SECTION III

DRAINAGE DESIGN REQUIREMENTS

DRAINAGE DESIGN REQUIREMENTS

A. General: All storm sewers and appurtenant construction shall conform to the City of Houston Department of Public Works and Engineering Standard Construction Details for Wastewater Collection, Water Lines, Storm Drainage and Street Paving (See section F2 of this chapter) and all subsequent revisions. Any storm sewers and sanitary sewers which are located underneath or within one (1) foot of the paving section shall be bedded and backfilled with cement stabilized sand which meets or exceeds minimum 100 psi and contains not less than 1-1/2 sack cement per ton of sand. Backfill with cement sand to within one (1) foot of subgrade. Water lines to be bedded and backfilled in accordance with City of Houston Technical Specifications.

Trench excavation shall comply with all provisions contained in Article 1015Q (Texas Civil Statutes, Annotated).

B. Requirements Unique to Major Thoroughfares

1. The high point of top of curb should be at or not more than 3" below finished grade and the gutter to slope to inlet on minimum 0.25% grade.

2. Paving elevations, grades and storm sewer design shall be such that not more than one traffic lane of water shall pond in the low gutter of curbed sections during a 25 year event rainfall.

3. Storm sewers shall be designed from the following criteria:

A minimum 150' wide strip each side of and adjacent to the proposed road right-of-way shall be considered an impervious surface contributing runoff to the storm sewer and an in depth study of runoff and characteristics shall be made of all land areas contributing runoff to the roadway. The contributing runoff from all areas outside the two 150' wide strips shall be computed according to section C below.

C. General Design Requirements

1. Design Rainfall Intensities

1.1 The 2-year storm, as derived from the National Weather Service Technical Paper 40 and Hydrometeorological Report 35 publications, shall be used for storm sewer and roadside ditch design in Galveston County. The 2-year rainfall intensity may be computed using the following equation:

$$i = \frac{b}{(d + TC)^e}$$

Where I = rainfall intensity (inches per hour)

TC = Time of Concentration (minutes)

b = 75.01; d = 16.2; e = 0.8315

For example, the rainfall intensity for an area that has a TC of 25 minutes would be 3.42 inches per hour.

1.2 Determination of Time of Concentration

Time of concentration can be calculated from the following formula:

$$TC=10a^{0.1761}+15$$

Where: TC = Time of Concentration (minutes)
a = the subarea in acres

For example, the Time of Concentration for a 2-acre subarea would be 26.3 minutes.

1.3 Rational Method

The Rational method calculates the peak runoff for a storm drain system using the following equation for runoff:

Q = Sum(CA)i

Where:

C = Runoff Coefficient

A = Area (acres)

i = Rainfall Intensity (inches per hour)

The rational method will be used for design on all storm sewered areas up to 600 acres in size. The Rational Method will be considered applicable for all storm sewered areas up to 1,200 acres and for areas served by roadside ditches to 500 acres in size.

1.3 Calculation of Runoff Coefficient

The runoff coefficient "C" values in the Rational Method formula will vary based on the land use. Land use types and "C" values which can be used are as follows:

Land Use Type	Runoff Coefficient
Residential Districts	
Lots more than 1/2 acre	0.35
Lots 1/4-1/2 acre	0.45
Lots less than 1/4 acre	0.55
Multi-Family Areas	
Less than 20 DU/AC	0.65
20 DU/AC or Greater	0.80
Business Districts	0.80
Industrial Districts	
Light Areas	0.65
Heavy Ares	0.75
Railroad Yard Areas	0.30
Parks/Open Areas	0.18

Alternatively, the runoff coefficient "C" in the Rational Method formula can be calculated from the equation:

$$C=0.6I_a+0.2$$

Where:

C=watershed coefficient

I_a=percent impervious area.

For example, if the percent impervious is 0.9, then the runoff coefficient would be 0.74.

If this alternate equation is used rather than the values tabulated above, the details of the computation of C are to be provided as part of the drainage calculations.

2. Offsite Flows: Runoff originating outside the development's limit, but entering the development's system, shall be designed at 1 cfs/acre or at a rate determined by complete study of the area using the Harris County Flood Control District Site Runoff Curves for a 25-year storm event (Figure 1).

In the event a swale ditch is needed to intercept runoff and direct it to the proper storm sewer system or drainage outfall ditch utilize the following guidelines:

2.1 Provide Contour Map showing area to be drained along with calculations to support ditch size and grades.

2.2 Locate in an easement sufficient in width to allow for proper maintenance operations. See drainage standard drawings.

3. Mapping Requirements: Provide a Contour Map and Drainage Area Map for all areas which are to be drained by the proposed drainage system.

4. Drainage Calculations and Roughness Coefficients: Submit drainage calculations to support line sizes and slopes. The "n" coefficient in Manning's Formula shall be 0.013 for concrete pipe and 0.024 for corrugated metal pipe.

5. Hydraulic Grade Line: A graphical plot and calculations of the hydraulic gradient shall be furnished by the design engineer. The hydraulic gradient shall be calculated assuming the top of the outfall pipe as the starting water surface. At drops in pipe invert, should the upstream pipe be higher than the hydraulic grade line, then the hydraulic grade line shall be recalculated assuming the starting water surface to be at the top of pipe at that point. For the design storm, the hydraulic gradient shall at all times be below the gutter line for all newly developed areas. For approved streets with ditch sections, the hydraulic gradient shall be 0.5' below the edge of pavement or natural ground elevation, whichever is lower.

6. Storm Sewer Pipe Sizes: The minimum size for storm sewers and inlet leads shall be twenty-four inches (24") inside diameter pipe or equivalent cross section area. Box culverts shall be at least 2' by 2'.

7. Storm Sewer Flow Velocities: Storm sewers shall be designed to have a minimum velocity of three feet per second (3'/sec) when flowing full. Storm sewers should be constructed to flow in subcritical hydraulic conditions if possible. Maximum velocities should not exceed 8 feet per second without use of energy dissipation downstream. Maximum velocities should not exceed 12 feet per second.

8. Storm Sewer Junctions: Larger pipes upstream should not flow into smaller pipes downstream unless construction constraints prohibit the use of a larger pipe downstream, or the improvement are outfalling into an existing system, or the upstream system is intended for use in detention.

Match crowns of pipe at any size change unless severe depth constraints prohibit.

9. Soil Borings and Bedding: For all storm sewers having a cross sectional area equivalent to a forty-two inch (42") inside diameter pipe or larger, soil borings with logs shall be made along the alignment of the storm sewer at intervals not to exceed five-hundred feet (500') and to a depth not less than three feet (3') below the flowline of the sewer. The required bedding of the storm sewer as determined from these soil borings shall be shown in the profile of each respective storm sewer. When the trench is opened, if in the judgement of the Design Engineer, conditions differ from the design bases, he may authorize changes in the bedding indicated on the drawings. Such changes shall be shown on the record drawings.

10. Roadside Ditches:

10.1 Design Flows: The rainfall runoff criteria shall be determined based on the projected land use, and the rational method as described above. The design storm event for the roadside ditches shall be a 2-year rainfall. Design capacity for a roadside ditch shall be to 0.5 feet below the edge of pavement or the natural ground at the right-of-way line, whichever is lower. The design must include and extreme event analysis to indicate that structures will not be flooded.

10.2 Slide Slopes: The minimum preferred unlined or unimproved roadside ditch section should have a side slope no steeper than three (3) horizontal to one (1) vertical configuration. Steeper slopes will be allowed when the existing right of way is limited or other construction features dictate the design. The steepest slope shall not exceed two (2) horizontal to one (1) vertical.

10.3 Bottom widths: The minimum bottom width for roadside ditches should be two fee (2') unless design hydraulics will support a narrower or vee ditch configuration.

10.4 Roughness Coefficients: The "n" coefficient in Manning's Formula for ditch calculations shall be based on the surface treatment of the completed channel section with 0.040 as the minimum coefficient for unlined dirt ditches and 0.025 for ditches with paved inverts.

10.5 Flowline Slope: The minimum grade or slope of roadside ditches shall be 0.10 percent (0.1 foot per 100 feet).

For grass lined sections, the maximum design velocity shall be 3.0 feet per second during the design event.

10.6 Allowable Depth: The minimum depth of roadside ditches shall be eighteen inches (18") from the top of the pavement, and the maximum depth shall be not more than four feet (4'). Extreme conditions may warrant a deeper ditch, specific approval of which must be obtained from the County Engineer.

10.7 Culvert Capacity: Culverts will be placed at all driveway and roadway crossings, and other locations where appropriate. A graphic plot and calculations of the hydraulic gradient employing culvert design parameters shall be shown for each drainage ditch section and shall be 0.50' below the edge of pavement or natural ground elevation, whichever is lower. Head losses in culverts shall conform to TxDOT Hydraulic Manual, Chapter 4-Culverts, or equivalent. Culverts will be designed assuming inlet control.

10.8 Culvert Size: The minimum size culvert shall have a cross section area equal to or greater than an eighteen-inch (18") inside diameter pipe. Roadside culverts are to be sized based on drainage area. Calculations are to be provided for each block based on drainage calculations. Pipe culverts shall conform to ASTM Specifications C-76, Class III, for reinforced concrete pipe. All proposed and reasonably expected future culverts shall be included in the hydraulic profile. The size of culvert used shall not create an additional head loss of more than 0.20' greater than the normal water surface profile prior to placement of the culvert. All driveways to have culverts; no paved dips for driveways.

10.9 Erosion Protection: Erosion control methods acceptable to the County Engineer shall be utilized in ditch designs where the velocities of flow are calculated to be greater than five feet (5') per second or where soil conditions indicate their need. All ditches and channels require seeding, fertilizing, hydromulching with a short and long term grass in accordance with section K of this chapter. Ditch invert protection will be used at the upstream and downstream ends of all culverts.

10.10 Outfalls: Outfalls from storm sewers and ditches shall enter at the grade of the outfall ditch or in a manner acceptable to the applicable Galveston County Drainage District and Galveston County Engineer. If necessary, drop type outfall structures shall be used to prevent erosion.

10.11 Shoulder Width: The shoulder widths for roadways shall be a minimum of 6 feet (6') from the edge of pavement to the adjacent edge of ditch bank.

10.12 Right-of-way: The minimum distance between the right-of-way line and adjacent edge of the bank of ditch shall be two feet (2').

10.13 Storm Sewer Inlets: Storm water discharging from a ditch into a storm sewer system must be received by use of an approved structure (i.e., stubs with ring grate or type "E" Manholes. The capacity of type "E" inlet is 20 cfs.).

10.14 Lot Drainage: All side lot or back lot drainage facilities shall be underground storm sewers constructed in accordance with the specifications herein. Individual lot drainage shall be exempted from this requirement.

11. Major Channels: Major drainage ways through a subdivision shall be designed and constructed to accommodate the 100-year peak rate of runoff, in the manner prescribed by the applicable Galveston County Drainage District and the Galveston County Engineer. For channels with drainage areas of 300 acres or less, the site runoff curves (Figure 2) may be used. For larger drainage areas, a more detailed hydrologic analysis should be performed. A minimum of 20' to 30' maintenance berm is required on each side and must be seeded, mulched, and fertilized. If topsoil is needed to obtain a successful stand of grass, it shall be provided. Water surface elevation shall be calculated using Manning's Equation and the continuity equation. For the design storm event, the water surface should be calculated to remain within banks.

12. Major Channel Structures: If the developer proposes to construct major structures, such as box culverts or bridges across drainage channels, such structures shall conform to drawings and specifications of TxDOT as well as the County Engineer. See Section V.A-1, Structures. Head losses in culverts shall conform to TxDOT Hydraulic Manual, Chapter 4-Culverts, or equivalent. Generally, corrugated metal pipe will not be approved for permanent installation of culverts in Galveston County right-of-way except at railroad crossings.

D. Flood Plain Development Guidelines and Procedures

The following requirements shall apply to all developments planned within the 100-year flood plain:

1. Any construction and/or fill that would obstruct flow and cause any increase in flood levels must be fully offset with conveyance improvements.

2. Flood plain storage volumes shall not be reduced by way of fill. Where flood plain fill is proposed and is demonstrated not to adversely affect conveyance, compensatory storage equal in volume and effect shall be excavated.

Specific procedures to be followed for analysis of development proposed within the flood plain are outlined below:

1. The existing designated 100-year flood plain and floodway should be plotted on a map of the proposed development. The designated flood levels and floodway may be obtained from the Galveston County Engineering Department or the appropriate Galveston County Drainage District.

2. A hydraulic profile should be developed utilizing the HEC-2 computer program or other acceptable hydraulic modeling technique which provides a reasonable comparison with the designated flood levels and floodway.

3. The effect of the proposed development and the encroachment into the flood plain area should be incorporated into the hydraulic model and the resulting flood plain determined. Careful consideration should be given to providing an accurate modeling of effective flow areas taking into account the expansion and contraction of the flow.

4. The required channel improvements or other means of off-setting increases in flood plain elevations should then be incorporated into the hydraulic model. The resulting flood levels should be determined to verify that the improvements sufficiently offset the encroachment.

5. Once it has been determined that the proposed improvements adequately offset the encroachment, a revised floodway for the stream must be computed and delineated.

6. All hydraulic model data should be submitted with appropriate supporting information and computations to the Galveston County Engineer and/or the appropriate Galveston County Drainage District for review.

E. DOWNSTREAM IMPACT ANALYSIS

The following paragraphs describe general procedures to be used to determine the effect a proposed development has on downstream flood conditions.

General Criteria

The task of determining what downstream areas may be impacted by a proposed development is not an easy one. Varying rainfall patterns over a watershed and changing land-use conditions in other areas of the watershed may affect the extent and area of impact due to a proposed development. Also, developments of a similar nature located in different parts of a watershed may have different downstream impacts.

Because of these various factors and uncertainties, the criteria outlined below are general in nature. Specific projects should be closely coordinated with Galveston County Engineer and/or the appropriate Galveston County Drainage District from their inception in order to avoid costly revisions and delays in project completion.

The following are generally recommended criteria and procedures to be followed:

1. The location of the proposed project should be submitted by the project engineer to the Galveston County Engineer and/or the appropriate Galveston County Drainage District for comment.

2. The Galveston County Engineer and/or the appropriate Galveston County Drainage District will indicate the downstream areas which are considered to be of concern with respect to the potential impact of the proposed project.

3. The project engineer will then determine the impact on the areas of concern and present data to satisfy the Galveston County Engineer and/or the appropriate Galveston County Drainage District that no adverse impact will result.

To satisfy the Galveston County Engineer and/or the appropriate Galveston County Drainage District that no adverse impact will result, three potential courses of action may be followed:

1. Provide channel improvements through the area of concern which fully offset the increased flow rates caused by the proposed development, or;

2. A detention basin or other acceptable detention system may be designed to eliminate any increase in peak flow rates to the receiving stream, or;

3. A flood routing study may be performed which shows that the proposed project will not increase peak flow rates through the critical area under reasonable assumptions regarding rainfall distribution and land use within the watershed.

These three alternative courses of action are not intended to be mutually exclusive. A combination of solutions involving these approaches may be obtained. For example, a combination of some downstream channel improvements and detention storage may be used. A detailed routing study may show that the proposed development may increase downstream flow rates to a minor extent which may be compensated for by minor channel improvements or a small detention system. However, in lieu of a detailed routing study; the design of offsetting channel improvements or detention will be based on the assumption that the peak runoff rate from the proposed development occurs at the same time as the peak runoff rate for the receiving stream through the critical reach. The design of improvements under items (1) and (2) above shall follow the procedures in common engineering practice at that time.

Regarding routine studies to evaluate the impact on downstream critical reaches, the following general guidelines shall be followed:

1. Rainfall distribution over the watershed shall be in accordance with the HEC-1 default triangular distribution.

   However, the Galveston County Engineer and/or the appropriate Galveston County Drainage District may require additional analyses under different rainfall assumptions if it feels such analyses are warranted.

2. Channel improvements planned to be completed within a two-year period may be considered in the routine procedures.

3. Future land-use conditions within the watershed to be used in the routing study shall be defined by the Galveston County Engineer and/or appropriate Galveston County Drainage District.

4. Unless a alternative method is specifically approved by the Galveston County Engineer and/or the appropriate Galveston County Drainage District, the Corps of Engineers' HEC-1 program shall be used for performing the routing analysis. Optional routing methodologies should be reviewed with the Galveston County Engineer and/or the appropriate Galveston County Drainage District. Sub-area runoff computations and associated routing shall be performed on sub-areas which are of a size that allow reasonable determination of the timing of flows from the development in comparison with the overall timing of flood flows from the watershed. The sub-area breakdown, hydrograph coefficients, routing methodology, etc. should be submitted to the Galveston County Engineer and/or the appropriate Galveston County Drainage District for approval prior to performing detailed calculations.

F. Materials:

1. All storm sewers shall be constructed with reinforced concrete pipe, either precast pipe, box conduits or cast in place pipe. The use of corrugated galvanized metal pipe, or other approved equal, may be used only at the storm sewer outfall into unlined channels. The length of the outfall shall be determined on an individual basis as dictated by the construction requirements.

2. All storm sewer construction shall conform to the City of Houston, Department of Public Works and Engineering "Storm Sewer Standard Details Date 1996", City of Houston Drawings 02081-01 through 02081-10, 02084-02 through 02084-09,02317-03 through 02317-07, 02317-09, 02362-01 through 02362-10, 02633-01,06333-02,02641-01, 02642-01 and all subsequent revisions.

G. Storm Sewer Alignments

1. All cast in place concrete storm sewers shall follow the alignment of the right-of-way or easement.

2. All precast concrete pipe storm sewers should be designed in a straight line and tops of pipes should be matched at all pipe sized changes.

3. All storm sewer inlet leads shall be designed in a straight line.

4. Storm sewers shall be located in public street rights-of-way or in approved easements. Back lot easements are discouraged.

5. In all easements restricted to storm sewers, the pipe shall be centered within the limits of the easement. Minimum width of easement shall be 20 feet (20'). In the event of extreme depth and/or large sewers, additional width will be required to allow for proper maintenance operations. Bedding shall be provided in accordance with City of Houston requirements stated previously.

6. For storm sewers located in easements adjacent to public street rights-of-way, the minimum width of the easement shall be ten feet (10'). The minimum width shall be increased for larger pipe or conduit with the requirement that a minimum distance of five feet (5') shall be maintained from the easement line to the outside edge of the sewer, and a minimum distance of two feet (2') shall be maintained from the right-of-way line to the outside edge of the sewer pipe or conduit.

H. Manholes shall be located at:

1. All pipe size or cross section changes. Tops of pipe should be matched.

2. All pipe sewer intersections or P.I.'s.

3. All pipe sewer grade changes (precast pipe only).

4. All street intersections.

5. A maximum of seven-hundred feet (700') measured along the center line of the pipe sewer. Manholes are not required where inlet leads intersect a monolithic concrete storm sewer; however, manholes may be required as necessary to provide access for adequate maintenance of lead lines.

6. All inlet lead and conduit intersections with the pipe sewer where precast concrete pipe sewers are designed. Manholes are not required where inlet leads intersect a monolithic concrete storm sewer;however, manholes may be required as necessary to provide access for adequate maintenance of lead lines.

I. Inlets:

1. Shall be located at all low points on gutter gradient.

2. Inlet Spacing: Inlets must be spaced to serve the runoff calculated using the Rational Method as applied according to Section III.C of this document. Curb inlets shall be spaced so that the maximum travel distance of water in
the gutter will not exceed seven-hundred feet (700') one way for residential streets and three-hundred feet (300') one way on major thoroughfares and streets within commercial developments. It is preferable that curb inlets be located on intersecting side streets instead of major thoroughfares on all original designs or developments. Do not place inlets in circular portion of cul-de-sac streets unless special conditions warrant otherwise. Place inlets at the end of proposed pavement, if drainage will enter or leave pavement. Do not locate inlets adjacent to esplanade openings. Special conditions warranting other locations of curb inlets shall be determined on a case by case basis by the County Engineer.

3. Standard Inlet Type and Construction: Type "BB" Inlet or equal is to be used as a curb inlet on curbed streets. The capacity of a Type "BB" Inlet is 5 cfs and valley gutters are not permitted on public streets (public alleys exempted) on all original designs or developments. All inlets are to be constructed of brick masonry, cast concrete in place, or may be precast as approved by the County Engineer. Minimum lead size is 24".

4. Other Inlet Types: Certain instances may bring about the need for utilization of inlet types other than the standard "BB" and will be used only after receiving approval of the County Engineer. Do not use "Beehive" grate inlets or other "specialty" inlets. Do not use grate top inlets in unlined roadside ditch.

J. Consideration of Overland Flow

1. Design Frequency

The design frequencies for consideration of overland sheet flow will consider extreme storm events which exceed the capacity of the underground storm sewer system resulting in ponding and overland sheet flow through the development to the primary outlet.

2. Relationship of Structures to Street

All structures will be higher than the highest level of ponding anticipated resulting from the extreme event analysis.

3. Calculation of Flow

a. Streets will be designed so that consecutive high points in the street will provide for a gravity flow of drainage to the ultimate outlet.

b. The maximum depth of ponding at high points will be six inches above top of curb.

c. The maximum depth of ponding at low points will be 18 inches above top of curb.

d. Sheet flow between lots can be provided only through a defined drainage easement.

e. A map shall be provided to delineate extreme event flow direction through a proposed development and how this flow is discharged to the primary drainage outlet.

f. In areas where ponding occurs and no sheet flow path exists, then a calculation showing that runoff from the 100-year event can be conveyed and remain in compliance with the other terms of this section must be provided.

K. Seeding and Fertilizing for Erosion Control

1. Description

This item shall consist of preparing ground, providing and hydromulching seeds and fertilizer, rolling and other management practices along and across such areas that are required to be reseeded as designated as on the plans and in accordance with these specifications. A complete uniform and mowable stand of grass must result or the area will be immediately re-seeded until such is the result.

2. Materials

Seed: All seed must meet the requirements of the Texas Seed Law Including the labeling requirements for showing pure live seed (PLS=purity + germination) name and type of seed. Seed furnished shall be of previous season's crop and the date of analysis shown on each bag shall be within nine months of the time of use on the project.

Each variety of seed shall be furnished and delivered in separate bags or containers. A sample of each variety of seed shall be furnished for analysis and testing when directed by the Engineer. Seeding shall be a combination of Bermuda grass (hulled) at 15 lbs/acre and Rye grass 25 lbs/acre for a total of 40 lbs/acre.

Fertilizer: Fertilizer shall be delivered in bags or containers clearly labeled showing the analysis. The fertilizer is subject to testing In accordance with the Texas Fertilizer Law. Fertilizer that is powered or caked will be rejected. A pelleted or granulated fertilizer which has an analysis of 12-12-12, (percent of nitrogen, phosphoric acid, and potash nutrients) shall be uniformly applied at a rate of 830 lbs/acre. In the event it is necessary to substitute a fertilizer of different analysis, the total amount of nutrients furnished and applied per acre shall equal that specified for each nutrient. Any such substitutions shall be approved in advance by the Engineer.

Mulch: Mulch for use with hydraulic application of grass seed and fertilizer shall consist of specially prepared wood cellulose fiber or shredded paper fiber. It shall be processed in such a manner that it will not contain germination or growth inhibiting factors. It shall be dyed green to allow visual metering of its application. The fibers shall have the property of becoming evenly dispersed and suspended when agitated in water. When sprayed uniformly on the surface of the soil, the fibers shall form a blotter-like ground cover, which readily absorbs water, and allows infiltration to the underlying soil. Weight specifications from suppliers, and for all applications, shall refer only to air dry weight of the fiber, a standard equivalent to 10 percent moisture. The mulch material shall be supplied in packages having a gross weight not in excess of 100 pounds, and shall be marked by the manufacturer to show the air dry weight content. Suppliers shall be prepared to certify that laboratory and field testing of their product has been accomplished, and that it meets all of the foregoing requirements.

Topsoil: As needed 3" in depth spread and rolled on exposed slopes and other exposed areas.

The topsoil shall be fertile loam, easily cultivated and free from objectionable material, and shall have a relatively high erosion resistance and be readily able to support the growth of the planting, seeding or sodding specified.

The County shall be notified at least 2 weeks in advance of obtaining topsoil from any material source to permit inspection and to prepare for a necessary checking and measurement.

Trash, wood, brush, stumps and other objectionable materials encountered shall be removed and disposed of as directed by the Engineer prior to beginning of work required by this item. Material may be stockpiled in the designated areas only. The source and stockpile areas shall be kept drained, insofar as practicable, during the period of use. Trash, wood, brush, stumps and other objectionable materials must not be allowed to contaminate the stockpiled topsoil so the site must be cleared and cleaned by the Contractor prior to stockpiling the topsoil and kept clean while the job is in progress.

The selected topsoil material shall be used to improve designated areas for planting and seeding purposes.

The spreading of the topsoil shall be undertaken as soon as the grading operations have been completed. Topsoil shall be spread, so as to form a uniform cover 3 inches thick prior to rolling. After topsoil has been placed, shaped, and rolled it shall be seeded within 48 hours. The stockpile areas shall be cleaned, regraded to preconstruction condition, and seeded at that time.

3. Construction Methods

All exposed topsoil shall be seeded. All areas to be seeded shall be cultivated to a depth of 4 inches. The seed bed shall be firmed with a roller not exceeding 90 pounds for each foot of roller width and then cultivated sufficiently to reduce the soil to a state of good tilth when the soil particles on the surface are small enough and lie closely enough together to prevent the seed from being covered too deep for optimum germination. The proper cross-section shall be maintained throughout the process of cultivation and any necessary reshaping shall be done prior to any planting of seed.

Seeding and fertilizing shall be accomplished by hydromulching only.

The application of the mulch slurry shall be made with hydraulic equipment, which has a built-in agitation system with an operating capacity sufficient to

agitate, suspend and homogeneously mix slurry. The slurry distribution lines shall be large enough to prevent

stoppage and shall be equipped with hydraulic spray nozzles which provide even distribution of the slurry on the slopes to be seeded. The fiber mulch shall be applied at the rate of 2,000 pounds per acre in combination with water, fertilizer, and seed, and shall be sprayed over the soil in a uniform coat. The mulch shall be kept moist by daily application of water if necessary, until the seeds in the mulch have germinated and rooted in the soil and are visible growing above the soil surface.

4. Sprinkle Irrigation

Description

This item shall consist of providing and properly applying water on all seeded areas, and any other area as directed by the Engineer and as herein specified.

Materials

Water shall be clean and free of industrial wastes and other substances harmful to the growth of grass.

Construction Methods

This works shall be done within 24 hours after rolling the seed bed or as directed by the Engineer. The developer will furnish and operate sprinklers, nozzles, or other approved equipment which will insure the distribution of water in a uniform and controllable rate of application. The developer shall apply the water as necessary to cause the seed to germinate and sprout and without causing erosion or displacement of the topsoil.

5. Acceptance

Seeding shall not be accepted until the planted seed has germinated, rooted in the soil, and is visibly growing above the surface of the topsoil. The developer shall be responsible for the establishment and proper care of a stand of grass over the entire seeded area. It is the intent of these specifications to have a good, thick, mowable stand over the entire project and before final acceptance of same.

L. STRUCTURAL DESIGN CRITERIA

1. GENERAL

The structural design of flood control facilities encompasses all aspects of the design of modifications to existing channels and streams or new channels, from the selection of side slopes for earthen channels to major structures, such as bridges, culverts, drop structures, and retaining walls. Hydraulic structures should convey stormwater safely, control erosion, be cost effective, require minimal maintenance, and add safety and esthetics to the drainage system.

The intent of this section is to present recommended standard structural details and to outline the criteria and calculations required for approval of non-standard structures. Discussed in the sections to follow is the structural design of drainage channels (both lined and unlined), culverts, bridges, drop structures, closed conduits, backslope drains, sheet flow interceptors, and storm sewer outlets.

2. DESIGN CONSIDERATION

The structural design of any non-standard drainage structure will require an independent structural analysis in accordance with the recommendations of a geotechnical study. The construction drawings should include a scaled drawing of sufficient size of the particular structure with appropriate typical sections, dimensions, and construction specifications and notes. In the design of such structures, the following effects should be considered as minimum:

a. Lateral earth pressures.

b. Buoyant forces.

c. Bank stability, including channel bottom rotational stability, when designing vertical drop structures.

d. Scour and erosion forces.

e. Dead loads, live loads, and impact loads.

f. Wheel loadings in accordance with HS20-44.

g. Bearing capacity of soils.

h. Backfill effects, especially when expansive soils are involved.

i. Negative pressure at drop structure overflow nappe.

j. Fault lines.

k. Construction loadings

The latest applicable standards should always be used in the design of hydraulic structures.

Structures should generally be able to be built by local contractors using common construction techniques in the Galveston County area. Construction techniques not common to the area or patented building materials and processes should be avoided. Structures should also be designed so contract bidding will be competitive.

3. SOILS CONSIDERATIONS

General Geotechnical Requirements

A subsurface soils investigation should be an integral part of improvement projects in Galveston County, Texas. A detailed subsurface investigation should be made by taking soil samples and analyzing the samples for various conditions that will affect the structural integrity of proposed structures. The field effort should define soil stratifications and groundwater conditions. Soil borings will be required at a minimum of every 1,000 feet along a channel in which improvements are proposed as well as at all proposed major structures. Each boring should be a minimum of 1.5 times the proposed channel depth or conduit invert.

Galveston County is essentially divided into two broad zones with regard to the surface soils. Those areas, which lie generally on the Mainland, tend to be more clayey, while those generally on the Island and Peninsula tend to be sandier. A major problem with the sandy soils is that they are highly erosive. The clay soils tend to be very expansive and can generate large soil pressures on structures.

Channel Side Slope Stability

Laboratory test should be conducted to measure the undrained and drained shear strengths of appropriate soil strata and evaluate the grain size, permeability

and competence of cohesionless zones. Index testing can be utilized along with specific test results to select proper soil parameters. All tests should be performed in accordance with American Society for Testing and Materials (ASTM) procedures where appropriate.

Slope stability should be analyzed for the design cases as follows:

a. End of Construction Case, which models the initial undrained condition of the soil.

b. Long Term Design Case, which represents steady state piezometric and stress conditions. When a ditch slope is excavated, altered stress conditions create pore pressure changes within the slope and the undrained strength of the bank soils is mobilized. With time, the soil pore pressures adjust to the imposed stress and piezometric conditions, and the bank soils rely on their available strength for long term stability.

c. Rapid Dragdown Case, which models the condition where high flood waters saturate and piezometrically "load" a ditch slope, and then quickly recede leaving a large unbalance of piezometric head in the bank slope.

4. CHANNEL DESIGNS

General

Flood control channels vary widely in make-up from totally earthen channels where adequate right-of-way exists to totally concrete lined where right-of way is very limited. In some instances, the channel section is a combination of these two extremes. This section defines the parameters for the design of these various channel sections.

Earthen Channels

The most common flood control channel in Galveston County is a totally earthen channel. This is generally the most economical design except in the already developed areas where land costs are extremely high. The initial construction cost for a concrete lined channel is generally three to four times that of an earthen channel.

In the design of an earthen channel, consideration of long term maintenance has a very strong influence on design parameters. The following are minimum requirements to be used in the design of all earthen channels: Refer to Exhibit D-5-1.

a. Maximum earthen side slopes should be 3 (horizontal) to 1 (vertical). Slopes flatter than 3 to 1 may be necessary in some areas due to local soil conditions.

b. Minimum bottom width is six (6) feet.

c. A minimum maintenance berm is required on either side of the channel of between 20 to 30 feet depending on channel size. For top widths less than 60 feet, 20-foot berms are acceptable and for top widths more than 60 feet, 30-foot berms are required.

d. Backslope drains or interceptor structures are necessary at a minimum of 1,000 feet intervals to prevent sheet flow over the ditch slopes. A standard detail is presented in Exhibit D-5-2.

e. Channel slopes must be revegetated immediately after construction to minimize bank erosion.

f. Flow from roadside ditches must be conveyed to the channel through a roadside ditch interceptor structure and pipe (Exhibit D-5-3).

Concrete-Lined Trapezoidal Channels

In instances where flow velocities are excessive, channel confluences create a significant erosion potential, or right-of-way is limited, fully or partially concrete lined channels may be necessary. The degree of structural analysis required varies significantly depending on the intended purpose and the steepness of the slope on which paving is being placed.

Presented below are minimum requirements for partially and fully concrete lined trapezoidal channels (Exhibit D-5-4):

1. All slope paving should include a minimum 18-inch toe wall at the top and sides and a 24-inch toe wall across or along the channel bottom for clay soils. In sandy soils, a 36-inch toe wall is recommended across the channel bottom.

2. Fully lined cross-sections should have a minimum bottom width of eight (8) feet.

3. Concrete slope protection placed on 3:1 slopes should have a minimum thickness of 4 inches and 6 x 6 x W 2.9 x W2.9 welded wire fabric or equivalent reinforcing.

4. Concrete slope protection placed on 2:1 slopes should have a minimum thickness of 4-inches and 6 x 6 x W4.5 x W10 welded wire fabric or equivalent reinforcing.

5. Concrete slope protection placed on 1.5:1 slopes should have a minimum thickness of 5-inches and 4 x 4 x W4 x W10 reinforcement or equivalent. Poured in place concrete side slopes should not be steeper than 1.5:1.

6. In instances where the channel is fully lined, no backslope drainage structures are required. Partially lined channels will require backslope drainage structures as outlined.

7. Weep holes should be used to relieve hydrostatic head behind lined channel sections. Refer to Exhibit D-5-5.

8. Where construction is to take place under conditions of mud and/or standing water, a seal of slab of Class C concrete should be placed in channel bottom prior to placement of concrete slope paving. Refer to Exhibit D-5-4.

9. For bottom widths of twenty (20) feet and greater, transverse grade beams shall be installed at twenty (20) feet spacing on center. Grade beams shall be one foot wide, one foot-six inches deep, and run the width of the channel bottom. Refer to Exhibit D-5-4.