STORM DRAINAGE DESIGN MANUAL

FOR THE

CITY OF PORT ARANSAS, TEXAS

JOB NO. 6100.A5.00

Adopted by Ordinance 92-8
May 21, 1992

REVISED OCTOBER 2005

Adopted by Ordinance 2006-04
Revising Division 4, Drainage Sections 21-161 &
21-162 of the Port Aransas City Code

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I. INTRODUCTION:

A. Purpose:

The purpose of this design manual is to establish the design criteria and design procedures to be used in the planning and construction of storm drainage systems for the City of Port Aransas, Texas. These criteria and procedures were used in the preparation of the Storm Drainage Master Plan, which is a separate set of 13 – 24" x 36" maps. A brief discussion of this Master Plan is in Part VI of this manual.

B. Authorization:

The preparation of this design manual was authorized by action of the City of Port Aransas City Council on December 21, 1990.

C. 2005 Revision:

The revisions to the Master Plan were authorized by the City of Port Aransas. This Design Manual has been updated to include recent data and wording that corresponds to current practices and removes any unnecessary information. The revisions to the plans included updating the status of the proposed improvements, inserting property data, introducing a color scheme, and revising the downtown area encompassed by SH 361, 11th Street, Avenue G, and Cotter Street. Due to the impracticality of incorporating detention ponds in the middle of the downtown area and business district, the Master Plan required modifications to account for the additional flow produced by the increasing impervious surfaces experienced in the recent years. It is important to point out that the recalculations and updated designs were only applied to the downtown area. It was assumed that the 1992 edition of the Master Plan still applies to the remainder portions of Port Aransas.

II. CITY OF PORT ARANSAS DRAINAGE POLICY:

A. General:

1. Intent –

   It is the intent of the City of Port Aransas, that all public drainage improvements constructed (after the date of the acceptance of the Storm Drainage Master Plan and this Storm Drainage Design Manual) conform to the requirements set out within these documents. The requirements set out in these documents were established to improve the current storm drainage in the City and are intended to reduce damage due to storm water but the City and their agents do not imply that conformance with these standards will preclude all damage due to storm water in the future.

2. Jurisdiction –

   This policy shall govern the planning, design and construction of storm drainage facilities within the City of Port Aransas, Texas and within all areas subject to its extraterritorial jurisdiction.

3. Design of Storm Drainage System –

   a. Master Plan: The storm drainage system shown in the Master Plan is designed on the basis that, at full development, only 20% of the drainage area outside the downtown area is covered with impervious material (i.e. paving and structures) and that the runoff from the site will not exceed the "Q" in the formula Q = CIA where C is not greater than .2 and I is for a 2 year storm frequency. The downtown area, which is encompassed by SH 361, 11th St., Ave. G and Cotter St. has been revised

and redesigned to compensate and allow for additional drainage (higher C factors) in certain areas as depicted on Exhibit II-1.

b. Additions To The Storm Drainage System: All determination of runoff and storm drainage design for storm drainage facilities shall be based on methods and criteria as set out in this Storm Drainage Design Manual unless otherwise approved by the City of Port Aransas.

4. Storm Water Detention –

When analysis (using the design criteria in this manual) of an area to be served by a new drainage facility indicates that when fully developed the area served will have a weighted C factor greater than its allotted designated value, improvements may require facilities that will provide storm detention on site. See Division V of this manual for information on storm water detention.

5. Storm Drainage Master Plan –

Master planning of drainage is needed to provide sufficient drainage for new and vacant areas as well as to insure continuation of sufficient drainage for existing urban areas. In preparing the Master Plan for the undeveloped areas, only relatively large areas were considered. It is not the intent of the Master Plan to propose drainage facilities to serve every small parcel of land simply because it is not practical to do so. The proposed drainage facilities shown in the Master Plan should be considered the recommended "Frame Work" of the drainage system.

6. Flexibility in Storm Drainage Master Plan –

It should be recognized that as time passes and conditions change it may be desirable as well as necessary to be flexible and to modify the Master Plan to stay current with new conditions. It is also important to understand that being flexible does not mean modifying the Master Plan simply to fulfill the needs of one person or one group. Proposed modifications will be carefully studied by the City of Port Aransas to insure that they are beneficial to the entire area before such modifications are approved.

7. Level of Flood Protection –

It would be desirable if storm drainage facilities proposed in the Master Plan were designed so that all drainage facilities would handle a 100 year frequency storm. Unfortunately, in Port Aransas this is not economically feasible. Standard practices used in other cities do not necessarily apply in Port Aransas. Due to the topography of Port Aransas, it is only economically feasible to design storm drainage facilities for a 2-year frequency storm. Protection from flooding of the habitable portions of homes and businesses due to the lower frequency storms must be provided by elevating homes and businesses to be at least the FEMA 100 year flood elevation of 8.0 feet above Mean Sea Level.

B. Right-of-Way Requirements:

1. State Highway No. 361 –

It is recommended that on the west side of State Highway 361, a drainage right-of-way be obtained that is at least 30 feet wide and extends from Ave. G southward to the City Limits.

2. Outfall No. 1 – (See Sheet 1 of the Storm Drainage Master Plan)

It is recommended that a drainage right-of-way be obtained that is at least 65 feet wide and extends from State Highway 361 westward approximately 2,000 feet.

3. Outfall No. 2 – (See Sheet 2 of the Storm Drainage Master Plan)

   It is recommended that a drainage right-of-way be obtained that is at least 80 feet wide and extends from State Highway 361 westward approximately 3,200 feet.

4. Outfall No. 3 – (See Sheet 3 of the Storm Drainage Master Plan)

   It is recommended that a drainage right-of-way be obtained that is at least 80 feet wide and extends from State Highway 361 westward approximately 2,400 feet.

5. Outfall No. 4 – (See Sheet 4 of the Storm Drainage Master Plan)

   It is recommended that a drainage right-of-way be obtained that is at least 80 feet wide and extends from State Highway 361 westward approximately 2,400 feet.

6. Outfall No. 5 – (See Sheet 5 of the Storm Drainage Master Plan)

   It is recommended that a drainage right-of-way be obtained that is at least 30 feet wide and extends from State Highway 361 westward approximately 1,500 feet.

7. Outfall No. 6 – (See Sheet 5 of the Storm Drainage Master Plan)

   No additional right-of-way is required.

8. Outfall No. 7 & 8 – (See Sheet 7 of the Storm Drainage Master Plan)

   No additional right-of-way is required.

9. Outfall No. 9 – (See Sheet 7 of the Storm Drainage Master Plan)

   It is recommended that a drainage right-of-way be obtained that is at least 65 feet wide and extends from State Highway 361 westward approximately 1,100 feet.

10. Outfall No. 10 – (See Sheet 9 of the Storm Drainage Master Plan)

    No additional right-of-way is required.

11. Outfall No. 11 – (See Sheet 11 of the Storm Drainage Master Plan)

    No additional right-of-way is required.

12. Outfall No. 12 – (See Sheet 11 & 13 of the Storm Drainage Master Plan)

    Minor acquisitions right-of-way may be required when final construction plans are prepared.

13. Outfall No. 13 – (See Sheet 13 of the Storm Drainage Master Plan)

    No additional right-of-way is required.

14. Outfall No. 14 – (See Sheet 13 of the Storm Drainage Master Plan)

    It is recommended that a drainage right-of-way be obtained that is at least 15 feet wide and extends from the intersection of Cotter Avenue and Alister Street northward approximately 300 feet to the existing bulkhead.

15. Outfall No.15 – (See Sheet 13 of the Storm Drainage Master Plan)

    No additional right-of-way is required.

16. Outfall No. 16 – (See Sheet 12 of the Storm Drainage Master Plan)

    No additional right-of-way is required.

17. Outfall No. 17 – (See Sheet 10 of the Storm Drainage Master Plan)

    It is recommended that a drainage right-of-way be obtained that is at least 15 feet wide and extends from the intersection of Port Street and the road to the county fishing pier westward approximately 150 feet.

18. Outfall No. 18 – (See Sheet 10 of the Storm Drainage Master Plan)

    It is recommended that a drainage right-of-way be obtained that is at least 50 feet wide and extends from Ross Avenue westward approximately 1,000 feet.

19. Outfall No. 19 – (See Sheet 9 & 11 of the Storm Drainage Master Plan)

    There is existing right-of-way for most of this proposed outfall, but is recommended that additional drainage right-of-way be obtained to provide a total width of at least 50 feet.

C. Engineer's Certification:

Construction drawings for all drainage facilities shall be submitted to the City of Port Aransas for review and approval. Construction shall not begin until approval is obtained. Preparation of plans shall conform to the requirements set out in paragraph "J" of this division. Each sheet of the drawings shall be dated, sealed and signed by a Professional Engineer registered in Texas. Upon request by the City, the first sheet of the construction drawings shall contain the following certification.

I, _____ A PROFESSIONAL ENGINEER REGISTERED IN THE STATE OF TEXAS, DO HEREBY CERTIFY THAT:

1. THE DRAINAGE IMPROVEMENTS SHOWN IN THESE DRAWINGS HAVE BEEN DESIGNED TO CONFORM TO THE REQUIREMENTS OF THE CITY OF PORT ARANSAS MASTER STORM DRAINAGE PLAN AND STORM DRAINAGE DESIGN MANUAL.

2. WHEN THE SITE IS FULLY DEVELOPED, THE STORM WATER FLOW LEAVING THE SITE WILL NOT EXCEED THE APPROPRIATE "Q" VALUE FOR THE DESIGNATED "C" VALUE AND TIME OF CONCENTRATION CALCULATED FOR THE SITES.

   ON SITE STORM WATER DETENTION* WAS/WAS NOT (select one) UTILIZED TO MEET THIS REQUIREMENT.
   - Storm water detention basins will be provided with a safety factor of at least 2

3. UPON REQUEST OF THE CITY OF PORT ARANSAS, I WILL FURNISH DETAILED DRAINAGE CALCULATIONS ON ALL OR ANY PORTION OF THE DRAINAGE IMPROVEMENTS SHOWN ON THESE DRAWINGS.

Date:_____ (Signature and Seal)_____

D. Storm Drainage Calculations:

Calculations to support all or a portion of the drainage design may be required to be submitted to the City of Port Aransas for review and approval. Construction shall not begin until approval is obtained. To facilitate an orderly and timely review by the City, the calculations in a form similar to the Master Drainage Plan Sheets are preferred, but other organized and neat notes will be accepted. These calculations shall bear the seal of a Registered Professional Engineer licensed in the State of Texas and shall contain a statement by said Engineer that the design calculations have been prepared in compliance with the requirements of this manual.

E. Minimum Slopes and Grading Requirements:

All single family, multifamily, commercial and industrial sites shall be graded to provided positive drainage away from buildings towards streets and/or storm drainage facilities. The following minimum slopes shall be utilized.

Unpaved Areas -	Minimum 0.5% Slope
Asphalt Surface -	Minimum 1% Slope
Asphalt Valleys -	Minimum 0.5% Slope
Concrete Surface -	Minimum 0.35% Slope
Concrete Valley and Curbs -	Minimum 0.35% Slope

The finished floor of any structure, at any point, shall be above the center line of the adjacent perimeter street.

Any exceptions to the provisions of this paragraph must be approved by the City of Port Aransas. Complete data and calculations justifying the exception must be submitted before it will be considered.

F. Street Drainage:

Streets may be used for storm water drainage only to the extent that the calculated storm water flow does not exceed the flows in Chart IV-1. It is the intent of this policy that the calculated water surface (2 year frequency storm) shall not rise more than 6" above the top of the curb on streets with curb and gutter or above the paved center line of the street of those streets not having curb and gutter. The standard street cross-section shall not be modified to increase the water carrying capacity. At the point where the water carrying capacity of the street is exceeded, inlets and storm sewer shall be provided.

G. Inlets:

Inlets shall normally be of the curb type and shall conform to the details shown in Division VIII of this manual. Grate and/or area inlets may be used in special cases when approved by the City of Port Aransas. When grate or area inlets are proposed for use, detailed information and the justification may be required to be submitted for review and approval to the City of Port Aransas. Construction shall not begin until approval is obtained.

The hydraulic capacity of all inlets shall be included in all storm drainage facility designs.

H. Storm Sewer and Open Channels:

1. General –

   All storm drainage, to the greatest extent practical, shall be transported in closed storm sewer, except where designated to be open channels (ditches) in the Master Drainage Plan, or in cases specifically approved by the City of Port Aransas. Approved material for closed storm sewer is reinforced concrete pipe, precast concrete box and cast-in-place concrete box.

2. Closed Storm Sewer –

   a. Pipe: Pipe for storm sewer shall be reinforced concrete pipe conforming to A.S.T.M. Specification C-76, Class III with a minimum wall thickness "B", unless an alternate material is approved by the City of Port Aransas. When requested, provide engineering computations for trench loading and pipe strength design for all concrete pipe having more than 10 feet of cover or concrete pipe that is subject to traffic loading.

In some cases, the use of alternate pipe material may be allowed if the situation warrants its use. Detailed calculations, information and justification must be submitted for review and approval to the City of Port Aransas. Construction shall not begin until approval is obtained.

b. Matching Pipe Crowns: Whenever possible, the crown elevations (top of pipe) of pipe or conduit shall be matched at manholes, junction boxes, inlets, etc. Example: An 18" diameter pipe and a 24" diameter pipe enter a common manhole-the flow line of the 18" pipe will be 6" higher than the flow line of the 24" pipe.

c. Minimum Pipe Size: Pipe shall have a minimum diameter of 12". A larger pipe shall not discharge into a smaller pipe, even though the capacity of the smaller pipe may be greater due to a greater hydraulic gradient.

d. Concrete Box: Precast and cast-in-place reinforced concrete box may be adaptations of Texas State Department of Highways and Public Transportation Standards. Provide engineering computations for all concrete box if Texas State Department of Highways and Public Transportation Standards are not used.

3. Open Channels –

When open channels are approved for use in the storm drainage system, they shall be designed in accordance with Part IV of this manual.

I. Bridges and Culverts:

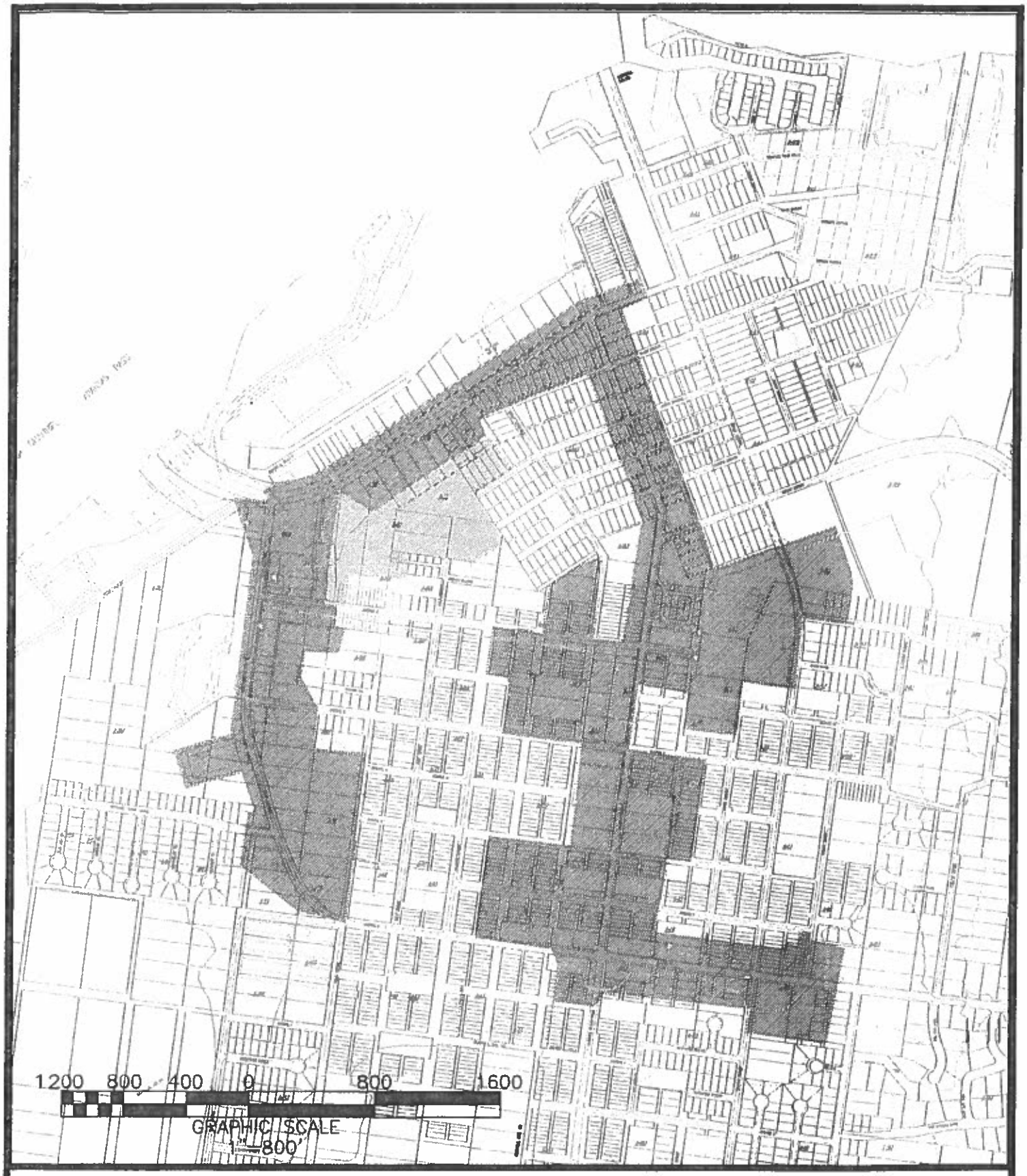
Construction plans for bridges, concrete box culverts and related structures may be adaptations of Texas State Department of Highways and Public Transportation Standards. Provide engineering computations for all bridges and culverts if Texas State Department of Highways and Public Transportation Standards are not used. The use of low water crossings in public rights-of-way are not desirable but may be approved by the City of Port Aransas for special cases.

J. Preparation of Construction Drawings and Specifications:

1. Storm Drainage System Layout Sheets –

The layout sheet should include the following information:

a. Property lines, lot and block numbers, dimensions right-of-way and easement lines, and street names.
b. Location, size and type of inlets, manholes, pipe, headwalls, culverts, bridges and channels.
c. Proposed top and invert elevations of all inlets, manholes, etc.
d. Existing spot elevations and/or contour lines at a suitable interval to indicate the slope of the existing ground.
e. Suitable labeling to aid in relating to plan sheets.
f. Existing or proposed utilities where they cross the proposed improvements.
g. North arrow, scale, title block, etc.



LEGEND

- C=0.4
- C=0.3
- C=0.2

EXHIBIT II-I

DOWNTOWN AREA RUNOFF COEFFICIENTS

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III. DETERMINATION OF STORM RUNOFF:

A. General:

The runoff charts developed for this manual were derived using the "Rational Method". The "Rational Method" is a generally accepted procedure for determining runoff from small areas. There is some disagreement among authoritative sources as to the maximum area to which the "Rational Method" is applicable. Recommended maximum areas range from 200 acres to 3,200 acres. Since the maximum area in this master plan is 366 acres, the "Rational Method" is appropriate.

B. Rational Method:

The equation used in determining runoff by the "Rational Method" is as follows:

$$Q = CIA$$

Q = Runoff in cubic feet per second.
C = Runoff Coefficient – In drainage basins having minimum natural slope, it is a function of permeability of the surface.
I = Rainfall intensity in inches per hour.
A = Area in acres.

C. Runoff Coefficients:

The coefficients C used in deriving the runoff values are as follows:

Type of Drainage Area	Runoff Coefficient – C
Parking Areas:	0.90
Business Areas:	0.40
Apartments and Condo Areas:	0.30
Single-Family Areas:	0.20
Parks, Playgrounds, etc.:	0.10
Permanently Unimproved Areas	0.10

D. Rainfall Intensity:

1. General –

The rainfall intensity values used in this manual are based on Technical Paper No. 40 prepared by the U. S. Department of Commerce and the Weather Bureau. In 1985, the Texas State Department of Highways and Public Transportation Bridge Division Hydraulics Manual developed a mathematical equation for the 2-year frequency intensity based on Technical Paper No. 40. This equation was used in the preparation of the Rainfall Intensity Curve for Nueces County shown on Chart III-3.

Formula for 2 Year Frequency Rainfall Intensity:

$$I = \frac{71}{(T_c+9.4)^{.824}}$$

I = 2 year intensity in inches per hour.

T_c = Time of concentration in minutes

E. Time of Concentration – Kerby Equation:

1. General –

The Kerby Equation was developed from data obtained in watersheds having water courses less than 1200 ft., slopes less than 1% and areas less than 10 acres. Given that Port Aransas can be generally characterized by these parameters, this equation is relevant and applicable for design purposes.

$$Tc = 0.83\left(\frac{NL}{S.05}\right)^{0.467}$$

Tc = Time of Concentration
N = Kerby Coefficient
L = Length of Longest Water Course
S = Avg. Slope along that Water Course

Values of N for use in the Kerby formula:

N	Type of Surface
0.02	Smooth impervious surface
0.10	Smooth bare packed soil, free of stones
0.20	Poor grass, cultivated row crops or moderately bare surfaces
0.40	Pasture or average grass cover
0.60	Deciduous timberland
0.80	Conifer timberland, deciduous timberland with deep forest litter or dense grass cover

2. Correlation Between C and N – The following relationship between the Rational and Kerby coefficients can be used for design purposes.

C	N
0.4	0.06
0.3	0.2
0.2	0.35
0.1	0.5

F. Explanation of Tables and Charts:

1. Tables –

Tables III-1 through III-6 show the storm water runoff in cubic feet (cfs) per second per acre for various times of concentrations and for C values ranging from 0.10 to 0.90. They have been prepared using the criteria set out herein. They are included simply as an aid to the designer.

2. Charts –

Charts III-1 and III-2 are used to calculate times of concentration and may be used in lieu of the Kerby Equation to calculate storm water runoff.

Chart III-3 shows the 2 year frequency rainfall curve for Nueces County and is included as an aid to the designer.

G. Index of Division III Tables and Charts:

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA

RUNOFF PER ACRE - C = 0.20

F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	1.577
6	7.46	1.492
7	7.08	1.417
8	6.75	1.349
9	6.44	1.288
10	6.17	1.234
11	5.92	1.183
12	5.69	1.138
13	5.48	1.096
14	5.28	1.057
15	5.11	1.021
16	4.94	0.988
17	4.78	0.957
18	4.64	0.928
19	4.51	0.901
20	4.38	0.876
21	4.26	0.852
22	4.15	0.830
23	4.04	0.808
24	3.94	0.788
25	3.85	0.769
26	3.76	0.751
27	3.67	0.734
28	3.59	0.718
29	3.51	0.703
30	3.44	0.688
31	3.37	0.674
32	3.30	0.661
33	3.24	0.648
34	3.18	0.635
35	3.12	0.624
36	3.06	0.612
37	3.01	0.601
38	2.95	0.591
39	2.90	0.581
40	2.86	0.571
41	2.81	0.562
42	2.76	0.553
43	2.72	0.544
44	2.68	0.536
45	2.64	0.527
46	2.60	0.520

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
47	2.56	0.512
48	2.52	0.505
49	2.49	0.497
50	2.45	0.491
51	2.42	0.484
52	2.39	0.477
53	2.36	0.471
54	2.32	0.465
55	2.29	0.459
56	2.27	0.453
57	2.24	0.448
58	2.21	0.442
59	2.18	0.437
60	2.16	0.432
65	2.04	0.407
70	1.93	0.386
75	1.84	0.367
80	1.75	0.350
85	1.67	0.335
90	1.60	0.321
95	1.54	0.308
100	1.48	0.297
105	1.43	0.286
110	1.38	0.276
115	1.33	0.267
120	1.29	0.258
130	1.21	0.243
140	1.15	0.229
150	1.09	0.217
160	1.03	0.207
170	0.99	0.197
180	0.94	0.189
190	0.90	0.181
200	0.87	0.174
210	0.84	0.167
220	0.81	0.161
230	0.78	0.156
240	0.75	0.150
250	0.73	0.146
260	0.71	0.141
270	0.68	0.137
280	0.67	0.133

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.10
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	0.788
6	7.46	0.746
7	7.08	0.708
8	6.75	0.675
9	6.44	0.644
10	6.17	0.617
11	5.92	0.592
12	5.69	0.569
13	5.48	0.548
14	5.28	0.528
15	5.11	0.511
16	4.94	0.494
17	4.78	0.478
18	4.64	0.464
19	4.51	0.451
20	4.38	0.438
21	4.26	0.426
22	4.15	0.415
23	4.04	0.404
24	3.94	0.394
25	3.85	0.385
26	3.76	0.376
27	3.67	0.367

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	0.359
29	3.51	0.351
30	3.44	0.344
31	3.37	0.337
32	3.30	0.330
33	3.24	0.324
34	3.18	0.318
35	3.12	0.312
36	3.06	0.306
37	3.01	0.301
38	2.95	0.295
39	2.90	0.290
40	2.86	0.286
41	2.81	0.281
42	2.76	0.276
43	2.72	0.272
44	2.68	0.268
45	2.64	0.264
46	2.60	0.260
47	2.56	0.256
48	2.52	0.252
49	2.49	0.249
50	2.45	0.245

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	0.242
52	2.39	0.239
53	2.36	0.236
54	2.32	0.232
55	2.29	0.229
56	2.27	0.227
57	2.24	0.224
58	2.21	0.221
59	2.18	0.218
60	2.16	0.216
65	2.04	0.204
70	1.93	0.193
75	1.84	0.184
80	1.75	0.175
85	1.67	0.167
90	1.60	0.160
95	1.54	0.154
100	1.48	0.148
105	1.43	0.143
110	1.38	0.138
115	1.33	0.133
120	1.29	0.129
125	1.25	0.125

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.20
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	1.577
6	7.46	1.492
7	7.08	1.417
8	6.75	1.349
9	6.44	1.288
10	6.17	1.234
11	5.92	1.183
12	5.69	1.138
13	5.48	1.096
14	5.28	1.057
15	5.11	1.021
16	4.94	0.988
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Tc Minutes	I2 Inch/Hour	Q CFS/Acre
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53	2.36	0.471
54	2.32	0.465
55	2.29	0.459
56	2.27	0.453
57	2.24	0.448
58	2.21	0.442
59	2.18	0.437
60	2.16	0.432
65	2.04	0.407
70	1.93	0.386
75	1.84	0.367
80	1.75	0.350
85	1.67	0.335
90	1.60	0.321
95	1.54	0.308
100	1.48	0.297
105	1.43	0.286
110	1.38	0.276
115	1.33	0.267
120	1.29	0.258
125	1.25	0.250

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.30
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	2.365
6	7.46	2.238
7	7.08	2.125
8	6.75	2.024
9	6.44	1.933
10	6.17	1.850
11	5.92	1.775
12	5.69	1.707
13	5.48	1.644
14	5.28	1.585
15	5.11	1.532
16	4.94	1.482
17	4.78	1.435
18	4.64	1.392
19	4.51	1.352
20	4.38	1.314
21	4.26	1.278
22	4.15	1.244
23	4.04	1.213
24	3.94	1.183
25	3.85	1.154
26	3.76	1.127
27	3.67	1.102

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	1.077
29	3.51	1.054
30	3.44	1.032
31	3.37	1.011
32	3.30	0.991
33	3.24	0.971
34	3.18	0.953
35	3.12	0.935
36	3.06	0.918
37	3.01	0.902
38	2.95	0.886
39	2.90	0.871
40	2.86	0.857
41	2.81	0.843
42	2.76	0.829
43	2.72	0.816
44	2.68	0.803
45	2.64	0.791
46	2.60	0.779
47	2.56	0.768
48	2.52	0.757
49	2.49	0.746
50	2.45	0.736

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	0.726
52	2.39	0.716
53	2.36	0.707
54	2.32	0.697
55	2.29	0.688
56	2.27	0.680
57	2.24	0.671
58	2.21	0.663
59	2.18	0.655
60	2.16	0.647
65	2.04	0.611
70	1.93	0.579
75	1.84	0.551
80	1.75	0.525
85	1.67	0.502
90	1.60	0.481
95	1.54	0.462
100	1.48	0.445
105	1.43	0.429
110	1.38	0.414
115	1.33	0.400
120	1.29	0.387
125	1.25	0.375

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.40
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	3.154
6	7.46	2.984
7	7.08	2.833
8	6.75	2.698
9	6.44	2.577
10	6.17	2.467
11	5.92	2.367
12	5.69	2.275
13	5.48	2.191
14	5.28	2.114
15	5.11	2.042
16	4.94	1.976
17	4.78	1.914
18	4.64	1.856
19	4.51	1.802
20	4.38	1.751
21	4.26	1.704
22	4.15	1.659
23	4.04	1.617
24	3.94	1.577
25	3.85	1.539
26	3.76	1.503
27	3.67	1.469

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	1.436
29	3.51	1.405
30	3.44	1.376
31	3.37	1.348
32	3.30	1.321
33	3.24	1.295
34	3.18	1.271
35	3.12	1.247
36	3.06	1.224
37	3.01	1.203
38	2.95	1.182
39	2.90	1.161
40	2.86	1.142
41	2.81	1.123
42	2.76	1.105
43	2.72	1.088
44	2.68	1.071
45	2.64	1.055
46	2.60	1.039
47	2.56	1.024
48	2.52	1.009
49	2.49	0.995
50	2.45	0.981

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	0.968
52	2.39	0.955
53	2.36	0.942
54	2.32	0.930
55	2.29	0.918
56	2.27	0.906
57	2.24	0.895
58	2.21	0.884
59	2.18	0.873
60	2.16	0.863
65	2.04	0.815
70	1.93	0.772
75	1.84	0.735
80	1.75	0.701
85	1.67	0.670
90	1.60	0.642
95	1.54	0.616
100	1.48	0.593
105	1.43	0.572
110	1.38	0.552
115	1.33	0.534
120	1.29	0.517
125	1.25	0.501

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.50
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	3.942
6	7.46	3.730
7	7.08	3.542
8	6.75	3.373
9	6.44	3.221
10	6.17	3.084
11	5.92	2.959
12	5.69	2.844
13	5.48	2.739
14	5.28	2.642
15	5.11	2.553
16	4.94	2.470
17	4.78	2.392
18	4.64	2.320
19	4.51	2.253
20	4.38	2.189
21	4.26	2.130
22	4.15	2.074
23	4.04	2.021
24	3.94	1.971
25	3.85	1.924
26	3.76	1.879
27	3.67	1.836

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	1.795
29	3.51	1.757
30	3.44	1.720
31	3.37	1.685
32	3.30	1.651
33	3.24	1.619
34	3.18	1.588
35	3.12	1.559
36	3.06	1.530
37	3.01	1.503
38	2.95	1.477
39	2.90	1.452
40	2.86	1.428
41	2.81	1.404
42	2.76	1.382
43	2.72	1.360
44	2.68	1.339
45	2.64	1.319
46	2.60	1.299
47	2.56	1.280
48	2.52	1.261
49	2.49	1.244
50	2.45	1.226

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	1.210
52	2.39	1.193
53	2.36	1.178
54	2.32	1.162
55	2.29	1.147
56	2.27	1.133
57	2.24	1.119
58	2.21	1.105
59	2.18	1.092
60	2.16	1.079
65	2.04	1.019
70	1.93	0.966
75	1.84	0.918
80	1.75	0.876
85	1.67	0.837
90	1.60	0.802
95	1.54	0.771
100	1.48	0.741
105	1.43	0.715
110	1.38	0.690
115	1.33	0.667
120	1.29	0.646
125	1.25	0.626

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.60
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	4.731
6	7.46	4.476
7	7.08	4.250
8	6.75	4.048
9	6.44	3.865
10	6.17	3.701
11	5.92	3.550
12	5.69	3.413
13	5.48	3.287
14	5.28	3.171
15	5.11	3.063
16	4.94	2.964
17	4.78	2.871
18	4.64	2.784
19	4.51	2.703
20	4.38	2.627
21	4.26	2.556
22	4.15	2.489
23	4.04	2.425
24	3.94	2.365
25	3.85	2.308
26	3.76	2.254
27	3.67	2.203

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	2.155
29	3.51	2.108
30	3.44	2.064
31	3.37	2.022
32	3.30	1.982
33	3.24	1.943
34	3.18	1.906
35	3.12	1.871
36	3.06	1.837
37	3.01	1.804
38	2.95	1.772
39	2.90	1.742
40	2.86	1.713
41	2.81	1.685
42	2.76	1.658
43	2.72	1.632
44	2.68	1.607
45	2.64	1.582
46	2.60	1.559
47	2.56	1.536
48	2.52	1.514
49	2.49	1.492
50	2.45	1.472

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	1.452
52	2.39	1.432
53	2.36	1.413
54	2.32	1.395
55	2.29	1.377
56	2.27	1.359
57	2.24	1.343
58	2.21	1.326
59	2.18	1.310
60	2.16	1.295
65	2.04	1.222
70	1.93	1.159
75	1.84	1.102
80	1.75	1.051
85	1.67	1.005
90	1.60	0.963
95	1.54	0.925
100	1.48	0.890
105	1.43	0.858
110	1.38	0.828
115	1.33	0.800
120	1.29	0.775
125	1.25	0.751

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.70
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	5.519
6	7.46	5.222
7	7.08	4.958
8	6.75	4.722
9	6.44	4.510
10	6.17	4.317
11	5.92	4.142
12	5.69	3.982
13	5.48	3.835
14	5.28	3.699
15	5.11	3.574
16	4.94	3.458
17	4.78	3.349
18	4.64	3.248
19	4.51	3.154
20	4.38	3.065
21	4.26	2.982
22	4.15	2.903
23	4.04	2.829
24	3.94	2.759
25	3.85	2.693
26	3.76	2.630
27	3.67	2.570

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	2.514
29	3.51	2.460
30	3.44	2.408
31	3.37	2.359
32	3.30	2.312
33	3.24	2.267
34	3.18	2.224
35	3.12	2.182
36	3.06	2.143
37	3.01	2.104
38	2.95	2.068
39	2.90	2.033
40	2.86	1.999
41	2.81	1.966
42	2.76	1.934
43	2.72	1.904
44	2.68	1.874
45	2.64	1.846
46	2.60	1.818
47	2.56	1.792
48	2.52	1.766
49	2.49	1.741
50	2.45	1.717

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	1.693
52	2.39	1.671
53	2.36	1.649
54	2.32	1.627
55	2.29	1.606
56	2.27	1.586
57	2.24	1.566
58	2.21	1.547
59	2.18	1.529
60	2.16	1.510
65	2.04	1.426
70	1.93	1.352
75	1.84	1.285
80	1.75	1.226
85	1.67	1.172
90	1.60	1.123
95	1.54	1.079
100	1.48	1.038
105	1.43	1.000
110	1.38	0.966
115	1.33	0.934
120	1.29	0.904
125	1.25	0.876

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.80
F = 2 Years $I = \frac{71}{(Tc + 9.4)^{.824}}$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	6.308
6	7.46	5.968
7	7.08	5.667
8	6.75	5.397
9	6.44	5.154
10	6.17	4.934
11	5.92	4.734
12	5.69	4.551
13	5.48	4.383
14	5.28	4.228
15	5.11	4.085
16	4.94	3.952
17	4.78	3.828
18	4.64	3.712
19	4.51	3.604
20	4.38	3.503
21	4.26	3.408
22	4.15	3.318
23	4.04	3.233
24	3.94	3.153
25	3.85	3.078
26	3.76	3.006
27	3.67	2.938

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	2.873
29	3.51	2.811
30	3.44	2.752
31	3.37	2.696
32	3.30	2.642
33	3.24	2.591
34	3.18	2.541
35	3.12	2.494
36	3.06	2.449
37	3.01	2.405
38	2.95	2.363
39	2.90	2.323
40	2.86	2.284
41	2.81	2.247
42	2.76	2.211
43	2.72	2.176
44	2.68	2.142
45	2.64	2.110
46	2.60	2.078
47	2.56	2.048
48	2.52	2.018
49	2.49	1.990
50	2.45	1.962

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	1.935
52	2.39	1.909
53	2.36	1.884
54	2.32	1.860
55	2.29	1.836
56	2.27	1.813
57	2.24	1.790
58	2.21	1.768
59	2.18	1.747
60	2.16	1.726
65	2.04	1.630
70	1.93	1.545
75	1.84	1.469
80	1.75	1.401
85	1.67	1.340
90	1.60	1.284
95	1.54	1.233
100	1.48	1.186
105	1.43	1.143
110	1.38	1.104
115	1.33	1.067
120	1.29	1.033
125	1.25	1.001

PORT ARANSAS STORM DRAINAGE DESIGN CRITERIA
RUNOFF PER ACRE - C = 0.90
F = 2 Years

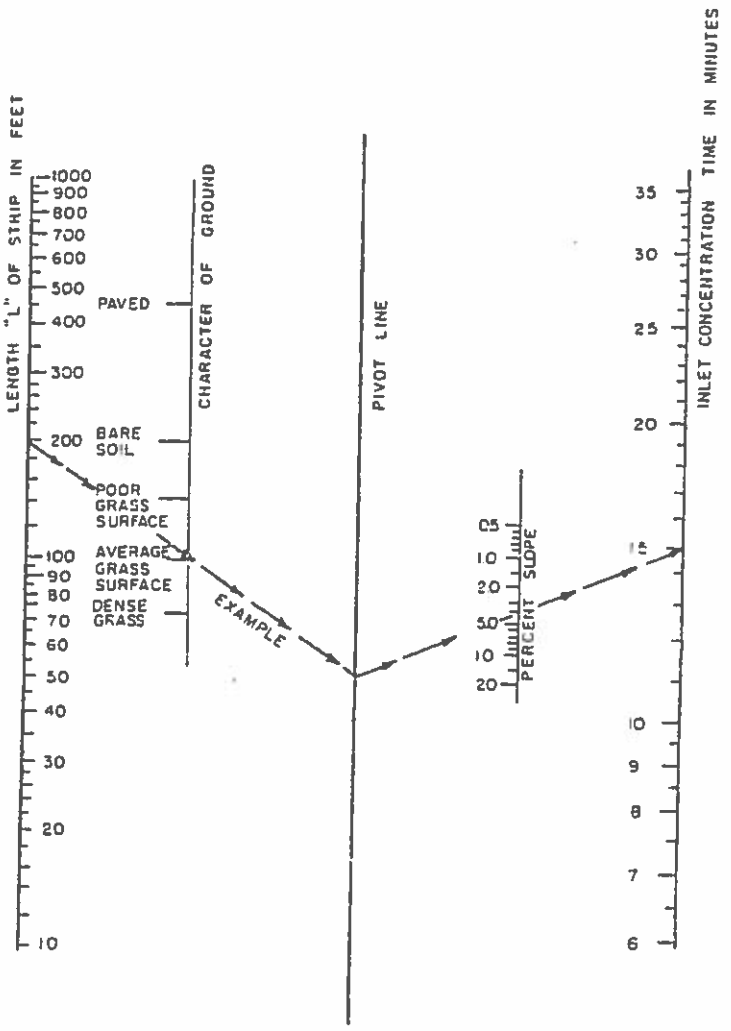
$$I = \frac{71}{(Tc + 9.4)^{.824}}$$

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
5	7.88	7.096
6	7.46	6.714
7	7.08	6.375
8	6.75	6.071
9	6.44	5.798
10	6.17	5.551
11	5.92	5.326
12	5.69	5.120
13	5.48	4.931
14	5.28	4.756
15	5.11	4.595
16	4.94	4.445
17	4.78	4.306
18	4.64	4.176
19	4.51	4.055
20	4.38	3.941
21	4.26	3.834
22	4.15	3.733
23	4.04	3.638
24	3.94	3.548
25	3.85	3.462
26	3.76	3.382
27	3.67	3.305

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
28	3.59	3.232
29	3.51	3.162
30	3.44	3.096
31	3.37	3.033
32	3.30	2.972
33	3.24	2.914
34	3.18	2.859
35	3.12	2.806
36	3.06	2.755
37	3.01	2.706
38	2.95	2.659
39	2.90	2.613
40	2.86	2.570
41	2.81	2.528
42	2.76	2.487
43	2.72	2.448
44	2.68	2.410
45	2.64	2.373
46	2.60	2.338
47	2.56	2.304
48	2.52	2.271
49	2.49	2.239
50	2.45	2.208

Tc Minutes	I2 Inch/Hour	Q CFS/Acre
51	2.42	2.177
52	2.39	2.148
53	2.36	2.120
54	2.32	2.092
55	2.29	2.065
56	2.27	2.039
57	2.24	2.014
58	2.21	1.989
59	2.18	1.965
60	2.16	1.942
65	2.04	1.834
70	1.93	1.738
75	1.84	1.653
80	1.75	1.576
85	1.67	1.507
90	1.60	1.444
95	1.54	1.387
100	1.48	1.335
105	1.43	1.286
110	1.38	1.242
115	1.33	1.201
120	1.29	1.162
125	1.25	1.126

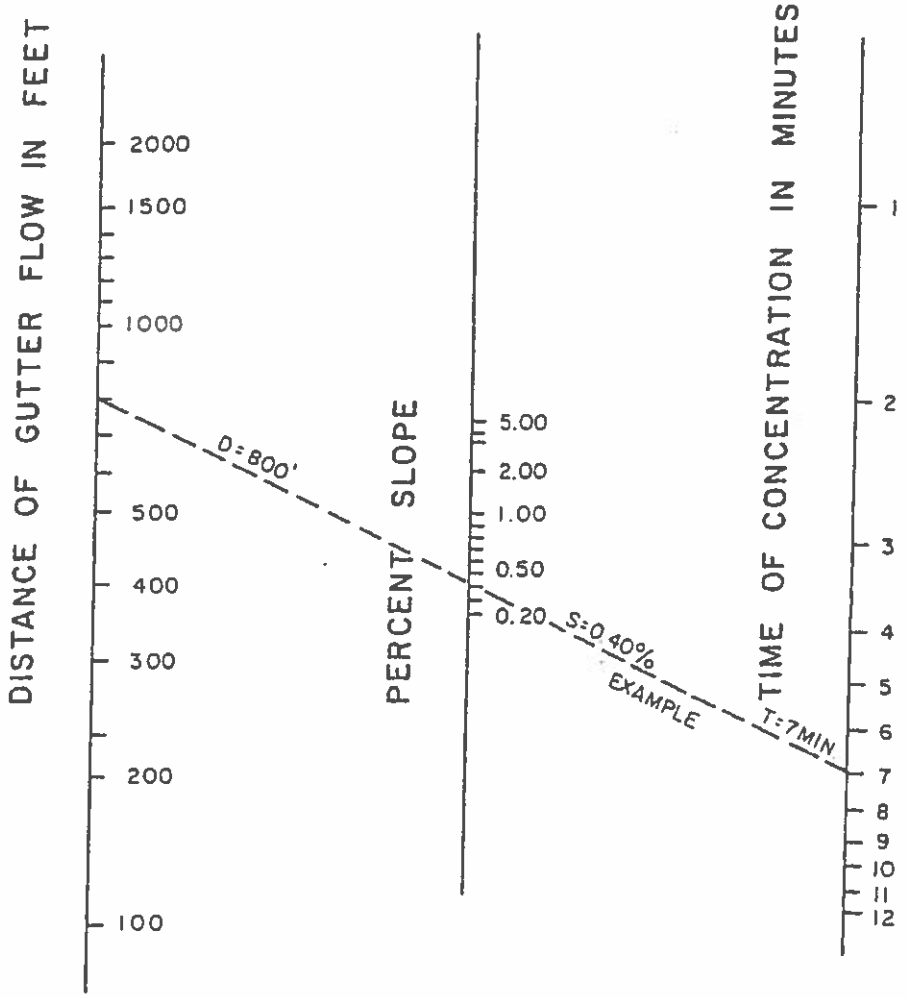
TIME OF CONCENTRATION OF OVERLAND FLOW



THIS CHART REPRODUCED FROM "DESIGN" THIRD EDITION BY E.E. SEELYE

STORM DRAINAGE DESIGN MANUAL PORT ARANSAS, TEXAS
CHART III – 1 NOMOGRAPH – TIME OF CONCENTRATION FOR OVERLAND FLOW
Job No. 6100.A5.00 Page 17

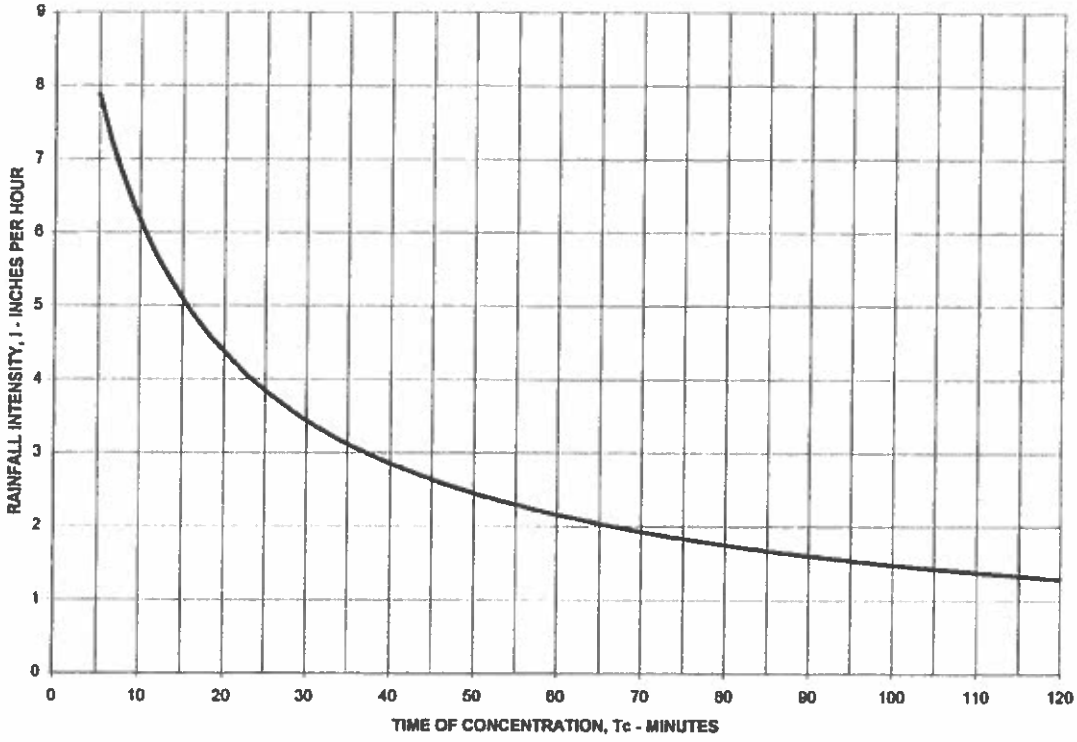
TIME OF CONCENTRATION OF GUTTER FLOW



STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

CHART III - 2
NOMOGRAM - TIME OF CONCENTRATION FOR GUTTER FLOWS IN STANDARD STREET SECTIONS

THIS CURVE IS BASED ON THE FORMULA: $I=71/(Tc+9.4)^{0.824}$



STORM DRAINAGE DESIGN MANUAL PORT ARANSAS, TEXAS
CHART III-3
TWO YEAR FREQUENCY RAINFALL
INTENSITY CURVE FOR NUECES CO.
Job No. 6100.A5.00 Page 19

IV. STORM DRAINAGE DESIGN:

A. General:

All storm drainage calculations shall be based on Mannings Equation for Flow as set out hereinafter. Mannings Equation is based on open channel flow; however, in this design manual it will be used also for storm sewer flowing under pressure, i.e., the hydraulic gradient rises above the top of the conduit. All storm drainage design shall begin at the downstream end and proceed upstream.

B. Mannings Equation for Flow:

$$Q = \frac{A \times 1.486 \times R^{2/3} \times S^{1/2}}{n}$$

Q = Discharge in cubic feet per second
A = Cross sectional area of the drainageway in square feet
n = Roughness coefficient
R = Hydraulic radius in feet = $\frac{A}{p}$
p = Wetted perimeter of the drainageway in feet
S = Slope of hydraulic gradient in foot per foot

C. Roughness Coefficients:

1. Reinforced Concrete Pipe - n = .012
2. Reinforced Concrete Boxes - n = .012
3. Concrete Lined Open Channels - n = .012
4. Unlined Open Channels - n = .025
5. PVC Pipe - n = .010
6. HDPE Pipe - n = .009

D. Design of Open Channels:

1. Unlined Channels –

   a. Maximum Side Slope: 3:1
   b. Maximum Velocity: 3.0 feet per second
   c. Minimum Free Board: 0.5 feet
   d. Minimum Right-of-Way Width: See Chart IV-7

2. Concrete Lined Channels –

   a. Maximum Side Slope: None
   b. Maximum Velocity: 5.0 feet per second
   c. Minimum Bottom Width: 4.0 feet
   d. Minimum Free Board: 0.5 feet
   e. Minimum Right-of-Way Width: See Chart IV-6

3. Hydraulic Gradient –

The hydraulic gradient may be assumed to be parallel to the channel flow line, except on those primary drainageways shown on the Storm Drainage Master Plan. In those cases, the designer shall have the option of assuming the hydraulic gradient is a straight line between point shown on the Storm Drainage Master Plan or computing the backwater curve to determine the water surface.

E. Design of Storm Sewer and Culverts:

1. Minimum Slope of Pipe - 0.05%

2. Maximum Velocity - 7.0 feet per second

3. Calculation of Head Losses –

In the hydraulic design of storm sewer and culverts, only the head loss due to friction need be considered. The head loss due to friction shall be calculated using Mannings Formula and the roughness coefficients set out herein.

4. Hydraulic Gradient –

a. Pipes Not Flowing Full: when the computed water surface is below the crown of the pipe, the hydraulic gradient may be assumed to be parallel to the flow line of the pipe.

b. Pipe Flowing Under Pressure: Pipes may be designed to flow under pressure, i.e., the hydraulic gradient may rise above the top of the pipe but it shall not rise above a point 6" above the top of the curb on those streets having curb and gutter and shall not rise above the centerline of the street of those not having curb and gutter.

F. Hydraulic Capacity of Inlets:

1. Curb Inlets –

Capacity of curb inlets at low points shall be designed as a rectangular orifice submerged with no approach velocity:

$$Q = C_D \sqrt{A_o 2gh}$$

Q = Discharge in cubic feet per second
C_D = Orifice Coefficient of Discharge (Use 0.6)
A_O = Area of Orifice in Square Feet
g = 32.2 ft./sec.^{2}
h = Head on Center of Orifice in Feet (Use 0.5 ft.)

The capacity of inlets on grade shall be taken as 60% of the capacity of inlets at low points.

The following table shall be used to determine the capacity of standard curb inlets.

Throat Opening	Capacity in CFS-Inlet at Low Point	Capacity in CFS-Inlet On Grade
5 feet	8.5	5.1
10 feet *	16.1	9.3

* On standard 10 ft. inlet throat opening is 9'-6".

2. Grate Inlets –

The capacity of grate inlets shall be designed according to the following formula:

$$Q = 0.4\ A_N \sqrt{64.4 \times h}$$

Q = Discharge in cubic feet per second
A_N = Net Area of Grate Openings in Feet
h = Head on Grate in Feet

The use of grate inlets will be considered on an individual basis only.

G. Explanation of Charts:

Chart IV-1 is used to determine the hydraulic capacity of standard street section. Underground storm sewer is required when storm runoff exceeds the street capacity based on this chart.

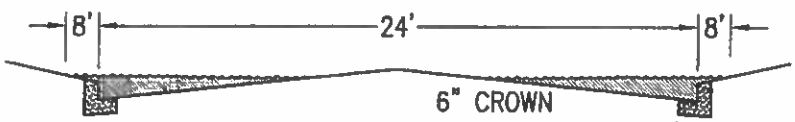
Charts IV-2, IV-6 and IV-7 are used to determine the hydraulic capacity of pipes and/or open channels and are included as an aid to the designer.

Charts IV-3, IV-4 and IV-5 are used to determine the hydraulic capacity of pipes that are not flowing full and are included as an aid to the designer.

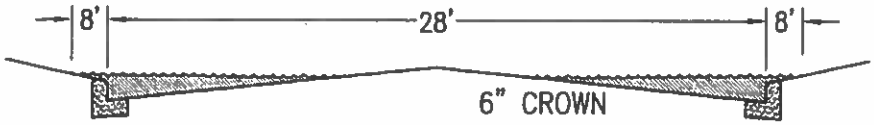
Charts IV-8 and IV-9 must be used in the design of open channels.

Section IV-1 is a recommended section for State Highway 361 and is subject to change by the Texas Department of Highways and Public Transportation.

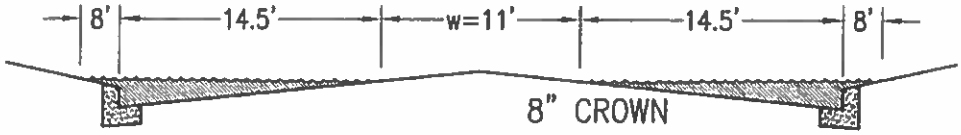
H. Index for Division IV Charts and Sections:



MINOR STREET



COLLECTOR STREET



MAJOR COLLECTOR STREET

SLOPE %	STREET CAPACITIES (CFS) FLOWING CURB FULL		
	MINOR ST.	COLLECTOR ST.	ARTERIAL ST.
0.20	8.3	9.8	10.1
0.30	10.2	12.0	12.4
0.40	11.8	13.8	14.3
0.50	13.2	15.5	16.00

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STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

CHART IV-1
HYDRAULIC CAPACITIES OF
STANDARD STREET SECTIONS
SEPT., 2005

PROPERTIES OF CIRCULAR AND RECTANGULAR SECTIONS

CIRCULAR CONCRETE PIPE				RECTANGULAR CONCRETE PIPE			
D (IN.)	A (S.F.)	r	MIN. WALL (IN.)	W (FT.)	H (FT.)	A (S.F.)	r
15	1.23	0.31	2.25	2	2	4.0	0.50
18	1.77	0.38	2.50	3	2	6.0	0.60
21	2.41	0.44	2.75	4	2	8.0	0.67
24	3.14	0.50	3.00	5	2	10.0	0.71
27	3.98	0.56	3.25	6	2	12.0	0.75
30	4.91	0.63	3.50	3	3	9.0	0.75
33	5.94	0.69	3.75	4	3	12.0	0.86
36	7.07	0.75	4.00	5	3	15.0	0.94
42	9.62	0.88	4.50	6	3	18.0	1.00
48	12.57	1.00	5.00	8	3	24.0	1.09
54	15.90	1.13	5.50	12	3	36.0	1.20
60	19.63	1.25	6.00	4	4	16.0	1.00
66	23.76	1.38	6.50	5	4	20.0	1.11
72	28.27	1.50	7.00	6	4	24.0	1.20
78	33.18	1.63	7.50	8	4	32.0	1.33
84	38.48	1.75	8.00	10	4	40.0	1.43
90	44.18	1.88	8.50	12	4	48.0	1.50
96	50.27	2.00	9.00	6	6	36.0	1.50
102	56.75	2.13	9.50	8	6	48.0	1.71

D = DIAMETER OF CIRCULAR PIPE IN INCHES
W = WIDTH OF RECTANGULAR PIPE IN FEET
H = HEIGHT OF RECTANGULAR PIPE IN FEET
A = CROSS SECTIONAL AREA IN SQ. FT.
r = HYDRAULIC RADIUS IN FEET

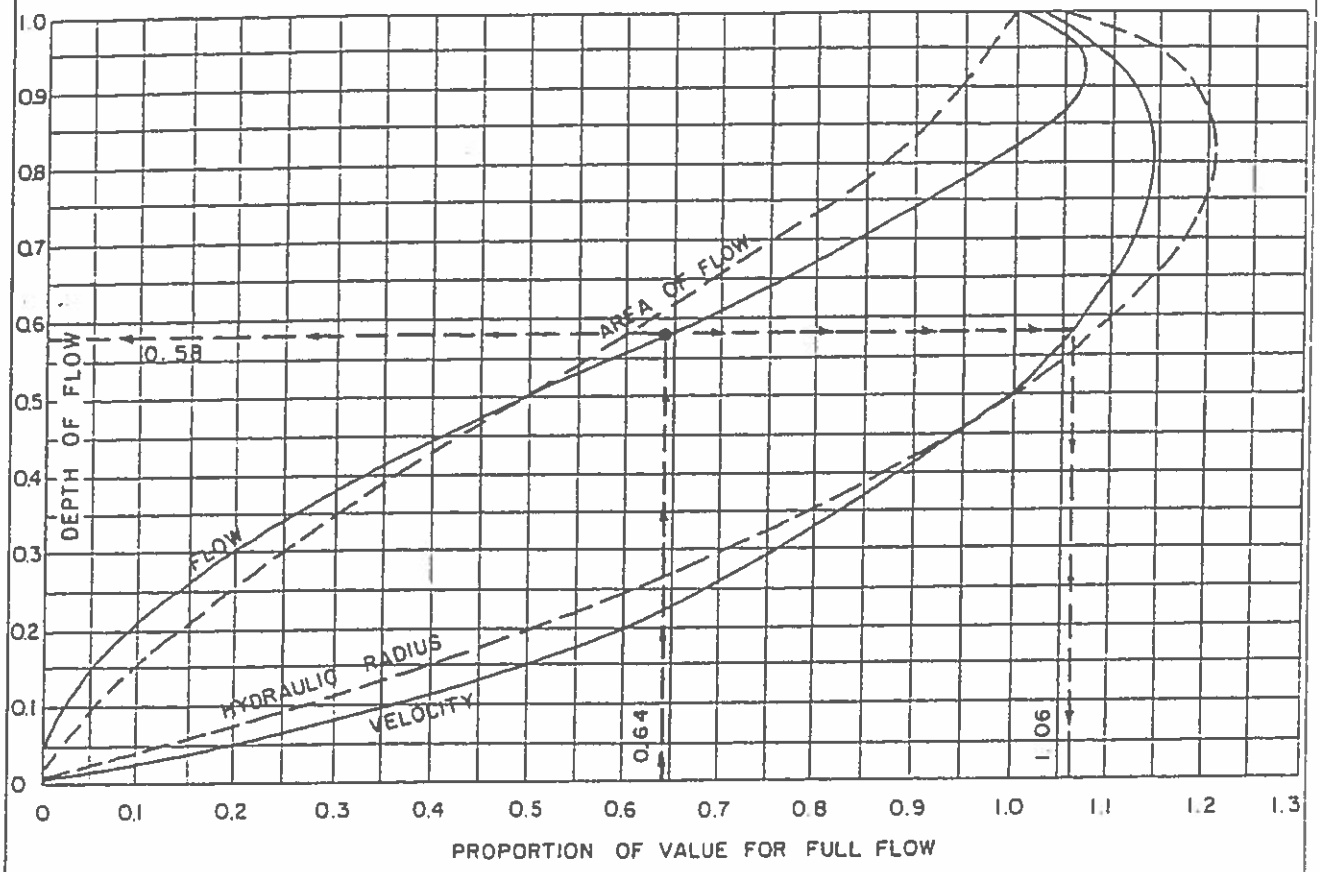
EXAMPLE:

DESIGN FLOW Q = 0.64 x FULL PIPE Q

FROM CHART:

DESIGN DEPTH OF FLOW = .58 x FULL DEPTH

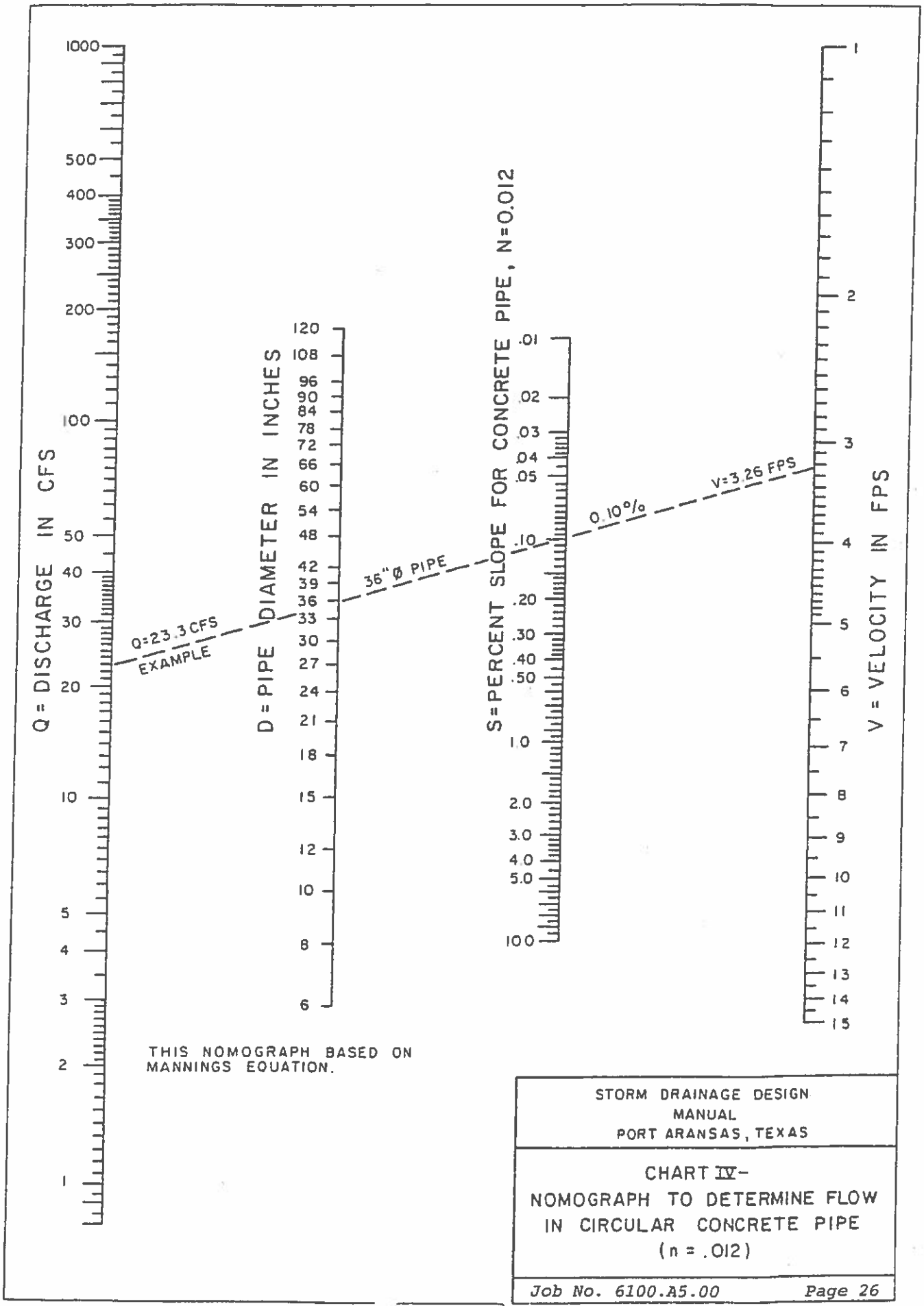
DESIGN VELOCITY = 1.06 x FULL PIPE VELOCITY



RELATIVE VELOCITY AND FLOW IN CIRCULAR PIPE FOR ANY DEPTH OF FLOW

STORM DRAINAGE DESIGN MANUAL
PORT. ARANSAS, TEXAS

CHART IV-3
HYDRAULIC ELEMENTS OF CIRCULAR SECTIONS

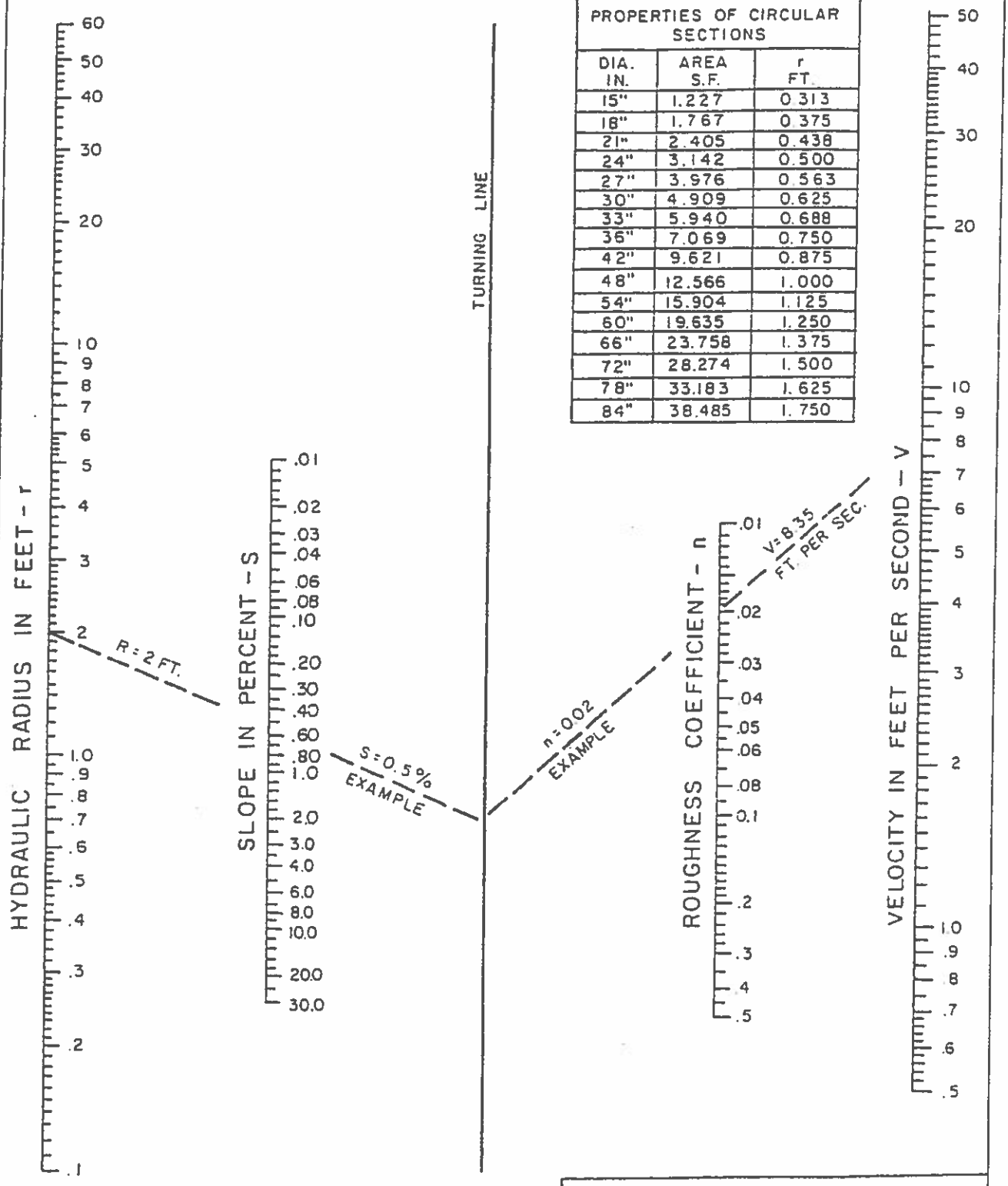


THIS NOMOGRAPH BASED ON MANNINGS EQUATION.

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

CHART IV-
NOMOGRAPH TO DETERMINE FLOW IN CIRCULAR CONCRETE PIPE
(n = .012)

PROPERTIES OF CIRCULAR SECTIONS		
DIA. IN.	AREA S.F.	r FT.
15"	1.227	0.313
18"	1.767	0.375
21"	2.405	0.438
24"	3.142	0.500
27"	3.976	0.563
30"	4.909	0.625
33"	5.940	0.688
36"	7.069	0.750
42"	9.621	0.875
48"	12.566	1.000
54"	15.904	1.125
60"	19.635	1.250
66"	23.758	1.375
72"	28.274	1.500
78"	33.183	1.625
84"	38.485	1.750



THIS NOMOGRAPH BASED ON MANNINGS EQUATION

$$V = \frac{1.486}{n} \times r^{2/3} \times (.01 \times S)^{1/2}$$

$$Q_{CFS} = A_{FT.^2} \times V_{FPS}$$

$$r = \frac{A_{FT^2}}{P_{FT.}} \; ; \; r = \frac{DIA\ FT.}{4}$$

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

CHART IV -
NOMOGRAPH TO DETERMINE VELOCITY FOR ANY SECTION

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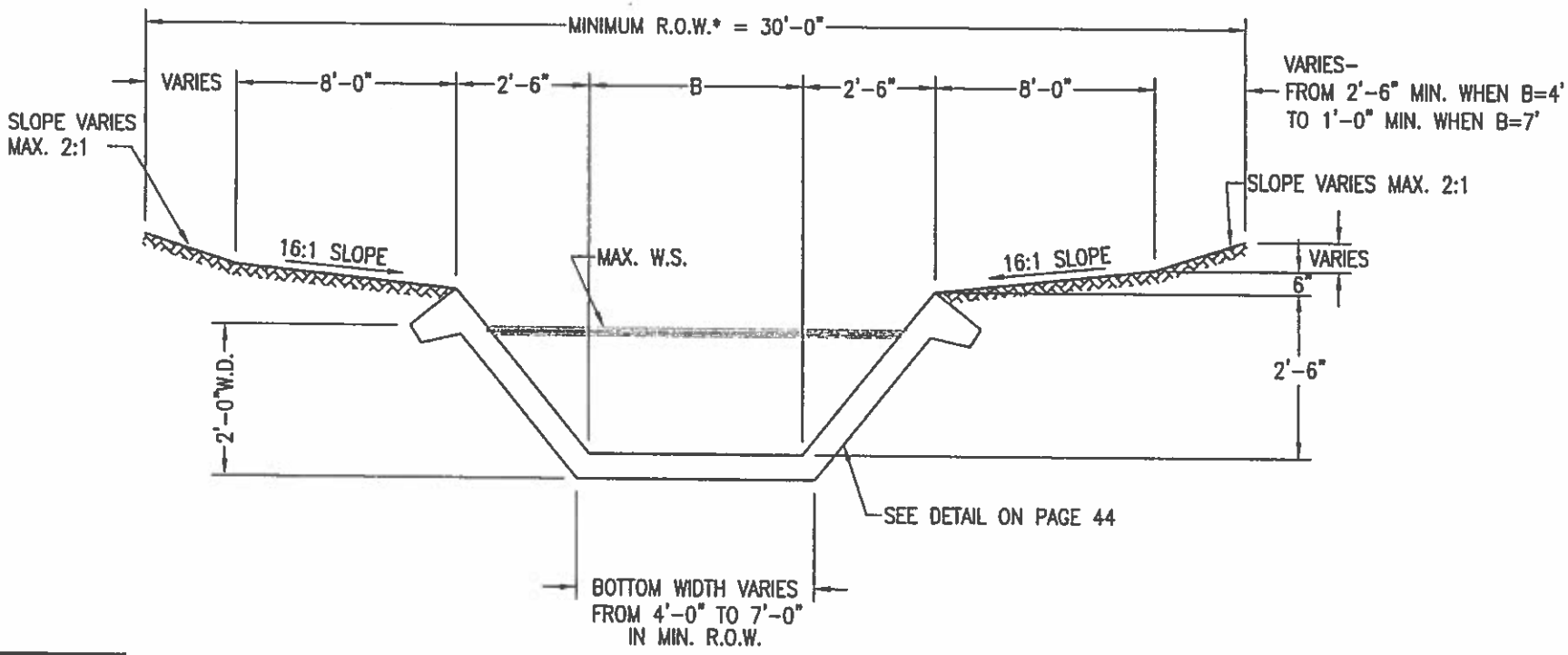
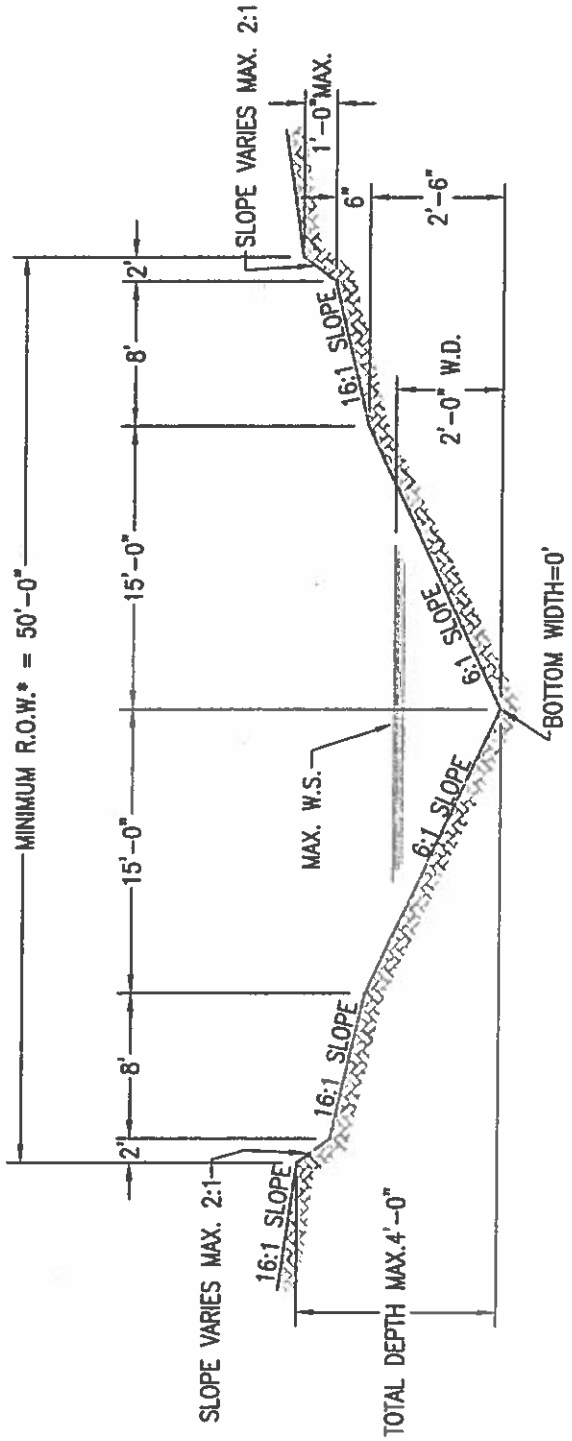


* INCREASE R.O.W. WIDTH AS NEED WHEN BOTTOM WIDTH EXCEEDS 7' OR TOTAL DEPTH OF DITCH EXCEEDS MIN. SLOPE REQUIREMENTS. R.O.W. WIDTH SHALL BE IN 5' INCREMENTS. (i.e. 30', 35', 40' ETC.)

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS
CHART IV-6
MINIMUM REQUIREMENTS FOR LINED OPEN CHANNELS
SEPT., 2005
U.E. JOB NO. 6100.A5.00 PAGE: 28



* INCREASE R.O.W. WIDTH AS TOTAL DEPTH OF DITCH OR BOTTOM WIDTH INCREASES. R.O.W. WIDTH SHALL BE IN 5' INCREMENTS. (i.e. 50' ,55' ,60' ETC.)

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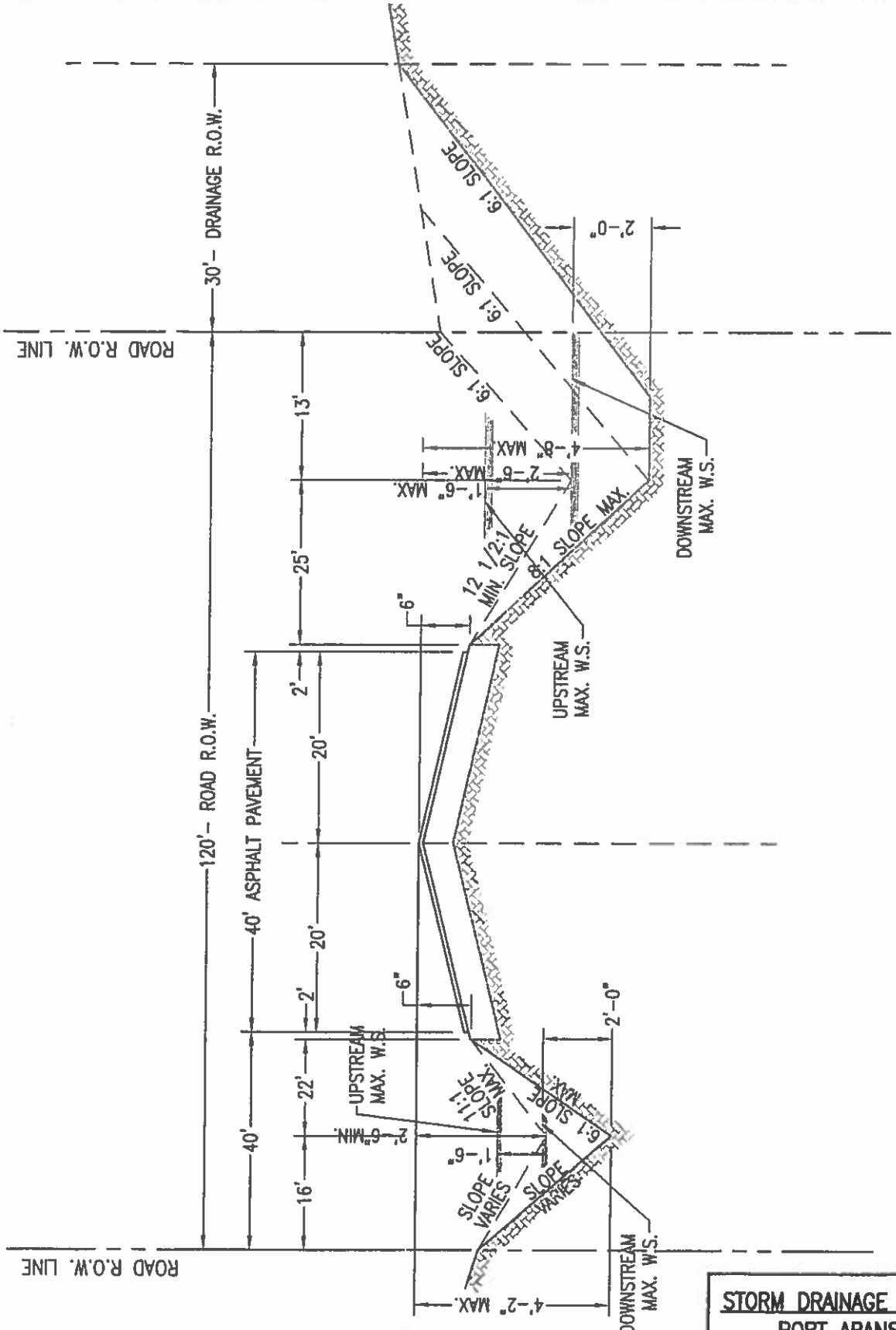
STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

CHART IV-7
MINIMUM REQUIREMENTS FOR
UNLINED OPEN CHANNELS
SEPT., 2005

U.E. JOB NO. 6100.A5.00 PAGE: 29



STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

SECTION IV-1
TYPICAL SECTION
OF STATE HIGHWAY 361
SEPT., 2005
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V. STORM WATER DETENTION:

A. General:

"Storm water detention" is the concept of holding back storm water runoff during periods of intense rainfall for more gradual release as the storm abates.

When analysis (using the design criteria in this manual) of an area to be served by a new drainage facility indicates that, when fully developed, the area served will have imperviousness that will allow more than the allotted/allowed quantity of the storm water to runoff of the site being served by the new storm water drainage system, improvements may require facilities that will provide "storm water detention" on the project site.

B. Basic Criteria:

Storm water detention systems shall be designed using the following basic criteria:

1. Design Frequency – 2 Year Storm
2. Capacity of a storm water detention basin shall be the computed volume.
3. Storm water detention basins shall have the ability to overflow to the storm drainage system without flooding any structure within the project site when rainfall intensity is computed using the formula:

$$I = \frac{99}{(Tc + 9.4)^{.730}}$$

4. First floor of all structures to be 12" above maximum water levels.
5. Storm water detention basin discharge system must be free flowing. Discharge systems using pumps are not acceptable.
6. The "ground water table" shall be considered when computing capacity of storm water detention basins.
7. Design of the storm water detention basins must give positive consideration to esthetics and erosion.
8. Parking lots utilized as storm water detention basins shall not allow water to exceed 6" in depth, except it may be 10" deep at limited areas, such as inlet depressions.

C. Design Methods:

Any well known Design Method such as the procedure found in the Soil Conservation Service's "National Engineering Handbook", Texas Dept. of H. & P. T. Hydraulic Manual or Corps of Engineers Computer Program HEC-1 are acceptable. Other reasonable methods to calculate storm water detention will be considered on an individual basis.

When requested by the City of Port Aransas, storm water detention calculations (including hydrographs, outfall rating curves and hydraulic profiles) shall be submitted to the City of Port Aransas for review and approval on any proposed project. Construction shall not begin until approval is obtained.

VI. STORM DRAINAGE MASTER PLAN:

A. General:

Certain areas were intentionally not included in the Master Drainage Plan. Those areas are as follows:

1. Areas that are too low to be developed under current laws and/or regulations. These occur on the west side of State Highway 361. See sheets 1 through 6, 8& 10.

2. Areas that are between the first row of dunes and the Gulf of Mexico and that require environmental permits for any construction. See Sheets 7, 9, 11 and 13.

3. Areas that are owned by the University of Texas or Nueces County, since private and/or commercial development is not anticipated. See Sheet 13.

4. Areas where existing storm sewer exists that is obviously adequate. See Sheets 5 & 6.

B. Methods Used for Hydraulic Computations:

1. Step 1: Each drainage basin was divided into smaller drainage areas. In some instances these drainage boundaries followed property boundaries. It was assumed that future development would follow these boundaries.

2. Step 2: Runoff for the design storm (2 year frequency) was determined by using the procedures set out in Division III of this manual.

3. Step 3: A hydraulic gradient equal to 1.5 was used at the outfalls into the Bay. This elevation correlates to the approximate average mean high tide measured in the past. The proposed storm drainage system improvements were then sized in accordance with Division IV of this manual to provide (as a minimum) the required capacity. It is important to note that the tide varies with time and can positively or adversely affect the efficiency of the entire system. It is also important to realize that the proposed hydraulic gradient is not always parallel to the flow line of the ditch in those areas where a backwater condition will occur due to the size of downstream drainage structures.

VII. SOURCES OF INFORMATION:

A. General:

In preparing any design manual of this type, it is impractical not to use information from other published sources. Listed in the next paragraph are those sources of information that were used in preparing this Storm Drainage Design Manual.

B. List of Sources:

1. Hydraulic Manual – Prepared and compiled by the Texas Department of Highways and Public Transportation – Bridge Division in 1985.

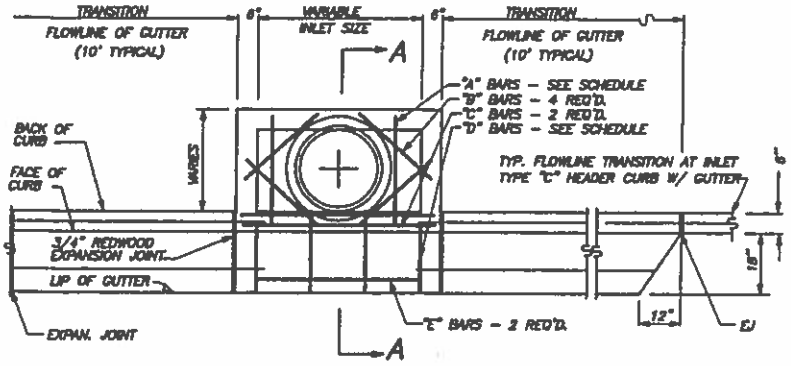
2. Technical Paper No. 40 – "Rainfall Frequency Atlas of the United States – Prepared by U. S. Department of Commerce and the Weather Bureau.

3. Handbook of Concrete Culvert Pipe Hydraulics published by the Portland Cement Association.

4. Data Book for Civil Engineers – Design Volume One – Third Edition written by E. E. Seelye and published by John Wiley and Sons, Inc.

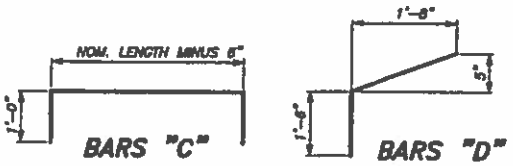
VIII. STANDARD STORM SEWER DETAILS:

A. Index of Division VIII Details:



PLAN OF STANDARD INLET

NOT TO SCALE



** THROAT OPENINGS SHALL HAVE A 6" X 6" CONCRETE SUPPORT PLACED AT MID-THROAT

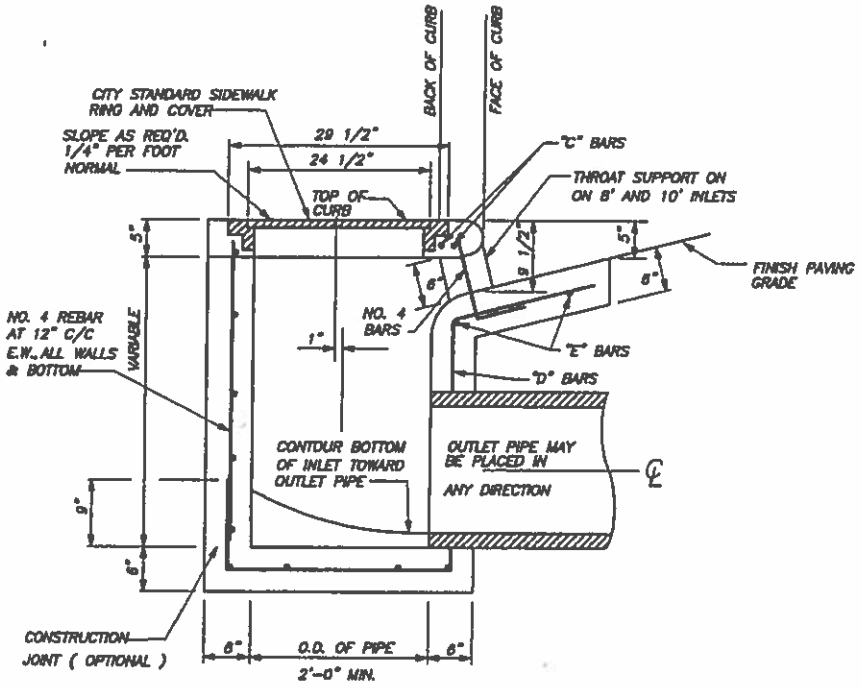
* NOMINAL LENGTH OF INLET SHALL BE DESIGNATED AS THE CLEAR WIDTH OPENING.

STANDARD CURB INLET STEEL SCHEDULE

ALL BARS No. 4 PREFORMED

INLET SIZE (Nom. Length)	NO. REQ'D./LENGTH				
	"A" BARS	"B" BARS	"C" BARS	"D" BARS	"E" BARS
4'	2/a	4/1'-10"	2/3'-6"	4/3'-2"	2/4'-6"
5'	2/a	4/3'-2"	2/5'-6"	4/3'-2"	2/5'-6"
6'	4/a	4/4'-0"	2/7'-6"	6/3'-2"	2/6'-6"
** 8'	4/a	4/4'-0"	2/9'-6"	6/3'-2"	2/8'-6"
** 10'	6/a	4/4'-0"	2/11'-6"	7/3'-2"	2/10'-6"
BENDING	STRAIGHT	STRAIGHT	SEE DET.	SEE DET.	STRAIGHT

a = O.D. + 6", 2'-6" MIN. MAX. PIPE I.D. = 48 INCHES



SECTION A-A

NOT TO SCALE

NOTE:
1. MANHOLE RING & COVER TO BE ALAMO IRON WORKS NO. 860-93.
2. PROVIDE SLEEVE WITH FELT PLUGS FOR DOWELS.
3. CONCRETE TO BE A MINIMUM OF 3000 P.S.I. COMPRESSIVE STRENGTH.

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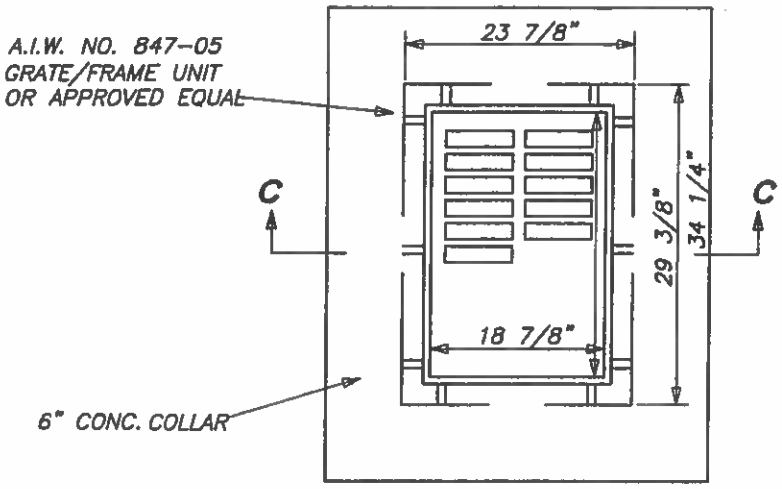
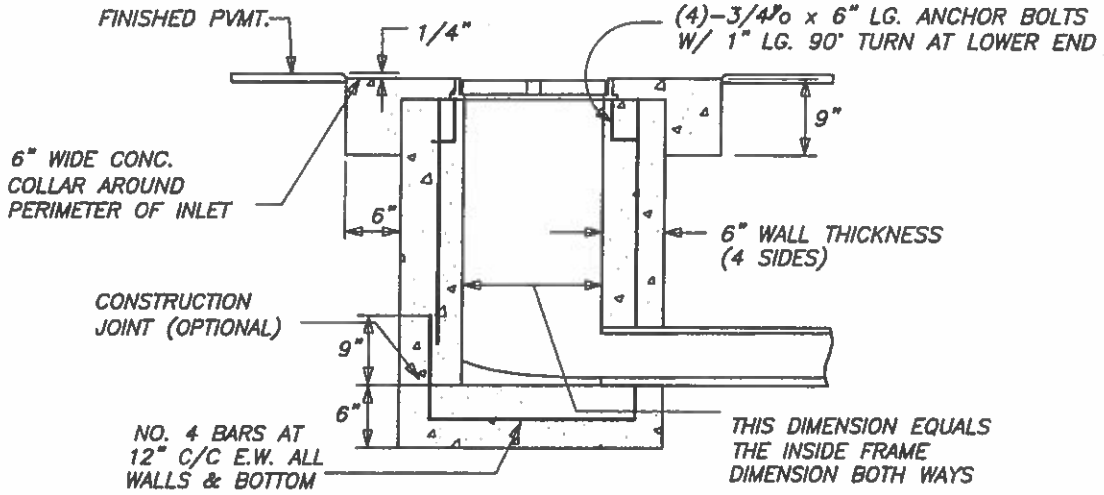
STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS
STANDARD STORM SEWER
DETAIL VIII-1
CURB INLET DETAIL
SEPT., 2005
U.E. JOB NO. 6100.A5.00 PAGE: 35



PLAN OF STANDARD GRATE INLET

NOT TO SCALE



SECTION C-C

NOT TO SCALE

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS
STANDARD STORM SEWER
DETAIL VIII-2
SINGLE GRATE INLET
SEPT., 2005
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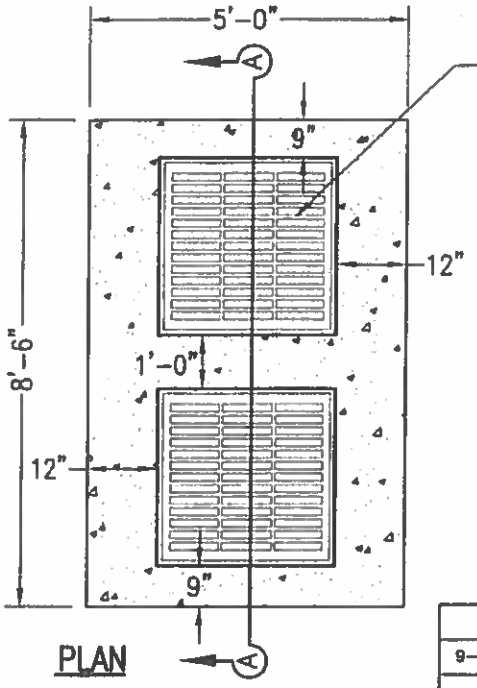
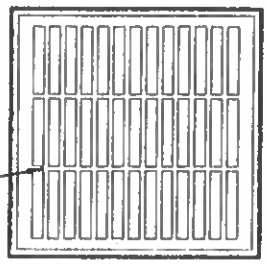
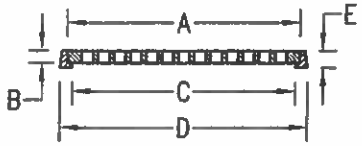


PLAN

VULCAN FOUNDRY SQUARE FRAME
AND GRATE NO. VFG 36x36
NET OPENING 2x4.47=8.94 SQ.FT.

WESTERN IRON WORKS
38 X 38 FRAME AND
GRATE W/T-FRAME

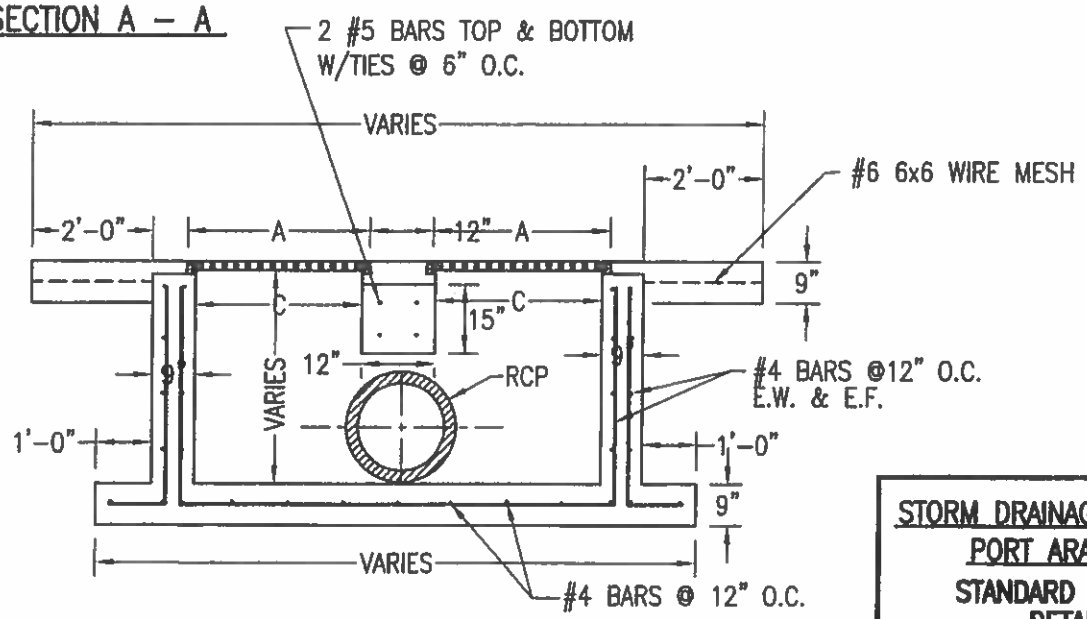




T-FRAME DETAIL

SIZE	DIMENSIONS					SLOT SIZE W	SLOT SIZE L	NO. OF SLTS	OPEN AREA	WEIGHTS (LBS)		
	A	B	C	D	E					GRATE	FRAME	SET
9-1/2X9-1/2	9 1/2	1	8	11	1 1/2	1	8	5	40	22	18	40
10 X 10	10	1	8	11 1/2	1 1/2	1	4 1/2	12	54	22	18	40
12 X 12	12	1	11	14 1/2	1 1/2	1	5	18	90	22	16	38
14 X 14	14	1	13 1/2	16 1/4	1 1/2	3/4	6	18	81	38	30	68
14 1/2X 14 1/2	14 1/2	1	13	15 3/4	1 1/2	5/8	6	20	75	38	30	68
16 X 16	16	1	15	17 3/4	1 3/4	3/4	6 3/4	20	101	38	36	74
18 X 18	18	1 5/8	16 3/4	20	2	1 1/2	8	14	168	49	46	95
20 X 20	20	1 1/2	18 1/4	21 1/2	2	1 1/4	8 1/2	16	170	78	48	126
24 X 24	24	2	22 1/2	26	2 1/2	1 3/4	10	18	315	100	60	160
26 X 26	25 3/4	2	24 1/2	28 1/2	3	1 3/4	12	22	462	180	62	242
28 X 28	28	2	26 1/4	30 1/4	2 3/4	1 5/8	8	33	429	198	100	298
32 X 32	31 1/2	2	30 1/4	33 3/4	2 3/4	1 3/4	9 1/4	33	534	210	125	335
38 X 38	38	2	36 3/8	40 1/2	2 3/4	1 3/4	11	39	751	325	175	500

SECTION A - A



DOUBLE GRATE INLET DETAILS

NOT TO SCALE

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STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS
STANDARD STORM SEWER
DETAIL VIII-3
DOUBLE GRATE INLET
SEPT., 2005
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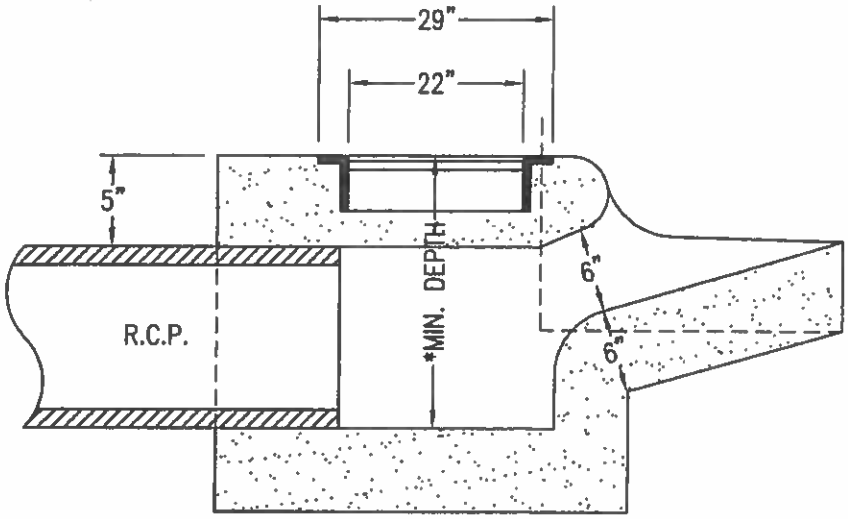
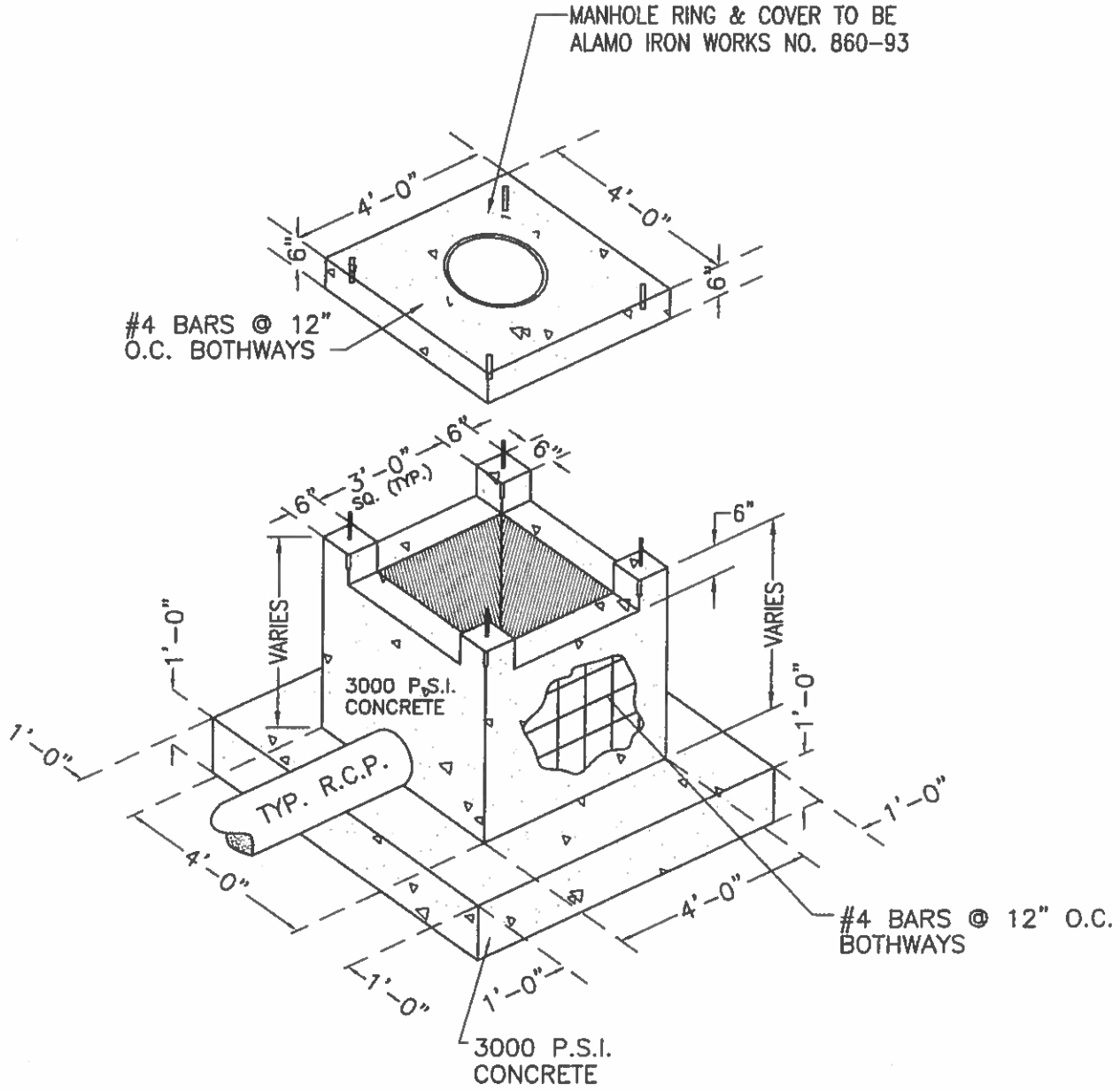


PIPE SIZE	SIDE AND REAR INLET PIPE ENTRANCE *	FRONT ENTRANCE *
15"	2.09'	3.01'
18"	2.42'	3.34'
21"	2.71'	3.63'
24"	3.00'	3.92'
27"	3.25'	4.17'
30"	3.58'	4.50'
33"	3.79'	4.71'
36"	4.16'	5.08'
42"	4.74'	5.66'
48"	5.34'	6.26'

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS

STANDARD STORM SEWER
DETAIL VIII-4
MINIMUM DEPTH OF
CURB AND GRATE INLET

SEPT., 2005



AREA INLET

NOT TO SCALE

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS
STANDARD STORM SEWER
DETAIL VIII-5
AREA INLET
SEPT., 2005
U.E. JOB NO. 6100.A5.00 PAGE: 39

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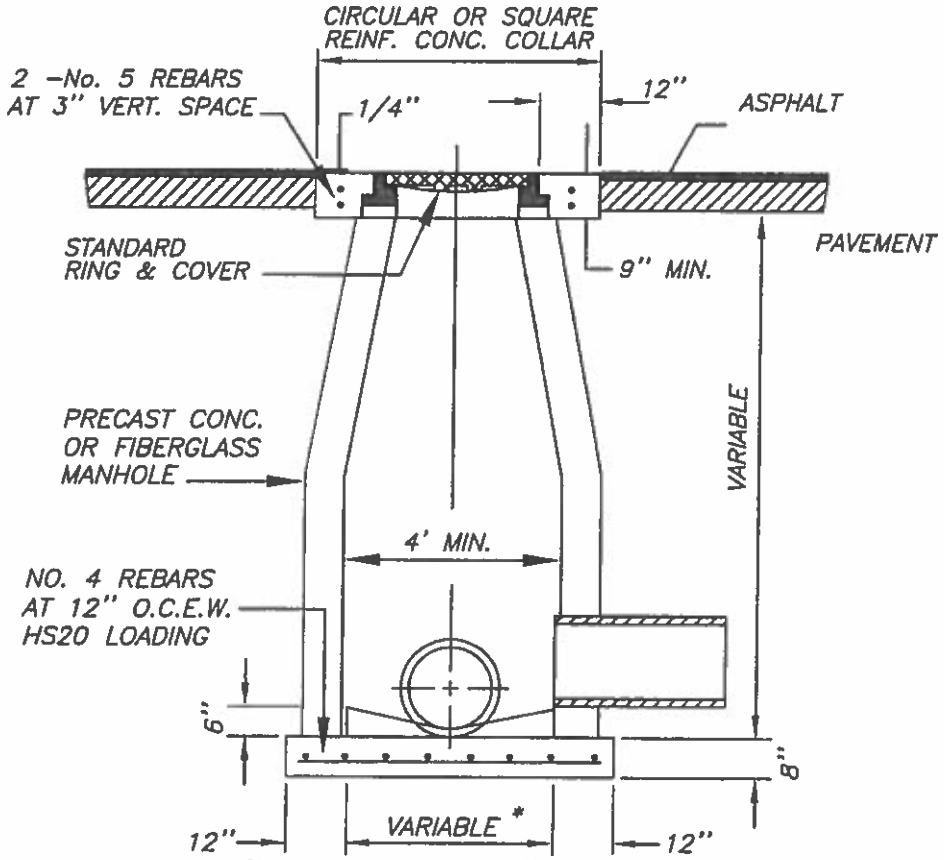
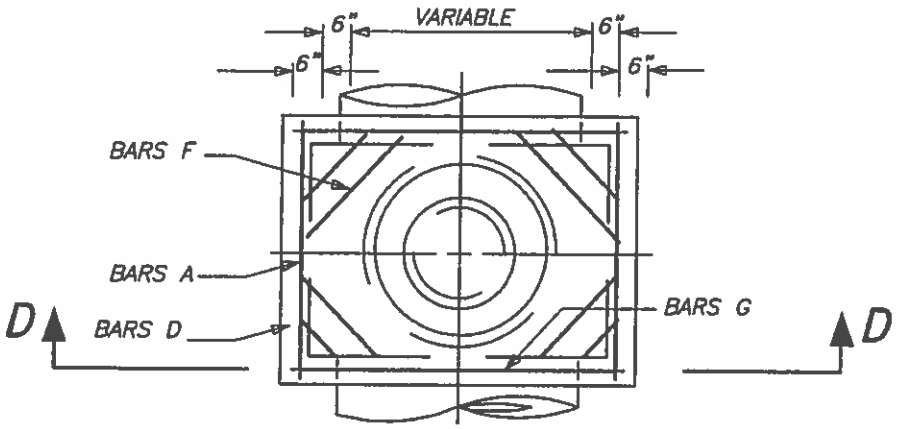


* 1 1/2 TIMES NOMINAL DIA.
OF PIPE (MIN. 4'-0")

SECTION D-D

TYPE "A" MANHOLE

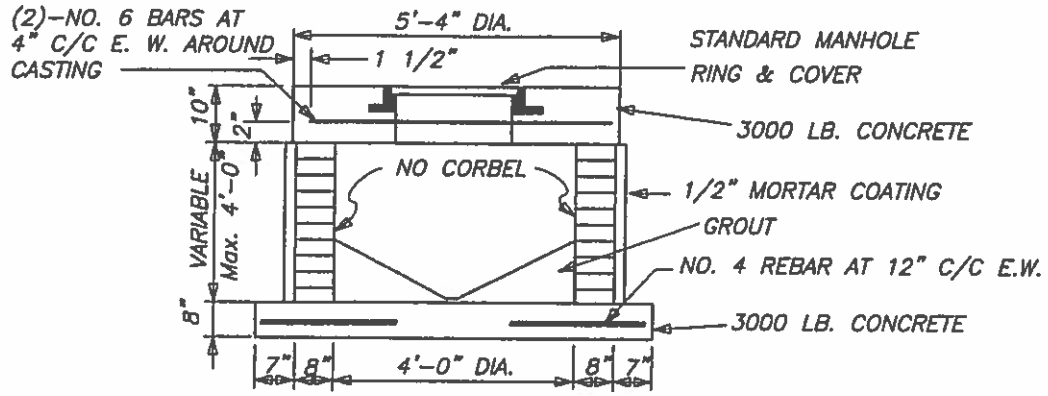
NOT TO SCALE



PLAN

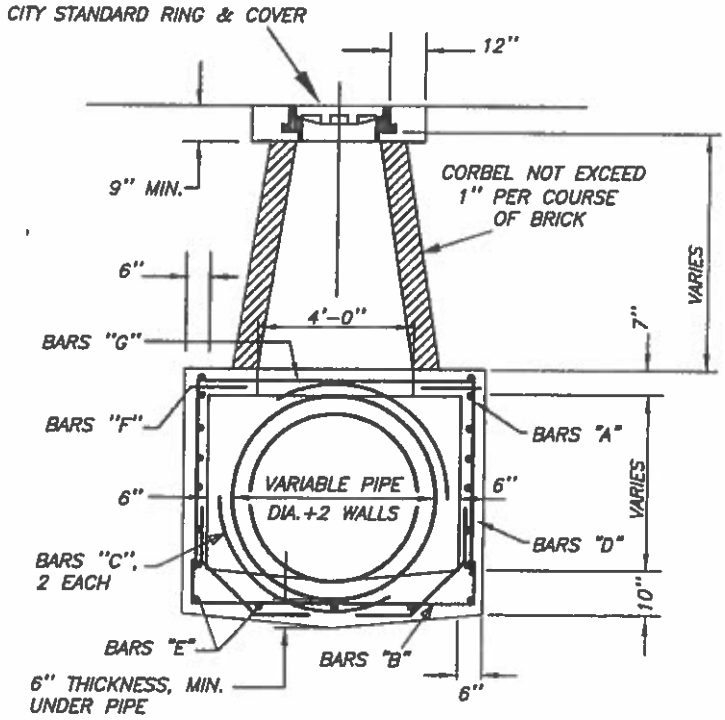
NOT TO SCALE

STORM DRAINAGE DESIGN MANUAL
PORT ARANSAS, TEXAS
STANDARD STORM SEWER
DETAIL VIII-6
TYPE "A" MANHOLE DETAIL
SEPT., 2005
U.E. JOB NO. 6100.A5.00 PAGE: 40



SECTION D-D

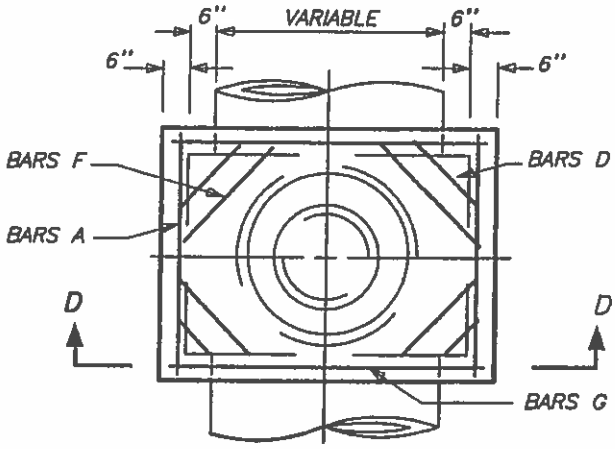
NOT TO SCALE



SECTION D-D

TYPE "B" MANHOLE

NOT TO SCALE



PLAN OF

TYPE "B" MANHOLE

NOT TO SCALE

STORM DRAINAGE DESIGN MANUAL
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DETAIL VIII–7
TYPE "B" MANHOLE DETAIL
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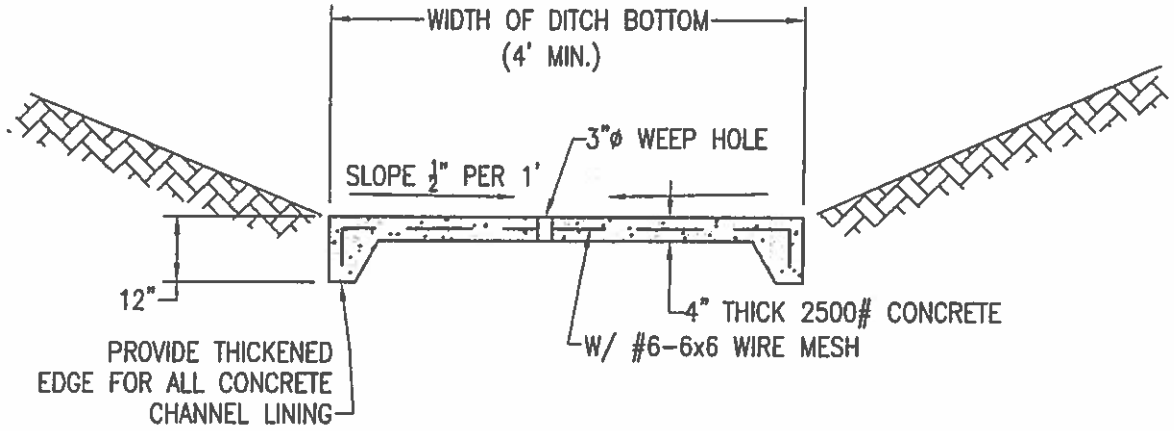
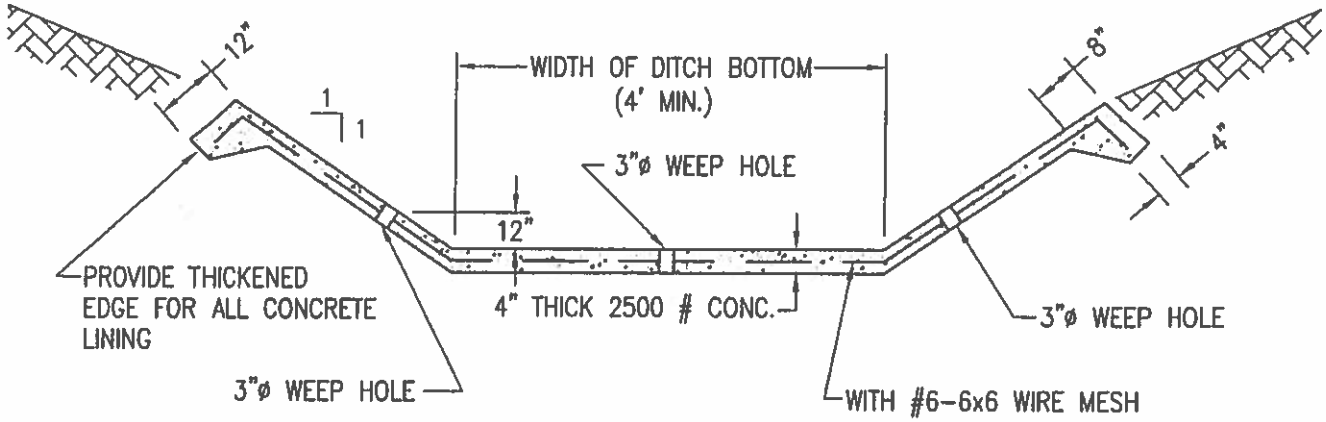


CONCRETE PILOT CHANNEL LINING

NOT TO SCALE



CONCRETE DITCH LINING

NOT TO SCALE

PROVIDE DOWELED EXPANSION JOINT AT MAXIMUM 40' O.C.

PROVIDE 3" ø WEEP HOLES AT MAXIMUM 20' O.C.

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STANDARD STORM SEWER
DETAIL VIII-8
CONCRETE LINING DETAILS

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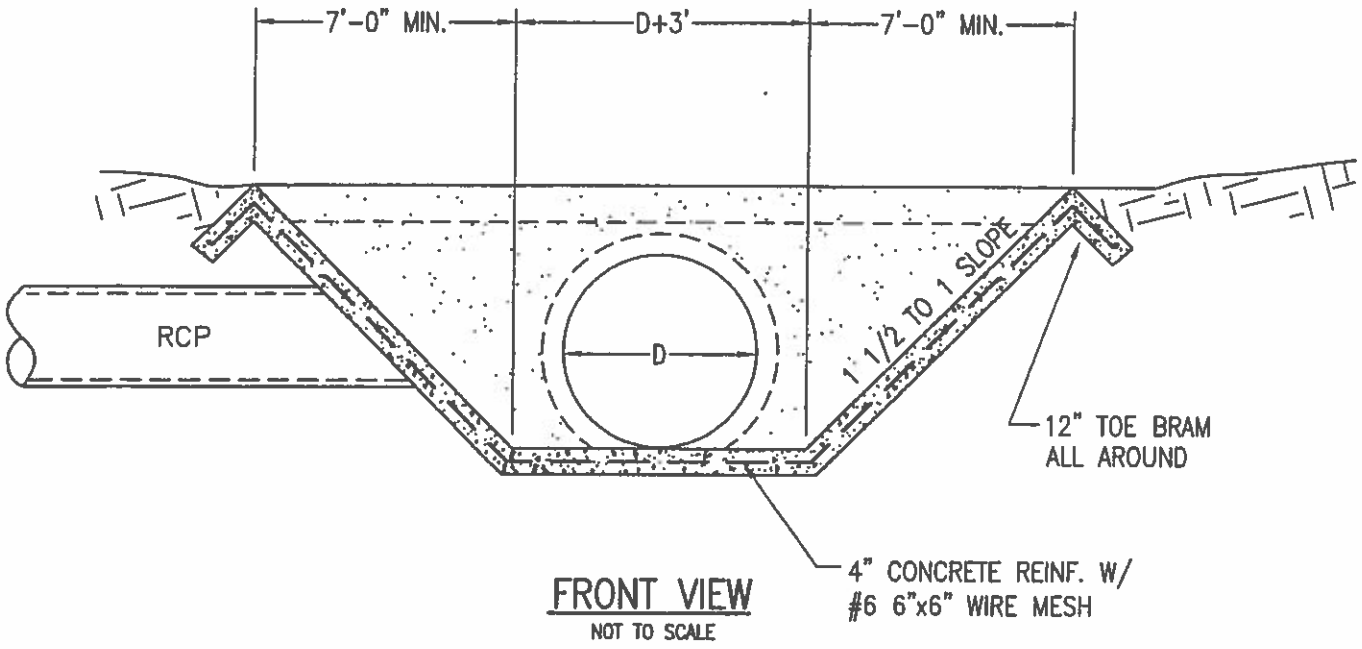
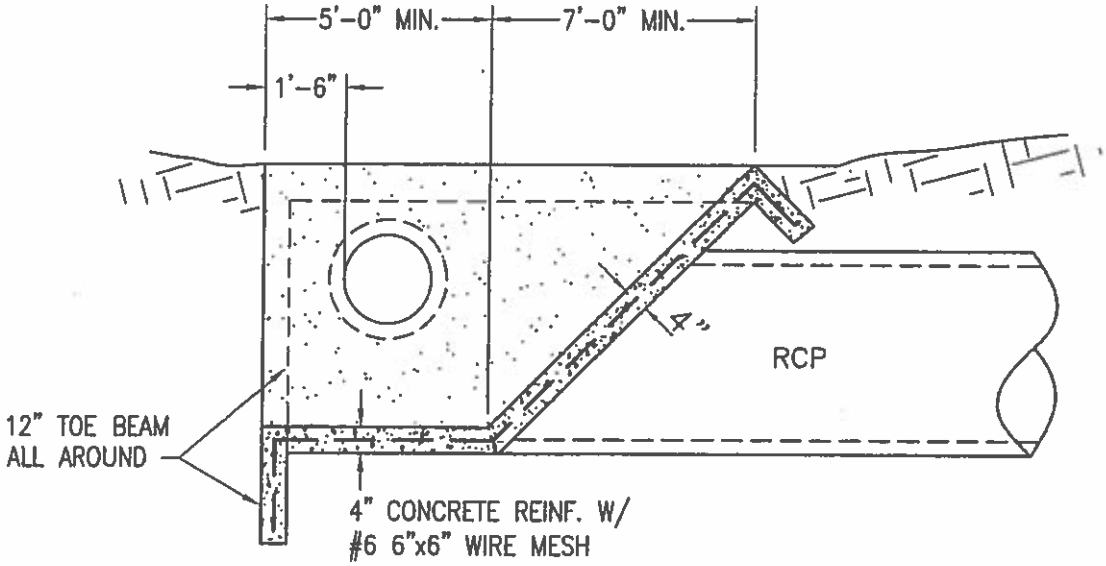


FRONT VIEW
NOT TO SCALE



SIDE VIEW
NOT TO SCALE

STORM DRAINAGE DESIGN MANUAL
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STANDARD STORM SEWER
DETAIL VIII-9
OUTFALL STRUCTURE DETAIL
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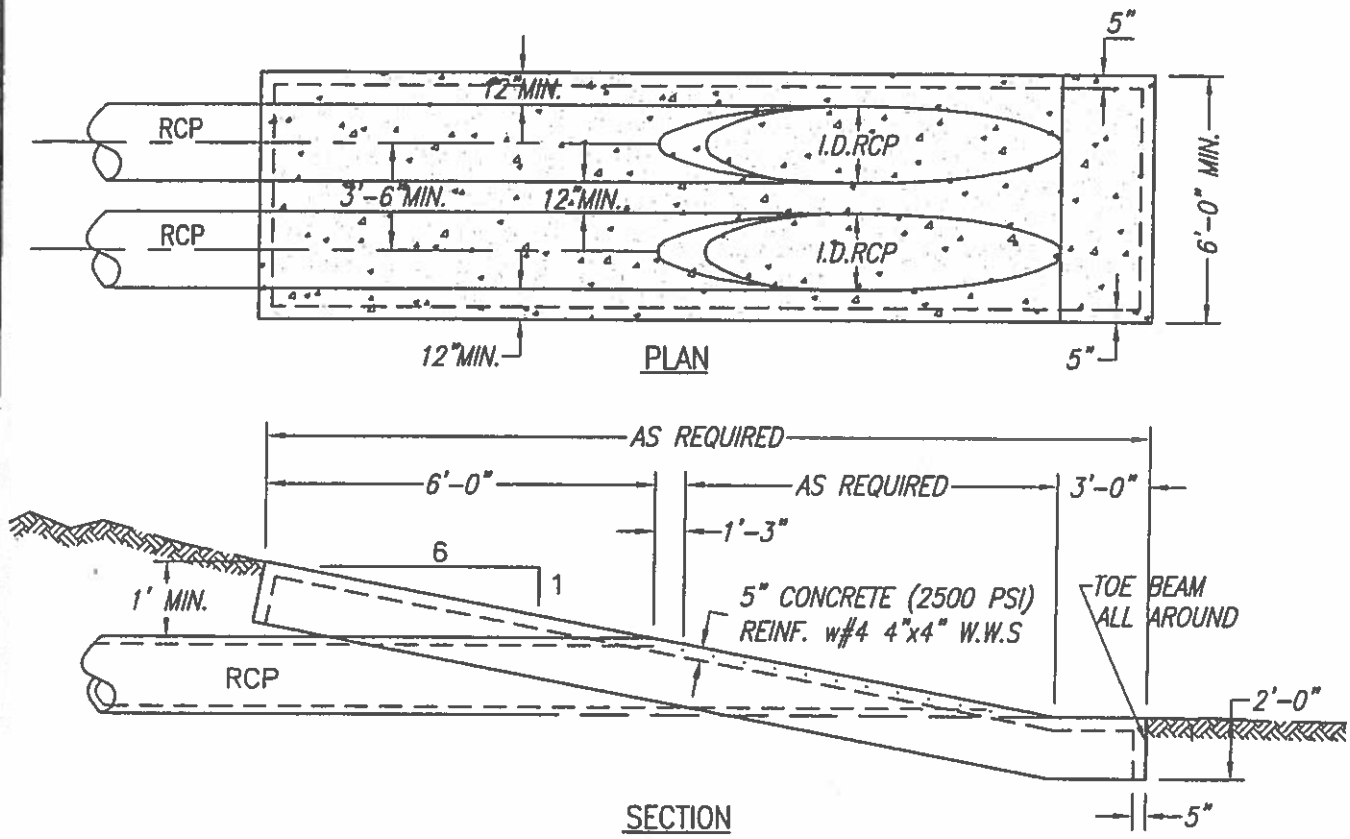

CULVERT W/6:1 END SLOPE

NOT TO SCALE

STORM DRAINAGE DESIGN MANUAL
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STANDARD STORM SEWER
DETAIL VIII-10
CULVERT W/6:1 END SLOPE DETAIL
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IX. REFERENCE MATERIAL:

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(This Section is for the use of the holder of this Manual.)