@fortworthtexas.gov or downloaded from the city website. This certificate must be completed, signed and sealed by a licensed professional engineer registered with the State of Texas.

All sections of the ***Project Information*** section must be filled out except for the surveyor information if no surveyor was required. The Property Owner Name should not be the same as the Engineer unless said Engineer owns the property.

The DFE for the property and how it was determined must be included within the ***CFRA Information*** section on the certificate. The DFE can be a single elevation or a range of elevations for those areas with steeper inclines. This information can be determined from either a City provided engineering study (available on request) or an independent engineering evaluation performed following guidance from the Stormwater Criteria Manual. In those instances where an independent engineering study is used, additional information may be requested by the City in support of the review.

It must be noted on the certificate if the proposed structure is to be mitigated against flood risk by either elevating to DFE, floodproofing (wet or dry), or some other means.

While an engineering study is not required to be submitted for City review for projects disturbing less than one acre, the engineer of record shall describe on the certificate how potential adverse impacts were considered. See *Texas Water Code, Chapter 11, Subchapter B* for more information on the State law prohibiting Development on a property from creating adverse drainage impacts on others. The following are considerations when addressing potential impacts:

- Estimated flood depth or velocity
- Potential change or block of existing drainage patterns
- Potential to increase flooding on, or otherwise adversely impact, adjacent properties
- Potential to adversely impact public Right of Way (ROW) or facilities

All submittals must also include a ***Project Boundary Map*** which shows the proposed Development activities in relation to the CFRA.

If the property owner feels a waiver from the CFRA Certificate of Compliance is justified or that the proposed work meets the definition of a minor project, then contact the SDS team for discussion and review. Waiver requests will be submitted on the Stormwater Waiver Form and reviewed following the Stormwater Waiver process.

4. Pre-Submittal Meeting (Optional for CFRA)

Before submitting a CFRA Certificate of Compliance, the property owner or engineer can request a meeting with SDS and Floodplain Management staff to discuss the proposed project and Development requirements. Contact staff at sds@fortworthtexas.gov to schedule the pre-submittal meeting. The meeting request form shall be completed and returned with attachments to SDS before a meeting can be scheduled.

5. Submittal of CFRA Certificate of Compliance

The completed and sealed CFRA Certificate of Compliance along with any supporting documentation must be submitted with the associated building permit application for review. For information on the procedure for digital submittals, visit the City's website or contact the Stormwater Development Services team at sds@fortworthtexas.gov.

6. Review and Acceptance

Upon receiving a CFRA Certificate of Compliance, the submittal will be initially reviewed for completeness. If found to be incomplete then the submission will be rejected for review and the applicant notified of deficiencies. Review will not proceed until a complete submittal is received.

City staff, or a contractor, will review the CFRA Certificate of Compliance submissions for general compliance with the Stormwater Criteria Manual and the Floodplain Provisions ordinance. Acceptance of the certificate does not relieve the property owner or engineer from responsibility ensuring the proposed project is in compliance with the Stormwater Criteria Manual and all other applicable local, state and federal requirements, and will accomplish the goal of CFRA management.

7. Post Construction Requirements

For all structures mitigated via elevation, a post-construction elevation certificate must be submitted to the city within 60 days of completion of construction. The certificate must be completed by a registered public land surveyor or licensed professional engineer and submitted to sds@fortworthtexas.gov.

2.5.7 Guidance for CFRA Models

For those projects located within the CFRA with a land disturbance of one acre or more, the CFRA models can be provided for use in the SDS Drainage Study submittal. These models are two-dimensional (2D) and as such require advanced software, an understanding of 2D modeling principles and model parameters, and experience and expertise in advanced hydrologic and hydraulic modeling. The following best practice guidelines are provided for Developers/engineers choosing to develop a model or use one of the City's CFRA models:

- Schedule a Stormwater PDC to discuss and fully document the proposed modeling approach
- For modifying the CFRA model:
  - Compare pre- and post-development conditions to current CFRA models
  - Limit model modifications (such as model parameters, re-meshing, roughness polygon n-values, etc.) to those relevant to the proposed site changes
  - Use the Fact Sheets made available with specific guidance (such as standard assumptions, boundary conditions, hydrology methods, meshing, limitations, etc.)
- Model Alternatives:
  - Depending on specific site location and conditions, alternative software models may be allowed, based on City staff concurrence
  - Drainage Study submittal must document alternate model approach circumstances and comparisons to the current CFRA model
- Tolerances and 2D unconfined flow models:
  - Due to software methodologies and technology, some variations or tolerances can be considered when comparing model results
  - A comparison of model output for pre- and post-project conditions should document any changes that result from software version or model assumptions.
  - Spatially varied impacts may be tolerated in circumstances that do not adversely impact (i.e. increase depth or velocity)
- Drainage study submittal:
  - Document in the technical memo what software was used, all model changes and include tables comparing existing and proposed conditions model results.
  - Include an exhibit showing the model structure link-node diagram for existing and proposed condition models comparison.
  - Include an exhibit correlating model link-node elements to site layout and design plans for existing and proposed conditions.

NOTE: This package is intended to be an informational guide to the CFRA Development review process. There may be additional information and documentation required based on individual circumstances.

HAVE QUESTIONS? To address questions concerning your project contact the Stormwater Development Services Team at sds@fortworthtexas.gov or call 817-392-1234.

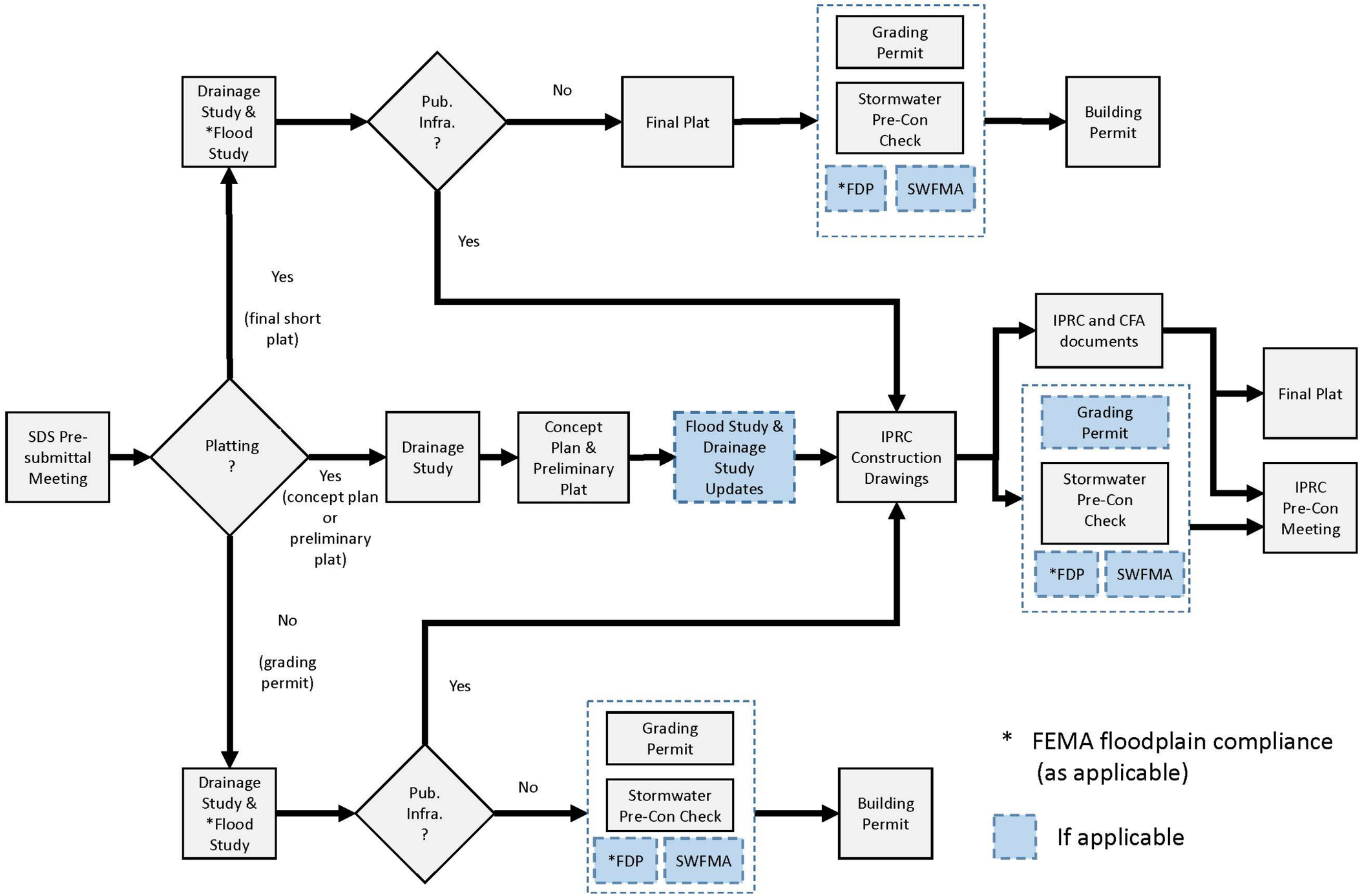

Figure 2.2 Generalized Stormwater Development Review Process

3 Stormwater Design Criteria

This chapter presents an integrated approach for meeting stormwater runoff quality and quantity management goals by addressing the key adverse impacts of Development on stormwater runoff. Its framework consists of three focus areas, each with options in terms of how the focus area is applied.

Design Focus Areas

The stormwater management focus areas and goals are:

- **Water Quality Protection**: Remove pollutants in stormwater runoff to protect water quality. Note: Water quality protection is encouraged and incentivized, but not a mandatory requirement in the City.
- **Streambank Protection**: Regulate discharge from the site to minimize downstream bank and channel erosion.
- **Flood Mitigation and Conveyance**: Control runoff within and from the site to minimize flood risk to people and properties for the conveyance storm as well as the flood mitigation storm.

Water quality design criteria are voluntary in City of Fort Worth. The controls may be used, however, to obtain Stormwater Fee Credits, in which case iSWM standards are applicable. Information on Stormwater Utility Fee Credits is contained in Appendix F of this manual.

While water quality protection is encouraged but not required in the City, steps for water quality protection are beneficial to sustainable Development and are recommended in the Development process.

Each of the Design Focus Areas shall be used in conjunction with the others to address the overall stormwater impacts from a Development site. When used as a set, the Design Focus Areas are intended to control the entire range of hydrologic events, from the smallest runoff-producing rainfalls up to the 100- year, 24-hour storm.

3.1 Design Options

There are multiple options provided to meet the criteria for water quality protection, streambank protection, conveyance, and flood mitigation. These design options are summarized in Table 3.2 and described in additional detail in Section 3.7.2.

Design criteria for streambank protection and flood mitigation are primarily based on an Adverse Impact Assessment. The purpose of the downstream assessment Adverse Impact Assessment is to protect downstream properties and channels from increased flooding and erosion potential due to upstream Development. An Adverse Impact Assessment is required to determine the Zone of Influence and the extent of improvements necessary for streambank protection and flood mitigation. An Adverse Impact Assessment shall be performed for streambank protection, conveyance, and flood mitigation storm events as described in Table 3.1, Table 3.3 and Section 3.7.3. Note that Developments that demonstrate no increase in impervious cover and sites proposing detention storage, with a total land disturbance of less than 5 acres and a contributing drainage area of less than 25 acres at outfall will not require a Adverse Impact Assessment. In cases where detention is proposed to waive Adverse Impact Assessment, detention volume must adequately address the increase in discharge due to the proposed Development.

If calculations indicate that a Development causes no adverse impacts to existing conditions, then it is possible that mitigation would not be required.

Table 3.1 Zone of Influence and Adequate Outfall Determination		
Item	**Parameter**	**Requirements**
1	Habitable Structures	• No new or increased flooding (0.00 feet) of existing insurable (FEMA) structures (habitable buildings).
2	Flood Elevations	• No increase greater than 0.1 feet in 1-, 5-, and 100-year flood elevations over existing roadways. No increase greater than 0.1 feet and 100-year flood elevations, unless contained in existing public channel, roadway, drainage easement and/or R.O.W.
3	Floodplain Ordinance	• Where provisions of the City's floodplain ordinance may be more restrictive, the floodplain ordinance shall have authority over the above provisions. • No rise is allowed in FEMA SFHA (floodplain) that results from physical changes within the floodplain or inundation limits that result from the 1 % annual chance storm with ultimate developed watershed conditions.
4	Channel Velocities	• Proposed channel velocities for 1-, 5-, and 100-year storms cannot exceed the applicable maximum permissible velocity shown in Table 3.16 and Table 3.17 of this manual. Exceptions to these criteria will require certified geotechnical /geomorphologic studies that provide documentation that the higher velocities will not create additional erosion. • If existing channel velocities exceed maximum permissible velocities shown in Table 3.16 and Table 3.17, no more than a 5% increase in velocities will be allowed.
5	Downstream Discharges	• No increase in downstream discharges caused by the proposed Development that, in combination with existing discharges, exceeds the existing capacity of the downstream storm drainage system or existing right-of- way.
6	Adverse Impact Assessment	• A Development of 5 acres or less, with proposed detention and draining a watershed less than or equal to 25 acres, a Adverse Impact Assessment is not required. The detention volume must adequately address the increase in discharge due to the proposed Development. • For watersheds of one hundred (100 ac) acres or less at any proposed outfall, the Adverse Impact Assessment may use the 10% rule of thumb when detention is proposed (as delineated in Section 2.4 of the Hydrology Technical Manual) or a detailed study (no detention) in order to determine the Zone of Influence (where pre-development and post-development flows are the same). • For all other watersheds, the Zone of Influence will be defined by a detailed hydrologic and hydraulic analysis (see Section 3.7 for more details). • In all cases, Adverse Impact Assessment shall always extend to or beyond the 10% point. • A Adverse Impact Assessment exemption may be acquired for small infill Developments which meet the specific criteria outlined in Section 3.7.2.

**Section 2.0 of the Hydrology Technical Manual* provides additional information on calculating discharges and velocities, as well as determining the downstream extent of the assessment.

Table 3.2 Summary of Options for Design Focus Areas		
Design Focus Area	**Required Adverse Impact Assessment**	**Design Options**
Water Quality Protection **(Not currently required by the City) Please note, water quality protection may be required by TRWD or other agencies.**	No	**Option 1:** Use *integrated* Site Design Practices for conserving natural features, reducing impervious cover, and using the natural drainage systems
		Option 2: Treat the Water Quality Protection Volume (WQV) by reducing total suspended solids from the Development site for runoff resulting from rainfalls of up to 1.5 inches (85th percentile storm)
		Option 3: Assist in implementing off-site community stormwater pollution prevention programs/activities as designated in an accepted stormwater master plan or TPDES Stormwater permit
Streambank Protection	Yes	**Option 1:** Reinforce/stabilize downstream conditions
		Option 2: Install stormwater controls to maintain or improve existing downstream conditions
		Option 3: Provide on-site controlled release of the 1- year, 24-hour storm event over a period of 24 hours (Streambank Protection Volume, SPV)
Flood Mitigation and Conveyance	Yes/No	**Flood Mitigation (3.7)** **Option 1:** Provide adequate downstream conveyance systems (Requires a Adverse Impact Assessment or application of the Simplified Finding of No Significant Impact as presented in Section 3.7.2)
		Option 2: Install stormwater controls on-site to maintain or improve existing downstream conditions. A Adverse Impact Assessment is not required for on-site controls in the form of detention when proposed site has less than 5 acres of land disturbance and is draining less than 25 acres at the outlet of the basin. Detention must completely mitigate the increase in peak discharge due to proposed Development.
		Option 3: In lieu of a Adverse Impact Assessment, mimic existing on-site runoff conditions (Does not require a Adverse Impact Assessment)
		Option 4: If downstream impacts are limited to a single adjacent property and involve only private runoff, then the Developer may obtain a notarized letter of permission from the affected property owner acknowledging the impacts from the subjected property in lieu of mitigation. The letter is not an option when public runoff is involved.
		Conveyance (3.8) Minimize localized site flooding of streets, sidewalks, and properties by a combination of on-site stormwater controls and conveyance systems

3.2 Design Storms

The City requires the following storm events to be used in the integrated stormwater design. Throughout the manual the storms will be primarily referred to by their storm event names.

Table 3.3 Storm Events

Storm Event Name	Storm Event Description	Design Standard [2]
"Water Quality" [1]	Criteria based on a volume of 1.5 inches of rainfall, not a storm frequency	
"Streambank Protection"	1-year return period	• Low flow channels and velocity check
"Conveyance"	5-year return period	• Secondary check for street inundation and open travel lanes
"Flood Mitigation"	100-year return period	• Open channels • Primary standard for street and storm drain in conjunction

[1] Currently encouraged and incentivized but not required in the City

[2] See Section 3.8 for specific design criteria

3.3 Design Criteria

The Design requirements for the City are:

1. All Development within the City Limits or its Extra-territorial Jurisdiction (ETJ) shall include planning, design, and construction of storm drainage systems in accordance with this Stormwater Criteria Manual, the Subdivision Ordinance, City's design manuals, and the CFA Ordinance. Please see definition of Development and project size limitations for specific design requirements under "Abbreviations and Definitions" in Section 1.2.
2. All drainage related plans and studies shall be prepared and sealed by a Licensed Professional Engineer with a valid license and a valid registered Firm number from the State of Texas. The engineer shall attest that the design was conducted in accordance with this Manual.
3. For currently developed areas within the City with planned Redevelopment, stormwater discharges and velocities from the project shall not exceed discharges and velocities from the existing developed conditions. Alternatively, a notarized letter of permission may be obtained from the affected property owner, acknowledging the proposed impact, as shown in Table 3.2, Option 4 under Flood Mitigation. The letter option is only available for private runoff, this option is not available when public runoff is involved. For public runoff, easements shall be obtained by the Developer.
4. All drainage analyses and design plans shall be formulated and based upon fully developed watershed or drainage area runoff conditions from the upstream area. Where detention is in place with a valid SWFMA or a master plan has been adopted, a Development may plan to receive less than fully developed flow from upstream. The rainfall frequency criteria for stormwater facilities, as enumerated within this Criteria Manual, shall be utilized for all drainage studies and design plans.
5. Stormwater must be carried to an "adequate or acceptable outfall". An Adequate Outfall is one that does not create or increase flooding or erosion conditions downstream and is in all cases subject to the approval of the TPW. See additional clarification in Table 3.1 and Section 3.7.3. An Adequate Outfall typically consists of a public storm drain, inlet, channel, culvert, creek or other public drainage facility that can be analyzed to determine adequate capacity or no adverse impact.

6. Proposed stormwater discharge rates and velocities from a Development shall not exceed the rates and velocities from existing conditions, unless a detailed study is prepared that demonstrates that no adverse impacts will be created, as defined in Table 3.1 and Section 3.7.3.
7. If a proposed Development drains into an improved channel or stormwater drainage system designed under a previous City drainage policy (Prior to 2006), then the hydraulic capacities of downstream facilities must be checked to verify that increased flows, caused by the new Development, will not exceed the capacity of the existing system or cause increased downstream structure flooding. If there is not sufficient capacity to prevent exceedance of existing rights of way or increased downstream flooding, then detention or other acceptable measures must be adopted to accommodate the increase in runoff due to the proposed Development. For projects which have an accepted Drainage Study and/or iSWM plan, including phased Developments which have some existing constructed phases after the adoption of the iSWM criteria in June 2006, findings in accepted studies will remain valid.
8. Stormwater runoff may be stored in detention and retention basins to mitigate potential downstream impacts caused by a proposed Development. Proposed detention or retention basins shall be analyzed both individually and as a part of the watershed system, to assure compatibility with one another and with the City's overall Stormwater Management Master Plan for that watershed (if available). Storage of stormwater runoff, near to the points of rainfall occurrence, such as the use of parking lots, ball fields, property line swales, parks, road embankments, borrow pits and on-site ponds is desirable and encouraged.
9. When detention is used to attenuate peak discharge from a proposed Development, runoff must be controlled for the applicable storms listed in Table 3.3 so that detained proposed peak discharges do not adversely impact downstream flooding and stream bank conditions, as described in Design Guidelines 5 and 6, above. Where detention is used to completely offset the impact of the Development, the proposed site is 5.0 acres or less and the contributing basin has a drainage area less than 25 acres at outlet, a Adverse Impact Assessment is not required.
10. Alternatives to detention or retention, for mitigation of potential downstream impacts caused by proposed Development, include: acquisition of expanded drainage easements, ROW, or letter of consent; downstream channel and/or roadway drainage system improvements or stream bank erosion protection. These alternatives will be considered, as presented by the Developer, by the Director of the Development Services Department, on a case-by-case basis.
11. Stream bank stabilization and protection features to reduce or prevent erosion and sedimentation for creeks, streams, and channels shall be required, as specified in this Manual, and to ensure the intent of Design Guidelines 5 and 6, above.
12. All proposed Developments within the City Limits or Extra-territorial Jurisdiction (ETJ) shall comply with all local, county, state and federal regulations; whichever is more stringent. All required permits or approvals shall be obtained by the Developer from the governing jurisdiction.
13. The policy of the City is to avoid substantial or significant transfer of stormwater drainage runoff from one basin to another and to maintain historical drainage paths whenever possible. However, the transfer of stormwater drainage from basin to basin may be necessary in certain instances and will be reviewed and a waiver shall be requested using the Stormwater Waiver Request Form CFW-7.
14. All studies, design, construction plans, analysis, hydrology, hydraulics, exhibits and documents that are submitted to the City for review shall comply with this Manual.

3.4 Hydrologic Design Criteria

3.4.1 Types of Hydrologic Methods

There are a number of empirical hydrologic methods available to estimate runoff characteristics for a site or drainage sub basin. However, the following methods are authorized by the City to be used to support hydrologic site analysis for the design methods and procedures included in this manual subject to the limitations on their use included in this Manual:

- Rational and Modified Rational Method
- SCS Unit Hydrograph Method
- Snyder's Unit Hydrograph Method
- USGS & TXDOT Regression Equations
- iSWM Water Quality Protection Volume Calculation
- Water Balance Calculations

Table 3.4 provides the City limitations on the use of several accepted hydrologic methods

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Table 3.4 City of Fort Worth Constraints on Using Recommended Hydrologic Methods

Method	Size Limitations[1]	Comments
Rational[1]	0 – 200 acres	Method authorized for estimating peak flows and the design of small site or subdivision storm sewer systems.
Modified Rational[1,2, 3]	0 – 25 acres	Method can be used for final design in single basins up to 25 acres. However, modified rational method is not allowed for basins in series or when drainage area is diverted from pre-development outfalls.
Unit Hydrograph (SCS)	Any Size	Method can be used for estimating peak flows and hydrographs for all design applications.
Unit Hydrograph (Snyder's)	100 acres and larger	Method can be used for estimating peak flows and hydrographs for all design applications.
TXDOT Regression Equations	10 to 100 mi2	Method can be used for estimating peak flows for rural design applications.
USGS Regression Equations	3 – 40 mi2	Method can be used for comparison with other methods

[1] Note: Calculations previously accepted by the City using "C" coefficients from the 2006 manual shall be acceptable.

[2] MRM Methodology shall be as defined in Section 1.5.2 of the iSWM Hydrology Technical Manual.

[3] A City provided Modified Rational Method tool is available and its use is encouraged. Please contact SDS staff at SDS@fortworthtexas.gov.

- The City requires that the "C" coefficients presented in Table 3.5 be used in all Rational and modified Rational Method computations. Calculations previously accepted by the City using "C" coefficients from the June 2006 Manual shall be acceptable, as described in Section 1.3. Where existing land use does not correspond to Table 3.5, a composite "C" value may be calculated using 0.9 for impervious areas and 0.3 for pervious areas.
- For existing Development site conditions, a composite calculation shall be provided, and used as the baseline for comparing impacts.

- Rainfall distribution for the SCS Unit Hydrograph shall be based on the Frequency Rainfall Data provided in *Section 5.0 of the Hydrology Technical Manual* centered at the midpoint of the rainstorm (12th hour of a 24-hour storm).
- The percent impervious values presented in Table 3.5 shall be used in the SCS Unit Hydrograph calculations.
- The "Frequency Factors" referenced in *Section 1.2.3 of the Hydrology Technical Manual* are not required by the City.
- Figure 3.1 presents a sample computation summary sheet for the presentation of unit hydrograph method results. This form shall be completed even if the computations are performed on an acceptable computer program such as HEC-1 or HEC-HMS. Refer to Appendix B for acceptable modeling programs.
- An alternative method to determine Snyder's Lag is to determine the time of concentration (travel time) by the methodology described in *Section 1.3.6 of the Hydrology Technical Manual* and multiply this time of concentration by 0.6.
- The TxDOT and USGS Regression methods shall only be used for comparison of the reasonableness of other accepted determinations, not for final results or design iSWM Water Quality Protection Volume (WQv) calculation method is not required by the City.
- Fully Developed Conditions – For watershed hydrology, fully developed conditions include:
    - All existing developed areas shall reflect current land use, current zoning, or future land use per City's Comprehensive Plan, whichever yields the greatest runoff.
    - All existing undeveloped areas shall reflect anticipated future land use designated by zoning classification, by the City's Comprehensive Plan, or by an approved concept plan; whichever yields the greatest runoff.
- If the anticipated offsite future Development is unknown (not zoned or included in a comprehensive plan or other land plan), a minimum weighted runoff coefficient of 0.75 or equivalent SCS Curve Number with 75% impervious cover shall be used.
- The 100 year inundation limits in a detention pond shall be considered to be impervious cover (C=0.9, CN=98).
- Reach routing methods: lag routing is acceptable for pipes only, modified puls routing shall be used when a HEC-RAS model is available.
- Proposed rural residential subdivisions comprised of lots sizes 2 acres (net) or greater shall be considered to have no less than 20% impervious cover for proposed conditions (C=0.42).
-

Table 3.5 presents the Rational Method Runoff "C" Coefficients for the City. The basis of these coefficients is the standard zoning classification used by the City ("A-5, "A-21", etc.) An example of the determination of these coefficients is presented in Figure 3.2.

3.4.2 Rainfall Estimation

Rainfall intensities are provided in *Section 5.0 of the Hydrology Technical Manual* for the sixteen (16) counties within the North Central Texas Council of Governments. The intensities are based on a combination of data from Hydro-35 and USGS. These intensities, or those sourced from Atlas 14, shall be used for all hydrologic analysis within the applicable county.

Table 3.5 Runoff Coefficients

Description of Land Use	% Impervious	Runoff Coefficient "C"
Single Family		
Residential "A-43" one-acre lots (1) (2)	35	0.51
Residential "A-21" half-acre lots	37	0.52
Residential "A-10" 10,000 SF lots	49	0.59
Residential "A-7.5"	55	0.63
Residential "A-5"	61	0.67
Residential "MH", "A-R", "B",	65	0.69
Multi Family		
"CR"	65	0.69
"C"	79	0.77
"D"	93	0.86
Commercial, Industrial, House of Worship, School, Planned Development, Urban Residential (3)		
4% Open Space (Default if no site plan)	96	0.88
10% Open Space (Site plan required)	90	0.84
20% Open Space (Site plan required)	80	0.78
Parks, Cemeteries	7	0.34
Railroad Yard Areas	29	0.47
Streets & ROW: Asphalt, Concrete, or Brick	100	0.90
Drives, Walks, Roofs, Detention Ponds (4)	100	0.90
Gravel Areas	43	0.56
Unimproved Areas	0	0.30

Assumptions:

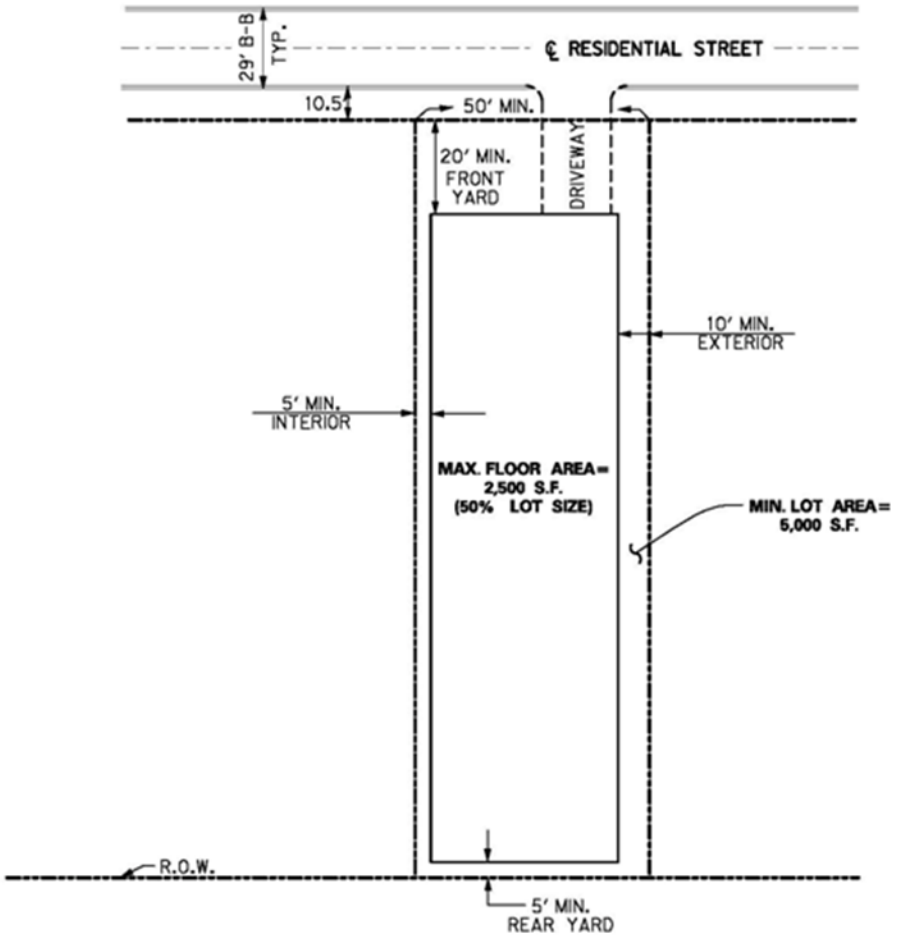
(1) For Residential Calculations:

- Current City Development standards for minimum lot size and maximum lot coverage (structure) for each classification
- Assumed 10.5' Parkway and 18' driveway
- Assumed 29' B-B street dimension
- Calculated by applying 90% runoff from impervious areas and 30% runoff from pervious areas

(2) Calculated from designated set-backs

(3) Includes R-1, R-2, UR and similarly intensive uses

(4) 100 year inundation limits



APPROX. USE OF LOT

AREA = 5,000 S.F. + R.O.W. (25'x50')

= 6,250 S.F. MAX.

C	USE	A	MAX. CA
0.9	STREET (14.5x150)	725	652.5
0.9	DRIVEWAY AND SIDEWALK	677	609.3
0.9	ROOF	2,500	2,250.0
0.3	LANDSCAPE AREA	2,348	704.4
	TOTAL CA		4,216.2
	CALC. C=CA/A		0.67

APPROXIMATION OF RUNOFF COEFFICIENT

C=0.67

Figure 3.1 Sample Calculation Sheet for Runoff Coefficient "C"

BY: DATE:	LOSS RATE METHOD		COMPUTATION SUMMARY SHEET							SHEET 1 OF 1 SUBWATERSHED MAJOR WATERSHED JOB/FILE NO.:
CK'D: DATE:	STREAM ROUTING		HYDROLOGY BY UNIT HYDROGRAPH METHOD							
ANALYSIS POINT	SUBWATERSHED AREA (AC)	WATERSHED AREA (AC)	UNIT HYDROGRAPH COEFFICIENTS				PEAK DISCHARGES (CFS)			COMMENTS
			SCS METHOD		SNYDER'S METHOD					
			C_N	Lag (HR)	C_p	T_p (HR)	Q_1	Q_5	Q_{100}	
1	2	3	4	5	6	7	8	9	11	12
REMARKS, SKETCHES AND COMPUTATIONS										

Figure 3.2 Computation Summary Sheet for Hydrology by Unit Hydrograph Method

3.5 Water Quality Protection

3.5.1 Introduction

iSWM requires the use of integrated Site Design Practices as the primary means to protect the water quality of our streams, lakes, and rivers from the negative impacts of stormwater runoff from Development. The integrated Site Design Practices shall be designed as part of the Drainage Studies and Construction Plans. In addition to the integrated Site Design Practices, required water quality protection can be achieved by two additional options: (1) by treating the water quality protection volume and (2) assisting with off-site pollution prevention activities. These three approaches are described below.

The City has currently opted to implement the streambank protection and flood mitigation and conveyance goals, but not the water quality protection component. The City does not require water quality protection for Development but strongly encourages this to be done. The City provides a stormwater fee credit (reduction) as an incentive for voluntary compliance with this component of stormwater management. See Appendix F for more information regarding fee credits.

3.5.2 Option 1: integrated Site Design Practices and Credits

The integrated Site Design Practices are methods of Development that reduce the "environmental footprint" of a site. They feature conservation of natural features, reduced imperviousness, and the use of the natural drainage system. In this option, points are awarded for the use of different Site Design Practices. A minimum number of points are needed to meet the iSWM requirements for Water Quality. Additional points can be gained to qualify for Development incentives. See Appendix F for additional details.

3.5.2.1 List of integrated Site Design Practices and Techniques

Twenty integrated Site Design Practices are grouped into four categories listed below. Not all practices are applicable to every site.

- Conservation of Natural Features and Resources
    1. Preserve Undisturbed Natural Areas
    2. Preserve Riparian Buffers
    3. Avoid Floodplains
    4. Avoid Steep Slopes
    5. Minimize Siting on Porous or Erodible Soils
- Lower Impact Site Design Techniques
    1. Fit Design to the Terrain
    2. Locate Development in Less Sensitive Areas
    3. Reduce Limits of Clearing and Grading
    4. Utilize Open Space Development
    5. Consider Creative Designs
- Reduction of Impervious Cover
    1. Reduce Roadway Lengths and Widths
    2. Reduce Building Footprints
    3. Reduce the Parking Footprint
    4. Reduce Setbacks and Frontages
    5. Use Fewer or Alternative Cul-de-Sacs

6. Create Parking Lot Stormwater "Islands"

- Utilization of Natural Features for Stormwater Management
  1. Use Buffers and Undisturbed Areas
  2. Use Natural Drainageways Instead of Storm Sewers
  3. Use Vegetated Swale Instead of Curb and Gutter
  4. Drain Rooftop Runoff to Pervious Areas

More detail on each site design practice is provided in the *integrated* Site Design Practice Summary Sheets in *Section 2.2 of the Planning Technical Manual*.

3.5.2.2 Integration of Site Design Practices into Site Development Process

During the site planning process described in Section 2.3, Step 1, there are several steps involved in site layout and design, each more clearly defining the location and function of the various components of the stormwater management system. To be more effective and easier to incorporate, integrated Site Design Practices shall be part of this overall Development process as outlined in Table 3.6.

Table 3.6 Integration of Site Design Practices with Site Development Process

Site Development Phase	Site Design Practice Activity
Site Analysis	• Identify and delineate natural feature conservation areas (natural areas and stream buffers) • Perform site reconnaissance to identify potential areas for and types of credits • Determine stormwater management requirements
Conceptual Plan	• Preserve natural areas and stream buffers during site layout • Reduce impervious surface area through various techniques • Identify locations for use of vegetated channels and groundwater recharge • Look for areas to disconnect impervious surfaces • Document the use of site design practices
Preliminary and Final Plan	• Perform layout and design of credit areas – integrating them into treatment trains • Ensure *integrated* Focus Areas are satisfied • Ensure appropriate documentation of site design credits according to local requirements

Table 3.6 Integration of Site Design Practices with Site Development Process	
Site Development Phase	**Site Design Practice Activity**
Construction	• Ensure protection of key areas • Ensure correct final construction of areas needed for credits • Inspect and maintain implementation of BMPs during construction
Final Inspection	• Develop maintenance requirements and documents • Ensure long term protection and maintenance • Ensure credit areas are identified on final plan and plat if applicable

3.5.3 Option 2: Treat the Water Quality Protection Volume

Treat the Water Quality Protection Volume by reducing total suspended solids from the Development site for runoff resulting from rainfall of 1.5 inches (85th percentile storm). Stormwater runoff equal to the Water Quality Protection Volume generated from sites may be treated using a variety of on-site structural and nonstructural techniques with the goal of removing a target percentage of the average annual total suspended solids.

A system has been developed by which the Water Quality Protection Volume can be reduced, thus requiring less structural control. This is accomplished through the use of certain reduction methods, where affected areas are deducted from the site area, thereby reducing the amount of runoff to be treated. For more information on the Water Quality Volume Reduction Methods see *Section 1.3 of the Water Quality Technical Manual*.

3.5.3.1 Water Quality Protection Volume

The Water Quality Protection Volume (WQv) is the runoff from the first 1.5 inches of rainfall. Thus, a stormwater management system designed for the WQv will treat the runoff from all storm events of 1.5 inches or less, as well as a portion of the runoff for all larger storm events. For methods to determine the WQv, see Section 1*.3 of the Water Quality Technical Manual*.

Water Quality requirements are encouraged but not required by the City. Information is included for reference if the Developer chooses to pursue such alternatives.

3.5.3.2 Recommended Stormwater Control Practices

Below is a list of recommended structural stormwater control practices. While these stormwater control practices are not mandatory in the City, they are highly recommended for sustainable Development. This information is provided for reference if the Developer chooses to pursue such an option. These structural controls are recommended for use in a wide variety of applications and have differing abilities to remove various kinds of pollutants. It may take more than one control to achieve a certain pollution reduction level. A detailed discussion of each of the controls, as well as design criteria and procedures, can be found in the *Site Development Controls Technical Manual*. Refer to Table 3.7 for details regarding primary and secondary controls.

- Bioretention
- Enhanced swales (dry, wet, wetland)
- Alum treatment
- Detention
- Filter strips
- Sand filters, filter boxes, etc.
- Infiltration wells and trenches
- Ponds
- Porous surfaces
- Proprietary systems
- Green roofs
- Rainwater harvesting
- Wetlands
- Submerged gravel

3.5.3.3 Using Other or New Structural Stormwater Controls

Innovative technologies are encouraged and will be reviewed for applicability. Any such system will be required to provide sufficient documentation as to its effectiveness and reliability. Third party proof of performance, maintenance, application requirements, and limitations will be required prior to approval of innovative new technology.

More specifically, new structural stormwater control designs will not be accepted until independent performance data shows that the structural control conforms to local and/or state criteria for treatment, conveyance, maintenance, and environmental impact.

3.5.3.4 Suitability of Stormwater Controls to Meet Stormwater Management Goals

The stormwater control practices recommended in this manual vary in their applicability and ability to meet stormwater management goals:

Primary Controls

Primary structural stormwater controls have the ability to fully address one or more of the steps in the integrated focus areas if designed appropriately. Structural controls are recommended for use with a wide variety of land uses and Development types. These structural controls have a demonstrated ability to effectively treat the Water Quality Volume (WQv) and have been shown to be able to remove 70% to 80% of the annual average total suspended solids (TSS) load in typical proposed urban runoff when designed, constructed, and maintained in accordance with recommended specifications. Several of these structural controls can also be designed to provide primary control for downstream streambank protection (SPv) and flood mitigation. These structural controls are recommended stormwater management facilities for a site wherever feasible and practical.

Secondary Controls

A number of structural controls are recommended only for limited use or for special site or design conditions. Generally, these practices either: (1) do not have the ability on their own to fully address one or more of the Steps in the integrated Focus Areas, (2) are intended to address hotspot or specific land use constraints or conditions, and/or (3) may have high or special maintenance requirements that may preclude their use. These types of structural controls are typically used for water quality treatment only. Some of these controls can be used as pretreatment measures or in series with other structural controls to meet pollutant removal goals. Such structural controls are not recommended for residential Developments.

Table 3.7 summarizes the stormwater management suitability of the various stormwater controls in addressing the integrated Focus Areas. The *Site Development Controls Technical Manual* provides guidance on the use of stormwater controls as well as how to calculate the pollutant removal efficiency for stormwater controls in series. The *Site Development Controls Technical Manual* also provides guidance for choosing the appropriate stormwater control(s) for a site as well as the basic considerations and limitations on the use of a particular stormwater control.

Table 3.7 Suitability of Stormwater Controls to Meet integrated Focus Areas

Category	*integrated* Stormwater Controls	TSS/ Sediment Removal Rate	Water Quality Protection	Streambank Protection	On-Site Flood Control	Downstream Flood Control
Bioretention Areas	Bioretention Areas	80%	P	S	S	-
Channels	Enhanced Swales	80%	P	S	S	S
	Channels, Grass	50%	S	S	P	S
	Channels, Open	-	-	-	P	S
Chemical Treatment	Alum Treatment System	90%	P	-	-	-
Conveyance System Components	Culverts	-	-	-	P	P
	Energy Dissipation	-	-	P	S	S
	Inlets/Street Gutters	-	-	-	P	-
	Pipe Systems	-	-	P	P	P
Detention	Detention, Dry	65%	S	P	P	P
	Detention, Extended Dry	65%	S	P	P	P
	Detention, Multi-purpose Areas	-	-	P	P	P
	Detention, Underground	-	-	P	P	P
Filtration	Filter Strips	50%	S	-	-	-
	Organic Filters	80%	P	-	-	-
	Planter Boxes	80%	P	-	-	-
	Sand Filters, Surface/Perimeter	80%	P	S	-	-
	Sand Filters, Underground	80%	P	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	40%	S	-	-	-
Infiltration	Downspout Drywell	80%	P	-	-	-
	Infiltration Trenches	80%	P	S	-	-
	Soakage Trenches	80%	P	S	-	-
Ponds	Wet Pond	80%	P	P	P	P
	Wet ED Pond	80%	P	P	P	P
	Micropool ED Pond	80%	P	P	P	P
	Multiple Ponds	80%	P	P	P	P
Porous Surfaces	Green Roof	85%	P	S	-	-
	Modular Porous Paver Systems	[2]	S	S	-	-
	Porous Concrete	[2]	S	S	-	-
Proprietary Systems	Proprietary Systems[1]	[1]	S/P	S	S	S
Re-Use	Rain Barrels	-	P	-	-	-
Wetlands	Wetlands, Stormwater	80%	P	P	P	P
	Wetlands, Submerged Gravel	80%	P	P	S	-

P = Primary Control: Able to meet design criterion if properly designed, constructed and maintained.

S = Secondary Control: May partially meet design criteria. Designated as a Secondary control due to considerations such as maintenance concerns. For Water Quality Protection, recommended for limited use in accepted community-designated areas.

- = Not typically used or able to meet design criterion.

[1] = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and should be verified by independent third-party sources and data, if used as a primary control. Third-party sources could include Technology Acceptance Reciprocity Partnership, Technology Assessment Protocol – Ecology, or others.

[2] = Porous surfaces provide water quality benefits by reducing the effective impervious area.

3.5.4 Option 3: Assist with Off-Site Pollution Prevention Programs and Activities

The City does not currently require off-site pollution prevention activities; however, some communities have implemented pollution prevention programs/activities in certain areas to remove pollutants from the runoff after it has been discharged from the site. This may be especially true in intensely urbanized areas facing site Redevelopment where many of the BMP criteria would be difficult to apply.

3.6 Streambank Protection

The second focus area is in streambank protection. There are three options by which a Developer can provide adequate streambank protection downstream of a proposed Development. The first step is to perform the required downstream assessment as described in Table 3.1, Table 3.2 and Section 3.7.3. If it is determined that the proposed project does not exceed acceptable downstream velocities or the downstream conditions are improved to adequately handle the increased velocity through the limits of the Zone of Influence, then no additional streambank protection is required. If on-site or downstream improvements are required for streambank protection, easements will need to be obtained in accordance with Section 3.11. If the downstream assessment shows that the velocities are within acceptable limits, then no streambank protection is required. Acceptable limits for velocity control are contained in Table 3.16 and Table 3.17.

3.6.1.1 Option 1: Reinforce/Stabilize Downstream Conditions

If the increased velocities are greater than the allowable velocity of the downstream receiving system, then the Developer must reinforce/stabilize the downstream conveyance system. The proposed modifications must be designed so that the downstream system is protected from the proposed velocities. The Developer must provide supporting calculations and/or documentation that the downstream velocities do not exceed the allowable range once the downstream modifications are installed.

Allowable bank protection methods include stone riprap and bio-engineered methods. Section 3.8.4 of this manual and *Sections 3.2 and 4.0 of the Hydraulics Technical Manual* provide design requirements g for open channels, culvert outfall protection, riprap aprons for erosion protection at outfalls, and riprap basins for energy dissipation.

3.6.1.2 Option 2: Install Stormwater Controls to Maintain Existing Downstream Conditions

The Developer may use on-site controls to keep downstream proposed discharges at or below allowable velocity limits. The Developer must provide supporting calculations and/or documentation that the on-site controls will be designed such that downstream velocities for the three storm events (Streambank Protection, Conveyance, and Flood Mitigation) are within an allowable range once the controls are installed.

3.6.1.3 Option 3: Control the Release of the 1-yr, 24-hour Storm Event

Twenty-four hours of extended detention may be provided for on-site, post-developed runoff generated by the 1-year, 24-hour rainfall event to protect downstream channels. The required volume for extended detention is referred

to as the Streambank Protection Volume (denoted SPv). The reduction in the frequency and duration of bankfull flows through the controlled release provided by extended detention of the SPv will reduce the bank scour rate and severity.

To determine the SPv refer to *Section 3.0 of the Hydrology Technical Manual*.

A 10% stormwater fee credit is available as an incentive for using this option. See Appendix F for more information.

3.7 Flood Mitigation

3.7.1 Introduction

Flood analysis is based on the design storm events as defined in Section 3.2, Table 3.3 for the conveyance storm and the flood mitigation storm.

The intent of the flood mitigation criteria is to provide for public safety; to minimize on-site and downstream flood impacts from the three storm events; to maintain the boundaries of the mapped 100-year floodplain; and to protect the physical integrity of the on-site stormwater controls and the downstream stormwater and flood mitigation facilities.

Flood mitigation must be provided for on-site conveyance systems, as well as downstream outfalls as described in the following sections.

3.7.2 Flood Mitigation Design Options

There are four options by which a Developer may address downstream flood mitigation. These options closely follow the four options for Streambank Protection. When on-site or downstream modifications are required for downstream flood mitigation, easements will need to be obtained in accordance with Section 3.11.

The Developer will provide all supporting calculations and/or documentation to show that the existing downstream conveyance system has capacity (Qf) to safely pass the fully developed flood mitigation storm discharge, including any increase due to the proposed Development, or demonstrate no adverse impact.

Flood mitigation criteria are intended to protect public safety by ensuring minimal upstream, on-site and downstream flood impacts. Table 3.2 of this Criteria Manual provides four options for Flood Mitigation in the City:

Option 1 – Confirm Adequate Downstream Conveyance Systems (Adverse Impact Assessment)

Option 2 – Provide On-Site Stormwater Controls (Detention)

Option 3 – Mimic Existing On-Site Runoff Conditions (Low Impact Design)

Option 4 – Obtain letter from impacted downstream property owner (limited to impacts of private runoff on one single adjacent property).

3.7.2.1 Option 1 – Provide Adequate Downstream Conveyance Systems

Provide calculations for analysis of the downstream conveyance system to confirm adequate capacity is available to convey the increased runoff, due to Development, within a drainage structure, easement, or right-of-way. This Adverse Impact Assessment can include any available existing conveyances systems (existing drainage pipes, channels, natural creeks and streams, easements or right-of-ways specified for drainage use). If the existing drainage systems do not have capacity to convey the increased runoff from the Development, additional stormwater controls will be necessary to safely discharge runoff without:

1. Causing new or increased flooding upstream of the Development
2. Causing new or increased flooding on the Development site
3. Causing new or increased flooding downstream of the Development

The Developer may provide additional conveyance by providing and/or modifying the off-site, downstream conveyance system through construction of additional drainage capacity or acquisition of drainage easements to contain impacts. The design and analysis of such systems will be required to show that the proposed systems safely

convey the required design storm events. Systems are required to be analyzed to an Adequate Outfall, (i.e. a Adverse Impact Assessment is required) as defined in Table 3.1 and Section 3.7.3.

If the Adverse Impact Assessment shows that all above runoff conditions have been met as defined in Table 3.1 and Section 3.7.3 of this manual, no on-site drainage controls are required to mitigate for increased runoff from the site due to the proposed Development.

Simplified Finding of No Significant Impact

For small infill Developments that meet specific criteria below, the Adverse Impact Assessment shall not be required.

Requirements:

1. The proposed Development is less than 5 acres of disturbed land;
2. The site developed drains directly to an existing public roadway, not an alley, and does not redirect drainage area from one street or watershed to another;
3. The receiving roadway has a longitudinal slope of at least 1%;
4. The site area is less than 10% of the existing offsite area drainage to the same receiving roadway;
5. The existing offsite area (excluding the site to be developed) has a rational C value of at least 0.6;
6. The ROW drainage capacity is not already exceeded in the flood mitigation storm event; and
7. The Development is not subject to existing flooding conditions, or overland flow generated from a 100-yr storm, and would not result in diversion or impoundment of existing offsite runoff.

Submittal of calculations to confirm these conditions will be required with the Drainage Study submission. Once reviewed and accepted by the City SDS, the site Development can be considered as having no significant impact and no mitigation is required.

3.7.2.2 Option 2 – Provide On-Site Stormwater Controls (Detention)

In the event that downstream conveyance systems, including receiving streams, do not have sufficient capacity, on-site stormwater controls may be proposed to mitigate the impact of increased discharges from the site to a level that meets the requirements of Table 3.1 and Section 3.7.3.

An Adverse Impact Assessment is not required for Developments that meet all three of the following conditions:

1. Sites proposing detention when the total site disturbance is less than 5.0 acres.
2. Detention facilities are designed to detain to pre-development peak discharge.
3. Proposing a stormwater detention facility with a contributing drainage area of less than 25 acres at detention outfall;

In cases where detention is proposed which will not require a Adverse Impact Assessment, detention volume must completely mitigate the increase in discharge due to the proposed Development.

In all other cases, Adverse Impact Assessment shall conform to this Manual and the *iSWM Hydrology Technical Manual*. Note that pre-development conditions onsite and offsite shall be the existing watershed condition, not fully developed conditions.

3.7.2.3 Option 3 – Mimic Existing On-Site Runoff Conditions

A Adverse Impact Assessment is not required. This option only requires that on-site improvements are provided to maintain/mimic existing runoff conditions. This option requires reduced percent imperviousness using integrated Site Design practices to mimic the existing runoff conditions (discharge, velocity, and concentration). No Adverse Impact Assessment is required in this option, however, a Adverse Impact Assessment may reduce the amount of on-site detention required. Calculations shall be submitted to substantiate the proposed discharges.

Stormwater controls for this option include the various types of structural and non-structural controls as described in this manual (Chapter 3) and listed below.

1. Stormwater Facilities
2. Integrated Site Design Practices
3. Regional Approaches
4. Erosion Control BMPs

3.7.2.4 Option 4 – Obtain Letter From Impacted Downstream Property Owner

When downstream impacts are limited to a single adjacent property and consist of only private Stormwater contributions, the Developer may obtain a notarized letter of permission from the affected property owner acknowledging the specific and quantified impacts in lieu of mitigation. This option is not available for situations where public runoff or public infrastructure is or would be involved. For situations involving public runoff or future public runoff, easements would need to be acquired by the Developer. Easements would need to be sized per this Manual.

3.7.3 Acceptable Downstream Conditions

As part of the Drainage Study, the downstream impacts of Development must be carefully evaluated for the two focus areas of Streambank Protection and Flood Mitigation. The purpose of the Adverse Impact Assessment is to protect downstream (and upstream) properties from increased flooding and downstream channels from increased erosion potential due to upstream Development. The importance of the Adverse Impact Assessment is particularly evident for larger sites or Developments that have the potential to dramatically impact downstream areas. The cumulative effect of smaller sites, however, can be just as dramatic and, as such, following the integrated Focus Areas is just as important for the smaller sites as it is for the larger sites.

The assessment, defined by the Development engineer, shall extend from the outfall of a proposed Development to a point downstream where the discharge from a proposed Development no longer has a significant impact, as defined in Table 3.1, on the receiving stream or storm drainage system. The City shall be consulted to obtain studies, records and maps related to the National Flood Insurance Program and the availability of Flood Insurance Studies and Flood Insurance Rate Maps (FIRMs) which may be helpful in this assessment. The assessment of ***upstream and downstream*** impacts shall be a part of the Drainage Study for all Development that are platting one acre or cause one (1) acre or more land disturbance. Items to be included in the Drainage Study can be found in the Drainage Study Checklist.

- Detailed Drainage Study and calculations for existing, proposed, and fully developed conditions (include digital submittal of hydrologic and hydraulic models, if utilized)
- Pre- and post-project conditions drainage area maps. Drainage area maps shall be of same scale and limits for both pre- and post-project conditions. Drainage area maps must clearly delineate all contributing areas draining to or through the entire site. Drainage area maps shall have topographic contour intervals no greater than two (2) feet, and show flow paths for each area.
- Discharges at critical downstream design points, including structures, ROW, inlets, storm drains, culverts, swales, channels, creeks, floodplains, and at locations where the conveyance cross section or slope change.
- Separate analysis for each outfall from the proposed Development
- Delineation of the Zone of Influence and determination of Adequate Outfall s.
- Final hydrology and hydraulics with all calculations and models, required mitigation and final stormwater controls identified with sizes with the structural details and specifications.
- Written narrative supporting methodology and conclusions of analysis. Include a description of how the items discussed in the Pre-Submittal meeting were addressed.
- Analysis must confirm that conditions regarding an acceptable outfall, as defined in Table 3.1, are met at each outfall location.
- Adequate Outfall shall be a public drainage system, or a creek (flow line) draining more than ten times the Development area.

- Discharging runoff from Development to residential properties downstream of the development is not allowed. Downstream public drainage facilities shall be designed and constructed to provide an Adequate Outfall if none exist.
- Provide a summary of results confirming compliance. Include Land Use maps and Soil Type maps (unit hydrograph method). Section 2.0 of the Hydrology Technical Manual provides additional information on calculating the discharges and velocities, as well as determining the extent of the Adverse Impact Assessment.
- Provide applicable and *relevant* record drawings to support analysis assumptions.
- Adverse Impact Assessment shall extend to the limit of the Zone of Influence.
- Provide hydrologic and hydraulic work maps to document and illustrate the analysis and relevant information. This shall include model cross sections with stationing that match the HEC-RAS model, pre/post outfall and junction flows, stations, inundation limits for existing, proposed and ultimate conditions, a legend, a scale, and 1 ft contours.
- If modelling includes reservoirs or stormwater detention facilities, then stage-storage discharge tables and assumed outlet control structure dimensions must be included.

3.8 Stormwater Conveyance Systems

3.8.1 Introduction

Stormwater system design is an integral component of both site and overall stormwater management design. Good drainage design must strive to maintain compatibility and minimize interference with existing drainage patterns; control flooding of property, structures, and roadways for design flood events; and minimize potential environmental impacts on stormwater runoff.

Stormwater collection systems must be designed to provide adequate surface drainage while at the same time meeting other stormwater management goals such as water quality, streambank protection, habitat protection, and flood mitigation.

3.8.1.1 Design

Unless regional detention is in place with a recorded SWFMA, or a master plan has been completed which indicates a plan for reduced discharges which shall be constructed within 12 months of the Development beginning construction; fully developed watershed conditions shall be used for determining runoff for the conveyance storm and the flood mitigation storm.

Only those drainage facilities with criteria described by this manual, and its reference manuals, are allowed.

3.8.2 Subdivision Drainage Site Grading

An engineered overall site grading plan shall be submitted with the subdivision's paving and drainage plans. The plan shall be consistent with the drainage area map included in the Drainage Study and Construction Plans. The plan shall include flow arrows and Type A, B, or C drainage for each lot within the subdivision as described in Federal Housing Administration (FHA) Land Planning Bulletin No. 3, as amended (see Appendix E). Type 1 or 2 block grading as shown in the FHA information is preferred. Type 1 or Type 2 is required for lots proposing a rear lot wall adjacent to a right of way or HOA draining to a right of way. Type 3 and block 4 grading is allowed only if:

- a swale, flume or channel is constructed at the rear of the lot to intercept runoff; and
- runoff from 3 or more lots is collected and conveyed within an underground drainage system, swale, flume or channel contained within a dedicated easement.

The engineer may utilize berms and swales to redirect flows. Grass swales shall have a minimum slope of 2% except where contained within a drainage easement, in which case a 1% minimum slope is allowed. The engineer shall provide more detailed information in addition to the lot grading type (A, B, or C) by indicating spot elevations

on each lot. For Type B lots, side-yard swales shall extend from 5 ft (minimum) behind the rear building line to the street, in order to collect runoff from the roof. Roof drains, if used along the rear building line of these lots, shall use splash blocks to direct the runoff into the side swales.

The finished floor elevation and surrounding grading must conform to current building codes adopted by the City and provide a minimum height of the finished floor of twelve (12) inches above the surrounding ground. Areas within 10' of the foundation shall be sloped to drain away from the foundation. Minimum slopes of 2% for structural improvements and 5% for non-structural elements, respectively, must be maintained away from the footing. See Figure 3.3.

If the site is complex and an overall site grading plan cannot be developed in accordance with the HUD standards, an individual grading plan for each lot shall be submitted by an engineer prior to issuing the Building Permit. The individual grading plans shall be coordinated with surrounding lots. For these complex plans, an "as-built" letter shall be submitted prior to final inspection.

Subdivision phasing, design and construction shall be executed in such a way that downstream existing or occupied SFR lots (e.g. Type A) do not receive runoff from upstream lots under construction (e.g. Type C). Where subdivision boundaries or phase boundaries bisect a block, only block grading Type 1 and 2 shall be used.

The requirement to provide rear lot drainage facility for block grading type 3 is not required when all of the following conditions are adhered to:

1. The swale shall be continuous and upstream side yard swales shall align (offset shall not exceed 1 foot) with downstream side yard swales (this requires alignment of lot lines);
2. The swale extending between rear building lines does not exceed 5% slope and retaining walls are not proposed;
3. The swale cross section shall minimize erosion potential;
4. The design shall include safeguards that ensure runoff is not lost to neighboring side lots and runoff is directed to the rear swale as intended. For example more pronounced high points (6 inches minimum);
5. The swale through the backyard shall not be less than 3 inches in depth;
6. The vertical distance between the side yard swale flowline and finished floor elevation shall be no less than 9 inches at the upstream end of the swale on the upstream (type C) lot. Everywhere else, including on the downstream lot (type A), the finished floor elevation shall have a minimum freeboard above the swale flow line of 12 inches; and
7. The design engineer shall provide standard swale details for each subdivision at a cross section that represents a worst case scenario for flow depth.

Four (4) inches of topsoil shall be provided for all disturbed areas not protected by impervious cover, in order to sustain vegetation after construction has been completed.

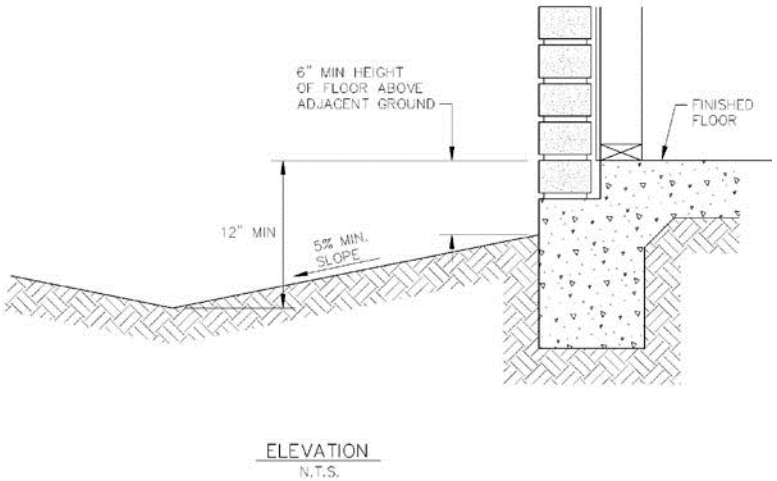


Figure 3.3 Grading Requirements Next to Building Foundation

3.8.3 Hydraulic Design Criteria for Streets and Closed Conduits

3.8.3.1 Introduction

This section is intended to provide criteria and guidance for the design of on-site flood mitigation system components including:

- Street and roadway gutters
- Stormwater inlets
- Parking lot sheet flow
- Storm drain pipe systems

3.8.3.2 Streets and Stormwater Inlets

Design Frequency

- Streets and roadway gutters: conveyance storm event
- Inlets on-grade: conveyance storm event
- Parking lots: conveyance storm event
- Storm drain pipe systems: conveyance storm event and flood mitigation storm event.
- Low points: flood mitigation storm event
- Combined Street ROW and storm drain pipe systems: flood mitigation storm event
- Drainage and floodplain easements: flood mitigation storm event

Design Criteria

The iSWM Inlet Design Methodology (*iSWM Hydraulics Technical Manual*) is adopted as part of this Manual and incorporated herein by reference. Under the City classification system, inlets have been classified into two major groups namely: Inlets in Sumps and Inlets on Grade with Gutter Depression. The only curb inlets that are allowed by the City are those in sumps and depressed inlets on grade. Grate inlets and combination inlets are not allowed.

Figures presented in the following sections shall be used to document all closed conduit calculations even if calculations are performed on an acceptable computer program u.

A “rooftop” section shall be used for concrete streets and a parabolic section for asphalt streets. Note that the nomograph in *Figure 1.2 of the iSWM Hydraulics Technical Manual* does not completely address cases where the crown elevation is lower than the top of curb elevation. For those cases a combination of *Figure1.2 and 1.3 in the iSWM Hydraulics Technical Manual* can be used or a standard hydraulics program such as HEC-RAS or FlowMaster can be applied.

The design storms required by the City are as follows:

Storm Sewer System

The design storm is the fully developed land use conditions for the flood mitigation storm for the combination of the closed conduit and surface drainage system, to the limits of ROW.

Runoff from the fully developed conveyance storm must be contained within the permissible spread of water in the gutter. The flood mitigation storm flow must be contained within the ROW. Adequate inlet capacity shall be provided to intercept surface flows before the ROW capacity is exceeded. Note: the capacity of the underground system may be required to exceed the conveyance storm in order to satisfy the flood mitigation storm criteria.

The 5-year closed conduit Hydraulic Grade Line (HGL) must be equal to or below the gutter line for pipe systems and one (1) foot or more below the curb line at inlets. For sump conditions without an existing structural overflow, the 100-year HGL must be one (1) foot below the curb at the inlet. For situations where no ROW exists, the 100-year HGL must be below finished ground. The 100-year HGL will be tracked carefully throughout the system and described in the hydraulic calculations tables provided herein and on the construction drawings.

Inlets in Sumps

Curb opening inlets in sumps (Type CO-S) are addressed in *Section 1.2.7 of the Hydraulics Technical Manual*. Drop inlets in sumps (Y Inlet) are addressed in *Section 1.2.9 of the Hydraulics Technical Manual*.

In sag or sump conditions, the storm drain and sump inlets shall be sized to intercept and convey a minimum of the 25-year storm and a positive structural overflow is required to provide for the remainder of the flood mitigation storm. The positive overflow structure must be concrete or other acceptable non-earthen structure with a minimum bottom width of four (4) feet extending from the sump inlet to the storm sewer outfall. It must be designed to pass at least 20 cfs with one (1) foot of freeboard from the top of curb to the adjacent finish floor elevations (minimum finish floor elevations for all lots adjacent to said overflows must be shown on the plat).

All flumes that pass through sidewalks shall have a bolted-down, rust-proof, 3/8-inch (min.) steel plate with a pedestrian-rated walking surface. The plate shall be recessed into the concrete sidewalk from face of curb to the property line. The plate must be secured to the concrete with bolts and flush with the top of sidewalk. A center support shall be added if the width of the flume exceeds two (2) feet. For wider flumes, additional supports shall be added so that no span exceeds two (2) feet.

Structural overflow for inlets in sumps, shall be a concrete flume. Fences must be kept behind the curb line of the flume and the flume placed in a drainage easement on a HOA lot. Where a structural overflow is not feasible, a waiver must be requested. If no structural overflow is constructed, the sump inlets must be designed with a 50% clogging factor (assume 50% of inlet opening is clogged). In a cul-de-sac where no structural overflow is feasible, additional on-grade inlet capacity may be provided upstream of the sump in lieu of additional sump inlets.

An explanation of the Inlets in Sumps Calculation Sheet is included in is included in the following sections. The calculations shall be included in construction plans and be consistent with Figure 3.5.

Inlets on Grade with Gutter Depression (Type CO-D, Figure 3.6)

The hydraulic efficiency of storm-water inlets varies with gutter flow, street grade, street crown, and with the geometry of the inlet depression. The design flow into any inlet can be greatly increased if a small amount (5% to 10%) of gutter flow is allowed to flow past the inlet. When designing inlets, prevention of clogging or from interference with traffic often takes precedence over hydraulic considerations. The computation sheet for Type CO-D Inlet in Table 3.7 shall be used for calculations and included in the construction plans.

The depression of the gutter at a curb opening inlet (See Figure 3.6) below the normal level of the gutter increases the cross-flow towards the opening, thereby increasing the inlet capacity. Also, the downstream transition out of the depression causes backwater which further increases the amount of water captured. Depressed inlets shall be used on all public streets and alleys. Recessed depressed inlets shall be used on all arterials.

The capacity of a depressed curb inlet on grade will be based on the methodology presented in *Section 1.2.7 of the iSWM Hydraulics Technical Manual*.

Drop Inlets (Area Drains)

1. Drop inlets serving a drainage area of 10 to 25 acres will be designed with a 50% clogging factor.
2. Grading plans to direct flow into drop inlets will be included in the construction plans. Where earthen swales or other means of collecting and directing runoff into drop inlets are needed, they shall be contained in appropriately sized drainage easements.
3. Consideration shall be given to a structural overflow in the same manner as described for sump inlets.
4. Drop inlets shall be contained and centered in a 20 ft x 20 ft easement and located where they can be easily accessed for inspection and maintenance by the City.

Headwalls

1. A headwall will be used to collect a drainage area of twenty-five (25 ac) acres or more flowing to one spot.
2. Areas that have been channelized or discharged from a storm drain system will use a headwall to reintroduce the flow to a new storm drain system. These provisions do not apply to special multi-stage outlet structures draining detention facilities.

3.8.3.3 Stormwater Inlets Computation Sheets

Explanation of the Inlets in Sumps Computation Sheet (Type CO-S), Figure 3.4

In order to facilitate the computations required in determining the various hydraulic properties for curb opening inlets and Y Inlets (drop inlets) in sumps, the Computation Sheet for Curb Opening and Drop Inlets shown in Figure 3.5 See Figure 3.4 for an illustration of a curb opening inlet.

Table Column Description:

Column 1 Inlet number and designation. Column 2 Slope of gutter in ft. per ft.

Column 3 Crown slope of pavement in ft. per ft. For parabolic crowns enter type of street section.

Column 4 Total gutter flow in cfs. For inlets other than the first inlet in a system, gutter flow is the sum of runoff from contributing area plus carry-over flow from inlet or inlets upstream.

Column 5 Depth of gutter flow in feet from the spread of water calculations in Figure 1.2 (iSWM Hydraulics Technical Manual), Section 1.2.4 or from direct solution of Manning's equation for triangular gutters.

Column 6 Depth of gutter depression in ft. (0.33 ft for a standard recessed curb inlet) Column 7 Depth of water at inlet opening in ft. Column 5 plus Column 6.

Column 8 Capacity of curb opening inlet or drop inlet in cfs per ft. of length of opening or perimeter around inlet from Figures 1.10, 1.12 or 1.14 in the iSWM Hydraulics Technical Manual or by direct solution.

Column 9 Assumed length of inlet opening or perimeter in feet. Column 10 Capacity of inlet in cfs. Column 8 times Column 9.

Column 11 Carry-Over flow passing inlet (into overflow swale) in cfs. Column 4 minus Column 10.

Column 12 Percent of flow captured by inlet. Column 10 divided by Column 4 times 100.

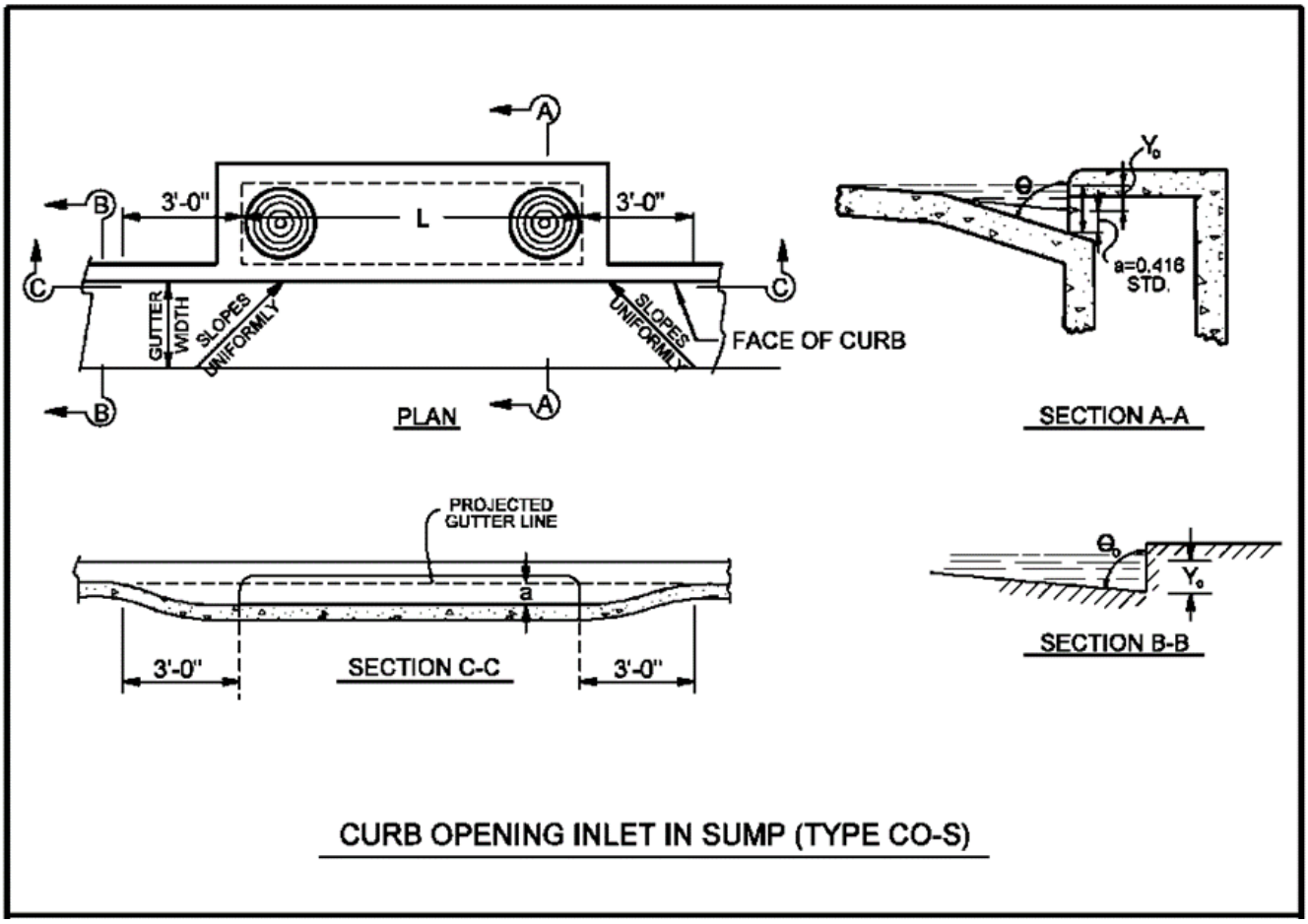


Figure 3.4 Type CO-S Inlet

COMPUTATION SUMMARY SHEET
FOR DETERMINING CAPACTIY OF
CURB OPENING INLET AND DROP INLETS IN SUMP

Inlet			Drainage Area				Manning's coefficient for pavement "n"	Crown Slope of Pavement "Sx" (ft/ft)	Long Slope "S" (ft/ft)	100-year Intensity (in/hr)	100-year Runoff (cfs)	100-year Carryover Flow (cfs)	Right-of-Way Capacity (cfs)	100-year Total Gutter Q (cfs)	Depth of Flow (1) "Yo" (ft)	Depth of Depression a (ft)	Depth of Flow at Opening "Y" (ft)	Capacity of Inlet Q/L (cfs/ft)	Length of Inlet L (ft)	Capacity of Inlet Q (cfs)	100-year Carryover Flow (2) "q" (cfs)	% Q100 Captured (%)	Comments
Design Point	Inlet No.	Station	Area No.	Area (acres)	Runoff "c"	Conc. Time (min)																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Notes (1) Include 5-year depth of flow and spread of flow for inlets located along arterial or collector streets.
(2) Include 25-year flow and depth calculations if carryover into overflow.

Figure 3.5 Computation Sheet for Curb Opening and Drop Inlets

Explanation of the Inlets On Grade with Gutter Depression (Type CO-D, Figure 3.6) Computation Sheet

In order to facilitate the computations required in determining the various hydraulic properties for Curb Opening Inlets Type CO-D on grade (depressed), Figure 3.7, the Computation Sheet for On Grade Curb Inlets has been prepared.

Table Column Description:

Column 1 Design Point for Inlet Column 2 Inlet number(s)

Column 3 Location of inlet by storm drain station number Column 4 Drainage area designation for incremental area

Column 5 Drainage area size (acres)

Column 6 Runoff coefficient “C” provided in Table 3.5 located in Section 3.4.1 under “Types of Hydrologic Methods”

Column 7 Time of concentration (minutes) Column 8 Longitudinal slope (ft/ft)

Column 9 Cross slope of the pavement (ft/ft)

Column 10 Cross slope of the gutter measured from the cross slope of the pavements. The cross slope is equal to the gutter depression (in) divided by the width of the depressed gutter (in)

Column 11 Depth of gutter flow "yo" in approach gutter from spread of water determinations in the *iSWM Hydraulics Technical Manual, Figure 1.3*, or from direct solution of Manning's equation for triangular gutters: yo = 1.245 Qo3/8 (n3/8/So3/16) (1/z)3/8. When the crown is overtopped, a composite analysis will be required.

Column 12 Spread of flow is calculated using Figure 1.2 in the iSWM Hydraulics Technical Manual or from direct solution of Manning’s Equation

Column 13 Equivalent cross slope is computed by using Figure 1.3 and 1.4 in the iSWM Hydraulics Technical Manual to determine the ratio of flow in the depressed gutter section to the total flow

Column 14 Street crown section type (straight crown [“rooftop”] or parabolic)

Column 15 Manning’s roughness coefficient (n) for pavement values located in Section 1.2.4 of the iSWM Hydrologic Technical Manual Table 1.2

Column 16 5-year rainfall intensity (in/hr), From Section 5.0 in the iSWM Hydrology Technical Manual

Tarrant County Rainfall Table

Column 17 5-year runoff, Q=CAi (cfs)

Column 18 5-year carryover flow from upstream inlet (cfs)

Column 19 5-year total gutter flow (Column 17 + Column 18) (cfs)

Column 20 100-year rainfall intensity (in/hr), from *Section 5.0 in the iSWM Hydrology Technical Manual Tarrant County Rainfall Table*

Column 21 100-year runoff, Q=CAi (cfs)

Column 22 100-year carryover flow from upstream inlet (cfs)

Column 23 100-year total gutter flow (Column 20 + Column 21) (cfs)

Column 24 Total right-of-way capacity (normally 2.5” over top of curb) (cfs)

Column 25 This indicates the controlling storm for inlet spacing, depending on which criteria (5-year in street or 100-year in ROW) may be exceeded. This indicates whether the inlet is sized for the 5-year or 100-year flows

Column 26 Length required for total interception of the design storm determination in Figure 1.8 of the iSWM Hydraulics Technical Manual or by direct solution of Manning's Equation. Please note that the example in Figure 1.8 does not consider inlet depression (slope).

Column 27 Actual length (L) in feet of the inlet which is to be provided (10', 15', or 20')

Column 28 Ratio of the length of inlet provided (L) to the length of the inlet required for 100% interception (LT). Column 26 divided by Column 29

Column 29 The efficiency of the provided inlet determined by Figure 1.9 in the iSWM Hydraulics Technical Manual.

Column 30 Discharge (Qi) in cubic feet per second in which the inlet in question actually intercepts in the design storm. Column 19 or 23 multiplied by Column 27

Column 31 Carry-over flow (q) is the amount of water which passes the inlet in a conveyance storm. A substantial portion of the 5-year flow shall be picked up by the inlet. The carry-over flow shall be accounted for in further downstream inlets.

Column 32 Carry-over flow (q) is the amount of water which passes the inlet in a flood mitigation storm. The carry-over flow shall be accounted for in further downstream inlets and shall be reflected in the inlet bypass flow (Column 17) in the Storm Drain Hydraulics Table, Figure 3.10 (minor variances may occur due to travel time routing in the Hydraulics Table).

Column 33 Label of the upstream inlet from where the bypass flow originated.

Column 34 Include notes.

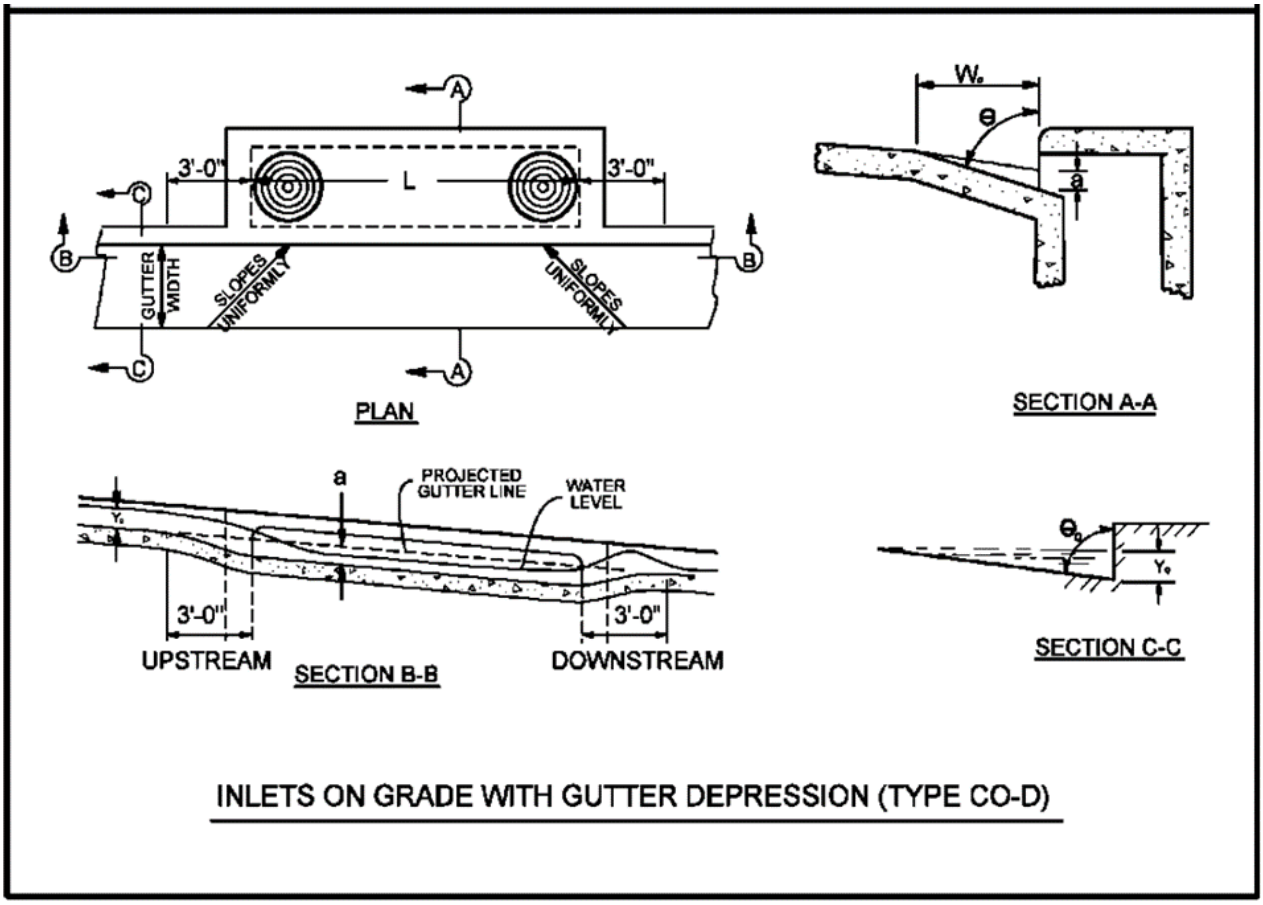


Figure 3.6 Type CO-D Inlet

COMPUTATION SUMMARY SHEET FOR DETERMINING CAPACTIY OF CURB OPENING INLET ON GRADE (DEPRESSED)

Inlet			Drainage Area				Crown Slope of Pavement	Long Slope	Cross Slope of Gutter	Depth of Flow (1)	Spread of Flow (2)	Equivalent Cross Slope	Street	Manning's coefficient	5-year	5-year	5-year Carryover	5-year Total	Street Capacity	100-year	100-year	100-year Carryover	Right-of-Way	100-year Total	Design	Length Required	Actual Provided		Efficiency	Inlet Capacity	5-year Carryover	100-year Carryover	Carryover Receiving	
Design Point	Inlet No.	Station	Area No.	Area (acres)	Runoff "c"	Conc. Time (min)	"Sx" (ft/ft)	"S" (ft/ft)	"S'x" (ft/ft)	"Yo" (ft)	"T" (ft)	"Se" (ft/ft)	Section (type)	for pavement "n"	Intensity (in/hr)	Runoff (cfs)	Flow (cfs)	Gutter Q (cfs)	(cfs)	Intensity (in/hr)	Runoff (cfs)	Flow (cfs)	Capacity (cfs)	Gutter Q (cfs)	Storm (3)	"L_T" (ft)	Length "L" (ft)	L/L_T	"E"	"Qi" (cfs)	Flow "q" (cfs)	Flow "q" (cfs)	Inlet No (4)	Comments
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		20	21	22	23	24	25	26	27	28	29	30	31	32	33	34

Notes:
(1) Specify flood event. Assumptions of full curb in all conditions may lead to overestimation of inlet capacity.
(2) Specify flood event. When the crown is overtopped, a composite analysis will be required.
(3) This is the controling storm for inlet spacing. Depending on which criteria (5-year or 100-year in ROW) may be exceeded.
(4) If carryover, add column to specify receiving inlet

Figure 3.7 Computation Summary Sheet for On Grade Curb Inlets

3.8.3.4 Streets and ROW

Depth in the street shall not exceed top of curb or exceed maximum spread of water limits for the fully developed conveyance storm. Limiting the spread of water allows one or more lanes to remain dry during the conveyance storm and helps prevent hydroplaning of vehicles. The fully developed flood mitigation storm shall be contained within the right-of-ways or easements.

Parking Lots

Parking lots shall be designed for the conveyance storm not to exceed top of curb, with maximum ponding at low points of one (1) foot. The flood mitigation storm shall be contained on-site or within dedicated easements.

Spread of Water Limits

Inlets shall be placed at intersections, low points of grade (sag), and spaced so that the spread of water in the street for the conveyance storm shall not exceed the guidelines provided below.

For all applications, the engineer/ Developer must use roadway sections as approved by the City. Road pavement sections shall not be altered, super elevated or warped at intersections to avoid a sag condition. Sag conditions at intersections (including minor/residential streets) shall be drained using an inlet.

If a roadway or thoroughfare is identified on a Master Thoroughfare Plan (MTP) then the following thoroughfare spread width criteria shall apply.

The following spread of water values shall be used for the various types of streets.

Thoroughfare (Divided)

1. Permissible Spread of Water - The permissible spread of water in gutters of major divided thoroughfares shall be limited so that one traffic lane on each side remains clear during the conveyance storm. Gutter flow shall be based on maximum storm duration of 15 minutes. The flood mitigation storm shall be contained within the ROW.
2. Conditions - Inlets shall be located at street intersections, at low points of grade, and where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when possible, on side streets when grades permit. In no cases shall the gutter depression at inlets exceed the standard. In super-elevated sections, inlets placed against the center medians shall have no gutter depression. Inlets shall be placed to intercept flow before it can cross the street.

Thoroughfares (Not Divided)

1. Permissible Spread of Water - The permissible spread of water in gutters of major undivided thoroughfares shall be limited so that one traffic lane in each direction will remain clear during the conveyance storm.
2. Conditions - Inlets shall be located at street intersections, low points of grades, and where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located on the side streets. In no case shall the gutter depression at inlets exceed the standard.
3. Super-elevated Sections - Intercept gutter flow at the point of zero crossfall to prevent flow from crossing the thoroughfare. Stormwater will not be allowed to cross major thoroughfares on the surface in valley gutters or otherwise.

Two-Lane Thoroughfares (one lane each direction)

1. Permissible Spread of Water - The permissible spread of water in gutters of a two-lane thoroughfares shall be limited to a maximum spread width of 10 feet during the conveyance storm.
2. Conditions - Inlets shall be located at street intersections, at low points of grade, and where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when possible, on side streets when grades permit. In no cases shall the gutter depression at inlets exceed the standard. In super-elevated sections, inlets placed against the center medians shall have no gutter depression. Inlets shall be placed to intercept flow before it can cross the street.

Collector Streets

1. Permissible Spread of Water - The permissible spread of water in gutters of collector streets shall be limited so that one standard lane of traffic will remain clear during the conveyance storm.
2. Conditions - Inlets shall preferably be located at street intersections, low points of grade, and where the gutter flow exceeds the permissible spread of water criteria. Inlets shall be located, when at all possible, on the side streets when grade permits. In no case shall the gutter depression at inlets exceed the standard

Minor Streets (Residential)

1. Permissible Spread of Water - The permissible spread of water in gutters for minor streets shall be limited by the height of the curb for the conveyance storm. The flood mitigation storm shall be contained within the R.O.W.
2. Conditions - Inlets shall be located at street intersections, low points of grade, and where the gutter flow exceeds the permissible spread of water criteria. In no case shall the gutter depression at inlets exceed the standard. Superelevation is not permitted on minor residential streets.

3.8.3.5 Storm Drain Pipe Design

This Section replaces the Closed Conduit System sections 1.2.9, most of 1.2.10, and 1.2.11 of the iSWM Hydraulics Technical Manual. Storm Drain Outfalls located within section 1.2.10 (page HA-49) of the iSWM Hydraulics Technical Manual are adopted and incorporated by reference into this Manual. Although, use of Table 1.10 may be substituted by a detailed hydrologic and hydraulic study, it is the purpose of this Section of the manual to consider the significance of the hydraulic elements of storm drains and their appurtenances to the storm drainage system. This Section is generally excerpted from the 1967 City Design Criteria Manual.

Design Criteria

Design Frequency

Flood Mitigation storm, less any gutter, roadway, ROW, and flume flows.

Velocities and Grades

All storm drains shall be free draining and have a positive slope. Adverse slopes are not allowed.

Velocities in sewers are important because of the possibilities of excessive erosion on the storm drain inverts. Table 3.9 shows the maximum velocities for most storm drainage design. Supercritical flow in main lines shall not be allowed for the conveyance and flood mitigation design storms. Storm drains in partial flow shall provide partial flow depth and velocity calculations.

The maximum hydraulic gradient shall not produce a velocity that exceeds 20 feet per second (fps). Table 3.9 shows the maximum velocities for most storm drainage design. Storm drains shall be designed to have a minimum mean velocity flowing full at 2.5 fps. A main is defined as any pipe connected to two or more inlets.

Table 3.9 Velocity in Storm Drains

Description	Maximum Allowable Velocity
Culverts (All types)	15 fps
Storm Drains (Inlet laterals)	25 fps
Storm Drains (Mains)	20 fps

Permanently submerged (below normal pool) storm drain outfalls are not allowed, except as required by TRWD for outfalls into the Trinity River federal floodway project area.

Storm drains shall operate with velocities of flow sufficient to prevent excessive deposits of solid materials, otherwise objectionable clogging may result. The controlling velocity is near the bottom of the conduit and considerably less than the mean velocity of the sewer. Storm drains shall be designed to have a minimum velocity

of 2.5 fps. Table 3.10, Minimum Grades for Storm Drains, indicates the minimum grades for concrete pipe (n = 0.013), flowing at 2.5 fps. The maximum slope for a lateral shall be 30%.

Table 3.10 Minimum Grades for Storm Drains

Pipe Size (Inches)	Concrete Pipe (Slope ft/ft).
21	0.0015
24	0.0013
27	0.0011
30-96	0.0010

Materials

Reinforced concrete pipe (RCP): Only RCP is allowed under pavement for public storm drains in the City. For pipe materials, other than RCP, only products on the Stormwater Approved Products List shall be used.

Polypropylene (PP) pipe products on the Stormwater Approved Products List may be used (up to a diameter of 60 inches) are allowed under pavement for public storm drains.

Profile-wall thermoplastic pipe (corrugated exterior with smooth interior), including High- Density Polyethylene (HDPE) pipe and Corrugated PVC (CPVC), may be used in the following specific situations:

- Profile-wall thermoplastic pipe is permitted for use in driveway culverts (i.e. across roadside ditches). Minimum allowable size shall be fifteen (15) inch internal diameter. Driveway permits will be required from the TPW Street Management office.
- Profile-wall thermoplastic pipe may be allowed for certain off-pavement applications (using Request for Waiver Form CFW-7).
- A request for waiver (Form CFW-7) shall be required for profile wall HDPE pipe up to thirty-six (36) inch in diameter under publicly maintained concrete pavement in residential streets. No exceptions to this rule will be considered for installation of HDPE/CPVC pipe under other publicly maintained street sections.
- Profile-wall thermoplastic pipe used as storm drain shall be installed in accordance with the appropriate City Standard Detail, and with all manufacturer's specifications, and shall meet or exceed ASTM D-2321, Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications. Note that Class I aggregate (City Standard Construction Specification Documents – Section 330510 (Old TPW Item 402.2) or NCTCOG Aggregate Grade 4) shall be required for pipe embedment.

All contractors shall be trained and certified by the manufacturer prior to installing PP/HDPE/CPVC pipe. A copy of the training certification and proof of insurance shall be provided to the City before any work shall commence.

Roughness Coefficients

In selecting roughness coefficients for concrete pipe, consideration will be given to the average conditions at the site during the useful life of the structure. The 'n' value of 0.015 for concrete pipe shall be used primarily in analyzing existing sewers where alignment is poor and joints have become rough. For example, concrete pipe is being designed at a location where it is considered suitable and there is reason to believe that the roughness would increase through erosion or corrosion of the interior surface, slight displacement of joints or entrance of foreign materials. A roughness coefficient will be selected which in the judgment of the designer, will represent the average condition.

For the design of new public storm drain and culvert infrastructure, the "design n" value noted in Table 3.11 shall be applied. Calculations for new public concrete or polypropylene pipe shall use a Manning's n of 0.013 and new public concrete boxes shall use a Manning's n of 0.015.

Table 3.11 Manning's Coefficients for Storm Drain Conduits	
Type of Storm Drain	**Manning's n**
Concrete and Polypropylene Pipe (Design n = 0.013)	0.012 – 0.015
Concrete Boxes (Design n = 0.015)	0.012 – 0.015
Corrugated Metal Pipe (CMP), Pipe-Arch and Box (Annular or Helical Corrugations - see *Table 1.8 in iSWM Hydraulics Technical Manual*. **NOTE: CITY OF FORT WORTH DOES NOT ALLOW CMP FOR NEW CONSTRUCTION**	0.022-0.037*
Profile Wall Thermoplastic High Density Polyethylene (HDPE) or Polyvinyl Chloride (PVC). (Design n = 0.013)	0.010-0.013
NOTE: Actual field values for conduits may vary depending on the effect of abrasion, corrosion, deflection, and joint conditions.	

*Note: analysis of existing conditions may require a different value than the stated design coefficients.

Manholes

Manholes shall be located at intervals not to exceed 550 feet on mains and laterals. Manholes must be installed at the upstream end of a system where two inlet laterals combine, and where a storm drain leaves the pavement, unless the outfall is within fifty (50) feet of the roadway and directly accessible via an obstacle free path and slopes less than 6%. Manholes shall be located at street intersections, sewer junctions, changes of grade and changes of alignment. When the storm drain is a concrete box instead of an RCP, four (4) foot diameter manhole risers may be installed instead of vaults to provide access. In all cases, steps or ranges shall be installed from the ground surface to the flowline of the pipe. Manholes shall not exceed 20 feet from rim elevation to flow line.

Full or Part Full Flow in Storm Drains

All storm drains shall be designed by the application of the Continuity Equation and Manning's Equation either through the appropriate charts or nomographs or by direct solutions of the equations as follows:

Q = AV, and

$Q = \frac{1.486}{n} A\, r^{\frac{2}{3}} S_f^{\frac{1}{2}}$, where

A = Cross-sectional area of pipe or channel.

V = Velocity of flow.

n = Coefficient of roughness of pipe or channel.

r = Hydraulic radius = A/P

Sf = friction slope in feet per foot in pipe or channel.

P = Wetted perimeter.

The size of pipe required to transport a known-quantity of storm runoff is obtained by substituting known values in the formula. In practice, the formula is best utilized in the preparation of a pipe flow chart which interrelates values of runoff, velocity, slope, and pipe geometry. With two of these variables known or assumed, the other two are quickly obtained from the chart. A pipe flow nomograph for circular conduits flowing full graph is shown in iSWM Hydraulics Technical Manual Figure 1.17. Equations for flow in conduits with other cross-sections are available in the TxDOT Hydraulic Design Manual, dated October 2011, Chapter 6, and Section 2. For circular conduits flowing partially full, graphs are presented in iSWM Hydraulics Technical Manual Figure 1.19a.

Hydraulic Gradient and Profile of Storm Drain

In storm drain systems flowing full (or partially full as discussed above), all losses of energy through resistance with flow in pipes, by changes of momentum, or by interference with flow patterns at junctions, must be accounted for by accumulative head losses along the system from its initial upstream inlet to its outlet. The purpose of accurate determinations of head losses at junctions is to include these values in a progressive calculation of the hydraulic gradient along the storm drain system. In this way, it is possible to determine the water surface elevation which will exist at each structure. The rate of loss of energy through the storm drain system shall be represented by the hydraulic grade line, which measures the pressure head available at any given point within the system.

The HGL shall be established for all storm drainage design in which the system operates under a head. The HGL is often controlled by the conditions of the sewer outfall; therefore, the elevation of the tailwater must be known. The hydraulic gradient is calculated upstream from the downstream end, taking into account all of the head losses that may occur along the line. The iSWM Hydraulics Technical Manual Table

1.10 provides a table of coincident design frequencies to assist with tailwater determination. The hydraulic gradient shall begin at the higher of the tailwater or depth of flow in the pipe at the downstream end. An alternative to the use of Table 1.10 is the performance of a detailed hydrologic and hydraulic study to determine coincident tailwater.

All head losses shall be calculated if the storm drain system is in a subcritical flow regime whether the system is flowing partially full or surcharged. Hydraulic calculations shall reflect partially full pipe where flow conditions would not surcharge the pipe. Supercritical flow is not allowed in main lines. If the system is in supercritical regime the section shall be marked “SUPERCRITICAL FLOW.” The presence of supercritical regime shall be confirmed by analyzing from downstream as well as upstream.

The friction head loss shall be determined by direct application of Manning’s Equation or by appropriate nomographs or charts as discussed in the first paragraph of this Section. Minor losses due to turbulence at structures shall be determined by the procedure of last section of this chapter (“Minor Head Losses at Structures) or in the iSWM Hydraulics Technical Manual. All HGL calculations will be carried upstream to the inlet.

The HGL shall in no case be above the surface of the ground or street gutter for the conveyance storm. Allowance of head must also be provided for future extensions of the storm drainage system. In all cases the maximum HGL must be twelve (12) inches below top of curb at any inlet for the conveyance storm.

Minor Head Losses at Structures

Detailed information on the calculation of minor head losses at structures is provided in the proceeding section. Figure 3.8 and Figure 3.9 provide details of minor losses for manholes, wye branches, and bends in the design of closed conduits. Minimum head loss used at any structure shall be 0.10 foot.

Hydrologic Methodology with MWH InfoWorks/SWMM Programs

InfoWorks SD by MWH Soft and the Stormwater Management Model (SWMM) family of programs have been applied to several complex storm sewer systems in the City. These programs include several hydrologic subarea runoff procedures. In addition to the hydrologic methods described in Section 3.4.1, the City accepts the following procedures when applying these programs:

- With case-by-case approval by TPW, the SWMM Method in which the flow is routed using a single linear reservoir, whose routing coefficient depends on surface roughness (Manning’s n), surface area, ground slope and catchment width.

• A version of the Unit Hydrograph Method in which a triangular unit hydrograph is developed using the time to peak (time of concentration times 0.6), total runoff time (time to peak times 2.67) and the peak of the unit hydrograph (2 divided by total runoff time). Refer to Appendix B, Stormwater computer models for more information.

Minor Head Losses at Structures Calculations

The following head losses at structures shall be determined for manholes, wye branches or bends in the design of closed conduits. See Figure 3.8 and Figure 3.9 for details of each case. Minimum head loss used at any structure shall be one-tenth (0.10) foot.

Except as otherwise provided herein, the basic equation that shall be used, where there are both upstream and downstream velocity, is set forth below with the various conditions of the coefficient "K_j" shown in Table 3.12.

$$h_j = \left(\frac{V_2^2}{2g}\right) - K_j \left(\frac{V_1^2}{2g}\right)$$ Where:

h_j = Junction or structure head loss in feet.

V_1 = Velocity in upstream pipe in fps.

V_2 = Velocity in downstream pipe in fps.

K_j = Junction or structure coefficient of loss.

In the case where the manhole is at the very beginning of a line or the line is laid with bends or on a curve, the equation used shall be the following without any velocity of approach.

$$h_j = K_j \frac{V_2^2}{2g}$$

60° Bend - 85%; 45° Bend - 70%; 22-1/2° Bend - 40%

The values of the coefficient "K_j" for determining the loss of head due to obstructions in pipes are shown in Table 3.13 and the coefficients are used in the following equation to calculate the head loss at the obstruction:

$$H_j = K_j \frac{V_2^2}{2g}$$

Table 3.12 Junction or Structure Coefficient of Loss			
Case No.	**Reference Figure**	**Description of Condition**	**Coefficient K_j**
I	3.8	Inlet on Main Line	0.50
II	3.8	Inlet on Main Line with Branch Lateral	0.25
III	3.8	Manhole on Main Line with 45º Branch lateral	0.50
IV	3.8	Manhole on Main Line with 90º Branch Lateral	0.25
V	3.8	Manhole on Main Line with no Branch	1.0
VI	3.9	45º Wye Connection or cut-in	0.75
VII	3.9	Inlet or Manhole at Beginning of Line	1.25
VIII	3.9	Conduit on Curves for 90º * Curve radius = diameter Curve radius = 2 to 8 diam. Curve radius = 8 to 20 diam.	 0.50 0.25 0.10
IX	3.9	Bends where radius is equal to diameter: 90º Bend 60º Bend 45º Bend 22-1/2º Bend Manhole on line with 60º Lateral Manhole on line with 22/1/2º Lateral	 0.50 0.43 0.35 0.20 0.35 0.75
* Where bends other than 90° are used, the 90° bend coefficient can be used with the following percentage factor applied: 60°- 85%, 45° – 70%, 22.5° – 40%			

Table 3.13 Head Loss Coefficients Due to Obstructions			
A/A_o*	**K_j**	**A/A_o***	**K_j**
1.05	0.10	3.0	15.0
1.1	0.21	4.0	27.3
1.2	0.50	5.0	42.0
1.4	1.15	6.0	57.0
1.6	2.40	7.0	72.5
1.8	4.00	8.0	88.0
2.0	5.55	9.0	104.0
2.2	7.05	10.0	121.0
2.5	9.70		
* A/Ao = Ratio of area of pipe to area of opening at obstruction.			

The values of the coefficient "K_j" for determining the loss of head due to sudden enlargements and sudden contractions in pipes are shown in Table 3.14, and the coefficients shall be used with the following equation to calculate the head loss at the change in section:

$$H_j = K_j \frac{V^2}{2g}, \text{ where,}$$

V = Velocity in smaller pipe

Table 3.14 Head Loss Coefficients Due to Sudden Enlargements and Contractions

$\frac{D_2}{D_1}$*	Sudden Enlargements K_j	Sudden Contractions K_j
1.2	0.10	0.08
1.4	0.23	0.18
1.6	0.35	0.25
1.8	0.44	0.33
2.0	0.52	0.36
2.5	0.65	0.40
3.0	0.72	0.42
4.0	0.80	0.44
5.0	0.84	0.45
10.0	0.89	0.46
~	0.91	0.47

* D2/D1 = Ratio of larger to smaller diameter

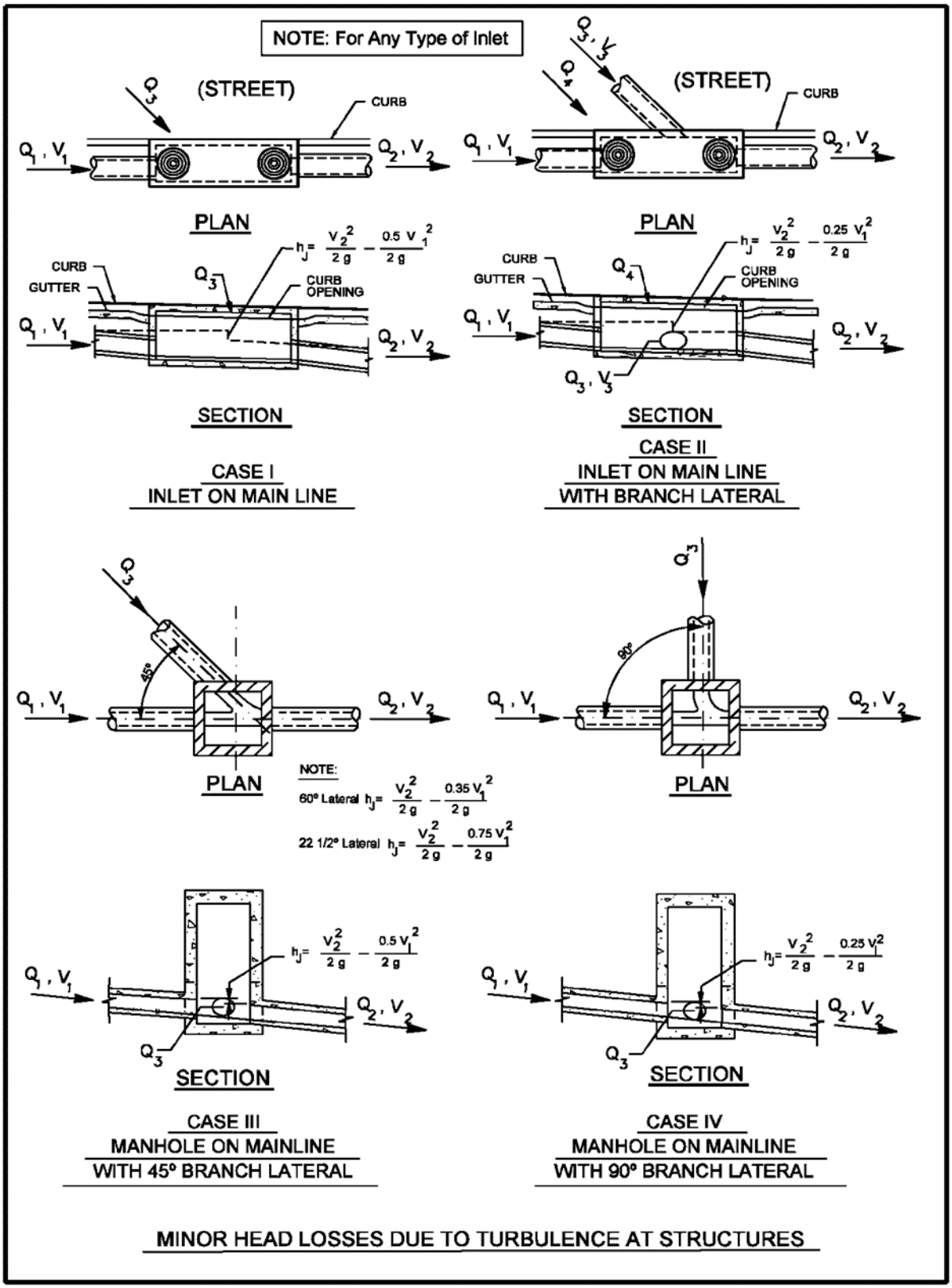


Figure 3.8 Minor Head Losses at Structures (1 of 2)

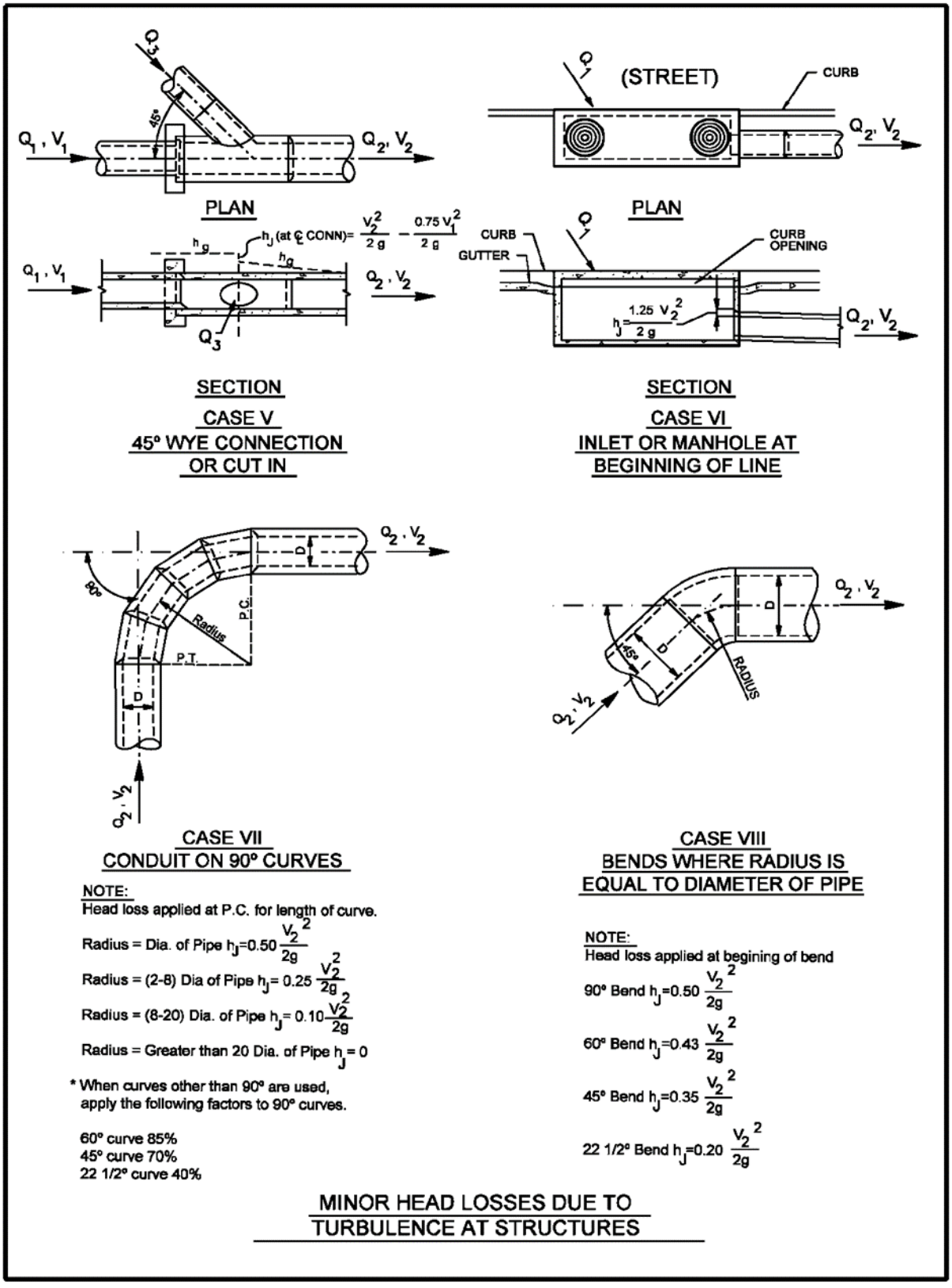


Figure 3.9 Minor Head Losses at Structures (2 of 2)

Storm Drain Design Examples

All storm drains shall be designed by the application of the Manning Equation either directly or through appropriate charts or nomographs. In the preparation of hydraulic designs, a thorough investigation shall be made of all existing structures and their performance on the waterway in question.

An example of using the method used in the manual for the design of a storm drainage system is outlined below and shown on Figure 3.10, Computations Sheet for Storm Drains. The design theory has been presented in the preceding chapters with their corresponding tables and graphs of information.

Preliminary Design Considerations

- Prepare a drainage map of the entire area to be drained by proposed improvements. The scale of the map shall not be less than 1 inch = 200 feet for project area although smaller scale maps for large offsite drainage areas may be used. A maximum contour interval of 2 feet shall be provided.
- Prepare a layout of the proposed storm drainage system, locating all inlets, manholes, mains, laterals, ditches, culverts, etc.
- Outline the drainage area for each inlet in accordance with present and future street Development.
- Indicate on each drainage area the code identification number and the direction of surface runoff by small arrows. Provide a runoff table showing area, “C” factor for each portion and composite “e”, Tc, I5, Q5, I100 and Q100. Provide zoning classifications or land use data.
- Show all existing underground utilities.
- Establish design rainfall frequency.
- Establish minimum inlet time of concentration.
- Establish the typical cross section of each street.
- Establish permissible spread of water on all streets within the drainage area.
- Plot profile of existing natural ground along the center line of the proposed storm drain.
- Extend downstream plan and profile beyond the end of the pipe to a point of acceptable outfall. The flowline or invert of proposed outlet shall be equal to or slightly higher (<1 foot) than receiving stream.

Runoff Computations

Storm drain hydraulics are shown on the computation sheet provided on Figure 3.10. The first 18 columns of the computation sheet cover the tabulation for runoff calculations:

Table Column	**Description**
Column 1	Enter the downstream storm drain station number.
Column 2	Enter the upstream storm drain station number. This is the design point. Design shall start at the farthest upstream point.
Column 3	Enter the distance (in feet) between the storm drain stations.
Column 4	Enter the designation of the drainage area(s) at the design point in Column 2 corresponding to the designations shown on the drainage area map.
Column 5	Enter the area in acres for the drainage area identified in Column 4.
Column 6	Enter the total drainage area in acres within the system corresponding to storm drain station shown in Column 2.
Column 7	Enter the runoff coefficient “C” for the drainage area shown in Column 5.
Column 8	Multiply Column 5 by Column 7 for each area.
Column 9	Determine the total “CA” for the drainage system corresponding to the inlet or manhole shown in Column 2.
Column 10	Determine inlet time of concentration (See *Section 1.2.4 iSWM Hydrology Technical Manual*).
Column 11	Determine flow time in the storm drain in minutes. The flow time is equal to the distance in Column 3 divided by 60 times the velocity of flow through the storm drain in ft/sec.

Column 12 Total time of concentration in minutes. Column 10 plus Column 11. Note that time of concentration only changes at a downstream junction with another drainage area(s). It remains the same from an inlet or junction to the next inlet or junction picking up additional drainage areas. The junction of two paired inlets with each other is not a downstream junction.

Column 13 The intensity of rainfall in inches per hour for the conveyance storm frequency from the appropriate county rainfall table in the iSWM Hydrology Technical Manual.

Column 14 The intensity of rainfall in inches per hour for the flood mitigation storm frequency from the appropriate county rainfall table in the iSWM Hydrology Technical Manual.

Column 15 The conveyance storm runoff in cfs. Column 9 times Column 13.

Column 16 The flood mitigation storm runoff in cfs. Column 9 times Column 14.

Column 17 The proposed inlet bypass during a flood mitigation storm. This shall correspond to the carry-over flow "q" in Column 31 of the On-Grade Inlet Capacity Calculations Table (minor variances may occur due to travel time routing in the Hydraulics Table).

Column 18 Design Discharge for the storm drain system ("Qpipe") in cfs. This shall be the greater of a substantial portion of Q5 (Column 15) or Q100-Qbypass (Column 16 minus Column 17).

Hydraulic Design

After the computation of the quantity of storm runoff entering each inlet, the size and gradient of pipe required to carry the design storm are determined. Any number of computer programs are available to provide design assistance for pipe sizing to the engineer. However, storm drain hydraulics must be converted and reported in Figure 3.10, Computation Sheet for Storm Drains. The hydraulic grade line (HGL) must be calculated for all storm drain mains and laterals using appropriate head loss equations. In all cases, the storm drain HGL must remain below grade and must be at least one (1) foot below top of curb at any inlet for the conveyance storm.

In partial flow conditions, the HGL represents the actual water surface within the pipe. Note that for partial flow conditions, the velocity of the flow shall be calculated based on actual area of flow, not the full flow area of the pipe or box.

Although the table is presented from upstream to downstream, the calculations are normally performed from the outfall upstream to each inlet. Unless partial flow conditions exist, the beginning hydraulic gradient (Column 22 of the last downstream section) must begin at either the top of pipe or at the hydraulic gradient of the receiving stream at the coincident frequency provided in *Table 1.10 of the Hydraulic Technical Manual*, whichever is higher. It is also acceptable to perform a detailed hydrologic and hydraulic study of the watershed of the receiving stream to determine the connected outfall hydraulic gradient.

Table Column Description

Column 19 Enter the selected pipe size.

Column 20 Enter the appropriate Manning's roughness coefficient "n" from Table 3.18

Column 21 Enter the required slope of the frictional gradient (hydraulic gradient) determined by Manning's equation. The pipe shall be designed on a grade such that the inside crown of the pipe coincides or is below the HGL when flowing full. In a partial flow condition, the friction slope is the slope of the water surface and shall follow the slope of the pipe.

Column 22 This is the beginning hydraulic gradient of the line. It is equal to the Design HGL (Column 31) for the next downstream segment, or the beginning HGL of the system as described above.

Column 23 This is the upstream HGL before the structure and is calculated as Column 22 plus the friction loss (Column 3 times Column 21).

Column 24 Velocity of flow in incoming pipe (main line) at the junction, inlet or manhole at the design point identified in Column 2.

Column 25 Velocity of flow in outgoing pipe (i.e. the pipe segment being analyzed) at junction, inlet or manhole at design point identified in Column 2.

Column 26 Velocity head of the velocity in Column 24.

Column 27 Velocity head of the velocity in Column 25.

Column 28 Head loss coefficient “Kj”, at junction, inlet or manhole at design point from Table 3.12, Table 3.13, or Table 3.14, or from Figure 3.8 and Figure 3.9.

Column 29 Multiply Column 26 by Column 28.

Column 30 Head Loss at Structure. At a junction or change in pipe size, this is Column 27 minus Column 29. At a bend or inlet, this is Column 27 times Column 28. In all cases this is 0.10’ minimum.

EXCEPTION: In a supercritical flow regime with partial flow conditions, head losses are not generated at upstream junctions. These may be designated as “SUPERCRITICAL PARTIAL FLOW” in the head loss calculations, but must be supported by Froude Number in the comments column. Any other proposed deviations from standard head loss calculations due to other unusual flow regimes must be accepted by TPW on a case-by- case basis.

Column 31 Design HGL at the design point identified in Column 2. Column 23 plus Column 30. This is the beginning HGL (Column 22) for any upstream pipe discharging into that junction.

Column 32 Invert elevation for the pipe being analyzed at the downstream storm drain station in Column 1.

Column 33 Invert elevation for the pipe being analyzed at the design point (upstream storm drain station) in Column 2.

Column 34 Top of curb elevation at the design point in Column 2.

The above procedure is followed for each section of the storm drain. At the outfall, the hydraulic gradient of the line must be at the same elevation or above the gradient of the conduit or channel receiving the storm runoff discharge. See Sections 1.2.10 iSWM Hydraulics Technical Manual for guidance on outfall hydraulic gradients. In lieu of the guidance in the Sections 1.2.10 iSWM Hydraulics Technical Manual it is acceptable to perform a detailed hydrologic and hydraulic study of the watershed of the receiving stream to determine the connected outfall hydraulic gradient.

With the hydraulic gradient established for a particular line, considerable latitude is available for the physical placement of the pipe flow line elevations. The inside top of the pipe must be on or below the hydraulic gradient, thus allowing the pipe to be lowered where necessary to maintain proper cover and to minimize grade conflicts with existing utilities.

COMPUTATION SHEET
HYDRAULIC COMPUTATIONS FOR STORM DRAINS

STORM DRAIN HYDRAULIC CALCULATIONS TABLE

FROM	TO	Pipe	Drainage Area			Runoff	Incr.	Total	Time of Concentration			5-year	100-year	Q5	Q100	Inlet	Q	Pipe			HGL		HEAD LOSS CALCULATIONS							Design	Invert Elev.		T/C	
		Length	Incremental		Total	"c"	cA	cA	Inlet	Travel	Total	Intensity	Intensity	Runoff	Runoff	bypass	pipe	Size	n	Sf	D/S	U/S	V1 (in)	V2 (out)	$V1^2/2G$	$V2^2/2G$	Kj	$KjV1^2/2G$	Hk	HGL	FROM	TO	ELEV.	
		feet	No.	Area	Area				min.	min.	min.	in/hr.	in/hr.	cfs	cfs	cfs	cfs	in.		ft/ft	Elev.	Elev.	ft/sec	ft/sec	ft.	ft.		ft.	ft.	Elev.	ft.	ft.	ft.	COMMENTS
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
LINE A																																		
4+00	5+42	142	A1	35.00	35.00	0.65	22.75	22.75	15.00		15.00	4.86	7.98	110.57	181.55	14.50	167.05	48	0.013	0.0135	818.17	820.09	13.29	13.29	2.74	2.74	0.00	0.00	0.00	820.09	813.16	816.00	822.50	A1=future phases
1+86	4+00	214	A2	0.50	35.50	0.65		23.08	15.00	0.18	15.18	4.86	7.98	112.14	184.14	11.80	172.34	54	0.013	0.0077	816.08	817.72	13.29	10.84	2.74	1.82	0.50	1.37	0.45	818.17	811.02	813.16	819.50	
1+43	1+86	43	A3	0.18	35.68	0.65	0.12	23.19	15.00	0.51	15.51	4.86	7.98	112.71	185.07	0.00	185.07	54	0.013	0.0089	814.96	815.34	10.84	11.64	1.82	2.10	0.75	1.37	0.74	816.08	809.59	810.52	818.00	
0+50	1+43	93	A4	0.56	36.24	0.65	0.36	23.56	15.00	0.57	15.57	4.86	7.98	114.48	187.98	0.00	187.98	60	0.013	0.0052	814.10	814.59	11.64	9.57	2.10	1.42	0.50	1.05	0.37	814.96	808.53	809.09	817.78	min Hk = 0.10'
0+00	0+50	50			36.24	0.65		23.56	15.00	0.57	15.57	4.86	7.98	114.48	187.98	0.00	187.98	60	0.013	0.0075	813.23	813.61	9.57	9.57	1.42	1.42	0.35	0.00	0.50	814.10	808.23	808.53	---	45° BEND
LINE A-2																																		
A 1+86	n. inlet	22	see note	0.25	0.25	0.65	0.09	0.16	15.00		15.00	4.86	7.98	1.24	2.65	0.00	2.65	21	0.013	0.0003	818.17	818.18	0.00	1.10	0.00	0.02	1.25	0.00	0.02	818.20	812.02	815.00	819.50	half A1 bypass + half A2
A 1+86	s. inlet	24	see note	0.25	0.25	0.65	0.09	0.16	15.00		15.00	4.86	7.98	1.24	2.65	0.00	2.65	21	0.013	0.0003	818.17	818.18	0.00	1.10	0.00	0.02	1.25	0.00	0.02	818.20	812.02	815.00	819.50	half A1 bypass + half A2
LINE A-3																																		
A 1+86	n. inlet	22	see note	0.18	0.18	0.65	0.09	0.12	15.00		15.00	4.86	7.98	9.28	14.08	0.00	14.08	21	0.013	0.0079	816.08	816.25	0.00	5.86	0.00	0.53	1.25	0.00	0.67	816.91	811.52	813.50	818.00	half (A1+A2 bypass) + half A3
A 1+86	s. inlet	24	see note	0.18	0.18	0.65	0.09	0.12	15.00		15.00	4.86	7.98	9.28	14.08	0.00	14.08	21	0.013	0.0079	816.08	816.27	0.00	5.86	0.00	0.53	1.25	0.00	0.67	816.93	811.52	813.50	818.00	half (A1+A2 bypass) + half A3
LINE A-4																																		
0+20	s, inlet	18	A4/2	0.28	0.28	0.65	0.18	0.18	15.00		15.00	4.86	7.98	0.88	1.45	0.00	1.45	21	0.013	0.0001	814.97	814.97	0.00	0.60	0.00	0.01	1.25	0.00	0.01	814.98	811.67	813.07	817.57	
0+20	0+37	17	A4/2	0.28	0.28	0.65	0.18	0.18	15.00		15.00	4.86	7.98	0.88	1.45	0.00	1.45	21	0.013	0.0001	814.97	814.97	0.00	0.60	0.00	0.01	1.25	0.00	0.01	814.98	811.67	813.07	817.57	north inlet
0+00	0+20	20			0.56	0.65	0.00	0.36	15.00		15.00	4.86	7.98	1.77	2.90	0.00	2.90	24	0.013	0.0002	814.96	814.96	0.60	0.92	0.01	0.01	0.75	0.00	0.01	814.97	810.22	811.42	817.78	
LINE B																																		
5+98	6+15	17	B1/2	3.20	3.20	0.65	2.08	2.08	15.00		15.00	4.86	7.98	10.11	16.60	6.49	10.11	21	0.013	0.0041	817.70	817.77	0.00	4.20	0.00	0.27	1.25	0.00	0.34	818.12	814.73	815.04	819.54	west inlet
4+50	5+98	148	B1/2	3.20	6.40	0.65	2.08	4.16	15.00	0.07	15.07	4.86	7.98	20.22	33.20	12.98	20.22	24	0.013	0.0080	816.02	817.20	4.20	6.44	0.27	0.64	0.50	0.14	0.51	817.70	813.00	814.48	819.48	
2+15	4+50	235	B2	5.20	11.60	0.65	3.38	7.54	15.00	0.45	15.45	4.86	7.98	36.64	60.17	23.53	36.64	30	0.013	0.0080	813.76	815.63	6.44	7.46	0.64	0.87	0.75	0.48	0.38	816.02	810.15	812.50	818.00	
0+50	2+15	165	B3	2.50	14.10	0.65	1.63	9.17	15.00	0.98	15.98	4.86	7.98	44.54	73.14	20.00	53.14	36	0.013	0.0063	812.27	813.31	7.46	7.52	0.87	0.88	0.50	0.43	0.44	813.76	808.00	809.65	815.65	
0+00	0+50	50	B4	1.80	15.90	0.65	1.17	10.34	15.00	1.34	16.34	4.86	7.98	50.23	82.47	0.00	82.47	48	0.013	0.0075	811.53	811.91	7.52	6.56	0.88	0.67	0.35	0.31	0.36	812.27	805.00	807.00	814.00	channel HGL=811.53
LINE B-1A																																		
B 5+98	n. inlet	17	B1/2	3.20	3.20	0.65	2.08	2.08	15.00		15.00	4.86	7.98	10.11	16.60	6.49	10.11	21	0.013	0.0041	817.70	817.77	0.00	4.20	0.00	0.27	1.25	0.00	0.34	818.12	814.73	815.04	819.54	east inlet
LINE B-2 A&B																																		
B 4+50	e. inlet	18	B2/2	2.60	2.60	0.65	1.69	1.69	15.00		15.00	4.86	7.98	13.11	19.98	11.77	8.21	21	0.013	0.0027	816.02	816.07	0.00	3.41	0.00	0.18	1.25	0.00	0.23	816.29	812.50	813.50	818.00	includes B1 bypass
B 4+50	w. inlet	18	B2/2	2.60	2.60	0.65	1.69	1.69	15.00		15.00	4.86	7.98	13.11	19.98	11.77	8.21	21	0.013	0.0027	816.02	816.07	0.00	3.41	0.00	0.18	1.25	0.00	0.23	816.29	812.50	813.50	818.00	includes B1 bypass
LINE B-3 A&B																																		
B 2+15	e. inlet	18	B3/2	1.25	1.25	0.65	0.81	0.81	15.00		15.00	4.86	7.98	10.97	18.25	10.00	8.25	21	0.013	0.0027	813.76	813.81	0.00	3.43	0.00	0.18	1.25	0.00	0.23	814.04	810.65	811.15	815.65	includes B2 bypass
B 2+15	w. inlet	18	B3/2	1.25	1.25	0.65	0.81	0.81	15.00		15.00	4.86	7.98	10.97	18.25	10.00	8.25	21	0.013	0.0027	813.76	813.81	0.00	3.43	0.00	0.18	1.25	0.00	0.23	814.04	810.65	811.15	815.65	includes B2 bypass
LINE B-4																																		
0+20	w. inlet	18	B4/2	0.90	0.90	0.65	0.59	0.59	15.00	0.00	15.00	4.86	7.98	2.84	14.67	0.00	14.67	24	0.013	0.0042	812.44	812.51	0.00	4.67	0.00	0.34	1.25	0.00	0.42	812.94	808.65	809.50	814.00	includes B3 bypass
0+20	0+38	18	B4/2	0.90	0.90	0.65	0.59	0.59	15.00	0.00	15.00	4.86	7.98	2.84	14.67	0.00	14.67	24	0.013	0.0042	812.44	812.51	0.00	4.67	0.00	0.34	1.25	0.00	0.42	812.94	808.65	809.50	814.00	east inlet; B3 bypass
0+00	0+20	15			1.80	0.65	0.00	1.17	15.00	0.00	15.00	4.86	7.98	5.69	29.34	0.00	29.34	33	0.013	0.0031	812.27	812.31	4.67	4.94	0.34	0.38	0.75	0.25	0.12	812.44	807.00	807.90	814.00	

Notes:
1 Time of concentration (and intensity) only changes at downstream junctions. Paired inlets do not constitute a downstream junction.
2 HGL must be below grade along main or at least 1' below top of curb at each inlet (including entry loss of 1.25v2/2g).
3 Inlet spacing shall be determined by 5-year to top of curb or 100-year filling right-of-way, whichever is most restrictive.
4 Minimum head loss shall be 0.10 feet in a subcritical flow regime. Supercritical flow regimes do not generate head losses.

Figure 3.10 Computations Sheet for Storm Drains

3.8.4 Hydraulic Design Criteria for Channels, Culverts, Bridges and Detention Structures

3.8.4.1 Introduction

This Section is intended to provide design criteria and guidance on several on-site flood mitigation system components, including culverts, bridges, vegetated and lined open channels, storage design, outlet structures, and energy dissipation devices for outlet protection.

3.8.4.2 Open Channels

Design Frequency

The City requires that open channels are designed for the flood mitigation storm for fully developed watershed conditions. Channels may be designed with multiple stages (e.g., a “low-flow” or “pilot” channel section for common recurring flows, and a high flow section that contains the design discharge). The “low- flow” or “pilot” channel shall convey 2% of the design flood mitigation storm discharge.

General Criteria

- If relocation of a stream channel is unavoidable, the cross-sectional shape, meander, pattern, roughness, sediment transport, and slope shall conform to the existing conditions. Energy dissipation will be necessary when existing conditions cannot be duplicated.
- Streambank stabilization shall be provided, as a result of any stream disturbance such as encroachment and shall include both upstream and downstream banks as well as the local site.
- HEC-RAS or a hydraulic software program listed in Appendix B, Table B.1, Stormwater Modeling Programs and Design Tools shall be used to confirm the water surface profiles in open channels.
- The final design of artificial open channels shall be consistent with the velocity limitations for the selected channel lining. Maximum velocity values for selected lining categories are presented in Table 3.16 and Table 3. 17.
- Seeding and mulch shall only be used when the design value does not exceed the allowable value for bare soil. Velocity limitations for vegetative linings are reported in Table 3.17. Vegetative lining calculations and stone riprap procedures are presented in this Chapter and in Section 3.2 of the Hydraulics Technical Manual.
- The design of stable rock riprap lining depends on the intersection of the velocity (local boundary shear) and the size and gradation of the riprap material. More information on calculating acceptable riprap velocity limits is available in Section 3.2.7 of the Hydraulics Technical Manual. The Gregory Method shall be used for riprap design in the City.

Normal Depth (Uniform Flow)

For uniform flow calculations, the theoretical channel dimensions, computed by the slope-area methods outlined in this manual, are to be used only for an initial dimension in the design of an improved channel. Final design of public channels and roadside ditches shall require a HEC-RAS model. Exceptions will be for small outfall channels when the following conditions are true:

- Completely contained on the private Development site for on-site drainage
- Where no off-site drainage easement is required (i.e. not crossing or adjacent to another property that could be flooded if design storm occurs);
- No nearby downstream restrictions that would produce a backwater affect at the design location; and
- Where peak discharge is 10 cfs or less.

Backwater Profile (Gradually Varied Flow)

The City requires a hand computed or HEC-RAS backwater/frontwater analysis on any proposed open channel to determine the actual tailwater elevations, channel capacity and freeboard, and impacts on adjacent floodplains. If a stream or creek has an effective FEMA model, the engineer will be required to use a computer program for the analysis. If the current effective FEMA model for the stream is a HEC-2 model, the engineer has the option to either use that model, or convert to HEC-RAS for analysis of proposed conditions.

Supercritical Flow Regime

Supercritical flow will not be allowed. However, for lined channels, the hand computed frontwater or HEC-RAS analysis shall include a mixed-flow regime analysis, to confirm no supercritical flow occurs. The City requires that the computed flow depths in designed channels be outside of the range of instability, i.e. depth of flow shall be at least 1.1 times critical depth.

Channel Transitions or Energy Dissipation Structures or Small Dams

A HEC-RAS model or complete hand computed backwater analysis is a standard requirement for design of channel transitions (upstream and downstream), energy dissipation structures, and small dams. A backwater analysis will be required by the City, either hand computed or HEC-RAS, to determine accurate tailwater elevation, head losses, headwater elevations and floodplains affected by the proposed transition into and out of an improved channel, any on-stream energy dissipating structures, and small dams (less than six (6) feet). If the current effective FEMA model for the stream is a HEC-2 model, the engineer has the option to either use that model, or convert to HEC-RAS for analysis of proposed conditions. For larger dams, a hydrologic routing will be required, as well as hydraulic analysis, to determine impacts of the proposed structure on existing floodplains and adjacent properties.

Lined Channels

1. Channels shall be trapezoidal in shape and lined with reinforced concrete in accordance with City Standards and Specifications with side slopes not steeper than two (2) feet horizontal to one (1) foot vertical. The lining shall extend to and include the water surface elevation of the 100-year design storm plus one (1) foot of freeboard for the fully developed flood mitigation storm.
2. The channel bottom must be a minimum of eight (8) feet in width. (Overflow structures for storm sewer system sumps may have a minimum bottom width of six (6) feet.)
3. The maximum water flow velocity in a lined channel shall be fifteen (15) feet per second except that the water flow shall not be supercritical in an area from 100 feet upstream of a bridge to twenty-five (25) feet downstream of a bridge. Hydraulic jumps shall not be allowed from the face of a culvert to fifty (50) feet upstream from that culvert. In general, channels having supercritical flow conditions are discouraged.
4. Whenever flow changes from supercritical to subcritical, channel protection shall be provided to protect from the hydraulic jump that is anticipated (see comment in Item 3, above).
5. The design of the channel lining shall take into account the super elevation of the water surface around curves and other changes in direction.
6. A chain link fence six (6) feet in height shall be constructed on each side of the concrete or gabion channel lining.
7. TPW may require a geotechnical study and/or an underground drainage system design for concrete lined channels.
8. See City Standard Details for concrete lined channel section.

Earthen Channels

1. An earthen channel shall have a trapezoidal shape with side slopes not steeper than a 4:1 (horizontal and vertical) ratio and a channel bottom at least twelve (12) feet in width.
2. One (1) foot of freeboard above the flood mitigation frequency fully developed water surface elevation must be provided within all designed channels at all locations along the channel.

3. The side slopes and bottom of an earthen channel shall be smooth, free of rocks, and contain a minimum of six (6) inches of topsoil. The side slopes and channel bottom shall be re-vegetated with grass. No channel shall be accepted for maintenance by the City until a uniform (e.g., evenly distributed, without large bare areas) vegetative cover with a density of 70% has been established.
4. Each reach of a channel must have a ramp for maintenance access. Ramps shall be at least ten (10) feet wide and have 15% maximum grade. Twelve (12) feet width is required if the ramp is bounded by vertical walls.
5. Minimum channel slope is 0.0020 ft/ft (0.20%).
6. Erosion protection shall be provided at outfall to the receiving stream. The outfall of the earthen channel shall meet the flowline of the receiving stream or a drop structure shall be provided.
7. Channel shall be designed for subcritical flow regime; supercritical flow must be contained in flow transition armored channel sections

Roadside Ditches (Figure 3.15)

1. A roadside ditch ("rural") street section is not permissible, except when the City Plan Commission approves a waiver to the Master Thoroughfare Plan standard street sections No median ditches are allowed.
2. The design storm for roadside ditches shall be the fully developed conditions for the flood mitigation storm. The flood mitigation storm shall not exceed the right-of-way capacity defined as the natural ground at the right-of-way line or top of roadside ditch, unless contained within a designated drainage easement.

Design Considerations

1. For grass lined sections, the maximum design velocity shall be as defined in Table 3.17 for the flood mitigation design storm (Higher velocities are allowed if justified by a sealed geotechnical study).
2. A grass lined or unimproved roadside ditch shall have minimum two (2) feet bottom width and side slopes no steeper than four horizontal to one vertical (4:1). There shall be a four (4) foot strip at maximum 2% cross slope between the edge of pavement and the beginning of the ditch.
3. Minimum grades for roadside ditches shall be 0.0040 ft/ft (0.40%).
4. Manning's roughness coefficient for analysis and design of roadside ditches are presented in Table 3.15, Table 3.16, and Table 3.17 and in Section 3.2.3 in the iSWM Hydraulics Technical Manual.
5. Maximum depth will not exceed four (4) feet from center-line of pavement (highest elevation in pavement section).
6. If the ditch extends beyond the right-of-way line, an additional drainage easement shall be dedicated extending at least two (2) feet beyond the top of bank. Utility easements must be separate and beyond any drainage easements.
7. Hydraulic analysis of roadside ditches will require a HEC-RAS analysis for discharges greater than 10 cfs or where conditions other than normal depth are anticipated.

Culverts in Roadside Ditches

1. Culverts will be placed at all driveway, roadway crossings, and pedestrian crossings.
2. Erosion protection will be provided at the upstream and downstream ends of all culverts.
3. The size of culvert used shall not create a head loss of more than two-tenths (0.20) foot greater than the normal water surface profile without the culvert unless one (1) foot of freeboard within the roadside ditch is provided.
4. Roadside ditch culverts will be no smaller than twenty-four (24) inches inside diameter or equivalent for roadway crossings and fifteen (15) inches for driveway culverts.
5. A driveway culvert schedule shall be included on the face of the plat. It shall include, for each lot, culvert flowline depth below top of pavement, number and size of pipe required, and horizontal distance from edge of pavement to center of culvert (based on horizontal control requirements above).

Transitions between urban and rural street drainage

1. Runoff from a curb and gutter street shall be collected in an inlet and discharged to downstream channel or ditches via a storm drain pipe and headwall.
2. Runoff from a roadside ditch shall be collected using a headwall or Y-inlet, and connected into the urban storm drain system.

Channel Velocity Limitations

Maximum allowable:

- Lined Channels – Maximum velocities equal to fifteen (15 fps) feet per second.
- Grass Lined Channels – Maximum velocities refer to Table 3.17. Higher values are allowed if they are justified by a sealed geotechnical study/analysis of soil type and conditions.

Critical Flow Calculations

Section 3.2.5 Critical Flow Calculations of the iSWM Hydraulics Technical Manual is for reference only.

Vegetative Design

Section 3.2.6 Vegetative Design of the iSWM Hydraulics Technical Manual is for reference only.

Stone Riprap Design

Riprap design is to be by Method #2 (Gregory Method) described in *Section 3.2.7 of the iSWM Hydraulics Technical Manual*. A properly designed geotextile material is required under the granular bedding. The City standard specifications identify the type of geotextile to be used. Regardless of computed thickness, the minimum allowable riprap thickness is twelve (12) inches.

Section 3.2.7 of the iSWM Hydraulics Technical Manual, Stone Riprap Design Method #1: Maynard and Reese is for reference only.

Grouted Riprap

The City will allow grouted stone riprap as an erosion control feature. However, the design thickness of the stone lining will not be reduced by the use of grout. See the U.S. Army Corps of Engineers' design manual ETL 1110-2-334 on design and construction of grouted riprap. The Gregory Method shall be utilized. Table 3.20 shall be used to report results of the rip rap design utilizing the Gregory method.

Uniform Flow – Example Problems

Section 3.2.9 Uniform Flow – Example Problems in the iSWM Hydraulics Technical Manual is for reference only.

Rectangular, Triangular, and Trapezoidal Open Channel Design

Section 3.2.11 Rectangular, Triangular, and Trapezoidal Open Channel Design – Example Problems in the iSWM Hydraulics Technical Manual are for reference only.

Table 3.15 City of Fort Worth Manning's Roughness Coefficients for Design		
Lining Type	**Manning's n***	**Comments**
Grass Lined	0.035 0.050	Use for velocity check Use for channel capacity check (freeboard check)
Concrete Lined	0.015	
Rock Riprap	0.040	n = 0.0395d501/6 where d50 is the stone size of which 50% of the sample is smaller
Grouted Riprap	0.028	FHWA (Federal Highway Administration)
*Note: For analysis, Manning's coefficients in chart above shall be used.		

Table 3.16 Roughness Coefficients (Manning's n) and Allowable Velocities for Natural Channels		
Channel Description	**Manning's n**	**Max. Permissible Channel Velocity (ft/s)**
MINOR NATURAL STREAMS		
Fairly regular section:		
1. Some grass and weeds, little or no brush	0.030	3.0 to 6.0
2. Dense growth of weeds, depth of flow materially greater than weed height	0.035	3.0 to 6.0
3. Some weeds, light brush on banks	0.035	3.0 to 6.0
4. Some weeds, heavy brush on banks	0.050	3.0 to 6.0
5. Some weeds, dense willows on banks	0.060	3.0 to 6.0
For trees within channels with branches submerged at high stage, increase above values by	0.010	
Irregular section with pools, slight channel meander, increase above values by	0.010	
Floodplain – Pasture		
1. Short grass	0.030	3.0 to 6.0
2. Tall grass	0.035	3.0 to 6.0
Floodplain – Cultivated Areas		
1. No crop	0.030	3.0 to 6.0
2. Mature row crops	0.035	3.0 to 6.0
3. Mature field crops	0.040	3.0 to 6.0
Floodplain – Uncleared		
1. Heavy weeds scattered brush	0.050	3.0 to 6.0
2. Wooded	0.120	3.0 to 6.0
MAJOR NATURAL STREAMS		
Roughness coefficient is usually less than for minor streams of similar description on account of less effective resistance offered by irregular banks or vegetation on banks. Values of "n" for larger streams of mostly regular sections, with no boulders or brush	Range from 0.028 to 0.060	3.0 to 6.0
UNLINED VEGETATED CHANNELS		
Clays (Bermuda Grass)	0.035	5.0 to 6.0
Sandy and Silty Soils (Bermuda Grass)	0.035	3.0 to 5.0

Table 3.16 Roughness Coefficients (Manning's n) and Allowable Velocities for Natural Channels		
Channel Description	**Manning's n**	**Max. Permissible Channel Velocity (ft/s)**
UNLINED NON-VEGETATED CHANNELS		
Sandy Soils	0.030	1.5 to 2.5
Silts	0.030	0.7 to 1.5
Sandy Silts	0.030	2.5 to 3.0
Clays	0.030	3.0 to 5.0
Coarse Gravels	0.030	5.0 to 6.0
Shale	0.030	6.0 to 10.0
Rock	0.025	15.0
For natural channels with specific vegetation type, refer to Table 3.17 for more detailed velocity control.		

Table 3.17 Maximum Velocities for Vegetative Channel Linings		
Vegetation Type	**Slope Range (%)[1]**	**Maximum Velocity[2] (ft/s)**
Bermuda grass	0-5	6.0
Bahia		4.0
Tall fescue grass mixtures[3]	0-10	4.0
Kentucky bluegrass	0-5	6.0
Buffalo grass	5-10 >10	5.0 4.0
Grass mixture	0-5[1] 5-10	4.0 3.0
Sericea lespedeza, Weeping lovegrass, Alfalfa	0-5[4]	3.0
Annuals[5]	0-5	3.0
Sod		4.0
Lapped sod		5.0

[1] Do not use on slopes steeper than 10% except for side-slope in combination channel.

[2] Use velocities exceeding 5 ft/s only where good stands can be maintained.

[3] Mixtures of Tall Fescue, Bahia, and/or Bermuda

[4] Do not use on slopes steeper than 5% except for side-slope in combination channel.

[5] Annuals - used on mild slopes or as temporary protection until permanent covers are established.

Source: Manual for Erosion and Sediment Control in Georgia, 1996.

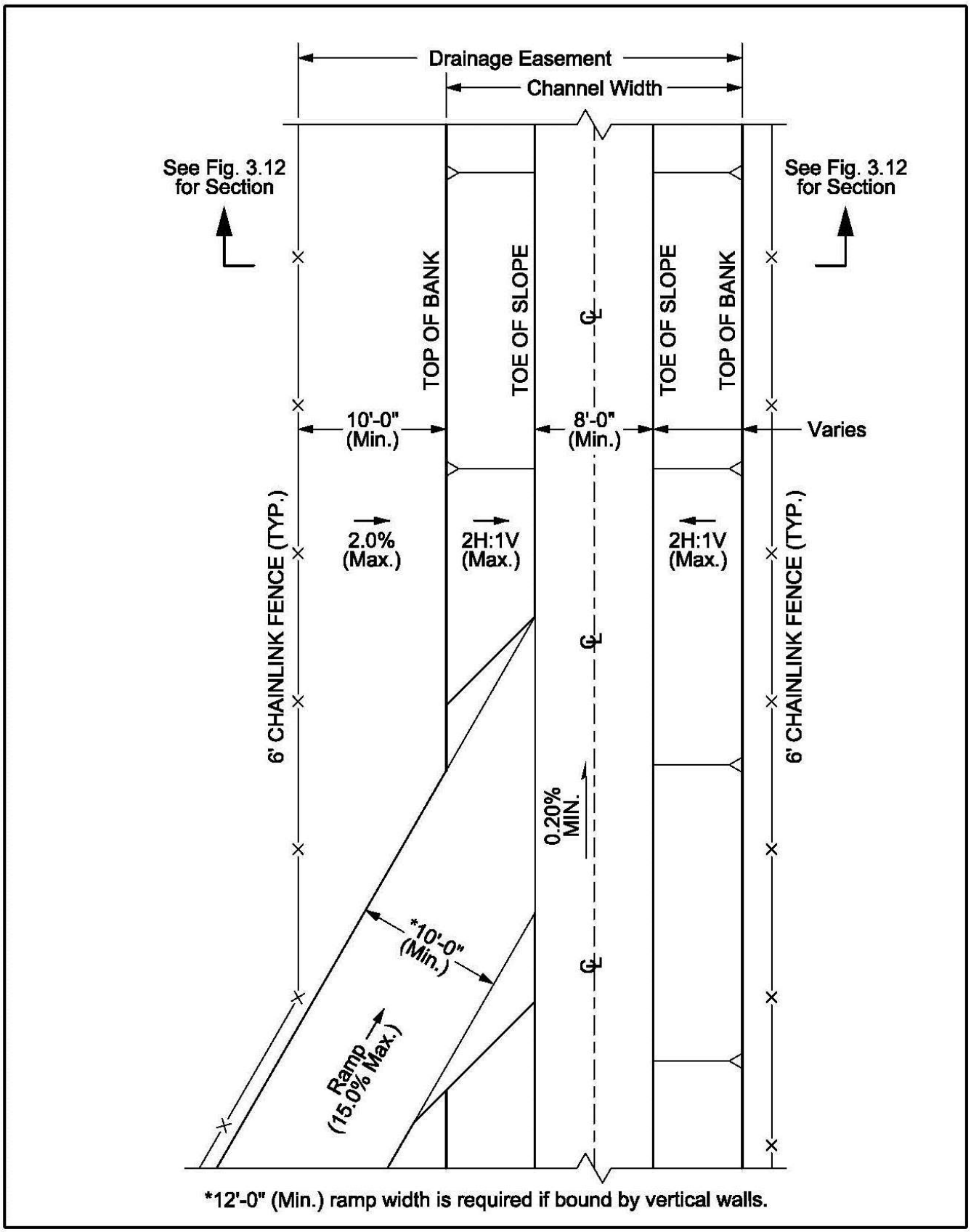


Figure 3.11 Plan View - Trapezoidal Concrete Lined Channel

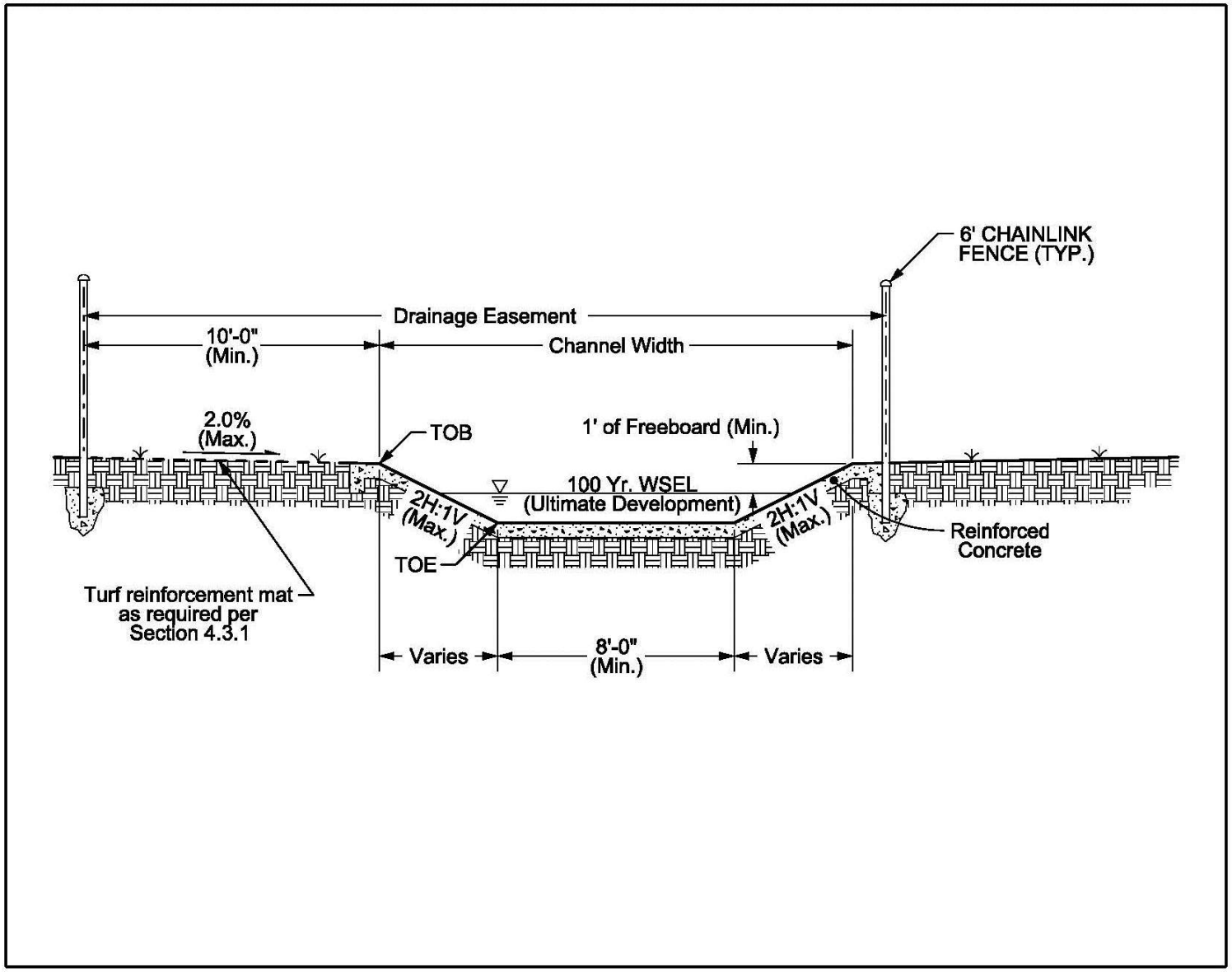


Figure 3.12 Section View - Trapezoidal Concrete Lined Channel

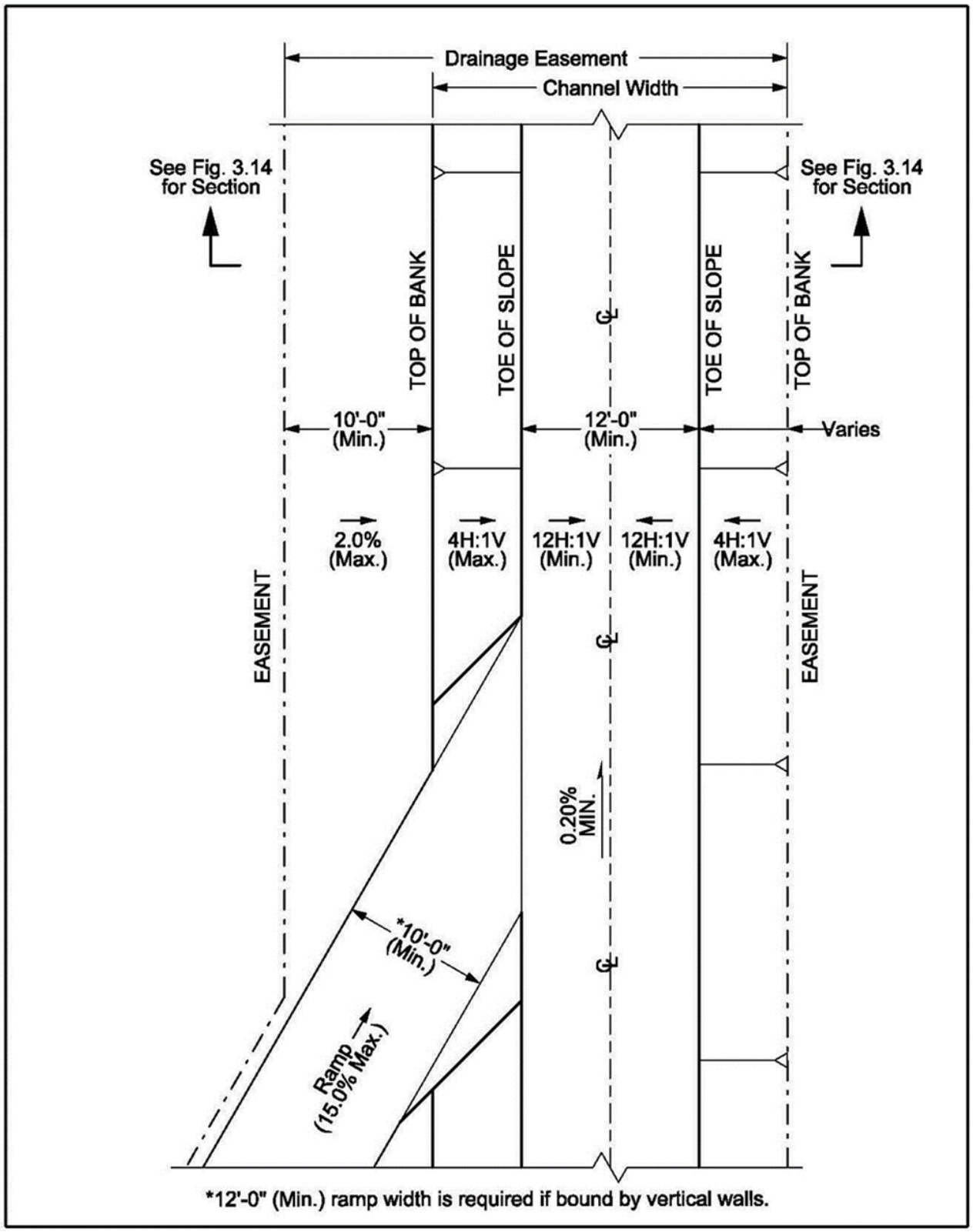


Figure 3.13 Plan View - Trapezoidal Earthen Channel

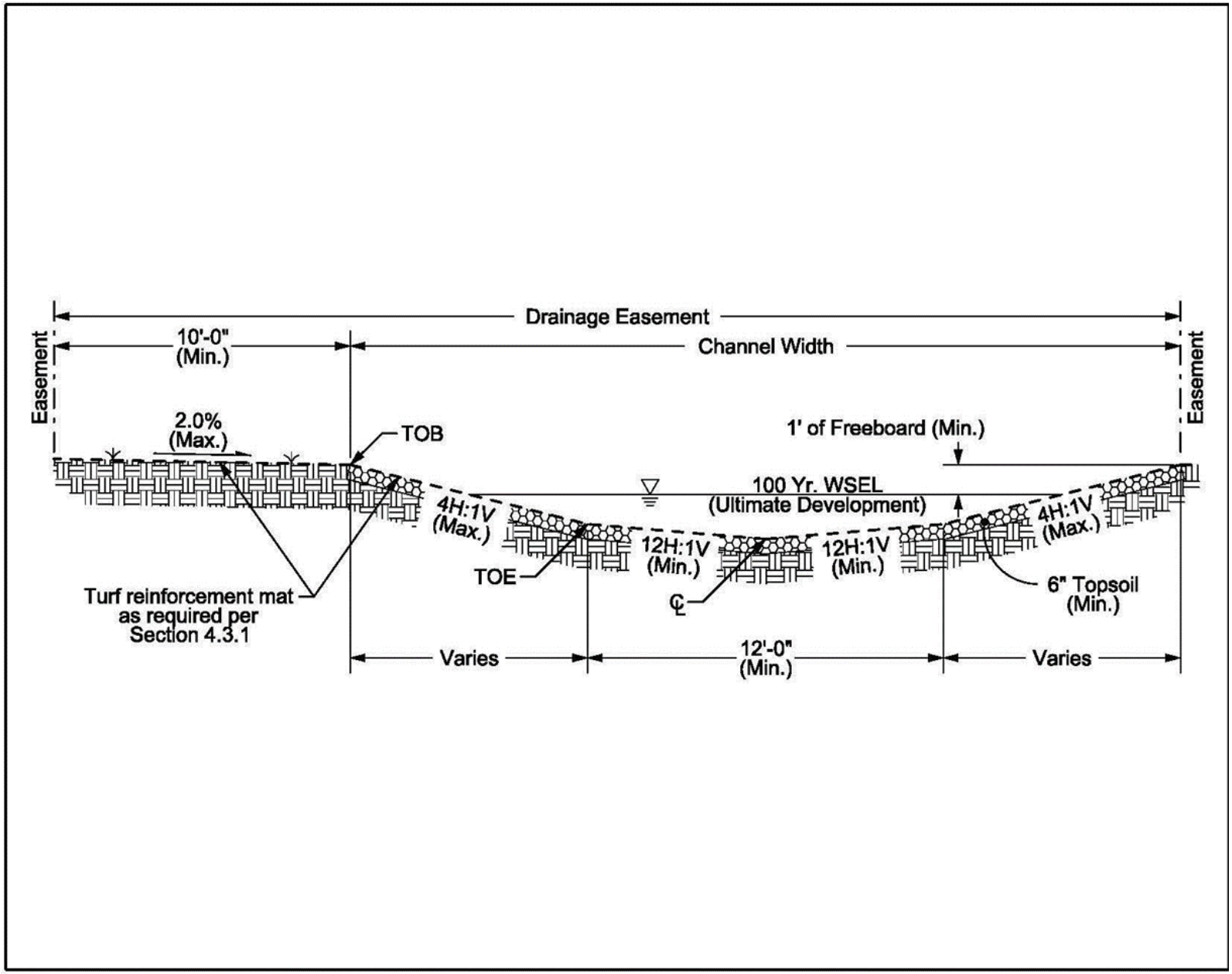


Figure 3.14 Section View - Trapezoidal Earthen Channel

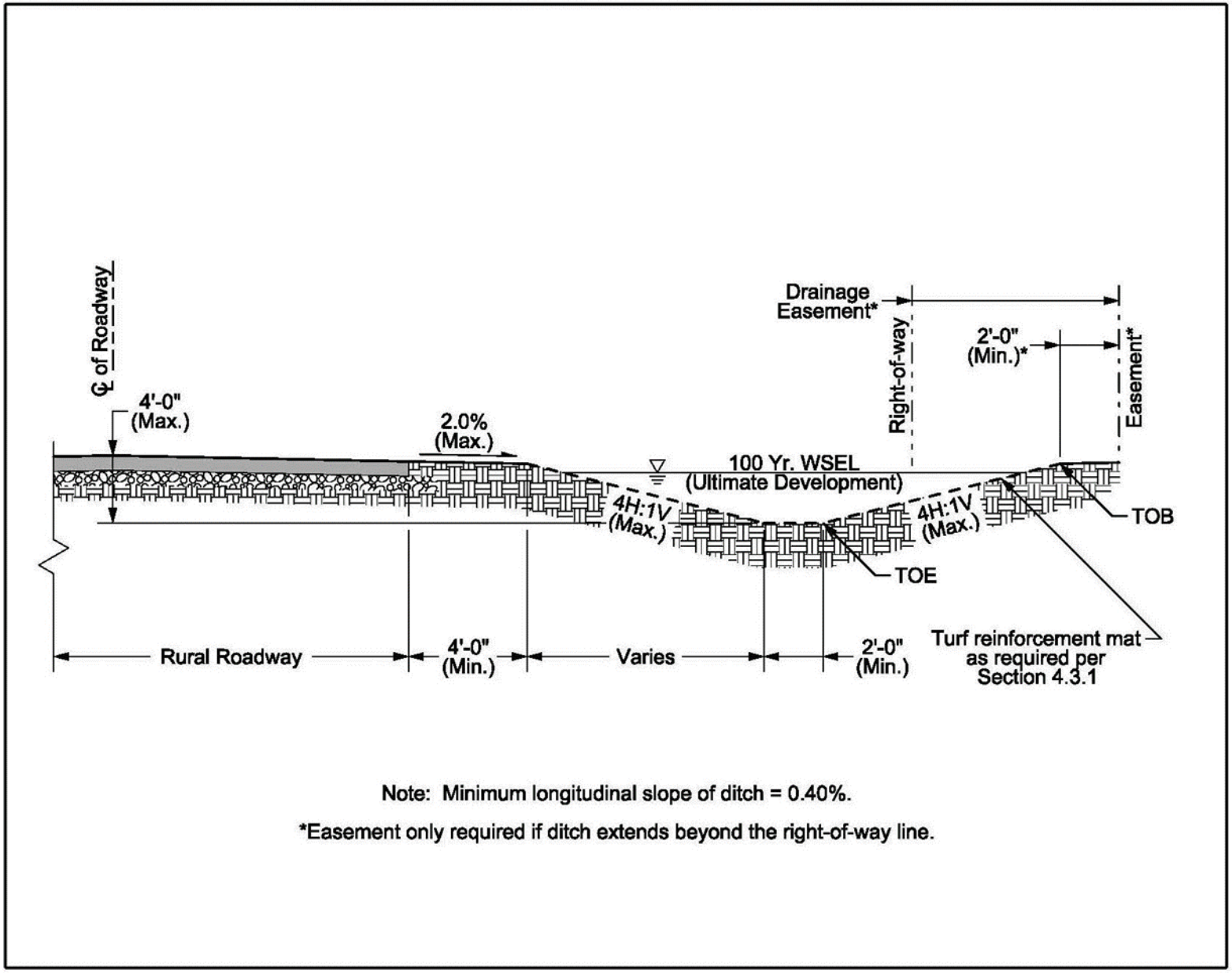


Figure 3.15 Typical Section – Rural Roadside Ditch

Vegetative Design

- A two-part procedure is required for final design of temporary and vegetative channel linings.
  - Part 1: the design stability component, involves determining channel dimensions for low vegetative retardance conditions, using Class D as defined in Table 3.18.
  - Part 2: the design capacity component, involves determining the depth increase necessary to maintain capacity for higher vegetative retardance conditions, using Class C as defined in Table 3.18.
- If temporary lining is to be used during construction, vegetative retardance Class E shall be used for the design stability calculations.
- If the channel slope exceeds 10%, or a combination of channel linings will be used, additional procedures not presented below are required. References include HEC-15 (USDOT, FHWA, 1986) and HEC-14 (USDOT, FHWA, 1983).

Table 3.18 Classification of Vegetal Covers as to Degrees of Retardance

Retardance Class	Cover	Condition
A	Weeping Lovegrass	Excellent stand, tall (average 30")
	Yellow Bluestem Ischaemum	Excellent stand, tall (average 36")
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall (average 12”)
	Native grass mixture Little bluestem, bluestem, blue gamma other short and long stem Midwest grasses	Good stand, unmowed
	Weeping lovegrass	Good stand, tall (average 24”)
	Laspedeza sericea	Good stand, not woody, tall (average 19”)
	Alfalfa	Good stand, uncut (average 11”)
	Weeping lovegrass	Good stand, unmowed (average 13”)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut (average 13”)
C	Crabgrass	Fair stand, uncut (10 – 48”)
	Bermuda grass	Good stand, mowed (average 6”)
	Common lespedeza	Good stand, uncut (average 11”)
	Grass-legume mixture: summer (orchard grass redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (6 – 8“)
	Centipede grass	Very dense cover (average 6”)
	Kentucky bluegrass	Good stand, headed (6 – 12”)
D	Bermuda grass	Good stand, cut to 2.5”
	Common lespedeza	Excellent stand, uncut (average 4.5”)
	Buffalo grass	Good stand, uncut (3 – 6”)
D	Grass-legume mixture: fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut (4 – 5”)
	Lespedeza sericea	After cutting to 2” (very good before cutting)
E	Bermuda grass	Good stand, cut to 1.5”
	Bermuda grass	Burned stubble

Note: Covers classified have been tested in experimental channels. Covers were green and generally uniform.

Source: HEC-15, 1988.

3.8.4.3 Culverts

Design Frequency

Culverts are cross drainage facilities that transport runoff under roadways or other improved areas.

- Culverts shall be designed for the fully developed conditions flood mitigation storm or in accordance with TxDOT requirements, if in the TXDOT right of way. Consideration when designing culverts includes: roadway height, tailwater or depth of flow, structures and property subject to flooding, emergency access, and road replacement costs.
- The flood mitigation storm shall be routed through all culverts to confirm building structures (e.g., houses, commercial buildings) are not flooded or increased damage does not occur to the roadway or adjacent property for this design event.
- For multiple barrel culverts the City requires the placement of one of the barrels at the flowline of the stream with the other barrels at a higher elevation to create a single flow path for lower flow and reduce sediment and debris accumulation. The low-flow portion of the low barrel(s) shall convey at least 2% of the design 100-year discharge.

Velocity Limitations

- The maximum velocity shall be consistent with channel stability requirements at the culvert outlet.
- Refer to Table 3.9 for maximum allowable velocities for reinforced concrete pipe. Outlet protection shall be provided where discharge velocities will cause erosive conditions.
- To ensure self-cleaning during partial depth flow, a minimum velocity of two and a half (2.5 fps) feet per second is required for the streambank protection storm when the culvert is flowing partially full.

Length and Slope

- The maximum slope using concrete pipe is 10% before pipe-restraining methods must be taken.
- Maximum vertical distance from throat of intake to flowline in a drainage structure is ten (10) feet.
- Drops greater than four (4) feet will require additional structural design.

Headwater Limitations

- The allowable headwater is the depth of water that can be ponded at the upstream end of the culvert during the design flood, which will be limited by one or more of the following constraints or conditions:
  - Headwater will be non-damaging to upstream property.
  - Culvert headwater plus twelve (12) inches of freeboard shall not exceed top of curb or pavement for low point of road over culvert, whichever is lower.
  - Ponding depth will be no greater than the elevation where flow diverts around the culvert.
  - Elevations will be established to delineate floodplain zoning.
- Either the headwater shall be set to produce acceptable velocities or stabilization/energy dissipation shall be provided where these velocities are exceeded.
- The constraint that gives the lowest allowable headwater elevation establishes the criteria for the hydraulic calculations.

Tailwater Considerations

- If the culvert outlet is operating with a free outfall, the critical depth and equivalent hydraulic grade line shall be determined.
- For culverts that discharge to an open channel, the stage-discharge curve for the channel must be determined. See *Section 2.1.4 of the Hydraulics Technical Manual* on methods to determine a stage-discharge curve.
- If an upstream culvert outlet is located near a downstream culvert inlet, the headwater elevation of the downstream culvert will establish the design tailwater depth for the upstream culvert.

- If the culvert discharges to a lake, pond, or other major water body, the expected high water elevation of the particular water body will establish the culvert tailwater.

Other Criteria

- In designing debris control structures, the *Hydraulic Engineering Circular No. 9* entitled Debris Control Structures is adopted and shall be used.
- If storage is being assumed or will occur upstream of the culvert, refer to *Section 2.0 of the Hydraulics Technical Manual* regarding storage routing as part of the culvert design.
- Culvert skews shall not exceed 45 degrees as measured from a line perpendicular to the roadway centerline without approval.
- The minimum allowable pipe diameter for a roadway culvert shall be twenty-four (24) inches. A minimum diameter of fifteen (15) inches may be used for driveway culverts.
- Erosion, sediment control, and velocity dissipation shall be designed in accordance with S*ection 4.0 of the Hydraulics Technical Manual*.
- The City requires a backwater analysis using HEC-RAS to evaluate the proposed structure for final design.
- For each culvert design, a completed Culvert Hydraulics Checklist, or similar HEC-RAS summary report, shall be attached to the Drainage Study or Flood Study, and included on the construction plan sheets. A summary of HEC-RAS results and hydraulic workmap shall be included in the constructions plans.

Corrugated Metal Pipe Culvert

Corrugated Metal Pipe (CMP) is not allowed in the City and shall not be used for any public storm drain or culvert.

Nomographs

Nomographs are not allowed by City for final sizing of culverts. The reference for nomographs is FHWA HDS-5. A backwater analysis using HEC-RAS is required.

Culvert Design Example

Section 3.3.5 Culvert Design Example of the iSWM Hydraulics Technical Manual is adopted by reference with the following modification: the nomograph procedure is acceptable for preliminary sizing only.

Design Procedures for Beveled-Edged Inlets

Section 3.3.6 Design Procedures for Beveled-Edged Inlets of the iSWM Hydraulics Technical Manual is adopted by reference with the following modification: the nomograph procedure is acceptable for preliminary sizing only.

Flood Routing and Culvert Design

Refer to *Section 3.3.7 Flood Routing and Culvert Design of the iSWM Hydraulics Technical Manual*.

Erosion, Sediment Control, Velocity Dissipation

Section 3.2.7 iSWM Hydraulics Technical Manual Gregory Method is adopted by reference for culvert outfall protection for riprap sizing, gradation, and bedding. Use Section 4.0 of that manual for spatial dimensions of riprap and other energy dissipation design.

3.8.4.4 Bridges

Design Frequency

Bridges are cross drainage facilities with a span of twenty (20) feet or larger. Bridges shall be designed for the flood mitigation storm for fully developed watershed conditions.

Design Criteria

- A backwater analysis using HEC-RAS is used for final design of the proposed structure. For bridges up to 100 feet long, measured from abutment to abutment, two (2) feet of freeboard is required from design water surface elevation to low chord. For a bridge greater than one hundred (>100) feet long, one (1) foot of freeboard is required. The Bridge Hydraulics Documentation Checklist must be completed and submitted to the City with the Drainage Study and construction plans. Backwater analysis will be required using HEC-RAS, for any proposed bridge, to determine accurate tailwater elevations, velocities, head losses, headwater elevations, profiles and floodplains affected by the proposed structure. If the current effective FEMA model is a HEC-2 model, the engineer has the option to either use that model, or convert to HEC-RAS for analysis of proposed conditions.
- The contraction and expansion of water through the bridge opening creates hydraulic losses. These losses are accounted for through the use of loss coefficients. Table 3.19 gives required values for the Contraction (Kc) and Expansion (Ke) Coefficients for the most commonly encountered design situations.
- A completed bridge hydraulics checklist, or similar HEC-RAS summary report, shall be completed and provided with the Drainage Study and Flood Study, and included on the construction plans. Summary HEC-RAS results and hydraulic workmap shall be included in the construction plans.

Additional design information is located in *Section 3.4 of the Hydraulics Technical Manual*.

Table 3.19 Recommended Loss Coefficients for Bridges

Transition Type	Contraction (Kc)	Expansion (Ke)
No losses computed	0.0	0.0
Gradual transition	0.1	0.3
Typical bridge	0.3	0.5
Severe transition	0.6	0.8

3.8.4.5 Detention Structures

Design Frequency

The streambank protection, conveyance, and flood mitigation storms for the 24-hour storm duration shall be used for design of detention structures. Analysis shall consider both the existing watershed plus developed site conditions and fully developed watershed conditions.

Design Criteria

Stormwater detention shall be provided to mitigate increased peak flows in the City waterways in specific circumstances as defined below. The purpose of the mitigation is to mitigate downstream flooding impacts from upstream Development. In some instances, detention may be shown to exacerbate potential flooding conditions downstream. Therefore, the Zone of Influence criteria shall be applied in addition to these criteria. Design data for dams will be submitted to the City on Form CFW-5, Preliminary and Final Dam Maintenance Emergency Action Plan.

1. Detention Basins shall be required when downstream facilities within the Zone of Influence are not adequately sized to convey a design storm based on current City criteria for hydraulic capacity.
2. Proposed stormwater discharge from a site shall not exceed the calculated discharges from existing conditions, unless sufficient downstream capacity above existing discharge conditions is available.
3. The Modified Rational Method (see Section 1.5.2 in the iSWM Hydrology Technical Manual) is allowed for planning and conceptual design for watersheds of 200 acres and less. For final design purposes the Modified Rational Method is allowed only for watersheds of 25 acres and less. Modified Rational Method is not acceptable for basins in series. Note that the only Modified Rational Method allowed is defined in Section 1.5 in the iSWM Hydrology Technical Manual. The purpose of the preliminary plat is to denote future improvements that shall be required. Sizing is not exact and may result in undersized detention/retention pond requirements.
4. Detention Basins draining watersheds over 25 acres shall be designed using a detailed unit hydrograph method acceptable to the City of Fort Worth. The acceptable methods are Snyder's Unit Hydrograph (greater than one hundred (>100) acres) and SCS Dimensionless Unit Hydrograph (any size). The SCS method is also allowed for basins with watersheds less than 25 acres (see Table 1.2 in the iSWM Hydrologic Technical Manual).
5. For inline detention basins draining an area greater than the Development, the Zone of Influence analysis shall be extended to a point downstream where the inline structure controls 10% of less of the watershed,
6. Detention Basins shall be designed for the Streambank Protection, Conveyance, and Flood Mitigation storms for the 24-hour storm duration.
7. Detention basin embankments shall have a ten (10) foot crown width. A minimum 10' easement shall be provided from the outside top of bank. For access to the pond bottom, provide a maintenance ramp of at least ten (10) feet wide with a maximum slope of 15%. Twelve (12) feet width is required next to vertical walls. Trees shall not be planted on the crown.
8. Detention Basins shall be designed with at least one ten (10) foot wide maintenance access location, with a 15% maximum grade. Trees shall not be planted with the 10' access.
9. A freeboard of one (1) foot is required for all detention ponds.
10. Grassed side slopes shall be 4:1 or flatter and less than twenty (20) feet in height. Slopes protected with concrete riprap shall be no steeper than 2:1. A detailed geotechnical investigation and slope stability analysis is required for grass and concrete slope pavement slopes greater than twelve (12) feet in height. See final stabilization requirements in Section 4.3.1. Trees shall not be planted on pond side slopes.
11. A calculation summary shall be provided on construction plans. For detailed calculations of unit hydrograph studies, a separate report shall be provided to the City for review and referenced with date, engineer and title on the construction plans. Stage-storage-discharge values shall be tabulated and flow calculations for discharge structures shall be shown on the construction plans.
12. An emergency spillway shall be provided at the 100-year maximum storage elevation with sufficient capacity to convey the fully urbanized flood mitigation storm assuming blockage of the closed conduit portion outlet works with six (6) inches of freeboard. Spillway requirements must also meet all appropriate state and federal criteria. Design calculations will be added for all spillways.
13. All detention basins shall be stabilized against significant erosion and shall include a maintenance plan.
14. A landscape plan shall be provided for all detention ponds.
15. Stormwater Facility Maintenance Agreement (SWFMA) is required for all detention and retention facilities.
16. Detention basin outlet structures shall be designed to minimize the likeliness of clogging and shall include features to prevent activation of the emergency spillway if such activation would create an uncontrolled discharge. Detention ponds shall discharge to public drainage facilities or creeks; "flow spreaders" are no allowed. The use of orifice plates or non-standard structures is not allowed.
17. Dry detention basins are sized to temporarily store the volume of runoff required to provide flood protection up to the flood mitigation storm. Dry detention basin design shall consider multiple uses such as recreation. Pilot channels shall follow the edges of the basin to the extent practical. The bottom of the basin shall have a

minimum grade of 1% per Figure 3.17, although swales may have minimum grades of 0.5%. Concrete flumes shall be provided for slopes less than 0.5% and may have slopes as shallow as 0.2%. They shall be at least six (6) feet wide. Trees shall not be planted along swales or pilot channels. A minimum of 10' distance between the swale/channel flow line to trees is required.

18. Extended detention dry basins are sized to provide extended detention of the streambank protection volume over 24 hours and can also provide additional storage volume for normal detention (peak flow reduction) of the flood mitigation storm event.
19. The outlet control structure must be marked with red paint at the sediment removal depth (10% of the pond volume). If a structure is not proposed a concrete marker near the basin outfall indicating sediment removal depth must be provided.
20. Routing calculations must be used to demonstrate that the storage volume and outlet structure configuration are adequate. See Section 2.0 of the Hydraulics Technical Manual for requirements on the design of detention storage.
21. Stormwater lift stations are not allowed.
22. Underground detention ponds are not allowed for public runoff.
23. A detention pond design summary and checklist shall be provided with the Drainage Study and included in the construction plans.
24. State TCEQ rules and regulations regarding impoundments shall be followed. According to current (2009) guidelines, dams fall under the jurisdiction of the TCEQ Dam Safety Program if they meet one or more of the following criteria (See NCTCOG iSWM Program Guidance – Dam Safety and Water Rights):
    - they have a height greater than or equal to 25-feet and a maximum storage capacity greater than or equal to fifteen (15) acre-feet;
    - they have a height greater than six (6) feet and a maximum storage capacity greater than or equal to fifty (50) acre-feet;
    - they are a high or significant hazard dam as defined in the regulations (relating to Hazard Classification Criteria), regardless of height or maximum storage capacity; or
    - they are used as a pumped storage or terminal storage facility.
25. In accordance with Texas Water Code §11.142, all permanent surface impoundments not used solely for domestic or livestock purposes must obtain a water rights permit from the TCEQ. A completed permit for the proposed use, or written documentation stating that a permit is not required, must be obtained.
26. Underground stormwater detention facilities shall:
    - Not be allowed for conveyance of public runoff;
    - Comply with guidance in the NCTCOG iSWM Technical Manuals;
    - Provide adequate access to allow for required cleaning, maintenance and inspection; and
    - Be constructed of RCP, PP, CMP, or HDPE and allow for cleaning by a jetter hose.

Items 7, 10, 12, 13, 24 and 25 also apply to amenity ponds.

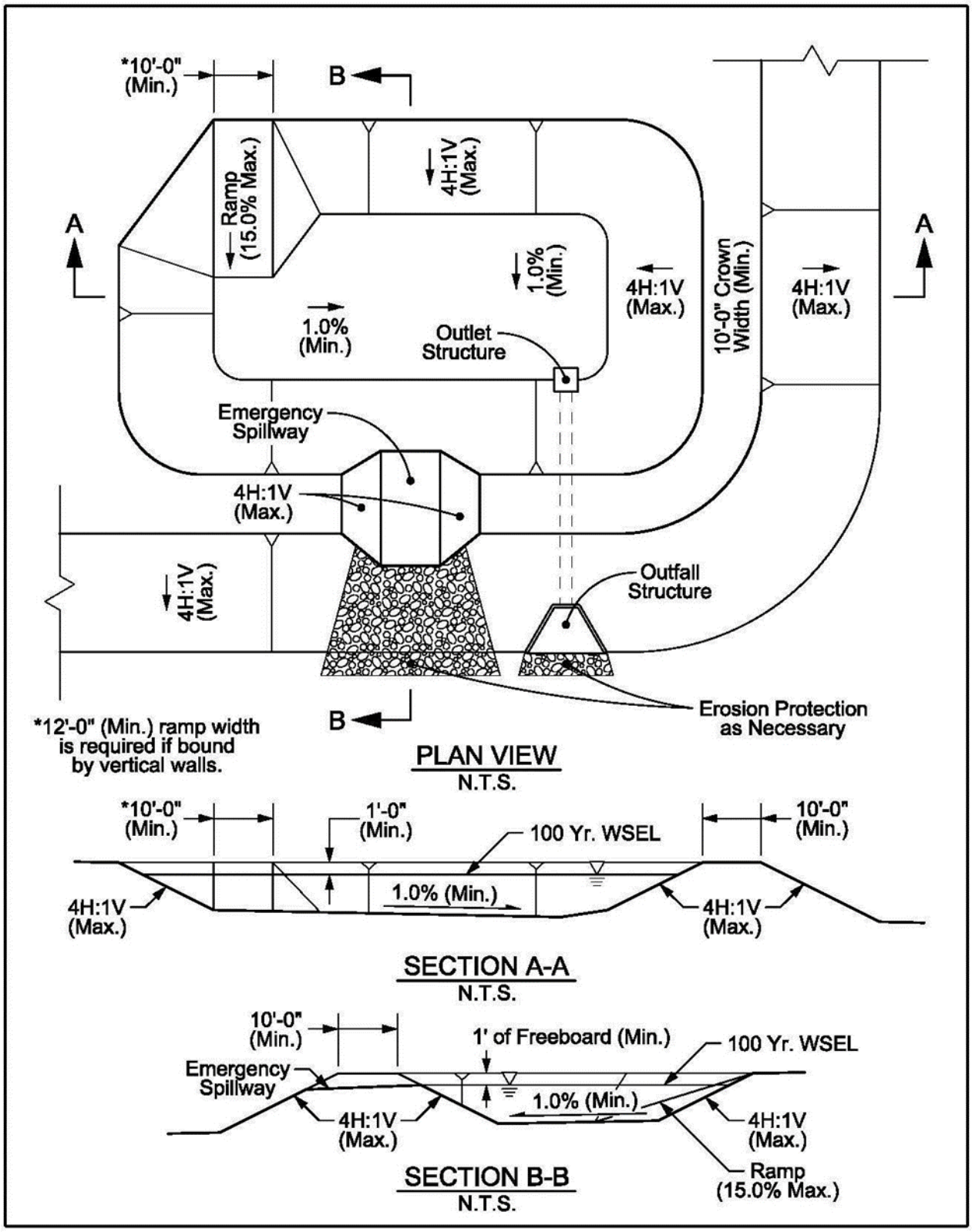


Figure 3.16 Dry Detention Pond Schematic

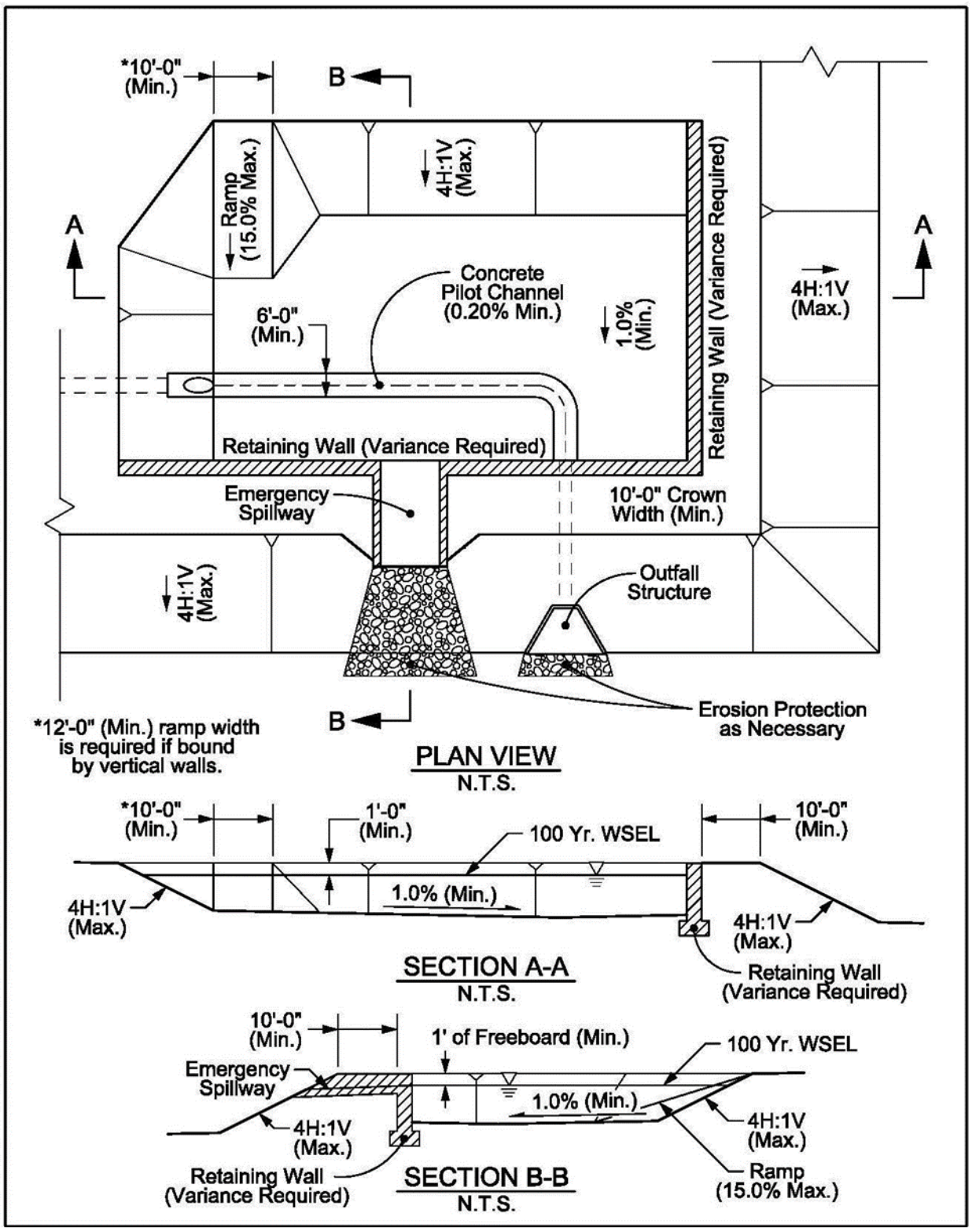


Figure 3.17 Dry Detention Pond with Pilot Channel Schematic

Outlet Structures

Extended detention (ED) orifice sizing is required in design applications that provide extended detention for downstream streambank protection or the ED portion of the water quality protection volume. The release rate for both the WQv and SPv shall discharge the ED volume in a period of 24 hours or longer. In both cases an extended detention orifice or reverse slope pipe must be used for the outlet. For a structural control facility providing both WQv extended detention and SPv control (wet ED pond, micropool ED pond, and shallow ED wetland), there will be a need to design two outlet orifices – one for the water quality control outlet and one for the streambank protection drawdown.

Design Frequency

- Water quality storm
- Streambank protection storm
- Conveyance storm
- Flood mitigation storm

Design Criteria

- Estimate the required storage volumes for streambank protection, conveyance storm, and flood mitigation.
- Design extended detention outlets for each storm event.
- Outlet velocities shall be within the maximum allowable range based on channel material as shown in Table 3.16 and Table 3.17.
- Design necessary outlet protection and energy dissipation facilities to avoid erosion downstream from outlet devices and emergency spillway(s).
- Perform buoyancy calculations for the outlet structure and footing. Flotation will occur when the weight of the structure is less than or equal to the buoyant force exerted by the water.

Additional design requirements are located in *Section 2.2 of the Hydraulics Technical Manual*.

Energy Dissipation

Design Frequency

All drainage system outlets, whether for closed conduits, culverts, bridges, open channels, or storage facilities, shall provide energy dissipation to protect the receiving drainage element from erosion.

- Conveyance storm
- Flood mitigation storm (100-year)
- Assume fully developed watershed conditions

Design Criteria

- Energy dissipaters are engineered devices such as rip-rap aprons or concrete baffles placed at the outlet of stormwater conveyance systems for the purpose of reducing the velocity, energy and turbulence of the discharged flow.
- Erosion at culvert, pipe and engineered channel outlets are common. Determination of the flow conditions, scour potential, and channel erosion resistance shall be standard procedure for all designs. All culvert and pipe outfalls, and channel transitions shall be provided with energy dissipation and erosion control.
- Energy dissipaters shall be employed at all concentrated outfalls no matter the velocity.
- Energy dissipation devices or controls shall also be employed in downstream channels whenever the velocity of flows leaving a stormwater management facility exceeds the erosion velocity of the downstream area channel system.
- Energy dissipater designs will vary based on discharge specifics and tailwater conditions.
- Outlet structures shall provide uniform redistribution or spreading of the flow without excessive separation and turbulence.
- Energy dissipaters are a required component of the iSWM Construction Plan.

Recommended Energy Dissipaters for outlet protection include the following:

- Riprap apron
- Riprap outlet basins
- Baffled outlets
- Grade Control Structures

Refer to *Section 4.0 of the Hydraulics Technical Manual* and the *Federal Highway Administration Hydraulic Engineering Circular No. 14 entitled, Hydraulic Design of Energy Dissipaters for Culverts and Channels*, for the design procedures of other energy dissipaters.

Channel Transitions, Energy Dissipation Structures, or Small Dams

A backwater analysis is required by the City, using HEC-RAS or the computer programs listed in Appendix B. The backwater analysis shall determine accurate tailwater elevation and velocities, head losses, headwater elevations, velocities and floodplains affected by the proposed transition into and out of: 1) an improved channel; 2) any on-stream energy dissipating structures; and 3) small dams (less than six (6) feet). If the current effective FEMA model for the stream is a HEC-2 model, the engineer has the option to either use that model, or convert to HEC-RAS for analysis of proposed conditions. For larger dams, a hydrologic routing will be required, as well as hydraulic analysis, to determine impacts of the proposed structure on existing floodplains and adjacent properties.

Examples of Open Channel Transition Structures

Examples of open channel transition structures are included in the drawings in Appendix C – City of Fort Worth Miscellaneous Details and Specifications Straight Drop Structure, Bureau of Reclamation Baffled Chute (Basin IX). The computer program associated with FHWA Hydraulic Engineering Circular No. 14 (HEC-14) is "HY8" dated March 2012. This program provides the engineer a tool to aid in the design, selection, and sizing of a broad range of energy dissipaters including some of those listed in Section 4.0 of the iSWM Hydraulics Technical Manual. Channel transition structures and "drop" structures shall be designed in accordance with the iSWM Hydraulics Technical Manual and HEC-14.

Stone Rip Rap Design – Gregory Method Results Table

Table 3.21 Rock Rip Rap Sizing – Gregory Method shall be used to report results of the Gregory channel riprap design method. Table 3.20 shall be used to report the results of the Gregory Culvert Outfall Protection Method. A properly designed bedding layer is required under the granular bedding.

Table 3.20 Rock Riprap Sizing – Culvert Outfall Protection

From *Section 3.2.7 iSWM Hydraulics Technical Manual, September 2014*

Determine D50 size of riprap stone (size at which 50% of the gradation is finer weight):	Units	Size by Frequency (Select Largest)		
		100-year	5-year	1-year
V = outfall velocity	ft/sec			
γ_s = saturated surface dry (SSD) specific weight of stone (150-175 lb/ft³)	lb/ft³			
$D50 = \sqrt{\frac{V}{1.8\left[2g\left(\frac{\gamma_s - \gamma_w}{\gamma_w}\right)\right]^{1/2}}}$ Where: γ_w = 62.4 lb/ft³, and g = 32.2 f/s² If γ_s is 160 lb/ft3 or greater, then the equation may reduce to: $D50 = \sqrt{\frac{V}{18}}$	feet			
Maximum d50 (controlling size)	inches			

Table 3.21 Rock Riprap Sizing – Gregory Method				
From *Section 3.2.7 iSWM Hydraulics Technical Manual, September 2014*				
Step 1: Calculate Boundary Shear:	Units	Size by Frequency (Select		
		100-year	5-year	1-year
Q = peak discharge	cfs			
b = bottom width of channel	feet			
y = depth of peak flow	feet			
γS = specific weight of stone (150-175 lb/ft³)	lb/ft³			
A = cross-sectional area of flow	ft²			
WP = wetted perimeter	feet			
R = hydraulic radius of channel = A/WP	feet			
S = slope of energy gradient	ft/ft			
To = average tractive stress on channel bottom = γw*R*S (γw = 62.4 lb/ft³)	lb/ft²			
Φ = Angle of side slope (14° for 4:1 slopes)	degrees			
Θ = Angle of repose of rock, usually 40°)	degrees			
To' = average tractive stress on channel side slopes = To[1-(Sin2Φ/Sin2Θ)]1/2	lb/ft²			
Step 2: Determine the tractive stress in a bend in the channel:				
T = the greater of To or To' from above	lb/ft²			
r = centerline radius of bend (10000' if straight)	feet			
w = water surface width at upstream end of bend	feet			
Tb = local tractive stress in bend = 3.15T(r/w)-1/2	lb/ft²			
Step 3: Determine D50 size of riprap stone (size at which 50% of the gradation is finer weight):				
T = Design shear stress (greatest of To, To' or Tb)	lb/ft²			
D50 = required average stone size = T/0.04□s-□w)	feet			
Maximum d50 (controlling size)	inches			
Step 4: Select minimum riprap thickness from grain size curves (*Fig. 3.12 to 3.17 iSWM Hydraulics Technical Manual*).				
D50 (max)= (Select from smaller side of band at 50% finer gradation)	lb/ft²			
Riprap Size = (min thickness is 12")	inches			
Step 5: Select riprap gradations table (*Fig. 3.18 to 3.19 iSWM Hydraulics Technical Manual*)				
Riprap Gradation Figure based on riprap thickness in Step 4	Figure			
Step 6: Select bedding thickness from grain size curves (*Fig. 3.12 to 3.17 iSWM Hydraulics Technical*				
Bedding Gradation Figure	Figure			
Note: See steps 7-10 in the *Section 3.2.7 for iSWM Hydraulics Technical Manual* additional guidance.				

3.8.5 Stormwater Detention Facility Maintenance

3.8.5.1 Dry Detention Ponds

Note: Modifications affecting the storage capacity and/or outlet structure of a detention facility will require a SWFMA amendment. An O & M manual revision may be required. Revised configuration and calculations must be approved by Stormwater Development Services.

The following shall be included in a checklist and on the plans:

- Pond Bottom Elevation:
- Depth of pond (ft):
- Pond side slopes (1V:?H):
- Length and width of pond at top bank
- Length and width of pond at pond bottom
- Width (ft) and slope of maintenance access road/pad:
- Fully developed ultimate 100-year WSEL in pond:
- Pond volume at ultimate 100-year WSEL (ft3):
- Depth of sediment requiring removal (10% of pond volume elevation):
- Pond orifice diameter and orifice flowline:
- (if there are multiple orifices/weirs, write the parameters of all)
- Pre-developed/existing 100 Year condition (cfs) generated by site:
- Pond release rate (cfs) at fully developed Ultimate 100 yr WSEL:
- Pond Freeboard Elevation:
- Bottom Width of Emergency Spillway:
- Pond emergency spillway bottom elevation:
- Emergency spillway 100 yr flow elevation:
- Freeboard elevation of Emergency Spillway
- (6” above spillway 100 yr elevation):
- Capacity of emergency Spillway (cfs):
- Pond inlet pipe diameter(s), if any:
- Pond outlet pipe diameter(s) and slope:
- Inlet flowline of Pond Outlet Pipe:
- Bottom width (min 6’) and slope of pilot channel:

Dry Detention Facility

A dry detention pond/basin is a storage basin designed to provide water quantity control through detention of Stormwater runoff. The purpose of detention is to allow some of the water to exfiltrate into the ground and the remainder of the water to release slowly over a period of time to reduce downstream water quantity impacts. Dry detention basins are designed to completely drain following a storm event and are normally dry between rain events. They provide limited pollutant removal benefits and are not intended for water quality treatment alone.

Scope and Responsibilities

All Stormwater Facilities that serve a land Development shall be privately constructed and owned, and maintenance shall be the responsibility of the Owner, except as specifically approved in writing by the Director of Transportation and Public Works. The “Landowner” or “Association” listed on the Stormwater Facility Maintenance Agreement is responsible for facility operation and maintenance.

The facility operation requires funding for future monitoring and maintenance costs so the facility functions as designed though the life of the facility. The total annual cost for facility maintenance is estimated to be about 2%

to 5% of the construction cost of the facility, associated structures, and landscape. The “Landowner” or “Association” are solely responsible for funding all monitoring and maintenance costs.

The City will inspect facilities to enforce compliance with the Stormwater Facility Maintenance Agreement, but the City will not be responsible for operation and maintenance of the Facility.

Reporting and Record Retention

A written monthly report shall be kept of maintenance actions and inspections. At a minimum the report shall document the condition of the entire Stormwater Facility, its berms, outlet structure, pond areas, access roads, and ancillary components. Components of the Stormwater Facility which need maintenance or replacement to perform their design function shall be noted in the inspection report along with the corrective actions taken.

The written monthly reports shall be maintained by the “Landowner” or “Association” and submitted yearly to the City. Annual reports shall be submitted to:

City of Fort Worth Stormwater Management

200 Texas Street

Fort Worth, TX 76102

Written records regarding the facility operation and maintenance shall be maintained in proper order and available for the City review at any time.

Upon or prior to the transfer of the ownership of a Stormwater Facility by any method other than heirship, Owner shall transfer a copy of monthly logs to new Owner.

Facility Construction, Maintenance, and Inspection

When City staff finds deficiency in the operation and maintenance of the facility, the city, its authorized agents and employees, may, with written mailed or hand delivered notice to the Owner, enter the property on which the Stormwater Facility is located to inspect the Stormwater Facility. The City shall provide the Owner with a copy of the inspection findings and a directive to commence with any repairs, if necessary. Noted deficiencies that are not corrected within the times specified in the City directive will result in fines.

In the event the owner fails to commence with repairs or provide adequate maintenance of the Stormwater Facility the city, its authorized agents and employees, may, but has no obligation to, enter upon the Stormwater Facility and (i) take whatever steps necessary to correct deficiencies identified in the inspection report and (ii) make necessary repairs or perform necessary maintenance. The city shall charge the costs of such repairs to the owner. In the event that the owner fails to pay the city the amount demanded by the city, the city shall impress a lien for the costs of such work upon the property owned by Owner.

General Maintenance Procedures

The structural and functional integrity of the Facility shall be maintained at all times by removing and preventing drainage interference, obstructions, blockages, or other adverse effects into, through, or out of the system.

Routine maintenance should be performed on dry detention basins to ensure that the facility is properly functioning. In the event of snow, check to make sure that the materials used to de-ice the surrounding areas stay out of the practice to avoid clogging and further pollution. Note that it might take longer for the water to infiltrate into the ground during the winter months and early spring. If the dry detention basin is not draining properly, check for clogging of the outflow/outlet structures.

Typical inspection activities and repair/removal schedule are list below. The items listed below may require more frequent inspection and maintenance during the first year of facility service. A maintenance checklist is included in Exhibit D.

Table 3.22 Dry Detention Pond Inspection, Maintenance, & Repair		
Activity	**Inspection Schedule**	**Removal/Repair Schedule**
Remove litter, debris, and unwanted vegetation from facility	Inspect facility for nuisance items weekly and after storm events equal to or greater than 0.5”.	Remove nuisance items promptly either during inspection or before next rainfall event.
Monitor standing water and mosquito activity	Inspect facility for standing water weekly and after storm events equal to or greater than 0.5”.	Determine and address cause of standing water. Remove standing water promptly either during inspection or within 24-48 hours of inspection.
Mow side slopes to limit unwanted vegetation – REMOVE CLIPPINGS FROM FACILITY	Mow monthly between April to October or when vegetation exceeds 12” in height.	Remove clippings immediately after mowing.
Monitor and remove sediment buildup	Monitor sediment monthly and after storm events equal to or greater than 0.5”. Remove sediment at depth specified by Engineer in Exhibit B	Sediment depth should be noted on monthly inspection checklist. When removal depth is reached, remove buildup promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Remove litter, debris, and unwanted vegetation from contributing basin to minimize outlet clogging and improve aesthetics	Inspect contributing basin for nuisance items weekly and after storm events producing 0.5” or greater.	Remove nuisance items promptly either during inspection or before next rainfall event.
Repair and revegetate undercut and/or eroded areas.	Inspect for undercut/eroded areas monthly and after storm events equal to or greater than 0.5”.	Repair promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Seed or sod to restore dead or damaged ground cover	Inspect for dead/damaged ground cover monthly and after storm events equal to or greater than 0.5”.	Repair promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Inspect for damage to the embankments, berm, access ramp, outlet control	Inspect monthly and after storm event equal to or greater than 0.5”.	Repair promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Perform structural repairs to inlets and outlets	Inspect inlets and outlets for structural defects monthly and after storm events equal to or greater than 0.5”.	Repair promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Ensure that inlet and outlet devices are free of debris and operational.	Inspect weekly and after storm events equal to or greater than 0.5”.	Repair promptly, prior to next inspection cycle or before next rainfall event.
Storm drain inspection	Yearly visual inspection at joints, CCTV every 15 years to confirm system integrity	Repair storm drain when sink holes form, when sagging, cracks, leaks, corrosion, or blockage impact storm drain function

3.8.5.2 Underground Stormwater Detention Facilities:

Note: Modifications affecting the storage capacity and/or outlet structure of a detention facility will require a SWFMA amendment. An O & M manual revision may be required. Revised configuration and calculations must be approved by Stormwater Development Services.

The following items shall be on the checklist and construction plans:

- Facility Bottom Elevation:
- Depth of facility (ft)
- Depth of base stone (ft)
- Depth of top stone (ft)
- Length and width of facility
- Fully developed ultimate 100-year WSEL in pond:
- Pond volume at ultimate 100-year WSEL (ft3):
- Depth of sediment requiring removal
- Facility orifice diameter and orifice flowline:
- (if there are multiple orifices/weirs, write the parameters of all)
- Facility outlet pipe diameter(s) and slope:
- Pre-developed/existing 100 Year condition (cfs) generated by site:
- Facility release rate (cfs) at fully developed Ultimate 100 yr WSEL:
- Facility Freeboard Elevation:
- Overflow/Emergency Outlet elevation:
- Capacity of emergency Overflow/Emergency outlet (cfs):
- Facility inlet pipe diameter(s)

Underground Facility

Underground detention is detention storage located in underground tanks or vaults designed to provide water quantity control through temporary storage of stormwater runoff. In addition they can improve water quality by removing heavy amounts of sediment.

Scope and Responsibilities

All Stormwater Facilities that serve a land Development shall be privately constructed and owned, and maintenance shall be the responsibility of the Owner, except as specifically approved in writing by the Director of Transportation and Public Works. The “Landowner” or “Association” listed on the Stormwater Facility Maintenance Agreement is responsible for facility operation and maintenance.

The facility operation requires funding for future monitoring and maintenance costs so the facility functions as designed though the life of the facility. The total annual cost for facility maintenance is estimated to be between $1,000 and $1,500 depending on the size of the facility. The “Landowner” or “Association” are solely responsible for funding.

The City will inspect facilities to enforce compliance with the Stormwater Facility Maintenance Agreement, but the City will not be responsible for operation and maintenance of the Facility.

Reporting and Record Retention

A written monthly report shall be kept of maintenance actions and inspections. At a minimum the report shall document the condition of the entire Stormwater Facility, its berms, outlet structure, pond areas, access roads, and ancillary components. Components of the Stormwater Facility which need maintenance or replacement to perform their design function shall be noted in the inspection report along with the corrective actions taken.

The written monthly reports shall be maintained by the “Landowner” or “Association” and submitted yearly to the City. Annual reports shall be submitted to:

City of Fort Worth Stormwater Management

200 Texas Street

Fort Worth, TX 76102

Written records regarding the facility operation and maintenance shall be maintained in proper order and available for the City review at any time.

Upon or prior to the transfer of the ownership of a Stormwater Facility by any method other than heirship, Owner shall transfer a copy of monthly logs to new Owner.

Facility Construction, Maintenance, and Inspection

When City staff finds deficiency in the operation and maintenance of the facility, the city, its authorized agents and employees, may, with written mailed or hand delivered notice to the Owner, enter the property on which the Stormwater Facility is located to inspect the Stormwater Facility. The City shall provide the Owner with a copy of the inspection findings and a directive to commence with any repairs, if necessary. Noted deficiencies that are not corrected within the times specified in the City directive will result in fines.

In the event the owner fails to commence with repairs or provide adequate maintenance of the Stormwater Facility the city, its authorized agents and employees, may, but has no obligation to, enter upon the Stormwater Facility and (i) take whatever steps necessary to correct deficiencies identified in the inspection report and (ii) make necessary repairs or perform necessary maintenance. The city shall charge the costs of such repairs to the owner. In the event that the owner fails to pay the city the amount demanded by the city, the city shall impress a lien for the costs of such work upon the property owned by Owner.

General Maintenance Procedures

The structural and functional integrity of the Facility shall be maintained at all times by removing and preventing drainage interference, obstructions, blockages, or other adverse effects into, through, or out of the system.

Routine maintenance should be performed on the underground detention facilities to ensure that the facility is properly functioning. Routine maintenance includes the removal of debris from inlet and outlet structures and cleaning sediment built up inside the structure. Inspection and maintenance may be difficult for an underground system, but generally these underground systems can be inspected by looking in an access opening. Sometimes maintenance requires an individual who is certified in OSHA confined space entry. In a situation where safety concerns arises, the inspection should stop and the safety concern addressed. Once the concern is addressed, the inspection can continue. Once site construction is complete the underground facility must be thoroughly cleaned and inspected prior to service.

Facility inspection and maintenance should follow manufacturer’s guidelines and develop/adjust a site specific O&M plan for the underground detention once in normal service. Typical inspection activities and repair/removal schedule are list below. The items listed below may require more frequent inspection and maintenance during the first year of facility service. A maintenance checklist is included in Exhibit D.

Table 3.23 Underground Detention Inspection, Maintenance, & Repairs		
Activity	**Inspection Schedule**	**Removal/Repair Schedule**
Remove litter, debris, and unwanted vegetation from contributing basin to minimize outlet clogging and improve aesthetics	Inspect contributing basin for nuisance items weekly and after storm events producing 0.5" or greater.	Remove nuisance items promptly either during inspection or before next rainfall event.
Remove any trash/debris in the underground trash racks, vaults or tanks.	Inspect semi-annually for trash/debris in the facility (min 2x per year)	Remove nuisance items in the facility promptly either during inspection or before next rainfall event.
Clean underground detention if hazardous or foreign substances are spilled in the contributing drainage area		Treat hazardous or foreign substances spills per OSHA guidelines. Clean facility per Manufacturer guidelines. Contaminated material must be disposed of per OSHA guidelines and shall not be discharged into the receiving system
Perform structural repairs to inlet and outlets.	Inspect inlets and outlets for structural defects monthly and after storm events equal to or greater than 0.5".	Repair promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Monitor sediment buildup	Monitor sediment monthly and after storm events equal to or greater than 0.5". Remove sediment when depth of sediment measures 3"	Sediment depth should be noted on monthly inspection checklist. When removal depth is reached, remove buildup promptly, prior to next inspection cycle or before next rainfall event, whichever will come first.
Clean out underground detentions with vacuum or boom trucks.	Monitor sediment monthly and after storm events equal to or greater than 0.5". Remove sediment when depth of sediment measures 3"	Vacuum maintenance is recommended if sediment has been collected to an average depth of 3"
Ensure that inlet and outlet devices are free of debris and operational.	Inspect weekly and after storm events equal to or greater than 0.5".	Repair promptly, prior to next inspection cycle or before next rainfall event.
Storm drain inspection	Yearly visual inspection at joints, CCTV every 15 years to confirm system integrity	Repair storm drain when sink holes form, when sagging, cracks, leaks, corrosion, or blockage impact storm drain function

3.9 Stormwater Control Selection

3.9.1 Control Screening Process

Outlined below is a screening process for structural stormwater controls that can effectively treat the water quality volume, as well as provide water quantity control. This process is intended to assist the site designer and design engineer in the selection of the most appropriate structural controls for a Development site and to provide guidance on factors to consider in their location. This information is also contained in the *iSWM Technical Manual – Site Development Controls* section.

The following four criteria shall be evaluated in order to select the appropriate structural control(s) or group of controls for a Development:

- Stormwater treatment suitability
- Water quality performance
- Site applicability
- Implementation considerations

In addition, the following factors shall be considered for a given site and any specific design criteria or restrictions need to be evaluated:

- Physiographic factors
- Soils
- Special watershed or stream considerations

Finally, environmental regulations shall be considered as they may influence the location of a structural control on site or may require a permit.

The following steps provide a selection process for comparing and evaluating various structural stormwater controls using a screening matrix and a list of location and permitting factors. These tools are provided to assist the design engineer in selecting the subset of structural controls that will meet the stormwater management and design objectives for a Development site or project.

Step 1 Overall Applicability

The following are the details of the various screening categories and individual characteristics used to evaluate the structural controls.

Table 3.24 - Stormwater Management Suitability

The first category in the matrix examines the capability of each structural control option to provide water quality treatment, downstream streambank protection, and flood control. A blank entry means that the structural control cannot or is not typically used to meet an integrated Focus Area. This does not necessarily mean that it should be eliminated from consideration, but rather it is a reminder that more than one structural control may be needed at a site (e.g., a bioretention area used in conjunction with dry detention storage).

- ***Ability to treat the Water Quality Volume (WQv)***: This indicates whether a structural control provides treatment of the water quality volume (WQv). The presence of “P” or “S” indicates whether the control is a Primary or Secondary control, respectively, for meeting the TSS reduction goal.
- ***Ability to provide Streambank Protection (SPv)***: This indicates whether the structural control can be used to provide the extended detention of the streambank protection volume (SPv). The presence of a “P” indicates that the structural control can be used to meet SPv requirements. An “S” indicates that the structural control may be sized to provide streambank protection in certain situations, for instance on small sites.
- ***Ability to provide Flood Control (Qf)***: This indicates whether a structural control can be used to meet the flood control criteria. The presence of a “P” indicates that the structural control can be used to provide peak reduction of the flood mitigation storm event.

Table 3.25 - Relative Water Quality Performance

The second category of the matrix provides an overview of the pollutant removal performance for each structural control option when designed, constructed, and maintained according to the criteria and specifications in this manual.

- ***Ability to provide TSS and Sediment Removal***: This column indicates the capability of a structural control to remove sediment in runoff. All of the Primary structural controls are presumed to remove 70% to 80% of the average annual TSS load in typical urban proposed runoff (and a proportional removal of other pollutants).
- ***Ability to provide Nutrient Treatment***: This column indicates the capability of a structural control to remove the nutrients nitrogen and phosphorus in runoff, which may be of particular concern with certain downstream receiving waters.
- ***Ability to provide Bacteria Removal***: This column indicates the capability of a structural control to remove bacteria in runoff. This capability may be of particular concern when meeting regulatory water quality criteria under the Total Maximum Daily Load (TMDL) program.
- ***Ability to accept Hotspot Runoff***: This last column indicates the capability of a structural control to treat runoff from designated hotspots. Hotspots are land uses or activities that produce higher concentrations of trace metals, hydrocarbons, or other priority pollutants. Examples of hotspots might include: gas stations, convenience stores, marinas, public works storage areas, garbage transfer facilities, material storage sites, vehicle service and maintenance areas, commercial nurseries, vehicle washing/steam cleaning, landfills, construction sites, industrial sites, industrial rooftops, and auto salvage or recycling facilities. A check mark indicates that the structural control may be used on hotspot site. However, it may have specific design restrictions. Please see the specific design criteria of the structural control for more details in the Site Development Controls Technical Manual. Local jurisdictions may have other site uses that they designate as hotspots. Therefore, their criteria shall be checked by the design engineer as well.

Table 3.26 - Site Applicability

The third category of the matrix provides an overview of the specific site conditions or criteria that must be met for a particular structural control to be suitable. In some cases, these values are recommended values or limits and can be exceeded or reduced with proper design or depending on specific circumstances. Please see the specific criteria section of the structural control for more details.

- ***Drainage Area***: This column indicates the approximate minimum or maximum drainage area considered suitable for the structural control practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway can be permitted if more than one practice can be installed. The minimum drainage areas indicated for ponds and wetlands shall not be considered inflexible limits and may be increased or decreased depending on water availability (baseflow or groundwater), the mechanisms employed to prevent outlet clogging, or design variations used to maintain a permanent pool (e.g., liners).
- ***Space Required (Space Consumed)***: This comparative index expresses how much space a structural control typically consumes at a site in terms of the approximate area required as a percentage of the impervious area draining to the control.
- ***Slope***: This column evaluates the effect of slope on the structural control practice. Specifically, the slope restrictions refer to how flat the area where the facility is installed must be and/or how steep the contributing drainage area or flow length can be.
- ***Minimum Head***: This column provides an estimate of the minimum elevation difference needed at a site (from the inflow to the outflow) to allow for gravity operation within the structural control.
- ***Water Table***: This column indicates the minimum depth to the seasonally high water table from the bottom or floor of a structural control.

Table 3.27 - Implementation Considerations

The fourth category in the matrix provides additional considerations for the applicability of each structural control option.

- ***Residential Subdivision Use***: This column identifies whether or not a structural control is suitable for single family residential subdivision development (not including high-density or ultra-urban areas).

- ***Ultra-Urban***: This column identifies those structural controls appropriate for use in very high-density (ultra-urban) areas, or areas where space is a premium.
- ***Construction Cost***: The structural controls are ranked according to their relative construction cost per impervious acre treated, as determined from cost surveys.
- ***Maintenance***: This column assesses the relative maintenance effort needed for a structural stormwater control, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging), and reported failure rates. All structural controls require routine inspection and maintenance by the property owner.

The *Site Development Controls iSWM Technical Manual* contains an exhaustive discussion and detailed examples of stormwater controls that can be implemented in land Development to meet the goals of protecting water quality, minimizing streambank erosion, and reducing flood volumes. It is an excellent planning and design resource document and has valuable design examples that the City encourages local Developers to consider in their site planning. Although it is primarily oriented toward water quality issues, these stormwater controls bring additional and valuable benefits for flood control and streambank protection. Many of the listed stormwater control features and techniques enhance the aesthetics and value of land Developments, as well as providing a drainage function.

The City of Fort Worth is currently requiring streambank protection, conveyance and flood control components of the integrated stormwater management approach. However, the Stormwater Control Selection (Section 3.9) of applicable features may be applied in local Developments and Redevelopments. The City does not mandate the use of any of these stormwater controls, but recognizes the inherent values of their application in overall stormwater management.

Therefore, the City adopts for design guidance and technical reference sections of the *iSWM Technical Manual*. There are, however, no City requirements for achieving Stormwater Quality (WQv) or Channel Protection (SPv) volumes. Stormwater utility fee credits may be available for design practices meeting these standards. See Appendix F for detailed information.

Table 3.24 Stormwater Treatment Suitability					
Category	***integrated* Stormwater Controls**	**Stormwater Treatment Suitability**			
		Water Quality Protection	**Streambank Protection**	**On-Site Flood Control**	**Downstream Flood Control**
Bioretention Areas	Bioretention Areas	P	S	S	-
Channels	Enhanced Swales	P	S	S	S
	Channels, Grass	S	S	P	S
	Channels, Open	-	-	P	S
Chemical Treatment	Alum Treatment System	P	-	-	-
Conveyance System Components	Culverts	-	-	P	P
	Energy Dissipation	-	P	S	S
	Inlets/Street Gutters	-	-	P	-
	Pipe Systems	-	P	P	P
Detention	Detention, Dry	S	P	P	P
	Detention, Extended Dry	S	P	P	P
	Detention, Multi-purpose Areas	-	P	P	P
	Detention, Underground	-	P	P	P
Filtration	Filter Strips	S	-	-	-
	Organic Filters	P	-	-	-
	Planter Boxes	P	-	-	-
	Sand Filters, Surface/Perimeter	P	S	-	-
	Sand Filters, Underground	P	-	-	-
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	S	-	-	-
Infiltration	Downspout Drywell	P	-	-	-
	Infiltration Trenches	P	S	-	-
	Soakage Trenches	P	S	-	-
Ponds	Wet Pond	P	P	P	P
	Wet ED Pond	P	P	P	P
	Micropool ED Pond	P	P	P	P
	Multiple Ponds	P	P	P	P
Porous Surfaces	Green Roof	P	S	-	-
	Modular Porous Paver Systems	S	S	-	-
	Porous Concrete	S	S	-	-
Proprietary Systems	Proprietary Systems[1]	S/P	S	S	S
Re-Use	Rain Barrels	P	-	-	-
Wetlands	Wetlands, Stormwater	P	P	P	P
	Wetlands, Submerged Gravel	P	P	S	-

P = Primary Control: Able to meet design criterion if properly designed, constructed and maintained.

S = Secondary Control: May partially meet design criteria. May be a Primary Control but designated as a Secondary due to other considerations. For Water Quality Protection, recommended for limited use in accepted community-designated areas.

- = Not typically used or able to meet design criterion.

[1] = The application and performance of propriety commercial devices and systems must be provided by the manufacturer and shall be verified by independent third-party sources and data if used as a primary control.

Table 3.25 Water Quality Performance					
Category	***integrated* Stormwater Controls**	**Water Quality Performance**			
		TSS/ Sediment Removal Rate	**Nutrient Removal Rate (TP/TN)**	**Bacteria Removal Rate**	**Hotspot Application**
Bioretention Areas	Bioretention Areas	80%	60%/50%	-	□
Channels	Enhanced Swales	80%	25%/40%	-	□
	Channels, Grass	50%	25%/20%	-	
	Channels, Open	-	-	-	
Chemical Treatment	Alum Treatment System	90%	80%/60%	90%	□
Conveyance System Components	Culverts	-	-	-	
	Energy Dissipation	-	-	-	
	Inlets/Street Gutters	-	-	-	
	Pipe Systems	-	-	-	
Detention	Detention, Dry	65%	50%/30%	70%	□
	Detention, Extended Dry	65%	50%/30%	70%	□
	Detention, Multi-purpose Areas	-	-	-	
	Detention, Underground	-	-	-	
Filtration	Filter Strips	50%	20%/20%	-	
	Organic Filters	80%	60%/40%	50%	□
	Planter Boxes	80%	60%/40%	-	
	Sand Filters, Surface/Perimeter	80%	50%/25%	40%	□
	Sand Filters, Underground	80%	50%/25%	40%	□
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	40%	5%/5%	-	
Infiltration	Downspout Drywell	80%	60%/60%	90%	
	Infiltration Trenches	80%	60%/60%	90%	
	Soakage Trenches	80%	60%/60%	90%	
Ponds	Wet Pond	80%	50%/30%	70%	□
	Wet ED Pond	80%	50%/30%	70%	□
	Micropool ED Pond	80%	50%/30%	70%	□
	Multiple Ponds	80%	50%/30%	70%	□
Porous Surfaces	Green Roof	85%	95%/16%	-	□
	Modular Porous Paver Systems	2	80%/80%	-	
	Porous Concrete	2	50%/65%	-	
Proprietary Systems	Proprietary Systems 1	1	1	1	
Re-Use	Rain Barrels	-	-	-	
Wetlands	Wetlands, Stormwater	80%	40%/30%	70%	□
	Wetlands, Submerged Gravel	80%	40%/30%	70%	□

□ = Meets suitability criteria.
- = Not typically used or able to meet design criterion.
1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and shall be verified by independent third-party sources and data if used as a primary control.
2 = Porous surfaces provide water quality benefits by reducing the effective impervious area.

Table 3.26 Site Applicability						
Category	**integrated Stormwater Controls**	**Site Applicability**				
		Drainage Area (acres)	**Space Req'd (% of Tributary imp.**	**Site Slope**	**Minimum Head Required**	**Depth to Water Table**
Bioretention Areas	Bioretention Areas	5 max3	5-7%	6% max	5 ft	2 ft
Channels	Enhanced Swales	5 max	10-20%	4% max	1 ft	Below WT
	Channels, Grass					
	Channels, Open					
Chemical	Alum Treatment System	25 min	None			
Conveyance System Components	Culverts					
	Energy Dissipation					
	Inlets/Street Gutters					
	Pipe Systems					
Detention	Detention, Dry		2-3%	15% across pond	6 to 8 ft	2 ft
	Detention, Extended Dry		2-3%	15% across pond	6 to 8 ft	2 ft
	Detention, Multi-purpose Areas	200 max		1% for Parking Lot; 0.25 in/ft for Rooftop		
	Detention, Underground	200 max				
Filtration	Filter Strips	2 max3	20-25%	2-6%		
	Organic Filters	10 max3	2-3%		5 to 8 ft	
	Planter Boxes		6%			
	Sand Filters, Surface/Perimeter	10 max3 / 2 max3	2-3%	6% max	5 ft per 2-3 ft	2 ft
	Sand Filters,	5 max	None			
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	1 max3	None			
Infiltration	Downspout Drywell					
	Infiltration Trenches	5 max	2-3%	6% max	1 ft	4 ft
	Soakage Trenches	5 max	27 ft per 1000 ft2 imp. area	6% max	1 ft	4 ft
Ponds	Wet Pond		2-3%	15% max	6 t 8 ft	2 ft, if hotspot or aquifer
	Wet ED Pond	25 min3				
	Micropool ED Pond	10 min3				
	Multiple Ponds	25 min3				
Porous Surfaces	Green Roof					
	Modular Porous Paver Systems	5 max	Varies			
	Porous Concrete	5 max	Varies			
Proprietary Systems	Proprietary Systems 1	1	1			
Re-Use	Rain Barrels					

Wetlands	Wetlands, Stormwater	25 min	3-5%	8% max	3 to 5 ft (shallow) 6 to 8 ft (pond)	2 ft, if hotspot or aquifer
	Wetlands, Submerged Gravel	5 min			2 to 3 ft	Below WT

- = Not typically used or able to meet design criterion.

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and shall be verified by independent third-party sources and data if used as a primary control.

2 = Porous surfaces provide water quality benefits by reducing the effective impervious area.

3 = Drainage area can be larger in some instances.

Table 3.27 Implementation Considerations

Category	integrated Stormwater Controls	Implementation Considerations			
		Residential Subdivision Use	High Density/Ultra Urban	Capital Cost	Maintenance Burden
Bioretention Areas	Bioretention Areas	□	□	Moderate	Low
Channels	Enhanced Swales	□		High	Low
	Channels, Grass	□		Low	Moderate
	Channels, Open	□		Low	Low
Chemical Treatment	Alum Treatment System	□	□	High	High
Conveyance System Components	Culverts	□	□	Low	Low
	Energy Dissipation	□	□	Low	Low
	Inlets/Street Gutters	□	□	Low	Low
	Pipe Systems	□	□	Low	Low
Detention	Detention, Dry	□		Low	Moderate to High
	Detention, Extended Dry	□		Low	Moderate to High
	Detention, Multi-purpose Areas	□	□	Low	Low
	Detention, Underground		□	High	Moderate
Filtration	Filter Strips	□		Low	Moderate
	Organic Filters		□	High	High
	Planter Boxes		□	Low	Moderate
	Sand Filters, Surface/Perimeter		□	High	High
	Sand Filters, Underground		□	High	High
Hydrodynamic Devices	Gravity (Oil-Grit) Separator		□	High	High
Infiltration	Downspout Drywell	□	□	Low	Moderate
	Infiltration Trenches	□	□	High	High
	Soakage Trenches	□	□	High	High
Ponds	Wet Pond	□		Low	Low
	Wet ED Pond	□		Low	Low
	Micropool ED Pond	□		Low	Moderate
	Multiple Ponds	□		Low	Low
	Green Roof		□	High	High
	Modular Porous Paver Systems		□	Moderate	High

Porous	Porous Concrete		□	High	High
Proprietary Systems	Proprietary Systems 1	1	□	High	High
Re-Use	Rain Barrels	□	□	Low	High
Wetlands	Wetlands, Stormwater	□		Moderate	Moderate
	Wetlands, Submerged Gravel	□	□	Moderate	High

□ = Meets suitability criteria

- = Not typically used or able to meet design criterion.

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and shall be verified by independent third-party sources and data if used as a primary control.

Step 2 Specific Criteria

The last three categories in the Structural Control Screening matrix provide an overview of various specific design criteria and specifications, or exclusions for a structural control that may be present due to a site's general physiographic character, soils, or location in a watershed with special water resources considerations.

Table 3.28 - Physiographic Factors

Three key factors to consider are low-relief, high-relief, and karst terrain. In North Central Texas, low relief (very flat) areas are primarily located east of the Dallas metropolitan area. High relief (steep and hilly) areas are primarily located west of the Fort Worth metropolitan area. Karst and major carbonaceous rock areas are limited to portions of Palo Pinto, Erath, Hood, Johnson, and Somervell counties. Special geotechnical testing requirements may be needed in karst areas. The local reviewing authority shall be consulted to determine if a project is subject to terrain constraints.

- Low relief areas need special consideration because many structural controls require a hydraulic head to move stormwater runoff through the facility.
- High relief may limit the use of some structural controls that need flat or gently sloping areas to settle out sediment or to reduce velocities. In other cases, high relief may impact dam heights to the point that a structural control becomes infeasible.
- Karst terrain can limit the use of some structural controls as the infiltration of polluted waters directly into underground streams found in karst areas may be prohibited. In addition, ponding areas may not reliably hold water in karst areas.

Table 3.29 - Soils

The key evaluation factors are based on an initial investigation of the NRCS hydrologic soils groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.

The design of structural stormwater controls is fundamentally influenced by the nature of the downstream water body that will be receiving the stormwater discharge. In addition, the designer shall consult with the appropriate review authority to determine if their Development project is subject to additional structural control criteria as a result of an adopted local watershed plan or special provision.

In some cases, higher pollutant removal or environmental performance is needed to fully protect aquatic resources and/or human health and safety within a particular watershed or receiving water. Therefore, special design criteria for a particular structural control or the exclusion of one or more controls may need to be considered within these watersheds or areas. Examples of important watershed factors to consider include:

Table 3.30 - Special Watershed or Stream Considerations

- ***High Quality Streams*** (Streams with a watershed impervious cover less than approximately 15%). These streams may also possess high quality cool water or warm water aquatic resources or endangered species. The design objectives are to maintain habitat quality through the same techniques used for cold-water streams, with the exception that stream warming is not as severe of a design constraint. These streams may also be specially designated by local authorities.

- ***Wellhead Protection***: Areas that recharge existing public water supply wells present a unique management challenge. The key design constraint is to prevent possible groundwater contamination by preventing infiltration of hotspot runoff. At the same time, recharge of unpolluted stormwater is encouraged to maintain flow in streams and wells during dry weather.
- ***Reservoir or Drinking Water Protection***: Watersheds that deliver surface runoff to a public water supply reservoir or impoundment are a special concern. Depending on the available treatment, a greater level of pollutant removal may be necessary for the pollutants of concern, such as bacteria pathogens, nutrients, sediment, or metals. One particular management concern for reservoirs is ensuring stormwater hotspots are adequately treated so they do not contaminate drinking water.

3.9.1.1 Step 3 Location and Permitting Considerations

In the last step, a site designer assesses the physical and environmental features at the site to determine the optimal location for the selected structural control or group of controls. Table 3.29 provides a condensed summary of current restrictions as they relate to common site features that may be regulated under local, state, or federal law. These restrictions fall into one of three general categories:

- Locating a structural control within an area when expressly prohibited by law
- Locating a structural control within an area that is strongly discouraged, and is only allowed on a case by case basis. Local, state, and/or federal permits shall be obtained, and the applicant will need to supply additional documentation to justify locating the stormwater control within the regulated area.
- Structural stormwater controls must be setback a fixed distance from a site feature.

This checklist is only intended as a general guide to location and permitting requirements as they relate to siting of stormwater structural controls. Consultation with the appropriate regulatory agency is the best strategy.

Table 3.28 Physiographic Factors

Category	*integrated* Stormwater Controls	Physiographic Factors		
		Low Relief	High Relief	Karst
Bioretention Areas	Bioretention Areas	Several design variations will likely be limited by low head		Use poly-linear or impermeable membrane to seal bottom
Channels	Enhanced Swales	Generally feasible. However, slope <1% may lead to standing water in dry swales	Often infeasible if slopes are 4% or greater	
	Channels, Grass			
	Channels, Open			
Chemical Treatment	Alum Treatment System			
Conveyance System Components	Culverts			
	Energy Dissipation			
	Inlets/Street Gutters			
	Pipe Systems			
Detention	Detention, Dry		Embankment heights restricted	Require poly or clay liner, Max ponding depth, Geotechnical tests
	Detention, Extended Dry			
	Detention, Multi-purpose Areas			
	Detention, Underground			NOT ALLOWED
	Filter Strips			
	Organic Filters			

Filtration	Planter Boxes			
	Sand Filters, Surface/Perimeter	Several design variations will likely be limited by low head		Use poly-linear or impermeable membrane to seal bottom
	Sand Filters, Underground			

Table 3.26 Physiographic Factors				
Category	*integrated* Stormwater Controls	Physiographic Factors		
		Low Relief	High Relief	Karst
Hydrodynamic Devices	Gravity (Oil-Grit) Separator			
Infiltration	Downspout Drywell	Minimum distance to water table of 4 ft		NOT ALLOWED
	Infiltration Trenches	Minimum distance to water table of 2 ft	Maximum slope of 6%; trenches must have flat bottom	NOT ALLOWED
	Soakage Trenches	Minimum distance to water table of 4 ft	Maximum slope of 6%; trenches must have flat bottom	NOT ALLOWED
Ponds	Wet Pond	Limit maximum normal pool depth to about 4 ft (dugout) Providing pond drain can be problematic	Embankment heights restricted	Require poly or clay liner Max ponding depth Geotechnical tests
	Wet ED Pond			
	Micropool ED Pond			
	Multiple Ponds			
Porous Surfaces	Green Roof			
	Modular Porous Paver Systems			
	Porous Concrete			
Proprietary Systems	Proprietary Systems 1			
Re-Use	Rain Barrels			
Wetlands	Wetlands, Stormwater		Embankment heights restricted	Require poly-liner Geotechnical tests
	Wetlands, Submerged Gravel			

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and shall be verified by independent third-party sources and data if used as a primary control.

Table 3.29 Soils		
Category	*integrated* Stormwater Controls	Soils
Bioretention Areas	Bioretention Areas	Clay or silty soils may require pretreatment
Channels	Enhanced Swales	
	Channels, Grass	
	Channels, Open	
Chemical Treatment	Alum Treatment System	
	Culverts	
	Energy Dissipation	

Conveyance System Components	Inlets/Street Gutters	
	Pipe Systems	
Detention	Detention, Dry	Underlying soils of hydrologic group “C” or “D” shall be adequate to maintain a permanent pool. Most group “A” soils and some group “B” soils will require a pond liner.
	Detention, Extended Dry	

Table 3.29 Soils

Category	*integrated* Stormwater Controls	Soils
	Detention, Multi-purpose Areas	
	Detention, Underground	
Filtration	Filter Strips	
	Organic Filters	
	Planter Boxes	Type A or B
	Sand Filters, Surface/Perimeter	Clay or silty soils may require pretreatment
	Sand Filters, Underground	
Hydrodynamic Devices	Gravity (Oil-Grit) Separator	
Infiltration	Downspout Drywell	Infiltration rate > 0.5 inch/hr
	Infiltration Trenches	Infiltration rate > 0.5 inch/hr
	Soakage Trenches	Infiltration rate > 0.5 inch/hr
Ponds	Wet Pond	“A” soils may require pond liner “B” soils may require infiltration testing
	Wet ED Pond	
	Micropool ED Pond	
	Multiple Ponds	
Porous Surfaces	Green Roof	
	Modular Porous Paver Systems	Infiltration rate > 0.5 inch/hr
	Porous Concrete	
Proprietary Systems	Proprietary Systems 1	
Re-Use	Rain Barrels	
Wetlands	Wetlands, Stormwater	“A” soils may require pond liner
	Wetlands, Submerged Gravel	

1 = The application and performance of proprietary commercial devices and systems must be provided by the manufacturer and shall be verified by independent third-party sources and data if used as a primary control.

Table 3.30 Special Watershed Considerations

Category	*integrated* Stormwater Controls	Special Watershed Considerations		
		High Quality Stream	Aquifer Protection	Reservoir Protection
Bioretention Areas	Bioretention Areas	Evaluate for stream warming	Needs to be designed with no exfiltration (ie. outflow to groundwater)	
	Enhanced Swales		Hotspot runoff must be adequately treated	Hotspot runoff must be adequately treated

Channels	Channels, Grass			
	Channels, Open			
Chemical Treatment	Alum Treatment System			
Conveyance System Components	Culverts			
	Energy Dissipation			
	Inlets/Street Gutters			

Table 3.30 Special Watershed Considerations

Category	*integrated* Stormwater Controls	Special Watershed Considerations		
		High Quality Stream	Aquifer Protection	Reservoir Protection
	Pipe Systems			
Detention	Detention, Dry			
	Detention, Extended Dry			
	Detention, Multi-purpose Areas			
	Detention, Underground			
Filtration	Filter Strips			
	Organic Filters			
	Planter Boxes			
	Sand Filters, Surface/Perimeter	Evaluate for stream warming	Needs to be designed with no exfiltration (ie. outflow to groundwater)	
	Sand Filters, Underground			
Hydrodynamic Devices	Gravity (Oil-Grit) Separator			
Infiltration	Downspout Drywell			
	Infiltration Trenches		Maintain safe distance from wells and water table. No hotspot runoff	Maintain safe distance from bedrock and water table. Pretreat runoff
	Soakage Trenches			
Ponds	Wet Pond	Evaluate for stream warming	May require liner if “A” soils are present Pretreat hotspots 2 to 4 ft separation distance from water	
	Wet ED Pond			
	Micropool ED Pond			
	Multiple Ponds			
Porous Surfaces	Green Roof			
	Modular Porous Paver Systems			
	Porous Concrete			
Proprietary Systems	Proprietary Systems 1			
Re-Use	Rain Barrels			
Wetlands	Wetlands, Stormwater	Evaluate for stream warming	May require liner if “A” soils are present Pretreat hotspots 2 to 4 ft separation distance from water	
	Wetlands, Submerged Gravel			

Table 3.31 Location and Permitting Checklist	
Site Feature	**Location and Permitting Guidance**
Jurisdictional Wetland (Waters of the U.S) U.S. Army Corps of Engineers Regulatory Permit	• Jurisdictional wetlands must be delineated prior to siting structural control. • Use of natural wetlands for stormwater quality treatment is contrary to the goals of the Clean Water Act and shall not be allowed. • Stormwater shall be treated prior to discharge into a natural wetland. • Structural controls may also be restricted in local buffer zones. Buffer zones may be utilized as a non-structural filter strip (i.e., accept sheet flow). • Shall justify that no practical upland treatment alternatives exist. • Where practical, excess stormwater flows shall be conveyed away from jurisdictional wetlands.
Stream Channel (Waters of the U.S) U.S. Army Corps of Engineers Section 404 Permit	• All Waters of the U.S. (streams, ponds, lakes, etc.) shall be delineated prior to design. • Use of any Waters of the U.S. for stormwater quality treatment is contrary to the goals of the Clean Water Act and shall be avoided. • Stormwater shall be treated prior to discharge into Waters of the U.S. • In-stream ponds for stormwater quality treatment are highly discouraged. • Must justify that no practical upland treatment alternatives exist. • Temporary runoff storage preferred over permanent pools. • Implement measures that reduce downstream warming.
Texas Commission on Environmental Quality Groundwater Management Areas	• Conserve, preserve, protect, recharge, and prevent waste of groundwater resources through Groundwater Conservation Districts • Groundwater Conservation District pending for Middle Trinity. • Detailed mapping available from Texas Alliance of Groundwater Districts.
Texas Commission on Environmental Quality Surface Water Quality Standards	• Specific stream and reservoir buffer requirements. • May be imperviousness limitations • May be specific structural control requirements. • TCEQ provides water quality certification – in conjunction with 404 permit • Mitigation will be required for imparts to existing aquatic and terrestrial habitat.

Table 3.31 Location and Permitting Checklist	
Site Feature	**Location and Permitting Guidance**

100-year Floodplain Local Stormwater review Authority	• Grading and fill for structural control construction is generally discouraged within the 100-year floodplain, as delineated by FEMA flood insurance rate maps, FEMA flood boundary and floodway maps, or more stringent local floodplain maps. • Floodplain fill cannot raise the floodplain water surface elevation by more than limits set by the appropriate jurisdiction.
Stream Buffer Check with appropriate review authority whether stream buffers are required	• Consult local authority for stormwater policy. • Structural controls are discouraged in the streamside zone (within 25 feet or more of streambank, depending on the specific regulations).
Utilities Local Review Authority	• Call appropriate agency to locate existing utilities prior to design. • Note the location of proposed utilities to serve Development. • Structural controls are discouraged within utility easements or rights of way for public or private utilities.
Roads TxDOT or DPW	• Consult TxDOT for any setback requirement from local roads. • Consult DOT for setbacks from State maintained roads. • Approval must also be obtained for any stormwater discharges to a local or state-owned conveyance channel.
Structures Local Review Authority	• Consult local review authority for structural control setbacks from structures. • Recommended setbacks for each structural control group are provided in the performance criteria in this manual.
Septic Drain fields Local Health Authority	• Consult local health authority. • Recommended setback is a minimum of 50 feet from drain field edge or spray area.
Water Wells Local Health Authority	• 100-foot setback for stormwater infiltration. • 50-foot setback for all other structural controls.

3.10 General Design Standards

3.10.1 Utilities

General – In the design of a storm drainage system, the engineer is frequently confronted with the problem of crossings between the proposed storm drain and existing or proposed utilities such as water, gas and sanitary sewer lines.

A minimum of two (2) feet of vertical clearance, and five (5) feet horizontal clearance, shall be provided between storm drain pipes and other public and private utilities. Clearance shall be measured outside of pipe to outside of pipe or conduit. If the utility separation required by another utility policy is greater, then the larger separation is required.

Water Lines – All existing water lines in the immediate vicinity of the proposed storm drains shall be clearly indicated on both the plan and profile sheets. When design indicates that an intersection of the storm drain line and the water main exists and the proposed storm drain cannot be economically relocated, then the existing water line shall be adjusted per Water Department specifications. A minimum of 2 feet vertical clearance shall be maintained, measured outside of pipe to outside of pipe.

Sanitary Sewers – All existing or proposed sanitary sewers in the immediate vicinity of the proposed storm drains shall be clearly indicated on both plan and profile sheets. When design indicates an intersection of the storm drain line and the sanitary sewer, then either line shall be adjusted by relocation. If neither line can be economically relocated, then an alternative design may be considered, provided it is supported by hydraulic calculations and accepted by DSD and the Water Department. The alternative design may include a box section in the storm drain to go over or under the sanitary sewer, or a sanitary sewer crossing through the storm drain. If the latter is chosen, the crossing must be installed in a manhole or vault to provide both access and additional capacity. In either alternative, the sanitary sewer must be ductile iron pipe or other material accepted by the Water Department.

All Other Utilities – All other utilities in the immediate vicinity of the proposed storm drain shall be clearly indicated on both the plan and profile sheets. Gas lines and other utilities not controlled by elevation shall be adjusted when the design indicates that an intersection of the storm drain line and the utility exists and the proposed storm drain cannot be economically relocated.

3.10.2 Headwalls, Culverts, and Other Structures

For headwalls, culverts and other structures, standard details adopted by the Texas Department of Transportation (TxDOT) shall be used. The appropriate detail sheets shall be included in any construction plans. Existing City standard headwalls may be used, provided that all slopes are modified to 4:1 or flatter. All headwalls and culverts shall be extended to or beyond the street right-of-way. TxDOT-accepted pedestrian rail shall be used for any headwall within ten (10) feet of a sidewalk or other normal pedestrian area.

3.10.3 Minimum Pipe Sizes

Minimum pipe sizes are twenty-four (24) inch diameter for mains and twenty-one (21) inch diameter for inlet leads (laterals). Minimum sizes of conduits of other shapes shall have equivalent cross-sectional areas. Any storm drain line with two or more inlets shall be considered a main line. Reinforced concrete box (RCB) sections shall have a height to width ratio no greater than 1:1.5 for RCB that are 4 feet or less in height. For RCB with a height of 5 feet or greater, any industry standard RCB size height to width ratio is acceptable.

3.10.4 Pipe Size Changes

Pipe collars or pre-fabricated transition sections shall be provided for all concrete pipe size changes. For polypropylene pipe, prefabricated transition sections or manholes shall be provided at pipe size changes.

Pipe invert elevations shall be maintained at pipe size change locations. Manholes shall be provided at pipe size changes when invert elevation is not maintained.

3.10.5 Pipe Connections and Curved Alignment

Prefabricated wye and tee connections and other unusual configurations can usually be fabricated by the pipe manufacturer. Radial pipe can also be fabricated by the pipe manufacturer and shall be used through all curved alignments. When field connections or field radii must be used, all joints and gaps must be fully grouted to prevent voids and cave-ins caused by material washout into the storm drain. The City requires the installation of junction boxes at locations where new storm drain pipes are proposed to connect directly to existing storm drain pipes and at angles of greater than 60^{O}.

3.10.6 Inlets

Inlets shall be used to drainage all curb and gutter streets (flumes are not allowed). All new curb inlets shall be ten (10), fifteen (15) or twenty (20) feet in length and shall have depressed openings. Recessed inlets shall be provided on roadways and thoroughfares that are identified on a MTP, and other four lane (two each direction) divided or undivided roadways. Locate inlets to allow for a minimum of five (5) feet between the driveway return and inlet edge. Standard inlet depth is 4.5 feet at the lateral line and 4.0 feet at the opposite end, with the bottom sloped to drain to the lateral line. Manhole steps shall be installed for any inlet over five (5) feet deep. Lateral lines shall be plumbed into the inlet at a manhole opening to expedite mechanical cleaning and inspection. Standard, or standard recessed inlets, are required. Type 2 inlets (box under pavement), or type 2 recessed inlets, shall only be used when there are existing utilities that cannot be relocated and conflict with the necessary location of a standard inlet.

Drop inlets shall be minimum four (4) foot square and shall have manhole access and steps. Due to excessive clogging, grate inlets are not allowed on any public storm drain.

Inlets shall be constructed per the standard details. They shall be located on straight sections of street/roadway, and shall not be modified to accommodate curved portions of street/roadway.

3.10.7 Streets

To minimize standing water, the minimum street grade shall be 0.50%. Along a curve, this grade shall be measured along the outer gutter line. The minimum grade along a cul-de-sac or elbow gutter centerline shall be 0.70%. Elbows may be designed with a valley gutter along the normal outer gutter line, with 2% cross slope from curb to the valley gutter. The minimum grade for any valley gutter shall be 0.50%. Where a crest or sag on a residential street, a PVI shall be used instead of a vertical curve where the total gradient change is no more than 1.5% ($\Delta \leq 1.5\%$) for a residential or collector street and no more than 1% for an arterial street.

3.10.8 Flow in Driveways and Intersections

At any intersection, only one street shall be crossed with surface drainage and this street shall be the lower classified street. Where an alley or street intersects a street, inlets shall be placed in the intersecting alley or street whenever the combination of flow down the alley or intersecting street would cause the capacity of the downstream street to be exceeded. Inlets shall be placed upstream from an intersection whenever possible. Surface drainage from a 5-year flood may not cross any street classified as a thoroughfare or collector. Not more than three (3.0 cfs) cubic feet per second in a conveyance storm may be discharged per driveway at a business, commercial, industrial, manufacturing, or school site. Where flume/curb cuts are used to meet the driveway discharge criteria, they shall not discharge more than 0.5 cfs per linear foot of flume width. Flumes shall not exceed 4 feet in width and be spaced no closer than the allowable driveway separation for the given street/roadway classification. In all cases, the downstream storm drainage system shall be adequate to collect and convey the flow, and inlets provide as required. The cumulative flows from existing driveways shall be considered and inlets provided as necessary where the flow exceeds the specified design capacity of the street.

3.11 Easements, Plats, and Maintenance Agreements

3.11.1 Easements

Easements are required for all drainage systems that convey stormwater runoff across a Development and must include sufficient area for operation and maintenance of the drainage system. Types of easements to be used include:

- ***Drainage easements*** shall be required for both on-site and off-site public stormwater drainage improvements, including standard engineered channels, storm drain systems, detention and retention facilities and other stormwater controls (Public Water). The Developer shall obtain downstream drainage easements until Adequate Outfall is determined. Drainage easements shall include a five (5) foot margin on both sides beyond actual top of bank for improved earthen channels. Retaining walls are not permitted within or adjacent to a drainage or floodplain easement in a residential area in order to reduce the easement width. Retaining walls adjacent to the channel are allowed in non-residential areas only if the property owner provides an agreement for private maintenance.
- Easement encroachments that may interfere with maintenance or operation of a facility are not allowed. Structures are not allowed to encroach in an easement or the air space above. An executed encroachment agreement is required for any private improvements that encroach on a drainage easement, such as trees, fences, and private utility crossings and connections.
- Retaining walls are not permitted to cross a drainage easement. If a drainage easement is bounded longitudinally by a retaining wall then a minimum five (5) additional feet of easement width shall be provided. Retaining walls shall be designed to allow for excavation and replacement of the storm drain facility without causing structural instability of the wall; documentation sealed by a structural engineer shall be provided.
- ***Floodplain easements*** shall be provided on sites along natural or improved drainageways (other than standard engineered channels to be maintained by the City) to encompass the fully developed 100-year floodplain plus a ten (10) foot buffer on both sides. The buffer shall be part of the floodplain easement itself and not a separate easement. Floodplain easements are not routinely maintained by the City. Retaining walls are not permitted within or adjacent to a floodplain easement in order to reduce the easement width.
- Natural creeks shall have a dedicated floodplain easement containing the inundation area of a 100-year frequency storm based on fully developed conditions, plus a ten (10) foot buffer horizontally adjacent to the inundation area (both sides of creek). The minimum finished floor elevation for lots impacted by natural creeks shall be a minimum of two (2) feet above the 100-year fully developed water surface elevation. In addition, a riparian area along the creek may be placed in a drainage easement for perpetual, limited maintenance by the City, subject to the approval of the City and an agreement to preserve natural conditions and habitat within the riparian area.
- Concrete-Lined Channels and Gabion-Lined Channels shall have drainage easements dedicated to meet the requirements of the width of the channel, the one (1) foot freeboard, access easement and the fence.
- ***Temporary drainage easements*** are not accepted in the City.
- ***Private drainage easements***, not dedicated to the City, are required for private stormwater drainage improvements (no public runoff), including private detention ponds and storm drains that drain runoff from more than one lot or for stormwater controls on a property. No Development shall prevent another from draining to an outfall, or storm drain system, that was intended to serve upstream Development. Private storm drain facilities, including private drainage easements, shall be extended to ensure that all existing and planned areas may drain to the intended outfall (defined by design plans or drains studies). Private drainage easements shall be sized using the same criteria as public drainage easements.
- ***Access easements*** shall be provided for access to public stormwater drainage improvements where necessary for maintenance.
- Dam easements shall be provided to encompass any proposed dams (including any dams already existing) and spillway structures. The 100-year water surface of any impounded lake shall be covered by a floodplain easement as described above. Dams and spillways shall comply with applicable City policy and state regulations.

- No construction shall be allowed within a floodplain easement without the written approval (floodplain permit) of the City of Fort Worth flood plain administrator or designee, and then only after detailed engineering plans and studies show that no increased flooding will result, and that no obstruction to the natural flow of water will result.
- In certain circumstances where detention is in place or a master drainage plan has been adopted, a Development may plan to receive less than fully developed flow conditions from upstream with the approval of the DSD.
- Any parallel utility easements must be separate and outside of drainage easements for channels, detention ponds and roadside ditches.
- Easements for stormwater controls, including detention basins, sediment traps and retention ponds, shall be negotiated between the City and the Property Owner, but will normally include essential access to all embankment areas and inlet and outlet controls. Essential access is defined as access in at least one location.
- The entire reach or each section of any drainage facility must be readily accessible to maintenance equipment. Additional easement(s) shall be required at the access point(s) and the access points shall be appropriately designed to restrict access by the public (including motorcycles).
- Drainage easements for structural overflows, swales, or berms shall be of sufficient width to encompass the structure or graded area and shall not be less than 15 feet in width.
- Easement Encroachments from structures shall be limited to: awnings and similar overhang architectural features that can be quickly and easily removed and elevated at 22 feet above the ground.

Minimum easement width requirements for storm drain pipe are shown in Table 3.30 and shall be as follows:

- Drainages easements shall be centered on storm drain pipe. The outside face of the proposed storm drain line shall be placed a minimum of five (5) feet off either edge of the storm drain easement. The proposed centerline of overflow swales should coincide with the centerline of the easement.
- A minimum of five (5) additional feet shall be dedicated when shared with other City owned utilities. Utility easements for franchise utilities shall be separate and outside of drainage easements.
- Box culvert minimum easement width shall be determined using Table 3.30 based on an equivalent box culvert width to pipe diameter.
- For parallel storm drain systems with a combined width greater than eight (8) feet the minimum easement shall be equal to the width of the parallel storm drain system plus twenty (20) additional feet.
- Drainage easements shall extend at least twenty-five (25) feet past an outfall headwall to provide an area for maintenance operations. Drainage easements along a required outfall channel or ditch shall be provided until the flowline reaches an Adequate Outfall. Storm drain centerline shall not be on property line, and shall be aligned so that the easement is not divided by a property line.

Table 3.32 Closed Conduit Easements

Pipe Size	Minimum Easement Width Required
39” and under	15 Feet
42” through 54”	20 Feet
60” through 66”	25 Feet
72” through 102”	30 Feet

- Box culverts and arch pipes shall have an easement width equal to the width of the box or arch plus twenty (20) additional feet. The edge of the box shall be located five (5) feet from either edge of the easement.

- Drainage easements shall encompass the entire width of an overflow flume plus five (5) feet on each side. For an easement containing both a concrete flume and a storm drain, the wider of the two easement criteria shall control.
- Alternatively, a drainage right-of way or HOA lot (not part of any adjacent lot) may be dedicated for the width of the flume provided that an additional easement is dedicated for any storm drain pipe to meet the total width requirements specified above.
- Drainage easements in a Single-Family Residential subdivision shall be located within an HOA open space lot.
- Additional easement width shall be provided when the top of the pipe is more than 5 feet below the existing or proposed top of ground (whichever is higher). The easement shall be a minimum 2 feet wider for each additional foot of depth beyond 5 feet.

3.11.2 Plats

All platting shall follow established Development standards for the City. Plats shall include information such as drainage easement width and location and minimum finish floor elevations that will be filed with the plat. A final plat shall include, but not be limited to, the following items:

1. All existing and proposed public and private drainage easements, including those recorded by separate instrument
2. Easements to be recorded by separate instrument shall be documented on the plat, labelled, and include a recorded document number.
3. Minimum finished floor elevations shall be 2’ above the 100 year fully developed condition and shall be shown on plat.
4. Labelled with the100 year fully developed inundation limits referencing the accepted study.
5. All floodplain easements
6. City Flood Risk Areas (CFRA) shall be delineated on plats. An easement would not be required for mapped and adopted CFRA.
7. FEMA SFHA delineation effective at the time of plat submission to the City
8. Legal disclosure for drainage provisions upon sale or transfer of property
9. Documentation of maintenance responsibilities and agreements including transfer of responsibility upon sale of the property
10. Floodplain easements and drainage easements that contain an open channel shall be platted as either parks or HOA open space lots to assure long term maintenance.
11. Drainage easements shall be platted within an open space lot, designated as a X lot, and maintained by a home owners association or property owners association.
12. Preliminary and final plats shall incorporate adjacent floodplain, open channel, drainage easement, creeks, or natural flow paths. These features shall not be “out platted”. The plat area shall extend to at least the centerline of the flow path, and may extend beyond to incorporate the entire feature or planned open space lot.
13. Standard notes and reference to accepted Drainage Study and Flood Study.
14. Driveway culvert table (if the subdivision has a rural street section), see driveway culvert criteria for more details.

Where plat notes reference a requirement to provide a Preliminary SWMP and Final SWMP, then the project shall require an accepted Drainage Study and issued Grading Permit before issuance of a building permit.

3.11.3 Maintenance Agreements

All drainage improvements constructed within a Development and any existing or natural drainage systems to remain in use shall require a maintenance agreement that identifies responsible parties for maintenance. Both private and public maintenance responsibility shall be defined and documented in the agreement. The maintenance agreement shall be written such that it remains in force upon sale or transfer of the property.

A Stormwater Facility Maintenance Agreement (SWFMA) must be prepared by the engineer for each stormwater control that will not be wholly maintained by the City, as part of the Operations and Maintenance Plan submittal. This agreement must outline both preventive maintenance tasks as well as major repairs, identify the schedule for each task, assign clear roles to affected parties, and provide a maintenance checklist to guide future owners, including an annual self-inspection to be provided to the City. Multiple stormwater controls may be contained within a single Stormwater Facility Maintenance Agreement. When areas are identified for detention also serve the Development as a parking lot, truck court or loading dock then the requirement for a SWFMA may be waived. Redevelopment of such a design shall provide equivalent detention and detain back to an undeveloped peak discharge.

3.11.3.1 City Maintenance

The City will provide for perpetual maintenance, in accordance with adopted city maintenance standards, of all public drainage facilities located within dedicated easements, and designed and constructed to the City standards. In addition, limited perpetual maintenance may be provided by the City for riparian areas placed in a drainage or other types of easement preserved in their natural state, subject to the approval of the City. Access shall be provided and dedicated by the Developer to all public stormwater facilities in Developments for maintenance and inspection by the City. All facilities shall be provided with access that meets the needs of the equipment used to perform maintenance activities.

3.11.3.2 Private Maintenance (SWFMA Required)

- Private drainage facilities include those drainage improvements which are located on private property and which handle only private water.
- Private drainage facilities may also include detention or retention ponds, dams, retaining walls adjacent to channels in nonresidential areas, and other stormwater controls which collect public water, as well as drainageways not constructed to City standards but which convey public water. Such facilities must be designed in accordance with sound engineering practices and reviewed and inspected by the City. A SWFMA shall be recorded before construction of the Development begins, or before a final plat is recorded.
- An agreement for perpetual maintenance of private drainage facilities serving public or private water shall be executed with the City and recorded with the County. The SWFMA shall be recorded, before the issuance of a building permit or site construction (IPRC pre-con). This agreement shall run with the land and can be tied to commercial property or to an owner's association, but not to individual residential lots.
- Access shall be provided by the Developer /owner to all private drainage facilities.
- A SWFMA shall be required for all mitigation and water quality devices; including those water quality devices and facilities required as a condition of Tarrant Regional Water District (TRWD) approval.

3.11.3.3 Maintenance Agreement Requirements

Details of the agreement must be set forth in a series of exhibits:

1. Exhibit A Legal Description-This includes the Metes and Bounds, a Surveyor's Drawing of the area occupied by the facility, and a copy of the preliminary or final plat containing the facility.
2. Exhibit B Design Plan and Specifications-these are summary documents intended for the use of future owners in conducting routine maintenance, inspections and repairs.
    a. Design Data and Calculations-This can be in the form of a letter or statement from the engineer which summarizes critical design calculations related to the functionality of the facility such as storage volume or TSS removal, and attest to the facility conforming to applicable City Stormwater Criteria or iSWM standards.

b. Schematic Plan-This shall be prepared by the engineer from construction drawings to show the general layout of the facility. Major features requiring regular or special maintenance shall be shown and labeled in general terms understandable to a layman. A profile shall be given showing critical elevations that control the function and capacity of the facility, and one or more cross-sections shall be provided to indicate the general grading of the facility. A typical example of a schematic plan for a simple detention basin is shown in Figure 3.18.
c. Details – detail drawings shall be provided for the outlet control structure(s), flumes, weirs, and all other structures associated with the facility.
d. Landscaping-Vegetation shall be shown consistent with the accepted Landscape Plan, either on the Schematic Plan or as a separate drawing.

3. Exhibit C Operations and Maintenance Plan-Specific maintenance tasks shall be defined for each element of the facility. Maintenance tasks specific to the facility shall be described in simple terms consistent with nomenclature contained in the Schematic and Landscape plans. An inspection and maintenance frequency shall be established for each task.
4. Exhibit D Maintenance Checklist-A checklist consistent with the Operations and Maintenance Plan shall be provided for the use of future owners in performing routine and special maintenance tasks. This list shall describe work required and frequency in language that is easy to understand and specific for the facility to be maintained. This form will be completed by the Owner and submitted to the City annually as part of a regular self-inspection program. See Inspection Checklist for Simple Detention Basin Form CFW-6 for an example checklist for a simple detention basin. In some cases, this example checklist can be used as is and included in Exhibit D.

Additional guidance for facility maintenance is provided in the iSWM Technical Manual, for several types of stormwater controls. The engineer must certify that the construction has been completed in accordance with the general plans and Schematic Plan. After approval of construction by the City, an engineer is expected to provide guidance to the owner's representative in implementing the accepted maintenance program and to co-sign the first annual inspection after the construction. A checklist for preparing a Stormwater Facility Maintenance Agreement is provided by the City and shall be completed and submitted with the SWFMA application.

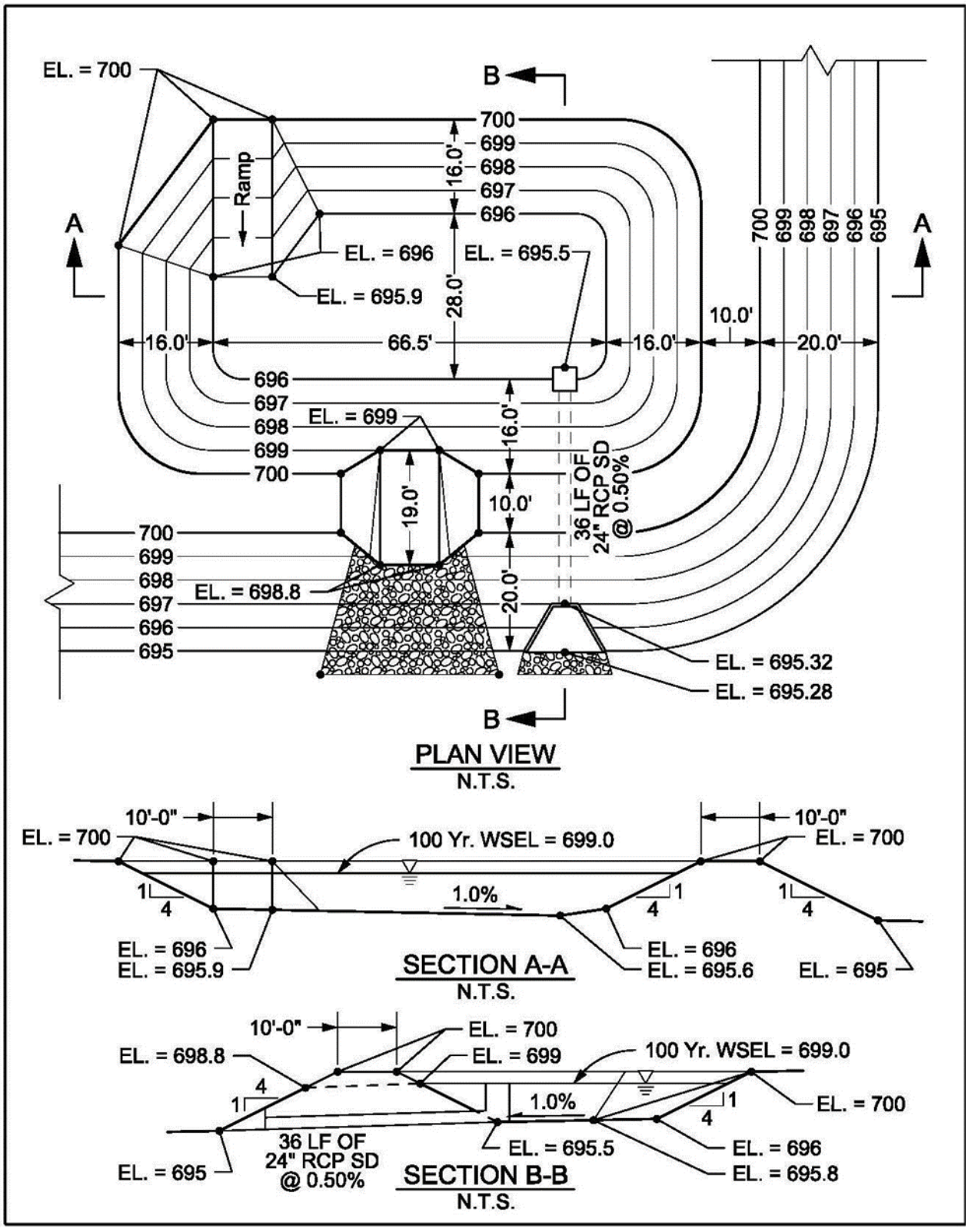


Figure 3.18 Typical Detention Pond Exhibit B – Example

3.12 Plan and Document Preparation Requirements

Plans and documents submitted for review by the Infrastructure Plan Review Center or for a Grading Permit shall include, but not be limited to, the following:

Cover sheet, General Requirements and Drafting Standards:

- All cover sheets for Developer projects shall comply with the current version of the cover sheet template promulgated by the City's Infrastructure Plan Review Center (IPRC).
- For Developer projects, the current version of the title block promulgated by the City's Infrastructure Plan Review Center (IPRC) shall be used.
- Full size drawings shall be submitted on 22" x 34" for both paper and electronic submissions.
- A copy of the recorded (or proposed) Final Plat or Draft Horizontal Control Plan of the project area must be included in the construction plans for Developer projects.
- Contact Information – Contact information for the City Project Manager; DigTess electric, gas, and communication utilities shall be included in the City Standard General Notes as set forth in the City's Standard Construction Specifications and Details. Telephone numbers for any other entities affected by the project, including but not limited to the Texas Department of Transportation (TxDOT) or a railroad company must be included in the General Notes.
- Fort Worth standard symbols and abbreviations must be used in construction plans. Refer to Section 8.3 (Water and Wastewater Main Plan and Profile Sheet Requirements) and Section 8.4 (Standard Abbreviations) for standard abbreviation and drafting symbols.
- All construction plans shall be submitted in black ink. Colored construction plans are not allowed.

General Plan View, Design & Layout:

- All construction plans shall be sealed by a Professional Engineer licensed by the State of Texas
- Label existing, proposed, and future utilities and/or provide line type legend
- Existing contours and existing features shall be dashed or other utility line type and shaded back
- Proposed contours and proposed features shall be of a solid or other utility line type and bold
- Existing contours must extend a minimum of 20' outside project boundary or to an appropriate tie-in
- Provide and label existing file numbers for existing storm drain infrastructure. File numbers to be obtained from existing infrastructure plans.
- Show and label proposed drainage infrastructure in plan and profile view consistent with calculations
- Retaining walls are not permitted in public right of way, drainage easements (unless approved via an encroachment agreement), or floodplain easements
- Retaining walls adjacent to public facilities (ROW, easements) must be designed to TX DOT standard and included in the IRPC or private plan set
- Add relevant notes as supplied by staff based on submitted plans such as erosion control notes or return to existing grade notes.

Grading and Drainage Plan & Profile:

- Show and label temporary or interim controls needed for phasing of storm drain systems for phased subdivisions such as temporary outfall channels, temporary headwalls, and temporary drop inlets.
- Storm line mains/channels must be presented in plan and profile view on the same sheet
- Storm laterals can be presented on one overall sheet
- Plan view horizontal scale must be 1"=40', vertical scale 1"=4'
- When water or sewer mains or laterals cross storm drains, a minimum clearance of 2 feet as measured from the outside diameter of each pipe shall be maintained.
- Water and sanitary laterals may not be located directly under inlet or junction boxes. A minimum of two (2) feet of horizontal clearance is required between laterals and outer edge of box/junction
- All easements for a channel must include the entire depth of the channel and 5' beyond top of bank on both sides

- Private storm infrastructure must be labeled or otherwise denoted as private
- Pipe profiles shall include pipe size, length, slope, flow line elevations, and 100-year HGL shown and labeled, headwater and tailwater shown and labeled for culverts, design frequency, headwall/end section callout, flow rate and velocity specified
- Channel profiles shall include lining type, existing and proposed centerline, proposed right and left top of bank, slope and 100-year water surface elevation, design flow, and velocity. Outfall details, drop structures, and energy dissipaters, shall be labeled and construction details shall be provided.
- The source of starting tailwater shall be stated on hydraulic tables. Hydraulic grade lines for plans, profiles and tables must be consistent at all locations.
- Upstream and offsite bypass for the current phase of Development shall be accounted for in the bypass column of hydraulic tables.
- Channel cross section(s) must be provided to show compliance with minimum channel requirements per Section 3.8.4
- Provide cross section for roads and alleys with relevant calculations (flow, velocity, depth, n, etc.)
- Grade to drain callouts are not acceptable
- Label top of curb elevations along street and around cul-de-sacs/elbows
- Finish pad elevations must be shown to document minimum finish floor elevation compliance with section 3.11 (min 2' above 100 year fully developed water surface)
- Show directional flow arrow on lots
- Label each lot grading type on the lot or provide a chart indicating the lot grading type
- Lot grading type detail(s) shall be provided
- Phased lot grading must be designed such that new construction will not increase runoff to existing homes
- Superelevation or pavement warping may not be used in lieu of inlets at low points.
- Flumes in lieu of inlets are not permitted, inlets shall be used to drain streets.

Floodplain, Easements, & Labels:

- Delineate and label floodplain and floodplain easement on all civil plan sheets. Floodplain label shall include a reference to the Floodplain Development permit number, Flood study number for FEMA floodplains, or SWM number for non-regulatory floodplains.
- Finish pad elevations must be shown to document minimum finish floor elevation compliance with Section 3.11 (min 2' above 100 year fully developed water surface)
- Retaining walls are not permitted in public right of way, drainage easements (unless a waiver is approved in conjunction with an encroachment agreement), or floodplain easements.

Erosion & Sediment Control Plan:

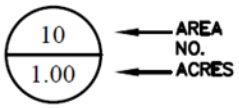
- Existing and proposed contours with labels and flow arrows must be shown on the erosion control plan
- Existing and proposed storm infrastructure must be shown on Erosion Control Plans
- City general Erosion Control Notes shall be added to the City Notes sheet
- A legend showing Erosion and Sediment Control measures must be provided
- The SWPPP location near the construction exit must be shown and labeled.
- A silt fence must be located at the toe of graded slopes
- Limits of disturbance, including off-site areas that will be disturbed and natural features to be protected within the disturbed areas, must be shown on the plan sheet
- Location, details, and notes for erosion controls must be provided
- Location, details, and notes for waste controls (toilets, demolition material, and other potential sources of pollution) must be shown on the plan sheet.
- BMP Design Calculations for erosion, sediment, and waste controls must be shown on the plan sheet
- Inspection and maintenance notes must be provided on the plan sheet.

- Sequence of BMP installation based on sequence of construction phases must be provided on the plan sheet.
- Schedule and phasing of temporary and permanent stabilization on different area of the site must be shown on the plan sheet.
- Temporary structures that will be converted into permanent stormwater controls must be shown on the plan sheet.
- Sites draining 10 or more acres must use sediment traps or ponds
- Top soils must be banked on site. If top soils are not banked on site, then comments describing the provisions being made for soil amendments must be included on the plan sheet.
- All plan sheets must be prepared by an engineer
- All erosion and sediment control plans must comply with Chapter 4 of this Manual

Drainage Area Maps:

- Project boundaries must be shown.
- Topography must be shown with 1 or 2 foot contour intervals. For areas more than one square mile, 5 or 10 foot contour intervals must be used.
- The map must be labeled with USDA hydrologic soil types or a separate soils map must be provided
- Perennial or intermittent stream centerlines must be shown.
- FEMA floodplains, studied floodplains, floodplain easements and open channels must be delineated on the map.
- Locations of wetlands, damns and impoundments must be shown.
- Roads, buildings and other impervious areas must be shown on the map.
- Locations and size major utility lines and easements must be shown on the map.
- Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow must be shown on the map.
- Locations and dimensions of channels, bridges, or culvert crossings must be shown on the map.
- Delineation of watershed boundaries with flow arrows must be shown on the map.
- Offsite drainage areas must be delineated on the map.
- Time of concentration calculations for each area and lag time calculations for hydrograph methods must be shown on the map.
- The longest flow path for each drainage area must be shown on the map.
- A computation table showing drainage areas, runoff coefficients or curve numbers, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100-year storms, for existing, proposed and ultimate conditions must be shown. The collection design point for each drainage area must also be shown
- The location of all site outfalls or where runoff leaves the site must be shown
- Zoning and land use must be shown on the map.
- Changes to watershed boundaries must be identified on the map.
- Composite calculations for runoff coefficients or curve numbers must be shown on the map.
- The entire Zone of Influence must be delineated.
- Downstream constrictions with runoff controls must be shown.
- Drainage area maps for existing, proposed and ultimate conditions must be provided. When the project is a multi-phase project, an overall drainage area map with all phases labeled must be provided.
- Proposed stormwater facilities with private maintenance (including private storm drains) must be provided. If detention is proposed, the volume required must be shown
- Drainage area map basin labels shall be consistent with hydrologic and hydraulic calculations tables
- Basins must be identified using an icon with the ID code and Area (flow rate may also be included)

DRAINAGE AREA



Construction Details

- All detail sheets provided in the construction plan set shall be comprised of at least one detail and a maximum of eight details to ensure that the details are not too small and all details are legible. This is dependent on the orientation and size of each detail.
- Provide only applicable details in accordance with the City Standard Construction Details related to the project.
- A backfill, embedment and surface detail assembly for all storm drain mains and laterals to be constructed shall be provided on the construction plans.
- Provide a customized and engineered (sealed) construction detail for any non-standard installations such as specialized junction structures, or other features that the City does not provide a standard detail for.

4 Stormwater Construction Criteria

This chapter presents an integrated approach for reducing the impact of stormwater runoff from construction activities on downstream natural resources and properties. The purpose is to provide design criteria for temporary controls during construction that protect water quality by:

- Preventing soil erosion;
- Capturing sediment on-site when preventing erosion is not feasible due to construction activities; and
- Controlling construction materials and wastes to prevent contamination of stormwater.

Temporary controls to protect water quality are known as Best Management Practices (BMPs). The design of the BMPs is to be coordinated with and done at the same time as the Drainage Study and Construction Plans. Construction BMPs complement and work with the site grading and drainage infrastructure.

Erosion Control BMPs are designed to minimize the area of land disturbance and to protect disturbed soils from erosion. Protection can be accomplished by diverting stormwater away from the disturbed area or by stabilizing the disturbed soil. Erosion control BMPs are most important on disturbed slopes and channels where the potential for erosion is greatest. The design of erosion control BMPs must be coordinated with related grading, drainage and landscaping elements. (e.g. channel armoring, velocity dissipaters, etc.)

Sediment Control BMPs are temporary structures or devices that capture soil transported by stormwater. The BMPs are designed to function effectively with the site drainage patterns and infrastructure. An effective design ensures that the sediment control BMPs do not divert flow or flood adjacent properties and structures. Some types of permanent drainage structures, such as retention basins, can also be designed to function as a sediment control BMP during construction.

Material and Waste Control BMPs prevent construction materials and wastes from coming into contact with and being transported by stormwater. These BMPs consist of a combination of notes to direct contractors and temporary construction controls.

The iSWM Construction Criteria are the minimum requirements for temporary controls during construction and are adopted and incorporated herein by reference. The state permit and requirements for stormwater discharges associated with construction activities must also be followed. More information on state requirements is provided in Section 4.2.

4.1 Applicability

The City has established requirements for controlling construction runoff for all land disturbance activities, even where there is less than 1.0 acre of disturbed surface.

Construction activities shall comply with the SWPPP requirements in the effective TPDES General permit relating to Stormwater Discharges from Construction Activities, of the Stormwater Pollution Control Ordinance and the appropriate federal (Environmental Protection Agency) and state (Texas Commission on Environmental Quality) regulations. When the ordinance and applicable regulations are in conflict, the most stringent requirements shall apply.

See Appendix D (Sediment and Erosion Control Guidelines for Small Sites).

4.2 Introduction

The City requires the use of temporary controls during construction to prevent or reduce the discharge of sediment and other pollutants from the construction site. The temporary controls are known as Best Management Practices (BMPs). BMPs may be activities, prohibitions, maintenance procedures, structural controls, operating procedures and other measures to prevent erosion and control the discharge of sediment and other pollutants.

Construction BMPs fall into three general categories: Erosion Control, Sediment Control, and Material and Waste Control. The first category prevents erosion, and the second catches soil from erosion that does occur. It is generally more effective and less expensive to prevent erosion than to treat turbid runoff. Material and waste controls are for other sources of stormwater pollutants on a construction site.

The following priorities shall be applied to the selection of construction BMPs:

- Retain native topsoil and natural vegetation in an undisturbed state by incorporating natural drainage features and buffer areas into the site design.
- Limit the area of disturbance and vehicle access to the site.
- Limit the extent of clearing operations and phase construction operations to minimize the area disturbed at any one time.
- Stabilize disturbed areas as soon as possible (not at the end of construction), particularly in channels and on cut/fill slopes.
- Minimize the disturbance of steep slopes during construction, and minimize slope length and steepness.
- Coordinate stream crossings and minimize the construction of temporary stream crossings.
- Provide sediment controls, including but not limited to perimeter controls, where stormwater discharges will occur from disturbed areas.
- Prevent tracking of sediment off-site through the establishment of stabilized construction entrances and exits.
- Control sediment and other contaminants from dewatering activities.
- Control discharges of construction materials and wastes.

4.2.1.1 State Requirements

In addition to the City requirements outlined in this chapter, land disturbing activities must comply with the Texas Commission on Environmental Quality (TCEQ) requirements under General Permit Number TXR150000, commonly referred to as the "Construction General Permit." This permit contains requirements for a Stormwater Pollution Prevention Plan (SWPPP), state and local notifications, and installation, maintenance, and inspection of best management practices on construction sites. The Water Quality Technical Manual contains information for preparing a SWPPP. However, compliance with the Construction General Permit is beyond the scope of this Manual and is the sole responsibility of the construction site operator(s).

4.3 Criteria for BMPs during Construction

The Erosion Control Plan shall include the following:

- Topography.
- Limits of all areas to be disturbed by construction activity, including off-site staging areas, utility lines, batch plants, and spoil/borrow areas.
- Location and types of erosion control, sediment control, and material and waste control BMPs;
- Construction details and notes for erosion control, sediment control, and material and waste control BMPs.
- Inspections and maintenance notes.
- All items listed in Section 3.12

BMPs and notes shall be provided for all the elements listed in this Section, unless site conditions render an element not applicable. BMPs shall be selected and designed according to the technical criteria in the *Construction Controls Technical Manual*. Site data gathered and analyzed in Step 1 of the integrated Development Process shall be the basis for selecting BMPs.

The minimum design storm for temporary BMPs is the 2-year, 24-hour duration storm event. Design calculations for all BMPs shall be included in the construction plans.

Plans for temporary BMPs shall be prepared by a Certified Professional in Erosion and Sediment Control (CPESC), a licensed Professional Engineer or registered Landscape Architect in the State of Texas who has documented experience in hydrology and hydraulics and erosion and sediment control.

It is the responsibility of the engineer to design appropriate BMP's for each site. If the most appropriate BMP is not in the NCTCOG BMP Manual, the engineer shall submit calculations and references for design of the BMP to City.

4.3.1 Erosion Controls

Erosion control is first line of defense and the primary means of preventing stormwater pollution. They shall be designed to retain soil in place and to minimize the amount of sediment that has to be removed from stormwater runoff by other types of BMPs. Fact Sheets for different types of Erosion Control BMPs are in the *iSWM Technical Manual*.

4.3.1.1 Limits of Disturbance

On the iSWM Construction Plans, clearly show the limits of the area to be disturbed and the area in acres draining to each outfall.

Design Criteria:

- Minimize the disturbance of steep slopes.
- Constrain the disturbed area to the minimum necessary to construct the project.
- Include the contractor's staging area, borrow/spoil area, utilities and any other areas on or off site that will be disturbed in support of the construction activity.
- Specify construction fencing or similar protective measures to prevent disturbance of natural drainage features, trees, vegetative buffers and other existing features to be preserved.

4.3.1.2 Slope Protection

Slope protection shall be provided for disturbed or cut/fill slopes that are one vertical on three horizontal (3H:1V) or steeper, fifty (50) feet in length or longer, or on highly erodible soils. Show the location and type of BMPs to be used on the plans.

Design Criteria:

- Where feasible, add notes that prohibit disturbing the slope until final site grading.
- Where a stabilized discharge point is available, provide temporary berms or swales to direct stormwater away from the slope until the slope is stabilized.
- Check dams shall be used within swales that are cut down a slope.
- Temporary terraces, vegetated strips or equivalent linear controls shall be specified at regular intervals to break-up slopes longer than fifty (50) feet until the slope is stabilized.
- Specify final stabilization measures to be initiated within 14 days of completing work on the slope.
- Hydromulch is prohibited for slope stabilization unless the slope is one vertical on five horizontal (5H:1V) or less.

4.3.1.3 Channel Protection

Show the location and type of BMPs used to prevent the erosion of channels, drainage ways, streambanks, and outfalls until permanent structures and final stabilization measures are installed.

Design Criteria:

- Provide temporary energy dissipaters at discharge points.
- If final channel stabilization consists of vegetation, anchored erosion control blankets, turf reinforcement mats, or an equivalent BMP that is resistant to channel flow shall be installed until the vegetation is established.
- If the BMPs include check dams, velocity dissipaters or other structures that extend into the channel, the BMPs shall be designed by a licensed engineer to function under the flow conditions produced by the design storm. The engineer shall verify that the BMPs will not divert flow or cause flooding of adjacent properties and structures.
- Specify final stabilization measures to be initiated within 14 days of completing work on the channel.

4.3.1.4 Temporary Stabilization

Portions of a site that have been disturbed but where no work will occur for more than 21 days shall be temporarily stabilized as soon as possible, and no later than 14 days from cessation of work, except when precluded by seasonal arid conditions or prolonged drought.

Temporary stabilization shall consist of providing a protective cover, without large bare areas, that is designed to reduce erosion on disturbed areas. Temporary stabilization may be achieved using the following BMP's: temporary seeding, soil retention blankets, fibrous mulches, hydro-mulches and other techniques that cover 100% of the disturbed areas until final stabilization can be achieved or until further construction activities take place.

Design Criteria:

- Stabilization measures shall be appropriate for the time of year, site conditions, and estimated duration of use.
- Stabilization BMPs shall be provided for soil stockpiles.

4.3.1.5 Final Stabilization

Final stabilization practices shall be specified for disturbed areas that are not covered by buildings, pavement or other permanent structures upon completion of construction. Final stabilization measures shall be coordinated with the site's landscaping plan.

Design Criteria:

- Final stabilization shall be specified to start within fourteen days of completing soil disturbing activities.
- If space is available, top soil shall be stockpiled during construction and distributed onto the surface of disturbed areas prior to final stabilization.
- If top soil has not been stockpiled, soil amendments (compost, fertilizer, etc.) shall be specified with the final stabilization measures.
- Final stabilization measures must provide a perennial vegetative cover with a uniform density of 70% of the native background vegetative cover or equivalent permanent measures (riprap, gabion, or geotextiles).
- Hydro-mulch will not be allowed in vegetated swales, channels or other drainage ways. BMPs may remain in place during stabilization; however, BMPs shall be removed after stabilization is achieved. The plan for final stabilization shall be coordinated with the permanent BMPs in the SWPPP and with the landscaping plan, if applicable.
- Include notes requiring temporary BMPs be removed within 30 days of establishing final stabilization.
- A Notice of Termination (NOT) must be filed in accordance with the TCEQ TPDES General Permit TXR15000, usually within 30 days after final stabilization of operational control. All parties that submitted a NOI shall submit a NOT within 30 days after final stabilization is established. When the owner of a residential subdivision transfers ownership of individual lots to builders before final stabilization is achieved, the SWPPP shall include controls for each individual lot in lieu of final stabilization. These controls shall consist of stabilization of the right-of-way and placement of structural BMPs at the low point of each individual lot or equivalent measures to retain soil on each lot during construction. Additionally, the builder must submit a valid NOI before or NOT can be submitted by the owner.

4.3.2 Sediment Controls

Sediment control BMPs shall be designed to capture sediment on the site when preventing erosion is not feasible due to on-going construction activity. Sediment control BMPs and their locations shall be designed to change with the different phases of construction as site conditions and drainage patterns change. Sediment controls for the initial phase of construction shall be installed before any site disturbing activities begin. Fact Sheets for different types of Sediment Control BMPs are in Section 3.0 of the Construction Controls Technical Manual.

4.3.2.1 Sediment Barriers

Sediment barriers may be linear controls (silt fence, compost socks, sediment logs, wattles, etc.), check dams, berms, sediment basins, sediment traps, active treatment systems and other structural BMPs designed to capture sediment suspended in stormwater.

Design Criteria:

- Sediment barriers shall be designed to treat the volume of runoff from the design storm.
- Sediment barriers are not required for areas of the site that are undisturbed.
- If linear controls are used as the only sediment barrier for a project, the linear control shall be provided at a rate of 100 linear feet per quarter-acre of disturbed area. A series of linear controls may be needed throughout the site and are not limited to the perimeter.
- Linear controls shall not be used across areas of concentrated flow, such as drainage ditches, swales and outfalls.
- A sediment basin shall be provided where stormwater runoff from 10 acres or more of disturbed area flows to a common drainage location, unless a basin is infeasible due to site conditions or public safety. The basin shall be designed for the volume of runoff from the total area contributing (on-site and off-site) to the common drainage location, not just the volume from the disturbed portion of the contributing area. Stormwater diversion BMPs may be used to divert stormwater from upslope areas away from and around the disturbed area to minimize the design volume of the sediment basin.
- Both existing topography and graded topography shall be evaluated when determining if 10 acres or more discharges to a common location.
- If a sediment basin is infeasible on a site of 10 acres or more, a series of smaller sediment traps and/or linear controls shall be provided throughout the site to provide an equivalent level of protection.
- Permanent detention and retention basins may be used as a sediment basin during construction if all sediment is removed upon completion of construction.

4.3.2.2 Perimeter Controls

A linear BMP shall be provided at all down slope boundaries of the construction activity and side slope boundaries where stormwater runoff may leave the site. Linear sediment barriers may be used to satisfy the requirement for perimeter controls.

4.3.2.3 Storm Drain Inlet Protection

Storm drain inlet protection shall not be used as a primary sediment control BMP unless all other primary controls are infeasible due to site configuration or the type of construction activity. Inlet protection is intended to be a last line of defense in the event of a temporary failure of other sediment controls.

Design Criteria:

- The operator will be expected to diligently monitor storm conditions and to remove inlet protection when there is a risk of flooding.
- Inlet protection shall only be specified for low point inlets where positive overflow is provided.
- Drainage patterns shall be evaluated to ensure inlet protection will not divert flow or flood the roadway or adjacent properties and structures.

4.3.2.4 Construction Access Controls

BMPs shall be provided to prevent off-site vehicle tracking of soil and pollutants.

Design Criteria:

- Limit site access to one route during construction, two routes are allowed for linear projects.
- Design the access point(s) to be at the upslope side of the construction site. Do not place the construction access at the lowest point on the construction site.
- Specify rock stabilization or an equivalent BMP for all access points.

- Include notes requiring soil tracked onto public roads be removed at a frequency that minimizes site impacts and prior to the next rain event, if feasible.
- Using water to wash sediment from streets is prohibited.

4.3.2.5 Dewatering Controls

Water pumped from foundations, vaults, trenches and other low areas shall be discharged through a BMP or treated to remove suspended soil and other pollutants before the water leaves the site. The plans shall include notes that prohibit discharging the water directly into flumes, storm drains, creeks or other drainage ways. Where state or local discharge permit requirements exist for the pollutant(s) suspected of being in the water, the plan shall include the discharge permit conditions.

4.3.3 Material and Waste Controls

Notes shall be placed on the iSWM Construction Plan for the proper handling and storage of materials and wastes that can be transported by stormwater. At a minimum, notes shall be provided for the materials and wastes in Table 4.1. Additional notes and BMPs shall be provided if other potential pollutants are expected to be on-site. Construction details shall be provided when necessary to ensure proper installation of a material or waste BMP.

All material and waste sources shall be located a minimum of fifty (50) feet away from inlets, swales, drainage ways, channels and waters of the U.S., if the site configuration provides sufficient space to do so. In no case shall material and waste sources be closer than twenty (20) feet from inlets, swales, drainage ways, channels and waters of the U.S.

Table 4.1 Requirements for Materials and Wastes	
Material or Waste	**Requirements**
Sanitary Facilities	Sanitary facilities shall be provided on the site, and their location shall be shown on the iSWM Construction Plan. The facilities shall be regularly serviced at the frequency recommended by the supplier for the number of people using the facility.
Trash and Debris	Show the location of trash and debris storage on the iSWM Construction Plan. Store all trash and debris in covered bins or other enclosures. Trash and debris shall be removed from the site at regular intervals. Containers shall not be allowed to overflow.
Chemicals and Hazardous Materials	The amount of chemicals and hazardous materials stored on-site shall be minimized and limited to the materials necessary for the current phase of construction. Chemicals and hazardous materials shall be stored in their original, manufacturer's containers inside of a shelter that prevents contact with rainfall and runoff. Hazardous material storage shall be in accordance with all Federal, state and local laws and regulations. Storage locations shall have appropriate placards and secondary containment equivalent to 110% of the largest container in storage. If an earthen pit or berm is used for secondary containment, it shall be lined with plastic. Containers shall be kept closed except when materials are added or removed. Materials shall be dispensed using drip pans or within a lined, bermed area or using other spill/overflow protection measures.
Fuel Tanks	On-site fuel tanks shall be provided with a secondary enclosure equivalent to 110% of the tank's volume. If the enclosure is an earthen pit or berm, the area shall be lined with plastic. Show the location of fuel tanks and their secondary containment on the iSWM Construction Plan.
Concrete Wash-out Water	An area shall be designated on the iSWM Construction Plan for concrete wash-out. A pit or bermed area, lined with plastic, or an equivalent containment measure shall be provided for concrete wash-out water. The containment shall be a minimum of 6 CF for every 10 CY of concrete placed plus a one (1) foot freeboard. The discharge of wash-out water to drainage ways or storm drain infrastructure shall be prohibited.
Hyper-chlorinated Water from Water Line Disinfection	Hyper-chlorinated water shall not be discharged to the environment unless the chlorine concentration is reduced to 4 ppm or less by chemically treating to dechlorinate or by on- site retention until natural attenuation occurs. Natural attenuation may be aided by aeration. Water with measurable chlorine concentration of less than 4 ppm is prohibited from being discharged directly to surface water. It shall be discharged onto vegetation or through a conveyance system for further attenuation of the chlorine before it reaches surface water. Alternatively, permission from the sanitary sewer operator may be obtained to discharge directly to the sanitary sewer.
Vehicle/Equipment Wash Water	Vehicle and equipment washing is prohibited on the site unless a lined basin is provided to capture 100% of the wash water. The wash water may be allowed to evaporate or hauled-off for disposal.
Soil Stabilizers	Lime or other chemical stabilizers shall be limited to the amount that can be mixed and compacted by the end of each working day. Stabilizers shall be applied at rates that result in no runoff. Stabilization shall not occur immediately before and during rainfall events. Soil stabilizers stored on-site shall be considered a hazardous material and shall meet all the requirements for chemicals and hazardous materials.
Concrete Saw-cutting Water	Slurry from concrete cutting shall be vacuumed or otherwise recovered and not be allowed to discharge from the site. If the pavement to be cut is near a storm drain inlet, the inlet shall be protected by sandbags or equivalent temporary measures to prevent the slurry from entering the inlet.

4.3.4 Installation, Inspection and Maintenance

The iSWM Construction Plan shall include details and notes that specify the proper installation, inspection and maintenance procedures for BMPs. The BMPs for the initial phase of construction must be implemented before starting any activities that result in soil disturbance, including land clearing. Notes shall indicate the sequence of BMP installation for subsequent phases of construction.

Notes on the iSWM Construction Plan shall indicate the frequency of inspections and the areas to be inspected. Inspections shall include:

- Inspecting erosion and sediment controls to ensure that they are operating correctly;
- Inspecting locations where vehicles enter or exit the site for evidence of off-site tracking;
- Inspecting material and waste controls to ensure they are effective; and
- Inspecting the perimeter of disturbed areas and discharge points for evidence of sediment or other pollutants that may have been discharged.

Erosion, sediment, and material and waste controls shall be repaired, replaced, modified and/or added if inspections reveal the controls were not installed correctly, are damaged, or are inadequate or ineffective in controlling their targeted pollutant.

Notes for maintenance of BMPs shall require the removal of sediment from BMPs when the sediment reaches half of the BMP's capacity or more frequently. Sediment discharged from the site shall be removed prior to the next rain event, where feasible, and in no case later than seven days after it is discovered. Upon completion of construction, sediment shall be removed from all storm drain infrastructure and permanent BMPs before the temporary BMPs are removed from the site.

Refer to Section 3.11 for further information on maintenance agreements.

5 References

City of Fort Worth Public Works Department, Storm Water Management Design Manual, March 2006 Fort Worth, Texas.

City of Fort Worth Public Works Department, Storm Drainage Criteria and Design Manual, December 10, 1967, amended June 1, 1975, December 17, 1986, and September 20, 1994, Fort Worth, Texas.

Harris County Flood Control District, October 2009, Policy, Criteria and Procedure Manual for Approval and Acceptance of Infrastructure, Houston, Texas.

Integrated Stormwater Management Criteria Manual for Site Development and Construction, December 2009, NCTCOG, Arlington, TX

integrated Stormwater Management Planning Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Program Guidance: Dam Safety and Water Rights, 2010 Edition, Revised April 2010. NCTCOG, Arlington, TX.

integrated Stormwater Management Water Quality Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Hydrology Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Hydraulics Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Site Development Controls Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Stormwater Management Construction Controls Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

integrated Storm Water Management Landscape Technical Manual, 2010 Edition, Revised September 2014. NCTCOG, Arlington, TX.

Texas Department of Transportation, October 2011, Hydraulic Design Manual, Austin, Texas.

U.S. Army Corps of Engineers, August, 1992, Design and Construction of Grouted Riprap, ETL 1110-2- 334.

U.S. Army Corps of Engineers, July 1991/June 1994, Hydraulic Design of Flood Control Channels, EM 1110-2-1601.

U.S. Department of the Interior Bureau of Reclamation , Hydraulic Design of Stilling Basins and Energy Dissipaters, March 1978, Engineering Monograph No. 25

Appendix A – Checklists and Forms

The checklists and forms provided in Appendix A are intended as examples and a starting point. The latest checklists and forms shall instead be downloaded from the City's website or obtained from the SDS team by emailing your request to SDS@fortworthtexas.gov

The checklists and forms shall be periodically updated by City staff to provide better guidance to applicants or other refinements. Applicants shall use the most recent version of checklists and forms. Checklists and forms shall be used as described with the manual and submitted with the corresponding applications.

Appendix A includes the following example forms:

Form CFW-1 Drainage Study Checklist

Form CFW-2 Flood Study Checklist

Form CFW-3 Culvert Hydraulics Documentation Checklist

Form CFW-4 Bridge Hydraulics Documentation Checklist

Form CFW-5 Preliminary and Final Dam Maintenance and Emergency Action Plan

Form CFW-6 Inspection Checklist for Simple Detention Basin

Form CFW-7 Request for Waiver from City of Fort Worth - Stormwater

Form CFW-8 Engineer's Checklist for Stormwater Facility Maintenance Agreement

Form CFW-9 Grading Permit Application

Form CFW-10 Final Grading Certificate

Form CFW-11 Certificate of Compliance City Flood Risk Areas

FORT WORTH®

DEVELOPMENT SERVICES
INFRASTRUCTURE DEVELOPMENT
200 Texas St, Fort Worth, TX 76102

DRAINAGE STUDY CHECKLIST

STORMWATER DEVELOPMENT SERVICES (SDS)
SDS@fortworthtexas.gov

Project Information:

Name: _____ Submittal Date: _____
Location: _____ Site / Plat Area (ac): _____
Description: _____ Disturbance Area (ac): _____
Land Use: _____ Construction Start Date: _____

Owner Information:

Name: _____
Company: _____
Phone: _____
Email: _____
Address: _____
_____

Engineer Information:

Name: _____ PE No.: _____
Firm: _____ Firm No.: _____
Phone: _____ **Additional Design Contact:**
Email: _____ Name: _____
Address: _____ Phone: _____
_____ Email: _____

This Drainage Study is submitted for the purpose of supporting the following development applications (check all that apply):

- ☐ Single-Phase Preliminary Plat
- ☐ Multi-Phase Preliminary Plat
- ☐ Concept Plan (Multi-Phase)
- ☐ Infrastructure Plan Review
- ☐ Grading Permit
- ☐ Final Plat
- ☐ Zone A (only) Flood Study
- ☐ Update To Previous Study _____ – 20___ – 0_____

Attachments:

- ☐ Sealed Report or Technical Memo
- ☐ Drainage Area Maps
- ☐ Hydrologic Analysis
- ☐ Hydrologic Model Files
- ☐ Pre & Post Project Maps
- ☐ Offsite Drainage Area Map
- ☐ Land Use Maps
- ☐ Soils Maps
- ☐ Downstream Assessment
- ☐ Hydraulic Analysis
- ☐ Hydraulic Model Files
- ☐ Hydraulic Work Maps
- ☐ Detention Pond Checklist
- ☐ Culvert Hydraulics Checklist
- ☐ Bridge Hydraulics Checklist
- ☐ Dam Maintenance & EAP
- ☐ Record Drawings
- ☐ Previous Applicable SWMP
- ☐ Other (list): _____

CFW-1

The Project would require the following items before starting Construction:

☐ Recorded Maintenance Agreement	☐ Offsite Easements	☐ Floodplain Development Permit	☐ CLOMR
☐ Public Infrastructure Plans	☐ Park Conversion	☐ Nationwide Permit	☐ 404 Permit
☐ Community Facilities Agreement	☐ TCEQ Water Rights	☐ Grading Permit	☐ TxDOT Permit
☐ Future Improvements Agreement	☐ TRWD Permit	☐ Adjacent Property Letter	☐ Utility Relocations
☐ Encroachment Agreement	☐ Parkway Permit	☐ Other (list): _____	

Describe any proposed waivers or variances:

Disclaimer: ***This checklist is intended to assist the developers engineer in preparing a drainage study, and the City's engineer in reviewing a drainage study. The checklist is not an exhaustive list of requirements and is not a substitute for familiarity with the CFW Stormwater Criteria Manual, NCTCOG iSWM Technical Manuals, other relevant resources or experience applying hydrologic and hydraulic engineering practices and principles.***

Item Description	Yes	No	N/A	Comments, Clarifications and Description
1. Engineering Report (Technical Memo for simple projects)				
a. Signed and sealed by PE Licensed in Texas				
b. Design methodology				
c. Key assumptions and unusual conditions				
d. Downstream assessment throughout Zone of Influence				
e. Summary of results and comparison of Pre/Post conditions				
f. Compliance with all no adverse impact criteria				
g. Mitigation plan and provision of an adequate outfall				

Item Description	Yes	No	N/A	Comments, Clarifications and Description
2. Planning and Data Collection				
a. List and reference previous drainage studies, iSWM Plans or watershed plans that considered the project area.				
b. Note the source and date of contour or topography information (2015 LiDAR contours freely available from the CFW GIS website).				
c. Is there known or suspected flooding or erosion downstream of the project? (If yes, describe and identify)				
d. Are there any known or suspected downstream constrictions such as undersized culverts?				
e. Are there any FEMA floodplains that require a flood study, CLOMR, LOMR, etc. If yes, list and reference any existing studies.				
f. Are there any known or suspected wetland areas, mitigation areas, waters of the US, or other natural habitat features that may require consideration, 404 permit, nationwide permit, or state or federal permit?				
g. Are there any existing impoundments or dams that could be, or become, subject to TCEQ permitting?				
h. Are there any existing environmental concerns that would require special treatment or design consideration (e.g. fuel station, vehicle maintenance, auto recycling, illegal dump sites, industrial facilities, etc.)?				
3. Does this project provide opportunities for Low Impact Design? If yes, then describe.				
a. Preserve floodplains, streams, drainage patterns, natural storage, or steep slopes?				
b. Preserve trees, natural vegetation, wetlands, or other natural features?				
c. Drain runoff to pervious or vegetated areas?				
d. Utilize natural drainage systems (without erosion) instead of storm drain systems.				
e. Reduce pavement, minimize impervious cover or use alternative materials				
4. Pre-Development Conditions Map				
a. Project boundaries				
b. Aerial photo representing existing conditions (imagery captured within 5 years of submission)				

Item Description	Yes	No	N/A	Comments, Clarifications and Description
c. Perennial and intermittent streams				
d. Delineate effective FEMA floodplains				
e. Delineate wetlands and natural habitat areas				
f. Location of dams and impoundments				
g. Existing roads, buildings and other impervious features				
h. Existing major utilities, pipelines and easements				
i. Existing stormwater conveyance systems, including: overland flow, storm drains, inlets, catch basins, channels, swales, culverts, bridges				
5. Post-Development Map				
a. Limits of clearing and grading				
b. Proposed street and lot layout (SFR)				
c. Site plan (buildings, facilities, parking lot, etc.)				
d. Construction phasing plan				
e. Location and size of proposed storm drains and other stormwater controls (e.g. ponds)				
f. Proposed dams or ponds subject to TCEQ requirements				
g. Proposed FEMA floodplain limits				
6. Pre-Development Drainage Area Maps shall include:				
a. Project boundaries				
b. Existing topography (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)				
c. USDA hydrologic soil types (or separate soils maps)				
d. Perennial or intermittent stream centerlines				
e. Delineate FEMA floodplains, studied floodplains, floodplain easements and open channels				
f. Location of wetlands, dams and impoundments				
g. Existing roads, buildings and other impervious areas				
h. Locations and size major utility lines and easements				

CFW-1

Item Description	Yes	No	N/A	Comments, Clarifications and Description
i. Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow				
j. Locations and dimensions of channels, bridges, or culvert crossings				
k. Delineation of watershed or drainage area boundaries, with correctly orientated flow arrows				
l. Delineate offsite drainage areas (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)				
m. Contours extend beyond project limits and offsite drainage areas to ensure the entire watershed has been delineated				
n. Delineate longest flow path each drainage area				
o. Provide time of concentration calculations for each area and lag time calculations for hydrograph methods.				
p. Computation table showing drainage areas, runoff coefficients or curve numbers, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100 year storms. Include a column to identify the collection point for each drainage area.				
q. Location of all site outfalls or where runoff leaves the site				
r. Delineate entire zone of influence and identify analysis points.				
s. Existing zoning and land use				
t. Composite calculations for runoff coefficients or curve numbers				
u. Drainage area and analysis point labels consistent with hydrologic and hydraulic calculations tables				
7. Post-Development Drainage Area Maps shall include:				
a. Project boundaries				
b. Existing and proposed topography (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)				
c. USDA hydrologic soil types (or separate soils maps)				
d. Perennial or intermittent stream centerlines				
e. Delineate FEMA floodplains, studied floodplains, floodplain easements and open channels				

CFW-1

	Item Description	Yes	No	N/A	Comments, Clarifications and Description
f.	Location of wetlands, dams and impoundments				
g.	Roads, buildings and other impervious areas				
h.	Locations and size major utility lines and easements				
i.	Location, size, and City File Number for existing stormwater conveyance systems such as storm drains, inlets, catch basins, channels, swales, and areas of overland flow				
j.	Locations and dimensions of channels, bridges, or culvert crossings				
k.	Delineation of watershed or drainage area boundaries, with flow arrows				
l.	Delineate offsite drainage areas (1 or 2 foot contour interval, 5 or 10 foot for areas more than one square mile)				
m.	Contours extend beyond project limits and offsite drainage areas to ensure the entire watershed has been delineated				
n.	Delineate longest flow path each drainage area				
o.	Provide time of concentration calculations for each area and lag time calculations for hydrograph methods.				
p.	Computation table showing drainage areas, runoff coefficients or curve numbers, time of concentration or lag times, rainfall intensities and peak discharges for the 1, 5, and 100 year storms, for existing, proposed and ultimate conditions. Include a column to identify the collection point for each drainage area.				
q.	Location of all site outfalls or where runoff leaves the site, including labels with pre/post/ultimate discharges.				
r.	Proposed and ultimate zoning and land use				
s.	Identify changes to watershed boundaries				
t.	Composite calculations for runoff coefficients or curve numbers				
u.	Delineate entire zone of influence and identify analysis points.				
v.	Show downstream constrictions with runoff controls				
w.	When the development is a multi-phase project provide an overall drainage area map with all phases labeled.				
x.	Proposed stormwater facilities with private maintenance (includes private storm drains, if detention is proposed, provide volume required)				

CFW-1

Item Description	Yes	No	N/A	Comments, Clarifications and Description
y. Drainage area and analysis point labels consistent with hydrologic and hydraulic calculations tables.				
8. **Hydrologic Analysis**				
a. Analysis methodology and inputs conform to Chapter 3.4 and relevant sections of the NCTCOG iSWM Technical Manuals.				
b. Selected hydrologic methods per Table 3.4				
c. Runoff coefficient and curve numbers per Table 3.5				
d. On site existing conditions per actual land use, not zoning				
e. Offsite conditions modelled as existing land use for comparison of pre- and post-development conditions				
f. Entire watershed (onsite and offsite areas) modelled per zoning or land use, which ever yields the highest peak discharge, for ultimate conditions hydrology.				
g. Ultimate conditions hydrology used for easement and stormwater facility sizing				
h. Unit hydrograph analysis performed using acceptable software package and models files provided.				
i. Modified Rational Method, if selected, was calculated using the equations described in the *NCTCOG Hydrology Technical Manual*, and not using a software package.				
j. The hydrologic analysis and downstream assessment is carried to, or beyond, the zone of influence based on the 10% rule of thumb. This is required even when detention is provided (except for the specific small site waiver).				
k. Hydrologic work map was provided and shows model basins and routing				
l. Junctions or calculation nodes provided at critical analysis points (e.g. at outfalls, culvert crossings, ponds, etc.)				
m. Reach modelling approaches applied per criteria manual and standard modelling conventions				
n. Pre- and post-development modelling include onsite storage (e.g. upstream of a road culvert) and floodplain storage to determine impacts of any watershed storage loss that result from the development				
o. Where a project discharges to more than one outfall, provide a corresponding analysis for each outfall				
p. Include mitigation design and analysis.				

Item Description	Yes	No	N/A	Comments, Clarifications and Description
q. All applicable hydrologic condition analyses, including but not limited to: existing, proposed, proposed with mitigation if applicable, and ultimate. A multi-phased development would include an additional condition for each phase.				
r. Rainfall depths per *NCTCOG iSWM Hydrology Technical Manual*.				
s. A summary results and comparison table was provided, and includes all junctions and design storms.				
t. Analysis for a Zone A floodplain includes all applicable design storms and complies with FEMA guidelines.				
9. Hydraulic Analysis				
a. Analysis methodology and inputs conform to Chapter 3.8 and other relevant sections of the Stormwater Criteria Manual, the NCTCOG iSWM Technical Manuals, and applicable references (e.g. HEC-RAS manual).				
b. Standard modelling conventions are adhered to (e.g. ineffective flow areas at culverts, cross-sections perpendicular to flow, bank stations contained well inside the floodplain, etc.)				
c. For 1D analysis, Manning's n per Table 3.15, Table 3.16 and other relevant technical references.				
d. Proposed multi-barrel culverts designed with one of the barrel flow lines at the stream centerline, and other barrels set higher to establish a single low flow drainage path				
e. Provide a hydraulic work map including, but not limited to: aerial imagery, cross sections, inundation limits, stream centerline, structures, flow change locations, labels, proposed easement limits, etc.				
f. Provide a summary table that correlates cross-sections to hydrologic nodes or add hydrologic nodes to RAS workmap				
g. Analysis considers appropriate tail water and effect of coincidental peaks				
h. Analysis sizes all driveway culverts and demonstrates that roadside ditch design meets design standards.				
i. Mixed flow regime analysis is included if Froude number(s) is 0.9 or above (supercritical flow check).				
j. Analysis shows compliance with all applicable design criteria in Chapter 3.8.				
k. Analysis shows compliance with all No Adverse Impact criteria throughout the entire Zone of Influence				

Item Description	Yes	No	N/A	Comments, Clarifications and Description
l. Results summaries for all design storms and watershed conditions are tabulated.				
m. Summary tables include a comparison of pre- and post-development conditions at all cross sections and critical locations.				
n. Culvert and bridge hydraulics checklists are completed and attached for all proposed hydraulic structures.				
o. Where a project discharges to more than one outfall, provide a corresponding analysis for each outfall.				
p. A dam breach analysis was performed and the results, dam maintenance plan and EAP are attached				
q. Drainage structure sizes and easement delineations (ultimate conditions 100-year flow)				
r. Flood elevations and corresponding minimum finished floor elevations for all potentially affect and proposed lots (ultimate conditions 100-year flow)				
s. Any other information pertinent to the preparation and review of project documents, including plat and construction plans.				

For additional information about the requirements, standards, criteria, or policies that apply to the preparation or review of a drainage study, please refer to the relevant portions of the CFW Ordinances, Policies and Stormwater Criteria Manual, NCTCOG Technical Manuals, and applicable engineering technical publications.

(Texas PE Seal)	I certify that this drainage study and all attached and referenced exhibits, documents and appendices were prepared under my responsible supervision and that the information presented on the checklist, report, and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City of Fort Worth does not waive any City standards or requirements unless a specific waiver request was submitted and approved. Signed: _____ Date: _____ Name: _____ Firm No: _____

CFW-1

FLOOD STUDY SUBMITTAL FORM

TRANSPORTATION & PUBLIC WORKS DEPARTMENT
STORMWATER MANAGEMENT
200 Texas St, Fort Worth, TX 76102

Submit flood study model requests to FLOODPLAIN MANAGEMENT group
Floodplain@fortworthtexas.gov
Pre-Submittal meetings are required before submitting flood studies, coordinated by STORMWATER DEVELOPMENT SERVICES (SDS)
SDS@fortworthtexas.gov
Submit Flood Studies to your firm's BIM360 folder, coordinated by SDS. Once Flood Study is accepted, submit Floodplain Development Permit application to SDS through Accela for approval

Project Information:

Name: _____ Submittal Date: _____
Location: _____ FIRM Panel: _____
Description: _____ SFHA Flood Zone Type: _____
Stream Name: _____ Pre-Sub Meeting Date: _____

Owner Information:

Name: _____
Company: _____
Phone: _____
Email: _____
Address: _____

Engineer Information:

Name: _____ PE No.: _____
Firm: _____ Firm No.: _____
Phone: _____
Email: _____
Address: _____

Additional Design Contact:

Name: _____
Phone: _____
Email: _____

This Flood Study is submitted in support of the following (check all that apply):

- ☐ Floodplain Development Permit
- ☐ Letter of Map Revision (LOMR)
- ☐ Conditional Letter of Map Revision (CLOMR)
- ☐ Letter of Map Amendment (LOMA)
- ☐ Corridor Development Certificate (CDC)
- ☐ Pre-Project Flood Study (LOMR to be submitted after construction)
- ☐ Letter of Map Revision based on Fill (LOMR-F)
- ☐ Conditional Letter of Map Revision based on Fill (CLOMR-F)
- ☐ CFW Project (City funded)

Attachments:

- ☐ Sealed Report or Technical Memo
- ☐ Hydrologic Work Maps
- ☐ Annotated FIRM
- ☐ CDC Application
- ☐ Hydrologic Analysis
- ☐ Hydrologic Analysis Tables
- ☐ Proposed/As-Built Plans
- ☐ WOTUS Delineation
- ☐ Hydrologic Model Files
- ☐ Hydraulic Work Maps
- ☐ Reference Study(s)
- ☐ 404 Permit
- ☐ Hydraulic Analysis
- ☐ Hydraulic Analysis Tables
- ☐ Property Owner Notification
- ☐ TxDOT Permit
- ☐ Hydraulic Model Files
- ☐ Geo-referenced GIS/CAD files
- ☐ ESA Compliance
- ☐ O&M Plan (detention basin, dam, berm levee)

CFW-2

The Project would require the following items:

☐ Recorded Maintenance Agreement	☐ Elevation Certificate	
☐ Public Infrastructure Plans	☐ TCEQ Water Rights	☐ Utility Relocations
☐ Community Facilities Agreement	☐ TRWD Permit	☐ Grading Permit
☐ Drainage Study	☐ Property Owner Notification	☐ Other (list): _____

Describe any proposed waivers, variances, or other information pertinent to the project (should have been discussed during the pre-submittal meeting):

Disclaimer: ***This form is intended to assist the developers engineer in preparing a flood study, and the City's engineer in reviewing a flood study. The form is not an exhaustive list of requirements and is not a substitute for familiarity with the CFW Stormwater Criteria Manual, NCTCOG iSWM Technical Manuals, other relevant resources or experience applying hydrologic and hydraulic engineering practices and principles.***

For additional information about the requirements, standards, criteria, or policies that apply to the preparation or review of the flood study, plesse refer to the relevant portions of the CFW Ordinances, Policies and Stormwater Criteria Manual, NCTCOG Technical Manuals, and applicable engineering technical publications.

Texas PE Seal (Optional)	I certify that this flood study and all attached and referenced exhibits, documents and appendices were prepared under my responsible supervision and that the information presented on the form, report, and attachments is correct to the best of my knowledge. I also understand that an acceptance of this study by the City of Fort Worth does not waive any City standards or requirements unless a specific waiver request was submitted and approved. Signed: _____ Date: _____ Name: _____ Firm No: _____

CFW-2

CULVERT HYDRAULICS DOCUMENTATION CHECKLIST

Project:		Date:
Road:	Watershed:	Stream:
Type of work:		
FEMA considerations (Detailed or Approx. Study?):		
Culvert location:		
Culvert size & shape:		
Culvert material:	Fill height:	Skew angle:
Hydrologic method used: Hydrograph USGS Station _____ Other (specify) _____		
Design frequency (yrs):		Drainage area:
Channel analysis:	Channel slope (m/m):	N values (channel):

100 Yr Proposed discharge (cfs):	100-Year Fully developed discharge - Q_{100} (cfs):
100 Yr Proposed tailwater (ft):	100-Year Fully developed tailwater (ft):
100 YR Proposed headwater (ft):	100-Year Fully developed headwater (ft):
Allowable highwater (ft):	
100 Yr Proposed velocity thru bridge (fps):	100-Year Fully developed velocity thru bridge (fps):
Design unconstricted velocity (fps)	100-Year unconstricted velocity (fps)
% Flow overtopping road for Q_{100}:	Height of water over road for Q_{100} (ft):
Est. overtopping frequency (years):	
Headwater computation method: THYSYS-CULVERT HEC-RAS* HEC 2 Other _____ *Required by CFW	
Comparison with existing hydraulic condition:	
Meets FEMA requirements_____Yes_____No_____N/A	
Outlet velocity excessive_____Yes___No	
Outlet protection/control:	
Safety end treatment:	
Comments:	

Form CFW-3

BRIDGE HYDRAULICS DOCUMENTATION CHECKLIST

Project:		Date:
Road:	Watershed:	Stream:
Type of work:		
FEMA considerations (Detailed or Approx. Study?):		
Bridge Length:	Pier Configuration:	
Bridge Width:	Bridge Low Chord and Roadbed Elev.:	
Hydrologic Method Used: Hydrograph Only Gauged - USGS Station _____ Other_____		
Design Frequency (yrs):*		Drainage Area:
Channel Dimensions:	Channel slope(ft/ft):	N value:

	DESIGN PROPOSED			100 YR EXISTING			100 YR PROPOSED			100 YR FULLY DEVELOPED		
STATION	Q (cfs)	V (fps)	WSEL (ft)	Q (cfs)	V (fps)	WSEL (ft)	Q (cfs)	V (fps)	WSEL (ft)	Q (cfs)	V (fps)	WSEL (ft)
EXIT												
FULL V												
BRIDGE												
APPR (CONSTR)												
APPR (UNCONS)												

Headwater computation method: HEC-RAS_____ OTHER_____	
Bridge/Roadway overtopping: _____Yes _____No	Overtopping Frequency(years):
% Flow overtopping road:	Height of water over road(ft):
Existing Bridge Length(ft):	Meets FEMA requirements: Yes_____No_____N/A
Type of Bridge Rail:	Skew:
Abutment protection (rock riprap, etc):	
Comments:	
*Complete for cases where "design frequency" (such as TxDOT structures) may be different than 100-year.	

Form CFW-4

FORT WORTH

TRANSPORTATION AND PUBLIC WORKS DEPT.
STORMWATER MANAGEMENT

PRELIMINARY AND FINAL DAM MAINTENANCE AND EMERGENCY ACTION PLAN

Fort Worth Stormwater Management

Please attach additional sheets as necessary for comments and descriptions.
Fold all sheets to 8½" x 11" or 9" x 12" and bind with a clip.

1. Project Information

A. Name of Development: _____ *B. Case No.:* _____

C. Dam Name, Number or Tributary: _____ *D. Date:* _____

E. Name of Owner: _____ *F. Telephone No.:* _____

G. Owner Contact Name: _____ *H. E-mail:* _____

I. Owner Address: _____

J. Engineer's Name: _____ *K. Texas P.E. No.:* _____

L. Engineering Firm: _____ *M. Telephone No.:* _____

N. Engineer Address: _____ *O. E-mail:* _____

2. Dam Summary Information (Item H not required for Preliminary Submittal)

A dam that meets the TCEQ guidelines must be registered with the TCEQ, have a breach analysis, hazard assessment, and emergency action plan per 30 TAC §299.

A. Dam height (feet):* _____

B. Impoundment surface area (acres): _____

C. Watershed size (acres): _____

D. Approx. impoundment volume (acre-feet): _____

*Height measured from the crest of the dam to the bottom of the outfall channel

For City Use: Reviewer: _____ *Date:* _____

Accepted *Not Accepted* *Case No.:* _____

Comments: _____

_____

Form CFW-5

E. Who will own and maintain dam (HOA, City park, etc.)? _____

F. Was dam previously registered and/or inspected by TCEQ? When? _____

G. TCEQ impoundment size classification (30 TAC §299.12): ____ *Exempt* ____ *Small* ____ *Intermediate* ____ *Large*

H. Hazard Assessment (from 6.B. below per 30 TAC §299.13): ____ *N/A* ____ *Low* ____ *Significant* ____ *High*

3. Attachments

_____ **Water Rights Permit (where applicable)**

_____ **Breach Analysis (where applicable)**

_____ **Emergency Action Plan (final submittal)**

	Yes	No	N/A	Comments and Descriptions
4. State Water Rights				
In accordance with Texas Water Code §11, all surface impoundments not used for domestic or livestock purposes must obtain a water rights permit from the TCEQ. For proposed City-owned dams, a completed permit, or written documentation from TCEQ stating that a permit is not required, must be submitted prior to final acceptance by the City.				
Has water rights permit been obtained or applied for? (For proposed City-owned dams, attach permit correspondence)	__	__	__	_____
5. Dam and Pond Site Map(s), showing:				
A. Proposed and existing contours, with recent aerial	__	__	__	_____
B. Existing and proposed FEMA floodplain limits	__	__	__	_____
C. Street and lot layout around dam and inundation area	__	__	__	_____
D. Contributing watershed (reduced scale if necessary)	__	__	__	_____
E. Hydrologic calculations for Q100 and PMF	__	__	__	_____
F. Location, size and capacity of proposed spillway	__	__	__	_____
G. Conceptual or final spillway and erosion protection design	__	__	__	_____

Form CFW-5

	Yes	No	N/A	Comments and Descriptions
6. Dam Breach Analysis – Attach and Include: (Required for Final Submittal only, for dams meeting the guidelines in Chapter 3.8.4 for Detention Structures in this manual).				
A. Breach analysis for "sunny day", "barely overtopping" or Q100, and Probable Maximum Flood (PMF) conditions	___	___	___	_____
B. Hazard Assessment based on potential for loss of life or property damage in breach/non-breach comparison	___	___	___	_____
C. Emergency Action Plan per current City standards	___	___	___	_____

(seal)	I certify that this Conceptual Stormwater Management plan, including this checklist, required attachments, and additional comments, was prepared under my responsible supervision and that the information presented on this checklist and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City does not waive any City standards or requirements unless a specific waiver request has been submitted and accepted. Signed _____ Date _____ Print Name:_____

Form CFW-5

INSPECTION CHECKLIST FOR SIMPLE DETENTION BASIN

Facility Name: _____ **Facility Agreement Number:** _____

Basin/Pond Number: _____ **Inspected By:** _____ **Date:** _____

Type of Inspection: Annual ____, Quarterly ____, Monthly ____, Routine ____, or Storm Event ____, (# days since event _____)

Basin Conditions:

1. Is there standing water or wet spots? Yes___ No ___ Comments _____
2. Does sides or bottom show signs of erosion, settling, cracking, etc? Yes___ No ___ Comments _____
3. Does dam or emergency spillway show signs of erosion, settling, cracking, or other problems? Yes___ No ___ Comments _____
4. Is there evidence of animal burrowing in dam? Yes___ No ___ Comments _____
5. Is there evidence of changes in shape or volume of basin? Yes___ No ___ Comments _____
6. Do vegetated areas need mowing? Yes___ No ___ Comments _____
7. Are there trees or woody growth in dam? Yes___ No ___ Comments _____
8. Are there areas that need to be re-vegetated? Yes___ No ___ Comments _____
9. Is there any accumulation of silt, trash, debris or litter in the basin? Yes___ No ___ Comments _____
10. Are there any other basin maintenance activities needed? Yes___ No ___ Comments _____

Structural Components:

1. Are pipes, channels, trash racks, etc. free of obstructions? Yes___ No ___ Comments _____
2. Are pipes, spillway or trash racks in need of repair? Yes___ No ___ Comments _____
3. Is the low flow or trickle channel in need of repair? Yes___ No ___ Comments _____
4. Is the outfall channel in need of repair? Yes___ No ___ Comments _____
5. Are there any other structural maintenance activities needed? Yes___ No ___ Comments _____

Plan for correcting deficiencies:

_____

_____

_____

_____

Signature:

_____

Owner's Representative

Date:

_____

Form CFW-6

REQUEST FOR WAIVER
FROM CITY OF FORT WORTH – STORMWATER

Submitted by:_____ Phone:_____ Email:_____

Company:_____Date:_____

Proposed Project Description

Name:_____

Type:_____

Location:_____(include map)

Existing Condition (show information on map or drawing)

CFW Maintained Facilities:_____

Existing Right-of-Way for CFW facility:_____

Topography:_____

Other Pertinent Data Related to Variance Request:

_____

_____

_____

Waiver Request

Specific criteria you want to vary:_____

_____

_____

Explain why the criteria needs to be varied or is not applicable:_____

_____

_____

Explain how the basis for the criteria will be satisfied:_____

_____

_____

List attachments supporting waiver request (preliminary design report excerpt, construction drawings, calculations, photographs, map, etc.:

Justification of Decision:_____

_____

_____

Notes:_____

_____

_____

Waiver Decision: Accepted ☐ Denied ☐

Reviewer Signature:_____ Date:_____

Form CFW-7

FORT WORTH

Transportation and Public Works Dept.
Stormwater Management

ENGINEER'S CHECKLIST FOR STORMWATER FACILITY MAINTENANCE AGREEMENT

Fort Worth Stormwater Management

Please attach additional sheets as necessary for comments and descriptions. Fit all sheets to 8½" x 11".

ORGANIZATION INFORMATION

1. Company (Applicant)	**Address:**
2. Contact's Information: Contact Name Mailing Address Telephone Number(s) Email	**3. Execution Information:** Signatory's Name Mailing Address Telephone Number(s) Email

4. Property Location:
(Note: If the property has not been addressed, please enter the legal description)

5. Associated Plat Numbers:
(Note: if request is related to multiple plat applications, please list each individually)

6. Associated Building Permit Numbers:
(Note: if request is related to multiple permits, please list each individually)

7. Associated iSWM Master Numbers:

AGREEMENT & ATTACHMENT INSTRUCTIONS

If the property owner is a **corporation**, the agreement must be signed by the President or a Vice-President of the company. If a **partnership**, the agreement must be signed by the managing partner. If the applicant is a **sole proprietor**, he/she signs the agreement on behalf of him or herself. Additionally, for corporations and partnerships, a copy of the *Articles of Incorporation*, showing signature authority for whoever signs the agreement must also be submitted (Note: Applicants may also submit a board resolution or power of attorney authorizing an agent or assign to sign on behalf of the property owner. The agreement must be completely filled out and three copies submitted to the Planning and Development Department. Signatures on all three agreement drafts must be original and notarized. Lastly, please submit a copy of the deed for the noted property.

NOTE: Agreement and all attachments should be submitted on 8 ½" x 11".

Form CFW-8

	Yes	No	N/A	Comments/Descriptions	Page 2 of 3
1. Legal Agreement – Standard agreement form provided by Department of Law.	☐	☐	☐		
2. Exhibit "A" - Legal Description (Attached)					
A. Metes and Bounds.	☐	☐	☐		
B. Surveyor's Drawing, with seal affixed and marked as "Drainage Easement".	☐	☐	☐		
C. Preliminary Plat.	☐	☐	☐		
3. Exhibit "B" - Design Plan and Specifications (Attached)					
A. Design Calculations – in accordance with iSWM.	☐	☐	☐		
B. Schematic Plan (See Example Detention Plan Schematic)- prepared in accordance with approved construction plans:	☐	☐	☐		
• Plan View showing critical structural elements .	☐	☐	☐		
• Critical structural elements are clearly labeled in layman terms.	☐	☐	☐		
• Profile including a longitudinal section showing all critical structural elements with elevations.	☐	☐	☐		
• Cross-sections as needed to show size and general grading.	☐	☐	☐		
NOTE: All Schematics should be submitted on 8 ½" x 11".					
C. Landscaping shown per approved Landscape Plans.	☐	☐	☐		
4. Exhibit "C" - Operations and Maintenance Plan (Attached)					
A. Routine Maintenance Specifications:					
1. Mowing as needed to control weeds and woody plants.	☐	☐	☐		
2. Trash removal from critical structural elements.	☐	☐	☐		
3. Additional maintenance.	☐	☐	☐		
B. Non-routine Maintenance Activities:					
1. Bank repair and stabilization.	☐	☐	☐		
2. Re-vegetation - required when 30% or more of area is unprotected.	☐	☐	☐		

Form CFW-8

	Yes	No	N/A	Comments/Descriptions Page 3 of 3
3. Sediment removal from the detention/retention facility when:	☐	☐	☐	
• Detention basin – when water depth is reduced 25% or more, or basin does not drain within 72 hours.	☐	☐	☐	
• Retention pond – when water depth is 4' or less.	☐	☐	☐	
• Sediment traps/forebay – when depth is reduced by 50% or more.	☐	☐	☐	
4. Structural repair/replacement for all damaged or deteriorated structures, trickle channel, trash rack, etc.	☐	☐	☐	
5. Mechanical equipment repairs.	☐	☐	☐	
6. Other maintenance Activities.	☐	☐	☐	
5. Exhibit "D" - Maintenance Checklist*				
A. Covers ordinary needs, in layman terms.	☐	☐	☐	
B. Structural components labeled consistent with Schematic Plan.	☐	☐	☐	

*See attached Inspection Checklist for Detention Basin

NOTE: All Exhibits should be submitted on 8 ½" x 11".

(seal)	I certify that this Stormwater Facility Maintenance Agreement, checklist, required attachments, and additional comments, was prepared under my responsible supervision and that the information presented on this checklist and attachments is correct to the best of my knowledge. I also understand that an acceptance of this plan by the City does not waive any City standards or requirements unless a specific waiver request has been submitted and approved. Signed_____ Date_____ Print Name:_____

Form CFW-8

GRADING PERMIT APPLICATION

Applicant to Complete Sections I through VII Below: Permit No._____

Questionnaire For: Commercial Construction or Grading activities.

What Type of Grading Permit is being applied for? (circle one) EARLY FINAL

Note: A Final Commercial Grading Permit is required even if an Early Grading Permit is obtained.

I. **Identification**:

Project Name: _____

Project Location: _____

Owner:

Name: _____ e-mail:_____

Address: _____ Phone: _____

Contractor:

Name: _____

Address: _____

Emergency Telephone No.:_____ e-mail:_____

II. **Do you have an approved iSWM Plan?** (circle one) yes no

An iSWM Plan (integrated Storm Water Management Plan) may have been approved if a Plat, Infrastructure Plans, or a Unified Residential Plan has been approved after March 2006.

If yes provide case/plan number(s), if known:

SWM _____ SWPPP _____

Plat _____ Urban Forestry Plan_____

DOE Number _____ Unified Residential Development Plan _____

III.	What is the total land disturbance associated with this permit?	_____ Acres	
IV.	Are you prepared to submit an iSWM plan now? (circle one)	yes	no
V.	Are you prepared to submit a SWPPP plan now? (circle one)	yes	no
VI.	Are you prepared to submit an Urban Forestry plan now? (circle one)	yes	no

VII. **Signature of Applicant or Authorized Agent:**

Signature: _____

Name: _____

Name of Company: _____

Address: _____

Phone No.: _____

VIII. **Conditions of Approval**

Approval is contingent upon compliance with City grading and development requirements including drainage, floodplain management, urban forestry and construction runoff control. A site grading plan sealed by an engineer is required for all land disturbances of 1.0 acre or more.

City Action:

Reviewer_____Date_____

Accepted / Not Accepted Comments _____

CFW-9

FINAL GRADING CERTIFICATE

Effective Date_____ **Case No.** (*From Early/Final Grading Permit*) _____

This certification is required after construction and grading activities are complete and prior to Certificate of Occupancy being issued.

OWNER/ DEVELOPER/ PERMITTEE INFORMATION

Project Name _____

Project Location _____

Project Description _____

_____

_____

Owner/Developer/Permittee _____

Address _____

Phone No. _____ e-mail _____

DESIGN PROFESSIONAL OR CONTRACTOR (Responsible Party)

Name_____

Address _____

Phone No. _____ e-mail _____

License/Certificate No _____ Expiration Date _____

To the best of my knowledge and personal inspection, the above described project has been constructed in substantial compliance with the plans dated_____ as accepted by the City of Fort Worth AND temporary BMPs have been removed.

Signature_____ Date _____

Printed Name _____

(Seal)

Form CFW-10

Transportation & Public Works
Stormwater Management
200 Texas Street, Fort Worth, TX 76102

CITY FLOOD RISK AREAS CERTIFICATE OF COMPLIANCE

STORMWATER DEVELOPMENT SERVICES (SDS)
SDS@fortworthtexas.gov

The certificate must be completed for all development located within the City Flood Risk Areas (CFRA) that have a land disturbance of less than one acre. Submittals must also include the Project Boundary Map showing the CFRA and proposed project.

PROJECT INFORMATION

Project Name:	Site/Plat Area (acres):
Project Address:	Land Disturbance Area (acres):
Description of Project:	

Property Owner Name:	Engineering Company:	Surveying Company:
Contact Name/Representative:	Contact Name:	Contact Name:
Property Owner Address:	Engineer Address:	Surveyor Address:
Property Owner Email:	Engineer Email:	Surveyor Email:
Property Owner Phone Number:	Engineer Phone Number:	Surveyor Phone Number:

CFRA INFORMATION

What is the Design Flood Elevation (DFE) for this property?

How was the DFE determined?	How will you mitigate flood risk?
❑ City provided engineering study ❑ Independent engineering evaluation performed per the Stormwater Criteria Manual	❑ Elevate Structure to DFE ❑ Floodproofing (attach additional details) Type: ❑ Other:

Briefly explain how any potential adverse impacts were addressed. (Additional pages may be attached if needed.) *See Texas Water Code, Chapter 11, for more information on the State law prohibiting development on a property from creating adverse drainage impacts on others.*

CERTIFICATION

I certify that the above referenced information and supporting analysis were prepared under my responsible supervision and is correct to the best of my knowledge. I also understand that an acceptance of this certificate by the City of Fort Worth does not waive any City standards or requirements unless a specific waiver request was submitted and approved.

Typed Name/Title:	Texas P.E. License Number:	Seal/Stamp:
Signature of Engineer:	Date:	

CFW-11

Appendix B: Stormwater Computer Models

B.1 Introduction

Stormwater management is becoming increasingly complex. The simple notion of collecting runoff and sending it efficiently to the nearest stream is being replaced with considerations of stormwater quantity and quality control, infrastructure management, master planning and modeling, financing, complaint tracking, and more. Information needs are critical to a successful local program. North Central Texas communities need to both invest in and be aware of new and emerging technologies that can provide the ability to collect, organize, maintain and effectively use vast amounts of data and information for their community's stormwater management activities.

There is a great deal of computer software that has been developed based on the intensive research effort in urban hydrology, hydraulics and stormwater quality. Computer models use the computational power of computers to automate the tedious and time-consuming manual calculations. Most models also include extensive routines for data management, including input and output procedures, and possibly including graphics and statistical capabilities.

Computer modeling became an integral part of storm drainage planning and design in the mid-1970s. Several agencies undertook major software developments and these were soon supplemented by a plethora of proprietary models, many of which were simply variants on the originals. The proliferation of personal computers in the 1990s has made it possible for virtually every engineer to use state-of-the-art analytical technology for purposes ranging from analysis of individual pipes to comprehensive stormwater management plans for entire cities.

In addition to the simulation of hydrologic and hydraulic processes, computer models can have other uses. They can provide a quantitative means to test alternatives and controls before implementation of expensive measures in the field. If a model has been calibrated and verified at a minimum of one site, it may be used to simulate non-monitored conditions and to extrapolate results to similar ungauged sites. Models may be used to extend time series of flows, stages and quality parameters beyond the duration of measurements, from which statistical performance measures then may be derived. They may also be used for design optimization and real-time control.

A local staff or design engineer will typically use one or more of these pieces of software in stormwater facility design and review, according to the design objectives and available resources. However, it should be kept in mind that proper use of computer modeling packages requires a good knowledge of the operations of the software model and any assumptions that the model makes. The engineer shall have knowledge of the hydrological, hydraulic and water quality processes simulated and knowledge of the algorithms employed by the model to perform the simulation.

B.2 Types of Models

In urban stormwater management there are typically three types of computer models that are commonly used: hydrologic, hydraulic and water quality models. There are also a number of other specialty models to simulate ancillary issues (some of which are sub-sets of the three main categories) such as sediment transport, channel stability, lake quality, dissolved oxygen and evapotranspiration, etc.

B.2.1 Hydrologic Models

Hydrologic models attempt to simulate the rainfall-runoff process to tell us “how much water, how often.” They use rainfall information or models to provide runoff characteristics including peak flow, flood hydrograph and flow frequencies. Hydrologic models can be either:

- Deterministic – giving one answer for a specific input set, or
- Stochastic – involving random inputs giving any number of responses for a given set of parameters;
- Continuous – simulating many storm events over a period of time, or
- Single Event – simulating one storm event;

- Lumped – representing a large area of land use by a single set of parameters, or
- Distributed – land areas are broken into many small homogeneous areas each of which has a complete hydrologic calculation made on it.

B.2.2 Hydraulic Models

Hydraulic models take a known flow amount (typically the output of a hydrologic model) and provide information about flow height, location, velocity, direction, and pressure. Hydraulic models share some of the differing characteristics of hydrologic models (continuous vs. single event) and add the following:

- One-dimensional – calculating flow information in one direction (e.g. downstream) only, or
- Multi-dimensional – calculating flow information in several dimensions (e.g. in and out of the channel and downstream);

- Steady – having a single unchanging flow velocity value at a point in the system, or
- Unsteady – having changing flow velocities with time;

- Uniform – assuming the channel slope and energy slope are equal, or
- Non-uniform – solving a more complex formulation of the energy and momentum equations to account for the dynamic nature of flows.

For most problems encountered in hydraulics, a simple one-dimensional, steady model will work well. But if the volume and time distribution of flow are important (for example, in a steeper stream with storage behind a series of high culvert embankments) an unsteady model is needed. If there is a need to predict with accuracy the ebb and flow of floodwater out of a channel (for example in a wide, flat floodplain where there are relief openings under a road) then a 2-dimensional model becomes necessary. If pressure flow and the accurate computation of a hydraulic grade line are important, an unsteady, non-uniform model with pressure flow calculating capabilities is needed.

B.2.3 Water Quality Models

The goal in water quality modeling is to adequately simulate the various processes and interactions of stormwater pollution. Water quality models have been developed with an ability to predict loadings of various types of stormwater pollutants.

Water quality models can become very complex if the complete cycle of buildup, wash-off and impact are determined. These models share the various features of hydrologic and hydraulic models in that it is the runoff flow that carries the pollutants. Therefore, a continuous hydrologic model with estimated pollution concentrations becomes a continuous water quality pollution model. Water quality models can reflect pollution from both point and nonpoint sources.

Water quality models tend to have applications that are targeted toward specific pollutants, source types or receiving waters. Some models involve biological processes as well as physical and chemical processes. Often great simplifications or gross assumptions are necessary to be able to model pollutant accumulations, transformations and eventual impacts.

Detailed short time increment predictions of “pollutographs” are seldom needed for the assessment of receiving water quality. Hence, the total storm event loads or mean concentrations are normally adequate. Simple spreadsheet-based loading models involve an estimate of the runoff volume which, when multiplied by an event mean concentration, provide an estimate of pollution loading. Because of the lack of ability to calibrate such models for variable physical parameters, such simple models tend to be more accurate the longer the time period over which the pollution load is averaged. An annual pollutant load prediction may tend toward a central estimate, while any specific storm prediction may be grossly in error when compared to actual loadings because antecedent conditions vary widely from week to week. Simulation models have the ability to adjust a number of loading parameters for calibration purposes and can simulate pollution accumulation over a long period. They can then more reliably predict loadings for any specific storm event.

While calibration data is not always needed in hydrologic or hydraulic models for an acceptably accurate answer, in water quality models the non-calibrated prediction is often off by orders of magnitude. Water quality predictions are not credible without adequate site-specific data for calibration and verification. However, even without specifically accurate loading values relative effects of pollution abatement controls can be tested using uncalibrated models.

B.2.4 Computer Model Applications

Stormwater computer models can also be categorized by their use or application:

Screening-level models are typically equations or spreadsheet models that give a first estimate of the magnitude of urban runoff quality or quantity. At times this is the only level that is necessary to provide answers. This is true either because the answer needs to be only approximate or because there is no data to justify a more refined procedure.

Planning-level models are used to perform "what if" analysis comparing in a general way design alternatives or control options. They are used to establish flow frequencies, floodplain boundaries, and general pollution loading values.

Design-level models are oriented toward the detailed simulation of a single storm event for the purposes of urban stormwater design. They provide a more complete description of flow or pollution values anywhere in the system of concern and allow for adjustment of various input and output variables in some detail. They can be more exact in the impact of control options, and tend to have a better ability to be calibrated to fit observed data.

Operational models are used to produce actual control decisions during a storm event. They are often linked with SCADA systems. They are often developed from modified or strongly calibrated design models, or can be developed on a site-specific basis to appropriately link with the system of concern and accurately model the important physical phenomena.

B.3 Summary of Acceptable Models

Computer models can be simple, representing only a very few measured or estimated input parameters or can be very complex involving twenty times the number of input parameters. The "right" model is the one that: (1) the user thoroughly understands, (2) gives adequately accurate and clearly displayed answers to the key questions, (3) minimizes time and cost, and (4) uses readily available or collected information. Complex models used to answer simple questions are not an advantage. However, simple models that do not model key necessary physical processes are useless.

There is no one engineering model or software that addresses all hydrologic, hydraulic and water quality situations. Design needs and troubleshooting for watershed and stormwater management occur on several different scales and can be either system-wide (i.e., watershed) or localized. System-wide issues can occur on both large and small drainage systems, but generally require detailed, and often expensive, watershed models and/or design tools. The program(s) chosen to address these issues shall handle both major and minor drainage systems. Localized issues also exist on both major and minor drainage systems, but unlike system-wide problems, flood and water quality solution alternatives can usually be developed quickly and cheaply using simpler engineering methods and design tools.

Table B.1 lists several widely used computer programs and modeling packages which are approved by the City for the specific uses listed in the Table.

For the purposes of this table, major drainage systems are defined as those draining to larger receiving waters. These are typically FEMA-regulated streams, or lakes or reservoirs. Minor drainage systems are smaller natural and man-made systems that drain to the more major streams. Minor drainage systems can have both closed and open-channel components and can include, but are not limited to, neighborhood storm sewers, culverts, ditches, and tributaries.

Table B.1 Stormwater Modeling Programs and Design Tools							
	Major System Modeling	**Minor System Modeling**	**Hydrologic Features**	**Hydraulic Features**	**Water Quality Features**	**Unsteady Flow**	**2-D Flow**
Hydrology Software							
HEC-1 [1]	X		X				
HEC-HMS	X		X				
PondPack		X	X	X			
StormCAD							
GEOPAK		X	X	X			
SWFHYD [1]	X		X				
Hydraulics Software							
HEC-RAS	X	X		X		X	
InfoWorks SD	X	X	X	X	X	X	X
XPSWMM	X	X	X	X		X	X
EPA SWMM	X	X	X	X	X	X	
ICPR	X	X	X	X		X	
Water Quality Software							
HSPF	X		X		X		
BASINS	X		X	X	X		
QUAL2K	X			X	X		
Design Tools							
Macra1(Gabion Channels)	X	X		X			
GeowacWIN (Gabion Retaining Walls)	X	X		X			
HY8 (Culverts and Energy Dissipators)	X	X		X			
CulvertMaster		X		X			
FlowMaster		X		X			

[1] Only where model currently exists

Appendix C – City of Fort Worth Miscellaneous Details and Specifications

C.1 Straight Drop Spillways

Overview

The three parts of a straight drop spillway (see Figure C.1) are:

- Upstream draw down reach
- Drop opening
- Downstream hydraulic jump reach

The drop structure shall be constructed of steel sheet piling. Reinforced concrete lining and riprap shall be placed upstream and downstream of the drop structure for erosion and scour protection.

Design Criteria

Design criteria for straight drop spillways are:

- Comply with general design criteria for all transition control structures as described in the "General Design Criteria" below.
- Design steel sheet piling to prevent bending or rotating.
- Coat steel sheet piling in accordance with industry standards to reduce rusting and scaling.
- Use concrete lining on the entire cross-section upstream and downstream of the drop.
- Tie the concrete lining to the steel sheet piling drop structure.
- Use a minimum six (6) inch thick slab on the downstream concrete lining due to the impact load and potential severe turbulence.
- Determine length of concrete lining upstream and downstream of the drop.
- Include twenty (20) feet of riprap at the ends of the concrete slope paving to decrease flow velocities and protect the concrete toe from scour (see Section 3.9 Stone Riprap Design)
- Materials and installation shall conform to City construction specifications.

General Design Criteria

General design criteria for transition control structures are:

- Design for a range of flows and tailwater conditions up to and including the 1% exceedance event. At a minimum, the structure shall be designed for 1-, 5-, and 100-year storms.
- Conduct a geotechnical investigation to assist with design of the structure.
- Locate transition control structures where flow is straight. Avoid channel bends and high turbulence areas.
- Provide structural erosion protection where maximum velocities are exceeded upstream and downstream of the transition control structure and where the hydraulic jump occurs.
- For drop structures in lateral channels at the confluence with the receiving channel:
  - Locate the drop just inside the ultimate right-of-way of the receiving channel.
  - Design the hydraulic jump to occur before it enters the receiving channel.

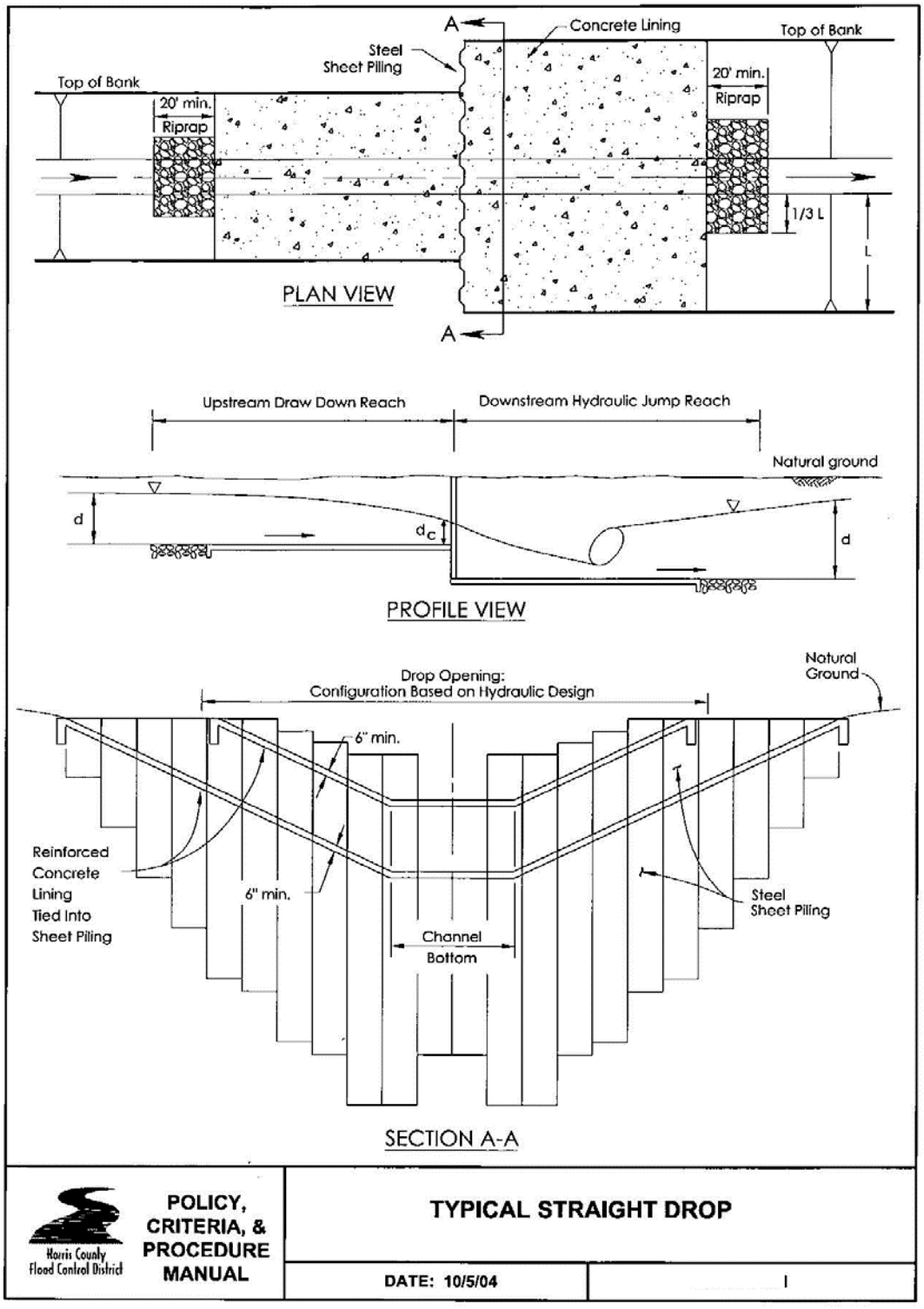


Figure C.1 Typical Straight Drop

C.2 Baffled Chutes

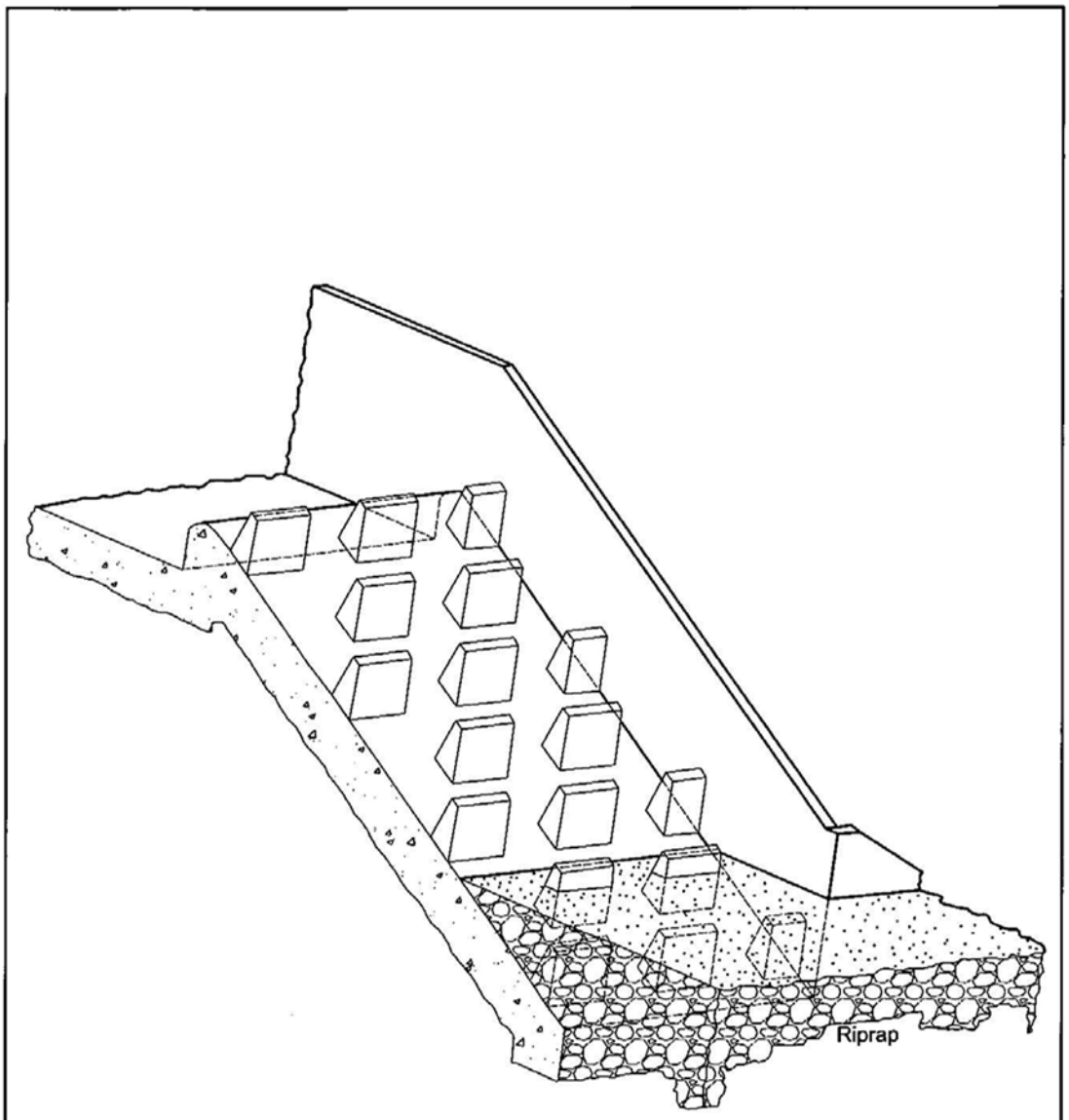
Overview

Baffled chutes are used to dissipate energy at abrupt changes in channel flowline and require no tailwater to be effective. They are generally selected over straight drop spillways for larger drop heights and where lateral channels drop into main channels. Baffle blocks prevent undue acceleration of the flow as it passes down the chute. Since the flow velocities entering the downstream channel are low, no stilling basin is needed. A generic baffled chute is shown in Figure C.2.

Design Criteria

Design criteria for baffled chutes:

- Comply with minimum design criteria for all transition control structures in the previous General Design Criteria.
- Use concrete lining on the entire cross section for the structure.
- Include twenty (20) feet of riprap at the upstream end of the concrete lining to decrease flow velocities and protect the concrete toe from scour (see Chapter
- Use an applicable structural and hydraulic design methodology for baffled chutes.
- Use fully developed watershed conditions for establishing the design flow rate to avoid rebuilding the baffled chute as the watershed develops.



See "Hydraulic Design of Stilling Basins and Energy Dissipators," Engineering Monograph No. 25, U.S. Department of the Interior, Bureau of Reclamation, 1984.

Harris County Flood Control District

POLICY, CRITERIA, & PROCEDURE MANUAL

BAFFLE BLOCK DROP

DATE: 10/5/04

Figure C.2 Baffle Block Drop

Appendix D – Sediment and Erosion Control Guidelines for Small Sites

SEDIMENT AND EROSION CONTROL GUIDELINE FOR SMALL SITES

As a builder, you are responsible for controlling soil and sediment on your job site during construction. This fact sheet provides some general guidelines that may be used for sites that involve construction activity that disturbs less than one acre of soil and are not required to obtain a Construction Stormwater Permit, but have the potential to discharge sediment and other non-stormwater discharges prohibited by city ordinance.

PERIMETER CONTROLS

Perimeter controls are used to capture sediment before it leaves the construction site. These types of controls include vegetative buffers, silt fencing, sediment traps and sediment logs. Sediment traps are small stormwater detention areas that allow sediment to settle out of runoff. A type of trap shown below (see sketch below) is called a cut-back curb. Cut- back curbs are small traps used to pond water behind the curb and gutter system. Frequent monitoring and maintenance of sediment traps is needed to ensure that deposited sediment doesn't reduce their capacity.

INLET PROTECTION

The purpose of inlet protection devices is to reduce the amount of sediment carried into the storm drain system. The device slows runoff and filters out sediment particles at the storm drain. Inlet protection devices are the last line of defense for capturing sediment and shall only be used if no other control measures are adequate as they can cause property damage due to flooding if not frequently inspected and maintained.

STABILIZED CONSTRUCTION EXIT

A stabilized construction exit is used to reduce the amount of sediment tracked from a site onto the street by vehicles or equipment. A stabilized construction exit is typically made by creating a driveway from 1.5 inches or larger aggregate on top of a geotextile mat located where vehicles or equipment exit the site.

TEMPORARY COVER

Temporary cover is used to reduce erosion and shall be applied immediately to areas where construction activity has ceased and is not planned to resume within 21 days or to temporary stockpiles of materials stored on site. Stockpiled material consists of gravel, sand, excavated soil, topsoil or any other similar material. These piles shall never be placed where stormwater is conveyed (e.g., curb and gutter, drainage ditch). Temporary cover may be obtained by planting fast-growing plants like rye, oats, or winter wheat, or it may be obtained by spreading straw, wood chips, erosion control blankets or geotextile fabric over the area.

WASTE DISPOSAL

All waste and construction debris shall be properly stored to prevent spills, leaks or discharges and to protect it from being carried away from the site by wind or water. All waste and debris shall be properly disposed of in compliance with local, state and federal regulations.

CONCRETE WASH WATER

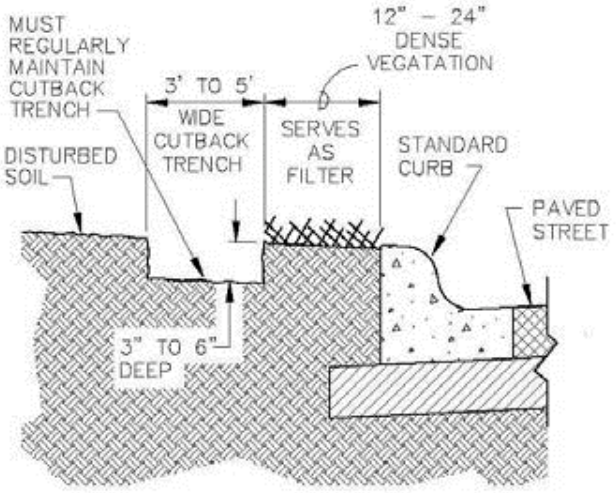
Concrete wash water must never be discharged or allowed to drain into the storm drain or adjacent properties. Wash water disposal must be limited to a defined area of the site or to an area designated by the Developer for cement washout. The area must be sufficient to contain all wash water and residual cement.

INSPECTIONS AND HOUSEKEEPING

To ensure your control measures are in good condition and working properly, they shall be inspected by Owner weekly and after any storm event. Good housekeeping shall be practiced at all times. Housekeeping includes cleaning and maintaining all erosion and sediment control devices, cleaning sediment off streets, and picking up all debris that has been deposited off site by wind or water. Soil or sediment that has been deposited or tracked onto any street shall be removed by the end of the day or before the next rain event.

REMOVAL OF EROSION CONTROLS

Erosion control devices shall remain in place and maintained until permanent vegetation is established. Once permanent vegetation is established, the control measures can then be removed.

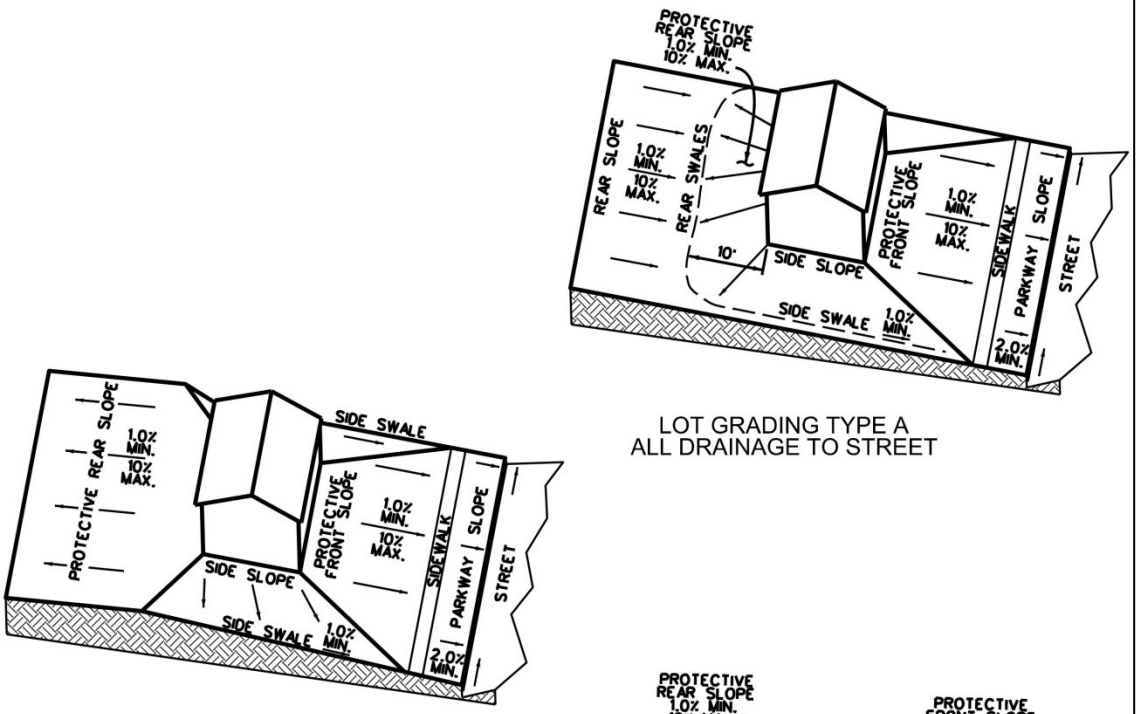


SECTION UNDERCUT LOT

NOT TO SCALE

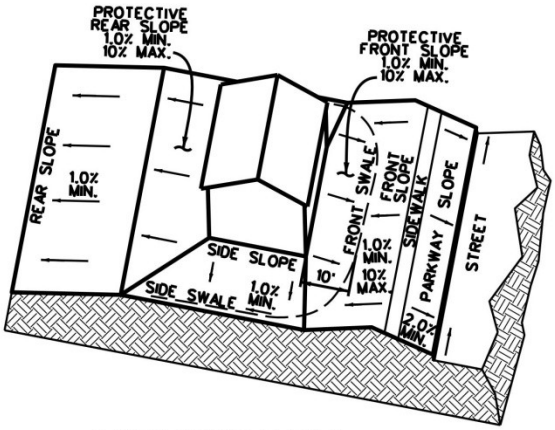
Appendix E – Single Family Residential Lot Drainage

E.1 Lot Drainage Types



LOT GRADING TYPE A
ALL DRAINAGE TO STREET

LOT GRADING TYPE B
DRAINAGE TO FRONT AND REAR LOT LINE



LOT GRADING TYPE C
ALL DRAINAGE TO REAR LOT LINE

GENERAL NOTES:

1. EXCEPT AS NOTED, BUILDING PAD GRADING TO BE PERFORMED BY HOUSE CONTRACTOR AFTER COMPLETIONOF SUBDIVISION IMPROVEMENTS.
2. ALL FINISH FLOOR ELEVATION SHALL BE MINIMUM OF 8" ABOVE THE HIGHEST GRADE ADJACENT TO BUILDING PAD. SEE CURRENT BUILDING CODE.FLOOR ELEVATIONS SHOWN ARE BASED ON THE MINIMUM FRONT SETBACK. ALL GRADING TYPE A & B LOT FINISH FLOORS SHALL BE AT LEAST 1.0 FT. ABOVE THE ROAD CROWN ALONG LOT FRONTAGE.
3. DRIVEWAY SLOPES BREAKS SHALL NOT EXCEED AN ALGEBRAIC DIFFERENCE OF ±14% WITHOUT PROPER VERTICAL CURVE.
4. MEANDER SWALES AROUND SPECIMEN TREES AND DO NOT DISTURB WETLAND VEGETATION.

TYPICAL FHA/VA THREE DIMENSIONAL GRADING PLAN

Single Family Residential Lot Drainage Types (Federal Housing Administration, Land Planning Bulletin No. 3)

E.2 Block Grading Types

(Source: Federal Housing Administration Land Planning Bulletin No. 3)

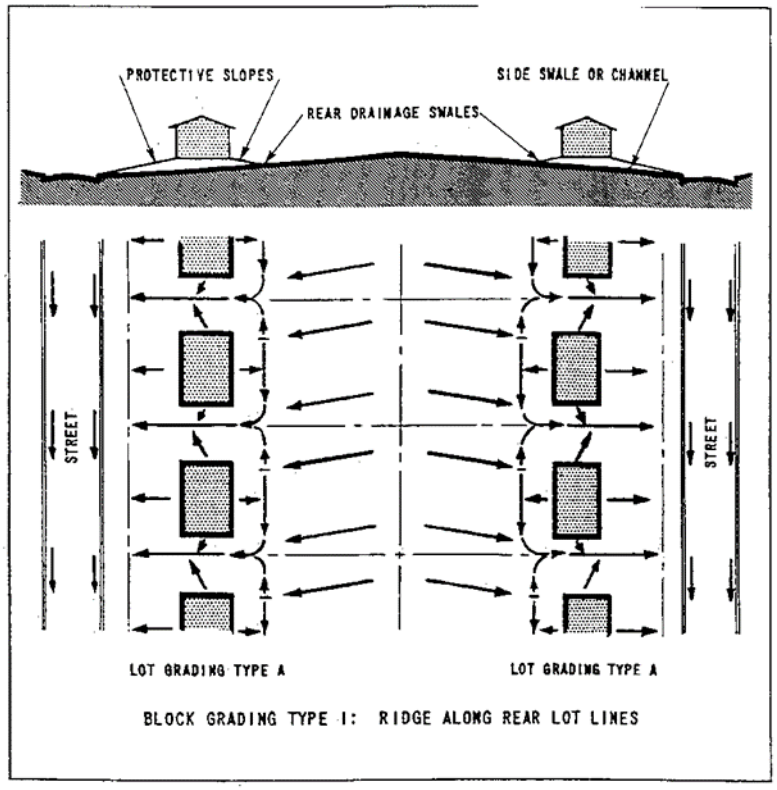
Block Grading Type 1 has a ridge along the rear lot lines and each lot is graded to drain surface water directly to the street independent of other properties. It is the most simple and desirable type of block grading. Topography, however, will often require other types of block grading types.

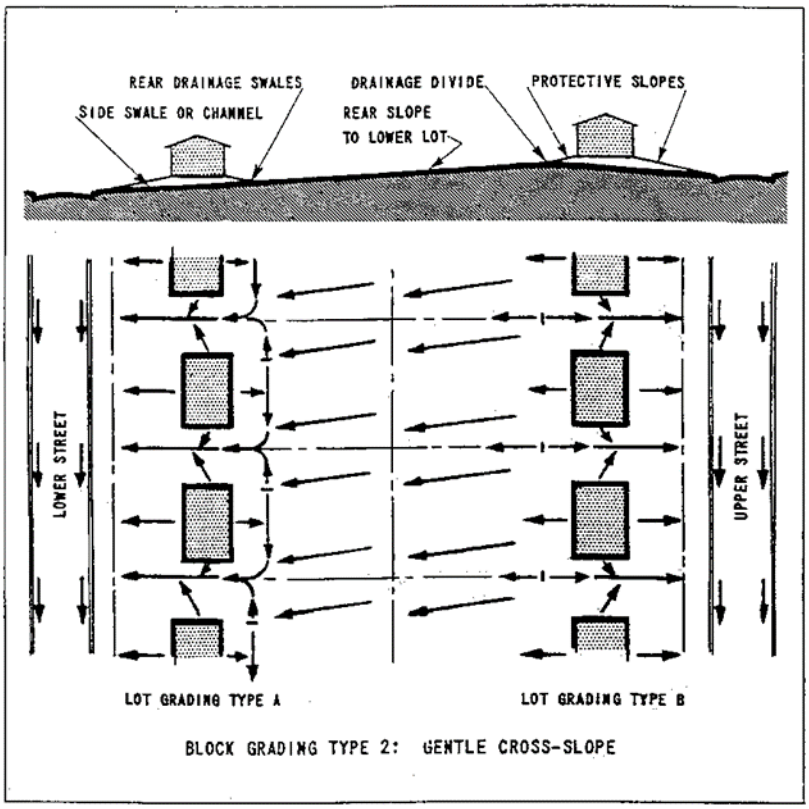
Block Grading Type 2 for a gentle cross-slope involves drainage of some surface water from lots of the high side of the block across the lower tier of lots. Difficulties are not encountered, however, if slopes are gentle and if the water always drains over short routes to the streets and does not concentrate or accumulate in volume at any point inside the block.

Block Grading Type 3 for steep cross-slopes and Type 4 for a valley along rear lot lines require special provision for block drainage and erosion control.

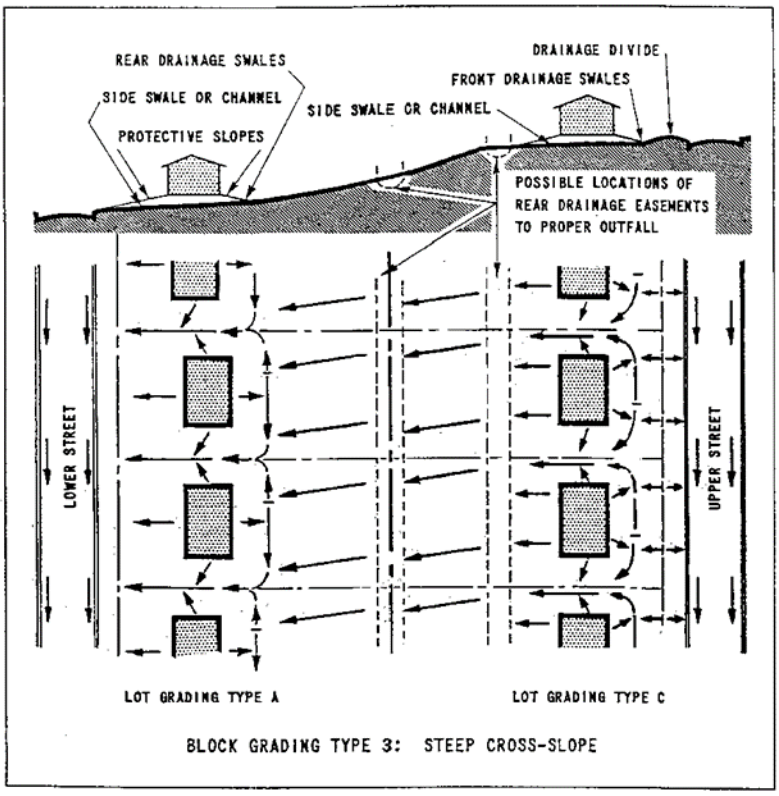
Erosion is controlled by provision of intercepting drainage swales in easements at the top of the rear lot incline or at intermediate locations along it, and by treatment of the steep slope itself.

Drainage easements in Block Types 3 and 5 must have alignment, width, and improvements appropriate for the expected use and maintenance. Assurance of a permanent outfall is essential. The easements must be permanently established by proper legal methods, with continuous maintenance assured by public authority, property-owners' association or individual owners, as appropriate to the situation. Walls, buildings and any other obstructions to drainage flow, such as dense planting or tight fencing, must be legally prohibited in the easement area.

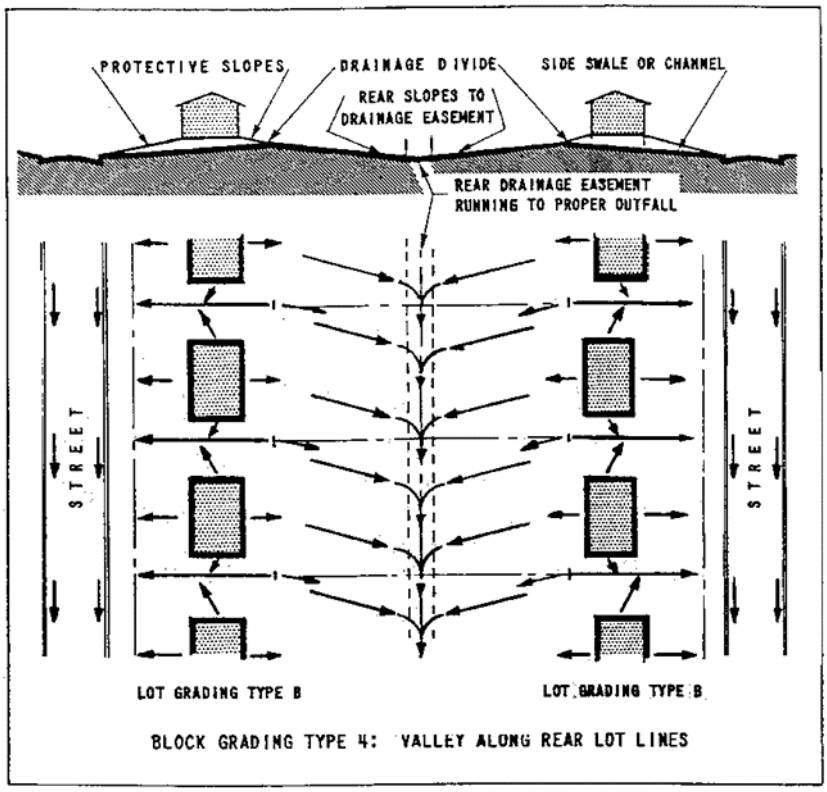




BLOCK GRADING TYPE 2: GENTLE CROSS-SLOPE



BLOCK GRADING TYPE 3: STEEP CROSS-SLOPE


PROTECTIVE SLOPES
DRAINAGE DIVIDE
SIDE SWALE OR CHANNEL
REAR SLOPES TO DRAINAGE EASEMENT
REAR DRAINAGE EASEMENT RUNNING TO PROPER OUTFALL
STREET
STREET
LOT GRADING TYPE B
LOT GRADING TYPE B
BLOCK GRADING TYPE 4: VALLEY ALONG REAR LOT LINES

Appendix F – Stormwater Utility Fee Credit Policy

Includes:

- Stormwater Utility Fee Credit Policy
- Development Incentives and Integrated Design Point System

Authority and Purpose

The City of Fort Worth (City) adopted an ordinance (No. 16781) creating a Storm Water Utility (Utility) in July 2006 to provide a stable and equitable funding for its storm water management program. Developed properties are charged monthly storm water utility fees based primarily on the amount of impervious area on a parcel of property. The ordinance establishing the Utility also gives the Transportation and Public Works Director the authority in Section 12.5-343(C) to grant credits (Credits) to rate payers who voluntarily use storm water quality management techniques or Best Management Practices (BMPs) to offset the impact of their property on storm water runoff. These credits are applied as percent discounts to regular monthly storm water fees.

A general scheme of granting credits was developed by citizen task force and presented to the City Council for comment in 2008. The purpose of this Credit Manual is to set out the specific conditions that must be achieved to qualify for Credits. Each credit listed below is given to encourage voluntary practices which will benefit the Storm Water Management (SWM) program.

Eligibility

It is infeasible to review, validate, and monitor practices at single-family residences. Therefore, only non-single family properties are eligible for credits. Credits are awarded to the water bill account.

Types of Credits

Credits are available under the following BMP categories. The percentages reflect maximum possible credit award.

1). Industrial Permit Compliance:	10%
2). Detention Maintenance:	20%
3). Zero Discharge:	80%
4). Channel Protection Detention:	10%
5). Water Quality Treatment:	25%
6). Inlet Trash Collection:	10%
7). Parking Lot Sweeping:	Minimum 5%, maximum on case-by-case
8). Student Education:	10%
9). Adopt-A-Creek:	5%
10). Special Measures:	Maximum on case-by-case

Conditions for Credit

The following general conditions apply:

- Credit is valid for a year, and will require yearly renewals;
- Deadline for annual renewals is March 31;
- Credit applicant agrees to their facility being inspected;
- Annual self-inspection of facilities and reporting is required for renewal;
- A maintenance plan for credits associated with detention and retention ponds is required;
- Incomplete or untimely submission by renewal deadline will be automatically suspended for 3 months.

Administration of Credit Program

The Credit program will be administered as follows:

- The Engineering Manager or designee in SWM will be responsible for the overall administration of the program;
- The Water Quality Engineer in SWM will be the point-of-contact for accepting, reviewing and authorizing the individual credit application;
- Once credit is authorized, the application will be sent to SWM's Billing Section which will be responsible for amending the account for change in storm water utility fees with the credit;
- Credit will be given to the applicant on the next billing cycle following receipt of completed application.

Next, the individual Credit categories are discussed.

Industrial Permit Compliance (10% credit)

Industrial facilities (Facility) in the City that are required by the Texas Commission on Environmental Quality (TCEQ) to obtain coverage under the Multi-Sector General Permit (TXR050000) for storm water discharge, or another applicable storm water general permit (TXG110000, TXG340000) or individual permit, may be eligible under this category. Facilities with a No Exposure Certification (NEC) are also eligible for the fee credit if compliance with all NEC requirements is maintained. The following conditions apply for this category:

a). The Facility is in compliance with all applicable permit requirements;

b). Water quality testing results from permitting are consistently at or below their benchmark levels or permitted effluent limits during each sampling event. When results exceed benchmarks or effluent limits, appropriate actions, documented in the Storm Water Pollution Prevention Plan, must be taken to reduce pollutant discharge. Continued elevated levels may result in suspension of Credit.

c). Copies of the water quality testing results must be submitted to the SWM Water Quality Engineer as and when they occur.

d). A copy of the Facility's annual compliance inspection report and a copy of the Facility's Storm water Pollution Prevention Plan (SWPPP) required by the permit.

Detention Maintenance Credit (20% credit)

A maximum of 20% credit will be given to impervious areas draining into detention and retention pond facilities which are maintained in accordance with a city approved maintenance plan. The owner of the facilities must submit an annual self-report by the March 31st deadline.

Zero Discharge Credit (80% credit)

A credit of up to 80% will be given for impervious areas which drain to a retention pond that is designed and operated to contain runoff from a 100-year 24-hour storm without discharge from the property. Retention pond with lower levels of service will be considered for a pro-rated credit. This credit is intended for runoff that's stored in retention ponds for later re-use. A signed and sealed study by a qualified engineer must be approved by SWM for this credit to be granted. Property owners interested in this credit should meet with SWM staff prior to engaging an engineer to perform the study to understand the engineering analysis required to meet the qualifying standards.

Channel Protection Detention Credit (10% credit)

A 10% credit will be given for impervious areas draining to a detention or retention facility that is designed to discharge a one year storm over 24 hours. The purpose of this control is to reduce the impact of flows and velocities on channel banks and is normally associated with the City's iSWM development standards. A signed and sealed study by a qualified engineer must be approved by SWM for this credit to be granted. Property owners interested in this credit should meet with SWM staff prior to engaging an engineer to perform the study to understand the engineering analysis required to meet the qualifying standards.

Water Quality Treatment Credit (25% credit)

Up to 25% credit will be given for impervious areas draining to a water quality treatment control BMP that on average annual basis removes 80% TSS or detains the 85th percentile storm (1.5") over 24-hours. A maintenance plan for the BMP is required. A signed and sealed study by a qualified engineer must be approved by SWM for this credit to be granted. Property owners interested in this credit should meet with SWM staff prior to engaging an engineer to perform the study to understand the engineering analysis required to meet the qualifying standards.

Inlet Trash Collection (10% credit)

Up to 10% credit will be given for impervious areas draining to inlet BMP devices that are designed and operated to collect litter and sediment from minor flows of less than one year storm frequency. The inlet BMP devices should not pose additional flooding risks around the inlet area. Approval must be given for the specific design of the fitting, including manufacturer's recommended maintenance and frequency. Annual self-reporting is required.

Parking Lot Sweeping (Minimum 5%, maximum on case-by-case basis)

The 5% credit will be given for a parking lot swept once weekly. More intense sweeping and cleaning in *environmentally sensitive areas* may be eligible for higher levels of credit on a case-by-case basis.

Student Education (10%)

Up to 10% credit will be given to public or private K-12 educational facilities where an average of one hour/student of age appropriate storm water related teaching is provided each year. Eligible topics include: flood protection, public safety and environmental stewardship and other subject material approved by the City. A sample educational template is available from the SWM Water Quality Engineer.

Adopt-A-Creek (5%)

Up to 5% credit will be given to qualifying organizations that commit to clean City waterways for trash. Organizations are encouraged to participate in city-wide cleanup efforts such as the Cowtown Great American Cleanup event while earning credits from this category.

Special Measures (maximum on case-by-case)

Recognizing that there may be measures for water quality improvement not identified in the previously listed category, this category allows awarding credit for special measures that are supportive of broader storm water management goals and objectives. These include measures that solve or improve water quantity and quality concerns for which the City has encountered various feasibility constraints. Credit under this category will be awarded on a case-by-case basis. In many cases, a signed and sealed study by a qualified engineer must be approved by SWM for this credit to be granted. Property owners interested in this credit should meet with SWM staff prior to engaging an engineer to perform the study to understand the engineering analysis required to meet the qualifying standards.

Fees

No fees are required to submit an application for a storm water credit. The cost of administering this program will be borne solely by SWM.

Application for Credits

All applicants must complete the attached Application for Storm Water Fee Credit. Industrial facilities applying for the Industrial Permit Compliance credit must also complete the Supplemental Industrial Permit Information form. All required attachments indicated in the forms or specified above must be included for the application to be considered complete.

The initial review of Storm Water Credit Applications will be completed within 60 days of the receipt of the application form and required documentations. The application forms will be checked for completeness and accuracy. If deficiencies are found during the review, a deficiency letter or email will be sent to the applicant. Upon receipt of required additional information, the review will resume and be completed within 60 days of receipt of additional information. Upon qualifications, a letter or email will be sent to the applicant notifying them of approval of the credit. The storm water utility fee reduction will be applied to the next regular billing cycle.

Inspections

Upon application for a credit, the applicant shall grant the City a right-of-entry to inspect the site at any time to verify the information submitted and to confirm compliance with applicable program requirements. If, after its review or inspection, the City finds the application to be inaccurate or the facility to be out of compliance, the applicant will be notified in writing and given up to 45 days to correct the deficiency. The applicant must provide written documentation to the City within 45 days of the original notice by the City that the facility is now meeting all program requirements along with evidence that the deficiency has been corrected. If the deficiency is not satisfactorily corrected, the fee credit will be terminated on the following billing cycle. The credit suspension will remain in effect a minimum of 6 months, after which time the facility may reapply for the fee credit. The reapplication must include evidence that the deficiency has been corrected and that the facility has been in compliance with the program requirements for at least 3 months prior to reapplication.

APPROVED:

Douglas W. Wiersig — Dec 22, 2014

Douglas W. Wiersig, P.E. — Date

FORT WORTH

Application for Storm Water Fee Credit

(Please Type or Print)

Check One: ☐ This is the first application for credit for this facility.

☐ This is a reapplication for renewed credit after a credit suspension.

PART I

A Facility Information

1. Facility Name:

2. Physical Address of Facility: (enter in spaces below)

Street Number:	Street Name:	Zip Code:

3. Mailing Address: Is mailing address same as above? ☐Yes ☐ If no, provide below

Street Number:	Street Name:	

City:	State:	Zip Code:

B Applicant Contact Information

1. Name:	2. Title:

3. Phone No.: ( ) Ext:	4. Fax No.: ( )

5. E-mail address:

C Credits applied for (check all that apply)

☐ **Industrial Permit Compliance** (complete *Supplemental Industrial Permit Information Form* and include all required attachments)

☐ **Zero Discharge** (submit drainage study by licensed Professional Engineer)

☐ **Detention Maintenance** (submit approved Maintenance Plan)

☐ **Channel Protection Detention** (submit design and calculations sealed by Professional Engineer)

☐ **Water Quality Treatment** (submit design and calculations sealed by Professional Engineer)

☐ **Inlet Trash Collection** (submit drainage map, inlet design details and manufacturer's recommendations for operation and maintenance)

☐ **Student Education** (submit information regarding curriculum and student hours).

☐ **Adopt a Creek** (submit information regarding proposed clean up project, including location of creek or channel, date of activity, number of volunteers expected, and specific support by City forces needed to accomplish project)

☐ **Parking Lot Sweeping** (submit map and schedule showing areas and frequency of sweeping to be accomplished)

FORT WORTH

Storm Water Fee Credit Application

PART II Signature and Approval

I hereby state that the information in this application, including all attachments and supplemental forms, is true to the best of my knowledge and acknowledge that any attempt to purposely supply incorrect information may result in denial of the credit application. I further understand the review of the documents submitted by me may take up to sixty (60) days to complete and that submissions which do not contain the correct information or that are otherwise incomplete will be delayed an additional sixty (60) days after the date the corrected or missing information is provided to the City.

Signature of Applicant	Title	Date

Submit application and all attachments to:
City of Fort Worth
TPW *Storm Water Management Division*
1000 Throckmorton St.
Fort Worth TX 76102

ATTN: Storm Water Utility Fee Review

Case No. _____ SW Act No._____

Credits approved: _____%

Approved by _____ Date _____

Supplemental Industrial Permit Information Form

A	Permit Information

1. Facility Name:
   (as listed on NOI or NEC)

2. TPDES Permit No.: 3. Primary SIC Code: 4. Industrial Sector:

5. Date Industrial Operations Began:
   for current owner/operator
6. Date NOI or NEC Filed with TCEQ:

B	Compliance with Current TPDES Storm Water Permit

1. Have all schedules of the current permit relating to monitoring, training, implementation of Best Management Practices (BMPs) and compliance with the Storm Water Pollution Prevention Plan (SWPPP) been met for the preceding 12 month period?

-or-

For facilities with a No Exposure Certification, have all eleven of the no exposure requirements been met for the preceding 12 month period?

☐Yes ☐No

If the answer is no, provide a summary description of the current permit requirement/schedule that has not been met, cause for non-attainment, compliance schedule, and current efforts to complete this activity (attach additional pages if necessary).

Supplemental Industrial Permit Information Form

C	Attachments

All required attachments must be included for the application to be considered complete (not required for facilities with No Exposure Certification).

ATTACHMENT 1	A copy of your Storm Water Pollution Prevention Plan: Include records for spills, Best Management Practice (BMP) maintenance, training, employee education, periodic inspections, and quarterly visual monitoring for the previous 12 month period. A copy of the permit does not need to be included.
ATTACHMENT 2	Most recent Annual Comprehensive Site Compliance Evaluation Report
ATTACHMENT 3	Annual Hazardous Metals Monitoring (Numeric Effluent Limitations) Have you obtained a waiver from hazardous metals testing for all or a portion of the metals and outfalls? Waivers may be obtained on a metal by metal basis, or on an outfall by outfall basis. ☐ A waiver has been obtained for all metals at all outfalls. Attach a copy of the signed waiver (form TCEQ-10425). ☐ A waiver has been obtained for only a portion of the metals and/or outfalls. Attach a copy of the signed waiver (form TCEQ-10425) and a copy of your most recent results (use EPA form 3320-1). ☐ A waiver has not been obtained. Attach a copy of your most recent results (use EPA form 3320-1).
ATTACHMENT 4	Benchmark Monitoring Report. Not all facilities must conduct benchmark monitoring. No SIC codes in Sectors I, P, R, V, W, X, Z, AB, AC, or AD require benchmark monitoring. Is Benchmark Monitoring required for your facility? ☐Yes ☐No If yes, attach a copy of your most recent Report of Benchmark Monitoring Data submitted to TCEQ (Form TCEQ-20091).

Point System

All sites that wish to receive City stormwater fee credits must provide on-site enhanced water quality protection. Under the integrated Site Design Practice option, sites that accumulate a minimum number of points by incorporating integrated Site Design Practices are considered to have provided enhanced water quality protection.

The point system is made up of three components:

1. The initial percentage of the site that has been previously disturbed sets the minimum requirement. This is shown in the left-hand column of Table F.1.

2. A minimum required total of Water Quality Protection (WQP) points are needed to meet the basic water quality criteria. This minimum is shown in the center column of Table F.1.

3. Optional additional points can be accumulated through additional use of Site Design Practices to be eligible for developer incentives. Each developer incentive attained requires ten (10) additional Site Design Practice points above the minimum required points as shown in the right-hand column of Table F.1.

As shown in Table F.1, the initial percentage of site disturbance sets the minimum required points necessary to meet Water Quality Protection criteria. If a Developer wishes to go beyond this minimum then the number of additional points required to attain specific development incentives is also given.

Table F.1 *integrated* Site Design Point Requirements

Percentage of Site (by Area) with Natural Features Prior to Proposed Development	Minimum Required Points for Water Quality Protection (WQP)	Additional Points Above WQP for Development Incentives
> 50%	50	10 points each
20 - 50%	30	10 points each
< 20%	20	10 points each

The minimum number of points required to achieve WQP, as shown in the center column of Table F.1, depends on the proportion of undisturbed natural features that exist on the site before it is developed. It is assumed that disturbing a site that has little previously disturbed area will cause more relative environmental impact than a site that has already incurred significant site disturbance. Therefore, disturbing a “pristine” site carries a higher restoration/preservation requirement.

For the purpose of this evaluation, undisturbed natural features are areas with one or more of the following characteristics:

- Unfilled floodplain
- Stand of trees, forests
- Established vegetation
- Steep sloped terrain
- Creeks, gullies, and other natural stormwater features
- Wetland areas and ponds

The number of points credited for the use of integrated Site Design Practices is shown in Table F.2. To determine the qualifying points for a site, the Developer must reference Table F.2 and follow the guidance for each practice in the *Planning Technical Manual*.

Using the area of the site that is eligible for a practice as a basis, points are given for the percent of that area to which the integrated Site Design Practice is applied. For example, if a planned site has four (4) acres of riparian buffer and the Developer proposes to preserve two (2) acres, then the site would qualify for 50 percent of the 8 credit points for iSWM Site Design Practice 2 (Preserve Riparian Buffers), because 50 percent of the site design

practice was incorporated. The actual points earned for iSWM Site Design Practice 2 would be 4 points (0.50 * 8 pts = 4 pts). To comply with water quality protection and to apply for site design credits, the Developer must submit the completed table and associated documentation or calculations to the City.

The Water Quality Protection Volume requirement is encouraged but not mandatory in the City, except as may be required by Tarrant Regional Water District for new facilities connecting directly with the Trinity River.

Table F.2 Point System for *integrated* Site Design Practices

*i*SWM Practice No.	Practice	Percent of Eligible Area Using Practice	Maximum Points	Actual Points Earned (% practice used * max. points)
Conservation of Natural Features and Resources				
1	Preserve/Create Undisturbed Natural Areas		8	
2	Preserve or Create Riparian Buffers Where Applicable		8	
3	Avoid Existing Floodplains or Provide Dedicated Natural Drainage Easements		8	
4	Avoid Steep Slopes		3	
5	Minimize Site on Porous or Erodible Soils		3	
Lower Impact Site Design				
6	Fit Design to the Terrain		4	
7	Locate Development in Less Sensitive Areas		4	
8	Reduce Limits of Clearing and Grading		6	
9	Utilize Open Space Development		8	
10	Incorporate Creative Design (e.g. Smart Growth, LEED Design, Form Based Zoning)		8	
Reduction of Impervious Cover				
11	Reduce Roadway Lengths and Widths		4	
12	Reduce Building Footprints		4	
13	Reduce the Parking Footprint		5	
14	Reduce Setbacks and Frontages		4	
15	Use Fewer or Alternative Cul-de-Sacs		3	
16	Create Parking Lot Stormwater “Islands”		5	
Utilization of Natural Features				
17	Use Buffers and Undisturbed Areas		4	
18	Use Natural Drainageways Instead of Storm Sewers		4	
19	Use Vegetated Swale Design		3	
20	Drain Runoff to Pervious Areas		4	
	Subtotal – Actual site points earned		100	
	Subtract minimum points required (Table F.1)		-	
	Points available for development incentives			
	Add 1 point for each 1% reduction of impervious surface		+	
	Total Points for Development Incentives			

Development Incentives

The Developer can use integrated Site Design Practice points in excess of the minimum required for water quality protection to qualify for development incentives provided by the City. Additional points can be earned for redevelopment sites. Each reduction of one (1) percent imperviousness from existing conditions qualifies for one (1) site design point. The total points available for development incentives shall be calculated per Table F.2. Each incentive requires ten (10) additional points above the minimum point required to meet water quality criteria, as stated in Table F.1.

A list of available development incentives includes:

1. Narrower pavement width for minor arterials
2. Use of vegetated swales in lieu of curb and gutter for eligible developments
3. Reduced ROW requirements, i.e. Sidewalk/Utility Easements
4. Increased density in buildable area, floor area ratios, or additional units in buildable area
5. Expedited plans review and inspection
6. Waiver or reduction of fees
7. Local government public-private partnerships
8. Waiver of maintenance, public maintenance
9. Stormwater user fee credits or discounts
10. Rebates, local grants, reverse auctions
11. Low interest loans, subsidies, tax credits, or financing of special green projects
12. Awards and recognition programs
13. Reductions in other requirements

The Development Incentives and Integrated Design point system described above are **not** adopted by the City. City development policies, however, encourage the incorporation of stormwater controls for achieving stormwater quality goals through the acceptance of perpetual, limited maintenance of preserved streams and by affording flexibility in placing stormwater quality treatment controls in land required for other purposes such as parks or commercial landscape areas.

The City has adopted a stormwater fee credit system, which provides monthly fee discounts where BMP's are provided. These include credits for the following structural BMP's:

- Water Quality Controls—25% credit
- Channel Protection Detention—10% credit
- Detention Basins—5% credit for maintenance and annual self-inspection in accordance with Private Maintenance Agreement

These credits apply to fees associated with impervious areas treated by these controls. Water quality and channel protection controls must be designed in accordance with standards adopted in this manual.