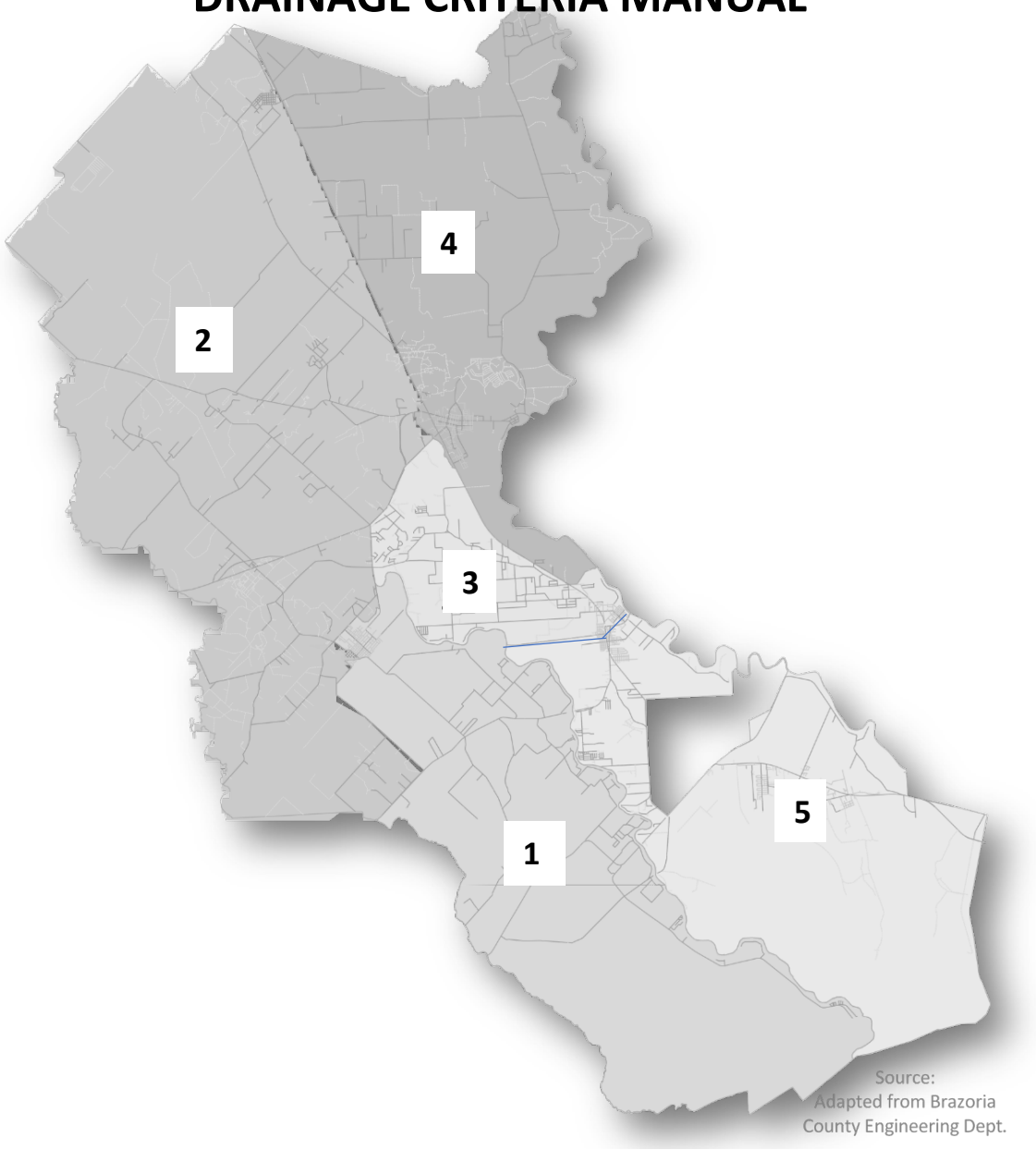
WEST BRAZORIA COUNTY
DRAINAGE DISTRICT NO. 11
DRAINAGE CRITERIA MANUAL



DISTRICT Phone No.: 979.345.4184
Mailing Address: P.O. Box 1227, West Columbia, TX 77486
Website: WWW.WBCDD11.ORG
Date of Latest Revision: 11/04/2019

THIS PAGE INTENTIONALLY BLANK

FOREWORD

INTENT OF GUIDELINES

The West Brazoria County Drainage District No. 11 (DISTRICT) is charged by law to manage the drainage within DISTRICT boundaries. The DISTRICT coordinates with Brazoria County, the Texas Department of Transportation (TxDOT), and various municipalities within the DISTRICT to manage surface drainage in the DISTRICT so as to protect life and property by (i) developing, constructing, and maintaining certain drainage services and facilities; and (ii) assessing private, public, and commercial activities by non-district entities, including but not limited to land survey; land modification; site development; and facility development, repair, replacement, and operation, for adherence to sound engineering practices and DISTRICT and Brazoria County drainage criteria.

To guide the DISTRICT in executing its responsibilities, the DISTRICT adopts and implements various technically based procedures. These procedures provide a framework for evaluation of existing and proposed drainage facilities and drainage-impacting development of land and structures. Implementation of these procedures provides a basis for planning, design, and management of drainage works and facilities across the DISTRICT in a beneficial manner.

DISTRICT OPERATION

DISTRICT operation is exercised by a five-member Board of Directors, each Director representing one of five population-based “Sections” within the DISTRICT. The Board uses Board-selected legal, accounting, and engineering assistance in the exercise of its duties.

Operating funds for the DISTRICT are obtained from several sources, including property taxes authorized by the State Legislature, government grants and awards for which it may be eligible, and fees the DISTRICT charges commercial and similar entities seeking letters of no objection.

RELATION OF DISTRICT AND BRAZORIA COUNTY DRAINAGE REQUIREMENTS

This present WEST BRAZORIA COUNTY DRAINAGE DISTRICT NO. 11 DRAINAGE CRITERIA MANUAL (D11 MANUAL) forms the basis for DISTRICT implementation of its goals and management responsibilities in accord with and supplementary to the Brazoria County Drainage Criteria Manual (BCDC MANUAL).

The D11 MANUAL expands, enhances, details, or provides alternatives to some drainage requirements and processes presented in BCDC MANUAL. Some requirements of the D11 MANUAL are in addition to requirements given in BCDC MANUAL. In the event of conflict between the BCDC MANUAL and the D11 MANUAL, the D11 MANUAL supersedes the BCDC MANUAL unless the DISTRICT determines otherwise.

FOCUS OF DISTRICT DRAINAGE MANUAL

There are voluminous amounts of existing technical publications dealing with drainage management and design. The U.S. Army Corps of Engineers (USACE), TxDOT, and the Natural Resources Conservation Service (NRCS) provide excellent comprehensive manuals and data; such materials provide much information that is not addressed in this D11 MANUAL that may be useful in evaluating and designing drainage in the DISTRICT.

This present D11 MANUAL is not intended to be inclusive; it focuses upon drainage evaluation and design for situations commonly encountered in the DISTRICT. Procedures, methods, and requirements presented are intended to be suitable for drainage issues commonly encountered in the DISTRICT.

Professional engineers with experience in drainage issues will be generally familiar with the procedures, methods, and requirements presented in this D11 MANUAL. When drainage situations of an unusual character are encountered, appropriate support from a registered professional engineer should be used.

REVISIONS TO DISTRICT DRAINAGE MANUAL

Revisions to the D11 MANUAL can be made at any time with the approval of the DISTRICT. Revisions apply to activities or requirements undertaken after the date of revision. Appendix B summarizes revisions to this D11 MANUAL.

SOURCES

The material in this D11 MANUAL is, in part, drawn from previously published materials including the BCDC Manual, the Harris County Flood Control District (HCFCD), the Harris County Engineering Department (HCED), TxDOT reports and manuals, the USACE and its Hydrologic Engineering Center, the National Weather Service (NWS), the Federal Emergency Management Agency (FEMA), and engineering product descriptions published by private business or trade organizations. The DISTRICT acknowledges with appreciation the information obtained from these various sources.

Some of the material presented is original to this document.

NOTATION

To facilitate the use of this D11 MANUAL, abbreviations are defined in each chapter where they first appear and in Appendix A.

PREPARATION

This document has been prepared for the West Brazoria County Drainage District No. 11 by Michael A. Collins, PE (PE # 39270, Firm F-15898)

ADOPTION

This DD11 MANUAL was initially adopted by the Directors of the DISTRICT at its monthly meeting on May 6, 2019.

TABLE OF CONTENTS

APPENDICES

FORMS, FIGURES, EXHIBITS, AND TABLES

FORMS, TABLES, and FIGURES appear at the end of the chapter in which they are first referenced. EXHIBITS are embedded in the text of chapters where they are first referenced.

FORMS

EXHIBITS

TABLES

FIGURES

THIS PAGE INTENTIONALLY BLANK

CHAPTER 1. DRAINAGE GOALS AND ACTIVITIES

1-1 LEGISLATIVE AUTHORITY AND DISTRICT COORDINATION

The West Brazoria County Drainage District No. 11 (DISTRICT) is a separate and distinct governmental body with certain taxing and regulatory authority. It coordinates with Brazoria County to provide review and comment upon land surveys and activities or proposals for development or modification of drainage or flood impacting facilities within the boundaries of the DISTRICT. The DISTRICT coordinates and supports the Brazoria County Engineering Department in drainage management within the boundaries of the DISTRICT.

1-2 SOURCE OF AUTHORITY

Assessment of drainage conditions and impacts by the DISTRICT recognizes the following elements of the Texas Water Code:

1-2.1 TEXAS WATER CODE CHAPTER 11 SECTION 11.021

The Texas Water Code Section 11.021 states that the water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the stormwater, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is the property of the state. Water imported from any source outside the boundaries of the state for use in the state and which is transported through the beds and banks of any navigable stream within the state or by utilizing any facilities owned or operated by the state is the property of the state.

1-2.2 TEXAS WATER CODE CHAPTER 11 SECTION 11.086

The Texas Water Code Sections 11.086 states that no person may divert or impound the natural flow of surface waters in Texas, or permit a diversion or impoundment to continue, in a manner that damages the property of another by the overflow of the water diverted or impounded. A person whose property is injured by an overflow of water caused by an unlawful diversion or impoundment has remedies at law and in equity and may recover damages occasioned by the overflow.

1-3 DISTRICT GOALS

The DISTRICT seeks to manage and control drainage and drainage-affecting activities in a manner that avoids or significantly reduces adverse impacts of both small- and large-scale flooding or drainage inadequacies, whether they be actual or potentially adverse impacts. Adverse impacts can occur in situations involving overland flow drainage, small drainage ditches or channels, small to large natural or man-made drainage works, watercourses, and facilities used to control or regulate drainage within the boundaries of the DISTRICT.

Adverse impacts of potential concern to the DISTRICT include damage or harm to people; homes, farms and farmland; and crops, livestock and livestock grazing; and business and commercial facilities. Prevention, elimination, or reduction of adverse impacts of inadequate drainage or flooding is done within a framework that recognizes not only potential harm but also the value of community growth and development.

1-4 MANAGEMENT APPROACH

The DISTRICT is divided into five sections of approximately similar population. Each of the five sections has a section Director. The Directors compose the DISTRICT Board.

Each director has responsibility for identifying drainage conditions and issues of concern within his or her section. Activities within sections are brought to the attention of the DISTRICT Board as a whole as may be necessary by regular reports from individual directors.

The Board identifies needs and actions and provides authorization of specific activities as may be necessary to address drainage-related issues.

The DISTRICT uses a registered professional engineer and other technical and legal professionals on an as-needed basis to assist the DISTRICT in the exercise of its duties. Activities identified for the DISTRICT may be executed on behalf of the DISTRICT by the DISTRICT'S Engineer. All activities by the DISTRICT'S Engineer are subject to review, approval, or voidance by the Board.

1-5 DISTRICT ACTIVITIES

DISTRICT drainage management goals and objectives are sought through specific requirements associated with the planning, design, or operation of actual or potential drainage projects or drainage-affecting activities.

In general, a "project" is an activity or group of related activities that modify or have the potential to modify or control runoff from an area, impact streamflow, or change flooding conditions. The DISTRICT, with the possible assistance of the District Engineer, reviews and assesses existing and proposed drainage conditions to prevent or limit adverse drainage impacts and improve existing drainage conditions by undertaking specific actions, including the following:

1-5.1 DRAINAGE IMPACT ASSESSMENT

With the assistance of its Engineer, the DISTRICT (i) assesses current and proposed drainage conditions to identify those conditions which do or could adversely affect existing or future drainage; and (ii) may institute actions to remedy adverse drainage conditions. The DISTRICT performs the following activities as may be needed to assess impacts upon drainage conditions:

a. Review of a land survey intended for official recording with Brazoria County.
b. Review and assessment of proposed modifications of existing drainage conditions and facilities.
c. Review and assessment of proposed new drainage works and facilities.
d. Review and assessment of the operation or maintenance of drainage facilities.

The DISTRICT may undertake assessment actions at the direction of Board members or the request of the general citizenry with the approval of Board members. Such assessment may result in specific activities or actions, including possible drainage project design and construction by the Board.

1-5.2 LETTERS OF NO OBJECTION

Review and assessment of proposed actions by individual citizens or commercial entities commonly utilize "Letters of No Objection."

Issuance of a Brazoria County building permit or record filing of certain types of surveys for a particular "project" requires that the DISTRICT provide to Brazoria County a "Letter of No Objection." The request for a Letter of No Objection by the DISTRICT is made by an "Applicant." The request is accompanied by submission of certain documents for technical review by the District Engineer.

Upon the District Engineer's finding of no significant adverse impact by the proposed project, a "Pre-Construction Letter of No Objection" is issued for subsequent submission to Brazoria County to obtain building or grading permits. If a potentially significant adverse impact is identified or there exists

adverse impacts that could occur, no Pre-Construction Letter of No Objection is issued. Suggestions may be made by the DISTRICT or District Engineer as to how objections may be addressed.

After construction of the project in question, compliance to the Plans for the proposed project is, in general, confirmed by review of the constructed project by the District Engineer and subsequent issuance of a "Post-Construction Letter of No Objection." Chapter 4 discusses Letters of No Objection in more detail.

1-5.3 COORDINATION

As part of its review and assessment activities, the DISTRICT coordinates with the Brazoria County Engineering Department, the Brazoria County Office of the Administrator for Floodplain/911 Management, the Texas Department of Transportation (TxDOT), and the cities and communities within the DISTRICT to address drainage issues as may arise from time to time.

1-5.3.1. Municipalities

Potential issuance of a Letter of No Objection for projects in unincorporated municipalities and villages are the responsibility of the DISTRICT, but the DISTRICT may look to such entities for assistance in identifying activities which may require a Letter of No Objection.

For projects or issues within incorporated municipalities in Brazoria County, the DISTRICT can and commonly does support these municipalities in assessing drainage impacts in particular situations. At the general direction or specific request of an incorporated municipality, the DISTRICT may evaluate a drainage project, issue, or concern for the purpose of possible issuance of a letter of no objection. Depending upon the results of the evaluation, the DISTRICT may issue a letter of no objection.

Incorporated municipalities currently within District coordinates are:

a. The City of Brazoria
b. The City of Sweeny
c. The City of West Columbia

It is the responsibility of the incorporated municipality to bring to the attention of the DISTRICT the need for drainage reviews by the DISTRICT within its municipal boundary.

1-5.3.2. Floodplain Management and the Office of the Brazoria County Floodplain Administrator

Review of projects in regard to modification of floodplains outside the boundaries of incorporated municipalities is the responsibility of the Brazoria County Office of the Administrator for Floodplain/911 Management. The DISTRICT commonly includes in its assessment of a project an informal review for compliance to floodplain regulations; should noncompliance to floodplain regulations be identified, such noncompliance may be noted and drawn to the attention of Brazoria County.

Within incorporated municipal boundaries, the DISTRICT, as part of its review for issuance of Letters of No Objection, assists the municipality regarding floodplain modifications when requested to do so by the municipality.

Technical details regarding floodplain management are provided in Chapter 5.

1-5.3.3. Texas Department of Transportation

The DISTRICT maintains an informal interaction with TxDOT. The DISTRICT notes to applicants for Letters of No Objection that drainage discharges to TxDOT drainage facilities require TxDOT approval.

1-5.3.4. Brazoria County Engineering Department

The DISTRICT interacts with the Brazoria County Engineering Department on an informal basis to identify and exchange technical information and provide technical support as appropriate for compliance to County development regulations.

The DISTRICT refrains from formally exercising its powers of review for drainage channels paralleling and draining county roadways and which lie in Brazoria County right-of-way; such drainage channels are considered the responsibility of Brazoria County.

1-5.3.5 U.S. Army Corps of Engineers

The United States Army Corps of Engineers (USACE) has authority over major outfall creeks and rivers within the District Boundaries. These major drainageways are formally identified as a "Water of the United States," and include the following:

- Brazos River
- St. Bernard River
- Bell Creek
- Caney Creek
- Jones Creek
- Mound Creek
- Varner Creek

Modifications to these waterways (themselves, not the adjacent floodplain) require the approval of the USACE. The authority of these drainageways extends to a distance of 20 feet beyond the limits of the water level corresponding to the ordinary highwater mark. Note that the highwater mark recognizes higher tide level waters in tidally affected portions of the above-listed waters.

1-5.4 INSPECTION, IMPROVEMENT, AND MAINTENANCE ACTIVITIES

DISTRICT Directors regularly perform inspections of drainage conditions within their respective sections.

To maintain the conveyance (i.e., flow carrying capacity) of drainage ditches and similar waterways, the DISTRICT regularly cleans and removes accumulated sediments and excess vegetation from ditches and other similar waterways under its authority.

Under the direction of a DISTRICT Director, the District Engineer performs technical and associated studies of potential drainage improvements. Such improvements may be initiated by a Director him- or her-self or at the request made to the Section Director by an interested party.

1-5.5 WATERSHED PLANNING

The DISTRICT performs studies and possible resulting construction projects which provide major improvements to drainage of commonly flooded land.

The DISTRICT also coordinates with ad-hoc groups seeking particular drainage improvements.

It is the DISTRICT Directors' policy to meet as a DISTRICT Board at the end of each fiscal year to evaluate activities undertaken during the year and identify new goals, needed improvements, and plans for the coming year.

1-5.6 ACTIVITIES NOT WITHIN DISTRICT RESPONSIBILITIES

The DISTRICT does not undertake the following activities:

a. Maintenance of drainage ditches and facilities on Brazoria County right-of-way.
b. Maintenance of drainage ditches and facilities on TxDOT right-of-way.
c. Construction and maintenance of ditches not in DISTRICT easements or rights-of-way. However, maintenance of critical drainage ditches for which easements or rights-of-way are unclear or not present may be undertaken at the discretion of the DISTRICT.

1-5.7 OTHER ACTIVITIES

This guidance in this DD11 MANUAL is not intended to disallow activities or projects not addressed in this D11 MANUAL if potential adverse drainage-related impacts are brought to the attention of the Board, assessed by the DISTRICT, and appropriately addressed by the project owners or their agents. The Board should be contacted regarding activities, projects, assessments, procedures, or techniques not specifically discussed or addressed in this D11 MANUAL.

1-5.8 CONFLICTS

Conflicts of information presented in this D11 MANUAL shall be resolved by the BOARD or the District Engineer.

1-6 RESPONSIBILITY IN DESIGN AND PROFESSIONAL ENGINEER INVOLVEMENT

While not required for all projects, professional engineer design or construction is required for many projects. When planning or design documents for projects requiring professional engineer preparation, such documents, by law, must be signed and sealed by a professional engineer.

When plans or design documents that require professional engineer preparation, preliminary versions of such plans or documents, if identified as “Not for Construction” (or similar), can be submitted for review by the DISTRICT without professional engineer sealing. Issuance of a letter of no objection, however, must be based upon submission of a signed and sealed set of plans or documents to the extent that they deal with drainage or drainage-impact features of a project. Plans and drawings can be submitted in a format acceptable to both the engineer and the DISTRICT.

Figure 1-1, developed by the Texas Board of Professional Engineers, summarizes whether or not a professional engineer registered in Texas is required when a Texas project involves the design, erection, construction, enlargement, alteration, repair of, or the creation of plans and specifications for a building. Such buildings are for convenience referred to a registered Texas Professional Engineer (Tx-PE)-Required-Project.

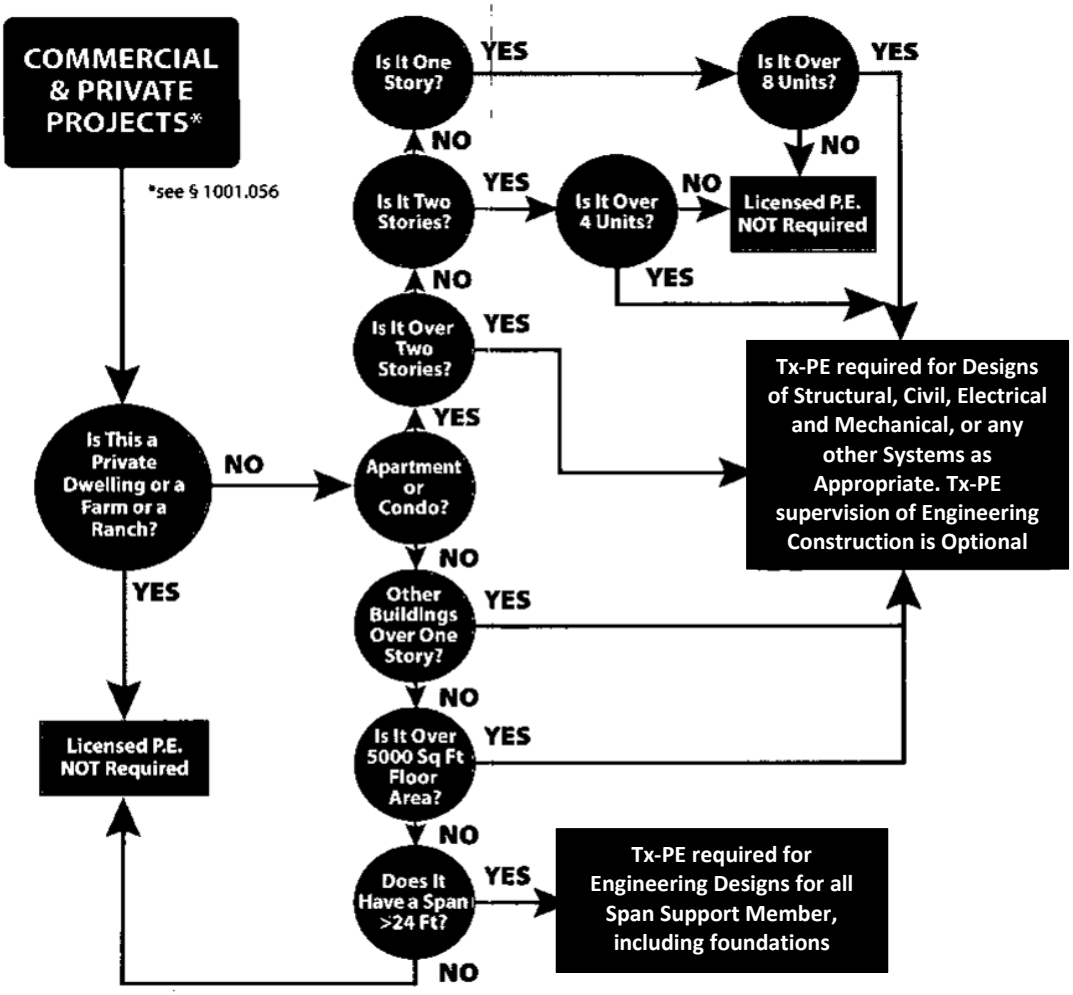
If a project involves an existing, anticipated, or proposed building or structure that can affect drainage when such building or structure is part of a Tx-PE-Required-Project, the DISTRICT requires that a Tx-PE professional engineer sign and seal final plans or as-built plans submitted for review for possible issuance of a letter of no objection.

1-7 GUIDANCE VS. SPECIFICATION

The material of this D11 MANUAL is intended to provide only guidance and general description of requirements for development of projects. This implementation of this guidance for a particular project provides a basis for generally describing what the DISTRICT considers suitable and acceptable for project design, construction, and implementation. This guidance does not replace or supersede judgments and decisions made by a Tx-PE for suitable project design, construction, and implementation.

HIS PAGE INTENTIONALLY BLANK

FIGURE 1-1: FLOW CHART FOR DETERMINING IF PROFESSIONAL ENGINEER IS REQUIRED FOR COMMERCIAL AND PRIVATE PROJECTS



Source: Adapted from Tx Board of Professional Engineers brochure

FIGURE 1-1: FLOW CHART FOR DETERMINING IF PROFESSIONAL ENGINEER IS REQUIRED FOR COMMERCIAL AND PRIVATE PROJECTS

HIS PAGE INTENTIONALLY BLANK

CHAPTER 2. POSSIBLE PROJECT IMPACTS

2-1 IMPACTS GENERALLY DESCRIBED

In general, a project is an activity or group of related activities that modify or have the potential to modify runoff from an area, impact streamflow, or change flooding conditions. While each project is unique, various projects may have features that can be the source of adverse impacts. Projects need to be implemented, designed, or operated in such a way as not to cause such impacts. Identification of potential adverse impacts is essential to developing a project that has no or only limited impacts.

Impacts may be beneficial or adverse. The West Brazoria County Drainage District 11 (DISTRICT) focuses on potentially adverse impacts but will recognize possible beneficial impacts in evaluating whether the DISTRICT will have no objection to a proposed project. If positive impacts are significant, the project's engineer should bring such impacts to the attention of the DISTRICT and the District Engineer.

If project conditions or implementation is determined or reasonably expected to have adverse drainage or flooding impacts, measures to prevent such adverse drainage or flooding effects must be included as part of the project.

Once potential adverse impacts are identified, mitigation of a project or project design can be undertaken to identify, design, or implement mitigation actions, design, or construction. Technical features of projects for mitigating adverse impacts commonly rely upon evaluation of hydrologic and hydraulic behavior of rainfall, runoff, and flow in conveyance and storage facilities; such behavior is described in Chapter 6 (Selected Hydrologic Methods) and Chapter 7 (Selected Hydraulic Methods).

If no significant adverse impacts are identified, then project evaluation regarding other non-drainage or flooding factors can proceed.

In short, impact assessment identifies potential runoff and flooding problems that a project may create, while mitigation encompasses actions to eliminate or significantly reduce potential runoff and flooding impacts of an existing or proposed project if such mitigation were not undertaken.

Adverse conditions produced can include the depth (or the presence) of flooding, duration of flooding, and frequency of flooding. Associated impacts from flooding can include excessive channel or ditch erosion, excessive soil deposition, loss of or damage to property, loss of life, loss of livestock, and loss of crops or inability to harvest crops

2-2 IMPACT IDENTIFICATION

Impacts can be diverse. It is the project owner's or his or her representative (usually the engineer for the project) responsibility to develop, design, and operate a project so as to remove potential adverse impacts. The DISTRICT reviews existing, proposed, or constructed projects to seek assurance that adverse impacts have been addressed in design, construction, or operation of a project.

The following describes in general terms types of adverse impacts that may occur.

2-2.1 SITE-BASED IMPACTS

Adverse impacts can arise from a proposed project site because of changes in the amount, rate, and frequency of runoff from a project site.

2-2.1.1 Increase in Site Runoff Rate or Volume

Stormwater discharges from the project site (as defined by the survey or similar geographic boundaries) may increase the discharge above that currently existing for the project site.

An increase in site runoff rate is evidenced by an increase in discharge, particularly peak discharge, because runoff occurs at a faster rate, reaches its peak more quickly, or discharges from a site more rapidly.

An increase in site runoff may also be reflected in an increase in the total volume of runoff because of increased imperviousness due to project construction.

Increased frequency of runoff of a particular magnitude may also occur because peak discharges are increased for rainfall events of unchanged frequency of occurrence.

2-2.1.2 Increase in On-Site Flooding or Ponding

Depending upon how drainage is managed for a proposed project, some areas of a site may become subject to greater flooding if drainage is retained on the site and not allowed to eventually flow from the site as it does under existing conditions.

2-2.2 DISCHARGES TO RECEIVING WATERS BEYOND PROJECT SITE BOUNDARIES

Drainage related effects and impacts beyond the bounds of a project site can include:

2-2.2.1 Flooding at and Near Off-project Site

Discharges from the project site can increase flow amounts or depths in the receiving water near the site in amounts such that the received waters at and near the project site suffer flooding or adverse flooding related behavior (e.g., channel erosion; overflow of roadways; frequency of flood conditions).

2-2.2.2 Downstream Impacts

Adverse impacts from project site discharges to receiving waters downstream (either a short or long distance) of the project site or from near-site receiving waters conveying project waters to downstream areas. Common impacts include increased river discharge for floods of similar frequency and consequently increased areas of inundation by floodwaters. If the peak discharge from a proposed development (in comparison to existing conditions) is increased, increased discharge peaks can be expected to be larger downstream.

Larger downstream peak discharges will increase the level of downstream flooding. To the extent that the proposed project increases the volume of flood and flood frequency, such increases can also be expected at downstream points. Discharges from the project site can increase flow amounts or depths in the ditches, channel, etc. downstream of the project in sufficient amounts to produce adverse impacts downstream of the project site.

2-2.2.3 Upstream of the Project Site

Discharges from the project site can increase flow amounts or depths in the ditches, channel, flood-lands, floodplains, etc. upstream of the project site in quantities sufficient to produce adverse impacts upstream of the project site. Discharges to near-site receiving waters can hydraulically impede flows from upstream areas. Such impediment causes a “backwater” effect which increases the flood water levels upstream of the near-site receiving waters. Such increases can result in expanded flooding of upstream areas.

2-3 IMPACTS OF VARIOUS SPECIFIC ACTIVITIES

The following summarizes various activities which may directly or indirectly adversely impact drainage conditions:

2-3.1 LAND SURVEY

Lands that are to be developed for commercial purposes, such as but not limited to, multiple residents (i.e., a subdivision or apartment complex), industrial, or commercial purposes can significantly affect future drainage conditions.

Consequently, potential drainage from such lands requires availability of land for appropriate drainage facilities. The District, therefore, requires that survey for commercial purposes that easements and rights-of-way be identified, both existing and proposed, be identified on the survey.

Requirements for surveys for private owners done for noncommercial purposes are given special considerations and exemptions; see the discussions in Chapters 4-10 and 8-2.

More specific information about establishing easements and rights-of-way are provided in Sections 4-10 and 8-3.

2-3.2 CHANGES IN LAND SURFACE AND DRAINAGE LAYOUTS

Changes in imperviousness, fill, blockage of runoff, creation of low areas, and redirection of runoff paths can all affect the amount and magnitude of runoff, particularly peak rates of runoff, by affecting the speed and duration of runoff. Runoff evaluation is described in Chapter 6.

Land surface and drainage system changes may result from development of new or modification of existing buildings and facilities, particularly because of flow redirection and increased imperviousness.

2-4 OUTFALLS

Outfalls are the devices, structures, and similar means by which a flow conveyance delivers flow to a downstream conveyance, termed the receiving water, such as a ditch, creek, or river. The outfall typically concentrates drainage waters from upstream into a single, isolated stream of flow into the receiving water.

Outfalls of DISTRICT-managed waters may discharge to:

a. Other downstream DISTRICT waters.
b. Ditches or drainageways through which the DISTRICT has a legal right, by easement or similar agreement, to discharge.
c. Ditches and channels in easements or rights-of-way operated by Brazoria County.
d. Ditches and channels in easements or rights-of-way operated by Texas state agencies (commonly, TxDOT).
e. Streams or rivers under federal control, such as the U.S. Army Corps of Engineers (USCOE).

When designing a project, the receiving water for an outfall needs to be recognized so that appropriate approvals or permissions can be secured.

2-5 FLOODPLAIN MODIFICATION

Modifications of land or structures or development of new structures in zones subject to regular flooding on a frequent or infrequent basis can affect flooding conditions by altering the following:

a. The area over which flooding may occur.

b. The volume of space available for temporary storage of floodwaters.
c. The amount and duration of flooding.
d. The depth of flooding.
e. The speed of the floodwaters.
f. Deposition or erosion of sediments and soils in flood-prone areas.

Any of these factors can endanger life and contribute to damage to buildings, facilities, vehicles, and the lands on which such buildings, facilities, vehicles, and lands are found.

Chapter 5 discusses in more detail how floodplain issues are addressed in regard to development or other activities in floodplains.

CHAPTER 3. MITIGATION TECHNIQUES

3-1 PURPOSE

Mitigation is the process of managing runoff from a project site to eliminate, all or in part, the adverse impacts of changes in runoff from a project site due to changes in the amount, rate, or frequency of runoff caused by proposed drainage-impacting projects or project modifications:

Common features of a project which can potentially produce adverse impacts have been discussed in Chapter 2. This chapter discusses common and not so common strategies to mitigate (i.e., reduce the adverse impact) of proposed projects or project modifications.

3-2 BASIS FOR COMPARISONS OF IMPACTS

Because runoff from a storm event varies widely from event to event, it is necessary to have a common point of comparison to assess the adverse impacts from project development. Consequently, comparisons are usually made with the following assumptions:

3-2.1 SIMILAR METROLOGIC BEHAVIOR

a. Similar metrological frequency of rainfall events.
b. Similar metrological duration of rainfall events.
c. Similar metrological frequency of site runoff.

These requirements are virtually always satisfied if the pre- and post-project rainfall characteristics are the same.

3-2.2 SIMILAR HYDRAULIC CONTROLS AND RECEIVING WATER CONDITIONS

Similar hydraulic controls and receiving water conditions usually include:

a. Similar tailwaters and other downstream water levels.
b. Similar receiving water discharges.

3-2.3 STORM EVENTS TO ANALYZE

For most DISTRICT projects, if discharge control is to be utilized, two storm events of a particular frequency of occurrence must be evaluated: One storm is for existing conditions, and one storm is for proposed conditions. As a minimum, a 100-yr storm event must be analyzed. Additional analysis of smaller event frequencies (e.g., 25-yr or 10-yr storm event) is also recommended or may be required.

3-3 COMMON MITIGATION STRATEGIES

There are three classes of actions that can be instituted to address adverse impacts:

a. Controlling site runoff.
b. Mitigating increased site runoff to offsite lands adjacent to or nearby the site prior to the runoff reaching a receiving water.
c. Mitigating the adverse impacts of increased runoff that reaches receiving waters.

or some combination of these above three.

Method b will rely upon some of the same methods as method “a” as well as upon the ingenuity of the design engineer in developing the offsite mitigation. Acts “a” and “c” are discussed in the following.

3-3.1 CONTROLLING SITE RUNOFF USING PONDS

Mitigation by controlling site runoff is achieved by limiting the peak discharge from the project site such that the peak discharge after project development is less than or equal to the peak discharge before project development.

Temporary storage of runoff waters is the most common method of reducing the peak discharge from a project site. Ponds are commonly used to provide storage of runoff waters.

There are three types of ponds: retention, detention, or a combined retention-detention pond:

a. **Retention ponds** receive flow inputs from rainfall, runoff, and direct discharges from some alternative source (e.g., pumping from a distant source). Retention ponds purposely retain most of the water inputs. Water levels in retention ponds vary slowly if at all. If pond levels become too high, water is usually drained using automatically discharging structures (e.g., a weir) to return water levels to normal levels. Detention ponds are used for a variety of purposes, including aesthetics, water quality, and facilitating detention pond design or construction in vertically limited areas.
b. **Detention ponds** receive flow inputs from rainfall, direct runoff, discharge from inflowing creeks, streams, and similar upstream sources, and from pumping from an upstream source. Waters accumulating in a detention pond are intentionally slowly discharged to lower the water level in a relatively short period (e.g., 24 to 48 hours). Detention ponds are used as a mitigation device.
c. **A combined retention-detention pond** is composed of a lower portion of the pond intended to serve as a retention pond and an upper portion of the pond designed to serve as a detention pond.

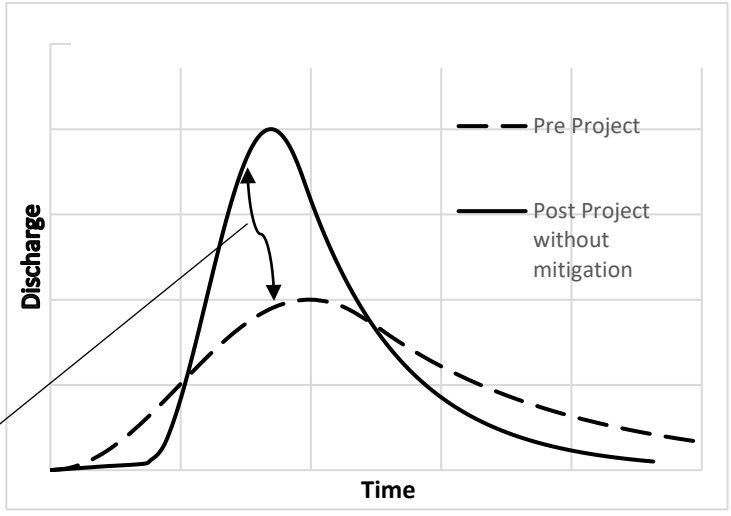
3-3.2 DETENTION STORAGE

The following discusses features to evaluate or consider in design ponds for detention storage.

3-3.2.1 Required Storage

The required storage volume of a pond to reduce peak post-project discharge to peak pre-project discharge is the positive volume of water between the inflow hydrograph volume for the inflow hydrograph for flow into the pond and discharge hydrograph from the pond site before pond construction. Exhibit 3-1 illustrates the pond volume required.

Storage volume = area between Pre-project and Post project Conditions for zones where curve for Post project without mitigation greater than curve for Pre-project conditions



The hydrographs are determined using the methods described in Chapter 6. Computation of the volume is commonly numerically done using small increments of time to computed discharge differences and then summing the positive differences over the duration of the storm event.

3-3.2.2 Pond Geometry

A detention pond should consist of three zones: an active storage zone (as determined from detention-storage calculations), a zone for the accumulation of sediments, and a freeboard zone.

To provide effective operation of a detention pond, the pond should have the following characteristics:

- To promote adequate drainage from the pond, the pond bottom should have a minimum 0.05% slope toward the discharge point of the pond.
- The minimum depth of the active storage zone of the pond below surrounding natural ground should be a minimum of 9 inches
- Storage space should be provided in the pond below the minimally required volume to store sediments that may drain into the pond; this storage space should be adequate to contain a minimum of five years of accumulated sediments or should be at least as much as 5% of the detention storage requirement.
- The pond should have a minimum freeboard of 3 inches

The surface area of the pond (at full depth) shall be at least 50 square-feet (sq-ft).

Ponds can be formed by direct excavation, widening of ditches, or blocking of flow paths.

3-3.2.3 Controlling Pond Discharge

A variety of means can control discharge from a detention pond. Whatever means is selected, appropriate hydraulic evaluation or analysis should be provided that demonstrates to the District Engineer the necessary control of the discharge from the pond. Common control devices include:

- Orifice plates and short lengths of small diameter pipes.
- Long lengths of small or moderate diameter pipes.
- Hydraulic gates and valves.
- Pumps with depth control operation.

3-3.2.4 Drainage Rates for Detention Ponds

Drainage from a detention pond should not be so fast as to have the peak discharge from the pond exceed that which existed for the site before pond construction. Subject to that limitation, ponds should have drainage devices such that the pond will empty in less time than necessary to have the necessary storage for the next rainfall event. Within the DISTRICT, the drainage time for the mitigation volume should be less than 96 hours from the start of the rainfall event that initiated the initial filling of the pond.

3-4 ALTERNATIVES TO DETENTION PONDS

Use of a detention pond, while extremely frequent, may sometimes be undesirable because of lack of available space, cost, or the need to use pumping for pond drainage. Alternatives to traditional detention storage may be suitable where (1) open space is limited, (2) contiguous open space is limited, (3) vertically limited topography occurs, (3) improved aesthetics are sought, (4) more environmentally friendly development is sought, (5) lesser cost is sought, (6) maintenance requirements are less demanding, or (7) engineering demonstration of effectiveness is more straightforward.

An alternative to a detention pond is acceptable to the DISTRICT if the alternative is adequately demonstrated to the DISTRICT to be effective. Such demonstration can be based upon actual documented experience in other situations, compliance with design standards provided by the

manufacturer of the alternative (if appropriate), or engineering evaluation or calculations showing the efficacy of the alternative.

Alternatives are presented in Tables 3-1 to 3-5.

3-5 MAINTENANCE OF MITIGATION CONTROLS

The use of various mitigation techniques, to remain effective, must be maintained. Adequate maintenance is required and expected by the DISTRICT in its issuance of a letter of no objection for a particular project. Failure to provide appropriate maintenance can result in the voiding of a letter of no objection.

The type and amount of maintenance vary with the type of mitigation control being used. Irrespective of the type of control, however, maintenance inspections should, at a minimum, be conducted at least annually, and appropriate corrective actions should be undertaken when needed.

Demonstration of adequate maintenance can be provided by unannounced inspection and record keeping of maintenance activities.

Common maintenance activities include the following:

- Replenishment of grass and similar vegetation when grass and other needed vegetation dies.
- Moving and removal of excessive grass or vegetation from channels and ponds.
- Repair of eroding surfaces.
- Removal of accumulating sediments and trash.
- Cleaning of clogged pipes and other discharge facilities.
- Repair of hydraulic structures, such as collapsing pipes.
- Repair or replacement of failing concrete or other hardened material on the channel bottom or side slopes.
- Servicing and assuring the operation of mechanical equipment.

3-6 MITIGATING RECEIVING WATER IMPACTS

Adverse impacts of increased runoff from a project site can possibly be mitigated by modifying the receiving water. Possibilities include the following:

3-6.1 MODIFYING RECEIVING WATER GEOMETRY

In this approach, the geometry or the channel roughness of the receiving water is modified in such a manner that maximum post-project levels do not exceed pre-project conditions.

For example, a received water creek is modified to make it deeper or wider so that post-project water levels are less than pre-project levels. If widening or deepening of a receiving water is proposed, regulatory approval of such widening or deepening by the agency in charge of the management of the receiving water, e.g., the West Brazoria County Drainage District 11 (DD11), US Army Corps of Engineers (USACE) must be obtained.

Evaluation of conditions in a ditch or creek that undergoes geometric modifications or other modifications that affect channel conveyance will typically require a hydraulic backwater analysis (see Chapter 7). A starting water level must be estimated at a point downstream of the project site. Backwater calculations start at this starting downstream level and proceed upstream sufficiently to and beyond the project site to a point where pre- and post-project waters become closely similar.

The pre- and post-project water levels would recognize the pre- and post-project channel configuration and pre- and post-project site runoff conditions.

3-6.2 MODIFYING UPSTREAM DISCHARGE

In this approach, flow controls are constructed upstream such that discharges to the river reach receiving the site runoff are impeded. The controls reduce the flows sent downstream from those existing before the modification. For example, a ponding area in the upstream channel might be constructed to slow flows sent to downstream points.

Such channel modifications would require a backwater analysis to show both beneficial and lack of adverse impacts. Care must be exercised to be sure that the controls do not adversely impact conditions farther upstream.

3-6.3 MODIFYING DOWNSTREAM CHANNEL CONDITIONS

Downstream channel controls or facilities might be constructed to reduce downstream water levels and consequent upstream water levels. Downstream modifying condition options would, in general, be expected to be limited, though, for example, downstream flow diversion might be used.

Care must be exercised to be sure that the controls do not adversely impact conditions farther downstream. Impacts of controls or facilities would require a backwater analysis to show both beneficial and lack of adverse impacts.

THIS PAGE INTENTIONALLY BLANK

TABLE 3-1. SOME METHODS TO MITIGATE INCREASES IN RUNOFF RATE OR VOLUME USING SURFACE STORAGE METHODS

METHOD	DESCRIPTION	POSSIBLE ADVANTAGES	POSSIBLE DISADVANTAGES
Traditional detention pond	Constructed pond or pond-like area to which runoff drains and from which stored water is slowly released. Discharge from a pond may be by gravity flow, pumping, or a combination of gravity flow and pumping	Easy to design and construct if sufficient land area and natural land slopes are present	Regular maintenance to assure non-filling of pond by sediment is needed. Effective drainage. Conducive to mosquitoes
Combined detention-retention pond	Two-layer pond storage system with variable depth detention in the upper layer and an approximately constant volume retention zone in the lower layer	Can contribute to visual enhancement of development site	Maintenance review to assure retention system remains ecologically healthy
Alternative /multiple outflow control structures	Selection of an outlet control structure (e.g., weir, pipes, multiple structures) to minimize peak discharge for the same detention volume; can include combination of structures	May facilitate use of more effective surface ponding	May require more complex design, evaluation, and construction
Mini ponds/ multiple ponds	Use of many smaller ponds rather than one large pond to avoid one large pond.	Adaptable to situations where site use is spread out and non-uniform	Total pond volume may be more than a single large pond; more analysis to judge effectiveness
Local surface ponding	Ground elevations used to intentionally form small, local ponding areas	Little construction needed; cost usually small.	Demonstration of effectiveness is difficult
Inline Storage	Conduits carrying runoff are oversized to create additional storage for runoff	May require less land surface areas; can be used in conjunction with other techniques	May increase drainage cost significantly; may difficult to demonstrate effectiveness

THIS PAGE INTENTIONALLY BLANK

TABLE 3-2. SOME METHODS TO MITIGATE INCREASES IN RUNOFF RATE OR VOLUME USING CHANNEL AND DITCH STORAGE

METHOD	DESCRIPTION	POSSIBLE ADVANTAGES	POSSIBLE DISADVANTAGES
In-channel storage	Widening of channel or ditch beyond minimal necessary for flow conveyance in order to extra provide space for storing runoff waters	Can sometimes be less expensive to implement	Detailed hydraulic analysis necessary to demonstrate effectiveness
Pond-channel chains	Several separate sequential ponds connected by pipes, channels, or ditches	Flexibility of pond locations	Detailed hydraulic analysis necessary to demonstrate effectiveness
Underground detention or storage	Any device (tank, enlarged pipe, gallery of pipes, etc. lying below the surface which captures rapid inflow and slowly drains the captured water away. Commercial system with special designs are available	Useful where surface area is limited.	Drainage of tank may be difficult where topography very limited.
Pipe galleries	Closely spaced rows of pipes to which runoff water are directed before most downstream pipe discharges runoff.	Can provide large amount of out of sight storage if gallery large	Detailed hydraulic analysis needed to demonstrate effectiveness if manufacturer data unavailable

THIS PAGE INTENTIONALLY BLANK

TABLE 3-3. SOME METHODS TO MITIGATE INCREASES IN RUNOFF RATE OR VOLUME USING SURFACE STORAGE AND SURFACE FLOW IMPEDIMENTS

METHOD	DESCRIPTION	POSSIBLE ADVANTAGES	POSSIBLE DISADVANTAGES
Mini-dams	Low height obstructions along flow drainage paths to accumulation water in small ponds along flow path behind each mini-dam (e.g., traffic bumps) and slow the rate of runoff	Can be adaptable to parking or open storage type areas	Obstructions and localized ponding may be objectionable or unacceptable; may be difficult to demonstrate effectiveness
Berms	Low height (typically earthen) obstructions across open drainage areas to promote ponding or diversion of runoff and slow rate of runoff	Easily constructed and in right situations; relatively inexpensive	Detailed hydraulic analysis necessary to demonstrate effectiveness
Parking lot storage	Use curbing and pavement sloping to create shallow ponding areas where runoff waters can temporarily be stored	Reduces need for other types of storage	Must be carefully designed to assure effectiveness
Diversion for Other Uses	Capture some of runoff and divert for other on-site purposes	Reduces required mitigation by other means	Erratic availability of diverted water

THIS PAGE INTENTIONALLY BLANK

TABLE 3-4. SOME METHODS TO MITIGATE INCREASES IN RUNOFF RATE OR VOLUME USING ENHANCED INFILTRATION

METHOD	DESCRIPTION	POSSIBLE ADVANTAGES	POSSIBLE DISADVANTAGES
French drains	Small diameter storm drains with perforations to allow water to drain into soil from pipe; pipe bedding to be highly permeable	Out of sight below ground drainage	Have limited capacity, particularly in flat topography
Modular pavement and grass areas	In areas subject to light vehicle traffic, use interlocking zones of pavement separated by zones of grass or pebbles.	Can enhance esthetic appearance	Limited capacity to reduce runoff
Infiltration trenches	Trenches with highly pervious material bottoms so that water draining into trench will more readily drain into underlying soil	May be useful in areas where open space limited	Capacity evaluation necessary; maintenance checks essential
Porous pavement	Specialized payment material for roadways and walkways which has both structural strength and high infiltration capacity	Makes effective use of required hard surface areas	Must combine with appropriate subsurface soils and possible drainage systems
Intervening vegetation	Use vegetation where hard surfaces are not needed to facility infiltration	Allows enhanced infiltration	Regular upkeep of vegetation necessary
Increased impervious-ness	Replace more impervious surface soils with high pervious surface soils in areas receiving large amounts of runoff.	Allows enhanced infiltration	Design must be carefully accomplished
Bio-swale or bio-infiltration fields:	Swales or large managed areas with vegetation and soil which enhances infiltration into channel bottom. Multiple swales could be considered.	Allows enhanced infiltration	Regular and careful maintenance and evaluation of effectiveness necessary
Vegetation management	Use vegetation in open areas where pavement surfaces are not needed to enhance infiltration. Maintain, enhance, or expand areas of vegetation to slow runoff and increase infiltration	Adaptable to large and small areas.	Careful choice and maintenance of vegetation necessary.

THIS PAGE INTENTIONALLY BLANK

TABLE 3-5. SOME METHODS TO MITIGATE INCREASES IN RUNOFF RATE OR VOLUME USING RUNOFF AND HYDRAULIC CONTROLS

METHOD	DESCRIPTION	POSSIBLE ADVANTAGES	POSSIBLE DISADVANTAGES
Ground slope / contour management	Modification or ground slope and drainage paths to increase lengths of drainage paths and increase time of concentration	Easily implemented on some sites	Must have suitable open area
Drainage path rerouting	Change in location and/or direction of drainage paths to lengthen paths and increase time of concentration	Easily implemented on some sites	Care must be taken where rerouting to occur
Drainageway roughing	Increase surface roughness of drainage path to slow the speed of runoff	Easily implemented on some sites	Roughening must be chosen to be long lasting
Swale filling	Fill small drainage ditches and swales with large diameter rock to allow water to drain but only at slow rates	Easily implemented on some sites	Capacity for large flows limited; overall increase in size of swale may be necessary.
Increased vegetation on overland flow areas or in drainage channels	Increase vegetation such as thick grass to slow speed of overland flow	Inexpensive	Maintenance may pose problems
Retention of swamps, sloughs, or natural or natural-like vegetative obstruction	Retain areas of natural flow accumulation and impediment to slow speed of runoff	Low cost option; environmentally less impacting	Loose land for development; animal life may be nuisance or dangerous

THIS PAGE INTENTIONALLY BLANK

CHAPTER 4. LETTERS OF NO OBJECTION

4-1 LETTER OF NO OBJECTION

A Letter of No Objection (LNO) is a written statement issued to an Applicant (the person or other entity requesting an LNO) by the West Brazoria County Drainage District 11 (DISTRICT) stating that the DISTRICT has no objection to a project because of known or anticipated drainage conditions caused by, arising from, modified by, impacting, aggravating, or otherwise produced by the project proposed or subsequently constructed by the Applicant.

A project is a tract, subtract, lot, or sub-lot of land and/or the structures and/or facilities, if any, on the tract, subtract, lot, or sub-lot proposed, delineated, or constructed by the Applicant.

Application for an LNO may be made by an authorized representative of the Applicant.

An LNO is issued on behalf of the DISTRICT by the District Engineer but is subject to review or revision by the DISTRICT Board of Directors (Board). The Board may void any LNO issued by the District Engineer. The BOARD may override a recommendation made by the District Engineer.

4-2 BRAZORIA COUNTY REQUIREMENTS

An LNO is required by Brazoria County (County) to obtain certain county construction or construction-related permits, regulatory exemptions (as specified by the County), or other such authorization or designations as may be specified by the county.

4-3 DISTRICT REQUIREMENT FOR LETTER OF NO OBJECTION

For any project involving or affecting drainage or flooding, an LNO is required for:

a. Any commercial or non-residential project.
b. A residential project with a residential building footprint over 5000 ft-sq.
c. Land surveys, unless exempted by DISTRICT, that (i) could potentially cause an adverse impact, (ii) involve a sale to a commercial entity, (iii) divide a tract into more than four parts with at least one subpart less than 10 acres in size, (iv) lack adequate right-of-way or setbacks, or (v) do not meet COUNTY requirements for survey pertaining to a “small subdivision” as defined by the COUNTY.
d. Any structure or facility the DISTRICT determines to require an LNO.

A commercial and/or non-residential project includes a building, facility, or tract of land used for (i) industrial, commercial, or business purposes, (ii) federal, state, county, or city purposes or services, (iii) public- or community-activities or services, (iv) for a park or cemetery, or (v) by religious, charitable, or non-profit organizations.

An LNO is not required for the following:

a. Residential single-family home or duplex (and attached structures such as a garage) with building footprint less than 5000 square-feet (sq-ft).
b. Non-residential farm or ranch building with a footprint less than 5000 sq-ft, including but not limited to (i) barns; (ii) out-buildings; (iii) service, repair, or storage buildings similar structures not connected to a residential single-family home or duplex.

If a residential single-family home or duplex and nearby (within 250 ft) non-residential farm or ranch buildings have a combined footprint of more than 5000 sq-ft, the combined structures shall be required to have an LNO.

4-4 PARTS OF A LETTER OF NO OBJECTION

An LNO which is not an LNO for Land Survey (LNO-Survey) issued by the DISTRICT consists of two parts:

a. Pre-Construction Letter of No Objection referred to as a Pre-Construction LNO.
b. Post-Construction LNO referred to as a Post-Construction LNO.

4-4.1 PRE-CONSTRUCTION LNO

In the context of an LNO, PLANS mean surveys, project descriptions, engineering plans, computations, engineering reports, as-built drawings, applicant submitted materials in support of an application for an LNO, written responses to questions from the District Engineer about a project, and other such documents as related to or describing drainage and drainage-related conditions or facilities of the project.

A Pre-Construction LNO is issued by the District Engineer on behalf of the DISTRICT (i) after review of PLANS submitted by the Applicant and a consequent determination by the District Engineer that the proposed project is compliant with drainage and drainage-related requirements of the COUNTY and the DISTRICT, and (ii) when the DISTRICT or the District Engineer has no objection to construction or other execution of the project as depicted and described in the PLANS and related documents submitted to the District Engineer, subject to the following:

a. Fees required by the District for a Pre-Construction LNO application are paid in full.
b. If the exercise of the Pre-Construction LNO for construction purposes is not accomplished within six months of the date of issuance of the Pre-Construction LNO, the Pre-Construction LNO shall become void unless such time this limitation is revised in writing by the District Engineer or the DISTRICT.

4-4.2 POST-CONSTRUCTION LNO

A Post-Construction LNO is issued by the DISTRICT to the Applicant after the Applicant provides demonstration to the District Engineer that (i) the project, in so far as project features and facilities relate to, are affected by, or affect project site drainage conditions, drainage or flooding on, to, or from lands upstream, or drainage or flooding on, to, or from downstream lands is constructed in substantial compliance with PLANS submitted by the Applicant for issuance of a Pre-Construction LNO.

4-4.3 LNO FOR LAND SURVEY

A Letter of No Objection for a land survey (“LNO-Survey”) can be issued by the DISTRICT upon request by an applicant who shall be the entity for whom the survey is being done if the application is for

a. A completed or proposed survey that neither shows or implies modification to existing drainage conditions on the site

and/or

b. The survey is for a tract of land which meets Brazoria County requirements for division of a “small subdivision”

Other survey-only related situations will be considered on a case-by-case but will be treated as if they are being done for commercial purposes unless information is provided to justify treatment as a non-commercial situation.

The format for an LNO for Land Survey shall be at the discretion and convenience of the Board and its Engineer.

Application for an LNO-Survey shall include the following information to be provided to the District Engineer:

- A copy of the survey (or preliminary information about the survey location if for a proposed survey) accompanied by a simple regional map showing the survey site in relation to named state or county roadways.
- Administrative information as identified for an LNO-Survey (Form 4-43 at the end of this chapter.)

The fee payable to the DISTRICT for application for possible issuance of an LNO-Survey shall be the same as that for site inspection for a pre-construction LNO (see Table 4-1) unless such survey is for noncommercial purposes. There shall be no fee for a survey done solely for non-commercial purposes.

No post-LNO survey (analogous to a **POST-CONSTRUCTION LNO)** shall be required.

4-5 REQUIREMENTS FOR COMPLIANCE

Substantial compliance to the Pre-Construction LNO shall be demonstrated by a least one of the following:

a. An engineer's seal with signature and date of signature on as-built drawings demonstrating, in so far as drainage issues are concerned, that the project is in substantial agreement with the PLANS as submitted for issuance of the Pre-Construction LNO.
b. An executed Post-Construction LNO issued by the DISTRICT or District Engineer that the constructed project, in so far as drainage issues are concerned, is in substantial compliance with the PLANS as submitted by the applicant for purposes of issuance of a Pre-Construction LNO.
c. Other such specific demonstration as may be required or specified by DISTRICT or the District Engineer.

4-6 DEMONSTRATION OF COMPLIANCE

The demonstration of compliance shall be at the choice of the District Engineer.

The District Engineer may elect not to require a Post-Construction LNO. If the District Engineer makes such election, the Applicant will be notified of such election prior to or at the time of issuance of the Pre-Construction LNO.

If demonstration of compliance is achieved for a required Post-Construction LNO, the DISTRICT or District Engineer shall issue a Post-Construction LNO.

4-7 POST-CONSTRUCTION LNO ISSUANCE

issuance of a Post-Construction LNO shall be contingent upon the following requirements:

a. Fees required by the DISTRICT for a Post-Construction LNO application are paid in full.
b. Materials and activities for demonstration of compliance are provided to the District Engineer within 45 days after completion of project construction unless the District Engineer increases the time for such provision.

c. Other such requirements that may be required by the District Engineer.

4-8 FAILURE OF DEMONSTRATION

If a Post-Construction LNO is not obtained by an Applicant within the allotted timeframe, the District Engineer will (i) inform the BOARD and (ii) request that the BOARD request that Brazoria County:

a. Not issue for the project any or all operating permits, occupancy permits, or utility service permits.
b. Revoke for the project all operating permits, occupancy permits, or utility service permits.

4-9. LNO DOCUMENTS

Sample LNO letters and an administrative information form used in the application for an LNO are provided at the end of this chapter.

4-10 PROCESS OF OBTAINING LETTER OF NO OBJECTION

To obtain an LNO, the following process is to be used. Failure to follow this process may result in a significant delay in the evaluation and potential issuance of an LNO.

The Applicant or Applicant's representative may perform any or all of the necessary steps to seek an LNO. The District Engineer cannot serve as a representative of a project requiring an LNO. The District Engineer cannot serve as the engineer for a project for which an LNO is sought unless such service is approved in advance by the BOARD.

4-10.1 PRE-CONSTRUCTION LETTER OF NO OBJECTION FOR A PROJECT

For the application for a Pre-Construction LNO, the following steps should be undertaken:

The Applicant or Applicant Representative makes contact (e.g., by telephone) with the Director of the DISTRICT section in which the proposed project lies and tells him of his/her desire to apply for an LNO. If the Applicant does not know in which the DISTRICT section the project or survey lies, the Applicant should contact the President of the DISTRICT Board. Contact information is provided on the DISTRICT's webpage.

After discussion with a Director, the Applicant will usually be directed to the District Engineer (to contact by phone or email). After being contacted, the District Engineer will discuss the project in question only if the Applicant has already spoken to a Director. In some cases, a Director will have the District Engineer initiate contact with the Applicant. The District Engineer will not conduct consultation or initiate a plan review of a project for which the Director has not been made aware by the Applicant of the proposed project.

The Applicant shall identify to the District Engineer the single point of contact for communications between the Applicant and the District Engineer. The District Engineer shall not be responsible for communicating with Applicant parties other than the single point of contact identified by the Applicant.

Upon proper procedural contact with the District Engineer by the Applicant, the District Engineer will provide the information to the Applicant for making an application for an LNO and submitting necessary information and fee in support of the application.

4-10.1.1 Information To Be Provided For Pre-Construction Letter Of No Objection Application

The Applicant or his/her representative should expect to provide as a minimum the following information over the course of the review process:

a. A completed administrative information sheet (a blank is provided in Form 4-2 and can also be provided by the District Engineer).
b. Identification of the single point of Applicant contact and contact information for the project.
c. An initial, brief description of the proposed project, including its physical address.
d. A simple location map sufficient to determine the approximate location of the project in reference to nearby roadways.
e. Payment to the DISTRICT of necessary fees.
f. Detailed documents (usually engineering plans) with supporting computations describing or otherwise defining the existing drainage and the proposed drainage for the project. (Only drawings related to drainage conditions and site layout are necessary.) Supporting calculations for drainage behavior and proposed mitigation (if any) should be provided.
g. Written responses to written questions and/or comments the District Engineer may have as a result of the review of the plans should be provided in a timely fashion.

The time to perform the necessary review for possible issuance of a Pre-Construction LNO will depend in part upon (i) project complexity, (ii) clarity, detail, and completeness of drawings, and (iii) completeness and clarity of supporting calculations as they may relate to drainage and mitigation. Failure of the Applicant to provide reasonable time for performance of the review by the District Engineer is not a cause for the issuance of a Letter of No Objection.

4-10.2 PRE-CONSTRUCTION LETTER OF NO OBJECTION FOR SURVEY: LNO-SURVEY

If the project in question is a survey without inclusion or modification of drainage or construction of a structure and a request is made for an LNO, the LNO letter shall be a Letter of No Objection-Survey (LNO-Survey).

An LNO-Survey must be requested by the Applicant. Requests by Brazoria County personnel on behalf of the Applicant are insufficient for issuance of an LNO.

Information to be provided for an application of an LNO-Survey must provide is identified in Section 4-4.2.. See also Section 4-4.3 and Form 4-3 for additional details.

4-10.3 EXEMPTIONS FROM PRE-CONSTRUCTION LNO REQUIREMENTS

If a person or other entity seeks exemption from the requirements for an LNO as may be required by the DISTRICT, the property owner or developer may notify the DISTRICT or the District Engineer and state the basis for the exemption. If the DISTRICT or the District Engineer does not agree with such exemption, the property owner or developer cannot use such exemption as a reason for not applying for an LNO.

4-10.4 POST-CONSTRUCTION LETTER OF NO OBJECTION FOR A PROJECT

The Applicant will be notified by the time of issuance of a Pre-Construction LNO that a Post-Construction LNO shall be required if such post-construction letter of no objection is to be required. The District Engineer may waive the requirement for a post-construction letter of no objection based upon the character of the project for which a pre-construction LNO was issued.

If a post-construction LNO is required, the Applicant will provide the following before the necessary post-construction review by the DISTRICT or District Engineer is undertaken:

a. An updated administrative information sheet (if changes in information have occurred).
b. Identification of the single point of Applicant contact and contact information to use for the Post-Construction review process. The contact information for the post-construction activities shall be

assumed to be the same as that for the pre-construction activities unless notice of change is given to the District Engineer.

c. A set of as-built (or similar) plans or drawings as may pertain to drainage and drainage conditions at the site of the constructed project. Failure to provide such as-built documents shall be considered a basis for non-issuance of the post-construction LNO. The District Engineer may waive or simplify the as-built plan or drawing requirements.
d. The District Engineer may require a site inspection of the completed project by the District Engineer by his representative(s). Failure to allow such inspection shall be considered a basis for non-issuance of the post-construction LNO.
e. The project shall be considered to have been completed as of the date of completion of construction and post-construction clean-up (or equivalent) for the site or other such date as agreed upon between the Applicant and the District Engineer.
f. Payment to the DISTRICT of necessary fee.
g. Other such information that may be required by the District Engineer. The as-built drawings shall be provided in a timely fashion to the District Engineer. The Applicant shall provide adequate and timely access to the constructed project site for site inspection by the District Engineer or his/her representative of the project as completed if requested by the District Engineer.

FORM 4-1. FEES FOR LETTERS OF NO OBJECTION AND ASSOCIATED ACTIVITIES

PRE-CONSTRUCTION LNO		
Facility/Type LNO	Fee	Comments
Request for LNO for Pipeline Crossing or other Utility Line Crossing	$750.00	Applies to <u>each</u> crossing of waterway, water body (as identified by the District Engineer), or water storage unit. Fee does not include fee for on-site inspection.
Pipeline or Utility Line Site Inspection	$500.00 per inspection, If determined necessary by the District-Engineer, or requested by Applicant	Applies to each individual crossing. Transport to a site (if off a paved road) for inspection shall be provided by the Applicant.
Request for LNO for Commercial Facility (Includes all non-residential facilities)	$500.00	Fee does not include more than 2 site inspections
Request for LNO for (i) solely Residential Facility of any size OR (ii) non-commercial survey for purposes of subdivision only	$0.00	No fee for residential facilities
Site Inspections for Pre-Construction LNO Purposes	$400.00, If determined necessary by the District-Engineer, or requested by Applicant	Per visit in excess of 2 visits
Change in Administrative Information Form and information	$50.00	Required if new information is necessary for LNO review and/or change in contact information and/or change in applicant representative
POST-CONSTRUCTION LNO		
Facility/Type LNO	Fee	Comments
Required or Requested Post-Construction LNO	$500.00 (per site)	For pipelines, applies to <u>each</u> crossing of waterway, water body, or water storage unit identified in Pre-Construction LNO.
Site Inspection of Commercial Facility or other nonresidential project/site for post-construction LNO purposes.	$500.00 (per site)	Per visit in excess of 1 visit
LNO for solely Residential Site of any size	$0.00	No fee for residential facilities
The Board reserves the right to apply additional fees if special or unusual conditions as determined by Board or the District Engineer exist.		

Fees should be paid by check or money order to: <u>West Brazoria County Drainage District No. 11</u>

and delivered by mail, express mail, or hand-delivered to:

West Brazoria County Drainage District No. 11, Attention: M. Ducroz

P.O. Box 1227, West Columbia, TX 77486

Project Identification (name) should be provided on check notation. Do not send fee to District Engineer.

THIS PAGE INTENTIONALLY BLANK

FORM 4-2. DRAINAGE DISTRICT 11 APPLICANT ADMINISTRATIVE INFORMATION FORM

- Complete this form (original or copy) and return to (1) Email: **michael.collins1492@gmail.com** OR (2) Michael Collins, DD#11 Engineer, 3530 County Road 580, West Columbia, TX 77486
- Form must be completed before evaluation of application can be started.
- If changes occur, resubmit the information form with $50.00 fee.

TO BE FILLED OUT BY APPLICANT	Please Type or Print with Clarity
Name of project as Assigned by project Applicant (Reference in all correspondence, emails, etc. with DD#11 Engineer) Use in all correspondence	
Owner of project: Name, Title, Company (if applicable), Mailing Address, Phone No.	
Applicant Representative: Name of (person submitting application or request for site inspection; can be same as owner.) Correspondence & questions concerning application will be directed to the applicant only.	
Applicant's Representative Contact Information (company name, title, phone no., mailing address, email address) Email is generally the preferred method of contact.	
Physical mailing address of project site (do not give PO Box).	
Nearest intersection of Federal, State, or county roads, with approximate distance and direction from project site (example: Hwy 36 & CR 903 at 1500 feet to southwest)	
Type of project: check closest description. If unsure mark other and provide short description: OTHER:	__ Pipeline __Commercial __ RV park __Residential ___Non-Commercial __Nonresidential
Project solely within official limits of a city (yes or no)? If yes, name city	
Signature of Applicant Representative/ Date (Required for complete application	
(For fees, see Form 4-1)	

FOLLOWING TO BE FILLED OUT BY DISTRICT ENGINEER		
Project Name and project No		
Comments by District Engineer		
Date of Pre/Post-construction Letter of No Objection Issuance (if issued)	Pre	Post
Reviewed by District Engineer		

Mailing Address for DIRECT CONTACT (IF NEEDED) with the DISTRICT:
West Brazoria County Drainage District No. 11; Attention: M. Ducroz; P.O. Box 1227; West Columbia, TX 77486

THIS PAGE INTENTIONALLY BLANK

FORM 4-3. PRE-CONSTRUCTION LETTER OF NO OBJECTION

(Completed by the District Engineer or the Board of the West Brazoria County Drainage District 11)

PRE-CONSTRUCTION LETTER OF NO OBJECTION

West Brazoria County Drainage District No. 11

This Pre-Construction Letter of No Objection is provided for the following: **WBCDD11 project No.:**

PROJECT NAME	
BASIS OF ISSUANCE (Discussion, email data, plans, reports, etc.)	
PROJECT SITE and/or DESCRIPTION and/or SITE DESCRIPTION	
APPLICANT (Name as on application)	Name: Organization:
OWNER and/or OWNER REPRESENTATIVE	Name: Title: Company:
LIMITATION(S) if any	1. Use of this Pre-Construction Letter of No Objection for obtaining construction permits from Brazoria County must be exercised within **6 months** of date of issuance. **Date of Issuance**: 2.
POST-CONSTRUCTION LETTER OF NO OBJECTION	_____ Will **NOT** Be Required _____ Will **BE REQUIRED**. Applicant requirements for as-built materials to be completed within **45** (Other: _____) days after completion of construction
NO OBJECTION CONFIRMATION	Michael A. Collins, PE, Engineer for the West Brazoria County Drainage District, issues this PRE-CONSTRUCTION LETTER OF NO OBJECTION on behalf of the West Brazoria County Drainage District for the above-described project. Michael A. Collins, PE 39270, Firm F-15898

Copies to:
Applicant Representative:
Director, Section Number
Mary Peter Cudd, Legal Counsel

THIS PAGE INTENTIONALLY BLANK

FORM 4-4. POST-CONSTRUCTION LETTER OF NO OBJECTION

(Completed by the District Engineer or the Board of the West Brazoria County Drainage District No. 11)

POST-CONSTRUCTION LETTER OF NO OBJECTION

West Brazoria County Drainage District No. 11

This Pre-Construction Letter of No Objection is provided for the following: **WBCDD11 project No.:**

PROJECT NAME	
BASIS OF ISSUANCE	____As-built drawings submitted on: ____ Site inspection(s) done on: ____ Other:
PROJECT SITE LOCATION / DESCRIPTION	
APPLICANT	Name: Organization:
OWNER and/or OWNER REPRESENTATIVE	Name: Title: Company:
POST-CONSTRUCTION LETTER OF NO OBJECTION REQUIRED BY PRE-CONSTRUCTION LETTER OF NO OBJECTION DATED:	
DATES OF NOTICE OF SUFFICIENCY /INSUFFICIENCY OF DEMONSTRATION OF COMPLIANCE AND REMEDY MADE	The Applicant has demonstrated sufficient compliance with the requirements for issuance of a Post-Construction Letter of No Objection, as evidenced by the following No Objection Confirmation.
NO OBJECTION CONFIRMATION	Michael A. Collins, PE, Engineer for the West Brazoria County Drainage District, issues this POST-CONSTRUCTION LETTER OF NO OBJECTION on behalf of the West Brazoria County Drainage District for the above-described project. Michael A. Collins, PE 39270, Firm F-15898

Copies to:
Applicant Representative:
Director, Section Number
Mary Peter Cudd, Legal Counsel

THIS PAGE INTENTIONALLY BLANK

FORM 4-5. DISTRICT GUIDELINES FOR LETTER OF NO OBJECTION TO LAND SURVEY

INTRODUCTION

The West Brazoria County Drainage District 11 (DISTRICT) requires a Letter of No Objection (LNO) for a proposed Project for which drainage modifications may occur or be expected. In some cases, the Project in question may involve a Land Survey solely as defined herein. In such cases, there are modified requirements for obtaining an LNO which replace the requirements for an LNO for a Project for which drainage modifications are expected. An LNO issued pursuant to these modified requirements is termed a Letter of No Objection-Survey (LNO-Survey).

DEFINITIONS FOR THESE GUIDELINES

Commercial Entity: A person operating as a business or a group or association of persons, companies, or corporations collectively acting as a single party for the purpose of conducting or commissioning a land survey. Any entity that is acting on behalf of a commercial entity is considered a commercial entity.

Division of Property: The decomposition of a tract of land into more than one sub-tract, the combining of more than one tract into a single tract, and/or the realignment of the boundaries of subtracts within a larger tract.

Drainage Easement: A defined portion of a tract of land, commonly a linear strip of at least a 15-foot width, that is or is to be used to facilitate drainage across a Property, such easement being delineated on a Property Survey registered with Brazoria County.

Land Survey: A metes and bounds delineation by a State of Texas licensed surveyor or engineer to (i) divide a land tract into two or more smaller adjoining tracts, (ii) realign or create the boundaries of adjoining subtracts to form a single, larger tract, (iii) create a single tract from combination of one or more adjoining tracts, or (iv) is some combination of these three.

LNO-Survey: A letter of no objection for a land survey as described in these guidelines.

Non-Commercial Entity: A party that is not a commercial entity.

Owner: The person or party that legally owns a Property for which a land survey is conducted or commissioned.

Property: The physical land upon which a survey is or is to be conducted.

APPLICABILITY

An LNO-Survey issued pursuant to these Guidelines must meet the following requirements:

a. The Land Survey is done or commissioned by a noncommercial owner or entity.
b. The Land Survey does not alter previously defined easements.
c. The Land Survey does not describe, prescribe, or imply changes in drainage behavior or land modifications which would result in changes in drainage behavior.
d. Commercial activities are not performed on the Property. (Agricultural or farming product sale by a property owner to the general citizenry by direct walk-in is not considered a commercial activity for these Guidelines if the facilities for such sale do not exceed 5000 sq-ft.

INSURANCE OF LNO-SURVEY

Issuance of an LNO-Survey is contingent on meeting requirements for Applicability identified above and provision of the following: (i) Name, address, and contact information on the Owner, and (ii) location of Property surveyed or to be surveyed in manner, form, and completeness acceptable to the DISTRICT.

THIS PAGE INTENTIONALLY BLANK

FORM 4-6. WEST BRAZORIA COUNTY DRAINAGE DISTRICT NO. 11

Letter of No Objection for Land Survey

This Letter of No Objection-Survey is issued by the West Brazoria County Drainage District No. 11 this

date of application: for the survey of the land tract identified as / described by

and as further described in the **attached copy or facsimile** of the survey (or description of proposed survey if survey not yet performed)

This survey (or proposed survey) is made or commissioned by (property owner or other):

Complete name, address, and contact information (mailing address, email address, phone number) of owner or party commissioning the survey:

This letter is issued under the assumption that the land tract in question meets the following criteria:

- Is done or commissioned by a noncommercial owner or entity.
- Does not alter previously defined drainage easements.
- Does not describe or imply change in drainage paths, structures, facilities, or land modifications which would change drainage behavior.

By dated signature below, the owner or party commissioning the survey affirms the above information.

_____

Signature/ date

All of the above to be completed by owner or party commissioning survey. Incomplete, inaccurate, or unreadable information will require resubmission of information. When completed, forward to West Brazoria County Drainage District No. 11 District Director or Engineer for the District.

Following to be completed by representative of the West Brazoria County Drainage District No. 11:
This Letter of No Objection for Land Survey for the above-described survey is issued by:

_____

Signature of District Director **OR** Engineer for the West Brazoria County Drainage District No. 11 / date
Signed form will be returned to owner or his representative at the above listed contact information.

THIS PAGE INTENTIONALLY BLANK

CHAPTER 5. FLOODPLAIN MANAGEMENT

5-1 BACKGROUND

Areas inundated time-to-time by floodwaters from a watercourse or other water body are generally termed "Flood Prone" areas. Specific areas delineated by governmental bodies, usually the Federal Emergency Management Agency (FEMA), are called for the purposes of this document "Designated Flood Zones." Designated Flood Zones are determined (to varying degrees of accuracy) by hydraulic engineering or similar studies conducted by, on behalf of, or in cooperation with FEMA.

5-1.1 FLOOD PRONE AREA HIERARCHY

For flood management and assessment within the West Brazoria County Drainage District 11 (DISTRICT), the following hierarchy is defined:

EXHIBIT 5-1. CLASSIFICATION OF FLOOD PRONE AREAS

Case	Description
	Designated Flood Zones NOT WITHIN Incorporated Municipalities
1	• Floodplains — Regulated by County
2	• Floodways — Regulated by County
	Designated Flood Zones WITHIN Incorporated Municipalities
3	• Floodplains — Regulated by municipality with possible assistance by DISTRICT
4	• Floodways — Regulated by municipality with possible assistance by DISTRICT
5	Designated Flood Zones WITHIN Incorporated Municipality IF Municipality does not exercise regulatory authority, but DISTRICT identifies on a case-by-case basis an area as a significantly FLOOD PRONE area: DISTRICT treats the area as FLOOD PRONE but not in a Designated Flood Zone (see Case 6 below)
	Areas NOT in Designated Flood Zone but identified as flood prone by DISTRICT on case-by-case basis
6	• WITHIN municipal boundaries — DISTRICT applies standards and requirements it considers appropriate when projects brought to its attention by municipality or observations by DISTRICT BOARD MEMBERS OR THE District Engineer
7	• NOT WITHIN municipal boundaries — DISTRICT applies standards and requirements it considers appropriate when Letters of No Objection sought or issues brought to its attention.

If a project area or its impacts extend into more than one of the above-defined areas, the DISTRICT exercises its powers as it deems appropriate for best drainage management.

5-1.2 DEFINITIONS AND EXPLANATORY NOTES

Flood Prone areas in the DISTRICT include Designated Flood Zones but can also include areas not formally delineated as a Designated Floodplain but which the District understands to have historical, antidotal, or direct evidence that shows evidence of significant or frequent flooding.

Formal delineation of Designated Flood Zones done for defining requirements for development in floodplains must conform to requirements for floodplain management defined in federal and local government regulation; the force of such regulation derives from not only local ordinance but possibly also federal and commercial property insurance requirements associated with property damage arising from flooding.

Within Brazoria County outside of the municipal boundaries of incorporated cities, floodplain management requirements are defined by Brazoria County through the Office of the Administrator for Floodplain/911 Management. These requirements also apply to all towns and villages in Brazoria County except incorporated municipalities. The DISTRICT understands that these floodplain management requirements are administered and enforced by Brazoria County within the county outside of the municipal boundaries of incorporated cities. Such understanding does not preclude the DISTRICT from addressing in an advisory fashion flooding issues it may identify in flood prone areas.

The DISTRICT does not assume floodplain management responsibilities in an incorporated municipality; the DISTRICT considers floodplain management within the corporate limits of an incorporated municipality the responsibility of the incorporated municipality.

Incorporated municipalities may request that the DISTRICT provide guidance in the administration of floodplains and flood prone areas within their corporate boundaries. The DISTRICT may elect to provide or decline such guidance.

However, if the DISTRICT chooses to possibly provide guidance to a municipality to address floodplain issues within the municipality, the DISTRICT does not assume responsibility for floodplain management within the municipality; the responsibility for floodplain management rests with the incorporated municipality. Providing guidance to an incorporated municipality does not exclude the DISTRICT from recognizing floodplain management issues in administration of its drainage management authority.

5-2 SPECIFICATION OF DESIGNATED FLOOD ZONES

FEMA identifies areas subject to flooding based upon the estimated risk of flooding. Within high-risk areas, two zones are distinguished as based upon a base flood condition. The base flood is a large flood selected for regulatory and administrative purposes as a severe flood. For Brazoria County, like many counties, the base flood is a 100-year (100-yr) flood.

The two zones defined within FEMA's high-risk flood areas are the floodway and the floodplain. These two zones compose a Designated Flood Zone.

The floodway is the flow width along the flowline path that has the narrowest width that can occur without raising the base flood level along a river reach more than one foot (this one-foot criterion is set by Brazoria County and may be changed by the County). The rest of the area of inundation lies in the floodplain. The floodway width is determined by detailed hydraulic analysis.

As described by the FEMA Map Service Center, flood zones are geographic areas that FEMA has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. Each zone reflects the severity or type of flooding in the area. The various flood zones are listed in Table 5-1.

5-2.1 CHANGING FLOOD ZONE AREAS

FEMA-delineated floodplains and floodways are delineated on published maps that are accessible by FEMA webpage download or available for inspection at the County Office of the Administrator for Floodplain/911 Management.

However, as new information becomes available or new flood studies are conducted, floodplain maps undergo revision. Since only periodic publication of revised maps is made, the published maps may not show the best available depiction of floodplain conditions.

Brazoria County makes available possibly more up-to-date delineation of flood zone limits. These data can be accessed on the Brazoria County Engineering Office webpage; this possibly more up-to-date information should be used if possible when evaluating flooding conditions at a project site.

5-2.2 INCONSISTENCIES

Data on flood depths or boundaries may sometimes be in apparent disagreement with FEMA floodplain map data. For example, published flood depth at the edge of a floodplain boundary may not match the actual ground level at the boundary. When the DISTRICT is evaluating a specific area in regard to application for a letter of no objection, such inconsistencies should be brought to the attention of the District Engineer for resolution. The District Engineer may confer with the Brazoria County through the Office of the Administrator for Floodplain/911 Management in regard to such inconsistencies. Generally, resolution will favor the more conservative, less risky interpretation of the data. However, to the extent the District Engineer must resolve the identified inconsistencies, it shall be the decision of the District Engineer as to how to resolve the inconsistency.

5-3 RESPONSIBILITIES AND AUTHORITIES

Floodplain management by the DISTRICT depends upon whether or not a project site or other area of concern does or does not lie within an incorporated municipality boundary.

In addressing floodplain management issues within or outside flood prone areas, the following definitions are used:

- Recreational vehicle (RV): A self-motorized, self-propelled mobile vehicle used for recreational and/or residential purposes. Such vehicles do not include mobile vehicles used for commercial purposes; recreational vehicles used for commercial purposes are considered ordinary commercial facilities.

- Mobile Home (MH): A mobile structure used for recreation and/or residential purposes which cannot be moved under its own power, but can only be moved by towing by another vehicle. Such a mobile home vehicle does not include vehicles used for commercial purposes; mobile home structures used for commercial purposes are considered ordinary commercial facilities.

5-3.1 DESIGNATED FLOODPLAIN AREAS IN COUNTY AREAS OUTSIDE MUNICIPALITIES

Within Brazoria County but outside the boundaries of an incorporated municipality, Brazoria County floodplain development regulations as administered by County Office of the Administrator for Floodplain/911 Management apply.

The District Engineer informally coordinates with Administrator for Floodplain/911 Management in the review of an LNO application. The District Engineer may note to an Applicant when a proposed development appears to lie in or close to an area inundated or potentially inundated by the base flood and direct that applicant should contact the County Office of Administrator for Floodplain/911 Management for additional information. It is the responsibility of the Applicant for a letter of no objection to initiate such contact.

5-3.2 DESIGNATED FLOODPLAIN AREAS WITHIN MUNICIPALITIES

Within incorporated municipalities, the municipality has the authority and responsibility to administer floodplain regulations. However, the municipality may turn to the DISTRICT for assistance in the application of floodplain management requirements. Such assistance does not imply the municipality is not responsible for actions it may take in regard to floodplain regulations.

In applying in an advisory fashion floodplain management principles and requirements within municipal boundaries, the District Engineer uses to the fullest extent possible the same requirements as those for Brazoria County outside municipalities.

5-3.3 DEVELOPMENT IN DESIGNATED FLOOD ZONE AREAS

Requirements vary with the location of a Designated Flood Zone area. For areas lying within municipal corporate boundaries and for which the DISTRICT provides guidance in administration of floodplains for the purpose of issuing letters of no objection, the DISTRICT applies the following guidelines for Designated Floodplains; these guidelines are also used in evaluating flooding in non-designated flood prone areas.

5-3.3.1 Facilities in the Designated Floodplain but Not in the Floodway

If a residential structure, commercial structure, public structure, farm structure (not exempted by the DISTRICT), or similar structure is proposed for construction or placement in a designated floodplain but not the floodway, the first-floor elevation of the structure must be at least 2 feet (2 ft) above the based flood level. This requirement does not apply to out-buildings such as small barns and sheds with less than 5000 sq-ft footprint. Other out-buildings may be exempted by the DISTRICT on a case by case basis.

If the structure in the floodplain is a mobile home or recreational vehicle (which is in a movable condition), the two-foot requirement is reduced to 21-inches. A recreational vehicle not in self-movable condition is considered to be the same as a commercial structure.

5-3.3.2 Facilities in Designated Floodway

If any residential structure, commercial structure, public structure, mobile home, farm structure, or similar structure is proposed for construction in a floodway, the structure must meet the same first-floor level requirements as those for facilities in a floodplain but not in a floodway.

In addition, the portion of a residential structure, commercial structure, public structure, mobile home, farm structure (including a barn or shed), or similar structure that lies below the required level of the first-floor level cannot significantly impede or block the flow of floodwaters. A structure, mobile home, or similar structure is considered to substantially hinder the flow if the footprint of the supporting structure (e.g., piers) and attached structures to the supporting structure below the level of the first-floor level block more than 4% of the structure's footprint of the first floor above the base flood level.

Recreational vehicles cannot be located in a floodway for a continuous period in excess of 21 days.

Mobile homes cannot be located in a floodway for a continuous period in excess of 5 days.

In addition, the structure in question must be certified by a Texas-registered Engineer that (i) the structure will not cause a rise in flood levels and (ii) the first-floor level will be a minimum of 24 inches (21 inches for RV's and MH's) above the base flood level, i.e., a "No-Rise Certificate" must be submitted to the DISTRICT by a Registered Engineer in Texas for the structure.

5-3.4 DEVELOPMENT IN FLOOD PRONE AREAS

In Flood Prone areas, information and restrictions for flood conditions not in a Designated Floodplain or Floodway can be recognized by the DISTRICT and District Engineer in the evaluation of projects for which letters of no objection are sought.

5-3.4.1 Modifications in Flood Prone Areas

Modifications to the conditions of a Flood Prone area that can increase the base flood level near a project of interest or upstream or downstream of a project must be mitigated so as to not increase the base flood level at, upstream of, or downstream of the project unless specifically allowed by the DISTRICT. Demonstration of no adverse Impacts from floodplain or floodway modification must be demonstrated by hydraulic modeling or similar backwater evaluation.

Modifications restricted to Flood Prone areas outside the floodplain may, at the discretion of the District Engineer, require demonstration of no adverse Impacts from floodplain or floodway modification using hydraulic modeling or other similar backwater evaluation.

Methods of evaluation must be acceptable to the District Engineer.

5-3.4.2 Major Drainageways

Major drainageways in the DISTRICT are considered to be the same as those identified in Section 1-5.3.5.

5-3.4.3 Minimum Setbacks Along Major Drainageways

Two setback criteria apply to Major Drainageways:

a. The United States Army Corps of Engineers (USACE) requires a 20-feet (ft) setback for any structure or facility from the ordinary highwater mark. The ordinary high water mark is the water level that can be expected to be produced by a body of water in non-flood conditions (Wikipedia, 2019). Facilities, such as seawalls, which do not meet the 20-ft setback requirement, must obtain approval from the USACE.
b. The DISTRICT requires that no fill for a residence, habitable structure, outbuilding (including garages and storage sheds), or vehicle pad (for a vehicle that cannot travel under its own power) be placed within a distance measured from the top of the bank of the major waterway equal to the approximate width (width rounded to the nearest 10 ft) of the major drainageway at the ordinary high water mark; this limitation shall apply only to the extent that such distance would allow complete or partial inundated by a base flood before any fill is placed.

5-3.4.4 Setbacks Along Flood Prone Drainageways

For areas identified as a flood prone area alone a drainageway not considered a major drainage way, no fill for a residence, habitable structure, outbuilding, or any vehicle pad (for a vehicle that cannot travel under its own power) may be placed within the setback distance (as defined for a major drainageway in item b of Section 5-3.4.2 above). However, within this setback distance, structures may be placed upon supporting structures (such as piers or similar supporting structures) provided (i) the finished first floor elevation of the structure or pad is a minimum of 2 ft above the base flood level, and (ii) the total footprint of piers supporting the first floor or pad does not exceed 4% of the area of the total first floor footprint or pad above the base flood level.

5-4 MITIGATION OF DEVELOPMENT IN FLOOD PRONE AREAS

Mitigation can be used to counteract the adverse impacts of activities in flood prone areas and overcome limits for development in Flood Prone areas. Actions proposed for overcoming limits or restrictions to development in Flood Prone areas can be discussed with the District Engineer as to their suitability.

5-4.1 LOSS OF FLOODPLAIN STORAGE

When fill is placed in a floodplain, the volume of the fill at and below the base flood level will reduce the capacity of the watercourse to carry a flood flow. Loss of capacity can cause increased flooding. Loss of storage can be compensated by the following:

5-4.1.1 Alter Watercourse Geometry

Reconfiguration of the watercourse geometry, such as increasing the channel width, can be done. Reconfiguration will require a backwater analysis to demonstrate the desired mitigation and lack of other adverse impacts.

5-4.1.2 Compensation Storage

Adding to floodplain storage by excavating some of the floodplain in an amount which equals or exceeds the volume of fill is a commonly used mitigation technique. The excavated volume must be located near the location of the fill to provide the necessary compensation. Multiple excavated volumes can be used to meet storage requirements. Each selected excavated volume shall:

a. Be on the same side of the floodway as the fill area; if fill is placed on both sides of the floodway, compensating storage must be provided on both sides of the floodway.
b. Not be in the floodway.
c. Be within approximately 0.5 miles of the fill location.

In addition, the excavation volume to be used for compensation must meet the following requirements:

a. Have an elevation no lower than the elevation of the flowline of the bottom of the watercourse in which the floodway occurs directly opposite of the excavated volume.
b. Have a bottom level at or above the normal water table elevation. The normal water table elevation shall be that elevation at any time of determination not less than 72 hours after flood or rain waters have inundated the excavation site. Previously collected data (to be made available to the District Engineer) or hand- or machine-dug test holes can be used to determine normal water table elevation if the proposed maximum depth of the excavated volume is less than 6 feet (ft).
c. If the depth of the excavated volume is proposed to exceed 6 ft, a minimum of one soil boring at the excavation site shall be made to determine whether the normal water table elevation is less than 6 ft below the land surface. If the normal water table is less than 6 ft below the land surface, the proposed excavated compensation volume cannot be used as an excavated compensation site with a proposed depth greater than 6 ft.
d. Excavation volume below 6 ft or below the water table can occur, but cannot be used in determining compensation storage.

5-4.2 FLOOD FLOW BLOCKING

In addition to possible loss of floodplain storage, structures such as berms, dikes, elevated pads, bridges, and roadways can block or speed passage of floodwaters or other natural drainage. If such blockage has not been recognized in the determination of floodplains or floodways (as might be the case if such blocking structures were constructed after the determination of the floodplain and floodway locations), mitigation of their impacts, beyond provision of compensation storage, may be necessary. Methods to reduce blocking effects include the following:

a. **Removal of Blockage:** Remove the structure causing the blockage
b. **Break-Away Walls or Barriers**: Use walls, fences, and similar systems that will break away from the lower portions of a structure (such as a mobile home) to allow passage of floodwaters.
c. **Pass-Through Portals**: Use open window-like areas in foundation walls that will allow entry and exit of floodwaters.
d. **Culvert Systems**: Use of large capacity culverts through berms or under roadways to allow passage of floodwaters.
e. **Diversion:** Routing of portions of the floodwaters to other areas that will not be adversely impacted by diversion waters.

The quantitative demonstration of the ability of the method to prevent blocking must be provided to the District Engineer.

THIS PAGE INTENTIONALLY BLANK

TABLE 5-1. FEMA DEFINED FLOOD ZONES

ZONE	DESCRIPTION
MODERATE TO LOW-RISK AREAS	
B and X (shaded): Area of moderate flood hazard, usually the area between the limits of the 100- year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.	
C and X: Area of minimal flood hazard, usually depicted on FIRMs as above the 500-year (unshaded): flood level. Zone C may have ponding and local drainage problems that don't warrant a detailed study or designation as base floodplain. Zone X is the area determined to be outside the 500-year flood and protected by levee from the 100- year flood.	
HIGH-RISK AREAS	
A: Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage. Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones.	
AE: The base floodplain where base flood elevations are provided. AE Zones are now used on new format FIRMs instead of A1-A30 Zones.	
A1-30: These are known as numbered A Zones (e.g., A7 or A14). This is the base floodplain where the FIRM shows a BFE (old format).	
AH: Areas with a 1% annual chance of shallow flooding, usually in the form of a pond, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.	
AO: River or stream flood hazard areas, and areas with a 1% or greater chance of shallow flooding each year, usually in the form of sheet flow, with an average depth ranging from 1 to 3 feet. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Average flood depths derived from detailed analyses are shown within these zones.	
AR: Areas with a temporarily increased flood risk due to the building or restoration of a flood control system (such as a levee or a dam). Mandatory flood insurance purchase requirements will apply, but rates will not exceed the rates for unnumbered A zones if the structure is built or restored in compliance with Zone AR floodplain management regulations.	
A99: Areas with a 1% annual chance of flooding that will be protected by a Federal flood control system where construction has reached specified legal requirements. No depths or base flood elevations are shown within these zones.	
HIGH RISK - COASTAL AREAS	
V: Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. No base flood elevations are shown within these zones.	
VE, V1 - 30: Coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage. Base flood elevations derived from detailed analyses are shown at selected intervals within these zones.	
OTHER	
D: Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood.	

THIS PAGE INTENTIONALLY BLANK

CHAPTER 6. SELECTED HYDROLOGIC METHODS

6-1 PURPOSE

Hydrology deals with the transformation of rainfall into runoff. Evaluation of rainfall and runoff are essential for determining potential drainage impacts.

The important parameters for evaluating runoff behavior for projects of interest to the West Brazoria County Drainage District 11 (DISTRICT) are peak discharge and volume of discharge. The time history of the runoff, which is called a hydrograph, is also important since its behavior can be used to assess potential ways to mitigate adverse impacts of increased runoff. Key hydrologic parameters and calculations for estimating discharge and runoff volume are (i) rainfall, (ii) runoff, (iii) time of concentration, (iv) peak discharge, (v) discharge hydrograph, and (v) mitigation volume. Methods for estimating these various parameters are the focus of this chapter, except for mitigation volume that is discussed in Chapter 3.

Necessary calculations can be by hand, simple to complex spreadsheet calculations, or complex computer models. Except for the discussion of computer models in the following section, the remainder of this chapter discusses methods suitable for hand, spreadsheet, or special, limited-purpose computer routines.

The method or methods used for hydrologic evaluation should be identified in materials submitted to the DISTRICT for review.

6-2 USE OF COMPUTER MODELS

Detailed description of hydrologic behavior can be estimated using computer models (see Table 6-1); such models typically incorporate alternative methods, a wide range of hydrologic parameters, or a more detailed spatial or temporal description that may be used in non-model methods. If a computer model is used to make various hydrologic calculations, parameters, and coefficients used in the model must be documented as part of the modeling documentation provided to the DISTRICT.

A variety of well-established models are available from federal and state agencies (or their agents). Those that can be used without special approval are identified in Table 6-1 provided that the modeling parameters and coefficients are documented in materials presented to the DISTRICT for review. Use of models other than those identified in Table 6-1 requires specific approval by the District Engineer.

6-3. RAINFALL

Rainfall is the driving force for runoff and consequent drainage needs. Rainfall can be described in terms of the duration and intensity of the rainfall event and the probabilistic frequency of the rainfall event. The depth of rainfall P in inches that occurs in T hours has an average intensity of “i” inches per hour, where

$$I = P/T \qquad \text{[eq 6-1]}$$

Rainfall events can be described in a probabilistic manner: If the probability that a particular size (i.e., amount of rain) rainfall event will be equaled or exceeded in any one year is “p” (>0% to <100%; >0.00 to <1.00), the recurrence interval is Y = 1/p. This event is termed the “Y” year storm event.

For example (using some common abbreviations), for a three hour duration = 3-hr rainfall event occurring in Sweeny, TX, which occurs in any one year with an event probability of 1 in 10 (i.e., 10% = 0.1 probability) is 1/0.1 = 10-year = 10-yr storm event with a statistically based 10-yr recurrence interval) has, based upon evaluation of many historical rainfall records (see Table 6-2), of about 5.06 inches = 5.06 inch of rain. Note the rainfall may last more than 3 hours, but over the first 3 hours of the rainstorm, the rainfall totals 5.06 inches.

As another example, the rainfall event that has a 1%" probability (i.e., a 1 in 100 rainfall event, referred to as a 100-yr storm or a storm with a 100-yr recurrence interval) of occurring in any one year and has on a duration of 6 hours = 6 hr has a magnitude of 11.0 inches = 11.0 in. Again, the rainfall may last more than 6 hours, but over the first 6 hours, the rainfall totals 11.0 in.

6-3.1 DESIGN STORM DURATION AND FREQUENCY

For hydrologic calculations involving existing and proposed projects, a conservative evaluation method is used. The DISTRICT commonly requires hydrologic evaluation of a project using a 100-yr storm event of 24 hours duration, unless there is a different DISTRICT-specified requirement or a technically valid reason (justifiable to the DISTRICT) for using something different.

Depending upon the particular situation and the intended use of the rainfall information, storm events smaller than the 100-yr event, such as a 25-or 10-yr storm event, are also frequently evaluated as part of the assessment of runoff conditions.

6-3.2 RAINFALL EVENT INTENSITY AND DEPTH

Rainfall event depth (or just rainfall depth) is the depth of rain over the continuous period from the beginning of a storm event to the end of the period of interest.

Rainfall event intensity is the rainfall depth divided by the duration of the continuous period from the beginning of a storm event to the end of the period of interest.

National Weather Service (NWS) rainfall depth and intensity for Sweeny, TX, are shown in Tables 6-2 and 6-3. These data represent interpolated data (by the NWS) from several actual rain gauge data sets in Brazoria and nearby counties.

Thus, as an example, a 25-year (25-yr) rainfall over a period of 12 hours (12 hr) generates for Sweeny a rainfall depth of 9.64 inches (9.64 in) (see Table 6-2). The average intensity is 9.64/12 = 0.80 in/hr, as also listed in Table 6-3.

Analysis results released in 2018 for Texas by the NWS and it's Hydrometeorological Design Services (see webpage: https://hdsc.nws.noaa.gov/hdsc/pfds/) provides detailed data on rainfall depth and intensity for various locations across Texas. These data update rainfall depth and intensity data presented in the Brazoria County Drainage Criteria Manual. Generally, the 2018 NWS data show greater rainfall amounts than that in the Brazoria County Drainage Criteria Manual, reflecting the new rainfall data collected as a consequence of the 2017 Hurricane Harvey.

A comparison by the DISTRICT between the NWS data for Sweeny and that for Damon and Freeport was made. A close comparison was found between the rainfall for the three locations for a 24-hour rainfall event; see Table 6-4. Since the three communities span the DISTRICT, it was concluded that the

Sweeny data could be taken as representative of the entire DISTRICT for the purposes of project analysis.

For a selected range of frequencies and event durations (see Table 6-3, continued), the Sweeny rainfall intensity for various recurrence intervals and durations can be closely approximated by

$$I = A/[(t+B)^{0.5}] \qquad \text{[eq 6-2]}$$

In which I is inches per hour, t is the period of interest in minutes, A and B are empirical coefficients (see Table 6-3, continued).

Table 6-3 data in this Drainage Manual or eq. 6-2 (when appropriate) should be used in place of the previous equation in the Brazoria County Drainage Criteria Manual, $I = C/[(t+D)^p]$ in which I = average inches per hour over the rainfall period of interest of t minutes, and C, D, and p are empirical coefficients found in the Brazoria County Drainage Criteria Manual.

6-3.3 TEMPORAL VARIATION OF STORM

The temporal behavior of rainfall varies with location and other factors. Scientific investigation has estimated characteristic temporal behaviors for various types of storm events for large geographic areas. Representative rainfall behavior for the DISTRICT is a Type III storm. Figure 6-1 presents the characteristic features of a Type III storm.

6-4. DRAINAGE AREA

Drainage area (also referred to as a watershed) is the area of upstream lands delivering runoff to a particular, single downstream point. The downstream collection point, often referred to as the base (or root, bottom, or outlet) of the watershed, may be a receiving water body (such a lake or river), a storm sewer inlet, a particular point of interest, or just another watershed. The boundary of the drainage area is a drainage divide; runoff waters do not naturally drain across drainage divides.

Drainage divides are defined by land elevation, ground slopes, agricultural fields, and manmade features such as pavement slopes, locations of downspouts, paved and unpaved yards, grading of fields, pastures, lawns, and other open areas, and many other features that are introduced by the urbanization process. (In complex drainage situations, particularly involving flow in broad floodplains, the drainage divide may shift with the depth of runoff or floodwaters. Such situations should be evaluated only by an experienced hydrologist.)

Topography can be determined by land surveys and topographic maps. The Brazoria County Engineering website has for most of Brazoria County, detailed contour maps based upon LiDAR surveys. (LiDAR is an aerial surveying method that measures the distance to a target by illuminating the target, i.e., the ground, with pulsed laser light and measuring the reflected pulses with a sensor. The differences in laser return times and wavelengths can then be used to make digital 3-D representations of the target area for map-making and other purposes.)

Because of the relatively flat areas in much of the DISTRICT, defining the boundary of a particular watershed may be difficult and subject to considerable error, even with LiDAR data.

6-5 RUNOFF

Runoff is the amount of rain which drains away from the area on which the rainfall falls. The rainfall that does not runoff becomes infiltration into the ground, accumulation in low and pond-like areas, evaporation, vegetative interception, and plant transpiration. From a practical standpoint, the difference between rainfall and runoff is considered to be infiltration and ponding accumulations. Often ponding accumulations are neglected, but care should be exercised when they are present. As discussed below, natural ponding can be a significant component for runoff evaluation.

6-5.1 INFILTRATION AND RUNOFF

Infiltration into the soil depends largely upon on the type of soil (primarily the upper layer of the soil profile), the type of vegetation or man-made material on the top of the soil, the slope of the ground surface, the use of the land as modified by land use, and possible farming practices (such as plowing) used on the topsoil. These factors are difficult to quantify with high accuracy.

Figure 6-2 provides an estimate of the typical fraction of rainfall that becomes runoff as a function of the storm event frequency and imperviousness. Two common methods used to more accurately estimate the net runoff are (i) a runoff coefficient, and (ii) a CN curve numbers.

6-5.1.1 Runoff Coefficient

In general terms, a runoff coefficient is the ratio of total runoff to the total amount of rainfall. The runoff coefficient, C_r, is an empirically based generalized coefficient that estimates the ratio of total runoff to total rainfall. Runoff is strongly influenced by imperviousness but will be influenced by the amount of rainfall (because of the depths of accumulating runoff as it flows across a surface). Figure 6-2 provides an estimate of runoff as a function of imperviousness and storm event frequency. Figure 6-2 also shows some typical levels of imperviousness.

6-5.1.2 Runoff Coefficient vs. Rational Coefficient

The Rational Method, discussed below, has a "runoff coefficient," designated as C. C reflects factors such as ground slope, land surface conditions, levels of development, and soil type. While similar in approximate magnitude to the runoff coefficient C_r, the Rational Method Runoff Coefficient C is not the same as C_r. C also reflects land surface or land use conditions, but unfortunately the described conditions (as given in commonly available data tables) for C do not directly compare to the describe conditions for C_r.

In addition, C is the dimensionless coefficient of runoff representing the ratio of peak discharge per acre to rainfall intensity; C_r represents the ratio of total runoff to total rainfall.

Thus, the value of C_r for a particular condition is not immediately identifiable with a corresponding value of C. Consequently, choice of C or C_r from tabular values should clearly recognize the conditions for which the C or C_r is being sought.

6-5.1.3 CN Curve Number

The CN curve method, developed by the US Soil Conservation Service (now the US Natural Resources Conservation Service, NRCS) provides an alternative method to estimate runoff. The CN number relates soil type as well as land use to rates of runoff. The general relation is depicted in Figure 6-4 and computed from the two equations

$$Qp = [(P - 0.2S)^2]/[P+0.8S] \quad \text{[eq 6-3]}$$

in which Qp is the peak discharge in inches (i.e., total discharge/area, with appropriate conversion of units),

$$S = (1000/CN) - 10 \qquad \text{[eq 6-4]}$$

and P is the total rainfall in inches (in). Qp as a function of P is shown in Figure 6-4.

Approximate locations of the soil types found in Brazoria County are shown in Figure 6-5; all are Group D soils. Group D soil is usually clay loam, silty clay loam, sandy clay, silty clay, or clay. Group D soils have high runoff potential because of low infiltration rates, commonly less than 0 to 0.5 inches/hour (in/hr).

CN values for various soil types and land use are given in Table 6-5.

6-5.2 MIXED CONDITIONS

If the drainage area of interest has more than one land use, soil type conditions, or other conditions by which runoff coefficients are to be determined, the effective coefficient should be determined by computing an area-weighted average coefficient value in which each sub-area has more or less similar values of the parameter being evaluated.

6-5.3 RUNOFF COEFFICIENT FOR PONDS

Ponds should be assigned a runoff coefficient of 1.0 (or equivalently a CN = 100 value) since pond waters, as an approximation to conditions during the runoff period, do not have time to infiltrate into the soil from the pond bottom.

If the pond surface area (at maximum extent) is less than 2% of the total drainage area, the runoff coefficient can be assigned the same runoff coefficient as lands adjacent to the pond.

6-5.4 RUNOFF FROM SWAMPY AND POORLY DRAINED LANDS

Swampy or land areas with near-zero slope, collectively termed poorly drainage lands, will generally drain only slowly and contribute little to peak discharge behavior. Areas with land slope less than 0.0001 foot/foot (ft/ft) = 0.01% can be considered poorly drained.

It is difficult to estimate the effects of poorly drained land, but when the poorly drained land composes more than about 2% of the total drainage area, the following method can be used to approximately estimate an effective runoff coefficient:

Table 6-6 provides adjustment factors to by which to reduce the runoff based upon the ratio of poorly drained or swampy area (as shown by a USGS map symbol for “marsh”, as estimated by direct inspection, or as estimated from a topographic map data to have near-zero slope) to the total drainage area for a range of flood frequencies. Adjustment factors are based upon the approximate location of the center of the poorly drained land.

In some cases, it is appropriate to apply the adjustment more than once. For example, assume a watershed has poorly drained lands equal to five percent in the upper third of the watershed and ten percent in the lower area. The overall reduction would be the product of the reductions for the upper are and the reduction for the lower area.

The swampy land slope discussed above is not intended to replace a reservoir routing procedure when an actual lake or reservoir is present.

6-6 TIME OF CONCENTRATION

The time of concentration, tc, is used in many different methods of hydrologic analysis. The time of concentration is the shortest (estimated) time for runoff from the most distant point in a drainage area to reach the base of a watershed. The path to follow for determining the longest distance from the upper end of the watershed to the base of the watershed is estimated in light of the general slopes of the watershed, and the path drainage waters would take from the most distant point in the watershed.

Conceptually at time tc, all portions of the watershed are contributing runoff to the base of the watershed. It is difficult to determine tc with accuracy; standard procedures are commonly used to estimate tc.

Runoff rate may reach a peak before the time the entire upstream drainage area is contributing. In this infrequent instance, only the portions of the drainage area able to contribute flow to the point of interest are included in estimating the time of concentration.

The total tc is typically broken into individual components reflecting the type of conditions along the longest path from the most distant point in the watershed. The time of travel along a particular path component is merely the overall distance of the travel path (D) divided by the flow speed (V) along the path, i.e., time = D/V. The total time of concentration is the sum of the individual times of concentration for the individual paths making up the total path.

Conditions along the total flow path may and often do include the following, in their common order of occurrence:

6-6.1 OVERLAND FLOW

Overland flow consists of potentially two components: Sheet flow, which occurs in the early portion of the overland flow, and shallow concentrated flow, which typically follows sheet flow if the drainage length is sufficiently long.

6-6.1.1 Sheet Flow

Sheet flow is more or less uniform across its entire surface. If the sheet flow travel time is calculated to be more than 30 minutes (30 min), the computed time should be verified as being reasonable in light of on-the-ground conditions.

Maximum distances for which sheet flow should be calculated should not exceed approximately 300 feet (300 ft). After 300 ft, the flow will usually become a shallow concentrated flow in which case flow direction becomes more dependent on details of the land surface topography.

Velocities for sheet flows can be estimated from Table 6-7.

6-6.1.2 Inlet Time and Minimum Sheet Flow Drainage Time

For small and medium-sized drainage areas (less than approximately one acre), Inlet time is the time for the surface flow to drain to a stormwater inlet or similar point of inflow to subsurface drainage from small drainage areas. Inlet times should be limited to 10 minutes for pavement or similar surfaces and 15 minutes for vegetative and natural surfaces.

6-6.1.3 Shallow Concentrated Flow

If the flow path exceeds about 300 ft and has not reached a defined watercourse, the flow becomes a shallow concentrated flow (also called overland flow). These flows typically flow in shallow natural drainage paths or paths defined by irrigation or farming practices, tilling practices, or erosion features. Shallow flow should be considered to lie between the sheet flow zone and a downstream ditch, channel, or similar watercourse.

Figure 6-6 can be used to estimate shallow concentrated flow speeds.

6-6.2 CONDUIT FLOW

Conduit flow is flow in pipes and other drainage conduits. Conduits may or may not be present in a particular drainage situation. Speeds in conduit flow can be estimated from the Manning equation (see Chapter 7) for the type and shape of the conduit.

Usually, the conduit will be considered as flowing full to simplify velocity estimates. The time to fill a conduit (before it begins to flow full) can usually be neglected without significant error unless the conduit is so large as to be unlikely to fill during a runoff event.

6-6.3 OPEN CHANNEL FLOW

Flow velocity in channels and ditches (and similar) are described by the Manning equation (see Chapter 7). Calculations can be simplified for travel time estimates by assuming uniform flow using the average bottom slope of the channel. Velocity may vary significantly with the amount of runoff draining to the channel.

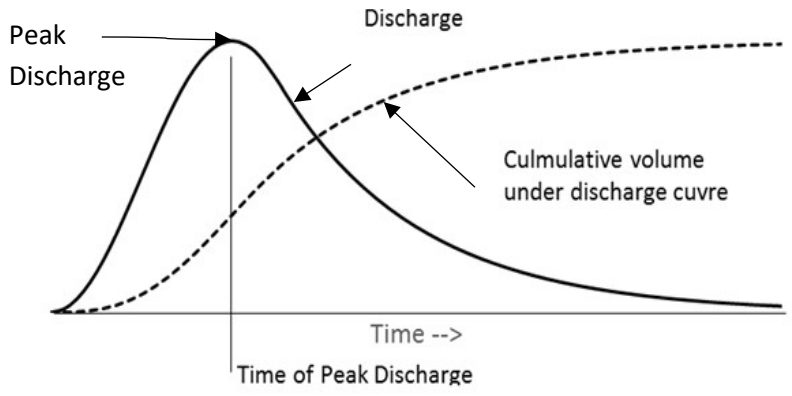
6-7 COMMON METHODS FOR RUNOFF ESTIMATION

The adjacent illustration shows a typical hydrograph, i.e., the time history of runoff.

Standard methods for discharge estimation to be used are based upon the size of the watershed.

If the drainage area of interest spans the size limits for a particular method, use the method corresponding to the largest watershed area within the bounds of a particular method.

EXHIBIT 6-1. EXAMPLE HYDROGRAPH



6-7.1 LARGE WATERSHEDS

Drainage areas that exceed 1 square mile (1 sq-mi) are considered large watersheds. Figure 6-3 provides standard curves for estimating peak discharges Qp for large watersheds for 10-, 25-yr, and 100-yr storm events.

The physical characteristics for the watershed should be approximately uniform when using any one of the several curves of Figure 6-3. If the physical characteristics are significantly different

over the watershed of interest, divide the watershed into different subareas with approximately similar levels of development. Estimate the peak discharge based upon the weighted average percentage of the total watershed.

The runoff curves of Figure 6-3 were developed for a typical watershed assuming adequate conveyance capacity and reasonably uniformly-spaced development. If the watershed has lakes or reservoirs (surface area more than 5% of the total area), for which the pond surface area remains approximately constant, the pond area can be approximated as an area of 100% development.

If a watershed has lakes or reservoirs with significantly varying water levels during a storm event, the watershed runoff should be analyzed with more sophisticated tools (i.e., computer models) that address storage behavior and multiple sub-watersheds.

6-7.1.1 Adjustment for Swampy or Poorly Drained Lands

If an area has a large lake or pond or swampy area (in amounts exceeding 2% of the total area), adjust the peak discharge using the methods of Section 6-4 to reduce the peak discharge obtained from Figure 6-3 using Table 6-6.

6-7.1.2 NRCS Unit Hydrograph for Larger Watersheds

To provide an approximate estimate of the time history of runoff in a large watershed, the NRCS Unit Hydrograph (Table 6-9) can be used with the following assumptions:

- The storm's total duration is 24 hours.
- The peak discharge is computed using Figure 6-3 (with possible adjustment for swampy lands).

The relative hydrograph shape (in terms of Q/Qp and t/tp) is given by the NRCS Unit Hydrograph. The total volume, Vtotal, of runoff is given by the methods of Section 6-4.

The time of concentration for the discharge peak is estimated from Kirpich equation (see, e.g., TxDOT Hydrology Manual, Section 11); the time of the peak discharge is assumed to be the time of concentration, in which

$$tc = 0.0078L^{0.77}/S^{0.385} \qquad \text{[eq 6-5]}$$

in which tc is in minutes, S is the representative slope of the primary or longest stream draining the watershed in ft/ft, and L is the Length of primary drainage path from the upstream limit of the watershed to the base of the watershed in ft.

The hydrograph described by this above method should be considered only approximate. Since it is an approximate method, it may be convenient to approximately relate watershed flow path length L to watershed area A using an idealized geometric shape, such that

$$L = k\,(A)^{0.5} \qquad \text{[eq 6-6]}$$

Note that the units of L and A should be consistent (i.e., if A is in sq-ft, L is in ft). Some shape factors are given in Exhibit 6-2 below.

For example, if the watershed were idealized as a square of side length b with the flow length measured along the diagonal, $A = b^2$ and $L = b\,(2^{0.5})$. Thus $k = 2^{0.5} = 1.44$. Exhibit 6-2 provides the shape factor for some common geometric shapes.

6-7.1.3 Adjustment of Kirpich Equation

In the Kirpich equation above, when the representative watershed slope S is less than 0.002 ft/ft, replace S by S_{low}, where

$$S_{low} = S + 0.0005 \qquad \text{[eq 6-7]}$$

For a watershed slope > 0.0003, let S_{low} = S. For a watershed slope between 0.002 and 0.003, interpolate between the slope limits of 0.002 and 0.003.

EXHIBIT 6-2: COMMON WATERSHED SHAPE FACTORS

Shape	Flow Path	Area	Flow Path Length	Shape Factor, k
Circle with diameter a	Along diameter	$\pi\ a^2$	a	$(1/\pi)^{0.5}$
Ellipse with major axis a and minor axis b	Along major axis	π a b	a	$[a/(b\ \pi)]^{0.5}$
Square with side length a	Along diagonal	a^2	a $(2)^{0.5}$	$2^{0.5}$
Rectangle with length a and width b	Along diagonal	a b	$(a^2+b^2)^{0.5}$	$[(a/b) +(b/a)]^{0.5}$
Trapezoid with length a, long base b, and short base c	Along diagonal	a [(b+c)/2]	$\{a^2+[0.5\ (b+c)]^2\}^{0.5}$	$\{[(2a)/(b+c)]+[(b+c)/(a)]\}^{0.5}$

6-7.2 SMALL WATERSHEDS

Small watersheds are less than 1 sq-mi in area. Different methods used depend upon whether only the peak flow or a full hydrograph is of interest.

6-7.2.1 Peak Discharge Using Rational Method

The Rational Method can be used for small watersheds. The Rational Method represents an accepted method for determining peak storm runoff rates for small watersheds that have a drainage system unaffected by complex hydrologic situations such as ponding areas and storage basins.

The peak discharge is given by

$$Q=C_f\,C\,I\,A \qquad \text{[eq 6-8]}$$

in which Q is the peak discharge during the runoff period in the cubic feet per second, C_f is the rainfall frequency factor (see below), C is the dimensionless coefficient of runoff (i.e., the "rational coefficient") representing the ratio of peak discharge per acre (ac) to rainfall intensity, A is the drainage area in ac, and I is the rainfall intensity for the recurrence interval of interest and the time of concentration for the drainage area. Note that 1 ac-in/hr = 1.008 cubic feet per second (cfs); for convenience, a 1 ac-in/hr ≈ 1 cfs conversion is commonly assumed.

Commonly accepted values of C as a function of land use, soil conditions, and other factors are given in Table 6-8.

Adjustment of the C value for use with larger (less frequent) storms can be made by using the frequency factor, C_f, the rainfall frequency factor, which accounts for more rapid rates of runoff to be expected with more severe storm events. Values for C_f are also given in Table 6-8. The product of C_f and C should not exceed 1.0

6.7.2 Hydrograph Development for Small Watersheds: Malcolm Hydrograph Method

The Malcolm Method hydrograph can be used for watersheds less than 1 square mile. The method computes the entire hydrograph; thus, it can provide an estimate of the peak discharge as well as the entire hydrograph for small watersheds. Exhibit 6-3 gives an example of the hydrograph generated by the method. Note that its detailed shape varies as the peak discharge, time of the peak, and the volume under the hydrograph change.

Malcolm's Method uses the following equations:

$Tp = Vt/(1.39Qp)$

$Qi = (Qp/2)[1- \cos(\pi\, ti/Tp)]$

For $ti <= 1.25\ Tp$

$Qi = 4.34Qp\ [\exp(-1.30ti/Tp)]$

For $ti > 1.25\ Tp$

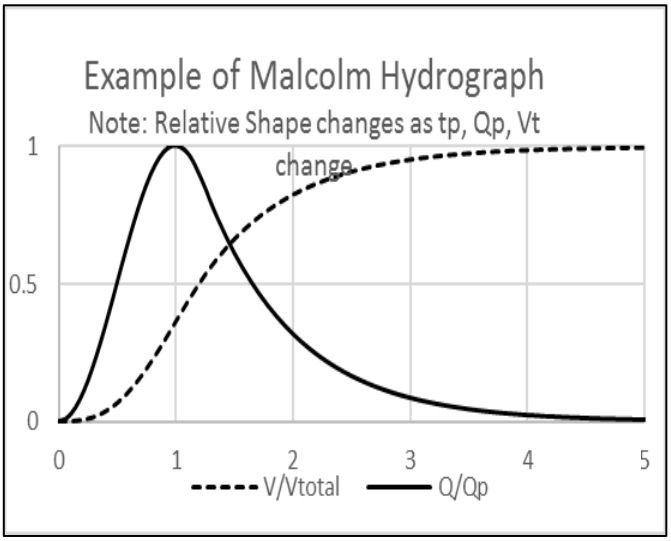
in which

Qp = peak design flow rate in cfs

Tp = time to Qp

Vt = total volume of runoff for the design storm in cu-ft

EXHIBIT 6-3



ti, Qi = the respective time and flow rates which determine the shape of the hydrograph

It is important to note the first equation above relates Tp to Vt and Qp; thus, only two of these three variables can be independently determined. Usually, Vt and Tp are known (from other calculations), and Qp is computed from the first of the above equations.

6-7.2.3 NRCS Unit Hydrograph Method

The NRCS Unit Hydrograph Method can also be used for small watersheds 1 of less square miles in area. The discharge hydrograph is computed from a standard dimensionless unit hydrograph, described by the ratio of the discharge to the peak discharge, Q/Qp, at any time t relative to the time to the peak discharge, t/tp. This standard dimensionless hydrograph is given in Table 6-9.

The time of peak tp for the NRCS hydrograph is given by

$$tp = (2/3)\ tc \qquad \text{[eq 6-9]}$$

in which tc is the time of concentration. Qp in cfs is given by

$$Qp = K_{nrcs}A/tp \qquad [eq\ 6\text{-}10]$$

in area A is in square-miles, and time to peak tp is in hours. K_{nrcs} is a coefficient that includes a units-conversion factor and an empirical hydrograph shape constant such that 3/8ths of the hydrograph area is under the rising limb of the hydrograph. K_{nrcs} is usually taken as 484

Change in the 484 value is sometimes made to reflect the topography of the watershed in question. For a flat, swampy area, the constant may decrease to about 300. However, adjustments to the 484 value are tenuous unless supported by actual runoff measurement. Consequently, it is recommended that the 484 value of the constant be used. Adjustments for swampy land can be made using the technique discussed in Section 6-4.

The actual hydrograph for the watershed in question is determined by multiplying values of t/tp by tp, Q/Qp by Qp, and V/Vp by Vp.

6-8 RURAL SUBDIVISIONS

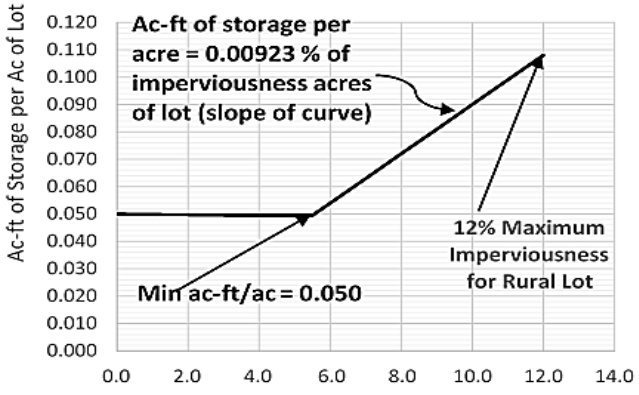
Rural watersheds may have limited impacts on natural runoff and have less requirements for mitigation.

6-8.1 QUALIFICATIONS

Watersheds undergoing development (existing or proposed) are rural watersheds if and only if the development has the following characteristics for the total area of development (whether existing or proposed):

- Total area of the development is at least 2 acres.
- No commercial facilities or activities in the area of development. Note that trailer parks, RV parks, and similar are considered commercial facilities. Buildings or structures for agricultural or farming product sales by a property owner to the general citizenry by direct walk-in are not considered commercial facilities for the purpose of this limitation if such facilities do not exceed 5000 sq-ft.
- No multi-family (in excess of two families) residential facilities.
- Individual lots are at least 1 acre in size. Maximum imperviousness of the development as a whole does not exceed 12 %
- Maximum imperviousness of any individual lot (excluding barns, sheds, and similar ancillary facilities) does not exceed 12%.
- Any single residence does not have a footprint in excess of 5000 sq-ft.
- The development lies totally outside the boundaries of an incorporated municipality.
- Land and drainage changes from the present level of the development and its

EXHIBIT 6-4.
ACRE-FEET OF MITIGATION STORAGE PER ACRE OF INDIVIDUAL RURAL LOT



For imperviousness between 5.5% and 12%, Ac-ft/ac = 0.05 +(0.00923) (%Impervious- 5.55%)

structures would not significantly alter natural drainage in the development or immediately adjacent lands

6-8.2 GENERAL DRAINAGE REQUIREMENTS

Drainage for rural subdivision must conform to the following:

- Minimum ground floor slab elevations as required by Brazoria County.
- Roadways must have a minimum right-of-way of 70 ft or as may be required by Brazoria County.
- Roadway drainage must conform to sound engineering practice. Roadway drainage must conform to requirements for roadway drainage as required by Brazoria County.
- Lot drainage must provide for adequate lot drainage, including the absence of intentional ponding or actual ponding of rainstorm waters and discharge to adjacent lots in excess of natural amounts of drainage to adjacent lots.

6-8.3 MITIGATION

General requirements for mitigation, as discussed in Chapter 3, apply. Peak runoff from a developed lot should not exceed that for the lot before development. Different techniques for runoff control can be used (see Chapter 3). If a detention pond is used, it must provide the detention shown by Exhibit 6-4.

6-9 CAUTIONS FOR HYDROLOGIC ANALYSIS

Particular cautions in using the various conventional runoff estimation methods include the following:

- Runoff coefficients may be lower than standard values because of flat or swampy ground.
- Natural infiltration may be limited due to common soil conditions; runoff coefficients may be consequently too low, and runoff may be therefore higher than commonly recognized. CN values and consequent runoff rates should reflect actual soil conditions.
- Time of concentration increases because of small runoff speed over low natural ground slopes.
- Slope estimation is difficult with commonly available data.
- Watershed boundaries are difficult to estimate, particularly in areas of limited topography.
- For large flood flows, flow across watershed boundaries (as determined solely by topography) may occur.
- Use standard hydrograph shapes for large watersheds with caution.

TABLE 6-1. HYDROLOGIC AND HYDRAULIC MODELS

This table classifies common models. Reference to any specific commercial product, process, or service by trade name, trademark, service mark, manufacturer, or otherwise does not constitute or imply endorsement or recommendation.

Model or Tool Name	Hydrologic model	Hydraulic model	Combined Model
HEC-1	X		
HEC-HMS	X		
Win TR-55/TR-20	X		
HydroCAD	X		
HEC-RAS*		X	
HEC-2		X	
WSPRO		X	
CulvertMaster		X	
Flow Master		X	
PondPack			X
EPA SWMM*			X
PC SWMM*			X
Info SWMM*			X
XPSWMM*			X
MIKE URBAN (SWMM or MOUSE)*			X
ICPR			X
InfoWorks ICM*			X
Mike 11			X
CivilStorm			X
MODRET			X
WinHSPF*			X
LSPC*			X
SWAT*			X
WARMF*			X
SUSTAIN*	X		
EPA National Stormwater Calculator	X		
MIDUSS			X
HY8		X	
Hydraulic Toolbox		X	

* Also water quality modeling capabilities.

Source: Adapted from Minnesota Pollution Control Agency; data as of 9/24/2018

651-296-6300, 800-657-3864 | Assistance | Web site policy

Web Address

https://stormwater.pca.state.mn.us/index.php?title=Classification_of_models_by_model_type

THIS PAGE INTENTIONALLY BLANK

TABLE 6-2. RAINFALL DEPTH

(For Sweeny, Texas: Representative for DISTRICT)

Partial duration series (PDS) based precipitation frequency estimates with 90% confidence intervals (in inches)

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.526 (0.398-0.695)	0.611 (0.464-0.795)	0.745 (0.567-0.978)	0.861 (0.646-1.15)	1.02 (0.749-1.41)	1.16 (0.823- .64)	1.29 (0.892-1.88)	1.43 (0.959-2.12)	1.61 (1.04-2.47)	1.74 (1.10-2.75)
10-min	0.833 (0.630-1.10)	0.969 (0.736-1.26)	1.18 ((0.900-1.55)	1.37 (1.03-1.83)	1.63 (1.20-2.25)	1.85 (1.32-2.62)	2.07 (1.42-2.99)	2.27 (1.52-3.37)	2.53 (1.64-3.89)	2.71 (1.72-4.29)
15-min	1.06 (0.804-1.40)	1.23 (0.936-1.60)	1.50 (1.14-1.97)	1.73 (1.30-2.30)	2.05 (1.49-2.82)	2.30 (1.63-3.25)	2.56 (1.77-3.71)	2.82 (1.90-4.20)	3.17 (2.06-4.89)	3.44 (2.18-5.44)
30-min	1.53 (1.16-2.02)	1.76 (1.34-2.30)	2.13 (1.62-2.80)	2.45 (1.84-3.26)	2.89 (2.11-3.97)	3.24 (2.30-4.58)	3.61 (2.49-5.23)	3.99 (2.68-5.93)	4.51 (2.93-6.94)	4.91 (3.11-7.77)
60-min	2.01 (1.53-2.66)	2.34 (1.78-3.04)	2.85 (2.17-3.74)	3.30 (2.47-4.39)	3.92 (2.86-5.39)	4.43 (3.14-6.25)	4.95 (3.42-7.18)	5.52 (3.71-8.21)	6.31 (4.10-9.72)	6.94 (4.39-11.0)
2-hr	2.45 (1.87-3.21)	2.94 (2.24-3.76)	3.69 (2.82-4.80)	4.36 (3.29-5.76)	5.33 (3.90-7.26)	6.12 (4.36-8.57)	6.97 (4.83-10.0)	7.91 (5.34-11.7)	9.26 (6.03-14.1)	10.4 (6.58-16.2)
3-hr	2.68 (2.05-3.50)	3.30 (2.51-4.18)	4.23 (3.24-5.46)	5.06 (3.84-6.66)	6.29 (4.63-8.54)	7.31 (5.23-10.2)	8.43 (5.86-12.0)	9.68 (6.55-14.2)	11.5 (7.50-17.4)	13.0 (8.26-20.2)
6-hr	3.10 (2.39-4.01)	3.93 (3.00-4.90)	5.16 (3.98-6.60)	6.29 (4.80-8.21)	7.97 (5.91-10.7)	9.39 (6.76-13.0)	11.0 (7.68-15.5)	12.8 (8.68-18.5)	15.4 (10.1-23.2)	17.6 (11.3-27.1)
12-hr	3.56 (2.77-4.57)	4.60 (3.51-5.66)	6.11 (4.75-7.74)	7.52 (5.78-9.73)	9.64 (7.18-12.9)	11.4 (8.28-15.7)	13.5 (9.47-18.9)	15.9 (10.8-22.8)	19.5 (12.8-29.0)	22.5 (14.5-34.3)
24-hr	4.04 ((3.16-5.14)	5.28 (4.05-6.41)	7.07 (5.53-8.88)	8.75 (6.78-11.2)	11.3 (8.48-15.0)	13.5 (9.82-18.3)	16.0 (11.3-22.2)	18.9 (13.0-26.9)	23.3 (15.4-34.3)	27.1 (17.4-40.8)
2-day	4.45 (3.51-5.62)	5.89 (4.54-7.07)	7.94 (6.26-9.90)	9.90 (7.72-12.6)	12.9 (9.73-16.9)	15.4 (11.3-20.8)	18.3 (13.0-25.2)	21.6 (14.9-30.4)	26.5 (17.6-38.5)	30.6 (19.7-45.5)
3-day	4.78 (3.78-6.00)	6.32 (4.90-7.56)	8.53 (6.75-10.6)	10.6 (8.32-13.5)	13.8 (10.5-18.1)	16.5 (12.2-22.2)	19.6 (14.0-26.8)	23.0 (15.9-32.2)	28.0 (18.6-40.4)	32.0 (20.7-47.3)
4-day	5.11 (4.05-6.40)	6.71 (5.23-8.03)	9.03 (7.17-11.2)	11.2 (8.79-14.1)	14.5 (11.0-18.9)	17.3 (12.8-23.1)	20.4 (14.6-27.8)	23.8 (16.5-33.1)	28.7 (19.1-41.3)	32.7 (21.2-48.1)
7-day	6.00 (4.78-7.46)	7.68 (6.07-9.22)	10.2 (8.14-12.5)	12.5 (9.83-15.6)	15.8 (12.1-20.5)	18.7 (13.8-24.7)	21.8 (15.6-29.4)	25.1 (17.5-34.7)	29.9 (20.0-42.6)	33.7 (21.9-49.1)
10-day	6.72 ((5.38-8.32)	8.46 (6.74-10.2)	11.1 (8.91-13.6)	13.5 (10.7-16.8)	16.9 (12.9-21.7)	19.8 (14.7-26.0)	22.8 (16.4-30.7)	26.1 (18.2-35.9)	30.8 (20.6-43.6)	34.5 (22.5-50.0)
20-day	8.71 (7.03-10.7)	10.6 (8.61-12.8)	13.6 (11.0-16.6)	16.2 (12.9-20.0)	19.8 (15.2-25.2)	22.7 (16.9-29.5)	25.7 (18.6-34.2)	28.9 (20.2-39.3)	33.3 (22.4-46.7)	36.8 (24.0-52.7)
30-day	10.4 (8.40-12.7)	12.4 (10.2-15.0)	15.7 (12.8-19.1)	18.4 (14.8-22.7)	22.2 (17.1-28.0)	25.1 (18.8-32.5)	28.1 (20.4-37.1)	31.2 (21.9-42.2)	35.4 (23.9-49.4)	38.8 (25.4-55.2)
45-day	12.8 (10.4-15.6)	15.1 (12.5-18.3)	18.8 (15.4-22.8)	21.9 (17.6-26.8)	25.9 (20.1-32.5)	29.0 (21.7-37.2)	32.0 (23.3-42.1)	35.1 (24.8-47.2)	39.2 (26.6-54.3)	42.3 (27.8-59.8)
60-day	15.1 (12.3-18.3)	17.5 (14.5-21.2)	21.7 (17.8-26.2)	25.0 (20.1-30.5)	29.3 (22.8-36.7)	32.6 (24.5-41.7)	35.7 (26.0-46.7)	38.8 (27.4-51.9)	42.8 (29.1-58.9)	45.8 (30.1-64.4)

Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

THIS PAGE INTENTIONALLY BLANK

TABLE 6-3. Partial duration series (PDS) based precipitation frequency estimates with 90% confidence intervals (in inches/hour)

(For Sweeny, Texas: Representative for DISTRICT)

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	6.31 (4.78-8.34)	7.33 (5.57-9.54)	8.94 (6.80-11.7)	10.3 (7.75-13.8)	12.3 (8.99-16.9)	13.9 (9.88-19.7)	15.5 (10.7-22.5)	17.1 (11.5-25.5)	19.3 (12.5-29.7)	20.9 (13.2-33.0)
10-min	5.00 (3.78-6.60)	5.81 (4.42-7.56)	7.10 (5.40-9.32)	8.21 (6.17-11.0)	9.80 (7.17-13.5)	11.1 (7.90-15.7)	12.4 (8.54-18.0)	13.6 (9.14-20.2)	15.2 (9.85-23.3)	16.3 (10.3-25.7)
15-min	4.25 (3.22-5.61)	4.92 (3.74-6.41)	6.00 (4.56-7.87)	6.91 (5.18-9.20)	8.19 (5.97-11.3)	9.20 (6.53-13.0)	10.2 (7.06-14.8)	11.3 (7.58-16.8)	12.7 (8.24-19.5)	13.8 (8.71-21.7)
30-min	3.06 (2.31-4.04)	3.52 (2.68-4.59)	4.26 (3.24-5.60)	4.90 (3.67-6.52)	5.78 (4.21-7.95)	6.49 (4.60-9.16)	7.21 (4.97-10.5)	7.97 (5.36-11.9)	9.01 (5.85-13.9)	9.83 (6.22-15.5)
60-min	2.01 (1.53-2.66)	2.34 (1.78-3.04)	2.85 (2.17-3.74)	3.30 (2.47-4.39)	3.92 (2.86-5.39)	4.43 (3.14-6.25)	4.95 (3.42-7.18)	5.52 (3.71-8.21)	6.31 (4.10-9.72)	6.94 (4.39-11.0)
2-hr	1.22 (0.932-1.60)	1.47 (1.12-1.88)	1.85 (1.41-2.40)	2.18 (1.65-2.88)	2.66 (1.95-3.63)	3.06 (2.18-4.28)	3.49 (2.42-5.01)	3.96 (2.67-5.83)	4.63 (3.02-7.06)	5.18 (3.29-8.10)
3-hr	0.893 (0.684-1.17)	1.10 (0.835-1.39)	1.41 (1.08-1.82)	1.69 (1.28-2.22)	2.10 (1.54-2.84)	2.44 (1.74-3.40)	2.81 (1.95-4.01)	3.22 (2.18-4.72)	3.83 (2.50-5.80)	4.32 (2.75-6.71)
6-hr	0.518 (0.399-0.670)	0.657 (0.500-0.818)	0.862 (0.665-1.10)	1.05 (0.802-1.37)	1.33 (0.986-1.79)	1.57 (1.13-2.17)	1.83 (1.28-2.60)	2.13 (1.45-3.09)	2.58 (1.69-3.87)	2.94 (1.88-4.53)
12-hr	0.296 (0.230-0.380)	0.382 (0.292-0.469)	0.507 (0.394-0.643)	0.624 (0.480-0.808)	0.800 (0.596-1.07)	0.949 (0.687-1.30)	1.12 (0.786-1.57)	1.32 (0.899-1.89)	1.62 (1.06-2.40)	1.87 (1.20-2.85)
24-hr	0.168 (0.132-0.214)	0.220 (0.169-0.267)	0.294 (0.230-0.370)	0.365 (0.282-0.468)	0.471 (0.353-0.623)	0.562 (0.409-0.763)	0.666 (0.470-0.924)	0.788 (0.540-1.12)	0.972 (0.642-1.43)	1.13 (0.727-1.70)
2-day	0.093 (0.073-0.117)	0.123 (0.095-0.147)	0.165 (0.130-0.206)	0.206 (0.161-0.262)	0.268 (0.203-0.352)	0.321 (0.236-0.434)	0.382 (0.271-0.525)	0.451 (0.310-0.634)	0.552 (0.366-0.803)	0.636 (0.411-0.947)
3-day	0.066 (0.052-0.083)	0.088 (0.068-0.105)	0.118 (0.094-0.147)	0.148 (0.116-0.187)	0.192 (0.146-0.251)	0.230 (0.169-0.308)	0.273 (0.194-0.373)	0.320 (0.221-0.447)	0.388 (0.258-0.561)	0.445 (0.288-0.657)
4-day	0.053 (0.042-0.067)	0.070 (0.054-0.084)	0.094 (0.075-0.116)	0.117 (0.092-0.147)	0.151 (0.115-0.197)	0.180 (0.133-0.241)	0.213 (0.152-0.289)	0.248 (0.172-0.345)	0.299 (0.199-0.430)	0.341 (0.221-0.501)
7-day	0.036 (0.028-0.044)	0.046 (0.036-0.055)	0.061 (0.048-0.074)	0.074 (0.059-0.093)	0.094 (0.072-0.122)	0.111 (0.082-0.147)	0.130 (0.093-0.175)	0.149 (0.104-0.206)	0.178 (0.119-0.253)	0.201 (0.130-0.292)
10-day	0.028 (0.022-0.035)	0.035 (0.028-0.042)	0.046 (0.037-0.057)	0.056 (0.044-0.070)	0.070 (0.054-0.091)	0.082 (0.061-0.108)	0.095 (0.068-0.128)	0.109 (0.076-0.150)	0.128 (0.086-0.182)	0.144 (0.094-0.208)
20-day	0.018 (0.015-0.022)	0.022 (0.018-0.027)	0.028 (0.023-0.035)	0.034 (0.027-0.042)	0.041 (0.032-0.052)	0.047 (0.035-0.061)	0.053 (0.039-0.071)	0.060 (0.042-0.082)	0.069 (0.047-0.097)	0.077 (0.050-0.110)
30-day	0.014 (0.012-0.018)	0.017 (0.014-0.021)	0.022 (0.018-0.026)	0.026 (0.021-0.032)	0.031 (0.024-0.039)	0.035 (0.026-0.045)	0.039 (0.028-0.052)	0.043 (0.030-0.059)	0.049 (0.033-0.069)	0.054 (0.035-0.077)
45-day	0.012 (0.010-0.014)	0.014 (0.012-0.017)	0.017 (0.014-0.021)	0.020 (0.016-0.025)	0.024 (0.019-0.030)	0.027 (0.020-0.034)	0.030 (0.022-0.039)	0.033 (0.023-0.044)	0.036 (0.025-0.050)	0.039 (0.026-0.055)
60-day	0.010 (0.009-0.013)	0.012 (0.010-0.015)	0.015 (0.012-0.018)	0.017 (0.014-0.021)	0.020 (0.016-0.025)	0.023 (0.017-0.029)	0.025 (0.018-0.032)	0.027 (0.019-0.036)	0.030 (0.020-0.041)	0.032 (0.021-0.045)

Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

TABLE 6-3, Continued

Empirical approximations to National Weather Service (NWS) rainfall Intensity data (Table 6-3) suitable for use with Rational Equation for peak discharge estimation from small watersheds, for

5 minutes ≤ T_c ≤ 12 hours, 10 years ≤ Storm frequency = f ≤ 100 years

$I = A/[(T_c + B)^{0.5}]$

I = Average rainfall intensity in inches per hour at T_c

f = Storm frequency in years

T_c = Time of concentration in minutes

$A = -0.0027f^2 + 0.44950f + 22.898$

$B = -0.0004f^2 + 0.04980f + 0.9216$

f = frequency in years

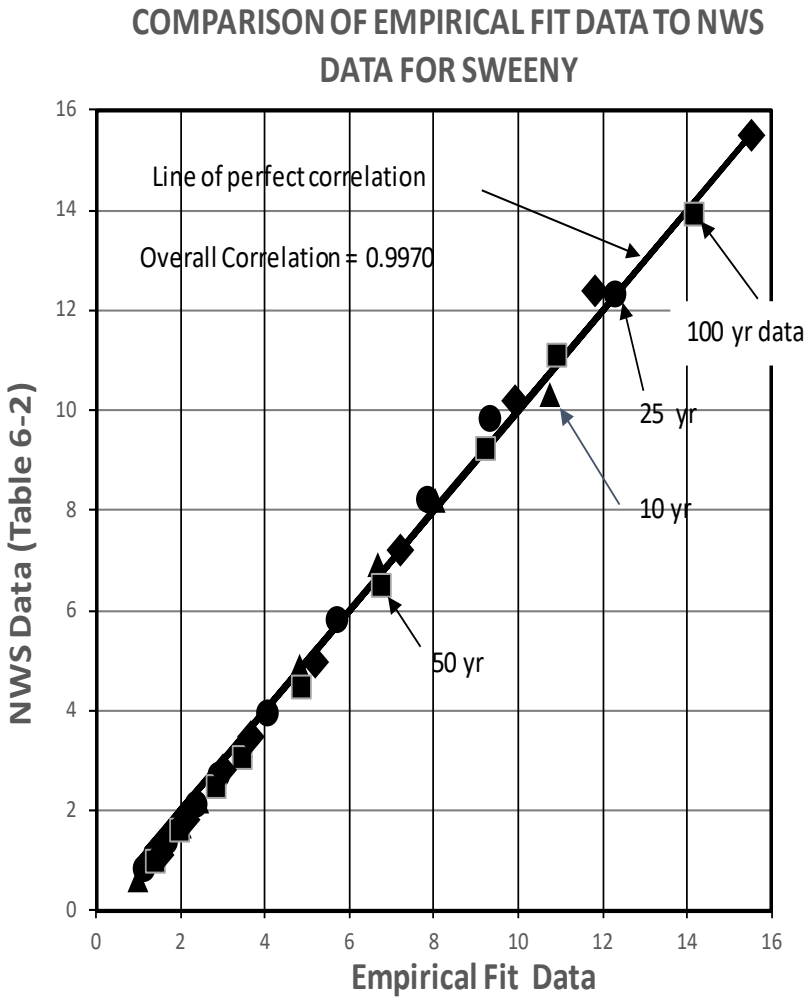
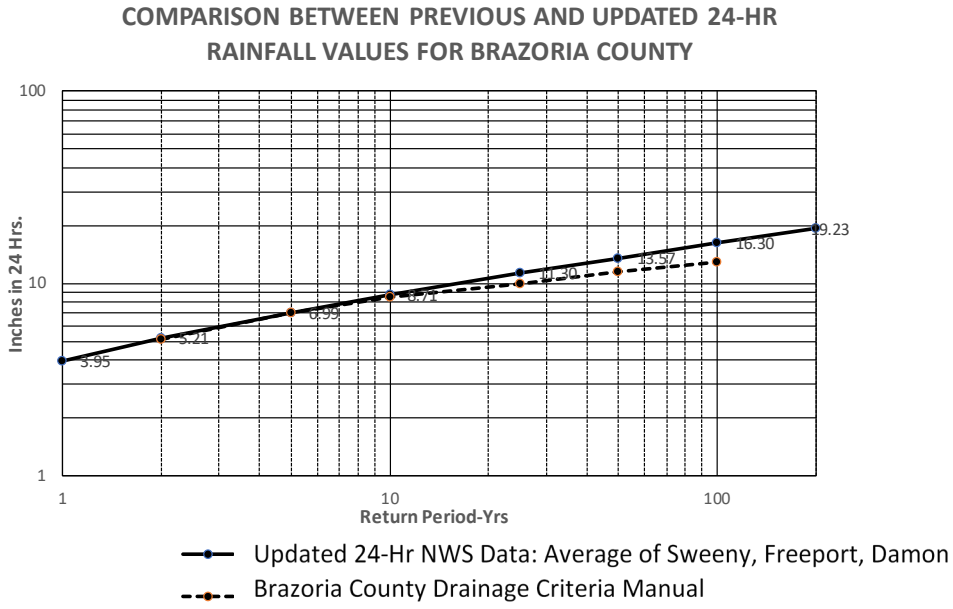
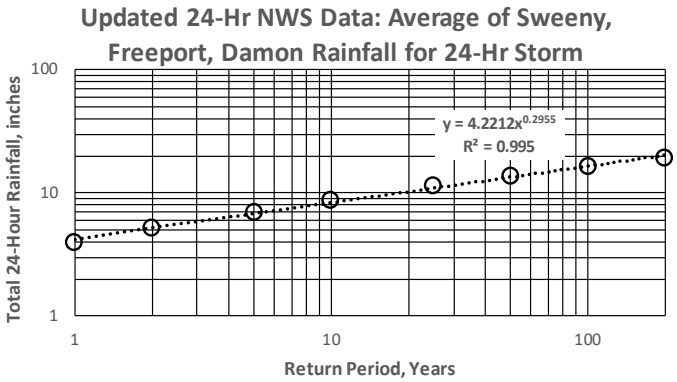


TABLE 6-4. COMPARISON BETWEEN PREVIOUS AND UPDATED VALUES OF 24-RAINFALL

Return Period-Yrs	Updated 24-Hr NWS Data: Average of Sweeny, Freeport, Damon	Brazoria County Drainage Criterial Manual	Sweeny, inches	Freeport, inches	Damon, inches
1	3.95		4.04	3.84	3.98
2	5.21	5.10	5.29	5.13	5.22
5	6.99	7.00	7.08	6.96	6.94
10	8.71	8.55	8.78	8.72	8.63
25	11.30	9.95	11.30	11.40	11.20
50	13.57	11.50	13.50	13.70	13.50
100	16.30	13.00	16.00	16.80	16.10
200	19.23		19.00	19.60	19.10





P_Y $P_y : 4.2212\ Y^{0.2955}$ $I_y : 0.1759\ Y^{0.2955}$

P_Y : 24-Hour rainfall, inches

I_Y : Average rainfall over 24-hour period, inches/hour

Y: Return interval in years

THIS PAGE INTENTIONALLY BLANK

TABLE 6-5. RUNOFF CURVE NUMBERS FOR TYPE D SOILS

URBAN AREAS	
Open space areas with grass cover	
Poor Condition: Grass cover < 50%	89
Fair Condition: Grass cover 50% to 75%	84
Good Condition: Grass cover > 75%	80
Impervious areas	
Paved parking lots, roofs, driveways	98
Streets and Roads	
Paved, with curbs and storm sewers (excluding ROW)	98
Paved, with open ditches (excluding ROW)	93
Gravel (including ROW)	91
Dirt (including ROW)	89
Commercial and business areas	95
Industrial	93
Residential Districts	
1/8 acre or less	92
1/4 acre	87
1/3 acre	86
1/2 acre	85
1 acre	84
2 acres	82
CULTIVATED AGRICULTURAL LAND	
Fallow	90-94
Row Crops	80-91
Small Grains	80-87
Close seeded or broadcast legumes or rotation meadow	83-89
UNDEVELOPED LANDS IN HUMID AREAS	
Pasture, grassland, range	
Poor (<50% cover	89
Fair (50% to 75% cover)	84
Good (>75% cover)	80
Meadow, continuous grass, lands mowed for hay	78
Brush	
Poor (<50% cover	83
Fair (50% to 75% cover)	77
Good (>75% cover)	73
Woods-grass in 50-50 combination	
Poor (<50% cover	86
Fair (50% to 75% cover)	82
Good (>75% cover)	79
Woods	
Poor (Forest litter, small trees, brush destroyed by grazing or burning	83
Fair (Woods grazed but not burned; some forest litter)	79
Good (Land protected from grazing; brush & litter adequately cover soil)	77
Farmsteads: Buildings, lanes, driveways, and surrounding lots	86

Source: Hydrology Training Series, Module 104 - Runoff Curve Number Computations, SCS, 1989

THIS PAGE INTENTIONALLY BLANK

TABLE 6-6. ADJUSTMENT FACTORS FOR PONDING

% of ponded & swampy area	Annual Storm Probability					
	50%	20%	10%	4%	2%	1%
Ponding occurs in central parts of the watershed or is spread throughout						
0.2	0.94	0.95	0.96	0.97	0.98	0.99
0.5	0.88	0.89	0.90	0.91	0.92	0.94
1.0	0.83	0.84	0.86	0.87	0.88	0.90
2.0	0.78	0.79	0.81	0.83	0.85	0.87
2.5	0.73	0.74	0.76	0.78	0.81	0.84
3.3	0.69	0.70	0.71	0.74	0.77	0.81
5.0	0.65	0.66	0.68	0.72	0.75	0.78
6.7	0.62	0.63	0.65	0.69	0.72	0.75
10	0.58	0.59	0.61	0.65	0.68	0.71
20	0.53	0.54	0.56	0.60	0.63	0.68
Ponding occurs only in upper reaches of watershed						
0.2	0.96	0.97	0.98	0.98	0.99	0.99
0.5	0.93	0.94	0.94	0.95	0.96	0.97
1.0	0.90	0.91	0.92	0.93	0.94	0.95
2.0	0.87	0.88	0.88	0.90	0.91	0.93
2.5	0.85	0.85	0.86	0.88	0.89	0.91
3.3	0.82	0.83	0.84	0.86	0.88	0.89
5.0	0.80	0.81	0.82	0.84	0.86	0.88
6.7	0.78	0.79	0.80	0.82	0.84	0.86
10	0.77	0.77	0.78	0.80	0.82	0.84
20	0.74	0.75	0.76	0.78	0.80	0.82
Ponding occurs only in lower reaches of watershed						
0.2	0.92	0.94	0.95	0.96	0.97	0.98
0.5	0.86	0.87	0.88	0.90	0.92	0.93
1.0	0.80	0.81	0.83	0.85	0.87	0.89
2.0	0.74	0.75	0.76	0.79	0.82	0.86
2.5	0.69	0.70	0.72	0.75	0.78	0.82
3.3	0.64	0.65	0.67	0.71	0.75	0.78
5.0	0.59	0.61	0.63	0.67	0.71	0.75
6.7	0.57	0.58	0.60	0.64	0.67	0.71
10	0.53	0.54	0.56	0.60	0.63	0.68
20	0.48	0.49	0.51	0.55	0.59	0.64

The above values (taken from the NRCS TR-55 Manual) were determined by the NRCS for experimental watersheds of less than 2,000 acres. These factors may still be used for larger basins in the absence of other data. For percentages beyond the range in the tables, the data may be extrapolated on semi-log paper with the reduction factor on the log scale.

THIS PAGE INTENTIONALLY BLANK

TABLE 6-7. SHEET FLOW VELOCITIES

Surface Condition	n (Roughness for Sheet Flow)
Smooth surfaces (pavement, concrete)	0.01
Fallow (no residue)	0.05
Cultivated Soils	
Residual cover <20%	0.06
Residual cover >20%	0.17
Grass	
Short prairie grass	0.15
Dense grass	0.24
Burmuda grass	0.41
Natural Range land	0.13
Woods	
Light underbrush	0.40
Dense underbrush	0.80

$V=[L^{0.2}\, S^{0.4}\, P_2^{0.5}]/\,[25.2\,(n^{0.8})]$

V: Average travel velocity, ft/sec

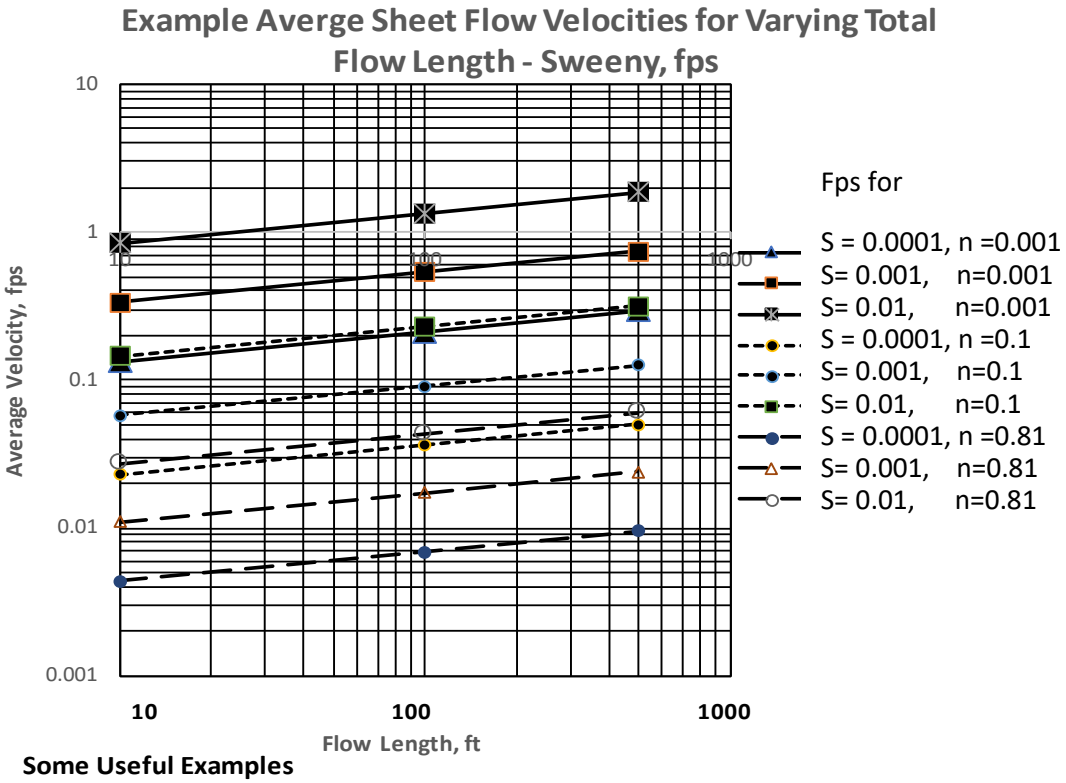
S: Representative land slope, ft/ft

L: Total flow length, ft

P2: 2-year, 24 hour inches of rain= 5.28 inches for Sweeny

n: Manning n

Source: Urban Hydrology for Small Watersheds, chap 3 TR 55, NRCS 2010



Some Useful Examples

Time in Minutes to Reach 500 feet

n	S=0.0001	0.001	0.01
0.011	28	11	5
0.1	166	66	26
0.8	878	350	139

Feet Traveled in 15 Minutes

n	S=0.0001	0.001	0.01
0.011	224	707	2237
0.1	25	78	246
0.8	3	10	31

THIS PAGE INTENTIONALLY BLANK

TABLE 6-8. RATIONAL METHOD RUNNOFF COEFFICIENTS & RAINFALL FREQUENCY FACTOR

	General	Based upon Representative Land Slope (2)		
	Range (1)	Less than 1%	1% - 3.5%	3.5%-5%
URBANIZED AREAS				
Residential Districts				
Single Family Areas (Lots greater than ½ acre)	0.30 - 0.50	0.30	0.35	0.40
Single Family Areas Single Family: Lots ¼ - ½ acre)	0.30 - 0.50	0.40	0.45	0.50
Single Family Areas (Lots less than ¼ acre)	0.30 - 0.50	0.50	0.55	0.60
Multi-Family Areas	0.40 - 0.75	0.60	0.65	0.70
Apartment Dwelling Areas	0.50 - 0.70	0.75	0.80	0.85
Business Districts				
Downtown Areas	0.70 - 0.95	0.85	0.87	0.90
Neighborhood Areas	0.50 - 0.70	0.75	0.80	0.85
Industrial Districts				
Light Areas	0.50 - 0.80	0.50	0.65	0.80
Heavy Areas	0.60 - 0.90	0.60	0.75	0.90
Railroad Yard Areas	0.20 - 0.35	0.20	0.30	0.40
Parks, Cemeteries	0.10 - 0.25	0.10	0.18	0.25
Playgrounds	0.20 - 0.35	0.20	0.28	0.35
Streets				
Asphalt	0.70 - 0.95	0.80	0.80	0.80
Concrete	0.70 - 0.95	0.85	0.85	0.85
Drives and Walks (concrete)	0.75 - 0.95	0.85	0.85	0.85
Roofs	0.75 - 0.95	0.85	0.85	0.85
Lawn Areas				
Sandy Soil	0.05- 0.20	0.05	0.08	0.12
Clay Soil	0.13 - 0.35	0.15	0.02	0.22
UNDEVELOPED AREAS				
Undeveloped Areas Sandy Soil				
Woodlands		0.15	0.18	0.25
Pasture		0.25	0.35	0.40
Cultivated		0.30	0.55	0.70
Undeveloped Clay Soil				
Woodlands		0.18	0.20	0.30
Pasture		0.30	0.40	0.50
Cultivated		0.35	0.60	0.80

RAINFALL FREQUENCY FACTOR

Frequency of Storm Event in Years	Factor
<= 10	1
25	1.1
50	1.2
100	1.25

Use linear interpolation for other frequencies

For frequency > 100, use 1.25

Sources

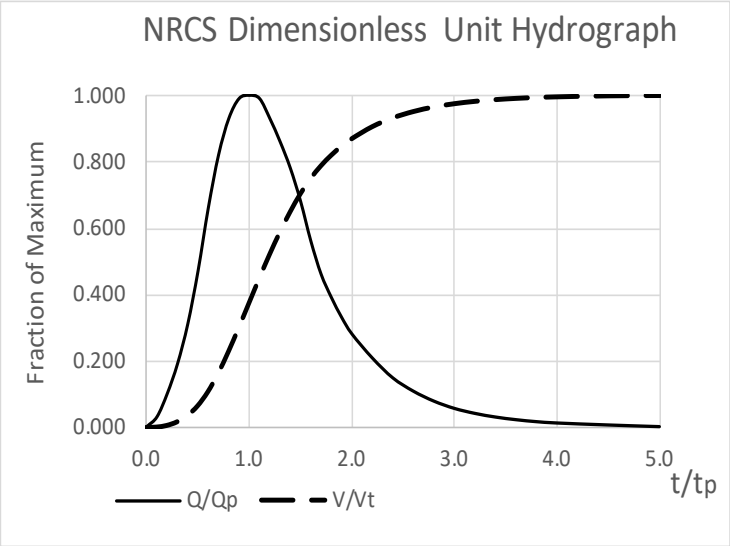
1 Handbook of Hydrology, Maidment, ed. (1992)

2 Source: Brazoria County Drainage Criteria Manual (2003)

THIS PAGE INTENTIONALLY BLANK

TABLE 6-9. NRCS DIMENSIONLESS UNIT HYDROGAPH

t/tp	Q/Qp	V/Vt
0.0	0.000	0.000
0.1	0.030	0.001
0.2	0.100	0.006
0.3	0.190	0.017
0.4	0.310	0.036
0.5	0.470	0.065
0.6	0.660	0.107
0.7	0.820	0.162
0.8	0.930	0.228
0.9	0.990	0.300
1.0	1.000	0.374
1.1	0.990	0.449
1.2	0.930	0.521
1.3	0.860	0.588
1.4	0.780	0.649
1.5	0.680	0.704
1.6	0.560	0.750
1.7	0.460	0.788
1.8	0.390	0.820
1.9	0.330	0.847
2.0	0.280	0.870
2.2	0.207	0.906
2.4	0.147	0.933
2.6	0.107	0.952
2.8	0.077	0.966
3.0	0.055	0.975
3.2	0.040	0.983
3.4	0.029	0.988
3.6	0.021	0.991
3.8	0.015	0.994
4.0	0.011	0.996
4.5	0.005	0.999
5.0	0.000	1.000
AVG:	0.390	



t= time; tp=time to peak; Q=discharge; Qp=peak discharge

V= runoff volume; Vt = total volume of runoff

Approximating Equations for Q/Qt (using consistent set of units)

$$Q/Qp = \{K/[\sigma (2\pi)^{0.5}]\} \{\exp-[0.5(\tau - \tau_m)^2 / \sigma^2]\}$$

K= Kq = Scale factor for dischage $\exp(x) = e^x$

K=Kv = Scale factor for volume

$\tau = t/tp$

t_p = time at peak Q $\pi \approx 3.1416$

t_m =time shift = 1 σ = standard deviation

EQUIVALENT FORMULA USING STANDARD EXCEL FUNCTIONS

Q/Qp = Kq*NORM(τ, tm, σ, false) V/Vt = Kv*NORM(t, tm, σ, true)

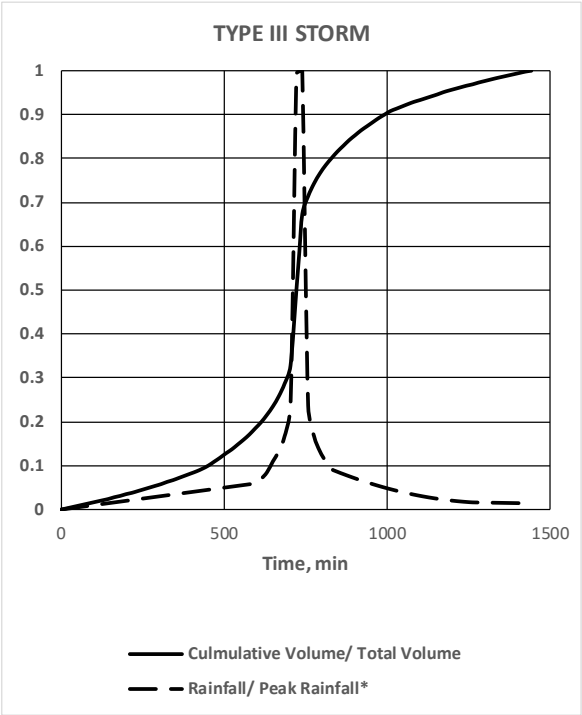
Parameter Values

Time Range for Discharge	Kq	τ_m	σ
0.5 < t/tp <= 1.0	1.00	1	0.40
1.0 < t/tp <= 1.7	1.37	1	0.55
1.7 < t/tp < infinity	1.30	1	0.80
Time Range for Volume	Kv	τ_m	σ
0.5 < t/tp <= 1.0	1.00	1	0.40
1.0 < t/tp <= 1.4	1.37	1	0.40
1.4 < t/tp < infinity	1.30	1	0.80

THIS PAGE INTENTIONALLY BLANK

FIGURE 6-1. TYPE III STORM CHARACTERISTICS

Minutes During 24-Hr Storm	Culmulative Volume/ Total Volume	Rainfall/ Peak Rainfall*
0	0.000	0.000
18	0.003	0.002
36	0.006	0.004
54	0.009	0.005
72	0.012	0.007
90	0.015	0.009
108	0.018	0.011
126	0.021	0.013
144	0.024	0.014
162	0.028	0.016
180	0.031	0.018
198	0.035	0.020
216	0.038	0.022
234	0.042	0.023
252	0.046	0.025
270	0.050	0.027
288	0.054	0.029
306	0.058	0.031
324	0.063	0.032
342	0.067	0.034
360	0.072	0.036
378	0.077	0.038
396	0.082	0.040
414	0.087	0.041
432	0.093	0.043
450	0.100	0.045
468	0.109	0.047
486	0.118	0.049
504	0.128	0.050
522	0.137	0.052
540	0.148	0.054
558	0.159	0.056
576	0.171	0.058
594	0.185	0.060
612	0.199	0.070
630	0.216	0.085
648	0.235	0.110
666	0.258	0.133
684	0.287	0.167
702	0.328	0.237
720	0.500	0.993
729	0.587	0.999
738	0.673	1.000
756	0.714	0.237
774	0.743	0.167
792	0.766	0.133
810	0.785	0.110
828	0.801	0.092
846	0.816	0.086
864	0.829	0.081
882	0.842	0.076
900	0.853	0.064
918	0.864	0.064
936	0.873	0.054



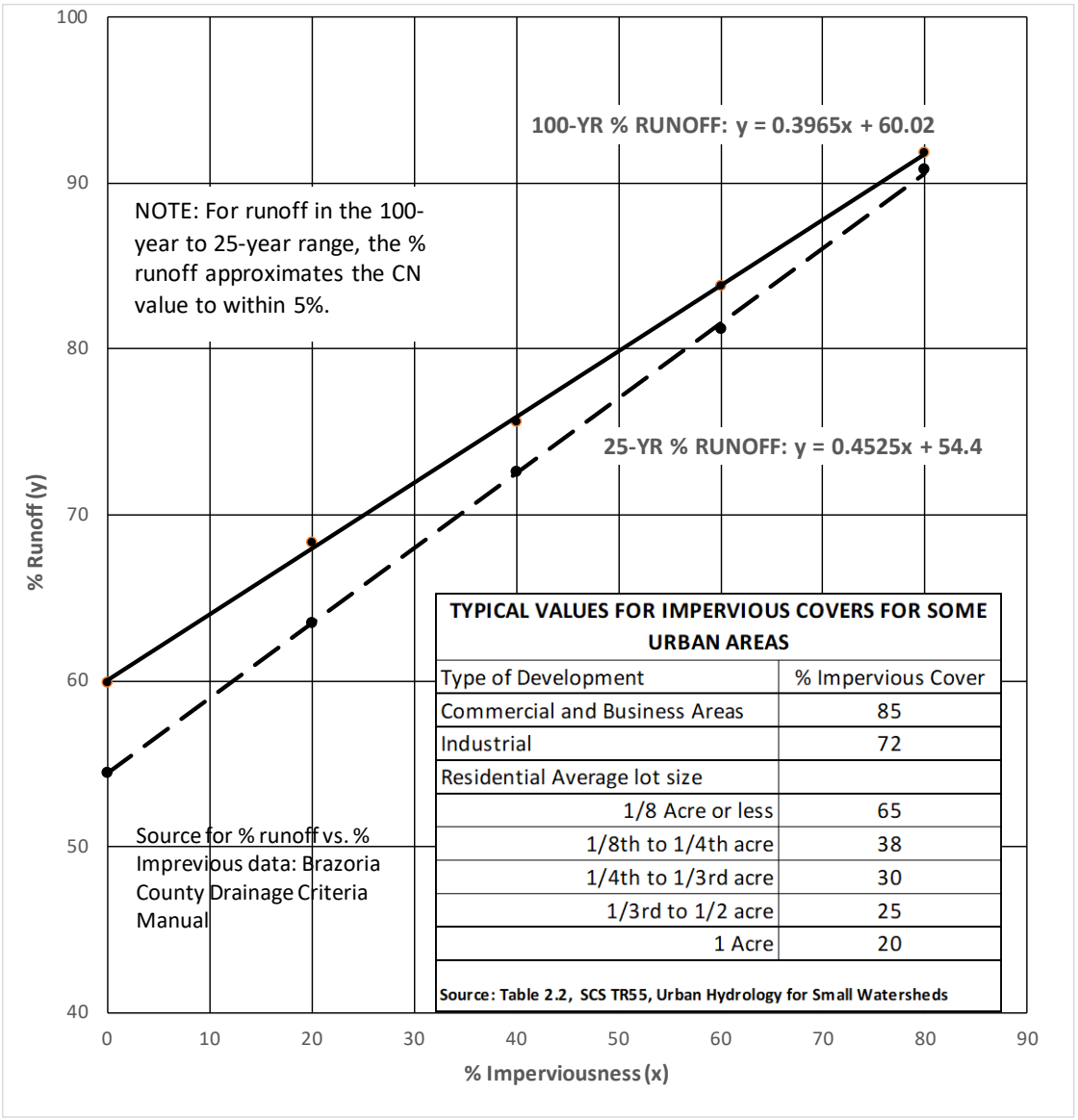
* Rainfall curve smoothed for less than 594 minutes & more than 1260 minutes

Minutes During 24-Hr Storm	Culmulative Volume/ Total Volume	Discharge/ Peak Discharg
954	0.883	0.054
972	0.892	0.0538
990	0.900	0.0462
1008	0.908	0.0462
1026	0.913	0.0308
1044	0.919	0.0308
1062	0.924	0.0308
1080	0.929	0.0289
1098	0.933	0.0231
1116	0.937	0.0250
1134	0.942	0.0249
1152	0.946	0.0250
1170	0.951	0.0289
1188	0.955	0.0231
1206	0.959	0.0212
1224	0.962	0.0212
1242	0.966	0.0212
1260	0.969	0.0173
1278	0.973	0.0231
1296	0.976	0.0192
1314	0.980	0.0192
1332	0.983	0.0192
1350	0.986	0.0173
1368	0.989	0.0173
1386	0.992	0.0173
1404	0.995	0.0173
1422	0.998	0.0173
1440	1.000	0.0116

Data sources: NOAA, NWS Atlas 14; Huff, Water Resouces Research 3(4), 100, 1967

THIS PAGE INTENTIONALLY BLANK

FIGURE 6-2. PERCENT RUNOFF



TYPICAL VALUES FOR IMPERVIOUS COVERS FOR SOME URBAN AREAS

Type of Development	% Impervious Cover
Commercial and Business Areas	85
Industrial	72
Residential Average lot size	
1/8 Acre or less	65
1/8th to 1/4th acre	38
1/4th to 1/3rd acre	30
1/3rd to 1/2 acre	25
1 Acre	20

Source: Table 2.2, SCS TR55, Urban Hydrology for Small Watersheds

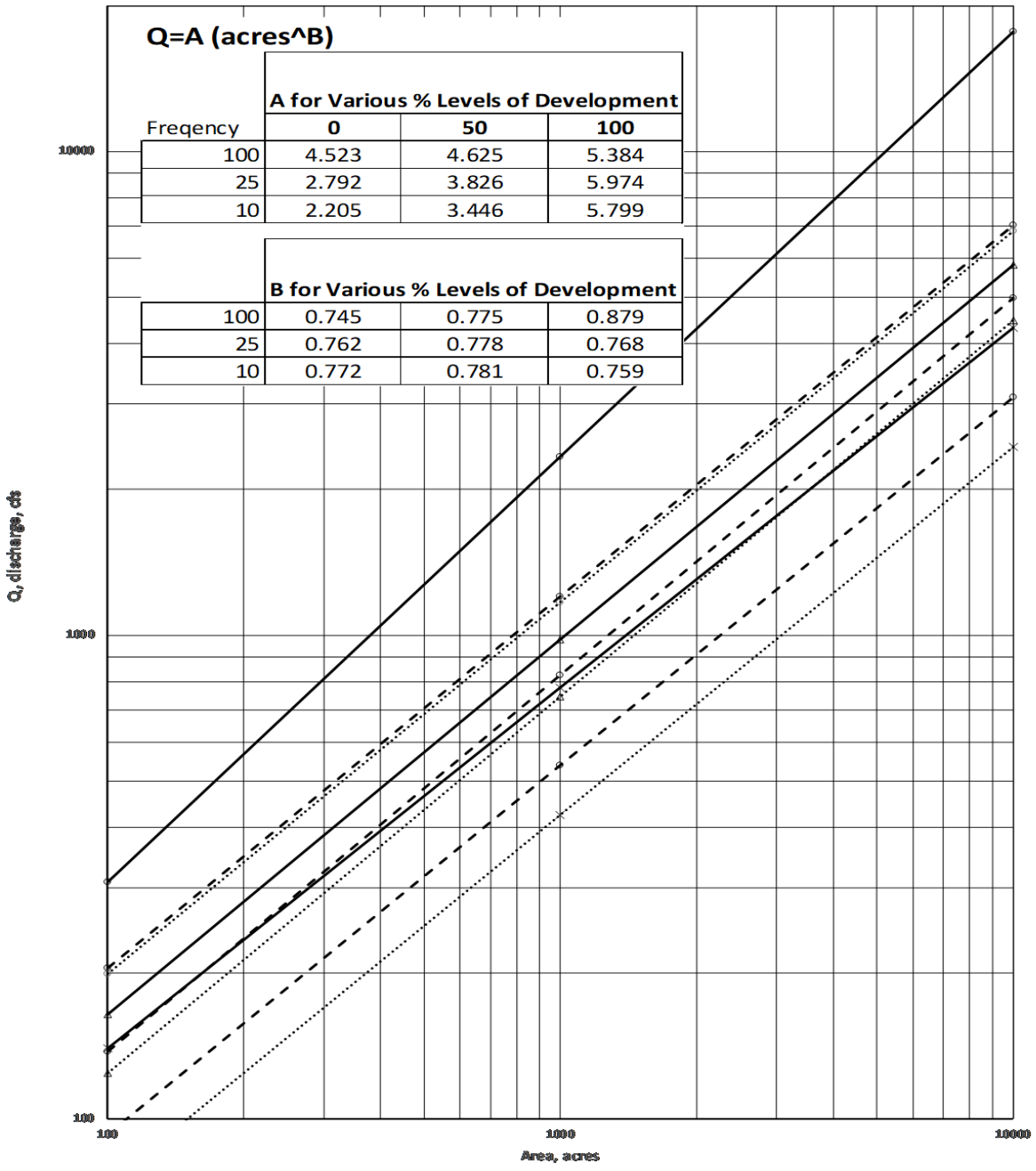
THIS PAGE INTENTONALLY BLANK

FIGURE 6-3. PEAK DISCHARGE FOR LARGE WATERSHEDS

Q=A (acres^B)

Freqency	A for Various % Levels of Development 0	50	100
100	4.523	4.625	5.384
25	2.792	3.826	5.974
10	2.205	3.446	5.799

	B for Various % Levels of Development		
100	0.745	0.775	0.879
25	0.762	0.778	0.768
10	0.772	0.781	0.759



Source: Brazoria County Drainage Criteria Manual, 2003

THIS PAGE INTENTIONALLY BLANK

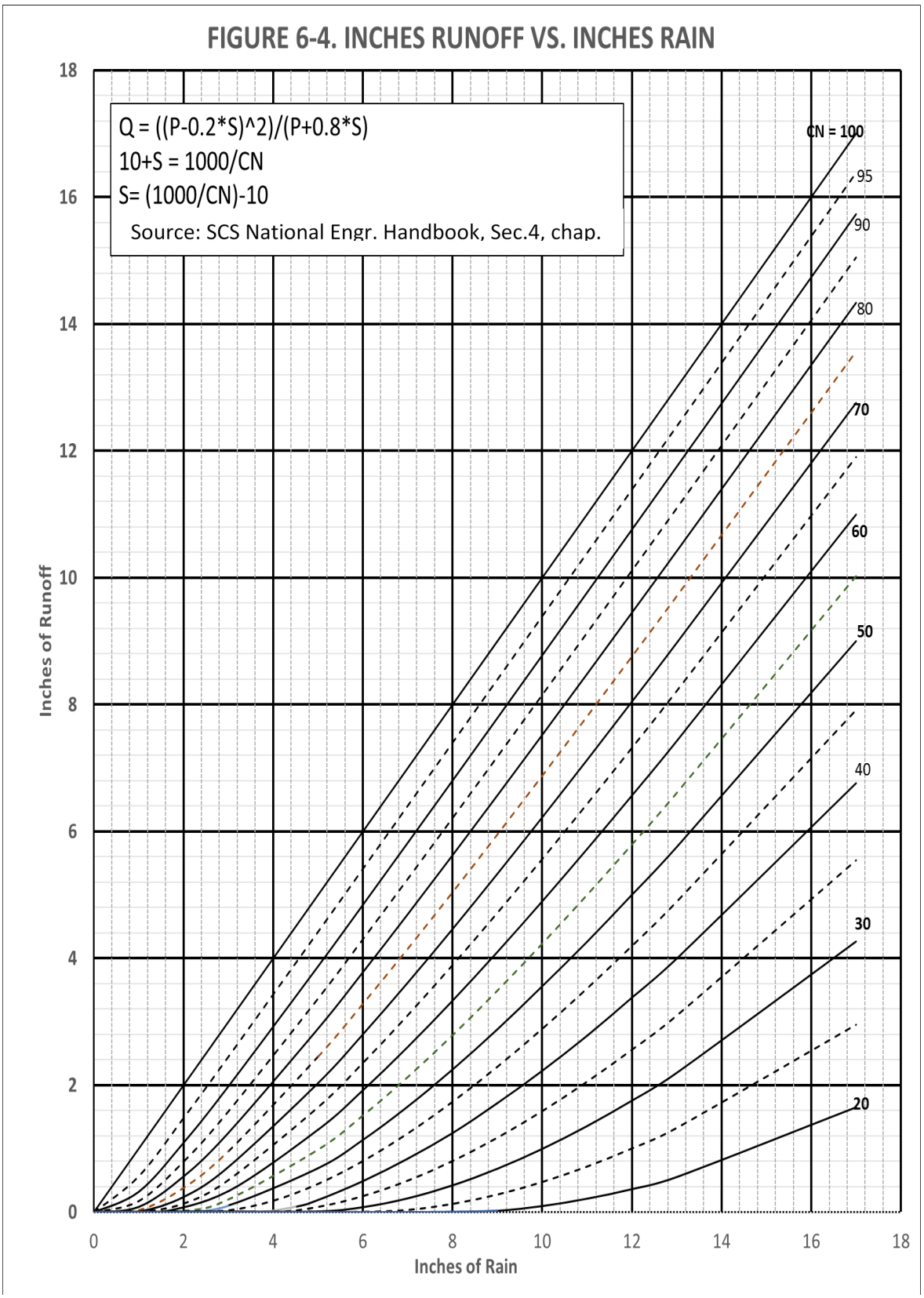
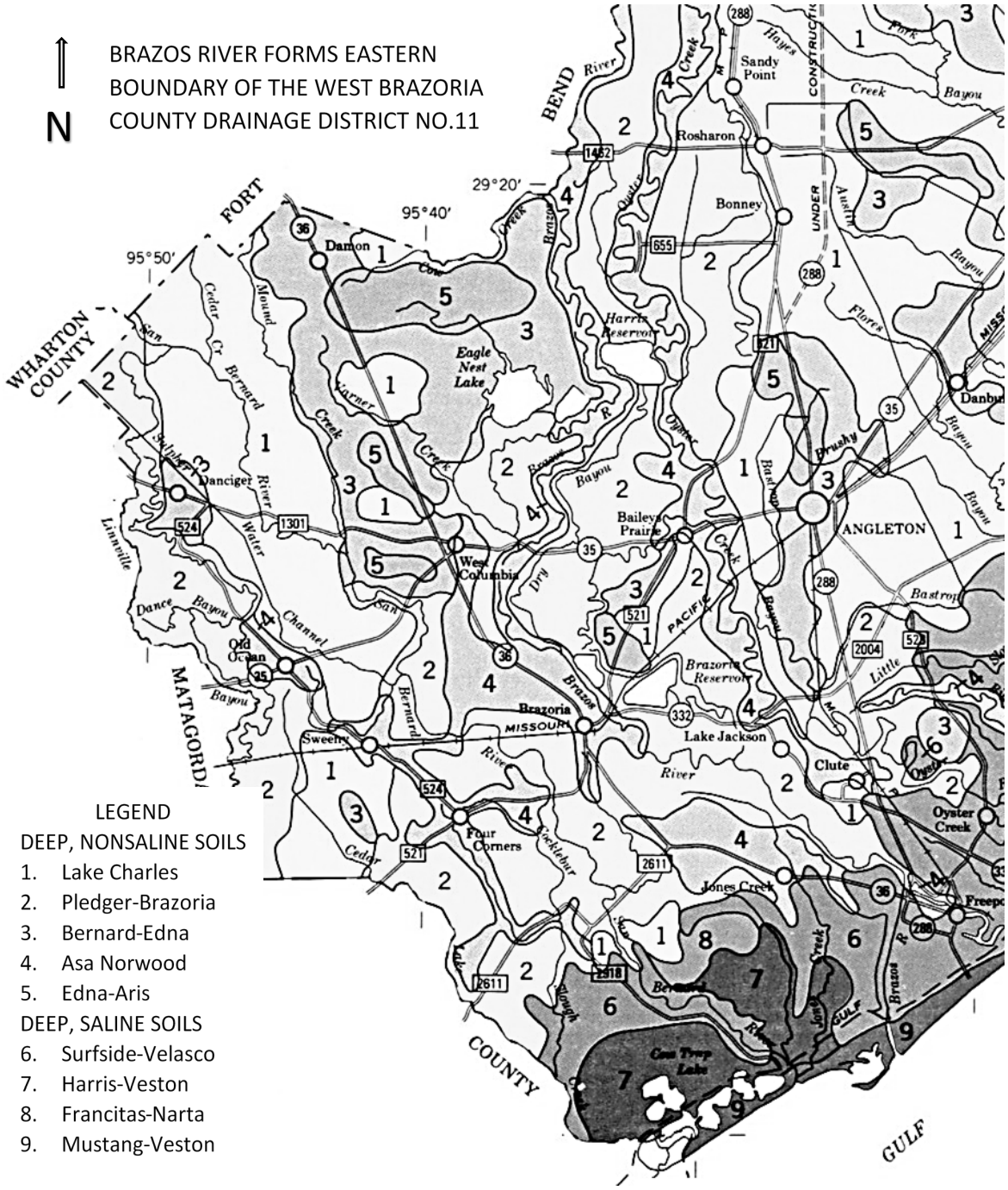


FIGURE 6-4. INCHES RUNOFF VS. INCHES RAIN
Q = ((P-0.2*S)^2)/(P+0.8*S)
10+S = 1000/CN
S= (1000/CN)-10
Source: SCS National Engr. Handbook, Sec.4, chap.
CN = 100
95
90
80
70
60
50
40
30
20
Inches of Runoff
Inches of Rain
0
2
4
6
8
10
12
14
16
18

THIS PAGE INTENTIONALLY BLANK

FIGURE 6-5. SOIL CLASSIFICATION FOR SOUTHWEST BRAZORIA COUNTY

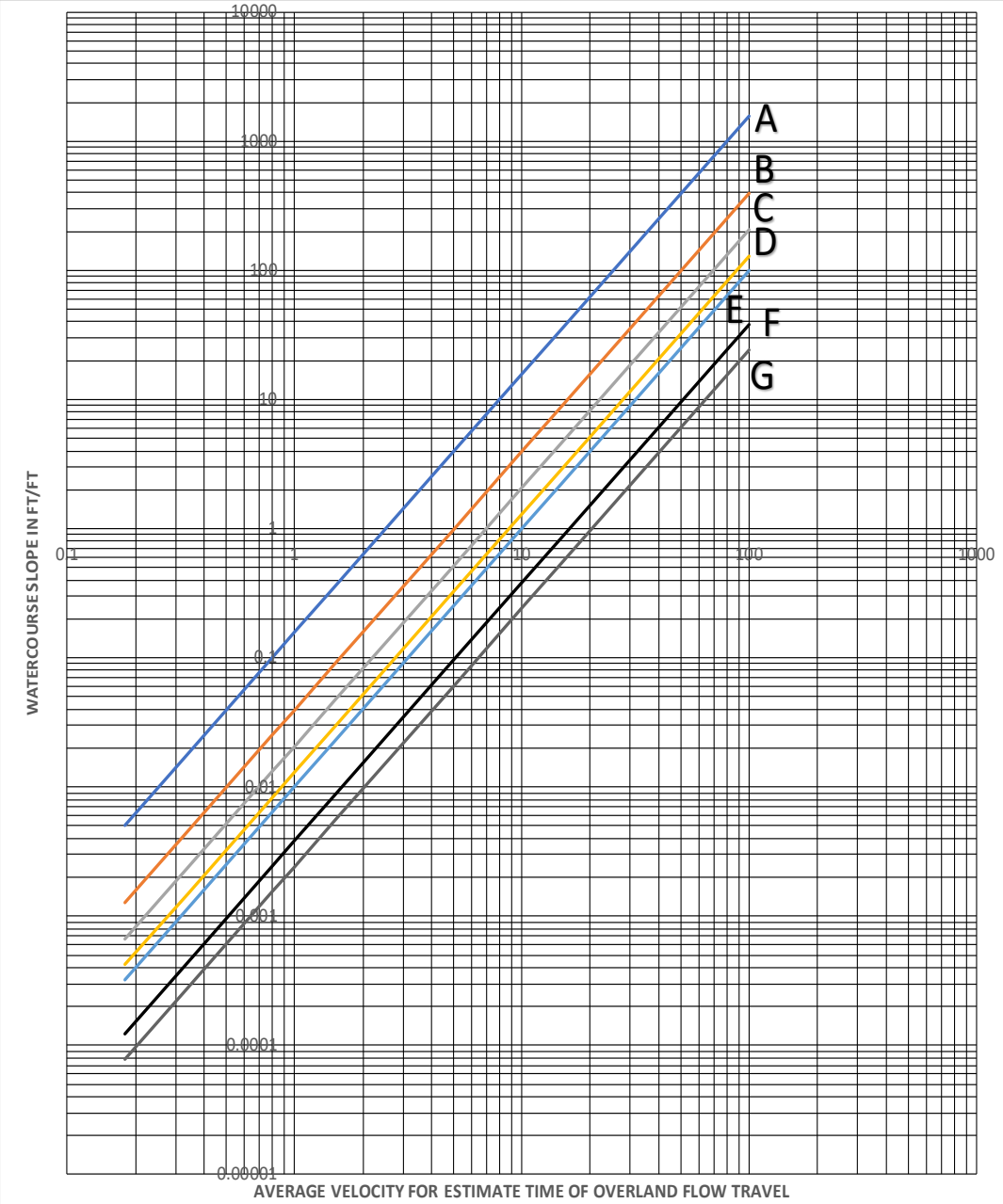


Each area outline on the map consists of more than one kind of soil. The map is thus meant for general planning rather than a basis for decisions for specific tracts.

Adapted from NCRS Soil Survey of Brazoria County, Texas, June 1981

THIS PAGE INTENTIONALLY BLANK

FIGURE 6-6. SHALLOWS CONCENTRATED (OVERLAND) FLOW



Plot lines in above figure based upon: V = (1.49/N(R^2/3) SQRT(S)

	Plots assume R = y						
	Forest with heavy ground litter and hay meadow	Minimum tillage cultivation, contour or striped cropped, and woodlands	Short Grass Pasture & Lawns	Cultivated Straight Row Crops	Nearly bare and untilled	Grassed Waterways	Pavement and small upland gullies
	A	B	C	D	E	F	G
n	0.202	0.101	0.073	0.058	0.051	0.05	0.025
R	0.2	0.2	0.2	0.2	0.2	0.4	0.2

THIS PAGE INTENTIONALLY BLANK

CHAPTER 7. SELECTED HYDRAULIC ANALYSES

7-1 SELECTED HYDRAULIC METHODS

Hydraulic methods are used to evaluate rates and depth of runoff, flow in watercourses (ditches, channels, streams, creeks, etc.), and flow into, through, and from conduits (i.e., circular, non-circular pipes and culverts), and other types of hydraulic systems. The use of commonly accepted and recognized, straightforward methods of hydraulic analysis are preferred when reasonable for evaluating drainage behavior. This present chapter identifies methods for conducting hydraulic analysis for most project design and evaluation of concern to the West Brazoria County Drainage District 11 (DISTRICT).

7-2 ROLE OF COMPUTER MODELS

A detailed description of hydraulic behavior, similar to hydrologic behavior, can be estimated using computer models. Such models typically incorporate backwater calculations using a detailed description of channel shape, hydraulic roughness, individual hydraulic controls, channel transitions, and diversion structures. Some models can be used to calculate flow in conduits and under bridges.

As with hydrologic models, well-recognized models are available from federal and state agencies (or their agents). Generally, hydraulic and related similar models for analysis of hydraulic conditions originally developed by the Hydrologic Engineering Center of the US Army Corps of Engineers (USACE-HEC) are acceptable for analyses possibly needed for projects intended for review by the DISTRICT. Other computer models specifically identified in Table 6-1 can be used without special approval, provided that the modeling parameters and coefficients are documented in materials presented to the DISTRICT for review.

Hydraulic computer models should be used only if:

a. The model applies to the situation of concern.
b. Coefficients required for the application of the model can be reasonably estimated.
c. The user of the model has experience with the use of the model.

Hydraulic analysis using computer models such as those in Table 6-1 should not be used unless the user is under the direction of a professional engineer. Plans, reports, and similar documents relying on computer-based backwater analyses and submitted to the DISTRICT for review must be sealed by a professional engineer.

Specialized computer models developed by county agencies are not recommended because they are based upon or calibrated using conditions not necessarily consistent with those found in the DISTRICT.

7-3 COMMON TYPES OF APPLICATION OF HYDRAULIC ANALYSES

Depending upon the situation, hydraulic methods may be used for standalone analysis or in conjunction with hydrologic analysis. Applications of hydraulic methods are commonly used for (i) design of a hydraulic structure or facility, including channels, ditches, and other watercourses, to achieve particular hydraulic behavior; (ii) comparison of hydraulic behavior under existing conditions to those under proposed conditions; or (iii) evaluation of flooding conditions along a watercourse.

Hydraulic analyses for various situations of common interest to the DISTRICT are discussed in the remainder of this chapter. These descriptions are intended to be of a summary nature; detailed methods of hydraulic analyses are more fully discussed in the Brazoria County Drainage Criteria

Manual, widely available hydraulic engineering references and textbooks, and computer model user manuals.

7-3.1 STEADY VS UNSTEADY FLOW

Virtually all hydraulic analyses for DISTRICT purposes can assume steady (time-invariant) flow. Unsteady flow is usually needed for hydrologic analysis involving storage and hydrograph behavior. If an applicant for a Letter of No Objection believes an unsteady hydraulic analysis is necessary, he or she should consult with the DISTRICT below undertaking such analysis.

7-3.2 UNIFORM FLOW IN CHANNELS AND CONDUITS

Uniform flow assumes an energy grade line slope to be similar to the channel or conduit slope. Consequently, the energy slope (such as used in the Manning equation, discussed below) can be used to estimate the depth of flow for a particular discharge, or, conversely, the discharge for a particular depth of flow. In general, the flow is defined by

$$H_d = H_u - H_L \qquad \text{[eq. 7-1]}$$

in which the subscripts "d" and "u" denote conditions at the downstream and upstream ends of a channel reach or conduit segment, H= hydraulic head (the sum of the elevation of the bottom of the channel, the flow depth, and the velocity head, $V^2/2g$, in which V = mean velocity and g is the acceleration of gravity), H_L is the head loss between the two ends of the channel or conduit segment. H_L is the sum of (i) localized head losses, commonly expressed as $K\ V^2/2g$ in which K is a head loss coefficient (which varies with the type of condition causing the head loss), and (ii) frictional losses as given by empirical equations such as the (commonly used) Manning equation (in common American units),

$$V = (1.49/n)\ R^{2/3}\ S_f^{1/2} \qquad \text{[eq. 7-2]}$$

In which R is the hydraulic radius in ft, n is the Manning roughness coefficient, and S_f is the friction slope (i.e., head loss per unit length of channel or conduit in, for example, ft/ft).

When $S_f = S_o$ (S_o = bottom slope or channel or conduit), uniform flow exists. Uniform flow is often assumed for approximating simplicity. Uniform flow can commonly be assumed for open ditch, swale, small channel flow, and long conduit flow situations.

The Manning roughness, n, is an empirical coefficient and is difficult to estimate with accuracy because it depends, in detail, at least upon the physical roughness of the channel, the depth of flow, the cross-section shape of the channel, the sinuosity of the channel, and the condition of vegetation in the channel. In conduits, n depends upon the type of conduit wall material and the cross-sectional shape of the conduit. Commonly recognized values for the roughness are listed in Table 7-1.

Table 7-2 provides adjustment factors to account for special features of a channel that may be commonly encountered in the DISTRICT. Reduce the adjustments such that the total adjustment does not exceed 30%.

Values of n used in hydraulic calculations should be identified in materials provided to the DISTRICT for review.

7-3.3 NON-UNIFORM FLOW APPLICATIONS AND RAPIDLY VARIED FLOW

Drainage and drainage control structures often require evaluation using non-uniform flow techniques. Examples include flow control and measurement structures, weirs, gates, channel restrictions, and

orifices. Such situations use the head loss characteristics of the device or control under consideration in conjunction with the energy equation to compute water surface elevation as a function of discharge (or vice versa).

In addition to the energy equation, such analyses commonly incorporate estimated or empirically determined coefficients. Table 7-3 provides some commonly used coefficients for non-uniform flow situations.

The use of non-uniform flow evaluation will almost always require a specification of either upstream or downstream flow and/or water depth conditions, e.g., specification of headwater or tailwater conditions. A tailwater condition is the starting point for most non-uniform flow calculations used in drainage analysis and design.

7-4 BACKWATER ANALYSIS AND STREAMFLOW MODELING

Streamflow evaluation (also referred to as "backwater analysis") uses the energy equation with the inclusion of energy losses due to such things as channel resistance, flow divergences or convergences, structures, etc. without assumption of uniform flow. An overview of the mathematical details of streamflow modeling is provided in the Brazoria County Drainage Criteria Manual (Section 3) or hydraulic engineering texts.

Generally (except for very simple applications), the use of backwater analysis requires trial and error analysis to determine flow depths for a particular discharge. Consequently, computer programs are commonly used to actually perform necessary computations.

7-5 FEATURES OF WELL-DESIGNED AND OPERATED CHANNELS

The following typical features and conditions should generally be recognized in a well-designed channel or similar hydraulic conveyance (see also guidelines in Table 7-4). Hydraulic calculations are typically used to evaluate such features and conditions.

Generally, the design of a channel should consider (see also guidelines in Table 7-4):

a. **Velocities:** Velocities that are too large can cause erosion, while velocities that are too low can contribute to deposition of sediments. Suggested representative velocities for channel design are those shown in Table 7-4.
b. **Flow Depth**: Flow depths in a conveyance should not be overly deep because they pose maintenance difficulties (e.g., promote sedimentation). Moderately shallow depths are preferred so long as the effects of increased runoff from future development are adequately recognized.
c. **Freeboard:** Freeboard is the height to the top of a channel or pond above the anticipated maximum elevation of the water surface in the conveyance or pond. There is not a hard and fast rule as to freeboard heights, but they should be selected in light of safety considerations, and the potential harm that would result should water levels rise above the top of a channel or pond structure. Three to six inches is a common minimum freeboard for ponds and smaller water watercourses for maximum water level conditions. Freeboard should be sufficient to provide adequate lateral drainage from connecting storm sewers; that is, connecting sewers should not have their crowns exposed.
d. **Maintenance Safety:** Watercourse side slopes requiring regular maintenance, e.g., side slopes of grass, should be sufficiently low so as to allow mowing equipment to be safely operated. Side slopes along sections of watercourses requiring maintenance should also be kept free of

obstructions, rubble, waste piles, leftover construction debris and materials, or other similar materials that might prevent access to or along the side slope.

e. **Setbacks:** Structures should not be placed extremely close to ditches and channels. Structures that are too close can block access for channel maintenance. Caution should be exercised if fence lines are present and would prevent channel maintenance; provision may have to be made for temporary removal and subsequent reinstallation of fences. Chapter 8 provides information for sizing setbacks distances.
f. **Maintenance Access:** Channels should be located so that practical pathways to move maintenance equipment to watercourses requiring maintenance and inspection should be available. Easement or right-of-way access along the watercourse channel should be secured as part of channel design if not already available. Widths of open area strips along the side of a watercourse should be provided and maintained to allow maintenance equipment access. See also discussion of easements in Chapter 8.
g. **Location of Channel:** The location of a channel should preferably follow existing channels and ditches, but providing the necessary drainage is paramount. Setbacks, maintenance access, operating space need to be recognized. The necessary outfall location must be recognized.

7-6 DESIGN FREQUENCY FOR NON-COASTAL ZONES

All ditches, channels, and drainageways under DISTRICT jurisdiction should usually be designed with capacity for a 100-year (100-yr), 24-hour (24-hr) rainstorm, except as follows:

- Roadside ditches in roadway right-of-way providing only local drainage: Use the 10-yr, 24-hr rainstorm for design purposes. Such local drainage must be demonstrated or confirmed.
- Special conditions for which lack of potential adverse impact using a smaller design storm level can be rigorously and quantitatively demonstrated to the District Engineer, such as for those example conditions listed in Table 7-4. However, if the design frequency is reduced from the 100-yr, 24-hour storm, it can be reduced to a storm event no smaller than a 10-yr, 24-hour storm.

Design storm frequency and duration for projects in coastal zones must undergo joint review by the DISTRICT and the Brazoria County Building Permits Director; only after such review would the DISTRICT consider issuing a letter of no objection.

7-7 POINTS OF EROSION AND SEDIMENT DEPOSITION CONCERN

The need for erosion protection should be assessed for points and locals where erosion potential is high. Locales or conditions for which there is a high potential for channel erosion include the following:

a. **Curvature:** The outer bank of erodible channels with a high curvature are a potential location for significant erosion; the interior of the curve may accumulate sediments.
b. **Bridges and Transitions:** The flow under bridges typically contract as it approaches the bridge structure. Erosion may become significant in such a zone. Any transition where significant flow constriction occurs has a potential for erosion. Conversely, the expansion of the flow downstream of a bridge or similar structure may promote sedimentation.
c. **Steep channels:** Steep channels promote high velocities, which can cause erosion.
d. **Channel confluences:** A mixture of high and low velocities can occur when two channel flows merge if one or both of the channels have moderate to high velocities, as they might during a storm period. Care should be exercised in the design of the confluence to avoid large differences in the velocities of the two channels.

e. **Outfalls:** The impact of the discharge from an outfall falling into a channel may create erosion and channel bottom holes. Avoid large drops in the outfall pipe and the receiving water surface.

7-8 TECHNIQUES FOR EROSION AND CHANNEL PROTECTION

Channel design factors depend in part upon whether the channel under consideration is to have only soil lining or to be all or partially concrete-lined. Channel lining using woven mats and blankets, geocells, geofabrics, and similar systems may be used when erosion or bank sloughing is a particular concern but require specialized expertise for their design and installation. Manufacturer design information should be consulted in such situations.

Common techniques for providing erosion and general channel protection include the following:

a. **Velocity Control in Channels:** Channel size should be sufficiently large to avoid high-velocity conditions under design conditions. Guidance for maximum velocities for channel design is provided in Tables 7-5 and 7-6.
b. **Avoiding Supercritical Flow:** Supercritical flow is defined as the condition in which the speed of small surface wave disturbances travel slower than oncoming flow (analogous to supersonic airflow). Unless intentional (as in the design of a weir), supercritical flow conditions are to be avoided. A flow can be determined to be supercritical if its Froude number is greater than one. The Froude number (in consistent units) is defined as $V/(gy)^{1/2}$ in which V is the mean channel velocity, y is the total depth of flow, and g = 32.2 feet/second^2 (32.2 ft/s^2)is the acceleration due to gravity. Caution should also be exercised for channel flows for which the Froude exceeds about 0.7; when this occurs, velocities and water surfaces tend to be unstable.
c. **Channel Lining**: Rather than using a channel lined with erodible materials, consider using concrete lining or hardened lining material, especially in zones near control structures, constrictions, and bridges. See Table 7-5 for factors in concrete-lined channel design.
d. **Grass Lining:** Grass or thick vegetative lining can often provide a viable alternative to concrete or similar channel linings if velocities are not expected to become too extreme. If grass lining is used, it must be thick, vibrant, suited for the climatic conditions, and be well maintained (i.e., be regularly inspected and refurbished if damaged or dying). See Table 7-6 for design guidelines for grass-lined channels.
e. **Roughness in Grass Lined Ditches.** Effective design of a grassed channel should recognize the condition of the grass to line the channel. The condition depends upon the expected quality of the grass stand, the expected height of the grass once established, and the velocity and depth of the flow itself. The retardance that a flow may experience is shown in Table 7-7. Because of the varying roughness that a grass channel can experience, the flow conditions should be check for a 10-, 25-, and 100-yr flow condition.
f. **Local Scour**: Localized zones of potentially high velocities along an erodible channel should be protected with some type of erosion protection materials, e.g., concrete, permanent fiber mats, riprap, or similar materials.
g. **Riprap Protection:** Riprap can be a cost-effective measure for protection of areas potentially subject to high velocities and velocities at a significant angle from the main direction of flow, e.g., the discharge of a flow from a culvert at right-angles to the receiving stream. Table 7-8 provides guidelines for construction of riprap protection.
h. **Bottom Slopes**: Channel bottom slopes should not be extreme. Avoid large slopes because they promote high velocities and undesirable flow behavior. Too low velocities promote sedimentation.

Bottom slopes should generally be between 1% and 0.05%. Channels with slopes of less than 0.01% will usually not naturally flow.

i. **Smooth Bottom Condition**: If the channel is to convey flow well at its design velocity, holes, large irregularities in the channel width, and depressions in the channel bottom should not be present unless their presence is accounted for in the capacity evaluation of the channel and its effective roughness.

j. **Side Slopes:** Soil side slopes guidelines are presented in Tables 7-6 and 7-7, but generally should generally not exceed 4 horizontal to 1 vertical. Smaller slide slopes may be required in sandy type soils.

k. **Bottom Width of Channels and Ditches**: To provide access for maintenance equipment, channels and ditches should, to the extent possible, allow for easy mowing. However, avoiding excessively high velocities to limit erosion and excessive low velocities to avoid sedimentation should be considered. Recommended maximum and minimum velocities based upon peak discharge during a storm event of a particular frequency are given in Tables 7-4, 7-5, and 7-6.

l. **Manmade Channel Curvature:** Sharp curves in channel alignment should be avoided and not exceed 90 degrees. The radius of the alignment curve should be less than three times the top width of the channel for the design flow in erodible channels. Lined channels can have sharper turns. If lining is to be provided in the curve, the lining should extend at least three channel widths (at the top width for the design flow) upstream of the end of the curve and downstream of the beginning of the channel curve.

m. **Confluences**: The alignment of two intersecting channels should be between 15 and 45 degrees; intersecting alignments outside this range are discouraged unless the channels are smaller ditches less than 3 ft deep at the design flow condition.

n. **Transitions:** Transitions between converging or diverging channel widths should be smooth and slowly varying. It is preferred that the length of a converging channel be at least as long as the difference in the upstream and downstream widths of the convergence zone. For a divergent channel width, it is preferred that the length of the divergence zone be at least three times the difference in the downstream and upstream widths of the divergence zone.

o. **Inspections:** Channels and other man-made or man-maintained watercourses should be regularly inspected for possible deficiencies, such as excessive vegetation; zones of localized erosion; general erosion (particularly side banks); collapsing hydraulic structures, such as drain pipes; poor drainage as evidenced by standing, nondraining waters; or excessively frequent overflow. Inadequate inspection may result in a watercourse not functioning as designed. When deficiencies are found, they should be remedied as soon as reasonably possible.

p. **Detention and Retention Pond Geometry:** Detention pond geometry and other design features are discussed in Chapter 3.

Additional information is provided in the Brazoria County Drainage Criteria Manual and Texas Department of Transportation (TxDOT) hydraulic design manuals.

7-9 CAUTIONS IN PERFORMING HYDRAULIC ANALYSES

Care should be exercised in the following when performing a hydraulic analysis:

Modeling Tool or Methodology: Selecting an appropriate model or calculation procedure for evaluating a particular hydraulic situation.

Using Hydrologic Inputs: Selecting appropriate hydrologic outputs to use as inputs for hydraulic calculations.

Choice of Coefficients. Selection of coefficients for hydraulic evaluation. This is likely the most important factor to which attention should be paid in hydraulic evaluation. The choice of an appropriate Manning n coefficient requires special care. The sensitivity of hydraulic evaluation results should be recognized; slight changes in some coefficients can produce significantly different hydraulic results.

THIS PAGE INTENTIONALLY BLANK

TABLE 7-1. VALUES OF THE MANNING ROUGHNESS COEFFICIENT "n" Channel

	Description	min	avg	max
A	**LINED OR BUILT-UP CHANNELS**	0.021	0.025	0.030
A1	*Corrugated Metal*	0.021	0.025	0.030
A2	*Nonmetal*			
a. Concrete				
	1. Trowel finish	0.011	0.013	0.015
	2. Float finish	0.013	0.015	0.016
	3. Finished, with gravel on bottom	0.015	0.017	0.020
	4. Unfinished	0.014	0.017	0.020
	5. On good excavated rock	0.017	0.020	---
	6. On irregular excavated rock	0.022	0.027	---
b. Concrete bottom float finished with sides of:				
	1. Dressed stone in mortar	0.015	0.017	0.020
	2. Random stone in mortar	0.017	0.020	0.024
	3. Cement rubble masonry, plastered	0.016	0.020	0.024
	4. Cement rubble masonry	0.020	0.025	0.030
	5. Dry rubble or riprap	0.020	0.030	0.035
c. Asphalt				
	1. Smooth	0.013		0.013
	2. Rough	0.016		0.016
B. EXCAVATED OR DREDGED				
a. Earth, straight and uniform				
	1. Clean, recently completed	0.016	0.018	0.020
	2. Clean, after weathering	0.018	0.022	0.025
	3. Gravel, uniform section, clean	0.022	0.025	0.030
	4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish				
	1. No vegetation	0.023	0.025	0.030
	2. Grass, some weeds (see also Table 7-5)	0.025	0.030	0.033
	3. Dense weeds or aquatic plants in deep channels	0.030	0.035	
	4. Earth bottom and rubble sides	0.028	0.030	0.035
	5. Stony bottom and weedy banks	0.025	0.035	0.040
	6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline excavated or dredged				
	1. No vegetation	0.025	0.028	0.033
	2. Light brush or banks	0.035	0.050	0.060
d. Rock Cuts				
	1. Smooth and uniform	0.025	0.035	0.040
	2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds, and brush cuts				
	1. Dense weeds, high as flow depth	0.050	0.080	0.120
	2. Clean bottom, brush on sides	0.040	0.050	0.080
	3. Dense brush, high stage	0.080	0.100	0.140

TABLE 7-1. Cont'd

C. NATURAL STREAMS			
C1. Minor streams (top width at flood stage < 100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts, or deep pools	0.025	0.030	0.033
2. Clean, winding, some pools, and shoals	0.033	0.040	0.045
C2. Floodplains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush	0.035	0.050	0.070
d. Trees			
1. Dense willows, summer, straight	0.110	0.150	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
C3. Major streams (top width at flood stage > 100 ft)			
"n" value is less than minor streams of similar desc. because banks offer less effective resistance.			
a. Regular section with no boulders or brush	0.025		0.060
b. Irregular and rough section	0.035		0.100
D. PIPE AND CONDUIT			
D1. Concrete			
a. Culvert, straight and free of debris	0.010	0.011	0.013
b. Culvert with bends, connections, and some debris	0.011	0.013	0.014
c. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
D2. Corrugated Metal Pipe			
a. Subdrain	0.017	0.019	0.021
b. Storm drain	0.021	0.024	0.030
D3. Corrugated Polyethylene (PE)			
a. Smooth interior walls	0.009		0.010
b. Corrugated inner walls	0.018		0.025
D4. Polyvinyl Chloride (PVE)			
a. *Smooth* inner walls	0.009		0.011

TABLE 7-2. ADJUSTMENT OF ROUGHNESS FOR EXCAVATED & NATURAL CHANNELS

n =(no+ n1 + n2+ n3+n4) m

	Channel Conditions	Value
Material Involved	Earth/soil	0.020
no	Rock Cut	0.025
	Fine Gravel	0.024
	Course Gravel	0.028
Degree of Irregularity	Smooth	0.000
n1	Minor	0.005
	Moderate	0.010
	Severe	0.020
Variation of Channel	Gradual	0.000
Cross-Section	Alternating Occasionally	0.005
n2	Alternating Frequently	0.010-0.015
Relative Effect of	Negligible	0.000
Obstructions	Minor	0.010-0.015
n3	Appreciable	0.020-0.030
	Severe	0.040-0.060
Vegetation	Low	0.005-0.010
n4	Medium	0.010-0.025
	High	0.025-0.050
	Very High	0.050-0.100
Degree of	Minor	1.000
Meandering	Appreciable	1.150
m	Severe	1.300

Maximum adjustment should be limited to 1.3 times unadjusted value

Source: Open-Channel Hydraulics by Ven Te Chow, Open Channel Hydraulics (1959).

THIS PAGE INTENTIONALLY BLANK

TABLE 7-3. COMMON HEAD LOSS COEFFICIENTS IN SUBCRITICAL FLOW

Loss Element [Data Source]	Characteristics	Equation for Use	Coefficient, C
Entrance Loss, conc pipe [3, 1]	Pipe projects from fill (no headwall); socket pipe end; V = velocity in pipe	$CV^2/2g$	0.2
Entrance Loss, conc pipe [3, 1]	Pipe projects from fill (no headwall); square pipe end; V = velocity in pipe	$CV^2/2g$	0.5
Entrance Loss, conc pipe [3, 1]	Pipe with headwall or headwall with wingwalls, socket pipe end, V = velocity in pipe	$CV^2/2g$	0.2
Entrance Loss, conc pipe [3, 1]	Pipe with headwall or headwall with wingwalls, square pipe end, V = velocity in pipe	$CV^2/2g$	0.5
Entrance Loss, conc pipe [3, 1]	Pipe with headwall or headwall with wingwalls, rounded pipe end, V = velocity in pipe	$CV^2/2g$	0.2
Entrance Loss, conc pipe [3, 1]	Pipe with end modification: mitered to conform to fill slope	$CV^2/2g$	0.7
Entrance Loss, conc pipe [3, 1]	Pipe with end section conformed to fill slope	$CV^2/2g$	0.5
Entrance Loss, conc pipe [3, 1]	Pipe with beveled end edges, 33.7 deg or 45 deg bevels	$CV^2/2g$	0.2
Entrance Loss, conc pipe [3, 1]	Pipe with side slope tapered to inlet	$CV^2/2g$	0.2
Entrance Loss CMP [3]	Projected from fill without headwall, V = velocity in pipe	$CV^2/2g$	0.9
Entrance Loss CMP [3]	Pipe with headwall or headwall with wingwalls, square pipe end, V = velocity in pipe	$CV^2/2g$	0.5
Entrance Loss CMP [3]	Pipe mitered to conforms to fill slope	$CV^2/2g$	0.7
Entrance Loss CMP [3]	Pipe end section conforms to fill slope	$CV^2/2g$	0.5
Entrance Loss CMP [3]	Pipe with beveled end edges, 33.7 deg or 45 deg bevels	$CV^2/2g$	0.2
Entrance Loss CMP [3]	Pipe with side slope tapered to inlet	$CV^2/2g$	0.2
Entrance Loss RC Box [3, 1]	Headwall parallel to Embankment, no wingwalls, square-edge on three edges	$CV^2/2g$	0.5
Entrance Loss RC Box [3, 1]	Headwall parallel to Embankment, three edges rounded to radis of 1/2 barrel dimension	$CV^2/2g$	0.2
Entrance Loss RC Box [3, 1]	Wingwalls at 30 deg to 75 deg to barrel, square-edge at crown	$CV^2/2g$	0.4
Entrance Loss RC Box [3, 1]	Wingwalls at 30 deg to 75 deg to barrel, top corner roundedt to radius = 1/12 barrel dimension	$CV^2/2g$	0.2
Entrance Loss RC Box [3, 1]	Wingwalls at 10 deg to 25 deg to barrel, square-edge at crown	$CV^2/2g$	0.5
Entrance Loss RC Box [3, 1]	Wingwalls parallel (extension of sides), square edge at crown	$CV^2/2g$	0.7
Entrance Loss RC Box [3, 1]	Wingwalls parallel (extension of sides), side or slope tapered inlet	$CV^2/2g$	0.2
Sudden Contraction [4]	Vu=inlet velocity; Vd =outlet velocity	$C(Vd^2-Vu^2)/2g$	0.5
Sudden Expansion [4]	Vd=inlet velocity; Vu=outlet velocity	$C(Vu^2-Vd^2)/2g$	1.0
Smooth Contraction [4]	Vu=inlet velocity; Vd =outlet velocity	$C(Vd^2-Vu^2)/2g$	0.1
Smooth Expansion [4]	Vd=inlet velocity; Vu=outlet velocity	$C(Vu^2-Vd^2)/2g$	0.2
Contraction Transition [2]	Straight line transition width: 10 deg to 30 deg,Vd =outlet velocity, Vu = inlet velocity	$C(Vd^2-Vu^2)/2g$	0.1
Expansion Transition [2]	Straight line transition width: 10 deg, Vu=inlet velocity; Vd =outlet velocity	$C(Vu^2-Vd^2)/2g$	0.2
Expansion Transition [2]	Straight line transition width: 15 deg, Vu = inlet velocity, Vd = outlet velocity	$C(Vu^2-Vd^2)/2g$	0.3
Expansion Transition [2]	Straight line transition width: 30 deg, Vu = inlet velocity, Vd = outlet velocity	$C(Vu^2-Vd^2)/2g$	0.4
Expansion Transition [2]	Straight line transition width: 40 deg, Vu = inlet velocity, Vd = outlet velocity	$C(Vu^2-Vd^2)/2g$	0.7
Bend [4]	Rc/B = 2.5, B = channel width, Rc = radius of bend	$CV^2/2g$	0.02
Bend [4]	Rc/B = 2.0, B = channel width, Rc = radius of bend	$CV^2/2g$	0.07
Bend [4]	Rc/B = 1.5, B = channel width, Rc = radius of bend	$CV^2/2g$	0.12
Bend [4]	Rc/B = 1.0, B = channel width, Rc = radius of bend	$CV^2/2g$	0.25
Gradual Bend [4]	D = total deflection angle (deg) of bend	$CV^2/2g$	0.001*D

Sources:

[1] Brazoria County Drainage Criteria Manual, Chaps. 4 & 5

[2] USACE, EM 1110-2-1601, Hydraulic Design of Flood Control Channels

[3] USACE, HEC-RAS Hydraulic Reference Manual, ver. 5.0, 2016

[4] Brater and King, Handbook of Hydraulics, 6th Edition, Chap. 8, 1976

THIS PAGE INTENTIONALLY BLANK

TABLE 7-4. GUIDELINES FOR CHANNEL DESIGN

ISSUE	CONDITION OR DISCUSSION
DEFINITION	**CHANNEL** is any drainageway such as an open surface creek, waterway, channel, ditch, swale, etc., except a roadside ditch. A **ROADSIDE DITCH** is an open surface drainageway which does and is intended to carry only runoff from the roadway ROW in which ditch lies. If ditch carries runoff from areas other than roadway ROW, then ditch must be treated as a channel. A drainageway which receives runoff via sewer pipes from areas beyond roadside ROW must be considered a channel. Note: If no legal ROW exists, the ROW (for drainageway design purposes) extends to 5-ft beyond the outer edges of the roadway.
STORM DURATION	Storm duration for channel design purposes: 24 hr.
DESIGN FREQUENCY	**ROADSIDE DITCH** (not channel; note definition above): • Ditch under DISTRICT jurisdiction: 5-yr Ditch not under County or TxDOT jurisdiction: minimum of (i) 5-yr frequency or (ii) frequency specified by County or TxDOT **CHANNEL** (not a roadside ditch): • If channel drains directly to watercourse under jurisdiction of County or TxDOT, design frequency must be as least as large as specified by County or TxDOT for channels. • 100-yr storm unless specified otherwise. • Exceptions to the 100-yr design storm requirement: 1. **Exception 1**: Storm Sewer Discharge Only: Only drainage to the channel is from storm sewer pipes (no direct drainage from overland flow), in which case the design capacity of the channel must be sufficient to convey the simultaneous discharges of incoming sewer pipes operating at their design capacity. 2. **Exception 2**: 25-yr design flow can be used if drainage area to channel: a. Is undeveloped land (no more than 2% of drainage area is impervious material, e.g., roofs, pavement); b. Is formally zoned or classified by Brazoria County as rural. c. Does not lie in County-designated floodplain. d. Does not lie in DISTRICT designated flood prone area. e. Channel does not discharge directly to watercourse under state or federal jurisdiction. f. 100-yr peak discharge is no greater than 1.10 x 25-yr discharge peak discharge.
IMPACT ASSESSMENT FOR CHANNEL	Lack of adverse impact by proposed flow in channel must be demonstrated for the design frequency and a 10-year storm event.
MAXIMUM VELOCITY	See Tables 7-5 and 7-6
MAXIMUM FLOW DEPTH	5 ft of depth at 100-yr flow condition for all in-bank flow
PREFERRED CHANNEL SHAPE	Channels-trapezoidal. Roadside ditch: Trapezoidal or triangular
FLOWLINE SLOPE	Min: 0.05%. Max: 1% (but erosion potential should be checked)
SIDE SLOPES	Concrete-lined: See Table 7-7. Grass-line: See Table 7-6.
MAXIMUM SLIDE SLOPES	See Tables 7-5, 7-6, 7-7
CURVES & TRANSITIONS	Maximum change in top of slope alignment should be gradual and not exceed a 1: 3 (transition width to transition length) change.
BRIDGE VS. CULVERTS	Use bridge if roadway over culvert crossing would obstruct flood flow and cause floodwaters to flow around ends of roadway crossing
FREEBOARD	• For 100-yr storm frequency: 0.1 ft min. For 10-yr storm frequency: 0.3 ft min. • For curves with 15% or more alignment change, increase freeboard on curves by at least maximum of: (i) 0.1 ft; (ii) one velocity head. • Be sufficient to provide adequate drainage from lateral storm sewers during 25-yr storm.
PARAMETERS	Manning n roughness: See Table 7-1 and (for grassed channels) Tables 7-5 & 7-6
EROSION PROTECTION	See text discussion and riprap protection (Table 7-8)

Source: Brazoria County Drainage Criteria Manual, 2003

THIS PAGE INTENTIONALLY BLANK

TABLE 7-5 GUIDELINES FOR HYDRAULIC DESIGN OF CONCRETE-LINED CHANNELS

Channel cross section shape	Trapezoidal preferred
Channel side slopes	• Slope of 3:1 (h to v), with minimum concrete thickness of 4-inch. • Slope of 1.5:1 (h to v), with minimum concrete thickness of 5-inch.
Minimum bottom width for trapezoidal shape	Size channel so that (1) Maximum velocities (given below) not exceeded. (2) Peak velocity for minimum design velocity equals or exceeds listed velocity
Maintenance Berm	See Table 8-1. MINIMUM CONVEYANCE & ACCESS-WAY WIDTHS
Roughness "n" to be use for design	Standard value of 0.015. See also Table 7-1. VALUES OF THE MANNING ROUGHNESS COEFFICIENT: "n."
Maximum velocity	Max 25-yr flow velocities not to exceed: • Riprap lined: 8 fps • Concrete lined: 10 fps Max 10-yr flow velocity • Riprap lined: 5 fps • Concrete lined: 6 fps
Minimum Velocity	Minimum design velocity = peak discharge velocity for 5-yr discharge condition: • Riprap lined: 1.5 fps • Concrete lines: 2 fps
Slope protection	Paved slopes to have minimum 18-inch toe wall
Material	• Class A concrete (minimum design strength of 3000 psi), per TxDOT specification 421 (latest edition). • Reinforcing to meet as minimum TxDOT specification 420 (latest edition).
Slope paving protection and stabilization	• Use toe walls at top, bottom, and end of paved slopes. • Use weep holes • Use back slope drains if channel not fully lined.

Sources: Brazoria County Drainage Criteria Manual, 203; TxDOT Specifications 420, 421, and 440, 2014.

THIS PAGE INTENTIONALLY BLANK

TABLE 7-6. GUIDELINES FOR GRASSED-LINED CHANNEL DESIGN

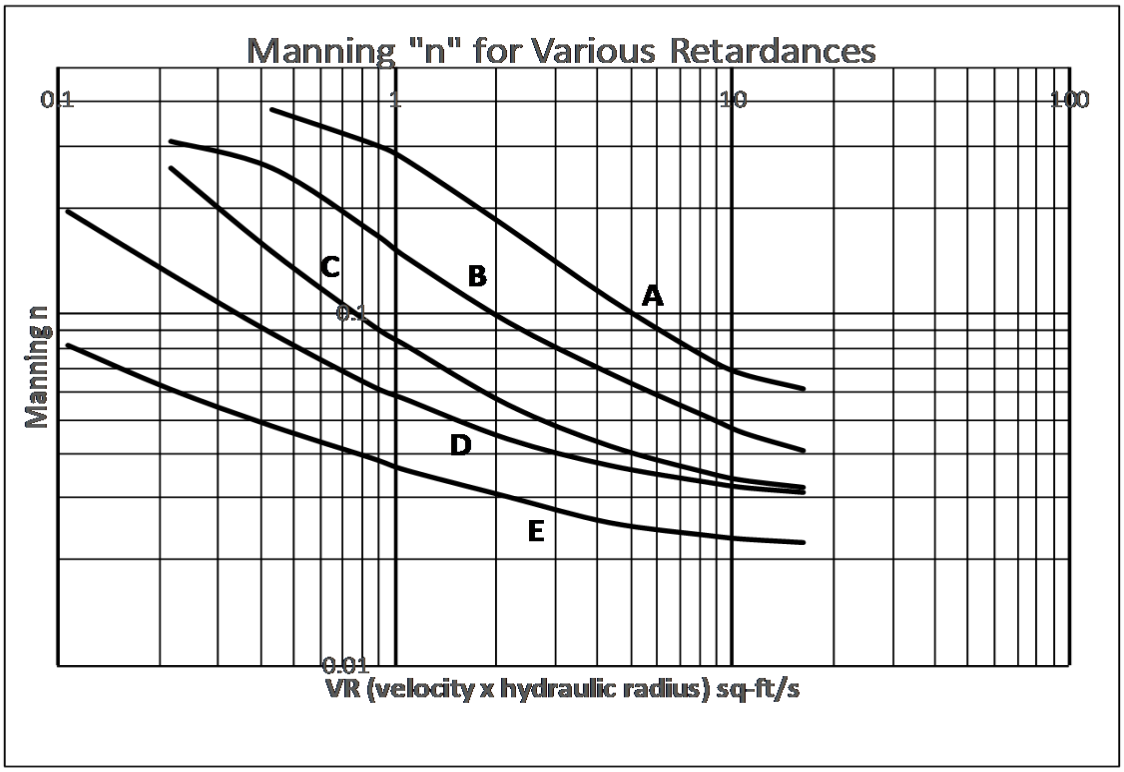
Channel cross section	Trapezoidal preferred
Channel side slopes (horizontal to vertical)	Preferred maximum of 5:1 but no steeper than 4:1 for channels 5 ft or less depth for clay soils. Sandy soils flatter side slopes may be necessary. Use geotechnical evaluation for channels deeper than 5 ft.
Bottom width for trapezoidal shape: Design discharge more than 10-yr discharge (at bank full conditions).	For peak discharge of design flow, size channel to 1. Have maximum velocity 5 fps or less 2. 25-yr peak discharge to be greater than 2 fps. 3. 10-yr peak discharge to be greater than 1 fps Do not narrow channel to less than 1 ft of width.
Bottom width for trapezoidal shape: Design discharge 10-yr or less discharge (at bank full conditions).	For peak discharge of design flow, size channel to 1. Have maximum velocity 5 fps or less 2. 10-yr peak discharge to be greater than 1 fps.
Maintenance Berm	See Table 8-1. MINIMUM CONVEYANCE & ACCESS-WAY WIDTHS
Allowable maximum velocities at peak design flow condition	Grass on predominately clay soil: 5.0 fps Grass on predominately sandy soil: 4.0 fps
Roughness "n" for design flow; "n" must be determined by trial and error using retardance curve below.	• Assume: Depth of flow equal to channel depth less freeboard for design flow conditions. • Select trial velocity V • Compute VR and determine n from chart below • Compute V from Manning equation; select another V if computed V does not match trial value of V • When trial V = computed V, assess whether V falls within allowable limits • If V within allowable limits not achieved, revise channel shape
Allowable maximum velocities at peak design flow condition	For 25-yr storm Grass on predominately clay soil: 5.0 fps Grass on predominately sand soil: 4.0 fps For 10-yr storm Grass on predominately clay soil: 3 fps Grass on predominately sandy soil: 2 fps
Side slope erosion protection	If velocity more than expected, use backslope interceptor drain at every 800 over distance where velocity requirement occurs
GRASS CONDITIONS – FACTORS FOR A GOOD STAND OF GRASS	
• Generally free of bare areas; absence of eroded areas	
• Density reasonably uniform	
• One type of grass dominates	
• Grass height moderately similar throughout	
• If maintained by mowing, mowing done on regular basis	
• Quality of grass reasonably uniform; few if any dead zones	
• Similarity of color and stage of growth	
• Free of fungus or disease	

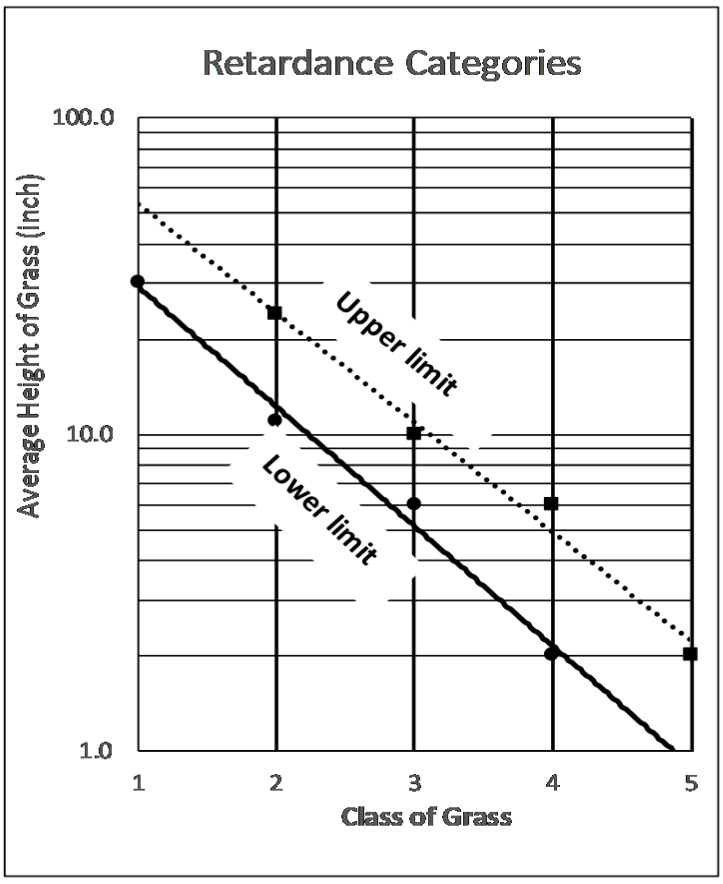
Source: Brazoria County Drainage Criteria Manual, 2003; Handbook of Channel Design for Soil and Water Conservation, Stillwater Outdoor Hydraulic Laboratory, SCS-TP-61, 1947, 1966

THIS PAGE INTENTIONALLY BLANK

TABLE 7-7. ROUGHNESS FOR VARIOUS GRASS HEIGHTS AND FLOW CONDITIONS

Data Source: Handbook of Channel Design for Soil and Water Conservation, Stillwater Outdoor Hydraulic Laboratory, SCS-TP-61, 1947 and 1966





Class	Good Stand of Grass	Fair Stand of Grass
1	A	B
2	B	C
3	C	D
4	D	D
5	E	E

Procedure:

1. Pick class of grass using Retardance Category (left); select appropriate letter category of retardance using Class Chart immediately above.
2. Use an estimated n value, estimated flow depth, and design Q, to compute R from Manning equation:
   $Q = \text{Area } V = \text{Area } (1.49/n)\, R^{1/6}\, S^{1/2}\, R^{1/2}$
3. Compute new depth from new R for selected design channel shape with bottom slope = S in ft/ft..
4. Compare computed n to estimated n. If different, set previous n to computed n and previous y to new y.
5. Return to step 2 to repeat calculation until estimated n = computed n

THIS PAGE INTENTIONALLY BLANK

TABLE 7-8. GUIDELINES FOR RIPRAP USE IN COMMON APPLICATIONS

Placement	Maximum side slope: 2h:1v
Placement	On toe of slopes, thickness should be greater than anticipated scour depth
Placement	Smaller blocks to be positioned among larger blocks so that approximately uniform mat surface is achieved.
Material - shape	Blocks more or less cubical in shape rather than elongated slabs No more than 25% of blocks can be 2.5 longer than width or thickness No bock length more than 3 times its width or thickness. Minimum thickness of individual blocks 6 inches
Material - type	Stone or concrete rubble; rubble not to have exposed reinforcing steel projecting from concrete; rock should be free from cracks, seams, and other defects which would tend to increase rate of deterioration
Material - condition	Riprap should free of dirt, foreign matter, deleterious material
Minimum riprap mat thickness for outfall/inlet protection	Minimum of (a) 18 inches; (b) 2 x d_{50}, or (c) 1.5 x d_{100}, where d_x is the rock size for which x% of the rocks in the rock mix are less than size d_x .
Minimum dimensions for riprap around culvert **outlets**	Minimum height above top of culvert pipe: Extend to the smaller of top of overlying embankment or the larger of (a) ½ pipe diameter; (b) 18 inches Minimum width beyond side of culvert: Extend to the smaller (i) of the full width of the channel on each side of the culvert or (ii) presence of riprap from another structure or side-by-side culvert; or (iii) the larger of (b) 1.5 x culvert diameter; (c) 18-inches. Minimum depth below culvert invert: To bottom of ditch or channel Minimum apron length downstream of outlet: Minimum of (a) 4 x pipe diameter (b) Opposite bank of channel (if present)
Minimum dimensions for riprap around culvert **inlets**	Minimum height above top of culvert pipe: Same as outlet. Minimum width beyond side of culvert: Extend to the smaller (i) of the full width of the channel on each side of the culvert or (ii) presence of riprap from another structure or side-by-side culvert; or (iii) the larger of (b) 1 x culvert diameter; (c) 12-inches. Minimum depth below culvert invert: Same of outlet. Minimum apron length upstream of inlet: Minimum of (a) 3 x pipe diameter (b) Opposite bank of channel (if present)

RAPRAP GRADUATION FOR COMMON USES

Examples of common uses: Toe of grass or paved slope surfaces in channels less than 5-ft deep; protection around inlet and outlets of pipes; side slopes at moderately curved (30 degrees or less) bends of ditches; collars around culvert ends; splash block areas

% Lighter by Weight	Stone Weight (lbs)		Volume, Cu-Ft (standard unit weight: 150 pcf)		Cubical shape (Each side, ft)*		Spherical shape (Diameter, ft)*	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
100	180	265	1.20	1.77	1.06	1.21	1.31	1.50
50	80	110	0.53	0.73	0.81	0.90	1.01	1.12
15	40	60	0.27	0.40	0.64	0.74	0.80	0.91

*Dimensions based upon theoretical cubic and spherical shape; provided only for guidance

Source: Brazoria County Drainage Criteria Manual, 2003; Criteria Manual for Design of Flood Control and Drainage Facilities in Harris County, Texas, 1984; USCOE Engineer Manual 1110-2-1601

THIS PAGE INTENTIONALLY BLANK

CHAPTER 8. SURVEY, DESIGN, AND CONSTRUCTION ISSUES

8-1 PURPOSE

This West Brazoria County Drainage District 11 (DISTRICT) Drainage Criteria Manual (DD11 MANUAL) does not generally address details of surveys, engineering design, or construction activities and documents. Design and construction details suitable for construction plans are presented in the Brazoria County Drainage Criteria Manual and construction drawings and specifications available from Brazoria County when applicable to the drainage feature or structure of interest. Other construction details and specifications are available from applicable documents of such agencies as the U. S. Army Corps of Engineers (USACE), the U.S. Bureau of Reclamation, Texas Department of Transportation (TxDOT), Harris County Flood Control District (HCFCD), and the Harris County Engineering Department (HCED).

However, DISTRICT experience suggests that certain aspects of project development, design, and construction are in need of particular emphasis to meet the policy objections of the DISTRICT. These are addressed in this chapter.

8-2 SURVEYS

Land surveys are important to drainage design because of the potential use of the surveyed land for activities affecting drainage. Consequently, a Letter of No Objection (LNO) may be required before formal filing of a survey with Brazoria County to confirm that necessary allowance has been provided for drainage easements or rights-of-way.

8-2.1 CONDITIONS FOR REQUIRED LETTER OF NO OBJECTION FOR SURVEY

Application for an LNO is required for surveys of an original tract meeting one or more of the following conditions:

a. **Sale to Commercial Entity:** The survey is done for the purposes and is required for sale of the original tract or portions of the original tract to a commercial entity. If the survey is done as part of the design of a commercial project for which an application for an LNO is required, no separate LNO for a survey is required; issuance of an LNO for the commercial project will suffice for an LNO for a survey for the project. However, for a survey to be considered as part of a commercial project for which an LNO is required, the application for the LNO for the commercial project must be made within six months of the date of the survey.
b. **Division into More Than Four Parts**: The survey will subdivide the original tract into more than four parts, and at least one part is smaller than 1 acre.
c. **Not a Small Subdivision:** The survey is done to develop a land-use subdivision that does not meet Brazoria County requirements for a small subdivision. A subdivision shall not be a small subdivision unless the County Court approves the subdivision to be a small subdivision (see Section 8-2.2 below).
d. **Lack of Right-of-Way and Setbacks:** The original tract is to be subdivided into subtracts or lots which do not provide for necessary drainage via rights-of-way, easements, or setbacks as may be required by the DISTRICT.

8-2.2 DEFINITION OF A SMALL SUBDIVISION

A small subdivision is a land development subdivision in the DISTRICT that the Brazoria County Court approves as a small subdivision as based upon the recommendation of the Brazoria County Engineer, such recommendation being based upon meeting the following Brazoria County conditions:

a. The property owner and/or developer does not lay out streets, alleys, squares, parks, or other parts of the tract intended to be dedicated to public use or for the use of purchasers or owners of lots fronting on or adjacent to the street, alley, square, park, or other parts.
b. No more than 4 parts result from the subdivision of a tract of land in question, and each part is at least one acre in area.
c. The original parcel to be divided cannot be the result of a division using the small subdivision process within 5 years from the date of application for small subdivision status.
d. Each subdivided part of the original parcel has adequate, separate (not shared) access to a publicly maintained road, with at least 60 feet of frontage along such road.
e. The proposed division is not expected to have an adverse impact on drainage as confirmed in writing by the District Engineer; such confirmation can be provided with an LNO from the DISTRICT.
f. Each part is of suitable size and condition to allow the provision of adequate water systems and sewer service facilities, as confirmed in writing by the Environmental Department of Brazoria County.
g. The owner submits an "Application for Variance from Platting Requirements" in the format prepared by the County Engineer's Office along with the required information and documents.
h. The property owner and/or developer shall provide necessary right-of-way dedications and setbacks.
i. The property owner and/or developer provides adequate right-of-way or easements for existing and proposed road and drainage facilities if such is required by the County Engineer or the District Engineer. The property owner and/or developer shall provide proof that all parties holding an interest in the tract have consented to such rights-of-way or easements.

8-2.3 EXEMPTIONS FROM CONDITIONS FOR REQUIRED LETTER OF NO OBJECTION FOR SURVEY

If a property owner or developer seeks exemption from the requirements for an LNO for a survey as may be required by Section 8-2.1, the property owner or developer shall notify the DISTRICT or the District Engineer and state the basis for the exemption. If the DISTRICT or the District Engineer does not confirm such exemption, the property owner or developer cannot use such exemption for not applying for an LNO.

8-2.4 GENERAL BASES FOR NOT ISSUING LETTER OF NO OBJECTION FOR SURVEY

The DISTRICT uses Brazoria County exemptions for not requiring an LNO for survey; these exemptions include the following:

a. **Division for Mortgage or Tax Purposes:** The division of a tract of land into two parts is done solely for one of the following purposes: establishing a lien, or establishing a different tax basis.
b. **Division to Change Line Between Two Existing Tracts and/or to Reconfigure Existing Tracts:** The division of a tract of land solely to change the line between two or more existing tracts or to reconfigure two or more tracts.
c. **Division for Family:** The tract is divided into four (4) or fewer parts, and each part is to be sold, given, or otherwise transferred to an individual who is related to the owner within the third degree by consanguinity or affinity, as determined under Chapter 573, Texas Government Code.
d. **Agricultural Use/Farm, Ranch, Wildlife, Timber:** The land is to be used primarily for agricultural use, farm, ranch, wildlife management, or timber production use within the meaning of the Texas Constitution.

e. **More than 10 Acres:** Property owner and/or developer divides the tract of land into two (2) or more parts, and all of the lots of the subdivision are more than 10 acres (10 ac) in area.
f. **Sold to Veterans:** Property owner and/or developer divides the tract into two or more parts that are sold to veterans through the Veterans' Land Board program.
g. **Undivided Interest:** Property owner and/or developer divides the tract into two or more parts and transfers them to persons who own an undivided interest in the original tract, and a plat is filed before any further development of any part of the tract.

8-2.5 PROCESS FOR OBTAINING A LETTER OF NO OBJECTION FOR A SURVEY

If an owner of a property seeks a letter of no objection for a survey (e.g., when required by Brazoria County) the requirements and processes for obtaining such a letter of no objection for survey from the District are the following (see also Form 4-5):

For the purposes of issuance of a letter of no objection fora survey, the following definitions apply:

a. **Commercial Entity:** A person operating as a business or a group or association of persons, companies, or corporations collectively acting as a single party for the purpose of conducting or commissioning a land survey. Any entity that is acting on behalf of a commercial entity is considered a commercial entity.

b. **Division of Property:** The decomposition of a tract of land into more than one sub-tract, the combining of more than one tract into a single tract, and/or the realignment of the boundaries of subtracts within a larger tract.

c. **Drainage Easement:** A defined portion of a tract of land, commonly a linear strip of at least a 15-foot width, that is or is to be used to facilitate drainage across a Property, such easement being delineated on a Property Survey registered with Brazoria County.

d. **Land Survey:** A metes and bounds delineation by a State of Texas licensed surveyor or engineer to (i) divide a land tract into two or more smaller adjoining tracts, (ii) realign or create the boundaries of adjoining subtracts to form a single, larger tract, (iii) create a single tract from combination of one or more adjoining tracts, or (iv) is some combination of these three.

e. **LNO-Survey:** A letter of no objection for a land survey as described in these guidelines.
f. **Non-Commercial Entity:** A party that is not a commercial entity.

g. **Owner:** The person or party that legally owns a Property for which a land survey is conducted or commissioned.

h. Property: The physical land upon which a survey is or is to be conducted.

The Survey for a letter of no objection for survey must meet the following requirements:

a. The Land Survey is done or commissioned by a noncommercial owner or entity.

b. The Land Survey does not alter previously defined easements.

c. The Land Survey does not describe, prescribe, or imply changes in drainage behavior or land modifications which would result in changes in drainage behavior.

d. Commercial activities are not performed on the Property. (Agricultural or farming product sale by a property owner to the general citizenry by on-site direct walk-in is not considered a commercial activity for if the facilities for such sale do not exceed 5000 sq-ft).

Issuance of an LNO-Survey is contingent on meeting requirements for Applicability identified above and provision of the following: (i) Name, address, and contact information on the Owner, and (ii) location of Property surveyed or to be surveyed in manner, form, and completeness acceptable to the DISTRICT.

8-3 EASEMENTS AND RIGHT-OF-WAY: ACCESS-WAYS FOR DRAINAGE

Easements provide space for a drainage watercourse (e.g., drainage ditch, channel, or similar flow conveyance) while limiting the intrusion onto the land of a property owner. A drainage "access-way" is defined to be a strip of land upon which a drainage watercourse can be located or accessed for watercourse construction, maintenance, inspection, or repair by the DISTRICT or its contractors without prior notice to or approval of the property owner on which the access-way is located.

The access-way consists of two parts: the conveyance-way and maintenance berms. The conveyance-way is used or intended to be used for a drainage watercourse operated by the DISTRICT without requiring approval by the property owner once the access-way has been established by agreement between the DISTRICT and the property owner. The DISTRICT would typically inform the current property owner of intended construction or similar activity in the conveyance-way before construction is initiated.

A maintenance berm is usually located on each side of the access-way. The berm is an area providing space for access to the conveyance-way and inspection, maintenance, and repair of the conveyance-way adjacent to the maintenance berm. Activities within the maintenance berms can be conducted at reasonable times by the DISTRICT or its contractors without property owner permission.

8-3.1 MINIMUM ACCESS-WAY WIDTHS

Minimum widths for conveyance-ways, maintenance berms, and access-ways for drainage purposes are given in Table 8-1; exceptions to these requirements are the following:

a. Situations identified on a case-by-case basis by the DISTRICT or the District Engineer, in which case the District Engineer may override the requirements of Table 8-1.
b. Conveyance-way widths as may be determined by a registered professional engineer in the State of Texas with demonstration to the District Engineer as being of sufficient width to convey a storm event runoff of at least a 100-year frequency and 24-hour duration, such conveyance being appropriate to the drainage to and across the property-in question assuming current land use and drainage patterns on and upstream of the area draining directly to the property-in-question.

8-3.2 SETBACKS

In addition to the setback requirements for waterways discussed in Chapter 6, the following also apply:

a. No structure may be placed such that it violates setback requirements of Brazoria County or a municipality.
b. No structure may be placed within 15-ft of the top of bank of an existing ditch or other watercourse under the jurisdiction of the DISTRICT.
c. No structure may be placed within an existing easement of the DISTRICT.

8-3.3 LOCATION AND CONFIGURATION OF ACCESS-WAYS

Unless specified otherwise by the District Engineer, access-ways shall be located, when required,

a. Along property lines or subtracts of land composing a larger tract.
b. Along existing natural watercourses under the jurisdiction of the DISTRICT.

Access-ways that consist of more than one straight-line segment should have straight-line segments no shorter than 25 ft each.

8-3.4 WHEN ACCESS-WAY DEDICATION IS REQUIRED

Access-way must be dedicated to the DISTRICT before issuance of an LNO when such access-ways are required by the above sections of this chapter or when the following situations occur:

a. All commercial property development for which an LNO is sought and no provision is provided in the development plans that will allow upstream drainage waters to drain to a downstream point without adverse impact.
b. All residential lot development when all lots do not have direct drainage access to (i) existing drainage facilities; (ii) existing or proposed storm sewers; (iii) existing or proposed drainage facilities located in the near vicinity of adjacent roadside rights-of-way; or (iv) drainage facilities operated by the DISTRICT. A residential lot development is exempted from this requirement if the residential lot development has been classified by the County as a small subdivision.
c. All planned residential development for which drainage from individual lots require the use of DISTRICT-operated drainage watercourses.
d. Survey is done of any subdivision or revision of a land tract or subtract when the tract or subtract is all or in part being used or proposed for use for commercial activities or facilities for which an LNO is required for implementation. The dedication of the access-way may be done separately or as part of the development project for which an LNO is being sought.

8-3.5 SITUATIONS WHEN ACCESS-WAYS MAY BE REQUIRED BY THE DISTRICT

The DISTRICT may require an agreement for an access-way on private property in the following situations:

a. A property owner requests that the DISTRICT design, construct or repair a drainage ditch, drainage appurtenance, or drainage structure on the owner's property in a location for which there is no DISTRICT access-way.
b. When adequate drainage is not provided for a property for which residential structures exist.
c. Survey of lands for purposes of division or combination of tracts of land, transfer of property ownership, or obtaining an LNO if the DISTRICT concludes that a DISTRICT access-way is necessary for effective drainage management by the DISTRICT.
d. Any situation the DISTRICT deems necessary on a case-by-case basis to significantly reduce the occurrence or damage from floods or flooding.

8-3.6 ESTABLISHING AN ACCESS-WAY

Steps to establish an access-way agreement between a property owner and the DISTRICT include the following:

a. The DISTRICT'S attorney will provide the format for an easement or an access-way (easement, right-of-way, or similar) document

b. The owner of the land on which an access-way easement is proposed may consult with the DISTRICT'S attorney regarding the easement document.
c. When access-way is required, the access-way document must be completed and recorded before issuance of an LNO for construction on the property on which the access-way is required.

8-3.7 ADDITIONAL ACCESS GUIDELINES

Departures from the guidelines and requirements of Section 8-3 for good cause are at the discretion of the DISTRICT. Other policies for access to private land for drainage facility construction, operation, and maintenance are detailed in Appendix C.

8-4. PROJECT DESIGN AND COMPLIANCE

Design of projects should conform to sound and recognized practices and procedures. In addition, the following apply for projects proposed in the DISTRICT:

8-4.1 ENGINEERING DESIGN

A project that requires a State of Texas Registered Professional Engineer (Tx-PE) for design of structures (see Chapter 1 and Figure 1-1) as part of the project shall have its drainage plan prepared by or under the direction of a Tx-PE.

Drainage plans must be prepared by a Tx-PE for the following:

a. The drainage design requires a determination of mitigation volumes for detention facilities for a project not classified as a rural subdivision.
b. The drainage design utilizes runoff mitigation techniques listed in (or similar to) those in Tables 3-1 to 3-5.
c. The design utilizes a computer model listed in Table 6-1 (or a model similar to one of those listed in Table 6-1 and approved by the District Engineer).
d. The design incorporates a flow control device or facilities to control rates of stormwater discharge from the project site as may be required as necessary or proposed for mitigation purposes.
e. The project lies all or in part in a base flood zone, as defined by Brazoria County.
f. The project lies in a riverine flood prone zone as specified by the DISTRICT for which fill cannot be placed (see Chapter 5).
g. The project has jurisdictional wetlands (see Section 8-5).

8-4.2 SEALING SIGNED DRAWINGS

Plans, drawings, and reports dealing with the design of a facility and its drainage prepared by or under the director of a Tx-PE shall sign and seal such plans, drawings, and reports. Other such signing and sealing as may be required by Texas law shall also be required.

8-4.3 RECORD OR AS-BUILT ENGINEERING DRAWINGS

When required by the DISTRICT or the District Engineer for (i) documentation of project construction and demonstration of compliance to proposed project features or (ii) other purposes specified by the DISTRICT or District Engineer, record or as-built drawings shall be submitted to the DISTRICT or the District Engineer. Such drawings shall be signed by the project design engineer, the project constructor, or a Texas-licensed Surveyor.

Record or as-built drawings submitted for compliance review shall be in a form suitable for comparison to design drawings. If submitted drawings are of unacceptable format to the District Engineer, the District Engineer may require amendments or additions to the drawings.

8-4.4 OTHER PLANS OR AS-BUILT DRAWINGS

For drainage plans not associated with facilities requiring design by a Tx-PE, such plans shall be submitted in form and content to clearly and accurately display drainage conditions and facilities. Drainage conditions (including points of ponding and outflow) before project development (for pre-construction LNO purposes) and after project development must be clearly shown. If as-built drawings must be submitted for such facilities, the District Engineer may require that the drawings (i) be signed and sealed by a Tx-PE or Land Surveyor registered in Texas, (ii) be certified by the project Owner under penalty of perjury as compliant with the plans for the proposed project, or (iii) undergo inspection by the District Engineer as many times as deemed necessary by the District Engineer.

8-5 WETLANDS

A wetland is an area where water covers the soil or is present either at or near the surface of the soil all year or for varying periods of time during the year, including the growing season.

8-5.1 COASTAL VS. INLAND WETLANDS

Two general categories of wetlands are recognized: (i) coastal or tidal or (ii) inland or non-tidal.

Coastal or tidal wetlands occur where seawater mixes with freshwater to form an environment of varying salinities and varying water levels. Many coastal wetlands in shallow coastal areas are unvegetated mudflats or sand flats.

Inland or non-tidal wetlands are most common on floodplains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land, along the margins of lakes and ponds, and in other low-lying areas where the groundwater intercepts the soil surface or where precipitation sufficiently saturates the soil.

8-5.2 JURISDICTIONAL VS. NON-JURISDICTIONAL WETLANDS

For regulatory and DISTRICT management purposes, wetlands are either jurisdictional or non-jurisdictional. Jurisdictional wetlands are wetlands that are considered to be a “water of the United States” and subject to requirements (among others) of the federal Clean Water Act. Non-jurisdictional wetlands are wetlands not designated as jurisdictional wetlands. Both types are present within the DISTRICT.

Jurisdictional wetlands are subject to strict federal requirements for protection and preservation. Disturbance of jurisdictional wetlands can be done only if federally permitted; various specific federal permits exist, which can be exercised by private and public entities to modify or otherwise disturb jurisdictional wetlands. The guidance of an environmental specialist or the Galveston District of the USACE should be consulted if a project could impact a jurisdictional wetland.

A determination by an experienced environmental specialist is necessary to determine if a wetland is or is not a jurisdictional wetland. The USACE may make such a determination or review, and possibly reverse, a determination made by others than qualified personnel of the USACE.

8-5.3 DISTURBANCE OF A WETLAND

A jurisdictional wetland shall not be disturbed except as may be allowed by federal permit. If there is doubt as to whether a wetland is a jurisdictional wetland, a qualified professional should be consulted.

If a wetland or wetland-like area is not a jurisdictional wetland, it is desirable but not required by the DISTRICT that project development seeks to prevent unnecessary wetland disturbance. Reasonable efforts should be taken by developers of a project to avoid disturbance of the wetland. Unnecessary

or extreme disturbance of a non-jurisdictional wetland without due concern for preservation of the wetland or application of a mitigating action can be the basis for not issuing a Letter of No Objection.

Neither the DISTRICT or District Engineer can or will make a determination as to whether a jurisdictional wetland exists on a particular site.

The following water bodies are exempt from classification as a jurisdictional wetland [per *Is that Wetland Jurisdictional? A Practical Guide to the New Clean Water Rule,* 2015, Channing J. Martin]:

a. Waste treatment systems, including treatment ponds and lagoons designed to meet requirements of the Clean Water Act.
b. Prior converted cropland.
c. Artificial, constructed lakes and ponds created on dry land, including settling basins, irrigation ponds, and cooling ponds, as well as artificially irrigated land that would revert to dry land should the application of irrigation water cease.
d. Water-filled depressions created in dry land incidental to mining or construction activity, including pits excavated to obtain gravel, sand, or fill.
e. Groundwater, including groundwater drained through subsurface drainage systems.
f. Stormwater control features used to convey, treat, or store stormwater that is created in dry land.
g. Wastewater recycling structures constructed on dry land.
h. Certain ditches, including: (i) Ditches with ephemeral flow: Ephemeral flow ditches have flowed for brief periods, usually following rainfall, provided the ditches are not a relocated tributary or are not excavated in a tributary. (ii) Ditches with intermittent flow: Intermittent flow ditches usually flow during the wet season, but not the dry season, provided the ditches are not a relocated tributary, are not excavated in a tributary, or do not drain a wetland. (iii) Isolated Ditches. These are ditches that do not flow, either directly or indirectly, into a traditionally navigable water, interstate water, or a territorial sea. Ditches that do not qualify as excluded are regulated if they otherwise meet the definition of a regulatory "tributary."

8-6 DISCHARGES TO OFF-SITE LOCALS

Certain stormwater discharges from construction or permanent facilities require control or notification to particular entities; it is the responsibility of the entity designing or conducting such discharges to appropriately control or to notify the appropriate entity of such discharges.

8-6.1 DISCHARGES TO TXDOT RIGHT OF WAY

Permanent or temporary discharges of stormwater discharge to TxDOT right-of-way (ROW) must obtain TxDOT approval. Such approval cannot be provided by the DISTRICT. TxDOT will require, at a minimum, information on the location of the proposed discharge, the tributary area to the point of discharge, and the expected discharge for various frequencies of storm events. The engineer or constructor should contact the TxDOT District Office (in Angleton) for details and any required approvals.

8-6.2 DISCHARGES TO TCEQ MS4

If the discharge is a discharge from a temporary construction activity located within a Texas Commission on Environmental Quality (TCEQ) Municipal Storm Water System (MS4) entity, a filing of a Notice of Intent to discharge must be filed with the MS4. The constructor should contact the TCEQ or the municipality's stormwater pollution control department (or similar) for additional details.

8-6.3 NO FLOW BLOCKAGE

Construction activities cannot divert or impound the natural flow of surface waters or allow a diversion or impoundment to continue in a manner that harms or otherwise adversely impacts the property of another by the overflow of the water diverted or impounded (see Section 1-2.2).

8-6.4 UNCONTROLLED RUNOFF

Drainage layout for proposed projects should not be such that:

a. Existing runoff onto the site is blocked so as to cause backup on adjacent properties when such backup did not occur in pre-construction conditions.
b. Uncontrolled overland flow runoff from the project site should not be allowed if such runoff did not occur prior to site development.

8-6.5 CONTROL OF POLLUTANT DISCHARGE

Construction should not be undertaken so as to allow the discharge of sediments and other stormwater pollutants to TxDOT, Brazoria County, or DISTRICT right-of-way. Special care is to be taken to avoid discharge of sediments, cut vegetation, floatables, miscellaneous paper, lumber, glass, or plastic trash by overland flow or other uncontrolled runoff. In the absence of other effective control measures, silt fences should be used.

8-7 STORMWATER POLLUTION PREVENTION FOR CONSTRUCTION ACTIVITIES

The DISTRICT abides by the rules for stormwater pollution control in regulations set forth by the federal Environmental Protection Agency (EPA) and the Texas Commission on Environmental Quality (TCEQ).

In response to those regulations, the District has adopted requirements that, as a minimum, should be followed for construction activities in the DISTRICT; additional requirements may be required by the TCEQ or the District Engineer.

8-7.1 REQUIRED FEATURES OF A STORMWATER POLLUTION PREVENTION PLAN (SWPPP)

Stormwater pollution prevention controls shall, at a minimum, be implemented for construction activities when such activities involve disturbance of soils or vegetation in a total site area in excess of 1.0 acres. The engineer designer or constructor of the construction project shall be responsible for preparation of the required SWPPP; the constructor shall be responsible for implementing the SWPPP. Minimal elements of a SWPPP include the following unless the District Engineer specifically removes a requirement because of inapplicability.

a. **Silt Fences or Hay Barriers:** Silt fences or hay sediment barriers shall be placed in and around the site to limit the discharge of construction-generated sediments.
b. **Replanting or Reseeding:** Upon completion of the project, areas of disturbed ground shall be (i) planted with grasses suitable for the soil condition, the location of the project, and time of the year; or (ii) seeded. Replanting, seeding, and other grass establishment activities should, at a minimum, conform to the requirements of Section 8.8.
c. **Sediment Barriers for Vegetation Establishment**: Sediment barriers should be maintained until replanted or reseeded grass has become established enough to adequately prevent soil erosion. When grass is established, the sediment barriers shall be removed and disposed of by the entity actually performing the construction.
d. **Disposal of Waste:** Disposal of non-hazardous construction waste shall be at one or more of the following: (i) a licensed recycling o reuse facility; (ii) left on-site if requested to do so by the DISTRICT or District Engineer; or (iii) a commercial or public landfill licensed to accept construction

waste. Waste or surplus materials cannot be disposed of at unapproved locations. Waste disposal shall include disposal of miscellaneous non-hazardous such as paper, plastic, empty drink and food containers, and floatables. Special disposal requirements apply for the following:

- **Concrete Truck Washout**: If concrete construction is used for a project, the SWPPP must provide for or specify the means of disposal of concrete truck washout that will not allow the discharge of the concrete truck washout to a watercourse or a stormwater drainage system without the use of disposal pits. However, concrete truck washout can be disposed of onsite by using one or more on-site disposal pits dedicated to such disposal. An on-site pit should be of such depth and size to prevent overflow of washout waters or discharge to storm waters. Upon completion of construction, the disposal pit shall be allowed to dry, so that concrete in the pit becomes hardened. After hardening, the hardened material should be removed and disposed of as a non-hazardous construction waste.
- **Dead or Cut Vegetation:** If dead or cut vegetation, such as woody natural materials, trees, or roots, are to be disposed of (i) offsite or (ii) burned. Offsite disposal shall be to a county approved or governmentally license site. Burning shall conform to burn requirements as defined for maintenance purposes (see Section 8-13 below).

e. **Disposal of Hazardous Waste**: Hazardous waste shall be disposed of at a licensed hazardous waste disposal facility.

f. **Posting SWPPP:** A copy of the SWPPP shall be posted at the construction site.

g. **Perform Inspection:** Regularly inspect SWPPP controls, and maintain a reporting log of when inspections are performed.

h. **Property Fence Replacement:** No fence beyond the limits of the construction site shall be disturbed or removed without the written permission of the owner of the property on which the fence exists. In the absence of specific details of fence replacement specified in an agreement between the property owner and the constructor of a project, the same requirements as specified for fence replacement due to DISTRICT maintenance activities (see below) shall, at a minimum, apply.

8-8 CONSTRUCTION ACTIVITIES

Policies for construction activities in the DISTRICT are described in Appendix C. Features of these procedures described below do not negate any of the requirements of Appendix C.

8-8.1 CONSTRUCTION GENERAL PERMIT

A stormwater construction general permit (CGP) issued by the TCEQ must be obtained for any construction project in the DISTRICT exceeding 1.0 acre in total size of the entire project site. A SWPPP prepared under such permit shall conform to and meet requirements of the CGP.

8-8.2 EROSION PROTECTION USING SOD OR GRASS

The DISTRICT requires that general soil erosion protection be used during and after construction, maintenance, or other construction-like activities that would result in unprotected soil surfaces for more than 21 days.

In general, erosion protection and control measures should be continued until a minimum of 95 percent of the area to be protected has been stabilized against continuing or future erosion, and there are no bare or dead spots greater than 10 square feet (10 sq-ft).

Replanting to remove dead spots should be done with 14 days after identification of impacted areas.

8-8.2.1 Sodding

Sodding can be used to limit erosion and may be an economical option for small areas. Before sodding, the area to be sodded should be raked to necessary grades and be free of unsightly bumps, ridges, depressions, and objectionable material, including gravel, large roots, stumps, wood, brush, debris, hard clods, clay balls, hardpan, refuse, or other deleterious materials.

Lay the sod strips so they butt tightly against adjacent sod strips. Stagger the sod square joint lines. Tamp and roll the sod to make a firm contact with the underlying sod bed. Peg sod squares to slopes steeper than 3 horizontal to 1 vertical (3H: 1V) with pegs driven through sod on approximately 18-inch centers.

After installation of the sod, remove sod clumps, soil, and any plant material from roadways and pavements. Trim edges along curbs and drives, walkways, etc. if such facilities are present.

Planting should not be done in periods so-identified in Table 8-2. Continue watering the sod until satisfactory growth is obtained or until at least 60 days after planting activities.

Other important data for sodding are provided in Table 8-2.

8-8.2.2 Seeding

Use only seed which complies with Texas Agricultural Code, Chapter 62, for "Seed and Plant Certification" and is not more than 9 months old prior to use for planting. Seed should contain no objectionable material, such as sticks, stems, or un-thrashed seed heads that will hinder proper distribution of the seed. Seed that is wet, moldy, starting to germinate, or otherwise damaged shall not be used.

Apply seeds only on the upper 4 inches of soil that is loose and uncompacted so that seeds can germinate and develop roots. Seeding rates should conform to the requirements of Table 8-3.

After seeding, fertilizer should be applied. After applying seed and fertilizer, apply straw mulch, fiber mat, or paper mesh as described below.

Keep seeded areas moist for 10 days immediately following placement. When watering seeded areas, use a fine spray to prevent erosion of seeds or soil. Reseed any areas damaged by erosion and as necessary to obtain a satisfactory growth of grass.

If rain is imminent, postpone seeding and fertilization until weather conditions exist such that the potential for the runoff of fertilizer from the site is minimized. If high wind conditions exist, then the subsequent application of the straw mulch, fiber mat, or paper mesh erosion control blanket should be postponed until weather conditions exist such that the blanket can be installed properly.

Maintenance should consist of watering and weeding, repair of all eroded areas, and any reseeding as necessary to establish a uniform stand of the specified grasses.

8-8.2.3 Fertilizing

Commercial fertilizer should be applied uniformly over the entire seeded area at prescribed rates; see Table 8-3.

Fertilizer should be pelleted or granulated with a 10-10-5 (nitrogen–phosphoric acid–potash) composition. The sources of nitrogen in the fertilizer should be roughly balanced between ammoniacal (quick release) and nitrate-nitrogen (slow-release). Fertilizer should be readily water-soluble. If

fertilizer of a different analysis is used, the total amounts of nutrients furnished and applied per acre should equal or exceed that specified for each nutrient.

Fertilizer should be dry and in good physical condition. Fertilizer that is powdered or caked should not be used.

8-8.2.4 Stabilization

To prevent the loss of seed or fertilizer by erosion, seeded and fertilized areas should be stabilized as soon as reasonably possible after seeding and fertilizing. Stabilization can be accomplished using various mulch, fiber mats, or paper mesh, as follows:

a. **Mulch:** Any mulch should be free of Johnson grass or other noxious weeds and foreign materials. Mulch should be kept in a dry condition prior to use and not be molded or rotted. Mulch should be spread uniformly over the area to be protected at the approximate rates given in Table 8-4. Tacking should be applied to hold the mulch in place.
b. **Wood Fiber Much:** Wood mulch is made from wood chips mechanically ground to create a mesh of intertwined fibers. A thermal refining process may be used to expand the wood fibers to create a more complex mass with a high amount of surface area, improving the ability to support vegetation and providing a shield to impacting rainfall.
c. **Fiber Mat:** Fiber mat should consist of machine-produced woven mat of wood, coir, straw, or a combination of various biodegradable fibers, with consistent thickness throughout the blanket. The fiber mat should have a mesh or netting for support. The mesh or netting should be bio- or photo-degradable and have high wet strength. The mat should not contain any weed seeds. The mat should be free of defects, rips, holes, flaws, deterioration, mold, rot, or damage. Fasten the blanket to the ground to protect the growth of the underlying grass using recommendations of the manufacturer.
d. **Paper Mesh:** Use paper mesh consisting of knitted construction of yarn with uniform openings interwoven with strips of biodegradable paper, furnished in rolls which have suitable protection for outdoor storage. The mesh should be free of defects, rips, holes, flaws, deterioration, mold, rot, or damage. Fasten the mesh to the ground to protect the growth of the underlying grass using recommendations of the manufacturer

Application rates are as given in Table 8-4. Recommendations of the mulch, fiber mat, or paper mesh manufacturer should be followed in storing and applying mulch or fiber mat for erosion control

8-9 DRAINAGE PIPE

Drainage pipe conveys stormwater and similar runoff under the ground surface. Drainage pipe is classified as a culvert pipe if the pipe conveys storm or runoff waters under a roadway. If the pipe is used for other purposes, it is said to be a drain pipe. Drain pipe uses include drainage from commercial and residential developments; outfalls from ponds, ditches, and channels; dewatering of low-lying areas; and as control devices for drainage from ponds and lakes. As used here, drain pipes include only drain pipes exterior to a building and its walls.

Culvert pipe and drain pipe within TxDOT, Brazoria County, or incorporated municipality right-of-way must conform to applicable standards and specifications of these entities. Culvert pipe and drain pipe not within TxDOT, Brazoria County, or incorporated municipality right-of-way in so far as drainage behavior is concerned are under the DISTRICT's review authority.

The remaining discussion of this section on drainage pipe applies only to culvert and drain pipe and their uses not within TxDOT, Brazoria County, or incorporated municipality right-of-way. To the extent that design or construction information is not addressed in the following, applicable TxDOT, Brazoria County, incorporated municipality, or other government agencies apply.

8-9.1 PIPE MATERIALS

Pipe materials acceptable for drainage works include:

a. **Corrugated Metal Pipe** (CMP), without or without full or partial bituminous paved interior. CMP may be made with steel or aluminum. CMP is manufactured to a variety of standards, including the American Association of State Highway and Transportation Officials (AASHTO) Standard M-36 for Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains; and AASHTO Standard M-190 for Bituminous-Coated Corrugated Metal Culvert Pipe and Pipe-Arches.
b. **Reinforced Concrete Pipe** (RCP), as manufactured according to the following AAHTO Standards: M-170 for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe; M-206 for Reinforced Concrete Arch Culvert, Storm Drain, and Sewer Pipe; M-207 for Reinforced Concrete Elliptical Culvert, Storm Drain, and Sewer Pipe; and M-242 Reinforced Concrete D-Load Culvert, Storm Drain, and Sewer Pipe.
c. **Thermoplastic pipe** may be (i) poly vinyl chloride (PVC) pipe, (ii) high density polyethylene pipe (HPDE), or (iii) polypropylene pipe, in part described by AASHTO Standard M-252 for Corrugated Polyethylene Drainage Pipe; Standard M-294 for Corrugated Polyethylene Pipe, 300- to 1500-mm Diameter; and ASTM International (formerly American Society for Testing and Materials) standard specification, F2619/2619M-13 Standard Specification for High Density Polyethylene (PE) Line Pipe.

8-9.2 PIPE AND APPURTENANCES

Pipe size is defined by its internal diameter (ID) or cross-sectional dimensions for the non-circular pipe. Pipe size should be sufficient to provide the required capacity and meet the following general criteria (exceptions can be considered by the District Engineer):

a. **Maximum velocities** not so large as to damage the pipe due to scour, pressure surges, or other conditions as based upon the maximum design discharge (e.g., the 100-yr storm event); see Table 8-5.
b. **Minimum velocities** sufficient to prevent significant accumulation of sediments and similar deposits in the pipe. This minimum can be selected as the maximum velocity that occurs during a moderate size storm event; see Table 8-5.
c. **Pipe Sizes:** Standard commercially available pipe sizes used should be used: 6-, 8- 12-, 18-, 24-, 36- Internal Diameter (ID), and larger in 6-inch (6-in) increments. Specific size ranges for various uses are given in Table 8-5.
d. **Roughness**: For design purposes, the standard n roughness values (see Table 8-5) should be used unless other information indicates a more appropriate value.
e. Maximum circular pipe diameter: 72-in.
f. **Maximum box culvert size:** Vertical and horizontal: 60-in.
g. **Hydraulic grade lines:** Hydraulic grade lines for conduit flow should be less than 0.1 ft/ft (to avoid high-velocity surges in pipe flow) and more than 0.0001 ft/ft (to ensure the flow of waters).

Recommended sizes of storm sewers and spacing of storm sewers appurtenances are summarized in Table 8-5. Note that different conditions apply, depending on whether the pipe is a culvert or only a drain pipe.

8-9.3 PIPE LOADS

A typical drain or culvert drainage pipe installation is shown in Figure 8-1. Loads on the installed pipe and the consequently needed pipe strength arise from soil column weight above the pipe (including water in soil pores if such water is present) and vehicles and structures on the land surface above the pipe. The effective load on a pipe is also affected by trench widths, installation conditions, and bedding.

The focus on these factors in the following discussion is selected for the purpose of achieving DISTRICT goals for drainage effectiveness. Drainage effectiveness will depend upon not only hydraulic capacity but also the effective and continued operation of the pipe in view of the loads on the pipe and the conditions under which such loads occur. While details of specifications for pipe design and installation must conform to Brazoria County specifications and standards, the following highlights issues of particular concern to the DISTRICT.

8-9.3.1 Pipe Installation Condition and Loads

Based upon the work of Marston and Spangler in the first half of the 20th century, four types of installation in a pipe trench can be distinguished to define load conditions from overlying soils, hydrostatic loads, and vehicle loads. The necessary pipe strength to carry these loads varies with the type of installation.

Vehicle and soil Loads on culvert pipes are defined in terms of D-loads that represent the net effect of the overlying soil column above the top of the pipe, potential vehicle loads on the surface above the pipe, and the type of pipe trench installation. Note that even for non-paved roads, such as dirt or crushed rock loads, vehicle loads may require consideration because haul trucks, farm equipment, or emergency vehicles (e.g., fire trucks) may require access along the roadway.

Vehicle loads for pipe design are standardized by the American Association of State Highway and Transportation Officials (AASHTO) as either H25 or HS25 (the two load types reflect different configurations of possible wheel axes numbers and position under a truck). In terms of general drainage design for common DISTRICT applications (pipe size less than 6-ft diameter and overburden heights of 8 ft or less), both the H25 and HS25 generate closely similar loads.

For various pipe diameters and depth of cover, the D-load is commonly given in terms of pounds per foot of diameter per foot of pipe length (i.e., lb/ft/ft). For pipe culverts, the pipe length would be the length of pipe covered by the width and adjacent embankments of the roadway above the top of the culvert. The applicable D-loads are used to determine the necessary pipe strength expressed in D-load format.

For many of the applications encountered by the DISTRICT, the type of installation may be difficult to define or know. Consequently, the DISTRICT uses a conservative approach to assess whether pipe size and necessary strength are reasonable for the intended application.

Table 8-6 provides the maximum D-load of the four standard pipe installation types for a range of depth of cover about the top of the pipe and the pipe diameter. These values give the most conservative estimate of the necessary pipe strength of the four installation types. The maximum pipe

diameter tabulated is 72-in and a maximum of 8-ft of cover; if the diameter or cover is greater than these limits, the actual pipe installation type should be used.

As an example, consider a 30-in = 2.5 ft diameter pipe with 2 ft of fill above the top of an RCP pipe: The D-loads for the four different types of pipe installations (data not shown) are 1272-, 1249-, 1235-, and 1219-lb/ft/ft, yielding a maximum value of 1272 lb/ft/ft (which is the value presented in Table 8-6). If the pipe were 14 ft long, the maximum load to be expected on the pipe would be 1272 x 2.5 x 14 = 44,520 lb.

8-9.3.2 Soil Load Only

A conservative estimate of the geostatic (i.e., soil) load (by itself) on a drain pipe is provided by using only the soil column load plus a small incremental load to account for soil load beyond the edge of the outside pipe diameter but neglecting the compensating (i.e., load reduction) soil arch load (which varies with pipe flexibility):

$$P_s = W_s\, d_o(H + 0.11 d_o) \qquad \text{[eq 8-1]}$$

In which P_s is the geostatic load in lb/ft of pipe length, d_o is the outer diameter of the pipe, H is the depth of fill above the crown of the pipe, and W_s is the unit weight of soil, commonly assumed to be 120 lb/cu-ft.

8-9.3.3 Hydrostatic Load

If the water table is at a level above the springline of the pipe, the hydrostatic load (i.e., water pressure load) should be included in the total load on the pipe by adding a hydrostatic load

$$P_h = W_w\, d_o\, h_s \qquad \text{[eq. 8-2]}$$

In which P_h is the hydrostatic load in lb/ft of pipe length, d_o is the outer diameter of the pipe, h_s = height of the water table above the springline, and W_w is the unit weight of water = 62.4 lb/cu-ft.

8-9.4 PIPE STRENGTH FOR RCP PIPE

RCP strength is expressed in terms of classes for various pipe loads. RCP pipe classes and the maximum load they are intended to support are given in Table 8-7. Thus, for example, if the D load was conservatively estimated as 1272 lb/ft/ft, the D-load falls in the 1001 to 1350 lb/ft/ft D-load range. A 1350 lb strength and a Class III RCP pipe would be specified for construction.

Alternatively, if the total load on a 6-in = 0.5 ft diameter, 8-ft long drain pipe due to overburden load and hydrostatic load were 3650 lb, the equivalent D load would be 3650/0.5/8 lb/ft/ft = 912 lb/ft/ft, and the necessary pipe class would be class II.

8.9.5 PIPE STRENGTH FOR CMP PIPE

For CMP pipe, allowable maximum fill heights, in view of pipe diameter and corrugation dimensions, are given in Table 8-8. For District review purposes, tables limits are limited to the pipes with nominal diameters of 48 or less inches.

8-9.6 STRENGTH OF THERMOPLASTIC PIPE AND OTHER TYPES OF PIPE

For thermoplastic pipe, D-loads for RCP can be used. The pipe class to carry the D-load can be determined from manufacturer specifications and guidelines.

For other types of pipe materials and cross-sectional geometries, pipe manufacturers or suppliers should be contacted.

8-10 ISSUES IN PIPE CONSTRUCTION METHODS

Particular issues to consider include the following:

8-10.1 EXCAVATION DEPTH

It is preferable, for safety reasons, to limit required excavation for drainage pipe placement to less than 5 ft. Trench excavation greater than 5 ft requires special trenching support and protection pursuant to the Occupational Safety and Health Administration (OSHA) regulations. In addition, even if the trench depth is less than 5-ft, but unstable trench walls are encountered, the trench walls should be braced.

8-10.2 TRENCH WIDTH AND PIPE SPACING

Trench widths must be of sufficient width to allow safe and proper pipe installation. Standard guidelines for trench widths are shown in Figure 8-1.

The floor of the trench should be excavated so as to provide a continuous bearing for the pipe throughout its length.

8-10.3 UNSTABLE FOUNDATION MATERIAL

Unstable material (e.g., soft, highly organic material; decaying vegetation; tree roots) should not lie immediately below the trench. Unstable material should be removed to at least 2 ft below the pipe flowline and be replaced with cement stabilized base or lean concrete. The material used to replace the unstable material should be placed in lifts no more than 8-inches thick.

8-10.4 PIPE BEDDING AND COVER

Individual conduits must be adequately supported by the materials beneath, around, and above the conduit. For specifying materials, four zones can be distinguished: (i) foundation, (ii) bedding, (iii) initial backfill, and (iv) final backfill (or “overfill”), as illustrated in Figure 8-1.

The unconsolidated soil materials used for bedding and cover are commonly described by the Unified Soil Classification System (USCS) that describes the texture and grain size of a soil using a two-letter classification, as shown in Table 8-9.

8-10.4.1 Foundation

The foundation underlies the overall pipe trench. Existing stable soil can be used if existing soil can provide a fixed and firm support for the overlaying pipe and trench materials. Existing rock is generally unsuitable because it can produce pressure points on the pipe wall. Fat clay soils (CH) are usually to be avoided because moisture changes can cause a significant volume increase or decrease. Elastic silts (MH), peat, or other organic unstable material should not be used for the foundation because they are highly compressible (per US Bureau of Reclamation, Geotechnical Training Manual No.7 recommendations). Unstable soil can be treated to stabilize it, as discussed in Section 8-10.3 above.

8-10.4.2 Bedding

Bedding is the material on which a pipe rests; it provides a base of support for the pipe and the fill which is placed around the pipe. Bedding maintains the grade line of the pipe and lessens the likelihood that the pipe will sag or undergo unacceptable deformation.

Bedding is placed before the pipe is placed so it can be compacted. Bedding material can be similar to the initial backfill material (discussed below).

After compaction, bedding should be a minimum of 6-inches thick for pipe greater than 30-inches. For pipe diameters greater than 12 but less than 24-in, the bedding thickness can be reduced to 4 in; see Figure 8-1.

The bedding trench width above the foundation should be no wider than the stable foundation material supporting the bedding.

8-10.4.3 Initial Backfill Zone

Backfill surrounds a pipe in order to provide supporting material for the pipe and distribute the load around the pipe so it can provide maximum support. The lower portion of the initial backfill zone below the springline is the haunch; backfill in the haunch is lightly compacted by the natural weight of the backfill, forcing material downward when the backfill is deposited in the trench. Addition compaction is provided by the compaction done on the initial backfill above the springline.

As soon as practicable after the completion of the laying and jointing of the pipe, backfilling should occur. Backfill should be placed in maximum 6-inch lifts. The backfill material should be placed and (for Category I, II, and III backfill, discussed below) compacted to 90% standard Proctor to either a minimum height equal to the crown (or the top of the bell for bell and spigot pipe) or 6 inches above the pipe spring line, whichever is greater.

8-10.4.4 Final Backfill/Overfill

Use select fill and compact to fill the trench above the top of the initial backfill material if the top of the material does not rise to the surface. Material can be the same or different material as that for the initial backfill material. Use of suitable on-site material is preferred. If bank sand is used, all material should pass a 3/8-in sieve and have clay in 5% to 30% amount which pass a #200 sieve. The final backfill should be compacted similar to the initial backfill.

8-10.4.5 Backfill and Bedding Materials

Different classes of materials can be used for bedding and backfill. Backfill materials, irrespective of source, should be free of deleterious material, including organic matter, foreign material, clay, balls, sticks, foreign objects, and other objectionable material. Manufactures recommendations for backfill materials should be followed, but guidelines for backfill are provided in the following:

a. Stone, Gravel and Sand Backfill: Backfill materials can be select fill consisting of sands and silts but not clay. Backfill from on-site or borrow sources should have a plasticity index not less than 12, nor more than 20 when tested in accordance with ASTM D4318 “Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils.” The maximum liquid limit should be less than 45.

Three standard categories of backfill material are distinguished:

- Category I (Crushed Stone): Angular crushed stone or rock, dense or open-graded with little or no fines (1/4 to 1-1/2 in. in size)
- Category II (Gravelly Sand): Clean, coarse-grained material, such, as gravel, coarse sands, and gravel/sand mixtures (1-1/2 in maximum in size)
- Category III (Sandy Silt): Coarse-grained material with fines including silty or clayey gravels or sands. Gravel or sand must comprise more than 50% of the Class III material (1.5-inch maximum size).

Backfill above the springline should be well compacted to indirectly increase compaction below the springline and maximize the bedding strength above the springline.

b. Flowable Backfill: Flowable backfill can be used as an alternative bedding, initial backfill, or final backfill for bedding material, as well as final backfill material meeting the requirements of this chapter. It may be an (i) an economical alternative to a Category I, II, or III material; (ii) facilitate placement of a pipe, particularly when trench width is limited; or (iii) be suitable for special types of applications, such as mud jacking, construction of (non-drainage) utility trenches, or plugging of abandoned sewers.

Flowable backfills include (i) a controlled low-strength material made of cement, water, sand, possibly air-entraining admixture, and often another filler material such as fly ash, granulated slag, or a fine aggregate, typically an air-entraining admixture; and (ii) cement stabilized sand (CSS), consisting of cement, water, and sand (with cement and sand in approximately equal amounts by weight). Flowable backfill, particularly CSS, may be recommended for use by manufacturers of certain types of pipe, such as thermoplastic pipe.

8-10.4.6 Compaction

Compaction around a pipe is necessary to develop the full load-bearing capability of the pipe. Appropriate compaction depends upon pipe material and load. The degree of compaction is commonly prescribed in terms of standard Proctor density (SPD) or modified Proctor density (MPD). Proctor density is based upon a standardized laboratory test to experimentally determine the optimal moisture content at which a given soil will achieve its maximum density. The degree of compaction is described in terms of the Proctor density that is achieved by the compaction.

Table 8-10 gives minimum compaction levels for standard pipe installations in terms of SPD levels. However, pipe manufacturer recommendations should be followed.

8-11 PIPE DESIGN AND CONSTRUCTION PRECEDENT

The design engineer should follow pipe manufacturer's recommendations for design and installation of pipe; such recommendations should take precedence over requirements that are specified in Section 8-9 if such recommendations are more stringent than those provided in Section 8-9 and 8-10.

8-12 OUTFALLS

Outfalls, i.e., the structure through which a pipe flow discharges to a receiving water, pose special concerns because of possible erosion at the exit to a receiving water in an erodible channel. When such outfalls exist, the project design, construction, and possible future maintenance activities should consider incorporating the following features:

a. Use of splash blocks or pads, constructed of reinforced concrete or cement stabilized sand.
b. Use of riprap to protect channel walls and bottom.
c. Outfall pipe diameter increase to reduced discharge velocity.
d. Reorientation of pipe alignment to lessen velocity impact.
e. Relocation of outfall to less erodible site.
f. Use of stilling pool to which discharge is initially directed.
g. Extension of pipe to reach deeper receiving water depths using bents for extension support.

8-13 MAINTENANCE ACTIVITIES

Maintenance activities by the DISTRICT or performed by a contractor on behalf of the DISTRICT should conform to the following:

8-13.1 DRAINAGE MANAGEMENT

Vegetation, sedimentation, and drainage control structures in DISTRICT access-ways should be regularly maintained and repaired to prevent runoff to areas or paths not intended for discharge of runoff waters.

8-13.2 WASTE DISPOSAL

The following waste disposal techniques are to be used as applicable to various types of maintenance:

a. **Disposal of Non-Hazardous Waste:** Dispose of non-hazardous waste at one or more of the following: (i) a licensed recycling or reuse facility, or (ii) a commercial or public landfill that received non-hazardous waste. Waste or surplus materials cannot be disposed of at unapproved locations. Disposal of concrete truck washout shall not be to a watercourse or stormwater drainage system; see SWPPP requirements for disposal options for concrete truck washout.
b. **Disposal of Hazardous Waste**: Dispose of hazardous waste at a licensed hazardous waste disposal facility.
c. **Onsite Burnable Waste:** Onsite burning for disposal of waste is permitted only if the waste material is generated as a result of access-way maintenance, land clearing, or maintenance along water canals, and no practical alternative to burning exists. “Practical alternative” is defined as “an economically, technologically, ecologically, and logistically viable.”

8-13.3 MAINTENANCE WASTE DISPOSAL BY BURNING

Outdoor burning of waste from waterway maintenance by the DISTRICT may be done under certain circumstances. In general, outdoor burning of waste is prohibited by the Outdoor Burning Rule, Title 30, Texas Administrative Code, Sections 111.201–221, administered by the TCEQ.

The following summarizes the statewide Outdoor Burning Rule as it pertains to maintenance by public entities such as the DISTRICT. Individual municipalities may have additional requirements. For additional details, the TCEQ, the municipality of interest, or the Texas Administrative Code, Sections 111.201–221, should be consulted.

8-13.3.1 Waterway Maintenance by Public Entities

Exceptions in the Outdoor Burning Rule allow for burning waterway maintenance waste plants. Maintenance waste plant growth includes trees, brush, grass, leaves, branch trimmings, or other plant growth.

Brazoria County is a designated nonattainment county. Nonattainment areas have not achieved compliance with National Ambient Air Quality Standards. For designated nonattainment counties, burning of waste plant growth is allowed onsite if the material is generated as a result of right-of-way maintenance, land clearing, or maintenance along water canals, and no practical alternative to burning exists. “Practical alternative” is defined as ‘an economically, technologically, ecologically, and logistically viable. Such burning is also subject to local ordinances that prohibit burning within the corporate limits of a city or town.

Burning must be onsite, that is, burning of maintenance waste plant growth must be burned on the property of the owner or any other person authorized by the owner (e.g., in a DISTRICT access-way).

8-13.3.2 General Requirements for Allowable Outdoor Burning

Outdoor burning that is otherwise authorized shall also be subject to the following requirements:

a. Burning cannot be done during a burn ban for the area in which the burning might take place.

b. Notification of any government entity having jurisdiction over the area of the burn, e.g., the county fire marshal, local fire department, or local law enforcement
c. Before prescribed or controlled burning for forest management purposes, the Texas Forest Service shall be notified.
d. Burning must be outside the corporate limits of a city or town except where the incorporated city or town has enacted ordinances that permit burning consistent with the Texas Clean Air Act, Subchapter E, Authority of Local Governments.
e. Burning shall be commenced and conducted only when wind direction and other meteorological conditions are such that smoke and other pollutants will not cause adverse effects to any public road, landing strip, navigable water, or off-site structure containing sensitive receptor(s). Sensitive receptors include residences, greenhouses, stables, etc. that are within 300 feet of, and in the general direction downwind from, the site of the burn. If so, obtain written permission from the occupants or operators of those structures before beginning the burn.
f. If, at any time, the burning causes or may tend to cause smoke to blow onto or across a road or highway, it is the responsibility of the person initiating the burn to post flag-persons on affected roads.
g. Burning must be conducted downwind of or at least 300 feet (90 meters) from any structure containing sensitive receptors (e.g., homes, businesses, barns with animals) located on adjacent properties unless prior written approval is obtained from the adjacent occupant with authority to issue such approval.
h. The initiation of burning should commence no earlier than one hour after sunrise. Burning shall be completed on the same day not later than one hour before sunset and shall be attended by a responsible party at all times during the active burn phase when the fire is progressing. In cases where residual fires and/or smoldering objects continue to emit smoke after this time, such areas shall be extinguished if the smoke from these areas has the potential to create a nuisance or traffic hazard condition. In no case shall the extent of the burn area be allowed to increase after this time.
i. Burning should not be commenced when surface wind speed is predicted to be less than six miles per hour (mph) (five knots) or greater than 23 mph (20 knots) during the burn period.
j. Burning should not be conducted during periods of actual or predicted persistent low-level atmospheric temperature inversions.

8-13.3.3 Outdoor Burning for Waste Disposal

Outdoor burning for waste disposal purposes requires notification to various entities; these requirements are summarized in Table 8-11.

8-13.3.4 Responsibility for Consequences of Outdoor Burning

The authority to conduct outdoor burning does not exempt or excuse any person responsible from the consequences, damages, or injuries resulting from the burning and does not exempt or excuse anyone from complying with all other applicable laws or ordinances, regulations, and orders of governmental entities having jurisdiction, even though the burning is otherwise conducted in compliance with the Outdoor Burning Rule.

8-13.3.5 Practical Alternatives to Burning

Potential options to the burning of maintenance waste plant growth include:

a. **Recycling:** Manually or mechanically separate salvageable metals from other material and sell them at a salvage yard.

b. **Composting:** Wastes from landscape maintenance can often be composted on-site easily and cleanly. Similar wastes, even paper, in some instances, can be composted under the right conditions.
c. **Mechanical chipping or mulching:** The mulch that is produced could be put to use for soil enrichment and moisture retention, or used to create compost. In some cases, the mulch could become a marketable product, be put to use where it is produced, or be given to individuals or nurseries. If the material cannot be used as a landscape mulch, chipping can still be useful to reduce the volume of waste that must be disposed of by some other means.

8-13.4 REPLACEMENT OF REMOVED FENCES

When access to private requires for construction or maintenance purposes removal of fences for construction or maintenance, such fences shall be replaced.

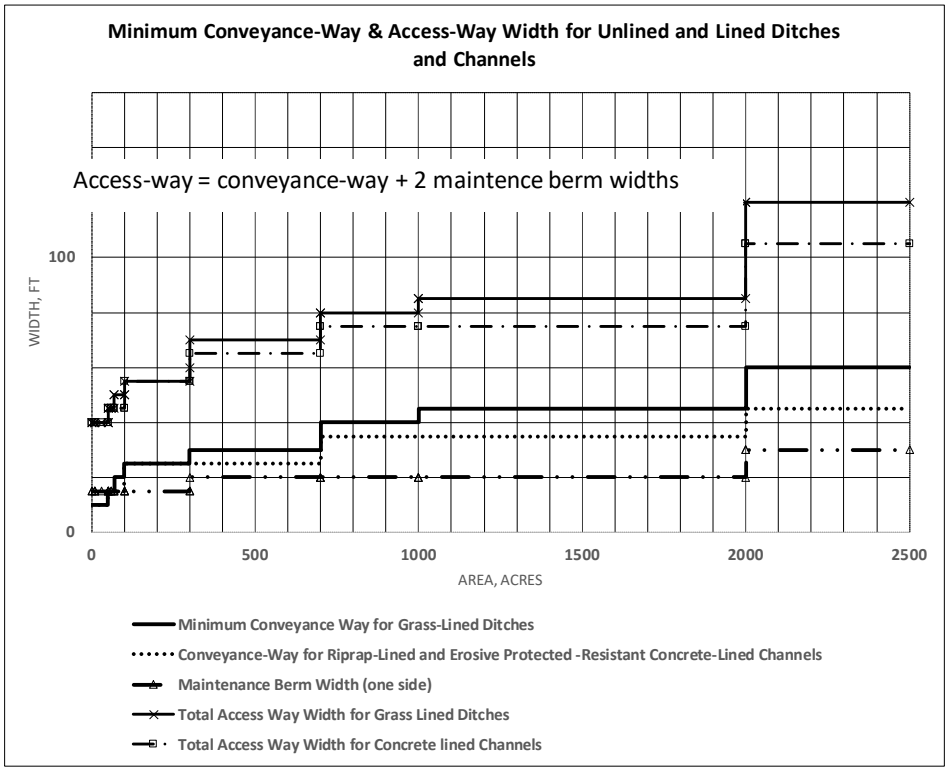
After initial removal, a temporary fence shall be constructed in a manner and location sufficient to contain livestock, pets, and/or children in the appropriate locations. This shall be coordinated with the landowner by the constructor.

Upon completion of the project, a fence shall be rebuilt in the location of the previous fence. The fence shall be the same type as the original fence, as nearly as possible.

THIS PAGE INTENTIONALLY BLANK

TABLE 8-1. MINIMUM CONVEYANCE- & ACCESS-WAY WIDTHS

Drainage Area Upstream of Downstream End of Access-way (ac)	Minimum Conveyance Way for Grass-Lined Ditches (ft)	Minimum Conveyance-Way for Riprap-Lined and Concrete-Lined Channels (ft)	One Maintenance Berm Width	Total Access Way Width for Grass Lined Ditches (ft). Includes maintenance berm each side of ditch or channel	Total Access Way Width for Riprap and Concrete- and Riprap-Lined Channels (ft). Includes maintenance berm each side of ditch or channel.
> zero acres & <= 10 acres	10	10	15	40	40
> 10 acres & <= 50 acres	10	10	15	40	40
> 50 acres & <= 70 acres	15	15	15	45	45
> 70 acres & <= 100 acres	20	15	15	50	45
> 100 acres & <= 300 acres	25	25	15	55	55
> 300 acres & <= 700 acres	30	25	20	70	65
> 700 acres & <= 1000 acres	40	35	20	80	75
> 1000 acres & <= 2000 acres	45	35	20	85	75
> 2000 acres & <= 2500 acres	60	45	30	120	105
> 2500 acres	See District Engineer				



The minimum conveyance widths are based upon approximate drainage channel geometry requirements for peak rates of runoff from a 25-year, 24-hour rainfall from upstream areas draining to a trapezoidal-shaped channel lined with grass or concrete and the representative maximum velocity that can occur in such channels without erosion. The minimum widths for the maintenance berms are based upon maintenance equipment requirements. (Source: Tables 3-3 and 3-4, Brazoria County Drainage Criteria Manual) .

THIS PAGE INTENTIONALLY BLANK

TABLE 8-2. GUIDELINES FOR USING SOD FOR EROSION CONTROL

Feature	Description
Type	Bermuda grass; St. Augustine, or other DISTRICT approved substitute.
Grass Condition	Living grass; 95% pure, vigorous condition, free of disease and insects.
Thickness	Have minimum ½ inch of roots in soil; roots not to project below soil mass; maximum grass height 1 inch prior to placement.
Fertilizer	Fertilize entire sodded area immediately following laying the sod. Immediately after fertilizing, water the entire area until a saturated depth of 2 inches has been reached. If rain is imminent, then the application of fertilizer shall be postponed until weather conditions exist such that the potential for the runoff of fertilizer from the site is minimized.
Water	If the sod bed is dry, dampen the surface with a fine mist of water immediately prior to sod installation. Immediately after sod placement, water the entire area until a saturated depth of 2 inches has been reached Maintain watering with fine mist on a daily basis (if no rain occurs) until grass is established.
Time of planting	All planting shall be done between the average date of the last freeze in the spring and six weeks prior to the average date for the first freeze in the fall, according to the U.S. Weather Bureau.

Source: Harris County Tx Construction Specification #162-5

THIS PAGE INTENTIONALLY BLANK

TABLE 8-3 SEEDING AND FERTILIZING RATES

SEEDING

SEED TYPE	SEEDING RATE PER ACRE
Use following from Oct. 1 to Mar. 31 (when soil temp. below 75 deg. F)[1]	
• Unhulled Bermuda Grass	• 50 lb
• Rye Grass	• 25 lb
• Approximate 50-50 Mixture of Bermuda and Rye Grass	• 40 lb
April 1-Sept. 30 (When soil temperatures rise above 65°F)[1]	
• Certified Bermuda Grass[2]	• 50 lb
• Common Bermuda Grass, minimum purity/germination of 95/85	• 50 lb PLS[3]
• Millet	• 10 lb
• Certified Bermuda Grass[2]	• 50 lb
• Hulled Bermuda Grass minimum purity/germination 95/85	• 50 lb PLS[3]
• Pensacola Bahia Grass Brown Top	• 20 lb
• Fox Tail Millet	• 20 lb
• Annual Ryegrass	• 25 lb
• Millet	• 25 lb
• Improved Bermuda Grass Cultivars	• 50 lb

FERTILIZING RATES

PURPOSE	lb/acre
• Fertilizing for sodding	• 480
• Fertilizing for seeding and erosion control blanket	• 400
• Fertilizing for hydro-mulching	• 400

Notes:
1. Planting dates are approximate
2. Certified Bermuda Grass must have a Blue Tag and tested by an accredited seed testing lab.
3. Seeding rate for "Pure Live Seed" (PLS) is used to determine the actual application rate of bulk material to apply. Example:
   a. Calculate PLS: PLS = (% germination x % purity)
      0.95 x 0.85 = 0.807 (80.7%) PLS
   b. Calculate quantity: Rate ÷ PLS = lbs. of seed needed for application
      50 lbs. ÷ 0.807 = 61.95 lbs. of seed needed per acre

Source: Harris County specifications, 2019; DISTRICT Director

THIS PAGE INTENTIONALLY BLANK

TABLE 8-4. MULCH, MATS AND MESH

Material (limitations)	Application Rate	Application tons/acre	Data Source
Mulch-Hay		1 to 1.5 tons/acre	Harris County Spec 164
Mulch-Straw		2.5 tons/acre	Harris County Spec 164
Mulch Tack	0.05 to 0.1 gallons/sq-yd		Harris County Spec 164
Fiber Mat	0.7 to 1.0 lbs/sq-yd		Harris County Spec 164
Paper Mesh	0.2 to 0.5 lbs/sq-yd		Harris County Spec 164

Cellulose Fiber Much			TxDOT Specification 164
Sandy soils (slope <s 3:1)	2500 lbs/ac	2.5 tons/ac	TxDOT Specification 164
Sandy soil, slope (slope > 3:1)	3000 lbs/ac	3.0 tons/acre	TxDOT Specification 164
Clay soils, slope < 3:1	2000 lbs/ac	2.0 tons/acre	TxDOT Specification 164
Clay soils, slope > 3:1	2300 lbs/ac	2.3 tons/acre	TxDOT Specification 164

Wood mulch (100% wood fibers)	Max slope: 4:1 Max slope length*: 18 ft	1.5 to 2.0 tons/acre (on max slope)	Manufacturer
Cellulose-paper	Max slope: 4:1 Max slope length*: 18 ft	1.5 to 2.0 tons/acre (on max slope)	Manufacturer (less than 50% effective)
Wood fiber mulch	Max slope: 2:1 Max slope length*: 28 ft	3.0 tons/per acre (on max slope)	Manufacturer (less than 50% effective)
Wood fiber mulch with tackifier	Max slope: 2:1 Max slope length*: 30 ft	3.0 tons/per acre (on max slope)	Manufacturer (less than 50% effective)
Stabilized Mulch Matrix	Max slope: 2:1 Max slope length*: 50 ft	3.5 tons/acre (on max slope)	Manufacturer (>50% effective)
Bonded Fiber Matrix	Max slope: 1:1 Max slope length*: 75 ft	4.0 tons/acre (on max slope)	Manufacturer (>50% effective)
Extended-Term Flexible Growth Medium	Max slope: >1:1 Max slope length*: 125 ft	4.5 tons/acre (on max slope)	Manufacturer (>50% effective)
*As measured on 3:1 slope			

Follow manufacturers specifications if different than above

Source: Harris County; TxDOT, manufacturer recommendations.

THIS PAGE INTENTIONALLY BLANK

TABLE 8-5. GENERAL DRAIN AND CULVERT PIPE DESIGN CRITERIA

(FOR PIPES NOT IN TXDOT OR BRAZORIA COUNTY RIGHT-OF-WAY)

Load	D-Class (H or HS vehicle load)
Pipe Class	Use Class III or stronger for all locations where vehicle load may occur
Interior Diameters	Laterals in storm sewer systems: minimum 18 inch Trunk lines in storm sewer systems: minimum 24 inch Standard sizes: 18-, 24-, 36- inch and larger in 6-inch increments Maximum: 60-inch Minimum: 18-inch Minimum box culvert size: 2 ft x 2 ft Culverts under driveways for vehicles: 12-inch Culverts under walkways (no vehicles): 6-inch
Manning n	Roughness: See Table 7-X Common design values: Concrete pipe, n =0.013 Concrete box, n =0.012 CMP: Varies with corrugation Thermoplastic: Varies with type of pipe
Manhole Spacing (maximum)	For 24” storm sewer: 300 ft or less For 36” storm sewer: 375 ft For 42” to 54” storm sewer: 450 ft For 60” or larger storm sewer: 900 ft
Bends	Use standard angles: 15-, 30-,45-, 60-, 90-degrees
Laterals	One lateral junction: 45-or 60-degree Two or more laterals: Use manhole unless trunk line diameter > twice lateral diameter
Design Velocity	Minimum: 2 ft/s (for common design storm event frequency, e.g. 5-yr event); Maximum: 12 ft/s (for maximum design storm, e.g., 100-yr event)
Design Flow Condition	Assume full flowing, non-pressurized flow
Manhole height	Minimum 1 ft from bottom of cover to invert

Source: TxDOT and Brazoria County Drainage Criterial Manual;

THIS PAGE INTENTIONALLY BLANK

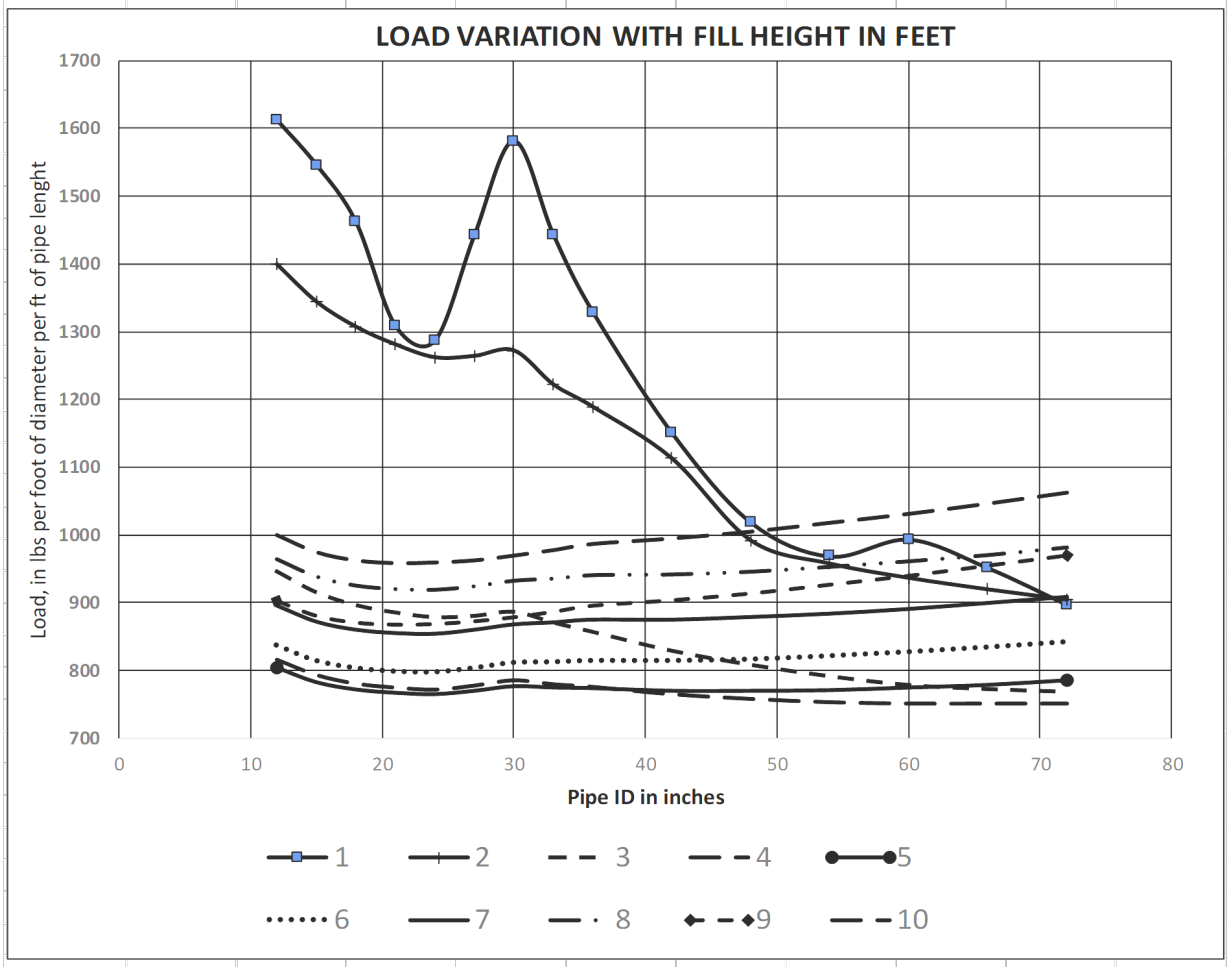
TABLE 8-6. MAXIMUM TYPE D LOADS ON CIRCULAR PIPE ACROSS FOUR CLASSES OF PIPE BEDDING

	FILL HEIGHT IN FEET ABOVE TOP OF PIPE									
Pipe Dia - Inches	1	2	3	4	5	6	7	8	9	10
12	1612	1399	947	817	805	838	896	964	902	1000
15	1546	1344	916	794	783	815	872	939	880	975
18	1462	1307	897	781	772	804	860	926	870	963
21	1309	1281	886	775	767	799	855	921	867	959
24	1287	1262	879	772	765	798	854	920	868	960
27	1442	1264	881	778	770	804	860	925	872	963
30	1581	1272	887	786	777	812	868	933	878	970
33	1443	1222	871	780	775	813	871	936	886	978
36	1329	1189	857	776	774	815	875	941	895	987
42	1151	1113	829	765	770	815	875	942	903	995
48	1019	992	808	758	770	817	879	946	913	1005
54	969	958	791	753	771	822	884	953	926	1018
60	994	937	778	751	775	828	891	961	939	1031
66	952	920	772	751	779	835	900	970	954	1046
72	898	905	768	751	786	843	909	981	969	1062

LOADS ARE GIVEN IN LBS PER FT OF DIAMETER PER FT OF PIPE LENGTH

Unit weight of soil = 120 lbs per cubic feet

Source data: Load based upon AASHTO HL-93 live load



Source: American Concrete Pipe Association, 2017

THIS PAGE INTENTIONALLY BLANK

TABLE 8-7. CONCRETE PIPE STRENGTH

Recommended RCP Strength Specifications For D-loads (lb/ft/ft)	**Pipe Strength (Class)**
0 to 800	800 (Class I pipe)
801 to 1,000	1,000 (Class II pipe)
1001 to 1,350	1,350 (Class III pipe)
1,351 to 2,000	2,000 (Class IV pipe)
2001 to 3,000	3,000 (Class V pipe)
Greater than 3,000	Contact Manufacturer

Source: American Concrete Pipe Association

THIS PAGE INTENTIONALLY BLANK

TABLE 8-8. CORRUGATED METAL PIPE SIZING

Fill Height Tables
Full Circle - Corrugated Steel - 2 2/3" x 1/2" Corrugations

CGM1E

Pipe Dia. (in)	Min. cover to top of subgrade	Metal Gage/Thickness 16 0.064 in.	14 0.079 in.	12 0.109 in.	10 0.138 in.	8 0.168 in.
		Maximum Fill Height Above Top of Pipe (ft)				
12	12	112	122	157	164	171
15	12	90	97	125	131	137
18	12	75	81	104	109	114
21	12	64	70	82	94	98
24	12	56	60	69	78	86
27	12	50	54	60	67	73
30	12	49	51	55	59	65
33	12	41	44	52	55	59
36	12	37	41	49	52	55
42	12	41	45 (57)	46 (90)	49 (94)	50 (98)
48	12	-**	43 (50)	44 (78)	46 (82)	47 (86)

Thickness in inches refers to the coated metal after galvanizing.
** Fill heights are shown only up to the maximum diameter allowed for that gage.
Fill heights in parentheses apply when pipe is 5% vertically elongated prior to installation.

Fill Height Tables
Full Circle - Corrugated Aluminum - 2 2/3" x 1/2" Corrugations

Pipe Dia. (in)	Min. cover to top of subgrad	Metal Gage/Thickness 16 0.064 in.	14 0.079 in.	12 0.109 in.	10 0.138 in.	8 0.168 in.
		Maximum Fill Height Above Top of Pipe (ft)				
12	12	45	45	77	-	-
15	12	36	37	56	-	-
18	12	28	30	36	43	49
21	-	-	-	-	-	-
24	12	22	23	25	28	31
27	12	20	21	23	25	27
30	12	18	18	21	23	24
33	12	16	17	20	21	22
36	12	-**	15	19	20	21
42	12	-	-	19	19	20
48	15		-	18	18	19

Thickness in inches refers to the clad sheet.
** Fill heights are shown only up to the maximum diameter allowed for that gage.

Fill Height Tables
Full Circle - Corrugated Steel - 3" x 1" or 5" x 1" Corrugations

Pipe Dia. (in)	Min. cover to top of subgrade	Metal Gage/Thickness 16 0.064 in.	14 0.079 in.	12 0.109 in.	10 0.138 in.	8 0.168 in.
		Maximum Fill Height Above Top of Pipe (ft)				
24	-	-	-	-	-	-
27	-	-	-	-	-	-
30	-	-	-	-	-	-
33	-	-	-	-	-	-
36	-	-	-	-	-	-
42	-	-	-	-	-	-
48	12	48	52 (60)	56 (89)	61 (107)	66 (118)

* Thickness in inches refers to the coated metal after galvanizing.

** Fill heights are shown only up to the maximum diameter allowed for that gage.
Fill heights in parentheses apply when pipe is 5% vertically elongated prior to installation.

Fill Height Tables
Full Circle - Corrugated Aluminum - 3" x 1" or 6" x 1" Corrugations

Pipe Dia. (in)	Min. cover to top of subgrad	Metal Gage/Thickness 16 0.064 in.	14 0.079 in.	12 0.109 in.	10 0.138 in.	8 0.168 in.
		Maximum Fill Height Above Top of Pipe (ft)				
24	-	-	-	-	-	-
27	-	-	-	-	-	-
30	12	27	30	35	41	46
33	-	-	-	-	-	-
36	12	23	24	28	30	34
42	14	21	22	24	26	28
48	16	20	20	22	23	24

Thickness in inches refers to clad sheet

** Fill heights are shown only up to the maximum diameter allowed for that gage.

Source: TxDOT Hydraulics Design Manual, 2016

THIS PAGE INTENTIONALLY BLANK

TABLE 8-9. USCS FOR UNCONSOILIDATED MATERIALS

USCS: UNIVERSAL SOIL CLASSIFICATION SYSTEM

Letter Key:

1st Letter Symbol	Description
G	Gravel
S	Sand
M	Silt
C	Clay
O	Organic

2nd Letter Symbol	Description
P	poorly graded (uniform particle sizes)
W	well-graded (diversified particle sizes)
H	high plasticity
L	low plasticity

Symbol Chart

Major divisions			Group symbol	Group name
Coarse grained soils more than 50% retained on or above No.200 (0.075 mm) sieve	gravel > 50% of coarse fraction retained on No.4 (4.75 mm) sieve	clean gravel <5% smaller than No.200 Sieve	**GW**	well-graded gravel, fine to coarse gravel
			GP	poorly graded gravel
		gravel with >12% fines	**GM**	silty gravel
			GC	clayey gravel
	sand ≥ 50% of coarse fraction passes No.4 (4.75 mm) sieve	clean sand	**SW**	well-graded sand, fine to coarse sand
			SP	poorly graded sand
		sand with >12% fines	**SM**	silty sand
			SC	clayey sand
Fine grained soils 50% or more passing the No.200 (0.075 mm) sieve	silt and clay liquid limit < 50	inorganic	**ML**	silt
			CL	clay of low plasticity, lean clay
		organic	**OL**	organic silt, organic clay
	silt and clay liquid limit ≥ 50	inorganic	**MH**	silt of high plasticity, elasticity
			CH	clay of high plasticity, fat clay
		organic	**OH**	organic clay, organic silt
Highly organic soils			**Pt**	peat

Source: Wikipedia, 2019; Source: Design Data 9, Standard Installations and Bedding Factors for the Indirect Design Method, American Concrete Pipe Institute, Nov 2013

THIS PAGE INTENTIONALLY BLANK

TABLE 8-10. STANDARD MINIMUM COMPACTION REQUIREMENTS

Installation Type (Note 2)	Bedding Thickness (Not in rock formations; see Note 3)	Compaction % Standard Proctor for Various Category of Soils	
		Compaction for Haunch & Outer Bedding (Notes 2, 4, 5)	Compaction for Lower Side of Bedding (Notes 2, 4)
1	Minimum D/24 but not less than 3-inch	90% for Category I	Category I: 90% Category II: 95% Category III: 100%
2	Same as Type 1	95% Category or Category II	Category I: 85% Category II: 90% Category III: 95%
3	Same as Type 1	90% Category I 90% Category II 95% Category III	Category I: 85% Category II: 90% Category III: 95%
4	None required	85% Category III; otherwise no compaction required	Category III: 85% Otherwise none

Soil Category	USCS Symbol (see Table 8-9	Equivalent Proctor Compaction Levels	
		Standard Proctor	Modified Proctor
I – Gravelly Sand	SW, SP, GW, GP	100%, 95%, 90% 85%, 80%	95%, 90%, 85% 80%, 76%
II – Sandy Silt	GM, SM, ML Also GC and SC with less than 20% passing #200 sieve		
III – Silty Clay	CL, MH, GC, SC	100%, 95%, 90% 85%, 80%	90%, 85%, 80% 75%, 70%

Notes

(1) D: Outside diameter in inches.
(2) Type as developed and defined by the American Concrete Pipe Institute
(3) If rock foundation, use D/12, but not less than 6 inches.
(4) Lower side is fill area below spring line
(5) Outer bedding is bedding beyond the limits of the outside diameter of pipe
(6) Compact soil in the outer bedding, haunch, and lower side zones, except under the middle1/3 of the pipe, to at least the same compaction as the majority of soil in the overfill zone.

Other notes

a. For Type 1 installation, crushed rock is not an appropriate material for bedding under the pipe. An uncompacted, non-crushed material must be used under the pipe.

b. For trenches, the top elevation shall be no lower than 0.1 H below finished grade or, for roadways, its top shall be no lower than an elevation of 1 foot below the bottom of the pavement base material.

c. For trenches, the width shall be as wide as necessary to be able to attain specified compaction in the haunch and bedding zones.

d. For trench walls within 10 degrees of vertical, the compaction or firmness of the soil in the trench walls and lower side zone need not be considered.

e. For trench walls with greater than 10 degree slope that consist of embankment, the lower side is tol be compacted to at least the same compaction as specified for the soil in the backfill zone.

f. Sub-trenches: see source materials

Source: Adapted from Design Data 9, Standard Installations and Bedding Factors for the Indirect Design Method, American Concrete Pipe Institute, Nov 2013

THIS PAGE INTENTIONALLY BLANK

TABLE 8-11. OUTDOOR BURNING

Purpose of Burning	Notify the TCEQ	Who Else to Notify	Rule Section in 30 TAC Sect 111
Domestic waste	Not required	a	111.209(1)
Diseased animal carcasses	Not required	a	111.209(2)
Animal remains and associated medical waste	Not required	a	111.209(3)
Plant growth on-site	Not required	a, b, c	111.209(4)
Plant growth at designated burn site	Verbally or in writing, by fire department employee; must be 24 hours before event	a, b,	111.209(5)
Crop residue	Verbally or in writing, when possible	a, b	111.209(6)
Brush, off-site, by county or city	In writing; also notify verbally when possible	a, b	111.209(7)

Notes

"Who Else to Notify":

a. Inform County Fire Marshall and if within a municipality, the local fire department or local law enforcement officials.

b. Before conducting the burn, determine whether any structures containing sensitive receptors (for example, residues, greenhouses, stables, etc.) are within 300 feet of, and the general direction downwind from, the site of the burn. If so, obtain written permission from the occupants of operators of those structures before beginning the burn.

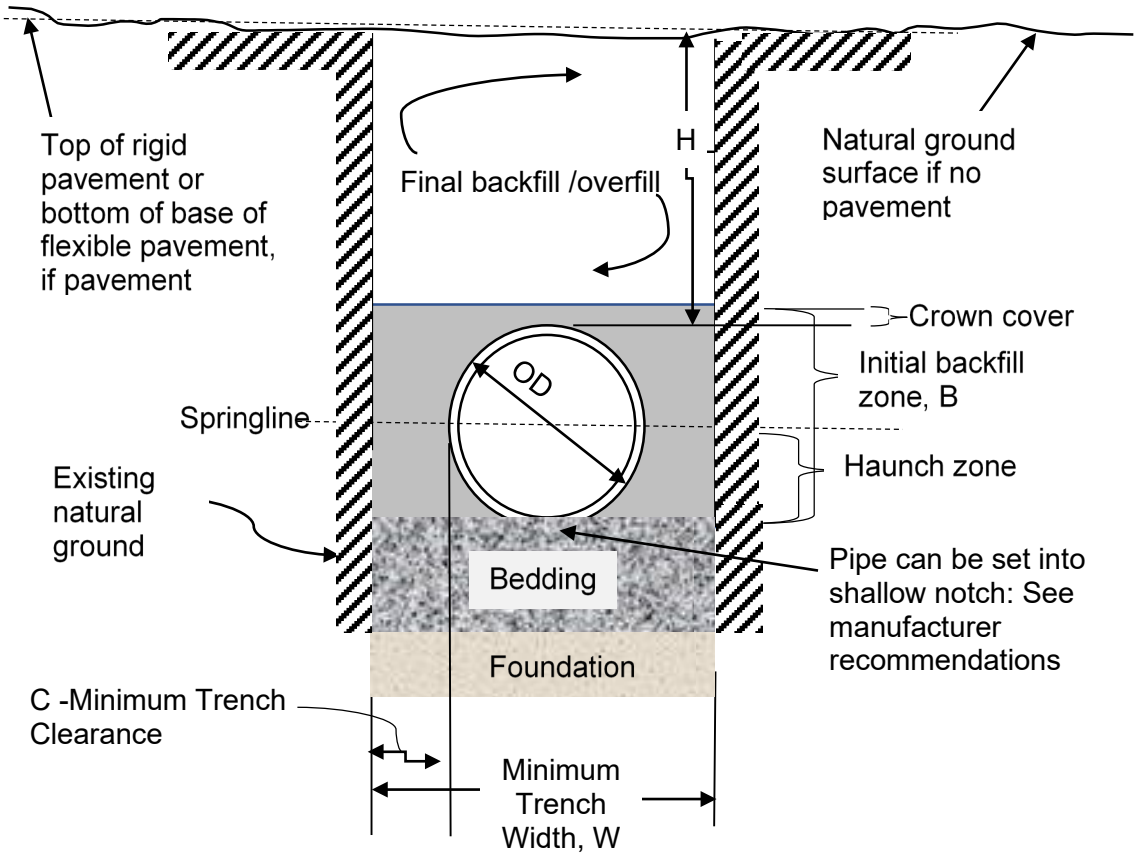
c. The Brazoria County Fire Marshall's office should be notified of proposed burning activities (ph: 979-864-1201); the Brazoria County Fire Marshall's office indicates that the Air Quality Division of the TCEQ should also notified (ph: 713-767-3714)

"Plant growth on-site" purpose applies to burning of vegetation resulting from access-way (as defined in Chapter 8) maintenance.

Source: Outdoor Burning in Texas, Field Operations, TCEQ,

THIS PAGE INTENTIONALLY BLANK

FIGURE 8-1. TYPICAL PIPE INSTALLATION DETAIL



H – Minimum Final fill/overfill height to (i) pavement or bottom of roadway fill or (ii) natural ground surface if no roadway material	See Table 8-6 (Load table for roadways) Minimum 6 inches for non-roadways and ID 12-inch and smaller Minimum 12 inches for non-roadways and ID >12 inch
Foundation thickness	As necessary to avoid rock and other unyielding material or soft muck, refuse, or similar easily compressible material
Bedding thickness	4 inch for 24-inch ID and smaller pipe 6 inch for 30-inch ID and larger pipe
Crown cover	Minimum 6 inch above pipe barrel pipe, or 6 inch above top of corrugation
B – Minimum thickness of initial backfill	6 inch pipe; place fill in maximum 6-inch lifts
C – Minimum trench clearance each side of pipe, single pipe installation or outer pipe for parallel pipe installation	Pipe ID < 24-inch: 8 inches Pipe ID: Between 24 and 60-inchs: 18 inches Pipe ID: 60-inch or larger: see manufacturer recommendations
C – Minimum clearance between pipes for parallel pipe installation	Pipe ID: ID smaller than 24-inch pipe: 12 inches Pipe ID: Between 24 and 60-inchs: 1.5 OD Pipe ID: 60-inch or larger: see manufacturer recommendations
W - Minimum Trench Width (one pipe)	Clearance on each side of pipe + OD
Compaction: Compaction as required by loading, except for middle 1/3 OD pipe width in haunch zone which can be loosely packed; see Table 8-10	
Above guidelines do not supersede manufacturer or supplier recommendations. ADAPATED FROM: Brazoria County Drainage Criteria Manual, 2003; ADS Hydraulic Design Handbook 2013; Design Data 9, ACPA, Standard Installations and Bedding Factors for the Indirect Design Method, 2013.	

THIS PAGE INTENTIONALLY BLANK

CHAPTER 9. PIPELINES AND UNDERGROUND CONVEYANCES

9-1 PIPELINE AND UNDERGROUND UTILITY CONSTRUCTION

For the purpose of this chapter, petrochemical pipelines and other underground utilities for conveyance of fluids, communication equipment, or power transmission equipment are defined as underground conveyances. “Underground conveyances,” as used in this section, do not include water or sewer lines.

The requirements of this chapter are limited to the construction of underground conveyances requiring disturbance or removal of (i) the land surface, (ii) surface and near-surface vegetation, and/or (iii) the ground or subsurface soils.

9-2 UNDERGROUND CONVEYANCES IN EASEMENTS OR RIGHTS-OF-WAY

Easements, rights-of-way, and agreements for construction or maintenance, either beneath the natural and ordinary land surface or water bodies, are generically and collectively termed “underground conveyance-ways.” Construction or maintenance activities involving construction-like activities in and along underground conveyance-ways must be conducted in accord with the following:

a. Drainage blockages of overland flow, swales, drainage ditches, or drainage ways shall not block surface water drainage in such a way that results in inundation of lands beyond the underground conveyance-way unless allowed under separate agreement among affected parties.
b. Inlets and outlets to drainage culverts shall not at any time be entirely blocked.
c. Pipeline construction in or closely adjacent and approximately parallel to a roadside drainage ditch shall not block at any one time the drainage in the ditch or any segment of the drainage ditch (in the direction along the side of the roadway) more than 250 feet in length.
d. Berms, soil piles or accumulations, levees, dikes, permanent access road, residual construction road, and similar flow blocking or flow redirecting structures created as a result of underground conveyance-way construction or maintenance activities shall not remain near (within 100 feet) of or within an underground conveyance-way.
e. Underground conveyances shall not cross any water pipeline, sanitary sewer, or storm sewer under a paved road.
f. The final ground elevation above a pipeline after the construction of an underground conveyance shall conform to the natural ground elevation that existed prior to start of construction, irrespective of whether the location of the conveyance is or is not at a crossing of a water body. Final ground elevations above and near an underground conveyance shall not obstruct surface drainage to, across, or from the location of the underground conveyance.

9-3 CROSSINGS OF AND NEAR WATERBODIES

The requirements of this chapter are supplemental to any federal, state, or county requirements applicable to underground conveyance-ways; they do not supersede or replace applicable federal or state requirements that may exist.

9-3.1 DEFINITION OF WATERBODY

A waterbody to which these requirements of this chapter apply includes natural or man-made rivers, creeks, ditches, drainageways, swales, overland flow zones, lakes, ponds, federal or state jurisdictional wetlands, or swamps (i) not under the jurisdiction of a federal or state agency or Brazoria County, as

distinct from the West Brazoria County Drainage District 11 (DISTRICT) or (ii) lie in an easement of a federal or state agency or Brazoria County agency exclusive of the DISTRICT.

The District Engineer shall have the authority to resolve disagreements with Applicants for an LNO as to whether a waterbody exists in so far as the applicability of these requirements.

9-3.2 REQUIREMENTS FOR MAINTAINING AND PROTECTING OF DRAINAGE

Activities for conveyance construction must conform to the following:

a. Construction of a crossing of a water body with limited flow or ill-defined flow direction (such as a pond, a wetland, or a swamp) shall not block more than 1/2 of the distance of the full length of the crossing of the water body at any one time during the period of construction. Within 30 days after construction across the waterbody in question, the waterbody shall be restored to its pre-construction condition.
b. An underground conveyance lying in a crossing area shall be located below the natural ground. The final position or location of the conveyance-way facilities in or near a water body crossing shall not be above ground unless specifically approved by the District Engineer.
c. Construction of an underground conveyance in or near (within 100 feet) a roadside drainage ditch shall not block any segment of the drainage ditch at any one time more than 48 hours.
d. Surface drainage swales, drainage ditches, and drainageways shall not be blocked longer than 24 hours.
e. Temporary or permanent drainage blockages of swales, drainage ditches, or drainage ways shall not block drainage in a way that results in the inundation of lands beyond the underground conveyance-way (unless allowed under separate agreement among affected parties).
f. Inlets and outlets to drainage culverts shall not at any time be blocked.
g. Underground conveyance-way crossings shall be configured so that the crown of any conveyance structure or facility is at least 3 feet blow bottom boundary of the river, creek, ditch, or other water body unless explicitly approved otherwise by the District Engineer.
h. Construction of a river, creek, or ditch crossing by an underground conveyance shall not block the flow width of more than $1/3^{th}$ of the total width of river, stream, or creek crossing at any one-time during construction or maintenance activities.

9-3.3 PROTECTION AND CARE OF WETLANDS

The requirements for protection and care of wetlands discussed in Chapter 8 apply to the construction of pipelines and underground conveyances.

9-3.4 COMPLIANCE TO REQUIREMENTS

Inspection by the District Engineer of conditions along, below, or in underground conveyance-ways by the District Engineer or Board members to assess compliance to the requirements for construction and maintenance specified in this chapter shall be at the discretion of the District Engineer. Owners or constructors of underground conveyance-ways shall cooperate with the District Engineer for making such inspections. Travel to off-road inspection sites shall be provided by the underground conveyance-way owner or constructor if requested by the DISTRICT.

Failure to comply with the above-described requirements shall void any Letter of No Objection issued by the DISTRICT or the District Engineer for construction of the underground conveyance-way in question, with any such voidance being transmitted to any agency issuing a permit for construction of the underground conveyance in question.

APPENDIX A. NOMENCLATURE

APPENDIX A. NOMENCLATURE

	A
AASHTO	American Association of State Highway and Transportation Officials
ac	Acre
ASPH	Asphalt or asphaltic
	B
BCDC MANUAL	Brazoria County Drainage Criteria Manual
BOARD	DD11 five-member board
	C
CGP	Construction General Permit
CL	Class
cfs	Cubic feet per second
Conc	Concrete
CMP	Corrugated metal pipe
cu-ft	Cubic foot (feet)
cu-yd	Cubic yard(s)
	D
Director	Member of DD11 Board
DISTRICT	West Brazoria County Drainage District 11
DIA	Diameter
DD11	West Brazoria County Drainage District No. 11
DD11 MANUAL	DD 11 drainage criteria manual
D_o	outside diameter
	E
EXT, EXIST	Existing
EPA	US Environmental Protection Agency
	F
FEMA	Federal emergency management agency
FIRM	Flood insurance rate map
ft	foot (feet)
Flood Prone	Area recognized by DD11 to be subject to frequent flooding
fps	feet per second
	G
GA	Gage
GALV, GAL	Galvanized
GAT	Gate
GR	Grade
HCED	Harris County Engineering Department
HCFCD	Harris County Flood Control District
hr	Hour
HWY, Hwy	Highway
	I
in, in.	Inch (inches)
	J
NONE	
	K
NONE	
	L
lb	Pound(s)
LNO	Letter of No Objection
	M
MANH	Manhole
MTRL, MTL	Material
MED	Medium
MTL	Metal
MIN	Minimum
MISC	Miscellaneous
MH	Mobile home
MS4	Municipal Separate Storm Water System
	N
n	Manning roughness coefficient
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
	O
OD	Outside diameter
	P
PLANS	Documents submitted in conjunction with a project
project	A plan or activity presented for review by DD11
	Q
NONE	
	R
ref	Reference

reinf	Reinforced
RCP	Reinforced concrete pipe
ROW	Right-of-way
RD	Road
RDWY	Roadway
RV	Recreations vehicle
	S
SCHD	Schedule
SEC	Section
sq-ft	Square foot (square feet)
sq-mi	Square-mile
stab	Stabilized
stand	Standard
stl	Steel
	T
TCEQ	Texas Council on Environmental Quality
TxDOT	Texas Department of Transportation
Tx-PE	Registered professional engineer in Texas
	U
USCS	Universal Soil Classification System
USACE	United States Army Corp of Engineers
	V
NONE	
	W
waterbody	A body of standing or flowing water
watercourse	A body of flowing water
waterway	A body of flowing water
W/	With
	X
X-SEC	Cross-section
	Y
yd	Yard
yr	Year
	Z
NONE	

APPENDIX B. REVISIONS TO WEST BRAZORIA COUNTY DRAINAGE DISTRICT DRAINAGE CRITERIA MANUAL*

March 4, 2018: "CHAPTER 4. LETTERS OF NO OBJECTION" adopted by Board of Directors.

May 6, 2018: DD11 Manual dated 5/6/2018 formally adopted by the Board of Directors.

May 19, 2019: Added Appendix D regarding easement agreements.

November 4, 2019:

- Updated DD11 mailing address on the front page.
- Revised for clarity: Form 4-1 , text of Section 6-3; Fig. 8-1
- Revised Form 4-1 to include fee for change in Administrative Information Form
- Revised format of Section 6-3.2 and added equation 6-2.
- Added second page to Table 6-3 (identified as Table 6-3 Continued).
- Change dates: Footer and Hurricane Harvey.
- Make corrections and format changes to Fig. 6-6
- Revise wording in Chap. 4 (sections 4-3, 4-4).
- Revise wording in Chap 5 (sections 5-1, 5-2, 5-3, 5-4).
- Add FORMs 4-5 and 4-6.
- Misc. grammar, spelling, and punctuation corrections.

*non-substantive corrections (e.g., insertion or deletion of a comma, semi-colon, or period and spelling corrections) are not necessarily listed.

THIS PAGE INTENTIONALLY BLANK

APPENDIX C. EXCERPTS FROM DISTRICT POLICIES AND PROCEDURES OF THE WEST BRAZORIA COUNTY DRAINAGE DISTRICT NO. 11

Revised 12 March 2012

3.0 POLICIES FOR PERMISSION TO WORK ON PRIVATE PROPERTY

3.01 When a landowner requests drainage work to be done on a channel or ditch on the landowner's property, the District will cause either a permanent drainage easement or a license agreement to be prepared. The Director who represents that landowner will present the landowner with samples of both a license agreement and an easement and will offer both options.

3.02 The District's attorney will provide the format for the easement document; however, an attorney for the landowner may consult with the District's attorney regarding the document. The width of the drainage easement will be determined by the guidelines set forth in the Brazoria County Drainage Criteria Manual. The easement document must be signed by the landowner and notarized. The District will record the notarized document in the Official Records of Brazoria County, Texas. The easement document will have provisions that allow the District to bring representatives of other local, state, or federal agencies onto the property to coordinate with the regulations of those agencies as they relate to the District. The easement document must be recorded before any drainage work may commence.

3.03 When the District initiates a project on private property where no drainage easement exists, the District may proceed with the work when a license agreement, satisfactory to the District's attorney, has been executed between the landowner and the District. License agreements that have been executed will be delivered to the District's attorney or engineer for filing prior to beginning work.

3.04 No drainage work will commence in areas under the jurisdiction of the U.S. Army Corps of Engineers until the proper permit has been secured from the Corps. Prior to performing any work in conjunction with an inter-local agreement from another government agency, any necessary permit must be secured from the U.S. Army Corps of Engineers. For projects initiated by the District, any necessary permit from the Corps shall be secured by the District. For projects initiated by a landowner, any necessary permit from the Corps shall be secured by the landowner, and a copy of the permit will be provided to the District.

3.05 When a landowner in the District requests a road crossing on a ditch or channel, the following steps are necessary:

A. The District must determine that the crossing will have value to the District in the performance of its maintenance operations on the ditch or channel.

B. Preparation of, execution of, and recording of a drainage easement for the ditch or channel on the property must be completed.

C. The landowner must agree to purchase culverts and fill material as specified by the District. Culvert size will be determined by the District using the Brazoria County Drainage Criteria Manual. The District will estimate the cost of the culverts and the specified fill material. The landowner must pay the estimated amounts to the District before any materials are ordered and before any work is done.

The landowner must secure any permits which are necessary from any other local, state, or federal agency.

D. Directors will meet with each landowner after work is completed to review the job and secure the landowner's written approval.

4.0 POLICIES FOR CONTRACTORS

4.01 The District abides by the rules for sediment control in regulations set forth by the federal Environmental Protection Agency (EPA) and the Texas Commission on Environmental Quality (TCEQ). In response to those regulations, the District has adopted a Storm Water Pollution Prevention Plan. According to the plan, on all District jobs which involve disturbing the ground, the following steps shall be taken by contractors for the District:

A. At locations specified by the District's engineer, the contractor shall place silt fence or hay sediment barrier. The District has a drawing, prepared by the District's engineer, showing the details of installation of the sediment barriers. Copies of the detail drawing are available to the contractors for the District.

B. Upon completion of the project, areas of disturbed ground shall be planted with grasses listed on the NRCS list and fertilizer will be applied in amounts specified by the District.

C. Sediment barriers shall be maintained until grass has become established enough to adequately prevent soil erosion. When grass is established, the sediment barriers shall be removed and disposed of by the contractor.

D. The cost of these items shall be included in the cost of every project as a part of the project. There will be a specified bid item.

4.02 If it is necessary to remove a fence for the construction of a project, a temporary fence shall be constructed in a manner and location sufficient to contain livestock, pets, and/or children in the appropriate locations. This shall be coordinated with the landowner by the contractor. Upon completion of the project, a fence shall be rebuilt in the location of the previous fence. The fence shall be the same type as the original fence, as nearly as possible. The specifications for a barbed wire fence shall be:

A. Five strands of barbed wire.

B. A post every 10 feet. Every fifth line post shall be a minimum 3" top, 6-1/2 feet long treated wood post. Other line posts may be 6-1/2 feet long steel tee posts.

C. An H-brace shall be constructed at a maximum spacing of 1320 feet to match the length of a roll of barbed wire. H-braces may be required at a closer spacing to ensure proper wire tension.

D. Disposal of any old fence shall become the responsibility of the contractor. Removal of any temporary fence shall be the responsibility of the contractor.

4.03 Excavated material, on any project, shall be graded in such a manner as to allow mowing with conventional tractors and mowers. All excavated material must be placed within 200 feet of the drainage channel, unless special arrangements have been made with the

landowner. Landowners may agree to pay the additional cost to haul the excavated material farther. This agreement shall be in place before

any excavation begins. After excavated material is placed and graded, it shall be planted with the appropriate grass seed and fertilizer.

4.04 After completing work, contractors will deliver invoices and timesheets to the Director in which the work was performed. Invoices will arrive no later than the 20th day of each month. All invoices will be submitted to the Director(s) of the precinct(s) in which the work was performed. The invoices shall identify the precinct in which the work was done and the location of the project. Timesheets and other supporting documents shall be attached to the invoice. If the work is done in more than one precinct, the invoice shall show a breakdown of the cost of the work by precinct. The approved invoices shall be considered for payment at the regular [monthly] District meeting…. Invoices received after the 20th day of the month will be considered for payment at the meeting of the following month.

THIS PAGE INTENTIONALLY BLANK

APPENDIX D. WEST BRAZORIA COUNTY DRAINAGE DISTRICT #11 AGREEMENT FOR DRAINAGE EASEMENTS

(As of 2018 2 5 2018)

This agreement is made by and between West Brazoria County Drainage District No. 11, hereinafter referred to as Drainage District, and Landowner whose name appears below. Drainage District and Landowner are desirous of maintaining and/or improving drainage to his/her property and/or flow of water through or across his/her property to affect good drainage in the Drainage District and reduce the possibility of area flooding.

Landowner hereby grants an irrevocable agreement to Drainage District for the purpose of opening, digging, cleaning and maintaining ditches, sloughs, and creeks and inspecting, cleaning out silt, brush, trees and other obstructions to drainage and repairs, with the privilege and right at all times to said Drainage District, its directors, officers, agents, employees, workmen, and other representatives having ingress and egress in, along, upon and across the following premises:

LEGAL DESCRIPTION:

_____

_____

as described in deed recorded in File No. _____of the Official Records, Brazoria County, Texas.

PROPERTY ADDRESS OR STREET NO.: _____

This agreement shall be binding upon and inure to the benefit of Drainage District and Landowner, their successors, and assigns.

It is further understood and agreed that this instrument does not constitute a conveyance of any of the lands described nor of the minerals thereunder but grants only an agreement as provided herein.

Said Drainage District for itself, its successors and assigns binds and obligates itself, its successors and assigns as follows:

Drainage District shall not fence or otherwise enclose said described premises;

(2) Whenever it becomes necessary for Drainage District, its agents, contractors, servants, and employees to cut a fence on the described premises, Drainage District shall keep the gaps closed or guarded in such a manner as to prevent the entrance or exit of cattle or other livestock through such gaps and to restore all fences damaged or destroyed by its operations to their natural condition or better.

3) Drainage District shall spread any excavated dirt along the described premises and, if Landowner requests, on the adjoining land adjacent to the described premises in such a manner as will permit the land to be mowed, farmed, or traveled across by landowners; and all work shall be

accomplished in such a manner as not to interfere with drainage from adjacent land of Landowner, and adequate outlets for the drainage of water will be installed by Drainage District.

(4) Drainage District shall remove or cause to be disposed any trees, brush, or rubbish which may be cleaned from the described premises. Drainage District will not remove household garbage.

(5) Drainage District shall maintain crossings, where necessary, within the described

premises. The number and type of crossing, the length and width of the bridge, or the length and diameter of the pipes in the crossing shall be determined by the Drainage District.

(6) Drainage District will place proper barriers necessary to keep silt of eroded materials from being discharged into any waterway. Areas of soil disturbed by Drainage District work activity will be replanted by Drainage District with grass seed suitable for the site.

(7) To the extent allowed by the Constitutional laws of the State of Texas, Drainage District assumes the entire responsibility for the activities to be accomplished on the Landowner's property. Nothing contained herein shall ever be construed to place upon Landowner any manner of liability for injury to or death of persons or for damage to or loss of property arising from or in any manner connected with the acts, conduct or negligence of Drainage District in conducting its activities on Landowner's property.

(8) Upon completion of any work on Landowner's property, Drainage District shall promptly repair any material damage to Landowner's property caused by such work so as to restore the property to substantially the same condition it was in prior to commencement of such work.

WITNESS MY HAND, this _____ day of _____ 2019.

WEST BRAZORIA COUNTY DRAINAGE DISTRICT NO. 11

P.O. Box 1329

Brazoria, Texas 77422

LANDOWNER:

_____ _____

Signed Signed

Date: _____, 2019 Date: _____, 2019

Printed Name of Director:

_____

District ___, Director By: _____

Telephone: _____ Email:_____