

BROADWAY FLOOD CHANNEL HYDROLOGY & HYDRAULIC REVIEW

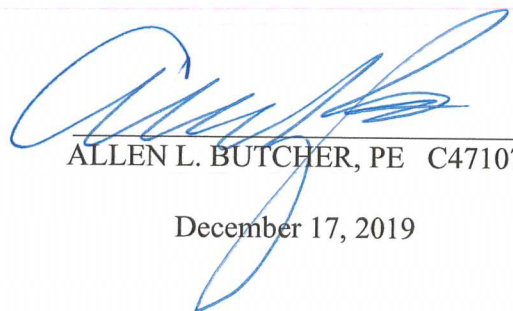
1118 N. Anza Street Townhomes
PDS2018-TM-5628, PDS2018-REZ-18-003

COUNTY OF SAN DIEGO / EL CAJON, CA

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December 17, 2019

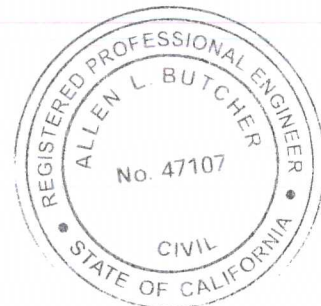


TABLE OF CONTENTS

1.	Introduction.....	1
2.	Declaration of Responsible Charge	2
3.	Post-Development Project Drainage.....	4
4.	Site Discharge	4
5.	Broadway Channel.....	5
6.	Tributary Area.....	5
7.	Hydrograph Calculations	6
8.	Broadway Channel Flow.....	7
9.	Broadway Channel Hydraulics	8
10.	Existing Conditions.....	8
11.	HEC-RAS Results.....	9
12.	Conclusion	10

EXHIBITS

- A. SOIL LAND USE TABLE
- B. UNIT HYDROGRAPH
- C. RAINFALL DISTRIBUTION
- D. RUNOFF HYDROGRAPH
- E. HEC-RAS RESULTS

APPENDIX

SELECTED COUNTY OF SAN DIEGO HYDROLOGY MANUAL EXCERPTS

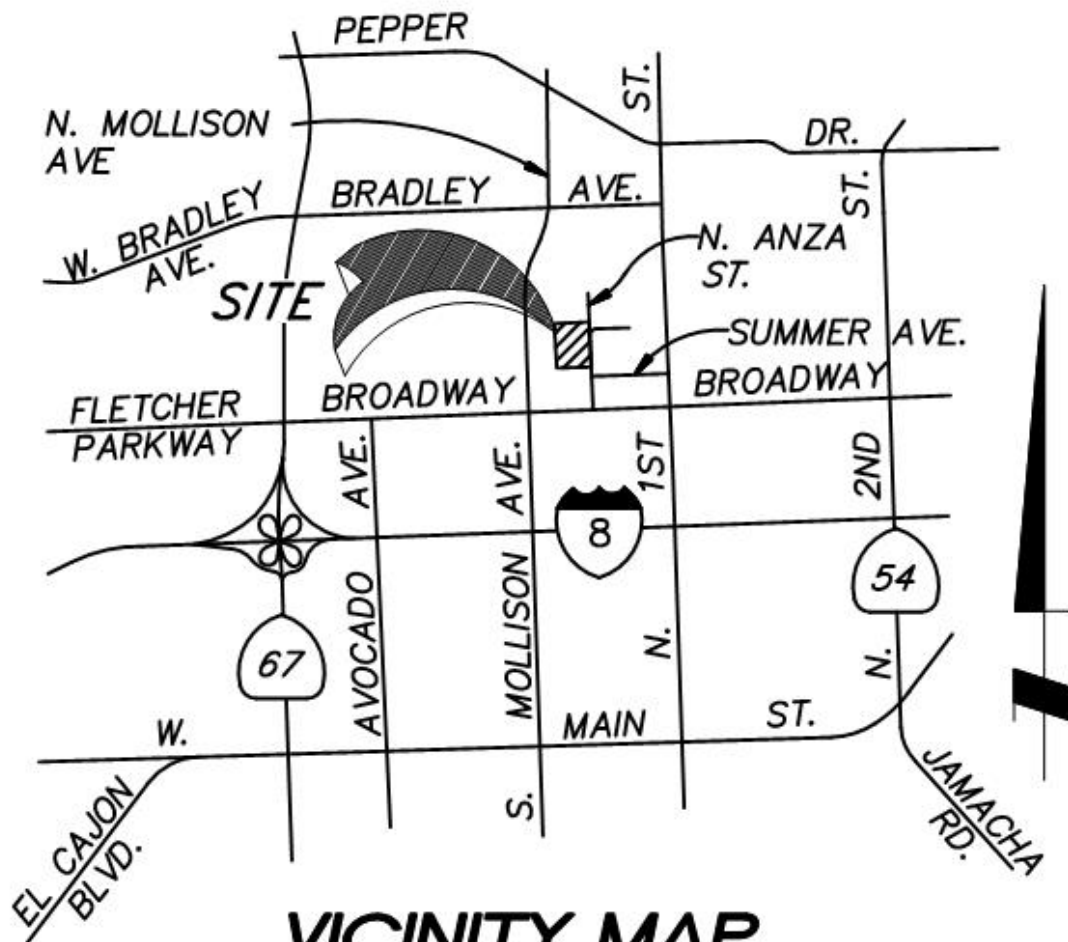
WORK MAPS

BROADWAY CHANNEL PLANS	#1
BASIN AND LAND USE	#2
SOIL MAPS	#3
FIELD SURVEY DATA (NAVD 88)	#4

1. Introduction

The project proposes a storm drain line in Anza Street connecting to the Broadway flood control channel, just downstream of the Anza Street box culvert. Although the project will still be tributary to the same receiving water and downstream watershed, discharge will enter the Broadway channel near Anza Street, approximately 800 feet upstream of the current location (Mollison Ave).

The scope of this report is limited to addressing the potential impacts from the additional project flows near the Anza Street box culvert, which is part of the Broadway Flood Control Channel.



VICINITY MAP

NOT TO SCALE
THOMAS BROTHERS PG. 1251,
GRID H-3 57TH EDITION

2. Declaration of Responsible Charge

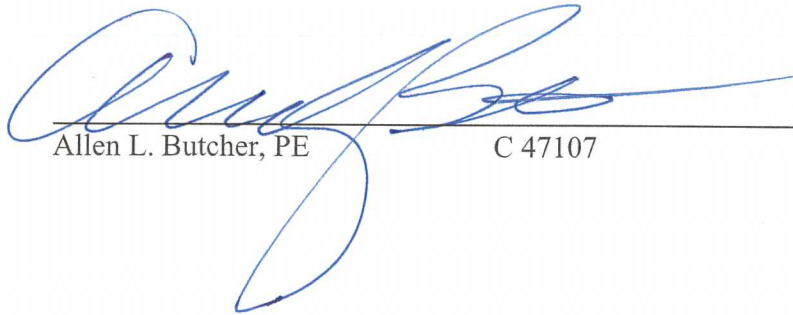
DECLARATION OF RESPONSIBLE CHARGE:

I hereby declare that I am the Engineer of Work for this project, that I have exercised responsible charge over the design of the project as defined in Section 6703 of the Business and Professions Code, and that the design is consistent with the current standards.

I understand that the check of the project drawings and specification by the County of San Diego is confined to a review only and does not relieve me, as the Engineer of Work, of my responsibilities for project design.

ENGINEER OF WORK:

SB&O, Inc.
3990 Ruffin Road, Suite 120
San Diego, CA 92123
Phone: 858-560-1141



Allen L. Butcher, PE

C 47107

12-17-2019
Date



3. Post-Development Project Drainage

The topography of the North Anza Street property slopes gently toward the southwest corner, continuing off-site southerly and westerly through the adjacent properties. Downstream drainage patterns are poorly defined, with overland flows eventually reaching Mollison Avenue gutter to the curb inlet connected to the Broadway Flood Channel at the Mollison box culvert.

The increased impervious area and drainage facilities associated with the proposed multifamily / attached development will increase runoff volumes and peak flow rates during large storm events, when compared to the current lower density development. Maintaining the current discharge locations could result in a greater burden from the concentrated surface discharge and corresponding greater velocities at the downstream properties which lack defined drainage facilities.

The post-development condition will raise the site through imported fill and be sloped easterly toward North Anza Street. Project runoff will be directed to two (2) storm water quality/HMP basins, which will discharge to a proposed 18" public storm drain in North Anza Street, connecting to the Broadway Flood Channel, downstream of the Anza box culvert. This approach eliminates the above potential impacts to the properties immediately downstream of the site. The new discharge location will transfer the majority of the site runoff (approximately 3.1 acres) from the Mollison Ave undercrossing to near Anza box culvert under-crossing, approximately 800 feet upstream of the current location.

4. Site Discharge

In order to determine the design flow for the new storm drain and to assess potential impacts at the Anza Street connection, the combined outflow from the Water Quality/HMP facilities needs to be estimated. The project Drainage Study includes detention routing (rational method hydrographs) of the two (2) water quality / HMP control facilities to determine the post development site runoff.

In order to confirm the maximum potential project impact, the 100-year 6-hour rational method peak flow for the areas tributary to the basins will be estimated using the minimum time of concentration of 5 minutes.

Basin	Peak Inflow (cfs)	Peak Outflow (cfs)
Biofiltration 1 / HMP-1	5.95	-----
Biofiltration 2 / HMP-2	9.60	-----
Site Total	15.55	-----

The above combined peak flows (without attenuation) will be added directly to the Broadway Channel peak flow (calculated by the County Unit Hydrograph Method). This approach provides the most conservative flow estimate.

5. Broadway Channel

The record plans for the Broadway Channel (City of El Cajon Drawing 3600, Sheet 17, 18 & 20 completed in 1967) do not provide design flow rates, depths or hydraulic data. The trapezoidal channel is concrete lined with a base width of 10 feet and 1:1 side slope. Reinforced Concrete Box culverts (double 7' wide x 5' tall) are used at both Mollison Avenue and Anza Street. Transitions for the base width and the sidewalls slope (20' long) occur upstream and downstream of the culverts, with the top of the channel lining extending up to the top of parapet (approximately 6.5' to 7' above the flowline). Due to the proximity of original residences and structures, the box culvert at the Anza crossing was extended an additional 70.69' upstream of the street right-of-way.

A copy of the record plans with typical sections are provided in Map Pocket #1.

The FIRM Panel for Broadway Creek (06073C1662G) was last updated in 2012 to reflect the 1988 Datum change. The 100-year floodway is generally shown within the channel limits, with shallow flooding at the Anza culvert (between Sections P and Q). The floodway table indicates a 20-foot or less top width, which would be contained within the concrete channel. The only published discharge (1,600 cfs for a tributary area of 3.8 sq. miles) for Broadway Creek is at the mouth approximately 2 miles downstream, which is at Forester Creek. This indicates that a single discharge was used for the entire study length. Note: The tributary area at Anza Street is 1.6 square miles (42%).

The City of El Cajon has a draft Citywide Drainage Master Plan, which compares peak flows to storm drain and channel capacities, to identify potential capacity issues. The estimated 100-year peak flow for the Broadway channel in the vicinity of Anza Street is estimated at 800 cfs.

Neither peak flow estimate is based upon the current County Hydrology Manual. Since the two estimates vary significantly, a Unit Hydrograph Model will be prepared to estimate the peak flow at the Anza culvert.

6. Tributary Basin

The Broadway Channel is located along the north limits of the City of El Cajon and conveys runoff from the Broadway Avenue corridor and the County properties located to the north and northeast. The channel flows westerly and then northerly to Forester Creek, which is tributary to the San Diego River at the City of Santee.

Based upon the County of San Diego ortho topo maps, and supplemented by visual field reviews, the area tributary to the Anza Street RCB crossing was delineated, with a tributary area in excess of 1 square mile, which confirms the need for Unit Hydrograph Methodology to provide flow estimates.

The soil group and land use data for the basin was compiled using a 1,000' grid methodology as described in the County Hydrology Manual. Land uses are predominately single family residential with some multifamily & commercial uses along the Broadway corridor.

See Tributary Drainage & Land Use / Soil Type exhibits in Map Pockets #2 & #3.

The Basin Factor $\bar{n}$, is defined as the visually estimated mean of the 'n' values of all channels within the basin area. The inverse of the Basin Factor is used in the calculation of the lag time, which determines the magnitude of the runoff response from excess rainfall. Guidance regarding the selection is limited for tributary areas that are between the urban, fully improved and mostly impervious (0.015) condition, and low intensity without drainage improvements (0.030). Except for the urban corridor along Broadway, much of the tributary basin has limited storm drain systems. The residential portion includes limited street improvements with unlined and poorly defined drainage swales (estimated $n=0.030$). Based upon the relative area of each, a Basin Factor of 0.025 was selected. The tributary area up to the Anza Street box culvert is summarized as follows;

Basin Data	Value
Total Area (ac)	1,016
Total Area (sq. mi)	1.59
Length (ft)	13,077
Length (mi)	2.48
Length to Centroid (ft)	9,675
Length to Centroid (mi)	1.83
Slope (ft/mi)	98.5
$\bar{n}$	0.025
CN ₂	77

The land use and soil type grid tables are provided in Exhibit "A".

7. Hydrograph Calculations

From the above data, the unit hydrograph input values are derived;

Hydrograph Data	Value
Lag Time, T_l	0.446 hrs.
Time to Peak, $T_p = 0.862 T_l$	0.384 hrs.
Computation Interval = $0.2 T_p$	5 mins
Precipitation Zone, PZN	1.49
100-year Return Period, CN _{2.45}	82
Storage, $S = 1000/CN-10$	2.987 in
Initial Abstraction, $I_a = 0.2 S$	0.597 in
Unit Runoff, $q_p = 484A/T_p$	2,000 cfs/in

The response unit hydrograph, adjusted to a 5-minute interval, is provided in Exhibit "B".

Using the rainfall totals and the County rainfall distribution pattern, a cumulative rainfall table was prepared. Since the rational method intensity formula is limited to the 6-hour peak rainfall period, a log-log interpolation of the remaining rainfall (difference between the P24 and P6) was used for the remaining 18 hours. Rainfall blocks (5 minute) were ranked and sorted in a 2/3-1/3 distribution with the peak rainfall occurring at the 16th hour of the 24-hour rainfall event.

Rainfall Totals	100-Year
6-Hour, P6	2.55 in
24-Hour Total, P24	5.20 in
Rainfall Total Ratio, P6/P24 =	0.49

The resulting rainfall distribution and excess rainfall tables (adjusted for the initial and equilibrium abstractions) are available in Exhibit “C”.

The runoff hydrograph is then derived by the convolution of each excess rainfall block and the unit hydrograph values at successive 5-minute time steps. The summation of the runoff response at each time step during the 24-hour rain event produces the runoff hydrograph.

A review of the resulting hydrograph in Exhibit “D” indicates that the peak flow rate at the downstream end of the Anza Street RCB is 1,597.2 cfs at 16.33 hours of the 24-hour storm event.

8. **Broadway Channel Flow**

The Anza culvert includes flows from the upstream channel and those entering from the existing Anza Street curb inlets. The tributary area from Anza Street is approximately 17 acres. A straight-line proration based upon the relative tributary areas was used to estimate the peak flow rates upstream and downstream of the box culvert.

As determined by the project detention analysis, the additional runoff from the Anza Street project is estimated at 1.8 cfs, which represents approximately 0.1% of the peak flow in the Broadway channel. The flow rates at the Anza culvert are summarized as follows;

Location	Tributary Area (ac)	Existing Peak Flow (cfs)	Post Project Peak Flow (cfs)
Anza Upstream	999	1,570.3	1,570.3
Anza Street Flows	17	26.9	42.5
Anza Downstream	1,016	1,597.2	1,612.8

9. Broadway Channel Hydraulics

Hydraulic analyses were prepared to determine the water surface elevations through the Anza Street culvert for both the existing and post project conditions using HEC-RAS (V5.07). The profile for the channel shows abrupt changes in bed slopes, with short (20') transitions between the trapezoidal and box culvert sections, which will yield a varied flow profile throughout the study area. The concrete lining and channel slope rates indicate supercritical flow regimes.

The record plans show a concrete lined trapezoidal channel with a base width of 10 feet, depths of 4.5 to 5.0 feet, with 1:1 side slope. Slopes heights are increased to 5.6' and reduced to 4.5' in the curved segment upstream of Anza Street. A two-foot wide bench is shown at the top of the channel, with a maximum 1.5:1 side slope above the bench (field conditions are generally flatter slopes).

Manning's 'n' for the concrete channel and culvert was set at 0.014 with bank stations set at the top of the concrete lining. Overbank areas were a mixture of graded earth, grass/weeds and turf, with a corresponding 'n' values at 0.020. Expansion and contraction coefficients were set at 0.1 and 0.3 respectively. Length adjustments were made for the curved alignments upstream and downstream of the Anza Street box culvert.

The Deck Roadway high chord elevation (both upstream and downstream) was set equal to the top of parapet elevation (which is approximately the right-of-way elevations). Upstream and downstream cross sections were set at 20' from the culvert headwalls to match the existing transitions for bed slope, channel width and side slope. Cross Section "names" are based upon the Engineer's stationing shown on the plan.

Although the typical section for the box culvert includes the sloped invert option toward the centerline, twin box openings were selected with 7' wide x 5' tall openings with a 6" wide center wall (rounded edges), with a constant slope over the 130.69 feet length. Chart #10 ~ 90-degree headwall, chamfered or beveled inlet with Scale #1 ~ Inlet edges chamfered 3/4" was selected.

In accordance with the San Diego County Hydraulic Design Manual, flows through the Anza Street box culvert were analyzed using the Culvert Method, with the solution criteria selected as "Computed Flow Control" to allow the program to determine Inlet or Outlet Control condition. Steady State Flow Analyses were run using the "Mixed" Flow Regime option.

10. Existing Conditions

The HEC-RAS cross sections are based upon the record plans which includes the profile of the proposed channel and culverts, with the typical sections providing the dimensions of the proposed facilities. The records plan for the channel lack detail and elevations related to the intersecting streets, adjacent ground conditions, and the nearby structures.

In order to confirm the adequacy of the existing facilities, a limited topographic survey was performed at the Anza Street crossing to verify elevation of the channel flowline and top of parapet, Anza Street road surface and curb inlets, and the finished floor of the four adjacent residences.

The results of the field survey are summarized as follows;

Description / Location	Elevation (NGVD 29)	Comment
Anza Culvert / Upstream	444.84 FL	Hold Record FL
RCB Opening Height	5.02' / 5.04'	Center & Edge of Box
Anza Parapet / Upstream	451.48 FS	451.7 Record
NE Residence FF	453.31 FF / 451.54 FG	Raised Foundation
SE Residence FF	453.06 FF / 451.61 FG	Raised Foundation
East Inlet	451.41 TC / 450.59 FL	Top of Curb/Gutter
Anza Street Centerline	451.21 FS Crown	Centerline @ Inlets
West Inlet	451.02 TC / 450.27 FL	Top of Curb/Gutter
Anza Culvert / Downstream	443.28 FL	
RCB Opening Height	5.03' / 5.10'	Center & Edge of Box
Anza Parapet / Downstream	451.66 FS	451.7 Record
NW Residence FF	451.84 FF / 451.02 FG	Lowest - Slab on Grade
SW Residence FF	452.08 FF / 451.01 FG	Raised Foundation
Anza Street Centerline	450.96 Crown – Passing Grade	Centerline @ South Houses

Notes:

- A. Anza centerline is a passing grade at RCB inlets. Inlets 180' further south and the gutter at Broadway curb return (315' south) are at lower elevations.*
- B. Survey elevations were adjusted to NGVD 29 datum. Upstream flowline matches record.*

11. HEC-RAS Results

The HEC-RAS analysis include two profiles for the existing (Profile1) and post development (Profile2). The flowline elevation of the culvert and parapet was adjusted to reflect the field survey results. A review of the models confirms that supercritical flows occurs in the channel upstream of Anza Street ($1.5 > F > 2.2$), with flow depths near or above 5 feet.

The water surface elevation at the upstream end of the culvert is estimated at 450.5, compared to the parapet elevation of 451.5 (1.0' freeboard). The water surface at the downstream end of the culvert is estimated at 450.2, which is 1.5 feet below the west parapet wall. The program defaults to critical depth at this location, which represents the maximum water surface elevation possible.

A review of the post-development analysis (Profile2) confirms that the additional project flows have a negligible impact on water surface elevations.

Based upon the field survey – the lowest adjacent finished floor (NW residence 451.8 FF) is 1.6' above the water surface elevation (450.2) at West parapet. The lowest finished floor on the upstream side (SE home 453.06) is more than 2.5' above water surface elevation (450.5) at East parapet.

12. Conclusion

The results of the HEC-RAS analyses demonstrate that the Anza Street culvert has adequate capacity to pass the estimated 100-year peak flow, as estimated by the County of San Diego Unit Hydrograph Methodology. The estimated peak flow is more conservative than the current FEMA value or the peak flow used in the City of El Cajon draft Drainage Master Plan.

The maximum additional runoff from the Anza Street project is estimated at 15.6 cfs, which represents approximately 0.1% of the peak flow in the Broadway channel (Note: This is well below the accuracy of the hydrology model, and the supporting data). The post development analysis confirms that the increase in water surface elevation is negligible from the additional project flows.

In order to confirm the adequacy of the existing facilities, a limited topographic survey was performed at the Anza Street crossing to verify elevation of the channel flowline and top of parapet, Anza Street road surface and curb inlets, and the finished floor of the four adjacent residences. Based upon the field survey – the lowest adjacent finished floor (NW) is 1.6' above the water surface elevation (450.2) at West parapet. The lowest finished floor on the upstream side (SE) is 2.5' above water surface elevation (450.5) at East parapet. The estimated water surface in the culvert is below the gutters at the existing curb inlets.

The field survey also revealed that the Anza Street curb inlets are at localized depressions. The profile of the Anza Street is generally downhill all the way to the Broadway gutters, located 315' south of the Anza undercrossing. The existing Broadway gutter is 1.8' below the lowest existing adjacent residence (NW). In the event of an extreme storm or capacity constraint, excess runoff would flow southerly to the Broadway gutters.

EXHIBIT A

SOIL LAND USE TABLE
UH WORKSHEETS

Grid #	Land Use	Soil Type	CN
A1	General Single Family/Detached	D	87
A2	General Single Family/Detached	C	83
B1	General Single Family/Detached	D	87
B2	General Single Family/Detached	D	87
C1	General Single Family/Detached	CD	85
C2	General Single Family/Detached	D	87
C4	General Single Family/Detached	C	77
C8	Open Brush - Good	C	75
C9	General Single Family/Detached	B	65
D1	Commercial, Office, Mixed Use	D	95
D2	Multiple Family Residential	D	90
D3	General Single Family/Detached	B	75
D4	General Single Family/Detached	B	75
D5	General Single Family/Detached	B	85
D6	Open Brush - Good	B	66
D7	Open Brush - Good	C	66
D8	General Single Family/Detached	B	70
D9	General Single Family/Detached	B	70
E3	General Single Family/Detached	B	75
E4	General Single Family/Detached	C	83
E5	General Single Family/Detached	C	83
E6	Multiple Family Residential	D	92
E7	General Single Family/Detached	D	87
E8	General Single Family/Detached	B	75
F2	General Single Family/Detached	B	75
F3	General Single Family/Detached	B	68
F4	General Single Family/Detached	C	79
F5	Education and Institutions	CD	92
F6	General Single Family/Detached	D	87
F7	MHP	BD	83
F8	General Single Family/Detached	B	70
F9	Church	B	82
G1	General Single Family/Detached	C	83
G2	General Single Family/Detached	C	83
G3	General Single Family/Detached	B	75
G4	General Single Family/Detached	B	70
G5	General Single Family/Detached	BD	83
G6	General Single Family/Detached	B	75
G7	General Single Family/Detached	B	70
G8	General Single Family/Detached	B	75
G9	General Single Family/Detached	B	70
H5	General Single Family/Detached	B	75
H6	General Single Family/Detached	B	75
H7	General Single Family/Detached	B	75
H8	General Single Family/Detached	B	75
I5	General Single Family/Detached	B	75
I6	General Single Family/Detached	B	75
I7	General Single Family/Detached	B	70
I8	General Single Family/Detached	B	75
I9	General Single Family/Detached	B	70
J6	General Single Family/Detached	B	75
J7	General Single Family/Detached	B	70
J8	Spaced Rural Residential - 1ac	B	68
J9	Open Brush - Good	B	63
Average			77
CN2			77

WORKSHEET 4-3 Anza/Broadway Peak Discharge Computation
(name of project)

*****For use with NRCS Hydrologic Method Computations*****

Items in boxes are required input parameters for the SDUH Peak Discharge Program.

Computed by: ALB / SB90 Date: 4/2019

Project Identification (Drainage Area Name): Broadway Channel

Geographic location of center of drainage area: Long: 32/42/3 " Lat: 116/54/52 "

Drainage Area: 1.59 - square miles

Storm Frequency (Section 2.3) 1.00 - year

6-Hour Storm Duration Precipitation (Appendix B) 2.55 - inches

24-Hour Storm Duration Precipitation (Appendix B) 5.2 - inches

Precipitation Zone Number (PZN): PZN = 1.0 1.49 2.0 3.0 4.0
(Section 4.1.2.4 and Appendix C)

PZN Adjustment Factor for
5-year to 35-year storm frequency (interpolate): 1.5 2.5 2.0 1.5
(Section 4.1.2.4 and Table 4-6)

PZN Adjustment Factor for
35-year to 150-year storm frequency (interpolate): 2.0 2.49 3.0 3.0 2.0
(Section 4.1.2.4 and Table 4-6)

PZN Adjusted Runoff Curve Number (interpolate
between nearest whole number PZN conditions): $CN_{1.0 \text{ or } 2.0}$ 77 $CN_{2.49}$ 82 $CN_{2.0 \text{ or } 3.0}$
(Sections 4.1.2.4 and 4.2.4, Tables 4-6 and 4-10)

Watershed Length (L) (Section 4.3.1): 2.48 - miles

Length to Centroid (L_c) (Section 4.3.1): 1.83 - miles

Slope (s) (Section 4.3.1): 98.5 - feet/mile Basin $\bar{n}$ Factor (Section 4.3.5): 0.025

Corps lag (T_L) = $24 \bar{n} ((L \times L_c)/s^{0.5})^m$ (Section 4.3.1.1)
OR

Corps lag (T_L) = $0.8 T_c$ (Section 4.3.1.2)

Lag Time: 0.446 - hours

Time to Peak = $0.862 \times$ Corps lag (Section 4.1.5.5):

Time to Peak: 0.384 - hours

WORKSHEET 4-2

ANZA

(name of project)

Curve Number Worksheet

RUNOFF CURVE NUMBER (for PZM Condition = 2.0) CN_2 :

column 1	column 2	column 3	column 4	column 5	column 6
GROUND COVER/ LAND USE	HYDROLOGIC CONDITION (field in- spection)	SOIL GROUP	CN_2 From Hydrology Manual, Table 4-2	FRACTION OF AREA A_i/A	PARTIAL CN_2 $CN_2 \times A_i/A$
1 2 9 RESIDENTIAL SFR-LD	FAIR	B B B	65 68 70	1.85 3.7 16.66	1.2 2.5 11.5
1 1	FAIR	C C	77 79	1.85 1.85	1.4 1.5
16 7 1 6 RES - SFR MED DEN	FAIR	B C CD	75 83 85	29.6 112.9 1.85	22.2 11.0 1.6
		D	87	11.1	9.7
1 1 1 1 1 1 1 RES ATTACH LHD	FAIR	B D D	85 90 92	1.85 1.85 1.85	1.6 1.7 1.7
1 1 1 1 1 1 1 COMM/IND SCHOOL CHURCH	FAIR	D CD B	95 90 75	1.85 1.85 1.85	1.8 1.7 1.4
2 1 1 OPEN BRUSH	GOOD	B BC C	63 69 75	3.7 1.85 1.85	2.3 1.4 1.3

Sums = 1.000 77.4

For entire basin $CN_2 = 77$

54

WORKSHEET 4-1

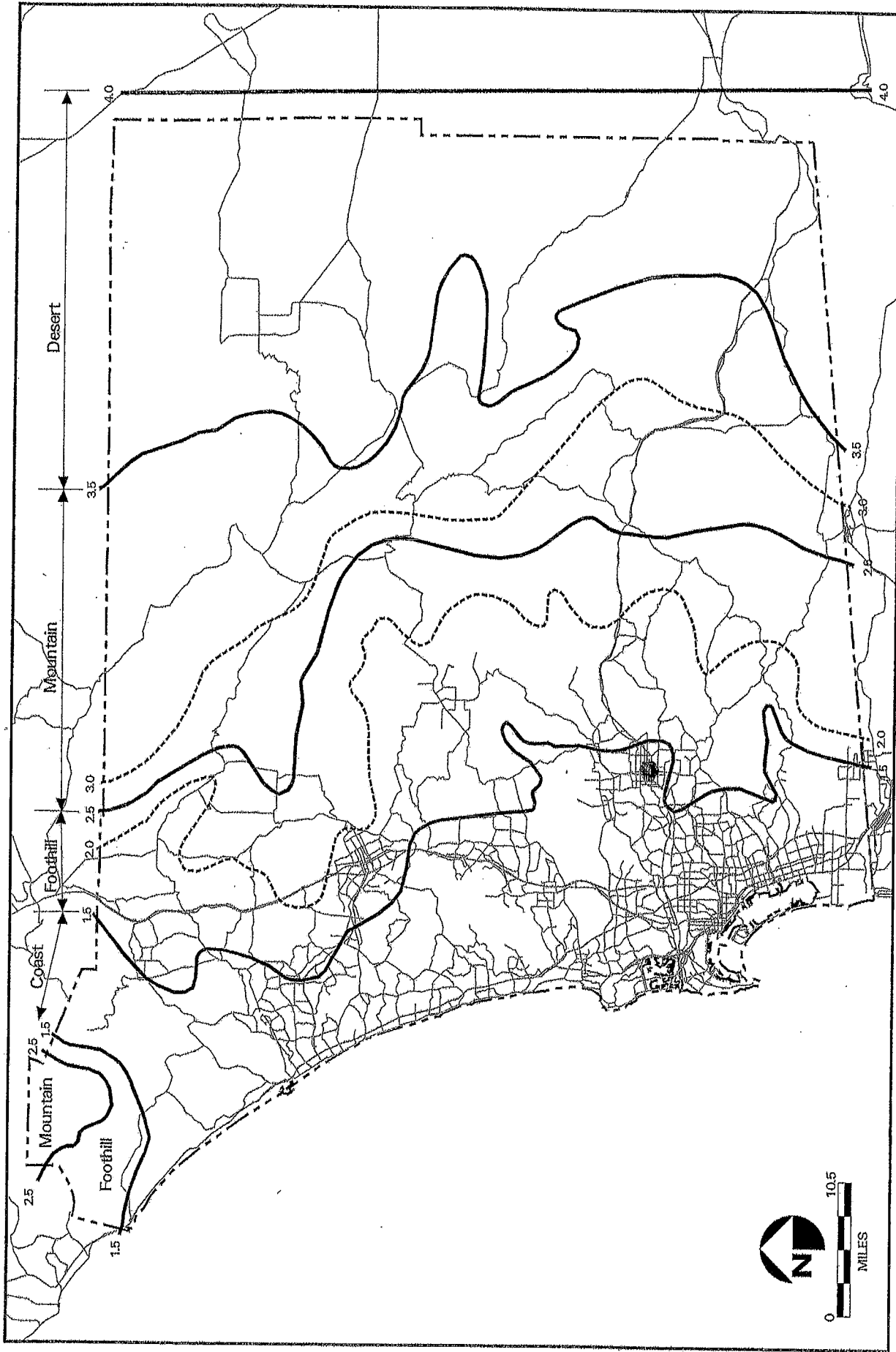
ANZA

(name of project)

Land Use Worksheet

DATE BY		HYDROLOGIC CONDITION											
		GOOD 3				FAIR 2				POOR 1			
		A	B	C	D	A	B	C	D	A	B	C	D
FALLOW STRAIGHT ROW	CR												
ROW CROPS STRAIGHT ROW	CR						N/A						
ROW CROPS CONTOURED	CR						N/A						
SMALL GRAIN STRAIGHT ROW	CR						N/A						
SMALL GRAIN CONTOURED	CR						N/A						
CLOSE SEEDED STRAIGHT	CR						N/A						
CLOSE SEEDED CONTOURED	CR						N/A						
IRRIGATED PASTURE	IP												
WATER SURFACES (DURING FLOODS)	WA						N/A				N/A		
ORCHARDS EVERGREEN	OE												
ORCHARDS DECIDUOUS*	OD												
VINEYARDS	VY												
URBAN LOW DENSITY	DL		N/A				12				N/A		
URBAN MEDIUM DENSITY	DL		N/A				16	9 1/2	6 1/2		N/A		
URBAN HIGH DENSITY	DL		N/A				1		2		N/A		
COMMERCIAL INDUSTRIAL	DL		N/A				1	1/2	1/2		N/A		
ANNUAL GRASS	AG												
BROADLEAF CHAPARRAL	BC												
MEADOW	ME												
NARROWLEAF CHAPARRAL	NC		N/A										
OPEN BRUSH	OB		2	2									
PERENNIAL GRASS	PG												
WOODLAND GRASS	WG												
WOODS (WOODLAND)	WO												
BARREN	BA		N/A								N/A		
TURF	TU												
FARMSTEADS	FS		N/A								N/A		
ROADS (DIRT)	RD		N/A								N/A		
ROADS (HARD SURFACE)	RD		N/A								N/A		

*For deciduous orchards, select the CN that applies to the land use or the kind and condition of cover during storm periods (winter time). For example, select annual grass CN values for annual grass or grass legume cover. If orchards are kept bare by disking or through the use of herbicides, use fallow CNs.



FIGURE

C-1

County of San Diego Hydrology Manual
Precipitation Zone Numbers (PZN)



EXHIBIT B

UNIT HYDROGRAPH

Broadway Channel

Time Unit Runoff

5	223.8
10	701.7
15	1,514.0
20	2,009.7
25	2,017.0
30	1,778.3
35	1,321.8
40	847.8
45	596.2
50	389.9
55	277.4
60	212.3
65	147.6
70	101.6
75	71.7
80	50.1
85	34.9
90	23.6
95	17.1
100	8.4
105	9.7
110	5.0
115	0.2

EXHIBIT C

RAINFALL DISTRIBUTION

Broadway Channel

CN 82
 S 2.195
 $I_a = .2S$ 0.439 .8S 1.7561
 $Q_a = (P - .2S)^2 / (P + .8S)$
 $F_a = S * (P - I_a) / (P - I_a + S)$

Sort	Time (Hrs)	Time (mins)	Rainfall	Cumm Rainfall P	Cumm IA	Abstraction Fa	Qa	Cumm Excess	Incr Excess
288	0.08	5	0.009	0.009	0.009	0.000	0.000	0.000	0.000
287	0.17	10	0.009	0.019	0.019	0.000	0.000	0.000	0.000
285	0.25	15	0.009	0.028	0.028	0.000	0.000	0.000	0.000
284	0.33	20	0.009	0.037	0.037	0.000	0.000	0.000	0.000
282	0.42	25	0.009	0.047	0.047	0.000	0.000	0.000	0.000
281	0.50	30	0.009	0.056	0.056	0.000	0.000	0.000	0.000
279	0.58	35	0.009	0.066	0.066	0.000	0.000	0.000	0.000
278	0.67	40	0.009	0.075	0.075	0.000	0.000	0.000	0.000
276	0.75	45	0.010	0.085	0.085	0.000	0.000	0.000	0.000
275	0.83	50	0.010	0.094	0.094	0.000	0.000	0.000	0.000
273	0.92	55	0.010	0.104	0.104	0.000	0.000	0.000	0.000
272	1.00	60	0.010	0.114	0.114	0.000	0.000	0.000	0.000
270	1.08	65	0.010	0.123	0.123	0.000	0.000	0.000	0.000
269	1.17	70	0.010	0.133	0.133	0.000	0.000	0.000	0.000
267	1.25	75	0.010	0.143	0.143	0.000	0.000	0.000	0.000
266	1.33	80	0.010	0.152	0.152	0.000	0.000	0.000	0.000
264	1.42	85	0.010	0.162	0.162	0.000	0.000	0.000	0.000
263	1.50	90	0.010	0.172	0.172	0.000	0.000	0.000	0.000
261	1.58	95	0.010	0.181	0.181	0.000	0.000	0.000	0.000
260	1.67	100	0.010	0.191	0.191	0.000	0.000	0.000	0.000
258	1.75	105	0.010	0.201	0.201	0.000	0.000	0.000	0.000
257	1.83	110	0.010	0.211	0.211	0.000	0.000	0.000	0.000
255	1.92	115	0.010	0.221	0.221	0.000	0.000	0.000	0.000
254	2.00	120	0.010	0.231	0.231	0.000	0.000	0.000	0.000
252	2.08	125	0.010	0.241	0.241	0.000	0.000	0.000	0.000
251	2.17	130	0.010	0.251	0.251	0.000	0.000	0.000	0.000
249	2.25	135	0.010	0.261	0.261	0.000	0.000	0.000	0.000
248	2.33	140	0.010	0.271	0.271	0.000	0.000	0.000	0.000
246	2.42	145	0.010	0.281	0.281	0.000	0.000	0.000	0.000
245	2.50	150	0.010	0.291	0.291	0.000	0.000	0.000	0.000
243	2.58	155	0.010	0.301	0.301	0.000	0.000	0.000	0.000
242	2.67	160	0.010	0.311	0.311	0.000	0.000	0.000	0.000
240	2.75	165	0.010	0.321	0.321	0.000	0.000	0.000	0.000
239	2.83	170	0.010	0.331	0.331	0.000	0.000	0.000	0.000
237	2.92	175	0.010	0.342	0.342	0.000	0.000	0.000	0.000
236	3.00	180	0.010	0.352	0.352	0.000	0.000	0.000	0.000

234	3.08	185	0.010	0.362	0.362	0.000	0.000		0.000	0.000
233	3.17	190	0.010	0.373	0.373	0.000	0.000		0.000	0.000
231	3.25	195	0.010	0.383	0.383	0.000	0.000		0.000	0.000
230	3.33	200	0.010	0.393	0.393	0.000	0.000		0.000	0.000
228	3.42	205	0.010	0.404	0.404	0.000	0.000		0.000	0.000
227	3.50	210	0.010	0.414	0.414	0.000	0.000		0.000	0.000
225	3.58	215	0.010	0.425	0.425	0.000	0.000		0.000	0.000
224	3.67	220	0.011	0.435	0.435	0.000	0.000		0.000	0.000
222	3.75	225	0.011	0.446	0.439	0.007	0.007		0.000	0.000
221	3.83	230	0.011	0.456	0.439	0.017	0.017		0.000	0.000
219	3.92	235	0.011	0.467	0.439	0.028	0.028		0.000	0.000
218	4.00	240	0.011	0.478	0.439	0.038	0.039		0.001	0.000
216	4.08	245	0.011	0.488	0.439	0.048	0.049		0.001	0.000
215	4.17	250	0.011	0.499	0.439	0.058	0.060		0.002	0.001
213	4.25	255	0.011	0.510	0.439	0.069	0.071		0.002	0.001
212	4.33	260	0.011	0.521	0.439	0.079	0.082		0.003	0.001
210	4.42	265	0.011	0.532	0.439	0.089	0.092		0.004	0.001
209	4.50	270	0.011	0.542	0.439	0.099	0.103		0.005	0.001
207	4.58	275	0.011	0.553	0.439	0.109	0.114		0.006	0.001
206	4.67	280	0.011	0.564	0.439	0.118	0.125		0.007	0.001
204	4.75	285	0.011	0.575	0.439	0.128	0.136		0.008	0.001
203	4.83	290	0.011	0.586	0.439	0.138	0.147		0.009	0.001
201	4.92	295	0.011	0.597	0.439	0.148	0.158		0.011	0.001
200	5.00	300	0.011	0.608	0.439	0.157	0.169	0.012	0.012	0.001
198	5.08	305	0.011	0.620	0.439	0.167	0.181	0.014	0.014	0.002
197	5.17	310	0.011	0.631	0.439	0.176	0.192	0.015	0.015	0.002
195	5.25	315	0.011	0.642	0.439	0.186	0.203	0.017	0.017	0.002
194	5.33	320	0.011	0.653	0.439	0.195	0.214	0.019	0.019	0.002
192	5.42	325	0.011	0.665	0.439	0.205	0.226	0.021	0.021	0.002
191	5.50	330	0.011	0.676	0.439	0.214	0.237	0.023	0.023	0.002
189	5.58	335	0.011	0.687	0.439	0.223	0.248	0.025	0.025	0.002
188	5.67	340	0.011	0.699	0.439	0.232	0.260	0.027	0.027	0.002
186	5.75	345	0.011	0.710	0.439	0.241	0.271	0.030	0.030	0.002
185	5.83	350	0.012	0.722	0.439	0.250	0.283	0.032	0.032	0.002
183	5.92	355	0.012	0.733	0.439	0.260	0.294	0.035	0.035	0.003
182	6.00	360	0.012	0.745	0.439	0.269	0.306	0.037	0.037	0.003
180	6.08	365	0.012	0.757	0.439	0.277	0.318	0.040	0.040	0.003
179	6.17	370	0.012	0.768	0.439	0.286	0.329	0.043	0.043	0.003
177	6.25	375	0.012	0.780	0.439	0.295	0.341	0.046	0.046	0.003
176	6.33	380	0.012	0.792	0.439	0.304	0.353	0.049	0.049	0.003
174	6.42	385	0.012	0.804	0.439	0.313	0.365	0.052	0.052	0.003
173	6.50	390	0.012	0.816	0.439	0.321	0.377	0.055	0.055	0.003
171	6.58	395	0.012	0.828	0.439	0.330	0.389	0.058	0.058	0.003
170	6.67	400	0.012	0.840	0.439	0.339	0.401	0.062	0.062	0.003
168	6.75	405	0.012	0.852	0.439	0.347	0.413	0.065	0.065	0.003
167	6.83	410	0.012	0.864	0.439	0.356	0.425	0.069	0.069	0.004
165	6.92	415	0.012	0.876	0.439	0.364	0.437	0.073	0.073	0.004

164	7.00	420	0.012	0.888	0.439	0.373	0.449	0.076	0.076	0.004
162	7.08	425	0.012	0.900	0.439	0.381	0.461	0.080	0.080	0.004
161	7.17	430	0.012	0.913	0.439	0.390	0.474	0.084	0.084	0.004
159	7.25	435	0.012	0.925	0.439	0.398	0.486	0.088	0.088	0.004
158	7.33	440	0.012	0.938	0.439	0.406	0.499	0.092	0.092	0.004
156	7.42	445	0.012	0.950	0.439	0.415	0.511	0.096	0.096	0.004
155	7.50	450	0.013	0.963	0.439	0.423	0.524	0.101	0.101	0.004
153	7.58	455	0.013	0.975	0.439	0.431	0.536	0.105	0.105	0.004
152	7.67	460	0.013	0.988	0.439	0.439	0.549	0.110	0.110	0.005
150	7.75	465	0.013	1.001	0.439	0.447	0.562	0.114	0.114	0.005
149	7.83	470	0.013	1.013	0.439	0.455	0.574	0.119	0.119	0.005
147	7.92	475	0.013	1.026	0.439	0.463	0.587	0.124	0.124	0.005
146	8.00	480	0.013	1.039	0.439	0.471	0.600	0.129	0.129	0.005
144	8.08	485	0.013	1.052	0.439	0.479	0.613	0.134	0.134	0.005
143	8.17	490	0.013	1.065	0.439	0.487	0.626	0.139	0.139	0.005
141	8.25	495	0.013	1.078	0.439	0.495	0.639	0.144	0.144	0.005
140	8.33	500	0.013	1.091	0.439	0.503	0.652	0.149	0.149	0.005
138	8.42	505	0.013	1.105	0.439	0.511	0.666	0.155	0.155	0.005
137	8.50	510	0.013	1.118	0.439	0.519	0.679	0.160	0.160	0.006
135	8.58	515	0.013	1.131	0.439	0.526	0.692	0.166	0.166	0.006
134	8.67	520	0.013	1.145	0.439	0.534	0.706	0.172	0.172	0.006
132	8.75	525	0.014	1.158	0.439	0.542	0.719	0.178	0.178	0.006
131	8.83	530	0.014	1.172	0.439	0.549	0.733	0.183	0.183	0.006
129	8.92	535	0.014	1.186	0.439	0.557	0.747	0.189	0.189	0.006
128	9.00	540	0.014	1.199	0.439	0.565	0.760	0.196	0.196	0.006
126	9.08	545	0.014	1.213	0.439	0.572	0.774	0.202	0.202	0.006
125	9.17	550	0.014	1.227	0.439	0.580	0.788	0.208	0.208	0.006
123	9.25	555	0.014	1.241	0.439	0.587	0.802	0.215	0.215	0.006
122	9.33	560	0.014	1.255	0.439	0.595	0.816	0.221	0.221	0.007
120	9.42	565	0.014	1.269	0.439	0.602	0.830	0.228	0.228	0.007
119	9.50	570	0.014	1.284	0.439	0.610	0.845	0.235	0.235	0.007
117	9.58	575	0.014	1.298	0.439	0.617	0.859	0.242	0.242	0.007
116	9.67	580	0.014	1.312	0.439	0.625	0.873	0.249	0.249	0.007
114	9.75	585	0.015	1.327	0.439	0.632	0.888	0.256	0.256	0.007
113	9.83	590	0.015	1.342	0.439	0.640	0.902	0.263	0.263	0.007
111	9.92	595	0.015	1.356	0.439	0.647	0.917	0.270	0.270	0.007
110	10.00	600	0.015	1.371	0.439	0.654	0.932	0.278	0.278	0.007
108	10.08	605	0.015	1.386	0.439	0.662	0.947	0.285	0.285	0.008
107	10.17	610	0.015	1.401	0.439	0.669	0.962	0.293	0.293	0.008
105	10.25	615	0.015	1.416	0.439	0.676	0.977	0.301	0.301	0.008
104	10.33	620	0.015	1.431	0.439	0.683	0.992	0.309	0.309	0.008
102	10.42	625	0.015	1.447	0.439	0.691	1.008	0.317	0.317	0.008
101	10.50	630	0.015	1.462	0.439	0.698	1.023	0.325	0.325	0.008
99	10.58	635	0.016	1.478	0.439	0.705	1.038	0.334	0.334	0.008
98	10.67	640	0.016	1.493	0.439	0.712	1.054	0.342	0.342	0.008
96	10.75	645	0.016	1.509	0.439	0.719	1.070	0.351	0.351	0.009
95	10.83	650	0.016	1.525	0.439	0.726	1.086	0.359	0.359	0.009

93	10.92	655	0.016	1.541	0.439	0.734	1.102	0.368	0.368	0.009
92	11.00	660	0.016	1.557	0.439	0.741	1.118	0.377	0.377	0.009
90	11.08	665	0.016	1.573	0.439	0.748	1.134	0.386	0.386	0.009
89	11.17	670	0.016	1.590	0.439	0.755	1.151	0.396	0.396	0.009
87	11.25	675	0.017	1.606	0.439	0.762	1.167	0.405	0.405	0.009
86	11.33	680	0.017	1.623	0.439	0.769	1.184	0.415	0.415	0.010
84	11.42	685	0.017	1.640	0.439	0.776	1.201	0.425	0.425	0.010
83	11.50	690	0.017	1.657	0.439	0.783	1.218	0.434	0.434	0.010
81	11.58	695	0.017	1.674	0.439	0.790	1.235	0.444	0.444	0.010
80	11.67	700	0.017	1.691	0.439	0.797	1.252	0.455	0.455	0.010
78	11.75	705	0.017	1.708	0.439	0.804	1.269	0.465	0.465	0.010
77	11.83	710	0.018	1.726	0.439	0.811	1.287	0.476	0.476	0.011
75	11.92	715	0.018	1.744	0.439	0.818	1.305	0.486	0.486	0.011
74	12.00	720	0.018	1.762	0.439	0.825	1.323	0.497	0.497	0.011
72	12.08	725	0.007	1.769	0.439	0.828	1.330	0.502	0.502	0.005
71	12.17	730	0.013	1.782	0.439	0.833	1.343	0.510	0.510	0.008
69	12.25	735	0.013	1.795	0.439	0.838	1.356	0.518	0.518	0.008
68	12.33	740	0.013	1.808	0.439	0.843	1.369	0.526	0.526	0.008
66	12.42	745	0.013	1.822	0.439	0.848	1.383	0.534	0.534	0.008
65	12.50	750	0.014	1.835	0.439	0.853	1.396	0.543	0.543	0.009
63	12.58	755	0.014	1.849	0.439	0.859	1.410	0.552	0.552	0.009
62	12.67	760	0.014	1.863	0.439	0.864	1.424	0.560	0.560	0.009
60	12.75	765	0.014	1.878	0.439	0.869	1.439	0.570	0.570	0.009
59	12.83	770	0.014	1.892	0.439	0.874	1.453	0.579	0.579	0.009
57	12.92	775	0.015	1.907	0.439	0.880	1.468	0.588	0.588	0.009
56	13.00	780	0.015	1.922	0.439	0.885	1.483	0.598	0.598	0.010
54	13.08	785	0.015	1.937	0.439	0.890	1.498	0.608	0.608	0.010
53	13.17	790	0.015	1.953	0.439	0.896	1.514	0.618	0.618	0.010
51	13.25	795	0.016	1.968	0.439	0.901	1.529	0.628	0.628	0.010
50	13.33	800	0.016	1.984	0.439	0.907	1.545	0.639	0.639	0.011
48	13.42	805	0.016	2.001	0.439	0.913	1.562	0.649	0.649	0.011
47	13.50	810	0.017	2.018	0.439	0.918	1.579	0.660	0.660	0.011
45	13.58	815	0.017	2.035	0.439	0.924	1.596	0.672	0.672	0.011
44	13.67	820	0.017	2.052	0.439	0.930	1.613	0.683	0.683	0.012
42	13.75	825	0.018	2.070	0.439	0.936	1.631	0.695	0.695	0.012
41	13.83	830	0.018	2.088	0.439	0.942	1.649	0.708	0.708	0.012
39	13.92	835	0.019	2.107	0.439	0.948	1.668	0.720	0.720	0.013
38	14.00	840	0.019	2.126	0.439	0.954	1.687	0.733	0.733	0.013
36	14.08	845	0.020	2.147	0.439	0.960	1.708	0.747	0.747	0.014
35	14.17	850	0.021	2.167	0.439	0.967	1.728	0.761	0.761	0.014
33	14.25	855	0.021	2.189	0.439	0.974	1.750	0.776	0.776	0.015
32	14.33	860	0.022	2.211	0.439	0.980	1.772	0.791	0.791	0.015
30	14.42	865	0.023	2.233	0.439	0.987	1.794	0.807	0.807	0.016
29	14.50	870	0.023	2.256	0.439	0.994	1.817	0.823	0.823	0.016
27	14.58	875	0.024	2.281	0.439	1.001	1.842	0.840	0.840	0.017
26	14.67	880	0.025	2.305	0.439	1.009	1.866	0.858	0.858	0.018
24	14.75	885	0.026	2.332	0.439	1.016	1.893	0.876	0.876	0.019

23	14.83	890	0.027	2.358	0.439	1.024	1.919	0.895	0.895	0.019
21	14.92	895	0.028	2.387	0.439	1.032	1.948	0.916	0.916	0.020
20	15.00	900	0.029	2.416	0.439	1.040	1.977	0.937	0.937	0.021
18	15.08	905	0.031	2.447	0.439	1.049	2.008	0.960	0.960	0.023
17	15.17	910	0.032	2.480	0.439	1.058	2.041	0.983	0.983	0.024
15	15.25	915	0.035	2.515	0.439	1.067	2.076	1.009	1.009	0.026
14	15.33	920	0.037	2.552	0.439	1.077	2.113	1.036	1.036	0.027
12	15.42	925	0.046	2.598	0.439	1.088	2.158	1.070	1.070	0.034
11	15.50	930	0.048	2.645	0.439	1.100	2.206	1.106	1.106	0.036
9	15.58	935	0.053	2.698	0.439	1.113	2.259	1.146	1.146	0.040
8	15.67	940	0.057	2.755	0.439	1.127	2.316	1.189	1.189	0.043
6	15.75	945	0.063	2.818	0.439	1.142	2.379	1.238	1.238	0.049
5	15.83	950	0.072	2.891	0.439	1.158	2.452	1.293	1.293	0.056
3	15.92	955	0.106	2.997	0.439	1.181	2.558	1.376	1.376	0.083
2	16.00	960	0.149	3.146	0.439	1.212	2.707	1.495	1.495	0.118
1	16.08	965	0.535	3.681	0.439	1.309	3.242	1.933	1.933	0.438
4	16.17	970	0.085	3.766	0.439	1.323	3.327	2.005	2.005	0.071
7	16.25	975	0.061	3.827	0.439	1.332	3.388	2.056	2.056	0.052
10	16.33	980	0.050	3.878	0.439	1.340	3.439	2.099	2.099	0.042
13	16.42	985	0.039	3.916	0.439	1.346	3.477	2.132	2.132	0.033
16	16.50	990	0.034	3.950	0.439	1.351	3.511	2.160	2.160	0.029
19	16.58	995	0.030	3.980	0.439	1.355	3.541	2.186	2.186	0.026
22	16.67	1000	0.028	4.008	0.439	1.359	3.569	2.210	2.210	0.024
25	16.75	1005	0.025	4.033	0.439	1.363	3.594	2.231	2.231	0.022
28	16.83	1010	0.024	4.057	0.439	1.366	3.618	2.252	2.252	0.020
31	16.92	1015	0.022	4.079	0.439	1.369	3.640	2.271	2.271	0.019
34	17.00	1020	0.021	4.100	0.439	1.372	3.661	2.289	2.289	0.018
37	17.08	1025	0.019	4.120	0.439	1.375	3.681	2.306	2.306	0.017
40	17.17	1030	0.019	4.138	0.439	1.378	3.699	2.322	2.322	0.016
43	17.25	1035	0.018	4.156	0.439	1.380	3.717	2.337	2.337	0.015
46	17.33	1040	0.017	4.173	0.439	1.382	3.734	2.351	2.351	0.015
49	17.42	1045	0.016	4.189	0.439	1.385	3.750	2.365	2.365	0.014
52	17.50	1050	0.016	4.205	0.439	1.387	3.766	2.379	2.379	0.014
55	17.58	1055	0.015	4.220	0.439	1.389	3.781	2.392	2.392	0.013
58	17.67	1060	0.015	4.235	0.439	1.391	3.796	2.405	2.405	0.013
61	17.75	1065	0.014	4.249	0.439	1.393	3.810	2.417	2.417	0.012
64	17.83	1070	0.014	4.262	0.439	1.395	3.823	2.429	2.429	0.012
67	17.92	1075	0.013	4.276	0.439	1.396	3.837	2.440	2.440	0.012
70	18.00	1080	0.013	4.289	0.439	1.398	3.850	2.452	2.452	0.011
73	18.08	1085	0.018	4.307	0.439	1.400	3.868	2.467	2.467	0.016
76	18.17	1090	0.018	4.324	0.439	1.403	3.885	2.483	2.483	0.015
79	18.25	1095	0.017	4.342	0.439	1.405	3.903	2.498	2.498	0.015
82	18.33	1100	0.017	4.359	0.439	1.407	3.920	2.513	2.513	0.015
85	18.42	1105	0.017	4.376	0.439	1.409	3.937	2.527	2.527	0.015
88	18.50	1110	0.016	4.392	0.439	1.411	3.953	2.542	2.542	0.014
91	18.58	1115	0.016	4.408	0.439	1.413	3.969	2.556	2.556	0.014
94	18.67	1120	0.016	4.424	0.439	1.415	3.985	2.570	2.570	0.014

97	18.75	1125	0.016	4.440	0.439	1.417	4.001	2.583	2.583	0.014
100	18.83	1130	0.015	4.455	0.439	1.419	4.016	2.597	2.597	0.014
103	18.92	1135	0.015	4.471	0.439	1.421	4.032	2.610	2.610	0.013
106	19.00	1140	0.015	4.486	0.439	1.423	4.047	2.624	2.624	0.013
109	19.08	1145	0.015	4.501	0.439	1.425	4.062	2.637	2.637	0.013
112	19.17	1150	0.015	4.515	0.439	1.427	4.076	2.649	2.649	0.013
115	19.25	1155	0.014	4.530	0.439	1.429	4.091	2.662	2.662	0.013
118	19.33	1160	0.014	4.544	0.439	1.430	4.105	2.675	2.675	0.013
121	19.42	1165	0.014	4.558	0.439	1.432	4.119	2.687	2.687	0.012
124	19.50	1170	0.014	4.572	0.439	1.434	4.133	2.699	2.699	0.012
127	19.58	1175	0.014	4.586	0.439	1.435	4.147	2.712	2.712	0.012
130	19.67	1180	0.014	4.599	0.439	1.437	4.160	2.724	2.724	0.012
133	19.75	1185	0.013	4.613	0.439	1.439	4.174	2.735	2.735	0.012
136	19.83	1190	0.013	4.626	0.439	1.440	4.187	2.747	2.747	0.012
139	19.92	1195	0.013	4.640	0.439	1.442	4.201	2.759	2.759	0.012
142	20.00	1200	0.013	4.653	0.439	1.443	4.214	2.770	2.770	0.012
145	20.08	1205	0.013	4.666	0.439	1.445	4.227	2.782	2.782	0.011
148	20.17	1210	0.013	4.678	0.439	1.446	4.239	2.793	2.793	0.011
151	20.25	1215	0.013	4.691	0.439	1.448	4.252	2.804	2.804	0.011
154	20.33	1220	0.013	4.704	0.439	1.449	4.265	2.815	2.815	0.011
157	20.42	1225	0.012	4.716	0.439	1.451	4.277	2.826	2.826	0.011
160	20.50	1230	0.012	4.728	0.439	1.452	4.289	2.837	2.837	0.011
163	20.58	1235	0.012	4.741	0.439	1.453	4.302	2.848	2.848	0.011
166	20.67	1240	0.012	4.753	0.439	1.455	4.314	2.859	2.859	0.011
169	20.75	1245	0.012	4.765	0.439	1.456	4.326	2.870	2.870	0.011
172	20.83	1250	0.012	4.777	0.439	1.458	4.338	2.880	2.880	0.011
175	20.92	1255	0.012	4.789	0.439	1.459	4.350	2.891	2.891	0.010
178	21.00	1260	0.012	4.800	0.439	1.460	4.361	2.901	2.901	0.010
181	21.08	1265	0.012	4.812	0.439	1.461	4.373	2.911	2.911	0.010
184	21.17	1270	0.012	4.824	0.439	1.463	4.385	2.922	2.922	0.010
187	21.25	1275	0.011	4.835	0.439	1.464	4.396	2.932	2.932	0.010
190	21.33	1280	0.011	4.846	0.439	1.465	4.407	2.942	2.942	0.010
193	21.42	1285	0.011	4.858	0.439	1.467	4.419	2.952	2.952	0.010
196	21.50	1290	0.011	4.869	0.439	1.468	4.430	2.962	2.962	0.010
199	21.58	1295	0.011	4.880	0.439	1.469	4.441	2.972	2.972	0.010
202	21.67	1300	0.011	4.891	0.439	1.470	4.452	2.982	2.982	0.010
205	21.75	1305	0.011	4.902	0.439	1.471	4.463	2.992	2.992	0.010
208	21.83	1310	0.011	4.913	0.439	1.473	4.474	3.001	3.001	0.010
211	21.92	1315	0.011	4.924	0.439	1.474	4.485	3.011	3.011	0.010
214	22.00	1320	0.011	4.934	0.439	1.475	4.495	3.021	3.021	0.010
217	22.08	1325	0.011	4.945	0.439	1.476	4.506	3.030	3.030	0.010
220	22.17	1330	0.011	4.956	0.439	1.477	4.517	3.040	3.040	0.009
223	22.25	1335	0.011	4.966	0.439	1.478	4.527	3.049	3.049	0.009
226	22.33	1340	0.010	4.977	0.439	1.479	4.538	3.058	3.058	0.009
229	22.42	1345	0.010	4.987	0.439	1.481	4.548	3.068	3.068	0.009
232	22.50	1350	0.010	4.998	0.439	1.482	4.559	3.077	3.077	0.009
235	22.58	1355	0.010	5.008	0.439	1.483	4.569	3.086	3.086	0.009

238	22.67	1360	0.010	5.018	0.439	1.484	4.579	3.095	3.095	0.009
241	22.75	1365	0.010	5.028	0.439	1.485	4.589	3.104	3.104	0.009
244	22.83	1370	0.010	5.038	0.439	1.486	4.599	3.113	3.113	0.009
247	22.92	1375	0.010	5.048	0.439	1.487	4.609	3.122	3.122	0.009
250	23.00	1380	0.010	5.058	0.439	1.488	4.619	3.131	3.131	0.009
253	23.08	1385	0.010	5.068	0.439	1.489	4.629	3.140	3.140	0.009
256	23.17	1390	0.010	5.078	0.439	1.490	4.639	3.149	3.149	0.009
259	23.25	1395	0.010	5.088	0.439	1.491	4.649	3.158	3.158	0.009
262	23.33	1400	0.010	5.098	0.439	1.492	4.659	3.167	3.167	0.009
265	23.42	1405	0.010	5.107	0.439	1.493	4.668	3.175	3.175	0.009
268	23.50	1410	0.010	5.117	0.439	1.494	4.678	3.184	3.184	0.009
271	23.58	1415	0.010	5.127	0.439	1.495	4.688	3.193	3.193	0.009
274	23.67	1420	0.010	5.136	0.439	1.496	4.697	3.201	3.201	0.009
277	23.75	1425	0.010	5.146	0.439	1.497	4.707	3.210	3.210	0.009
280	23.83	1430	0.009	5.155	0.439	1.498	4.716	3.218	3.218	0.009
283	23.92	1435	0.009	5.165	0.439	1.499	4.726	3.227	3.227	0.008
286	24.00	1440	0.009	5.174	0.439	1.500	4.735	3.235	3.235	0.008

5.174

Broadway Channel

I = 7.44 P6 D^{-0.645}

For duration less than 6 hours

P = I (D/60)

P24 =

5.174 in

Cum

Duration HRs	5 min Duration	P	Depth Adj	Area Adj	Adjusted P	Hyetograph Ordinate R	Rank	Ordinate
0.083	5	0.560	0.9560	0.9560	0.535	0.535	1	0.535
0.167	10	0.716	0.9560	0.9560	0.685	0.149	2	0.149
0.250	15	0.827	0.9560	0.9560	0.791	0.106	3	0.106
0.333	20	0.916	0.9560	0.9560	0.876	0.085	4	0.085
0.417	25	0.991	0.9560	0.9560	0.948	0.072	5	0.072
0.500	30	1.058	0.9560	0.9560	1.011	0.063	6	0.063
0.583	35	1.117	0.9600	0.9600	1.072	0.061	7	0.061
0.667	40	1.171	0.9640	0.9640	1.129	0.057	8	0.057
0.750	45	1.221	0.9680	0.9680	1.182	0.053	9	0.053
0.833	50	1.268	0.9720	0.9720	1.232	0.050	10	0.050
0.917	55	1.312	0.9760	0.9760	1.280	0.048	11	0.048
1.000	60	1.353	0.9800	0.9800	1.326	0.046	12	0.046
1.083	65	1.392	0.9803	0.9803	1.364	0.039	13	0.039
1.167	70	1.429	0.9807	0.9807	1.401	0.037	14	0.037
1.250	75	1.464	0.9810	0.9810	1.436	0.035	15	0.035
1.333	80	1.498	0.9813	0.9813	1.470	0.034	16	0.034
1.417	85	1.531	0.9817	0.9817	1.503	0.032	17	0.032
1.500	90	1.562	0.9820	0.9820	1.534	0.031	18	0.031
1.583	95	1.592	0.9823	0.9823	1.564	0.030	19	0.030
1.667	100	1.622	0.9827	0.9827	1.594	0.029	20	0.029
1.750	105	1.650	0.9830	0.9830	1.622	0.028	21	0.028
1.833	110	1.677	0.9833	0.9833	1.650	0.028	22	0.028
1.917	115	1.704	0.9837	0.9837	1.676	0.027	23	0.027
2.000	120	1.730	0.9840	0.9840	1.702	0.026	24	0.026
2.083	125	1.755	0.9843	0.9843	1.728	0.025	25	0.025
2.167	130	1.780	0.9847	0.9847	1.753	0.025	26	0.025
2.250	135	1.804	0.9850	0.9850	1.777	0.024	27	0.024
2.333	140	1.827	0.9853	0.9853	1.801	0.024	28	0.024
2.417	145	1.850	0.9857	0.9857	1.824	0.023	29	0.023
2.500	150	1.873	0.9860	0.9860	1.847	0.023	30	0.023
2.583	155	1.895	0.9863	0.9863	1.869	0.022	31	0.022
2.667	160	1.916	0.9867	0.9867	1.891	0.022	32	0.022
2.750	165	1.937	0.9870	0.9870	1.912	0.021	33	0.021
2.833	170	1.958	0.9873	0.9873	1.933	0.021	34	0.021
2.917	175	1.978	0.9877	0.9877	1.954	0.021	35	0.021
3.000	180	1.998	0.9880	0.9880	1.974	0.020	36	0.020
3.083	185	2.017	0.9881	0.9881	1.993	0.019	37	0.019
3.167	190	2.037	0.9882	0.9882	2.013	0.019	38	0.019
3.250	195	2.056	0.9883	0.9883	2.031	0.019	39	0.019

3.333	200	2.074	0.9883	2.050	0.019	40	0.019
3.417	205	2.092	0.9884	2.068	0.018	41	0.018
3.500	210	2.110	0.9885	2.086	0.018	42	0.018
3.583	215	2.128	0.9886	2.104	0.018	43	0.018
3.667	220	2.145	0.9887	2.121	0.017	44	0.017
3.750	225	2.163	0.9888	2.138	0.017	45	0.017
3.833	230	2.180	0.9888	2.155	0.017	46	0.017
3.917	235	2.196	0.9889	2.172	0.017	47	0.017
4.000	240	2.213	0.9890	2.188	0.016	48	0.016
4.083	245	2.229	0.9891	2.205	0.016	49	0.016
4.167	250	2.245	0.9892	2.221	0.016	50	0.016
4.250	255	2.261	0.9893	2.237	0.016	51	0.016
4.333	260	2.277	0.9893	2.252	0.016	52	0.016
4.417	265	2.292	0.9894	2.268	0.015	53	0.015
4.500	270	2.307	0.9895	2.283	0.015	54	0.015
4.583	275	2.322	0.9896	2.298	0.015	55	0.015
4.667	280	2.337	0.9897	2.313	0.015	56	0.015
4.750	285	2.352	0.9898	2.328	0.015	57	0.015
4.833	290	2.367	0.9898	2.342	0.015	58	0.015
4.917	295	2.381	0.9899	2.357	0.014	59	0.014
5.000	300	2.395	0.9900	2.371	0.014	60	0.014
5.083	305	2.409	0.9901	2.385	0.014	61	0.014
5.167	310	2.423	0.9902	2.399	0.014	62	0.014
5.250	315	2.437	0.9903	2.413	0.014	63	0.014
5.333	320	2.451	0.9903	2.427	0.014	64	0.014
5.417	325	2.464	0.9904	2.441	0.014	65	0.014
5.500	330	2.478	0.9905	2.454	0.013	66	0.013
5.583	335	2.491	0.9906	2.467	0.013	67	0.013
5.667	340	2.504	0.9907	2.481	0.013	68	0.013
5.750	345	2.517	0.9908	2.494	0.013	69	0.013
5.833	350	2.530	0.9908	2.507	0.013	70	0.013
5.917	355	2.543	0.9909	2.520	0.013	71	0.013
6.000	360	2.55	0.9910	2.527	0.007	72	0.007
6.083	365	2.568	0.9910	2.545	0.018	73	0.018
6.167	370	2.586	0.9910	2.563	0.018	74	0.018
6.250	375	2.604	0.9911	2.581	0.018	75	0.018
6.333	380	2.622	0.9911	2.598	0.018	76	0.018
6.417	385	2.640	0.9911	2.616	0.018	77	0.018
6.500	390	2.657	0.9911	2.633	0.017	78	0.017
6.583	395	2.675	0.9911	2.651	0.017	79	0.017
6.667	400	2.692	0.9911	2.668	0.017	80	0.017
6.750	405	2.709	0.9912	2.685	0.017	81	0.017
6.833	410	2.726	0.9912	2.702	0.017	82	0.017
6.917	415	2.743	0.9912	2.719	0.017	83	0.017
7.000	420	2.760	0.9912	2.736	0.017	84	0.017
7.083	425	2.777	0.9912	2.753	0.017	85	0.017
7.167	430	2.794	0.9913	2.769	0.017	86	0.017

7.250	435	2.811	0.9913	2.786	0.017	87	0.017
7.333	440	2.827	0.9913	2.802	0.016	88	0.016
7.417	445	2.844	0.9913	2.819	0.016	89	0.016
7.500	450	2.860	0.9913	2.835	0.016	90	0.016
7.583	455	2.876	0.9914	2.851	0.016	91	0.016
7.667	460	2.892	0.9914	2.867	0.016	92	0.016
7.750	465	2.909	0.9914	2.883	0.016	93	0.016
7.833	470	2.925	0.9914	2.899	0.016	94	0.016
7.917	475	2.941	0.9914	2.915	0.016	95	0.016
8.000	480	2.956	0.9914	2.931	0.016	96	0.016
8.083	485	2.972	0.9915	2.947	0.016	97	0.016
8.167	490	2.988	0.9915	2.962	0.016	98	0.016
8.250	495	3.004	0.9915	2.978	0.016	99	0.016
8.333	500	3.019	0.9915	2.993	0.015	100	0.015
8.417	505	3.035	0.9915	3.009	0.015	101	0.015
8.500	510	3.050	0.9916	3.024	0.015	102	0.015
8.583	515	3.065	0.9916	3.039	0.015	103	0.015
8.667	520	3.081	0.9916	3.055	0.015	104	0.015
8.750	525	3.096	0.9916	3.070	0.015	105	0.015
8.833	530	3.111	0.9916	3.085	0.015	106	0.015
8.917	535	3.126	0.9916	3.100	0.015	107	0.015
9.000	540	3.141	0.9917	3.115	0.015	108	0.015
9.083	545	3.156	0.9917	3.130	0.015	109	0.015
9.167	550	3.171	0.9917	3.144	0.015	110	0.015
9.250	555	3.185	0.9917	3.159	0.015	111	0.015
9.333	560	3.200	0.9917	3.174	0.015	112	0.015
9.417	565	3.215	0.9918	3.188	0.015	113	0.015
9.500	570	3.229	0.9918	3.203	0.015	114	0.015
9.583	575	3.244	0.9918	3.217	0.014	115	0.014
9.667	580	3.258	0.9918	3.232	0.014	116	0.014
9.750	585	3.273	0.9918	3.246	0.014	117	0.014
9.833	590	3.287	0.9919	3.260	0.014	118	0.014
9.917	595	3.301	0.9919	3.275	0.014	119	0.014
10.000	600	3.316	0.9919	3.289	0.014	120	0.014
10.083	605	3.330	0.9919	3.303	0.014	121	0.014
10.167	610	3.344	0.9919	3.317	0.014	122	0.014
10.250	615	3.358	0.9919	3.331	0.014	123	0.014
10.333	620	3.372	0.9920	3.345	0.014	124	0.014
10.417	625	3.386	0.9920	3.359	0.014	125	0.014
10.500	630	3.400	0.9920	3.373	0.014	126	0.014
10.583	635	3.414	0.9920	3.386	0.014	127	0.014
10.667	640	3.428	0.9920	3.400	0.014	128	0.014
10.750	645	3.441	0.9921	3.414	0.014	129	0.014
10.833	650	3.455	0.9921	3.428	0.014	130	0.014
10.917	655	3.469	0.9921	3.441	0.014	131	0.014
11.000	660	3.482	0.9921	3.455	0.014	132	0.014
11.083	665	3.496	0.9921	3.468	0.013	133	0.013

11.167	670	3.509	0.9921	3.482	0.013	134	0.013
11.250	675	3.523	0.9922	3.495	0.013	135	0.013
11.333	680	3.536	0.9922	3.508	0.013	136	0.013
11.417	685	3.549	0.9922	3.522	0.013	137	0.013
11.500	690	3.563	0.9922	3.535	0.013	138	0.013
11.583	695	3.576	0.9922	3.548	0.013	139	0.013
11.667	700	3.589	0.9923	3.561	0.013	140	0.013
11.750	705	3.602	0.9923	3.574	0.013	141	0.013
11.833	710	3.615	0.9923	3.587	0.013	142	0.013
11.917	715	3.628	0.9923	3.601	0.013	143	0.013
12.000	720	3.641	0.9923	3.614	0.013	144	0.013
12.083	725	3.654	0.9924	3.626	0.013	145	0.013
12.167	730	3.667	0.9924	3.639	0.013	146	0.013
12.250	735	3.680	0.9924	3.652	0.013	147	0.013
12.333	740	3.693	0.9924	3.665	0.013	148	0.013
12.417	745	3.706	0.9924	3.678	0.013	149	0.013
12.500	750	3.719	0.9924	3.691	0.013	150	0.013
12.583	755	3.731	0.9925	3.703	0.013	151	0.013
12.667	760	3.744	0.9925	3.716	0.013	152	0.013
12.750	765	3.757	0.9925	3.729	0.013	153	0.013
12.833	770	3.769	0.9925	3.741	0.013	154	0.013
12.917	775	3.782	0.9925	3.754	0.013	155	0.013
13.000	780	3.794	0.9926	3.766	0.012	156	0.012
13.083	785	3.807	0.9926	3.779	0.012	157	0.012
13.167	790	3.819	0.9926	3.791	0.012	158	0.012
13.250	795	3.832	0.9926	3.803	0.012	159	0.012
13.333	800	3.844	0.9926	3.816	0.012	160	0.012
13.417	805	3.856	0.9926	3.828	0.012	161	0.012
13.500	810	3.869	0.9927	3.840	0.012	162	0.012
13.583	815	3.881	0.9927	3.853	0.012	163	0.012
13.667	820	3.893	0.9927	3.865	0.012	164	0.012
13.750	825	3.905	0.9927	3.877	0.012	165	0.012
13.833	830	3.918	0.9927	3.889	0.012	166	0.012
13.917	835	3.930	0.9928	3.901	0.012	167	0.012
14.000	840	3.942	0.9928	3.913	0.012	168	0.012
14.083	845	3.954	0.9928	3.925	0.012	169	0.012
14.167	850	3.966	0.9928	3.937	0.012	170	0.012
14.250	855	3.978	0.9928	3.949	0.012	171	0.012
14.333	860	3.990	0.9929	3.961	0.012	172	0.012
14.417	865	4.002	0.9929	3.973	0.012	173	0.012
14.500	870	4.013	0.9929	3.985	0.012	174	0.012
14.583	875	4.025	0.9929	3.997	0.012	175	0.012
14.667	880	4.037	0.9929	4.009	0.012	176	0.012
14.750	885	4.049	0.9929	4.020	0.012	177	0.012
14.833	890	4.061	0.9930	4.032	0.012	178	0.012
14.917	895	4.072	0.9930	4.044	0.012	179	0.012
15.000	900	4.084	0.9930	4.055	0.012	180	0.012

15.083	905	4.096	0.9930	4.067	0.012	181	0.012
15.167	910	4.107	0.9930	4.079	0.012	182	0.012
15.250	915	4.119	0.9931	4.090	0.012	183	0.012
15.333	920	4.130	0.9931	4.102	0.012	184	0.012
15.417	925	4.142	0.9931	4.113	0.012	185	0.012
15.500	930	4.153	0.9931	4.125	0.011	186	0.011
15.583	935	4.165	0.9931	4.136	0.011	187	0.011
15.667	940	4.176	0.9931	4.148	0.011	188	0.011
15.750	945	4.188	0.9932	4.159	0.011	189	0.011
15.833	950	4.199	0.9932	4.170	0.011	190	0.011
15.917	955	4.210	0.9932	4.182	0.011	191	0.011
16.000	960	4.222	0.9932	4.193	0.011	192	0.011
16.083	965	4.233	0.9932	4.204	0.011	193	0.011
16.167	970	4.244	0.9933	4.216	0.011	194	0.011
16.250	975	4.256	0.9933	4.227	0.011	195	0.011
16.333	980	4.267	0.9933	4.238	0.011	196	0.011
16.417	985	4.278	0.9933	4.249	0.011	197	0.011
16.500	990	4.289	0.9933	4.260	0.011	198	0.011
16.583	995	4.300	0.9934	4.272	0.011	199	0.011
16.667	1000	4.311	0.9934	4.283	0.011	200	0.011
16.750	1005	4.322	0.9934	4.294	0.011	201	0.011
16.833	1010	4.333	0.9934	4.305	0.011	202	0.011
16.917	1015	4.344	0.9934	4.316	0.011	203	0.011
17.000	1020	4.355	0.9934	4.327	0.011	204	0.011
17.083	1025	4.366	0.9935	4.338	0.011	205	0.011
17.167	1030	4.377	0.9935	4.349	0.011	206	0.011
17.250	1035	4.388	0.9935	4.360	0.011	207	0.011
17.333	1040	4.399	0.9935	4.371	0.011	208	0.011
17.417	1045	4.410	0.9935	4.381	0.011	209	0.011
17.500	1050	4.421	0.9936	4.392	0.011	210	0.011
17.583	1055	4.432	0.9936	4.403	0.011	211	0.011
17.667	1060	4.442	0.9936	4.414	0.011	212	0.011
17.750	1065	4.453	0.9936	4.425	0.011	213	0.011
17.833	1070	4.464	0.9936	4.435	0.011	214	0.011
17.917	1075	4.475	0.9936	4.446	0.011	215	0.011
18.000	1080	4.485	0.9937	4.457	0.011	216	0.011
18.083	1085	4.496	0.9937	4.467	0.011	217	0.011
18.167	1090	4.507	0.9937	4.478	0.011	218	0.011
18.250	1095	4.517	0.9937	4.489	0.011	219	0.011
18.333	1100	4.528	0.9937	4.499	0.011	220	0.011
18.417	1105	4.538	0.9938	4.510	0.011	221	0.011
18.500	1110	4.549	0.9938	4.521	0.011	222	0.011
18.583	1115	4.559	0.9938	4.531	0.011	223	0.011
18.667	1120	4.570	0.9938	4.542	0.011	224	0.011
18.750	1125	4.580	0.9938	4.552	0.010	225	0.010
18.833	1130	4.591	0.9939	4.563	0.010	226	0.010
18.917	1135	4.601	0.9939	4.573	0.010	227	0.010

19.000	1140	4.612	0.9939	4.583	0.010	228	0.010
19.083	1145	4.622	0.9939	4.594	0.010	229	0.010
19.167	1150	4.632	0.9939	4.604	0.010	230	0.010
19.250	1155	4.643	0.9939	4.615	0.010	231	0.010
19.333	1160	4.653	0.9940	4.625	0.010	232	0.010
19.417	1165	4.663	0.9940	4.635	0.010	233	0.010
19.500	1170	4.674	0.9940	4.646	0.010	234	0.010
19.583	1175	4.684	0.9940	4.656	0.010	235	0.010
19.667	1180	4.694	0.9940	4.666	0.010	236	0.010
19.750	1185	4.704	0.9941	4.676	0.010	237	0.010
19.833	1190	4.714	0.9941	4.687	0.010	238	0.010
19.917	1195	4.725	0.9941	4.697	0.010	239	0.010
20.000	1200	4.735	0.9941	4.707	0.010	240	0.010
20.083	1205	4.745	0.9941	4.717	0.010	241	0.010
20.167	1210	4.755	0.9941	4.727	0.010	242	0.010
20.250	1215	4.765	0.9942	4.737	0.010	243	0.010
20.333	1220	4.775	0.9942	4.747	0.010	244	0.010
20.417	1225	4.785	0.9942	4.758	0.010	245	0.010
20.500	1230	4.795	0.9942	4.768	0.010	246	0.010
20.583	1235	4.805	0.9942	4.778	0.010	247	0.010
20.667	1240	4.815	0.9943	4.788	0.010	248	0.010
20.750	1245	4.825	0.9943	4.798	0.010	249	0.010
20.833	1250	4.835	0.9943	4.808	0.010	250	0.010
20.917	1255	4.845	0.9943	4.818	0.010	251	0.010
21.000	1260	4.855	0.9943	4.828	0.010	252	0.010
21.083	1265	4.865	0.9944	4.837	0.010	253	0.010
21.167	1270	4.875	0.9944	4.847	0.010	254	0.010
21.250	1275	4.885	0.9944	4.857	0.010	255	0.010
21.333	1280	4.895	0.9944	4.867	0.010	256	0.010
21.417	1285	4.904	0.9944	4.877	0.010	257	0.010
21.500	1290	4.914	0.9944	4.887	0.010	258	0.010
21.583	1295	4.924	0.9945	4.897	0.010	259	0.010
21.667	1300	4.934	0.9945	4.906	0.010	260	0.010
21.750	1305	4.943	0.9945	4.916	0.010	261	0.010
21.833	1310	4.953	0.9945	4.926	0.010	262	0.010
21.917	1315	4.963	0.9945	4.936	0.010	263	0.010
22.000	1320	4.973	0.9946	4.945	0.010	264	0.010
22.083	1325	4.982	0.9946	4.955	0.010	265	0.010
22.167	1330	4.992	0.9946	4.965	0.010	266	0.010
22.250	1335	5.002	0.9946	4.975	0.010	267	0.010
22.333	1340	5.011	0.9946	4.984	0.010	268	0.010
22.417	1345	5.021	0.9946	4.994	0.010	269	0.010
22.500	1350	5.030	0.9947	5.004	0.010	270	0.010
22.583	1355	5.040	0.9947	5.013	0.010	271	0.010
22.667	1360	5.049	0.9947	5.023	0.010	272	0.010
22.750	1365	5.059	0.9947	5.032	0.010	273	0.010
22.833	1370	5.068	0.9947	5.042	0.010	274	0.010

22.917	1375	5.078	0.9948	5.051	0.010	275	0.010
23.000	1380	5.087	0.9948	5.061	0.010	276	0.010
23.083	1385	5.097	0.9948	5.070	0.010	277	0.010
23.167	1390	5.106	0.9948	5.080	0.009	278	0.009
23.250	1395	5.116	0.9948	5.089	0.009	279	0.009
23.333	1400	5.125	0.9949	5.099	0.009	280	0.009
23.417	1405	5.135	0.9949	5.108	0.009	281	0.009
23.500	1410	5.144	0.9949	5.118	0.009	282	0.009
23.583	1415	5.153	0.9949	5.127	0.009	283	0.009
23.667	1420	5.163	0.9949	5.137	0.009	284	0.009
23.750	1425	5.172	0.9949	5.146	0.009	285	0.009
23.833	1430	5.181	0.9950	5.155	0.009	286	0.009
23.917	1435	5.191	0.9950	5.165	0.009	287	0.009
24.000	1440	5.200	0.9950	5.174	0.009	288	0.009

EXHIBIT D

HYDROGRAPH CALCULATIONS

Broadway Channel

I = 7.44 P6 D^{-0.645}

For duration less than 6 hours

P = I (D/60)

P24 =

Duration HRs	5 min Duration	5.174 in P	Cum Depth Area Adj	Adjusted P	Hyetograph Ordinate R	Rank	Ordinate
0.083	5	0.560	0.9560	0.535	0.535	1	0.535
0.167	10	0.716	0.9560	0.685	0.149	2	0.149
0.250	15	0.827	0.9560	0.791	0.106	3	0.106
0.333	20	0.916	0.9560	0.876	0.085	4	0.085
0.417	25	0.991	0.9560	0.948	0.072	5	0.072
0.500	30	1.058	0.9560	1.011	0.063	6	0.063
0.583	35	1.117	0.9600	1.072	0.061	7	0.061
0.667	40	1.171	0.9640	1.129	0.057	8	0.057
0.750	45	1.221	0.9680	1.182	0.053	9	0.053
0.833	50	1.268	0.9720	1.232	0.050	10	0.050
0.917	55	1.312	0.9760	1.280	0.048	11	0.048
1.000	60	1.353	0.9800	1.326	0.046	12	0.046
1.083	65	1.392	0.9803	1.364	0.039	13	0.039
1.167	70	1.429	0.9807	1.401	0.037	14	0.037
1.250	75	1.464	0.9810	1.436	0.035	15	0.035
1.333	80	1.498	0.9813	1.470	0.034	16	0.034
1.417	85	1.531	0.9817	1.503	0.032	17	0.032
1.500	90	1.562	0.9820	1.534	0.031	18	0.031
1.583	95	1.592	0.9823	1.564	0.030	19	0.030
1.667	100	1.622	0.9827	1.594	0.029	20	0.029
1.750	105	1.650	0.9830	1.622	0.028	21	0.028
1.833	110	1.677	0.9833	1.650	0.028	22	0.028
1.917	115	1.704	0.9837	1.676	0.027	23	0.027
2.000	120	1.730	0.9840	1.702	0.026	24	0.026
2.083	125	1.755	0.9843	1.728	0.025	25	0.025
2.167	130	1.780	0.9847	1.753	0.025	26	0.025
2.250	135	1.804	0.9850	1.777	0.024	27	0.024
2.333	140	1.827	0.9853	1.801	0.024	28	0.024
2.417	145	1.850	0.9857	1.824	0.023	29	0.023
2.500	150	1.873	0.9860	1.847	0.023	30	0.023
2.583	155	1.895	0.9863	1.869	0.022	31	0.022
2.667	160	1.916	0.9867	1.891	0.022	32	0.022
2.750	165	1.937	0.9870	1.912	0.021	33	0.021
2.833	170	1.958	0.9873	1.933	0.021	34	0.021
2.917	175	1.978	0.9877	1.954	0.021	35	0.021
3.000	180	1.998	0.9880	1.974	0.020	36	0.020
3.083	185	2.017	0.9881	1.993	0.019	37	0.019
3.167	190	2.037	0.9882	2.013	0.019	38	0.019
3.250	195	2.056	0.9883	2.031	0.019	39	0.019

3.333	200	2.074	0.9883	2.050	0.019	40	0.019
3.417	205	2.092	0.9884	2.068	0.018	41	0.018
3.500	210	2.110	0.9885	2.086	0.018	42	0.018
3.583	215	2.128	0.9886	2.104	0.018	43	0.018
3.667	220	2.145	0.9887	2.121	0.017	44	0.017
3.750	225	2.163	0.9888	2.138	0.017	45	0.017
3.833	230	2.180	0.9888	2.155	0.017	46	0.017
3.917	235	2.196	0.9889	2.172	0.017	47	0.017
4.000	240	2.213	0.9890	2.188	0.016	48	0.016
4.083	245	2.229	0.9891	2.205	0.016	49	0.016
4.167	250	2.245	0.9892	2.221	0.016	50	0.016
4.250	255	2.261	0.9893	2.237	0.016	51	0.016
4.333	260	2.277	0.9893	2.252	0.016	52	0.016
4.417	265	2.292	0.9894	2.268	0.015	53	0.015
4.500	270	2.307	0.9895	2.283	0.015	54	0.015
4.583	275	2.322	0.9896	2.298	0.015	55	0.015
4.667	280	2.337	0.9897	2.313	0.015	56	0.015
4.750	285	2.352	0.9898	2.328	0.015	57	0.015
4.833	290	2.367	0.9898	2.342	0.015	58	0.015
4.917	295	2.381	0.9899	2.357	0.014	59	0.014
5.000	300	2.395	0.9900	2.371	0.014	60	0.014
5.083	305	2.409	0.9901	2.385	0.014	61	0.014
5.167	310	2.423	0.9902	2.399	0.014	62	0.014
5.250	315	2.437	0.9903	2.413	0.014	63	0.014
5.333	320	2.451	0.9903	2.427	0.014	64	0.014
5.417	325	2.464	0.9904	2.441	0.014	65	0.014
5.500	330	2.478	0.9905	2.454	0.013	66	0.013
5.583	335	2.491	0.9906	2.467	0.013	67	0.013
5.667	340	2.504	0.9907	2.481	0.013	68	0.013
5.750	345	2.517	0.9908	2.494	0.013	69	0.013
5.833	350	2.530	0.9908	2.507	0.013	70	0.013
5.917	355	2.543	0.9909	2.520	0.013	71	0.013
6.000	360	2.55	0.9910	2.527	0.007	72	0.007
6.083	365	2.568	0.9910	2.545	0.018	73	0.018
6.167	370	2.586	0.9910	2.563	0.018	74	0.018
6.250	375	2.604	0.9911	2.581	0.018	75	0.018
6.333	380	2.622	0.9911	2.598	0.018	76	0.018
6.417	385	2.640	0.9911	2.616	0.018	77	0.018
6.500	390	2.657	0.9911	2.633	0.017	78	0.017
6.583	395	2.675	0.9911	2.651	0.017	79	0.017
6.667	400	2.692	0.9911	2.668	0.017	80	0.017
6.750	405	2.709	0.9912	2.685	0.017	81	0.017
6.833	410	2.726	0.9912	2.702	0.017	82	0.017
6.917	415	2.743	0.9912	2.719	0.017	83	0.017
7.000	420	2.760	0.9912	2.736	0.017	84	0.017
7.083	425	2.777	0.9912	2.753	0.017	85	0.017
7.167	430	2.794	0.9913	2.769	0.017	86	0.017

7.250	435	2.811	0.9913	2.786	0.017	87	0.017
7.333	440	2.827	0.9913	2.802	0.016	88	0.016
7.417	445	2.844	0.9913	2.819	0.016	89	0.016
7.500	450	2.860	0.9913	2.835	0.016	90	0.016
7.583	455	2.876	0.9914	2.851	0.016	91	0.016
7.667	460	2.892	0.9914	2.867	0.016	92	0.016
7.750	465	2.909	0.9914	2.883	0.016	93	0.016
7.833	470	2.925	0.9914	2.899	0.016	94	0.016
7.917	475	2.941	0.9914	2.915	0.016	95	0.016
8.000	480	2.956	0.9914	2.931	0.016	96	0.016
8.083	485	2.972	0.9915	2.947	0.016	97	0.016
8.167	490	2.988	0.9915	2.962	0.016	98	0.016
8.250	495	3.004	0.9915	2.978	0.016	99	0.016
8.333	500	3.019	0.9915	2.993	0.015	100	0.015
8.417	505	3.035	0.9915	3.009	0.015	101	0.015
8.500	510	3.050	0.9916	3.024	0.015	102	0.015
8.583	515	3.065	0.9916	3.039	0.015	103	0.015
8.667	520	3.081	0.9916	3.055	0.015	104	0.015
8.750	525	3.096	0.9916	3.070	0.015	105	0.015
8.833	530	3.111	0.9916	3.085	0.015	106	0.015
8.917	535	3.126	0.9916	3.100	0.015	107	0.015
9.000	540	3.141	0.9917	3.115	0.015	108	0.015
9.083	545	3.156	0.9917	3.130	0.015	109	0.015
9.167	550	3.171	0.9917	3.144	0.015	110	0.015
9.250	555	3.185	0.9917	3.159	0.015	111	0.015
9.333	560	3.200	0.9917	3.174	0.015	112	0.015
9.417	565	3.215	0.9918	3.188	0.015	113	0.015
9.500	570	3.229	0.9918	3.203	0.015	114	0.015
9.583	575	3.244	0.9918	3.217	0.014	115	0.014
9.667	580	3.258	0.9918	3.232	0.014	116	0.014
9.750	585	3.273	0.9918	3.246	0.014	117	0.014
9.833	590	3.287	0.9919	3.260	0.014	118	0.014
9.917	595	3.301	0.9919	3.275	0.014	119	0.014
10.000	600	3.316	0.9919	3.289	0.014	120	0.014
10.083	605	3.330	0.9919	3.303	0.014	121	0.014
10.167	610	3.344	0.9919	3.317	0.014	122	0.014
10.250	615	3.358	0.9919	3.331	0.014	123	0.014
10.333	620	3.372	0.9920	3.345	0.014	124	0.014
10.417	625	3.386	0.9920	3.359	0.014	125	0.014
10.500	630	3.400	0.9920	3.373	0.014	126	0.014
10.583	635	3.414	0.9920	3.386	0.014	127	0.014
10.667	640	3.428	0.9920	3.400	0.014	128	0.014
10.750	645	3.441	0.9921	3.414	0.014	129	0.014
10.833	650	3.455	0.9921	3.428	0.014	130	0.014
10.917	655	3.469	0.9921	3.441	0.014	131	0.014
11.000	660	3.482	0.9921	3.455	0.014	132	0.014
11.083	665	3.496	0.9921	3.468	0.013	133	0.013

11.167	670	3.509	0.9921	3.482	0.013	134	0.013
11.250	675	3.523	0.9922	3.495	0.013	135	0.013
11.333	680	3.536	0.9922	3.508	0.013	136	0.013
11.417	685	3.549	0.9922	3.522	0.013	137	0.013
11.500	690	3.563	0.9922	3.535	0.013	138	0.013
11.583	695	3.576	0.9922	3.548	0.013	139	0.013
11.667	700	3.589	0.9923	3.561	0.013	140	0.013
11.750	705	3.602	0.9923	3.574	0.013	141	0.013
11.833	710	3.615	0.9923	3.587	0.013	142	0.013
11.917	715	3.628	0.9923	3.601	0.013	143	0.013
12.000	720	3.641	0.9923	3.614	0.013	144	0.013
12.083	725	3.654	0.9924	3.626	0.013	145	0.013
12.167	730	3.667	0.9924	3.639	0.013	146	0.013
12.250	735	3.680	0.9924	3.652	0.013	147	0.013
12.333	740	3.693	0.9924	3.665	0.013	148	0.013
12.417	745	3.706	0.9924	3.678	0.013	149	0.013
12.500	750	3.719	0.9924	3.691	0.013	150	0.013
12.583	755	3.731	0.9925	3.703	0.013	151	0.013
12.667	760	3.744	0.9925	3.716	0.013	152	0.013
12.750	765	3.757	0.9925	3.729	0.013	153	0.013
12.833	770	3.769	0.9925	3.741	0.013	154	0.013
12.917	775	3.782	0.9925	3.754	0.013	155	0.013
13.000	780	3.794	0.9926	3.766	0.012	156	0.012
13.083	785	3.807	0.9926	3.779	0.012	157	0.012
13.167	790	3.819	0.9926	3.791	0.012	158	0.012
13.250	795	3.832	0.9926	3.803	0.012	159	0.012
13.333	800	3.844	0.9926	3.816	0.012	160	0.012
13.417	805	3.856	0.9926	3.828	0.012	161	0.012
13.500	810	3.869	0.9927	3.840	0.012	162	0.012
13.583	815	3.881	0.9927	3.853	0.012	163	0.012
13.667	820	3.893	0.9927	3.865	0.012	164	0.012
13.750	825	3.905	0.9927	3.877	0.012	165	0.012
13.833	830	3.918	0.9927	3.889	0.012	166	0.012
13.917	835	3.930	0.9928	3.901	0.012	167	0.012
14.000	840	3.942	0.9928	3.913	0.012	168	0.012
14.083	845	3.954	0.9928	3.925	0.012	169	0.012
14.167	850	3.966	0.9928	3.937	0.012	170	0.012
14.250	855	3.978	0.9928	3.949	0.012	171	0.012
14.333	860	3.990	0.9929	3.961	0.012	172	0.012
14.417	865	4.002	0.9929	3.973	0.012	173	0.012
14.500	870	4.013	0.9929	3.985	0.012	174	0.012
14.583	875	4.025	0.9929	3.997	0.012	175	0.012
14.667	880	4.037	0.9929	4.009	0.012	176	0.012
14.750	885	4.049	0.9929	4.020	0.012	177	0.012
14.833	890	4.061	0.9930	4.032	0.012	178	0.012
14.917	895	4.072	0.9930	4.044	0.012	179	0.012
15.000	900	4.084	0.9930	4.055	0.012	180	0.012

15.083	905	4.096	0.9930	4.067	0.012	181	0.012
15.167	910	4.107	0.9930	4.079	0.012	182	0.012
15.250	915	4.119	0.9931	4.090	0.012	183	0.012
15.333	920	4.130	0.9931	4.102	0.012	184	0.012
15.417	925	4.142	0.9931	4.113	0.012	185	0.012
15.500	930	4.153	0.9931	4.125	0.011	186	0.011
15.583	935	4.165	0.9931	4.136	0.011	187	0.011
15.667	940	4.176	0.9931	4.148	0.011	188	0.011
15.750	945	4.188	0.9932	4.159	0.011	189	0.011
15.833	950	4.199	0.9932	4.170	0.011	190	0.011
15.917	955	4.210	0.9932	4.182	0.011	191	0.011
16.000	960	4.222	0.9932	4.193	0.011	192	0.011
16.083	965	4.233	0.9932	4.204	0.011	193	0.011
16.167	970	4.244	0.9933	4.216	0.011	194	0.011
16.250	975	4.256	0.9933	4.227	0.011	195	0.011
16.333	980	4.267	0.9933	4.238	0.011	196	0.011
16.417	985	4.278	0.9933	4.249	0.011	197	0.011
16.500	990	4.289	0.9933	4.260	0.011	198	0.011
16.583	995	4.300	0.9934	4.272	0.011	199	0.011
16.667	1000	4.311	0.9934	4.283	0.011	200	0.011
16.750	1005	4.322	0.9934	4.294	0.011	201	0.011
16.833	1010	4.333	0.9934	4.305	0.011	202	0.011
16.917	1015	4.344	0.9934	4.316	0.011	203	0.011
17.000	1020	4.355	0.9934	4.327	0.011	204	0.011
17.083	1025	4.366	0.9935	4.338	0.011	205	0.011
17.167	1030	4.377	0.9935	4.349	0.011	206	0.011
17.250	1035	4.388	0.9935	4.360	0.011	207	0.011
17.333	1040	4.399	0.9935	4.371	0.011	208	0.011
17.417	1045	4.410	0.9935	4.381	0.011	209	0.011
17.500	1050	4.421	0.9936	4.392	0.011	210	0.011
17.583	1055	4.432	0.9936	4.403	0.011	211	0.011
17.667	1060	4.442	0.9936	4.414	0.011	212	0.011
17.750	1065	4.453	0.9936	4.425	0.011	213	0.011
17.833	1070	4.464	0.9936	4.435	0.011	214	0.011
17.917	1075	4.475	0.9936	4.446	0.011	215	0.011
18.000	1080	4.485	0.9937	4.457	0.011	216	0.011
18.083	1085	4.496	0.9937	4.467	0.011	217	0.011
18.167	1090	4.507	0.9937	4.478	0.011	218	0.011
18.250	1095	4.517	0.9937	4.489	0.011	219	0.011
18.333	1100	4.528	0.9937	4.499	0.011	220	0.011
18.417	1105	4.538	0.9938	4.510	0.011	221	0.011
18.500	1110	4.549	0.9938	4.521	0.011	222	0.011
18.583	1115	4.559	0.9938	4.531	0.011	223	0.011
18.667	1120	4.570	0.9938	4.542	0.011	224	0.011
18.750	1125	4.580	0.9938	4.552	0.010	225	0.010
18.833	1130	4.591	0.9939	4.563	0.010	226	0.010
18.917	1135	4.601	0.9939	4.573	0.010	227	0.010

19.000	1140	4.612	0.9939	4.583	0.010	228	0.010
19.083	1145	4.622	0.9939	4.594	0.010	229	0.010
19.167	1150	4.632	0.9939	4.604	0.010	230	0.010
19.250	1155	4.643	0.9939	4.615	0.010	231	0.010
19.333	1160	4.653	0.9940	4.625	0.010	232	0.010
19.417	1165	4.663	0.9940	4.635	0.010	233	0.010
19.500	1170	4.674	0.9940	4.646	0.010	234	0.010
19.583	1175	4.684	0.9940	4.656	0.010	235	0.010
19.667	1180	4.694	0.9940	4.666	0.010	236	0.010
19.750	1185	4.704	0.9941	4.676	0.010	237	0.010
19.833	1190	4.714	0.9941	4.687	0.010	238	0.010
19.917	1195	4.725	0.9941	4.697	0.010	239	0.010
20.000	1200	4.735	0.9941	4.707	0.010	240	0.010
20.083	1205	4.745	0.9941	4.717	0.010	241	0.010
20.167	1210	4.755	0.9941	4.727	0.010	242	0.010
20.250	1215	4.765	0.9942	4.737	0.010	243	0.010
20.333	1220	4.775	0.9942	4.747	0.010	244	0.010
20.417	1225	4.785	0.9942	4.758	0.010	245	0.010
20.500	1230	4.795	0.9942	4.768	0.010	246	0.010
20.583	1235	4.805	0.9942	4.778	0.010	247	0.010
20.667	1240	4.815	0.9943	4.788	0.010	248	0.010
20.750	1245	4.825	0.9943	4.798	0.010	249	0.010
20.833	1250	4.835	0.9943	4.808	0.010	250	0.010
20.917	1255	4.845	0.9943	4.818	0.010	251	0.010
21.000	1260	4.855	0.9943	4.828	0.010	252	0.010
21.083	1265	4.865	0.9944	4.837	0.010	253	0.010
21.167	1270	4.875	0.9944	4.847	0.010	254	0.010
21.250	1275	4.885	0.9944	4.857	0.010	255	0.010
21.333	1280	4.895	0.9944	4.867	0.010	256	0.010
21.417	1285	4.904	0.9944	4.877	0.010	257	0.010
21.500	1290	4.914	0.9944	4.887	0.010	258	0.010
21.583	1295	4.924	0.9945	4.897	0.010	259	0.010
21.667	1300	4.934	0.9945	4.906	0.010	260	0.010
21.750	1305	4.943	0.9945	4.916	0.010	261	0.010
21.833	1310	4.953	0.9945	4.926	0.010	262	0.010
21.917	1315	4.963	0.9945	4.936	0.010	263	0.010
22.000	1320	4.973	0.9946	4.945	0.010	264	0.010
22.083	1325	4.982	0.9946	4.955	0.010	265	0.010
22.167	1330	4.992	0.9946	4.965	0.010	266	0.010
22.250	1335	5.002	0.9946	4.975	0.010	267	0.010
22.333	1340	5.011	0.9946	4.984	0.010	268	0.010
22.417	1345	5.021	0.9946	4.994	0.010	269	0.010
22.500	1350	5.030	0.9947	5.004	0.010	270	0.010
22.583	1355	5.040	0.9947	5.013	0.010	271	0.010
22.667	1360	5.049	0.9947	5.023	0.010	272	0.010
22.750	1365	5.059	0.9947	5.032	0.010	273	0.010
22.833	1370	5.068	0.9947	5.042	0.010	274	0.010

22.917	1375	5.078	0.9948	5.051	0.010	275	0.010
23.000	1380	5.087	0.9948	5.061	0.010	276	0.010
23.083	1385	5.097	0.9948	5.070	0.010	277	0.010
23.167	1390	5.106	0.9948	5.080	0.009	278	0.009
23.250	1395	5.116	0.9948	5.089	0.009	279	0.009
23.333	1400	5.125	0.9949	5.099	0.009	280	0.009
23.417	1405	5.135	0.9949	5.108	0.009	281	0.009
23.500	1410	5.144	0.9949	5.118	0.009	282	0.009
23.583	1415	5.153	0.9949	5.127	0.009	283	0.009
23.667	1420	5.163	0.9949	5.137	0.009	284	0.009
23.750	1425	5.172	0.9949	5.146	0.009	285	0.009
23.833	1430	5.181	0.9950	5.155	0.009	286	0.009
23.917	1435	5.191	0.9950	5.165	0.009	287	0.009
24.000	1440	5.200	0.9950	5.174	0.009	288	0.009

Broadway Channel

Runoff Hydrograph

Time (hrs)	Runoff (cfs)	Time (hrs)	Runoff (cfs)	Time (hrs)	Runoff (cfs)	Time (hrs)	Runoff (cfs)
0.08	-	3.25	-	6.42	33	9.58	79
0.17	-	3.33	-	6.50	34	9.67	80
0.25	-	3.42	-	6.58	35	9.75	81
0.33	-	3.50	-	6.67	36	9.83	83
0.42	-	3.58	-	6.75	37	9.92	84
0.50	-	3.67	-	6.83	38	10.00	85
0.58	-	3.75	0	6.92	40	10.08	87
0.67	-	3.83	0	7.00	41	10.17	88
0.75	-	3.92	0	7.08	42	10.25	90
0.83	-	4.00	0	7.17	43	10.33	91
0.92	-	4.08	1	7.25	44	10.42	93
1.00	-	4.17	2	7.33	45	10.50	94
1.08	-	4.25	2	7.42	47	10.58	96
1.17	-	4.33	3	7.50	48	10.67	97
1.25	-	4.42	4	7.58	49	10.75	100
1.33	-	4.50	6	7.67	50	10.83	102
1.42	-	4.58	7	7.75	51	10.92	104
1.50	-	4.67	8	7.83	52	11.00	106
1.58	-	4.75	9	7.92	54	11.08	107
1.67	-	4.83	10	8.00	55	11.17	108
1.75	-	4.92	11	8.08	56	11.25	109
1.83	-	5.00	13	8.17	57	11.33	111
1.92	-	5.08	14	8.25	58	11.42	112
2.00	-	5.17	15	8.33	60	11.50	114
2.08	-	5.25	16	8.42	61	11.58	116
2.17	-	5.33	17	8.50	62	11.67	117
2.25	-	5.42	19	8.58	63	11.75	119
2.33	-	5.50	20	8.67	65	11.83	121
2.42	-	5.58	21	8.75	66	11.92	123
2.50	-	5.67	22	8.83	67	12.00	125
2.58	-	5.75	23	8.92	68	12.08	125
2.67	-	5.83	24	9.00	70	12.17	124
2.75	-	5.92	26	9.08	71	12.25	118
2.83	-	6.00	27	9.17	72	12.33	112
2.92	-	6.08	28	9.25	73	12.42	107
3.00	-	6.17	29	9.33	75	12.50	104
3.08	-	6.25	30	9.42	76	12.58	103
3.17	-	6.33	31	9.50	77	12.67	103

Broadway Channel

Runoff Hydrograph

Time (hrs)	Runoff (cfs)	Time (hrs)	Runoff (cfs)	Time (hrs)	Runoff (cfs)	Time (hrs)	Runoff (cfs)
12.75	104	15.92	474	19.08	171	22.25	120
12.83	106	16.00	537	19.17	169	22.33	119
12.92	107	16.08	710	19.25	167	22.42	119
13.00	109	16.17	997	19.33	165	22.50	118
13.08	111	16.25	1,384	19.42	163	22.58	117
13.17	113	16.33	1,597	19.50	161	22.67	116
13.25	115	16.42	1,583	19.58	159	22.75	116
13.33	117	16.50	1,432	19.67	157	22.83	115
13.42	120	16.58	1,179	19.75	155	22.92	114
13.50	122	16.67	921	19.83	154	23.00	114
13.58	125	16.75	749	19.92	152	23.08	113
13.67	128	16.83	608	20.00	150	23.17	114
13.75	131	16.92	513	20.08	149	23.25	114
13.83	134	17.00	445	20.17	147	23.33	113
13.92	138	17.08	385	20.25	146	23.42	113
14.00	141	17.17	338	20.33	144	23.50	112
14.08	145	17.25	303	20.42	143	23.58	111
14.17	150	17.33	273	20.50	141	23.67	110
14.25	154	17.42	249	20.58	140	23.75	109
14.33	160	17.50	230	20.67	139	23.83	108
14.42	165	17.58	214	20.75	138	23.92	107
14.50	171	17.67	198	20.83	136	24.00	107
14.58	177	17.75	187	20.92	135	24.08	104
14.67	183	17.83	175	21.00	134	24.17	98
14.75	190	17.92	165	21.08	133	24.25	85
14.83	197	18.00	158	21.17	132	24.33	67
14.92	205	18.08	165	21.25	131	24.42	50
15.00	213	18.17	161	21.33	130	24.50	35
15.08	222	18.25	162	21.42	129	24.58	24
15.17	233	18.33	166	21.50	128	24.67	17
15.25	244	18.42	171	21.58	127	24.75	11
15.33	257	18.50	175	21.67	126	24.83	8
15.42	273	18.58	178	21.75	125	24.92	6
15.50	293	18.67	178	21.83	124	25.00	4
15.58	318	18.75	178	21.92	123	25.08	3
15.67	369	18.83	176	22.00	122	25.17	1
15.75	419	18.92	175	22.08	122	25.25	1
15.83	445	19.00	173	22.17	121	25.33	0

Broadway Channel - Unit Hydrograph @ Anza Street

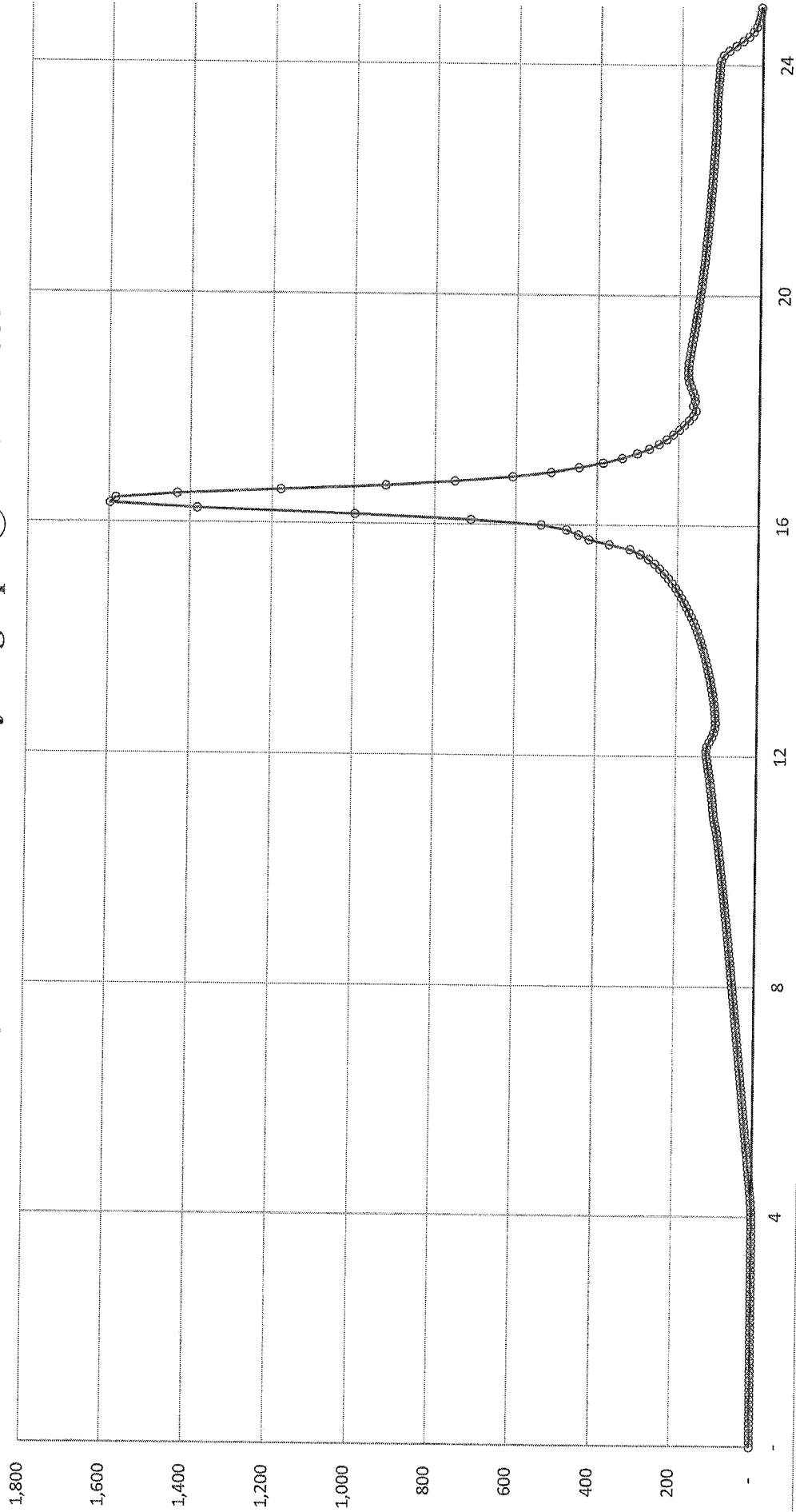


EXHIBIT E

HEC-RAS RESULTS (V 5.07)

PROFILE 1 = EXISTING

PROFILE 2 = POST PROJECT

PROFILE PLOT

SUMMARY TABLES

X	X	XXXXXXXX	XXXX	XXXX	XX	XXXX
X	X	X	X	X	X	X
X	X	X	X	X	X	X
XXXXXXXX	XXXX	X	XXX	XXXX	XXXXXX	XXXX
X	X	X	X	X	X	X
X	X	X	X	X	X	X
X	X	XXXXXXXX	XXXX	X	X	XXXXX

PROJECT DATA

Project Title: Anza Culvert 16R2 D
Project File : AnzaCulvert16R2D.prj
Run Date and Time: 10/8/2019 7:19:03 PM

Project in English units

Project Description:

Broadway Flood Control Channel
As-Built Plan Data
Culvert Method @ Anza
Street Crossing
UH Flows - County SD Methodology PZN 1.45 1597
SB&O JN
73760.60
Correct Geometry Length XSEC 2669.88
Ineff Flow Areas = RCB Width
US & DS of Anza Culvert
Adjust Overbank Lengths & Channel Height for S Curve
above Anza
Revised 2019 1008
Mixed Profile

Profile 1 is Existing
Condition UH Flows
Profile 2 is Post Development w/ Rational Method Peak
Flows
w/ Tc = 5 Min Un attenuated project flows.

PLAN DATA

Plan Title: Plan 15
Plan File : d:\73762 N Anza St\06 Entitlements\In-house Prelim Reports\HEC-RAS\Model 16R\AnzaCulvert16R2D.p15

Geometry Title: Broadway RCB29R2
Geometry File : d:\73762 N Anza St\06 Entitlements\In-house Prelim Reports\HEC-RAS\Model 16R
\AnzaCulvert16R2D.g06

Flow Title : UHCounty16R
Flow File : d:\73762 N Anza St\06 Entitlements\In-house Prelim Reports\HEC-RAS\Model 16R
\AnzaCulvert16R2D.f04

Plan Summary Information:

Number of: Cross Sections = 17 Multiple Openings = 0
Culverts = 1 Inline Structures = 0
Bridges = 0 Lateral Structures = 0

Computational Information

Water surface calculation tolerance = 0.01
Critical depth calculation tolerance = 0.01
Maximum number of iterations = 40
Maximum difference tolerance = 0.3
Flow tolerance factor = 0.001

Computation Options

Critical depth computed only where necessary
Conveyance Calculation Method: At breaks in n values only
Friction Slope Method: Program Selects Appropriate method
Computational Flow Regime: Mixed Flow

FLOW DATA

Flow Title: UHCounty16R
Flow File : d:\73762 N Anza St\06 Entitlements\In-house Prelim Reports\HEC-RAS\Model 16R\AnzaCulvert16R2D.f04

Flow Data (cfs)

River	Reach	RS	PF 1	PF 2
Broadway	1	3435.10	1570.3	1570.3

Broadway	1	2339.19	1597.2	1612.8
Broadway	1	1552	1597.2	1612.8

Boundary Conditions

River	Reach	Profile	Upstream	Downstream
Broadway	1	PF 1	Normal S = 0.0052	Normal S = 0.0125

GEOMETRY DATA

Geometry Title: Broadway RCB29R2
 Geometry File : d:\73762 N Anza St\06 Entitlements\In-house Prelim Reports\HEC-RAS\Model 16R
 \AnzaCulvert16R2D.g06

CROSS SECTION

RIVER: Broadway
 REACH: 1
 RS: 3435.10

INPUT

Description: Below First Street UC

Station Elevation Data			num= 8		
Sta	Elev	Sta	Elev	Sta	Elev
90	462.07	93	460.07	95	460.07
115	460.07	117	460.07	120	462.07

Manning's n Values

num= 3		
Sta	n Val	Sta
90	.02	95
		115
		115

Bank Sta:	Left	Right	Lengths:	Left Channel	Right	Coeff	Contr.	Expan.
	95	115		239.1	239.1		.1	.3

CROSS SECTION

RIVER: Broadway
 REACH: 1
 RS: 3196

INPUT
 Description: GB

Station Elevation Data				num=8			
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	460.82	93	458.82	95	458.82	100	453.82
115	458.82	117	458.82	120	460.82		
						110	453.82

Manning's n Values				num= 3			
Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
90	.02	95	.014	115	.02		

Bank Sta:	Left	Right	Lengths:	Left	Channel	Right	Coeff	Contr.	Expan.
	95	115		110	110	110		.1	.3

CROSS SECTION

RIVER: Broadway
 REACH: 1 RS: 3086

INPUT

Description: 5' Deep

Station Elevation Data				num=	8				
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	459.13	93	457.13	95	457.13	95	457.13	100	452.13
115	457.13	117	457.13	120	459.13	120	459.13	110	452.13

Manning's n Values				num=				3			
Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val
90	.02	95	.014	115	.02			115	.014		
											.02

Bank Sta:	Left	Right	Lengths:	Left	Channel	Right	Coeff	Contr.	Expan.
	95	115		110	110	110		.1	.3

CROSS SECTION

RIVER: Broadway
 REACH: 1 RS: 2976

INPUT

Description: 4.5' Deep

Station Elevation Data				num= 8			
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	457.44	93.5	454.94	95.5	454.94	100	450.44
114.5	454.94	116.5	454.94	120	457.44		
						110	450.44

Manning's n Values				num=	3			
Sta	n Val	Sta	n Val	Sta	n Val	Sta	n Val	

90	.02	95.5	.014	114.5	.02				
Bank Sta:	Left	Right	Lengths:	Left Channel	Right	Coeff	Contr.	Expan.	
95.5	114.5		110	110	110		.1	.3	

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 2866

INPUT

Description: 4.5' Deep
Station Elevation Data

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	455.74	93.5	453.24	95.5	453.24	100	448.74
114.5	453.24	116.5	453.24	120	455.74		

Manning's n Values

Sta	n Val	Sta	n Val
90	.02	95.5	.014
		114.5	.02

Bank Sta:	Left	Right	Lengths:	Left Channel	Right	Coeff	Contr.	Expan.
95.5	114.5		110	110	110		.1	.3

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 2756

INPUT

Description: GB - 4.5' Deep Section Upstream
Station Elevation Data

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	453.55	93	451.55	95.5	451.55	100	447.05
114.5	451.55	117	451.55	120	453.55		

Manning's n Values

Sta	n Val	Sta	n Val
90	.02	95.5	.014
		114.5	.02

Bank Sta:	Left	Right	Lengths:	Left Channel	Right	Coeff	Contr.	Expan.
95.5	114.5		89.12	86.59	84.52		.1	.3

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 2669.88

INPUT

Description: S Curve Above Anza 4.5/5.6
Station Elevation Data num= 8

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	453.34	92.6	451.94	94.6	451.94	100	446.34
114.5	450.84	116.5	450.84	120	453.34	110	446.34

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
90	.02	94.6	.014	114.5	.02

Bank Sta:	Left	Right	Lengths:	Left Channel	Right	Coeff	Contr.	Expan.
	94.6	114.5		81.87	78.66		.1	.3

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 2589.88

INPUT

Description: S Curve Above Anza 4.6 /5.6 Deep
Station Elevation Data num= 8

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	452.67	93.5	450.17	95.5	450.17	100	445.67
115.6	451.27	117.6	451.27	120	452.67	110	445.67

Manning's n Values num= 3

Sta	n Val	Sta	n Val	Sta	n Val
90	.015	95.5	.014	115.6	.02

Bank Sta:	Left	Right	Lengths:	Left Channel	Right	Coeff	Contr.	Expan.
	95.5	115.6		77.6	82.93		.1	.3

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 2509.88

INPUT

Description: Upstream 20' Transition / GB
Station Elevation Data num= 9

Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
90	451.7	93.5	449.5	95.5	449.5	100	445	110	445
115	450	115.6	450.6	117.6	451.7	120	451.7		

Manning's n Values									
Sta		n Val		Sta		n Val		Sta	
90		.02		95.5		.014		115.6	
Bank Sta:		Left	Right	Lengths:		Left	Channel	Right	Expan.
		95.5	115.6			169.52	170.69	172.12	.5
Ineffective Flow									
Sta		Flow		num=		Permanent			
90		97.75		451.7		T			
112.25		120		451.7		T			
								.3	

CULVERT

RIVER: Broadway
 REACH: 1 RS: 2489.88

INPUT										
Description: Anza Street RCB										
Distance from Upstream XS =				20						
Deck/Roadway Width				= 130.69						
Weir Coefficient				= 2.6						
Upstream Deck/Roadway Coordinates										
num= 11										
Sta		Hi	Cord	Lo Cord		Sta		Hi	Cord	Lo Cord
80		451.48	450		93.5		451.48	449.5		
97.75		451.48	449.84		104.75		451.48	449.84		
105.25		451.48	444.84		105.25		451.48	449.84		
112.25		451.48	444.84		130		451.48	450		
					97.75		451.48	444.84		
					104.75		451.48	444.84		
					112.25		451.48	449.84		

Upstream Bridge Cross Section Data									
Station		Elevation Data		num=		9			
Sta		Elev		Sta		Elev		Sta	
90		451.7		93.5		449.5		95.5	
115		450		115.6		450.6		117.6	

Manning's n Values					
Sta	n Val	Sta	num=	Sta	n Val
90	.02	95.5	.014	115.6	.02
Bank Sta: Left Right Coeff Contr. Expan.					
	95.5	115.6		.3	.5
Ineffective Flow num= 2					

Sta L	Sta R	Elev	Permanent
90	97.75	451.7	T
112.25	120	451.7	T

Downstream Deck/Roadway Coordinates

num=	11								
Sta	Hi	Cord	Lo	Cord	Sta	Hi	Cord	Lo	Cord
80	451.7	447.66		95	451.7	447.66		97.75	451.7 442.66
97.75	451.7	447.66		104.75	451.7	447.66		104.75	451.7 442.66
105.25	451.7	442.66		105.25	451.7	447.66		112.25	451.7 447.66
112.25	451.7	442.66		130	451.7	447.66			

Downstream Bridge Cross Section Data

Station	Elevation	Data	num=	8					
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
83	451	93	447.66	95	447.66	100	442.66	110	442.66
115	447.66	117	447.66	130	451				

Manning's n Values

Sta	n	Val	Sta	n	Val
83	.03	95	.014	115	.02

Bank Sta: Left Right Coeff Contr. Expan.

95	115	.3	.5
----	-----	----	----

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
83	97.75	451.7	T
112.25	130	451.7	T

Upstream Embankment side slope = 0 horiz. to 1.0 vertical

Downstream Embankment side slope = 0 horiz. to 1.0 vertical

Maximum allowable submergence for weir flow = .98

Elevation at which weir flow begins = 451.7

Energy head used in spillway design =

Spillway height used in design =

Weir crest shape = Broad Crested

Number of Culverts = 2

Culvert Name	Shape	Rise	Span
Culvert #1	Box	5	7

FHWA Chart # 10- 90 degree headwall; Chamfered or beveled inlet

FHWA Scale # 1 - Inlet edges chamfered 3/4 inch

Solution Criteria = Highest U.S. EG

Culvert Upstrm	Dist	Length	Top n	Bottom n	Depth	Blocked	Entrance	Loss	Coef	Exit	Loss	Coef
20	130.69	.014	.014	.014	0			.5		1		

Upstream Elevation = 444.84

Centerline Station = 101.25
Downstream Elevation = 443.37
Centerline Station = 101.25

Culvert Name	Shape	Rise	Span	
Culvert #2	Box	5	7	

FWHA Chart # 10- 90 degree headwall; Chamfered or beveled inlet
FWHA Scale # 1 - Inlet edges chamfered 3/4 inch
Solution Criteria = Highest U.S. EG
Culvert Upstrm Dist Length Top n Bottom n Depth Blocked Entrance Loss Coef Exit Loss Coef
20 130.69 .014 .014 0 .5 1

Upstream Elevation = 444.84
Centerline Station = 108.75
Downstream Elevation = 443.28
Centerline Station = 108.75

CULVERT OUTPUT Profile #PF 1 Culv Group: Culvert #1

Q Culv Group (cfs)		Culv Full Len (ft)
# Barrels	1	Culv Vel US (ft/s)
Q Barrel (cfs)		Culv Vel DS (ft/s)
E.G. US. (ft)		Culv Inv El Up (ft)
W.S. US. (ft)		Culv Inv El Dn (ft)
E.G. DS (ft)		Culv Frctn Ls (ft)
W.S. DS (ft)		Culv Exit Loss (ft)
Delta EG (ft)		Culv Entr Loss (ft)
Delta WS (ft)		Q Weir (cfs)
E.G. IC (ft)		Weir Sta Lft (ft)
E.G. OC (ft)		Weir Sta Rgt (ft)
Culvert Control		Weir Submerg
Culv WS Inlet (ft)		Weir Max Depth (ft)
Culv WS Outlet (ft)		Weir Avg Depth (ft)
Culv Nml Depth (ft)		Weir Flow Area (sq ft)
Culv Crt Depth (ft)		Min El Weir Flow (ft)

444.84
443.37
451.71

Warning: The program cannot perform supercritical flow through multiple culverts. The program sets the water surface to critical depth at the downstream end of the culverts and continues on.

CULVERT OUTPUT Profile #PF 2 Culv Group: Culvert #1

Q Culv Group (cfs)		Culv Full Len (ft)
# Barrels	1	Culv Vel US (ft/s)
Q Barrel (cfs)		Culv Vel DS (ft/s)
E.G. US. (ft)		Culv Inv El Up (ft)
W.S. US. (ft)		Culv Inv El Dn (ft)

444.84
443.37

E.G. DS (ft)	Culv Frctn Ls (ft)
W.S. DS (ft)	Culv Exit Loss (ft)
Delta EG (ft)	Culv Entr Loss (ft)
Delta WS (ft)	Q Weir (cfs)
E.G. IC (ft)	Weir Sta Lft (ft)
E.G. OC (ft)	Weir Sta Rgt (ft)
Culvert Control	Weir Submerg
Culv WS Inlet (ft)	Weir Max Depth (ft)
Culv WS Outlet (ft)	Weir Avg Depth (ft)
Culv Nml Depth (ft)	Weir Flow Area (sq ft)
Culv Crt Depth (ft)	Min El Weir Flow (ft)
	451.71

Warning: The program cannot perform supercritical flow through multiple culverts. The program sets the water surface to critical depth at the downstream end of the culverts and continues on.

CULVERT OUTPUT Profile #PF 1 Culv Group: Culvert #2

Q Culv Group (cfs)	Culv Full Len (ft)
# Barrels	1
Q Barrel (cfs)	Culv Vel US (ft/s)
E.G. US. (ft)	Culv Vel DS (ft/s)
W.S. US. (ft)	Culv Inv El Up (ft)
E.G. DS (ft)	Culv Inv El Dn (ft)
W.S. DS (ft)	Culv Frctn Ls (ft)
Delta EG (ft)	Culv Exit Loss (ft)
Delta WS (ft)	Culv Entr Loss (ft)
E.G. IC (ft)	Q Weir (cfs)
E.G. OC (ft)	Weir Sta Lft (ft)
Culvert Control	Weir Sta Rgt (ft)
Culv WS Inlet (ft)	Weir Submerg
Culv WS Outlet (ft)	Weir Max Depth (ft)
Culv Nml Depth (ft)	Weir Avg Depth (ft)
Culv Crt Depth (ft)	Weir Flow Area (sq ft)
	Min El Weir Flow (ft)
	451.71

Warning: The program cannot perform supercritical flow through multiple culverts. The program sets the water surface to critical depth at the downstream end of the culverts and continues on.

CULVERT OUTPUT Profile #PF 2 Culv Group: Culvert #2

Q Culv Group (cfs)	Culv Full Len (ft)
# Barrels	1
Q Barrel (cfs)	Culv Vel US (ft/s)
E.G. US. (ft)	Culv Vel DS (ft/s)
	Culv Inv El Up (ft)
	444.84

W.S. US. (ft)	Culv Inv El Dn (ft)	443.28
E.G. DS (ft)	Culv Frctn Ls (ft)	
W.S. DS (ft)	Culv Exit Loss (ft)	
Delta EG (ft)	Culv Entr Loss (ft)	
Delta WS (ft)	Q Weir (cfs)	
E.G. IC (ft)	Weir Sta Lft (ft)	
E.G. OC (ft)	Weir Sta Rgt (ft)	
Culvert Control	Weir Submerg	
Culv WS Inlet (ft)	Weir Max Depth (ft)	
Culv WS Outlet (ft)	Weir Avg Depth (ft)	
Culv Nml Depth (ft)	Weir Flow Area (sq ft)	
Culv Crt Depth (ft)	Min El Weir Flow (ft)	451.71

Warning: The program cannot perform supercritical flow through multiple culverts. The program sets the water surface to critical depth at the downstream end of the culverts and continues on.

CROSS SECTION

RIVER: Broadway
 REACH: 1 RS: 2339.19

INPUT

Description: Transition 20' Downstream / GB

Station Elevation Data		num= 8	
Sta	Elev	Sta	Elev
83	451	93	447.66
115	447.66	117	447.66
		130	451

Manning's n Values

Sta n Val		num= 3	
Sta	n Val	Sta	n Val
83	.03	95	.014
		115	.02

Bank Sta:	Left	Right	Lengths: Left Channel		Right	Coeff	Contr.	Expan.
	95	115	38.19	38.19	38.19		.3	.5

Ineffective Flow num= 2

Sta L	Sta R	Elev	Permanent
83	97.75	451.7	T
112.25	130	451.7	T

CROSS SECTION

RIVER: Broadway
 REACH: 1 RS: 2301

INPUT

Description:

Station Elevation Data				num=			
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
83	449.46	93	447.46	95	447.46	100	442.46
115	447.46	117	447.46	130	449.46		

Manning's n Values

num=			
Sta	n Val	Sta	n Val
83	.02	95	.014
		115	.02

Bank Sta:	Left	Right	Lengths:	Left	Channel	Right	Coeff	Contr.	Expan.
	95	115		30	30	30		.1	.3

CROSS SECTION

RIVER: Broadway

REACH: 1 RS: 2271

INPUT

Description:

Station Elevation Data				num=			
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
83	449.3	93	447.3	95	447.3	100	442.3
115	447.3	117	447.3	130	449.3		

Manning's n Values

num=			
Sta	n Val	Sta	n Val
83	.02	95	.014
		115	.02

Bank Sta:	Left	Right	Lengths:	Left	Channel	Right	Coeff	Contr.	Expan.
	95	115		30	30	30		.1	.3

CROSS SECTION

RIVER: Broadway

REACH: 1 RS: 2241

INPUT

Description: GB

Station Elevation Data				num=			
Sta	Elev	Sta	Elev	Sta	Elev	Sta	Elev
83	449.15	93	447.15	95	447.15	100	442.15
115	447.15	117	447.15	130	449.15		

Manning's n Values
Sta n Val Sta n Val Sta n Val
83 .02 95 .014 115 .02

Bank Sta: Left 95 Right 115 Lengths: Left 76 Channel 76 Right 76 Coeff Contr. .1 Expan. .3

CROSS SECTION

RIVER: Broadway
REACH: 1 RS: 2165

INPUT

Description:
Station Elevation Data num= 8
Sta Elev Sta Elev Sta Elev Sta Elev
83 448.54 93 446.54 95 446.54 100 441.54
115 446.54 117 446.54 130 448.54

Manning's n Values
Sta n Val Sta n Val Sta n Val
83 .02 95 .014 115 .02

Bank Sta: Left 95 Right 115 Lengths: Left 100 Channel 100 Right 100 Coeff Contr. .1 Expan. .3

CROSS SECTION

RIVER: Broadway
REACH: 1 RS: 2065

INPUT

Description:
Station Elevation Data num= 8
Sta Elev Sta Elev Sta Elev Sta Elev
83 447.74 93 445.74 95 445.74 100 440.74
115 445.74 117 445.74 130 447.74

Manning's n Values
Sta n Val Sta n Val Sta n Val
83 .02 95 .014 115 .02

Bank Sta: Left 95 Right 115 Lengths: Left 100 Channel 100 Right 100 Coeff Contr. .1 Expan. .3

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 1965

INPUT

Description:		Station Elevation Data		num=		8	
		Sta	Elev	Sta	Elev	Sta	Elev
		83	446.95	93	444.95	95	444.95
		115	444.95	117	444.95	130	446.95
						100	439.95
						110	439.95

Manning's n Values		num=		3
Sta	n Val	Sta	n Val	Sta
83	.02	95	.014	115
			.02	
				115
				.02

Bank Sta:	Left	Right	Lengths:	Left	Channel	Right	Coeff	Contr.	Expan.
	95	115		413		413		.1	.3

CROSS SECTION

RIVER: Broadway
REACH: 1
RS: 1552

INPUT

Description:			
Station Elevation Data			
Sta	Elev	Sta	Elev
83	441.78	93	439.78
115	439.78	117	439.78
		130	441.78
		95	439.78
		100	434.78
		110	434.78

Manning's n Values				num=	3	
Sta	n Val	Sta	n Val	Sta	n Val	
83	.02	95		115	.02	
				Lengths: Left Channel Right		
Bank Sta:	Left	Right		19.7	19.7	19.7
	95	115				
				Coeff Contr. Expan.		
				.1 .3		

SUMMARY OF MANNING'S N VALUES

River:Broadway

Reach	River Sta.	n1	n2	n3
1	3435.10	.02	.014	.02
1	3196	.02	.014	.02
1	3086	.02	.014	.02
1	2976	.02	.014	.02
1	2866	.02	.014	.02
1	2756	.02	.014	.02
1	2669.88	.02	.014	.02
1	2589.88	.015	.014	.02
1	2509.88	.02	.014	.02
1	2489.88	Culvert		
1	2339.19	.03	.014	.02
1	2301	.02	.014	.02
1	2271	.02	.014	.02
1	2241	.02	.014	.02
1	2165	.02	.014	.02
1	2065	.02	.014	.02
1	1965	.02	.014	.02
1	1552	.02	.014	.02

SUMMARY OF REACH LENGTHS

River: Broadway

Reach	River Sta.	Left	Channel	Right
1	3435.10	239.1	239.1	239.1
1	3196	110	110	110
1	3086	110	110	110
1	2976	110	110	110
1	2866	110	110	110
1	2756	89.12	86.59	84.52
1	2669.88	81.87	80	78.66
1	2589.88	77.6	80	82.93
1	2509.88	169.52	170.69	172.12
1	2489.88	Culvert		
1	2339.19	38.19	38.19	38.19
1	2301	30	30	30
1	2271	30	30	30
1	2241	76	76	76
1	2165	100	100	100
1	2065	100	100	100
1	1965	413	413	413

1 1552 19.7 19.7 19.7

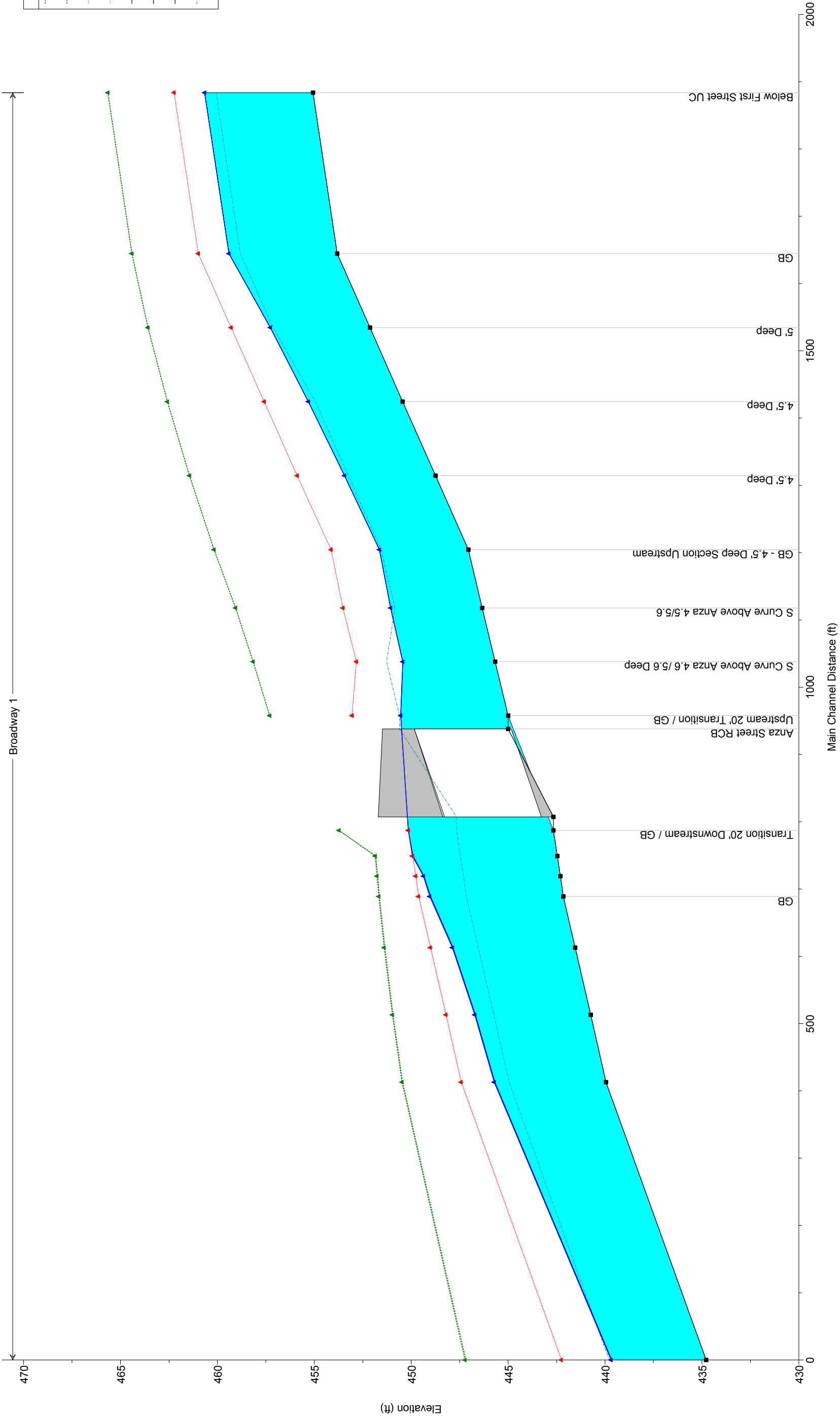
SUMMARY OF CONTRACTION AND EXPANSION COEFFICIENTS
River: Broadway

Reach	River Sta.	Contr.	Expan.
1	3435.10	.1	.3
1	3196	.1	.3
1	3086	.1	.3
1	2976	.1	.3
1	2866	.1	.3
1	2756	.1	.3
1	2669.88	.1	.3
1	2589.88	.1	.3
1	2509.88	.3	.5
1	2489.88	Culvert	
1	2339.19		.5
1	2301	.1	.3
1	2271	.1	.3
1	2241	.1	.3
1	2165	.1	.3
1	2065	.1	.3
1	1965	.1	.3
1	1552	.1	.3

HEC-RAS Plan: Plan15 River: Broadway Reach: 1

Reach	River Sta	Profile	Q Total (cfs)	Min Ch El (ft)	W.S. Elev (ft)	Crit W.S. (ft)	E.G. Elev (ft)	E.G. Slope (ft/ft)	Vel Chnl (ft/s)	Flow Area (sq ft)	Top Width (ft)	Froude # Chl
1	3435.10	PF 1	1570.30	455.07	460.66	462.24	465.65	0.005202	17.97	89.74	25.78	1.52
1	3435.10	PF 2	1570.30	455.07	460.66	462.24	465.65	0.005202	17.97	89.74	25.78	1.52
1	3196	PF 1	1570.30	453.82	459.41	460.99	464.41	0.005225	18.00	89.60	25.76	1.52
1	3196	PF 2	1570.30	453.82	459.41	460.99	464.41	0.005225	18.00	89.60	25.76	1.52
1	3086	PF 1	1570.30	452.13	457.27	459.30	463.58	0.007565	20.15	78.47	24.43	1.80
1	3086	PF 2	1570.30	452.13	457.27	459.30	463.58	0.007565	20.15	78.47	24.43	1.80
1	2976	PF 1	1570.30	450.44	455.31	457.59	462.58	0.008926	21.67	73.87	24.03	1.96
1	2976	PF 2	1570.30	450.44	455.31	457.59	462.58	0.008926	21.67	73.87	24.03	1.96
1	2866	PF 1	1570.30	448.74	453.44	455.89	461.44	0.010385	22.70	69.96	23.57	2.10
1	2866	PF 2	1570.30	448.74	453.44	455.89	461.44	0.010385	22.70	69.96	23.57	2.10
1	2756	PF 1	1570.30	447.05	451.64	454.14	460.18	0.011553	23.44	67.41	24.27	2.20
1	2756	PF 2	1570.30	447.05	451.64	454.14	460.18	0.011553	23.44	67.41	24.27	2.20
1	2669.88	PF 1	1570.30	446.34	451.06	453.53	459.06	0.010491	22.69	69.63	21.37	2.10
1	2669.88	PF 2	1570.30	446.34	451.06	453.53	459.06	0.010491	22.69	69.63	21.37	2.10
1	2589.88	PF 1	1570.30	445.67	450.43	452.83	458.16	0.010024	22.31	70.86	21.63	2.06
1	2589.88	PF 2	1570.30	445.67	450.43	452.83	458.16	0.010024	22.31	70.86	21.63	2.06
1	2509.88	PF 1	1570.30	445.00	450.54	453.06	457.30	0.005047	20.86	75.28	23.70	1.61
1	2509.88	PF 2	1570.30	445.00	450.54	453.06	457.30	0.005047	20.86	75.28	23.70	1.61
1	2489.88		Culvert									
1	2339.19	PF 1	1597.20	442.66	450.15	450.15	453.72	0.001806	15.17	103.52	41.14	1.00
1	2339.19	PF 2	1612.80	442.66	450.15	450.15	453.72	0.001842	15.17	103.52	41.14	1.00
1	2301	PF 1	1597.20	442.46	449.91	449.91	451.82	0.001351	11.62	167.21	47.00	0.82
1	2301	PF 2	1612.80	442.46	449.94	449.94	451.86	0.001354	11.66	168.43	47.00	0.82
1	2271	PF 1	1597.20	442.30	449.34	449.75	451.73	0.001799	12.81	148.05	47.00	0.94
1	2271	PF 2	1612.80	442.30	449.37	449.78	451.76	0.001799	12.85	149.32	47.00	0.94
1	2241	PF 1	1597.20	442.15	449.00	449.60	451.64	0.002059	13.40	139.25	45.32	1.00
1	2241	PF 2	1612.80	442.15	449.04	449.63	451.68	0.002039	13.40	141.12	45.79	0.99
1	2165	PF 1	1597.20	441.54	447.85	448.99	451.36	0.003064	15.27	116.22	39.04	1.20
1	2165	PF 2	1612.80	441.54	447.88	449.02	451.40	0.003040	15.28	117.66	39.46	1.19
1	2065	PF 1	1597.20	440.74	446.69	448.19	450.93	0.004035	16.68	102.92	34.90	1.36
1	2065	PF 2	1612.80	440.74	446.72	448.22	450.97	0.004006	16.70	104.12	35.29	1.35
1	1965	PF 1	1597.20	439.95	445.68	447.40	450.44	0.004781	17.60	95.70	32.44	1.47
1	1965	PF 2	1612.80	439.95	445.72	447.43	450.48	0.004737	17.61	96.87	32.85	1.46
1	1552	PF 1	1597.20	434.78	439.66	442.23	447.18	0.009701	21.99	72.63	19.76	2.02
1	1552	PF 2	1612.80	434.78	439.69	442.26	447.23	0.009668	22.02	73.24	19.82	2.02

Anza Culvert 16R2 D Plan: Plan 15 10/8/2019
Geom: Broadway RCB29R2 Flow: UHCounty16R



Legend
EG PF 2
EG PF 1
Crit PF 2
Crit PF 1
WS PF 2
WS PF 1
Ground
ROB

APPENDIX

COUNTY OF SAN DIEGO HYDROLOGY MANUAL EXCEPTS

3. Determination of frequency of design storm, and determination of total rainfall amount for the design storm and precipitation zone number (PZN) for the watershed location,
4. Preparation of incremental rainfall distribution,
5. Adjustment of incremental rainfall depths based on watershed area,
6. Determination of composite curve number (CN) for the watershed, which will represent different combinations of land use and soil type within the drainage area and describe the proportion of rainfall that runs off,
6. Adjustment of CN based on the PZN Condition,
7. Determination of excess rainfall amounts using the PZN adjusted composite CN for the watershed and the depth-area adjusted incremental rainfall distribution,
8. Using the dimensionless unit hydrograph approach, development of the hydrograph of direct runoff from the drainage area.

4.1 CONCEPTS AND EQUATIONS OF THE NRCS HYDROLOGIC METHOD

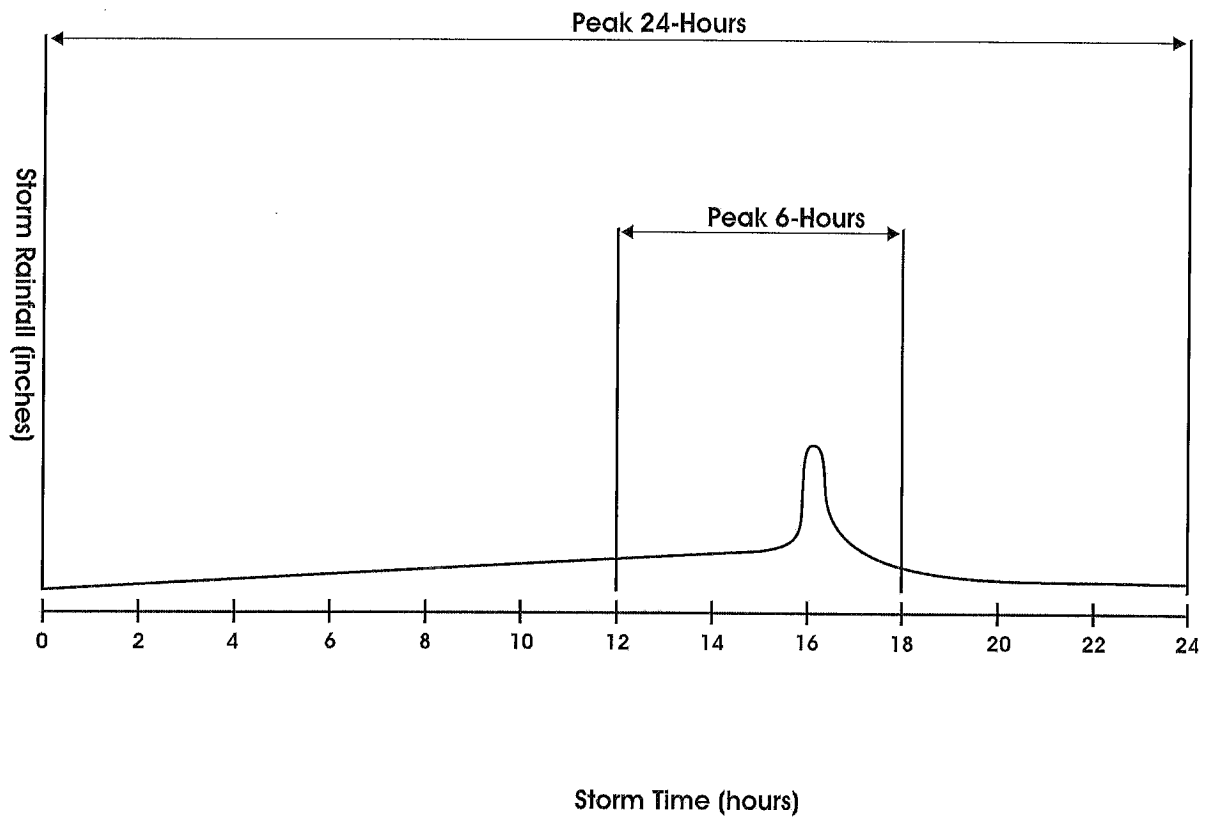
4.1.1 Rainfall Distribution

The hydrograph of storm runoff from a drainage area is based in part on the time distribution of rainfall during the storm. The variation in rainfall intensity that occurs from the beginning of the storm through the storm peak and the end of the storm is represented in the time distribution of rainfall. The time distribution of rainfall during a storm can be represented graphically as a hyetograph, a chart showing increments of average rainfall during successive units of time during a storm.

The rainfall distribution adopted for this manual is a nested storm pattern, based on the United States Army Corps of Engineers (USACE), Hydrologic Engineering Center (HEC) Training Document Number 15 (HEC TD-15), *Hydrologic Analysis of Ungaged Watersheds Using HEC-1* (USACE, 1982). A 24-hour nested storm shall be used for flood flow computations. The peak of the nested storm will occur at hour 16 of the 24-hour storm. The nested storm will be distributed about hour 16 of the 24-hour storm using a (2/3, 1/3) distribution. The nested storm pattern with (2/3, 1/3) distribution is shown in Figure 4-1. The nested storm is described below in Section 4.1.1.1, and the (2/3, 1/3) distribution is described below in Section 4.1.1.2.

The nested storm pattern with (2/3, 1/3) distribution supercedes the Type B and Type C rainfall distributions that were used in the 1993 edition of this manual for the westerly and easterly drainage areas of San Diego County, respectively. The nested storm pattern is appropriate for both the westerly and easterly drainage areas of San Diego County. A limitation of the Type B and Type C distributions was that each distribution was created for and applicable to the 6-hour and 24-hour durations only, and required separate analyses for to be prepared for each duration. In most cases, the 6-hour storm duration produced a higher peak flow rate, while the 24-hour storm duration generated a greater volume of runoff. Use of the nested storm pattern will eliminate the need for separate analyses for 6-hour and 24-hour storm durations. The Figures and Tables describing the 6-hour and 24-hour Type B and Type C rainfall distributions have been removed from this manual. The Figures and Tables describing these rainfall distributions can be obtained from the 1993 edition of this manual or from San Diego County DPWFCS if necessary for forensic study or other research.

In addition to the nested storm pattern with (2/3, 1/3) distribution, a rainfall depth-area adjustment based on the United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) Atlas 2 (NOAA Atlas 2), *Precipitation-Frequency Atlas of the Western United States, Volume IX, California* (NOAA, 1973) has been adopted with this manual. The rainfall depth-area adjustment based on NOAA Atlas 2 supersedes the Pacific Coastal Climate Area Reduction Ratio and the Arid and Semiarid



Time Distribution of Rainfall:
Nested Storm Pattern, with $(2/3, 1/3)$
Distribution

F I G U R E

4-1

Climate Area Reduction Factor given in the 1993 edition of this manual. The rainfall depth-area adjustment is discussed below in Section 4.1.1.3.

4.1.1.1 Nested Storm Pattern

The nested storm pattern is a synthetic storm with the maximum rainfall intensities for a given storm frequency nested for duration between 5 minutes and 24 hours. The maximum 5 minutes of rainfall is nested within the maximum 10 minutes; the maximum 10 minutes is nested within the maximum 15 minutes; and so forth until the 24-hour storm pattern is developed. Figure 4-1 shows the nested storm pattern. This hypothetical storm pattern is referred to in HEC TD-15 as a “balanced storm”, because of the consistent depth-frequency relation used for each peak duration interval. Use of a balanced storm permits the construction and arrangement of a storm event such that an average rainfall intensity of a specified frequency is provided for all durations – including one that matches the time-response characteristics of the particular watershed being analyzed. Every watershed is sensitive to a particular duration of rainfall that will produce the peak discharge, usually a duration approximating the time of concentration of the watershed. A nested duration design storm, analogous to a “balanced hydrograph”, ensures that each watershed will receive the design frequency depth of rainfall for its critical duration. Durations longer or shorter than the critical duration have little effect on peak discharge, although longer durations have considerable effect on total volume of runoff. Section 4.3.2 provides further guidance for creation of the rainfall distribution.

4.1.1.2 Shape of Rainfall Distribution Hyetograph

For preparation of the hyetograph (a chart showing increments of average rainfall during successive units of time during a storm) for a hydrologic study, increments of average rainfall shall be calculated using the methods described in Section 4.3.2, and a (2/3, 1/3) rainfall distribution nested about hour 16 of the 24-hour storm shall be used to distribute the rainfall increments. HEC TD-15 suggests a (1/2, 1/2) distribution in which the peak rainfall intensity is placed at the center of the storm; however, other distributions are not ruled out. A sensitivity analysis was performed for Orange County, California

watersheds (Hromadka, 1987) to determine the effect of these two storm distributions on peak flow rates. It was concluded that a reasonable variation of the design storm pattern shape would have a negligible effect on the modeling output of peak flow rate. However, the distribution of runoff volume varies within the runoff hydrograph depending upon the design storm pattern rainfall distribution. In reservoir or detention basin design the impacts on total storage volume required would be significant. This is the reason the (2/3, 1/3) distribution was adopted for this manual. Figure 4-1 shows the (2/3, 1/3) distribution nested about hour 16 of the 24-hour storm.

4.1.1.3 Rainfall Depth-Area Adjustment

The rainfall values on the isopluvial maps provided in Appendix B and the rainfall values that must be computed to create the ordinates of the nested storm pattern hyetograph represent point rainfall. However, the average rainfall over a given area will be less than the maximum point value in the area. NOAA Atlas 2 establishes a rainfall depth-area adjustment that may be applied to the point rainfall values. Figure 4-2 gives the adjustment to the point rainfall value for various rainfall durations as a function of watershed area. Table 4-1 provides the depth-area adjustment data points that are built in to the San Diego Unit Hydrograph (SDUH) Peak Discharge Program that is provided with this manual (the SDUH Peak Discharge Program is discussed in Section 4.3). These data points were obtained from Figure 4-2. For consistency between studies, it is recommended that the depth-area adjustment factors be interpolated from Table 4-1. The depth-area adjustment may be applied for watershed approximately 1 square mile or greater in size. The depth-area adjustment should be applied to the incremental rainfall amounts prior to arranging the incremental rainfall amounts in the (2/3, 1/3) distribution.

Table 4-1
RAINFALL DEPTH-AREA ADJUSTMENT DATA POINTS

Watershed Area (square miles)	Rainfall Depth-Area Adjustment for Duration				
	30-Minute	1-Hour	3-Hour	6-Hour	24-Hour
0	1.000	1.000	1.000	1.000	1.000
5	0.942	0.970	0.980	0.985	0.990
10	0.900	0.947	0.970	0.980	0.985
20	0.834	0.900	0.952	0.963	0.975
30	0.768	0.858	0.932	0.950	0.964
40	0.730	0.830	0.915	0.940	0.958
50	0.692	0.800	0.900	0.928	0.952
60	0.663	0.778	0.883	0.920	0.948
70	0.645	0.760	0.872	0.912	0.945
80	0.630	0.746	0.862	0.904	0.942
90	0.620	0.735	0.853	0.896	0.938
100	0.610	0.722	0.845	0.890	0.935
125	0.588	0.700	0.830	0.878	0.930
150	0.572	0.685	0.818	0.865	0.925
175	0.572	0.672	0.808	0.858	0.922
200	0.572	0.666	0.798	0.851	0.918
225	0.572	0.660	0.790	0.845	0.915
250	0.572	0.655	0.787	0.842	0.914
300	0.572	0.652	0.782	0.838	0.912
350	0.572	0.652	0.780	0.830	0.910
400	0.572	0.652	0.780	0.828	0.908

4.1.2 Runoff Curve Number

The hydrograph of storm runoff from a drainage area is also based in part on the physical characteristics of the watershed. The principal physical watershed characteristics affecting the relationship between rainfall and runoff are land use, land treatment, soil types, and land slope. The NRCS method uses a combination of soil conditions and land uses (ground cover) and land treatment (generally agricultural practices) to assign a runoff factor to an area. These runoff factors, called runoff curve numbers (CNs), indicate the runoff potential of an area. The higher the CN, the higher the runoff potential. The CN does not account for land slope. However, in the NRCS hydrologic method land slope is accounted for in the determination of watershed lag time (see Section 4.1.3).

The CN values in Table 4-2 are suitable for preparing hydrographs in accordance with the methods shown in Chapters 10 and 16 of NEH-4 and summarized in Section 4.2 of this manual. The CN values are based on hydrologic soil group and land use/land treatment. Tables 4-3, 4-4, and 4-5 provide descriptions of some of the terms used in Table 4-2, including vegetative condition and cover density. See the glossary for descriptions of land uses and hydrologic conditions listed in Tables 4-2 through 4-5. When a drainage area has more than one land use, a composite CN can be calculated and used in the analysis (see Section 4.2.3). It should be noted that when composite CNs are used, the analysis does not take into account the location of the specific land uses but treats the drainage area as a uniform land use represented by the composite CN.

Note: The CN values in Table 4-2 are unadjusted for PZN Condition. These are suitable where the PZN adjustment factor = 2.0, which represents the average PZN Condition. The PZN Condition and PZN adjustment factor are discussed in Section 4.1.2.4.

Table 4-2
RUNOFF CURVE NUMBERS¹ FOR PZNE CONDITION = 2.0

Cover Description	Cover Treatment or Practice ²	Hydrologic Condition ³	Average Percent Impervious Area ⁴	Curve Numbers for Hydrologic Soil Groups:			
				A	B	C	D
Developing urban areas and newly graded areas (pervious areas only, no vegetation).....				77	86	91	94
Impervious areas: Paved parking lots, roofs, and driveways (excluding right-of-way).....				98	98	98	98
Residential districts by average lot size: ⁴							
1/8 acre or less (town houses).....			65%	77	85	90	92
1/4 acre.....			38%	61	75	83	87
1/3 acre.....			30%	57	72	81	86
1/2 acre.....			25%	54	70	80	85
1 acre.....			20%	51	68	79	84
2 acres.....			12%	46	65	77	82
Streets and roads.....	Paved; curbs and storm drains (excluding right-of-way).....			98	98	98	98
	Paved; open ditches (including right-of-way).....			83	89	92	93
	Gravel (including right-of-way).....			76	85	89	91
	Hard surface (including right-of-way).....			74	84	90	92
	Dirt (including right-of-way).....			72	82	87	89
Urban districts ⁴	Commercial and business.....		85%	89	92	94	95
	Industrial.....		72%	81	88	91	93
Western desert urban areas:							
Natural desert landscaping (pervious areas only) ⁵				63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders).....				96	96	96	96

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS¹ FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice ²	Hydrologic Condition ³	Average Percent Impervious Area ⁴	Curve Numbers for Hydrologic Soil Groups:			
				A	B	C	D
Close-seeded legumes or rotated pasture.	Straight row	Poor	.....	66	77	85	89
		Good	.....	58	72	81	85
	Contoured	Poor	.....	64	75	83	85
		Good	.....	55	69	78	83
Cultivated land	Contoured and terraced	Poor	.....	63	73	80	83
		Good	.....	51	67	76	80
	Without conservation treatment	.....	.....	72	81	88	91
		With conservation treatment	.....	62	71	78	81
Fallow	Bare soil	.....	.....	77	86	91	94
	Crop residue cover	Poor	.....	76	85	90	92
Farmsteads (buildings, lanes, driveways, and surrounding lots)	.....	Good	.....	74	83	88	90
		.....	.....	59	74	82	86
	Irrigated pasture	Poor	.....	58	74	83	87
		Fair	.....	44	65	77	82
Orchards (deciduous)	.....	Good	.....	33	58	72	79
		(see glossary description)	.....	.....	.....	.....	.....
	Orchards (evergreen)	Poor	.....	57	73	82	86
		Fair	.....	44	65	77	82
Row crops	Straight row	Good	.....	33	58	72	79
		Poor	.....	72	81	88	91
	Contoured	Good	.....	67	78	85	89
		Poor	.....	70	79	84	88
.....	.....	Good	.....	65	75	82	86
							

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS¹ FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice ²	Hydrologic Condition ³	Average Percent Impervious Area ⁴	Curve Numbers for Hydrologic Soil Groups:			
				A	B	C	D
Small grain	Straight row	Poor	.....	65	76	84	88
		Good	.....	63	75	83	87
	Contoured	Poor	.....	63	74	82	85
		Good	.....	61	73	81	84
Vineyards ⁶	Disked	Poor	.....	76	85	90	92
		Good	.....	65	78	85	89
	Annual grass or legume cover	Poor	.....	50	69	79	84
		Fair	.....	38	61	74	80
Annual grass (Dryland pasture)		Poor	.....	67	78	86	89
		Fair	.....	50	69	79	84
		Poor	.....	38	61	74	80
		Good	.....	78	86	91	93
Barren Meadow		Poor	.....	63	77	85	88
		Fair	.....	51	70	80	84
		Good	.....	30	58	72	78
		Poor	.....	68	79	86	89
Open space (lawns, parks, golf courses, cemeteries, etc.) ⁷	Grass cover <50%	Poor	.....	49	69	79	84
		Fair	.....	39	61	74	80
	Grass cover 50% to 75%	Good	.....	68	79	86	89
		Poor	.....	49	69	79	84
Pasture or range land		Poor	.....	68	79	86	89
		Fair	.....	49	69	79	84
		Good	.....	39	61	74	80
		Poor	.....	67	79	86	89
Perennial grass		Poor	.....	50	69	79	84
		Fair	.....	38	61	74	80
		Good	.....	65	76	84	88
		Fair	.....	51	70	80	84

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS¹ FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice ²	Hydrologic Condition ³	Average Percent Impervious Area ⁴	Curve Numbers for Hydrologic Soil Groups: A B C D			
Turf ⁵		Poor		58	74	83	87
		Fair		44	65	77	82
		Good		33	58	72	79
Water surfaces (during floods)				97	98	99	99
Broadleaf chaparral		Poor		53	70	80	85
		Fair		40	63	75	81
		Good		31	57	71	78
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus		Poor		63	77	85	88
		Fair		55	72	81	86
		Good		49	68	79	84
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element		Poor		9	80	87	93
		Fair		9	71	81	89
		Good		9	62	74	85
Narrowleaf chaparral		Poor		71	82	88	91
		Fair		55	72	81	86
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush		Poor		9	66	74	79
		Fair		9	48	57	63
		Good		9	30	41	48
Open brush		Poor		62	76	84	88
		Fair		46	66	77	83
		Good		41	63	75	81

Table 4-2 (Continued)
RUNOFF CURVE NUMBERS¹ FOR PZN CONDITION = 2.0

Cover Description	Cover Treatment or Practice ²	Hydrologic Condition ³	Average Percent Impervious Area ⁴	Curve Numbers for Hydrologic Soil Groups:			
				A	B	C	D
Pinyon-juniper-pinyon, juniper, or both; grass understory		Poor		9	75	85	89
		Fair		9	58	73	80
		Good		9	41	61	71
Sagebrush with grass understory		Poor		9	67	80	85
		Fair		9	51	63	70
		Good		9	35	47	55
Wood or forest land		Thin stand, poor cover		45	66	77	83
		Good cover		25	55	70	77
Woods (woodland)		Poor		45	66	77	83
		Fair		36	60	73	79
		Good		28	55	70	77
Woodland-grass combination		Poor		57	73	82	86
		Fair		44	65	77	82
		Good		33	58	72	79

¹ Average runoff condition, and $I_a = 0.2S$.

² Hydrologic practices described as "straight row" and "contoured" are defined in the glossary.

³ For definition of hydrologic condition, see Tables 4-3, 4-4, and 4-5.

⁴ The average percent impervious area shown was used to develop the composite CNs. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. If the impervious area is not directly connected, the NRCS method has an adjustment to reduce the effect.

⁵ Composite CNs for natural desert landscaping should be computed based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CNs are assumed equivalent to desert shrub in poor hydrologic condition.

⁶ See glossary.

⁷ CNs shown are equivalent to those of pasture. Composite CNs may be computed for other combinations of open space cover type.

⁸ Includes lawns, cemeteries, golf courses and parks with ground cover of mowed and irrigated perennial grass.

⁹ CNs for Group A have not been developed.

Table 4-3

CLASSIFICATION OF NATIVE PASTURE OR RANGE

Vegetative Condition	Hydrologic Condition
Heavily grazed. Has no mulch or has plant cover on less than 50% of the area.	Poor
Not heavily grazed. Has plant cover on 50% to 75% of the area.	Fair
Lightly grazed. Has plant cover on more than 75% of the area.	Good

Table 4-4

**AIR-DRY WEIGHT CLASSIFICATION OF
NATIVE PASTURE OR RANGE**

Cover density	Plant and litter air-dry weight (tons per acre):		
	Less than 0.5	0.5 to 1.5	More than 1.5
Less than 50%	Poor	Poor+	Fair
50% to 75%	Poor+	Fair	Fair+
More than 75%	Fair	Fair+	Good

Table 4-5

CLASSIFICATION OF WOODS

Vegetative Condition	Hydrologic Condition
Heavily grazed or regularly burned. Litter, small trees, and brush are destroyed.	Poor
Grazed but not burned. There may be some litter but these woods are not protected.	Fair
Protected from grazing. Litter and shrubs cover the soil.	Good

4.1.2.1 Hydrologic Soil Group

Soil properties influence the relationship between rainfall and runoff since soils have differing rates of infiltration. Based on infiltration rates, the NRCS has divided soils into four hydrologic soil groups.

Group A

Soils have high infiltration rate when thoroughly wetted; chiefly deep, well-drained to excessively drained sand, gravel, or both. Rate of water transmission is high; thus runoff potential is low.

Group B

Soils have moderate infiltration rate when thoroughly wetted; chiefly soils that are moderately deep to deep, moderately well drained to well drained, and moderately coarse textured. Rate of water transmission is moderate.

Group C

Soils have slow infiltration rate when thoroughly wetted; chiefly soils that have a layer impeding downward movement of water, or moderately fine to fine textured soils that have a slow infiltration rate. Rate of water transmission is slow.

Group D

Soils have very slow infiltration rate when thoroughly wetted; chiefly clays that have a high shrink-swell potential, soils that have a high permanent water table, soils that have a claypan or clay layer at or near the surface, or soils that are shallow over nearly impervious material. Rate of water transmission is very slow.

A list of soils throughout San Diego County and their hydrologic classification is located on the map in Appendix A. Soil Survey maps can be obtained from local NRCS offices for use in estimating soil type. The NRCS maps are also available at the County of San Diego DPWFCS. Consideration should be given to the effects of urbanization on the

natural hydrologic soil group. If heavy equipment can be expected to compact the soil during construction or if grading will mix the surface and subsurface soils, appropriate changes should be made in the soil group selected.

4.1.2.2 Land Use/Land Treatment (Ground Cover)

Ground cover is used in combination with soil type to determine CN. Ground cover includes both land use and land treatment. Land use is defined as the type of watershed cover and includes every kind of vegetation, litter, mulch, and fallow as well as nonagricultural uses such as water surfaces (lakes, swamps, etc.) and impervious surfaces (roads, roofs, etc.). Land treatment applies mainly to agricultural land uses and it includes mechanical practices such as contouring or terracing and management practices such as grazing control or rotation of crops.

The NRCS has developed ground cover maps for San Diego County outlining vegetative and man-made cover. Ground cover maps can be obtained from local NRCS offices. The NRCS maps are also available at the County of San Diego DPWFCS. These maps may be used to determine the ground cover in the study area. Information on land use and treatment may also be obtained either by observation or by measurement of plant and litter density on sample areas. The CN values to be used for engineering design should correspond to the land use during the season for which maximum runoff is expected.

4.1.2.3 Urban Modifications

The urbanization of an area influences the relationship between rainfall and runoff by changing the percentage of impervious ground cover and changing the travel path of the runoff by concentrating flow in ditches, swales, gutters, channels, or pipes. The percentage of impervious area and the means of conveying runoff from impervious areas to the drainage system must be considered in computing CN for urban areas. Specifically, whether the impervious areas connect directly to the drainage system or outlet onto lawns or other pervious areas where infiltration can occur prior to entering the storm drain system must be considered.

The CN values given in Table 4-2 for urban land uses are based on directly connected impervious areas and specific assumed percentages of impervious area. An impervious area is considered directly connected if runoff from it flows directly into the drainage system. It is also considered directly connected if runoff from it occurs as concentrated shallow flow that runs over pervious areas (such as flow in a swale) and then into a drainage system. The CN values given in Table 4-2 were developed on the assumptions that:

- (a) pervious urban areas are equivalent to pasture in good hydrologic condition, and
- (b) impervious areas have a CN of 98 and are directly connected to the drainage system.

It is possible that CN values from urban areas could be reduced by not directly connecting impervious surfaces to the drainage system, but allowing runoff to flow as sheet flow over significant pervious areas. Sections 4.2.3.1 and 4.2.3.2 describe the method for adjusting CN values for land uses where impervious areas are not directly connected.

4.1.2.4 PZN Condition

The isopluvial lines representing total 6-hour and 24-hour rainfall depths that are provided in Appendix B are based on a regression analysis procedure developed from plotting the location of precipitation gauges on topography maps and developing regression equations that relate parameters of elevation and distance from the ocean to the precipitation lines. Similarly, the precipitation zone number (PZN) map provided in Appendix C was also developed to reflect the orographic effects in San Diego County. The basic categories of coast, foothill, mountain, and desert were selected as precipitation zones 1.0, 2.0, 3.0, and 4.0, respectively, because the NWS used these terms in forecasting rainfall amounts and because the county is divided into these climatic zones

for agricultural purposes. The lines between precipitation zones were adjusted to conform more closely to the isopluvial lines of equal precipitation. PZNs are read from the PZN map provided in Appendix C.

The hydrograph of storm runoff from a drainage area is based in part on the degree of watershed wetness at the beginning of the storm. The index of watershed wetness used with the runoff estimation method is PZN Condition. The PZN adjustment factor is a factor used to adjust the runoff curve number (Section 4.1.2) for the watershed to the appropriate PZN Condition. Three levels of PZN Condition are used (the PZN adjustment factors correspond to these PZN Conditions):

PZN Condition = 1.0. Lowest runoff potential. The watershed soils are dry enough for satisfactory plowing or cultivation to take place.

PZN Condition = 2.0. The average condition.

PZN Condition = 3.0. Highest runoff potential. The watershed is practically saturated from antecedent rains.

The CNs given in Table 4-2 are for PZN Condition = 2.0 (PZN adjustment factor = 2.0). CNs must be adjusted for PZN Condition based on the storm frequency and the location of the watershed within the county. The location of the watershed within the county is represented by the PZN from the map provided in Appendix C. The PZN adjustment factors for combinations of PZN and storm frequency are given in Table 4-6. The PZN adjustment factor can also be approximated by multiplying the previous 5 days of accumulated rainfall by 1.4. The maximum PZN adjustment factor is 3.0, representing PZN Condition 3.0, a saturated condition. Since the PZN adjustment factor is based on the previous 5-day precipitation amounts before major storms, a statistical analysis of these data provided the values listed in Table 4-6. Adjustment from PZN Condition 2.0 to other PZN Conditions can be accomplished by using the information shown in Tables 4-6 and 4-10 (see Section 4.2.4 for Table 4-10).

The adjustment for PZN Condition may be made to the composite CN for the watershed. It is not necessary to make the PZN Condition adjustment to each of the CNs for the different combinations of ground cover and soil group within the watershed before calculating the composite CN.

Table 4-6

**PZN ADJUSTMENT FACTORS FOR FLOW COMPUTATIONS
(San Diego County)**

Storm Frequency	Coast (PZN = 1.0)	1.5	Foothills (PZN = 2.0)	Mountains (PZN = 3.0)	Desert (PZN = 4.0)
Less than 35-year return period	1.5	2.0	2.5	2.0	1.5
Greater than or equal to 35-year return period	2.0	2.5	3.0	3.0	2.0

Notes: PZN is the precipitation zone number (see Map, Appendix C). The PZN adjustment factor represents the PZN Condition that the CN for the watershed should be adjusted to.

4.1.3 Rainfall-Runoff Relationship

A relationship between accumulated rainfall and accumulated runoff was derived by NRCS from experimental plots for numerous soils and vegetative cover conditions. The following NRCS runoff equation is used to estimate direct runoff from 24-hour or 6-hour storm rainfall. The equation is:

$$Q_a = \frac{(P - I_a)^2}{(P - I_a) + S} \quad (\text{Eq. 4-1})$$

- where: Q_a = accumulated direct runoff (in)
 P = accumulated rainfall (potential maximum runoff) (in)
 I_a = initial abstraction including surface storage, interception, evaporation, and infiltration prior to runoff (in)
 S = potential maximum soil retention (in)

S is based on the CN for the drainage area. The equation is:

$$S = 1000/CN - 10 \quad (\text{Eq. 4-2})$$

An empirical relationship used in the NRCS method for estimating I_a is:

$$I_a = 0.2S \quad (\text{Eq. 4-3})$$

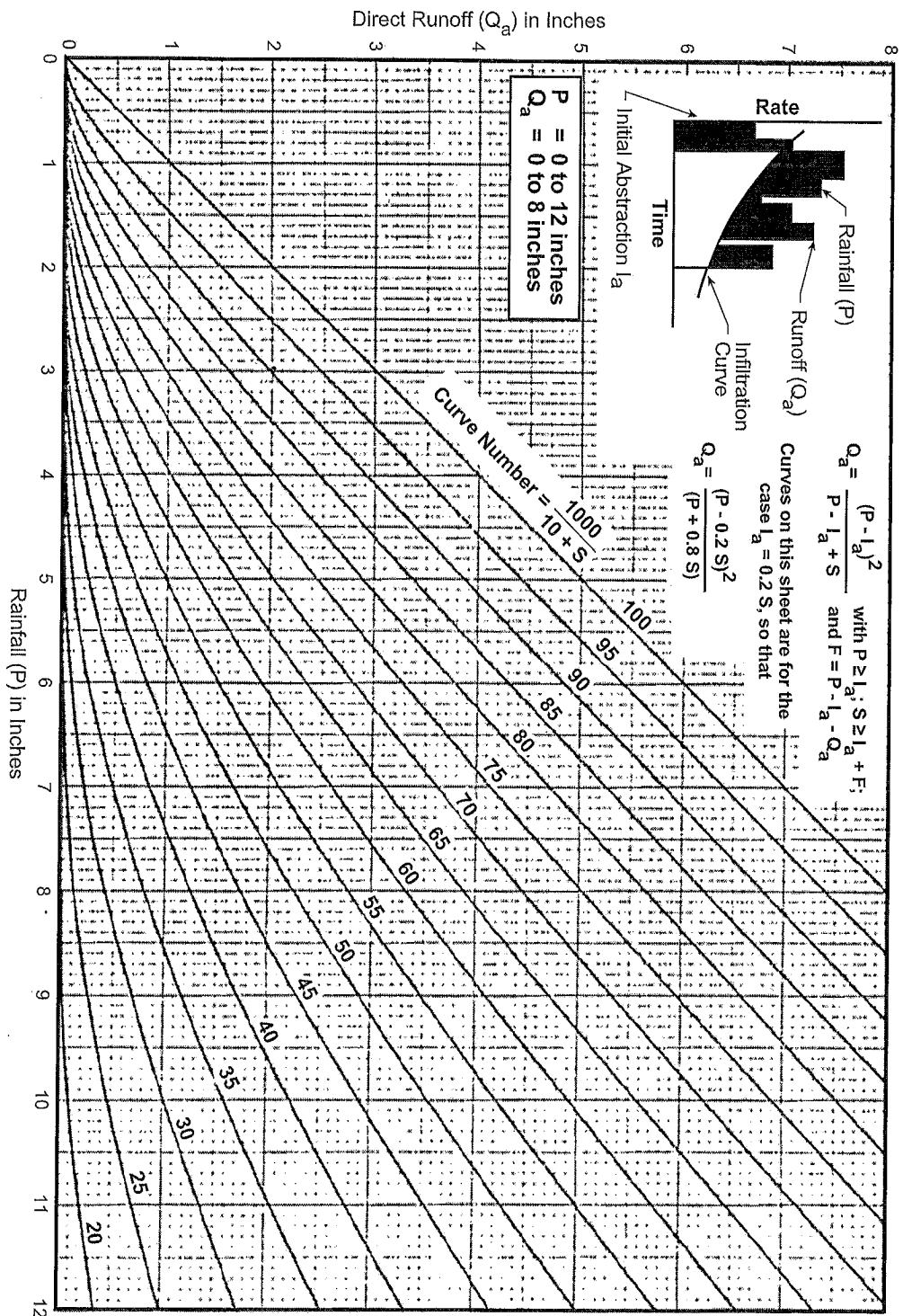
This is an average value that may be adjusted for flatter areas with more depressions if calibration data exists to substantiate the adjustment.

Substituting $0.2S$ for I_a in equation 4-1, the equation becomes:

$$Q_a = \frac{(P - 0.2S)^2}{(P + 0.8S)} \quad (\text{Eq. 4-4})$$

Equation 4-4 is subject to the limitation $P \geq 0.2S$.

Figure 4-3 shows a graphical solution of this equation. For example, 4.1 inches of direct runoff would result if 5.8 inches of rainfall occurred on a watershed with a CN of 85.



SOURCE: TR-55, Second Ed., June 1986

NRCS Solution of the Runoff Equation

FIGURE

4-3

4.1.4 Unit Hydrograph

The hydrograph of outflow from a drainage area is the sum of the elemental hydrographs from all the subareas, modified by the effects of transit time through the drainage area and storage in the stream channels. The NRCS method for estimating peak discharge and hydrographs is based on the unit hydrograph concept. The following discussion is taken from Chapter 16 of NEH-4.

To generate the peak discharge estimates and runoff hydrograph using the NRCS method, a rainfall distribution is used to estimate the variation in rainfall during the design storm event. Rainfall is divided into small time increments. The runoff hydrograph is then generated by developing incremental unit hydrographs for the different incremental rainfall time periods. The general procedure is to calculate the accumulated runoff (Q_a) using the NRCS derived equations for estimating Q_a presented below. Incremental values of Q_a are then obtained for each successive time period. These values are multiplied by the unit hydrograph peak to produce a peak value for the incremental hydrograph. The peak discharge values for incremental hydrographs provide the value for the ordinate. If the hand calculation method is used, the base of each triangle and the point of time at which the peak occurs are obtained by calculating the time from the beginning of runoff to the peak of the runoff, and the time from the peak of the runoff to the point where there is zero runoff. The result is a series of storm increments that when added together provide the runoff hydrograph.

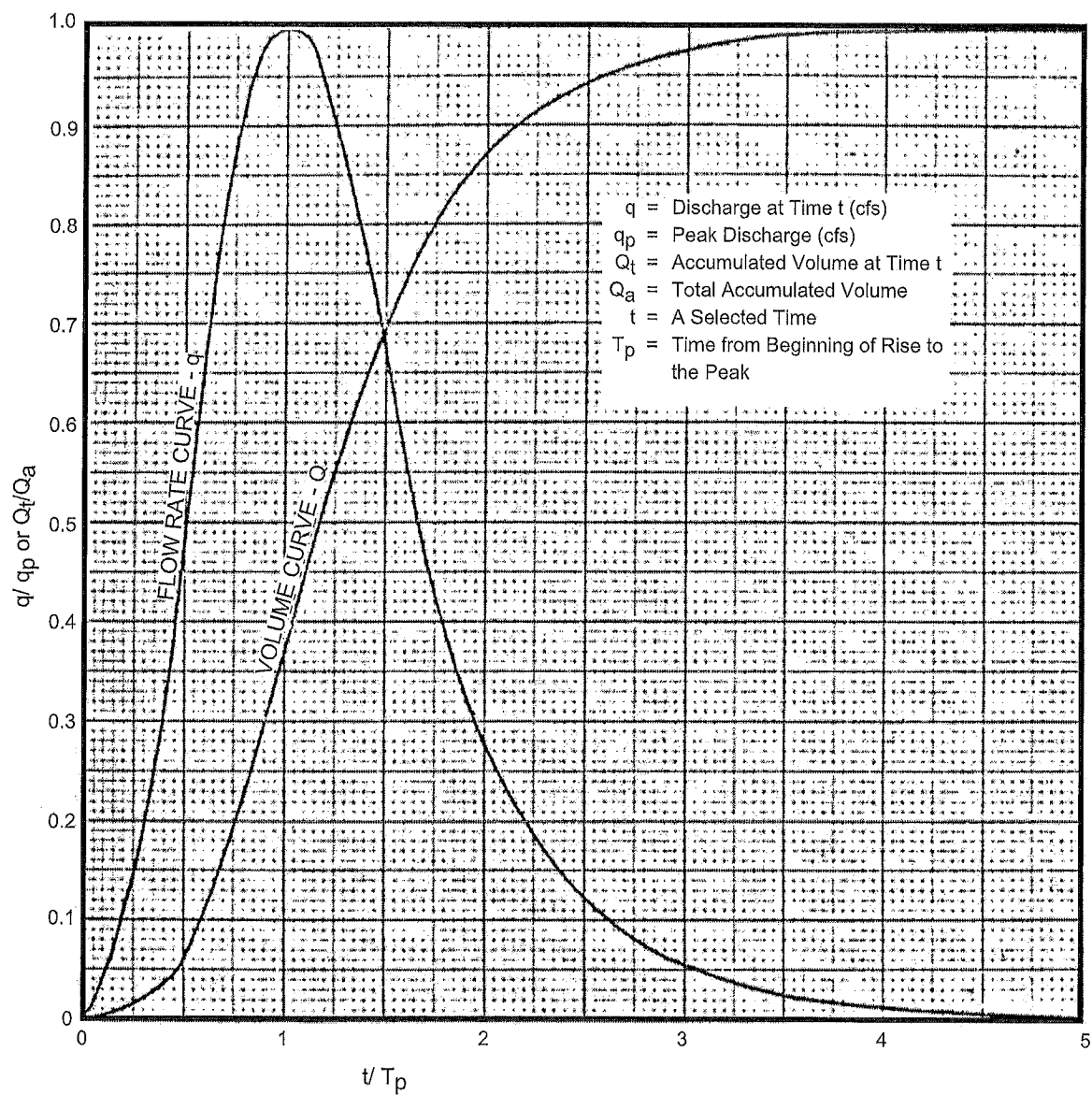
Since the physical characteristics of the drainage area, including shape, size, and slope, are constant from one storm to the next, the unit hydrograph approach assumes that there is considerable similarity in the shape of hydrographs from storms of similar rainfall characteristics (duration and intensity). Thus the unit hydrograph is a typical hydrograph for the drainage area with a runoff volume under the hydrograph equal to 1 inch from a storm of specified duration. For a storm of the same duration but with a different amount of runoff, the hydrograph of direct runoff can be expected to have the same time base as the unit hydrograph and ordinates of flow proportional to the incremental runoff volume.

Thus a storm that produces 2 inches of runoff would have a hydrograph with ordinates of flow equal to twice the ordinates of flow of the unit hydrograph. With 0.5 inches of runoff, the ordinates of flow of the hydrograph would be one-half of the ordinates of flow of the unit hydrograph.

The fundamental principles of invariance and superposition make the unit hydrograph an extremely flexible tool for developing synthetic hydrographs. The hydrograph of surface runoff from a watershed due to a given pattern of rainfall is invariable, and the hydrograph resulting from a given pattern of excess rainfall can be built up by superimposing the unit hydrograph due to the separate amounts of excess rainfall occurring in each unit period. This includes the principle of proportionality by which the ordinates of the hydrograph are proportional to the volume of excess rainfall.

The unit time or “unit hydrograph duration” is the optimum duration for occurrence of excess rainfall. In general, this unit time is approximately 20% of the time interval between the beginning of runoff from a short high-intensity storm and the peak discharge of the corresponding runoff.

The “storm duration” is the actual duration of the excess rainfall. The duration varies with actual storms. The dimensionless unit hydrograph used by NRCS (Figure 4-4) was developed by Victor Mockus. It was derived from a large number of natural unit hydrographs from watersheds varying widely in size and geographical locations. This dimensionless curvilinear hydrograph, also shown in Table 4-7, has its ordinate values expressed in a dimensionless ratio q/q_p or Q/Q_a and its abscissa values as t/T_p . This unit hydrograph has a point of inflection approximately 1.70 times the time to peak and the time-to-peak 0.2 of the time of base (T_b).



Dimensionless Unit Hydrograph and Volume Curve

FIGURE

4-4

Table 4-7

**RATIOS FOR THE NATURAL RESOURCES CONSERVATION SERVICE
DIMENSIONLESS UNIT HYDROGRAPH***

Values for (t/T _p) Increments ≈ 0.1			Values for (t/T _p) Increments = 0.2	
Time Ratios (t/T _p)	Discharge Ratios (q/q _p)	Mass Curve Ratios (Q _t /Q _a)	Time Ratios (t/T _p)	Discharge Ratios (q/q _p)
0	0.000	0.000	0	0.000
0.1	0.030	0.001	0.2	0.100
0.2	0.100	0.006	0.4	0.310
0.3	0.190	0.017	0.6	0.660
0.4	0.310	0.035	0.8	0.930
0.5	0.470	0.065	1.0	1.000
0.6	0.660	0.107	1.2	0.930
0.7	0.820	0.163	1.4	0.780
0.8	0.930	0.228	1.6	0.560
0.9	0.990	0.300	1.8	0.390
1.0	1.000	0.375	2.0	0.280
1.1	0.990	0.450	2.2	0.207
1.2	0.930	0.522	2.4	0.147
1.3	0.860	0.589	2.6	0.107
1.4	0.780	0.650	2.8	0.077
1.5	0.680	0.705	3.0	0.055
1.6	0.560	0.751	3.2	0.040
1.7	0.460	0.790	3.4	0.029
1.8	0.390	0.822	3.6	0.021
1.9	0.330	0.849	3.8	0.015
2.0	0.280	0.871	4.0	0.011
2.2	0.207	0.908	4.2	0.010
2.4	0.147	0.934	4.4	0.007
2.6	0.107	0.953	4.6	0.003
2.8	0.077	0.967	4.8	0.001
3.0	0.055	0.977	5.0	0.000
3.2	0.040	0.984	Total = 6.67	
3.4	0.029	0.989		
3.6	0.021	0.993		
3.8	0.015	0.995		
4.0	0.011	0.997		
4.5	0.005	0.999		
5.0	0.000	1.000		

*Runoff = 1 inch

Source: U.S. Department of Commerce, NEH4, 1985.

Elements of a Unit Hydrograph

The dimensionless curvilinear unit hydrograph (Figure 4-4) has 37.5% of the total volume in the rising side, which is represented by one unit of time and one unit of discharge. The dimensionless unit hydrograph also can be represented by an equivalent triangular hydrograph having the same units of time and discharge, thus having the same percent of volume in the rising side of the triangle (Figure 4-5).

This allows the base of the triangle to be solved in relation to the T_p using the geometry of triangles. Solving for the base length of the triangle, if one unit of time T_p equals 0.375 of volume:

$$T_b = \frac{1.00}{0.375} = 2.67 \text{ units of time,}$$

$$T_r = T_b - T_p = 1.67 \text{ units of time or } 1.67 T_p$$

where: T_b = time of base
 T_p = time to peak
 T_r = recession time

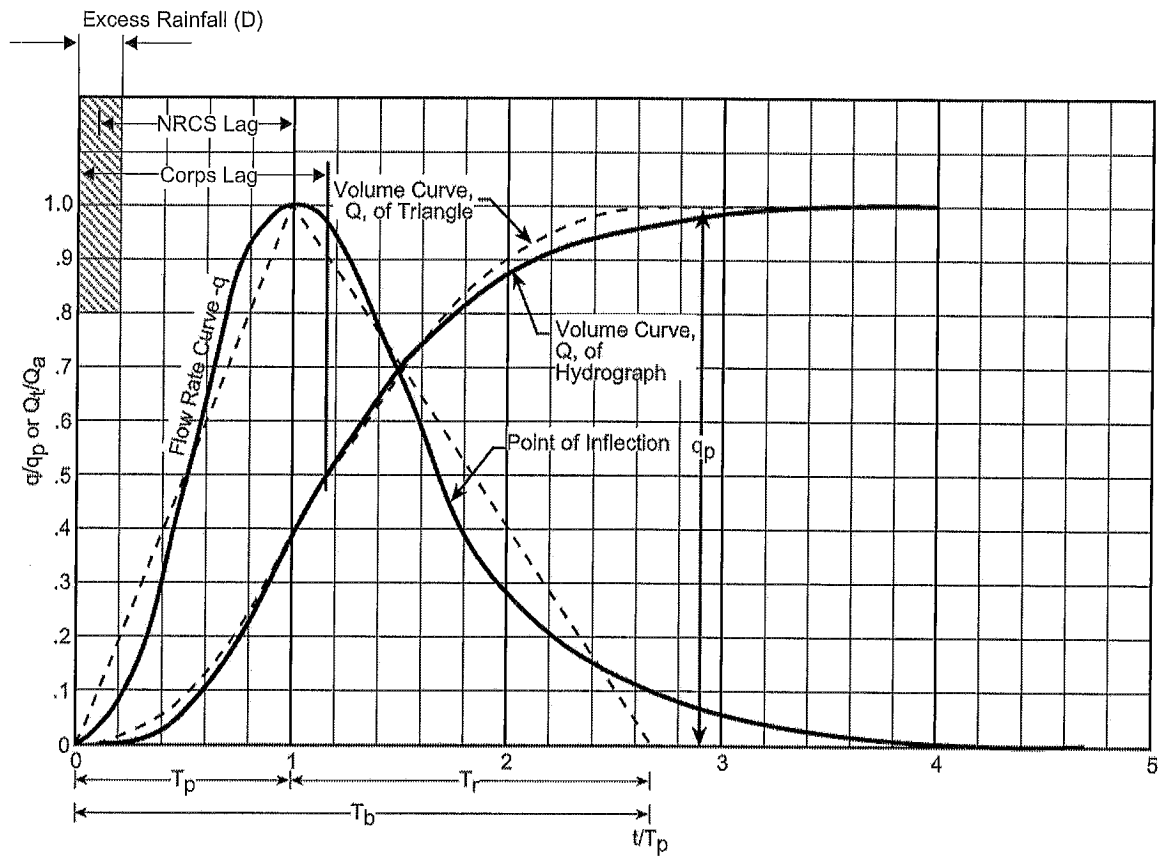
These relationships are useful in developing the peak rate equation for use with the dimensionless unit hydrograph.

Peak Rate Equation

From Figure 4-5 the total volume under the triangular unit hydrograph is:

$$Q_a = \frac{q_p T_p}{2} + \frac{q_p T_r}{2} = \frac{q_p}{2} (T_p + T_r) \quad (\text{Eq. 4-5})$$

$$\text{or, } 2Q_a = q_p (T_p + T_r)$$



Ref: NEH4, March 1985

Dimensionless Curvilinear Unit Hydrograph
and Equivalent Triangular Hydrograph

With Q_a in inches, T in hours, and area set at unity, solve for peak rate q_p .

$$q_p = \frac{2Q_a}{T_p + T_r} = \frac{2Q_a}{T_p (1.0 + T_r/T_p)} \quad (\text{inches per hour}) \quad (\text{Eq. 4-6})$$

Let

$$K = \frac{2}{1 + \frac{T_r}{T_p}} \quad (\text{Eq. 4-7})$$

Therefore,

$$q_p = \frac{KQ_a A}{T_p} \quad \text{for a unit Drainage Area} \quad (\text{Eq. 4-8})$$

($A = 1$ square mile)

In making the conversion from inches per hour to cubic feet per second and putting the equation in terms ordinarily used, including drainage area, A , in square miles, and the time, T , in hours, equation 4-12 becomes the general equation:

$$q_p = \frac{645.33 K A Q_a}{T_p} \quad (\text{Eq. 4-9})$$

Where q_p is peak discharge in cubic feet per second and the conversion factor 645.33 changes square mile inches per hour to cubic feet per second.

The relationship of the triangular unit hydrograph, $T_r = 1.67 T_p$, gives $K = 0.75$. Then substituting into equation 4-13 gives:

$$q_p = \frac{K_s A Q_a}{T_p} \quad (\text{Eq. 4-10})$$

with $K_s = 484$

K_s is a constant reflecting both the conversion of units and the shape of the hydrograph.

Any change in the dimensionless unit hydrograph reflecting a change in the percent of volume under the rising side would cause a corresponding change in the shape factor associated with the triangular hydrograph and therefore a change in the constant 484.

4.1.4.1 Curvilinear Unit Hydrographs

Obtaining constants for curvilinear hydrographs is similar to the procedure used for the triangular hydrograph. The total runoff volume (above the base flow) from the drainage area must be included in the hydrograph. Figure 4-6 shows the generalized curvilinear hydrograph.

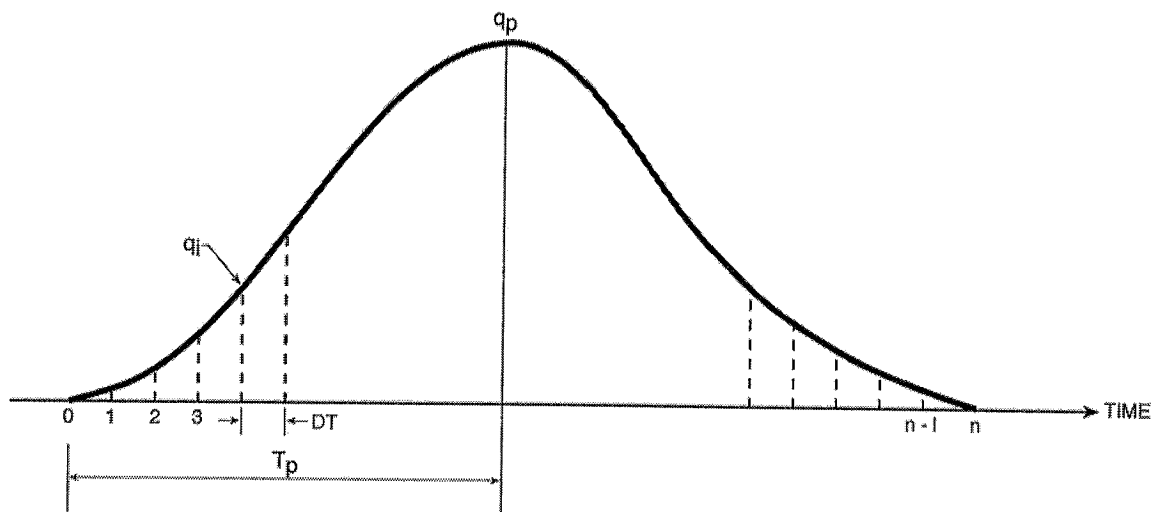


Figure 4-6. Trapezoidal Rule Illustration

q_i = the discharge in cubic feet per second at the end of time interval, i

DT = the length of the time interval in hours

q_p = the peak discharge that occurs at time T_p , as previously defined

Using the Trapezoidal Rule, the area under a curve is:

$$A = DX \left(\frac{1}{2} y_0 + y_1 + y_2 + \dots + y_{n-1} + \frac{1}{2} y_n \right)$$

$$\text{If } y_0 = y_n = 0, \text{ then } A = DX \left(\sum_{i=1}^{n-1} y_i \right).$$

Where A is the area, the y_i 's are the ordinates to the curve, DX is the distance between ordinates, and n is the total number of ordinates.

To calculate the volume under the hydrograph curve using the trapezoidal rule:

$$\begin{aligned} y_i &= q_i \\ DX &= DT \\ V &= DT \left(\sum_{i=1}^{n-1} q_i \right) \end{aligned} \quad (\text{Eq. 4-11})$$

where V is the volume in (cfs x hr)

If the following dimensionless ratios are used:

$$\begin{aligned} r_i &= q_i/q_p \\ r_t &= DT/T_p \end{aligned}$$

Then the expression for V becomes

$$V = r_t T_p \sum_{i=1}^n (r_i) q_p \quad (\text{Eq. 4-12})$$

This volume of the hydrograph is equal to the runoff volume from the drainage area:

$$V = Q_a A C \quad (\text{Eq. 4-13})$$

where: A = the drainage area in square miles
 Q_a = accumulated direct runoff
C = a constant to convert from square mile inches per hour to cubic feet per second
 $C = (5280^2 \text{ ft}^2 \text{ per mile}^2) / (12 \text{ inches per foot} \times 3600 \text{ second per hour})$
 $C = 645.33$

therefore:

$$Q_a A C = r_t T_p \sum_{i=1}^n (r_i) q_p \quad (\text{Eq. 4-14})$$

Solving for q_p :

$$\begin{aligned} q_p &= Q_a A C / (r_t T_p \Sigma(r_i)) \\ q_p &= (C / (r_t \Sigma r_i)) (A Q_a / T_p) \\ q_p &= K_s (A Q_a / T_p) \end{aligned} \quad (\text{Eq. 4-15})$$

$$\text{where: } K_s = 645 / (r_t \Sigma r_i) \quad (\text{Eq. 4-16})$$

K_s is a constant reflecting the units conversion and the shape of the hydrograph as previously defined in equation 4-14.

The summation of the ordinates (with $r_t = 0.2$) of the NRCS dimensionless unit hydrograph is 6.67 (Table 4-7). This gives a value of:

$$K_s = \frac{645}{(0.2/1) 6.67} = 484$$

Note that this is the same value computed for the NRCS triangular unit hydrograph (Figure 4-5).

4.1.4.2 Unit Hydrograph Rain Duration

Figure 4-5 shows the relationship between the period of excess rainfall (D) and the resulting unit hydrograph. The ratio D/T_p is usually taken as about 0.2, but it can vary. Large values of D/T_p may result in irregularly shaped hydrographs.

4.1.5 Time to Peak and Lag Time

Time to peak and Lag time are shown on Figure 4-5. Note that there are two definitions of lag time shown on Figure 4-5. Lag time as defined by the United States Army Corps of Engineers (Corps lag) differs from lag time as defined by the NRCS (NRCS lag). The relationships between time to peak, Corps lag, NRCS lag, duration of effective rainfall, and time of concentration are discussed in Sections 4.1.5.1 through 4.1.5.5, below. Depending on the method that will be used for NRCS hydrologic method calculations (i.e., whether the engineer will use the SDUH Peak Discharge Program, HEC-1, or hand computation); either time to peak, Corps lag, or NRCS lag will be required. Additionally depending on the data available for the study (i.e., whether a time of concentration for the study watershed has been calculated based on a rational method study, or whether watershed physical characteristics will be used to calculate Corps lag), it may be necessary to convert one parameter to another. The following discussions will define each parameter and relationships between the parameters. Section 4.3 will identify when each parameter should be used and the relationships to be used to convert one parameter to another.

4.1.5.1 Time to Peak

Time to peak is defined as the elapsed time from the beginning of unit effective rainfall to the peak flow for the point of concentration. Time to peak is used when NRCS hydrologic method calculations are performed by the hand computation method described in Section 4.3. Time to peak must be determined in order to calculate the Unit Hydrograph ordinates, which are at intervals of t/T_p . T_p may be calculated for a watershed based on Corps lag or time of concentration (see Sections 4.1.5.2 and 4.1.5.5, respectively).

4.1.5.2 Corps Lag

The lag relationship given in this section (herein referred to as Corps lag or Corps T_l) is based upon criteria developed by the United States Army Corps of Engineers (United

States Army Engineer District Los Angeles Corps of Engineers, 1976). Corps lag for a drainage area can be defined as the elapsed time (in hours) from the beginning of unit effective rainfall to the instant that the summation hydrograph for the point of concentration reaches 50% of ultimate discharge. Corps lag is an empirical expression of the physical characteristics of a drainage area in terms of time. Corps lag can be expressed by the empirical formula:

$$\text{Corps } T_l (\text{hours}) = 24 \bar{n} ((L \times L_c) / s^{0.5})^m \quad (\text{Eq. 4-17})$$

where: L = length to longest watercourse (miles)
 L_c = length along longest watercourse, measured upstream to a point opposite the watershed centroid (miles)
 s = overall slope of drainage area between the headwaters and the collection point (feet per mile)
 m = a constant determined by regional flood reconstitution studies (0.38 for San Diego County)
 $\bar{n}$ = the average of the Manning's n values of the watercourse and its tributaries (see Section 4.3.5)

Figure 4-4 shows that 50% of ultimate discharge ($Q/Q_a = 0.5$) occurs at $t/T_p = 1.16$. Since Corps lag is defined as the time at which 50% of ultimate discharge occurs, Corps lag is related to T_p by the following equations:

$$\text{Corps } T_l = 1.16 T_p \quad (\text{Eq. 4-18})$$

Or:

$$T_p = 0.862 \text{ Corps } T_l \quad (\text{Eq. 4-19})$$

for the typical NRCS dimensionless unit hydrograph.

4.1.5.3 NRCS Lag

Lag as defined by the NRCS for use with the NRCS dimensionless unit hydrograph (herein referred to as NRCS lag or NRCS T_1) differs from Corps lag. The NRCS lag of a watershed is defined as the time from the center of mass of excess rainfall to the time to peak of the unit hydrograph. NRCS lag is dependent on the period of effective rainfall (D) selected for the analysis. A small amount of variation is allowable in D , however D should be approximately $0.2T_p$. The center of mass of effective rainfall is found as $(D/2)$.

NRCS lag is found by first determining T_p using one of the equations given above in Section 4.1.5.2 or below in Section 4.1.5.5, and then selecting an appropriate D for the study based on T_p . NRCS lag is then determined by the following equation:

$$\text{NRCS } T_1 = T_p - D/2 \quad (\text{Eq. 4-20})$$

4.1.5.4 Relationship between Corps Lag and NRCS Lag

By combining equations 4-19 and 4-20 above, NRCS lag can also be calculated from Corps lag using the following relationship:

$$\text{NRCS } T_1 = 0.862 \text{ Corps } T_1 - D/2 \quad (\text{Eq. 4-21})$$

4.1.5.5 Relationships between T_p , T_c , and Corps Lag

When the lags determined from summation hydrographs for several gauged drainage areas are correlated to the hydrologic characteristics of the drainage areas, an empirical relationship is usually apparent. This relationship can then be used to determine the lags for comparable drainage areas for which the hydrologic characteristics can be determined, but for which the distribution graphs for concentration points cannot be determined because of inadequate hydrologic data. By comparing lag values (obtained from the analysis of rainfall-runoff data) to catchment T_c values estimated from a detailed RM analysis, a relationship is readily determined.

In McCuen (1982), NRCS T_p is related to T_c by:

$$T_p = 0.67 T_c \quad (\text{Eq. 4-22})$$

Where T_c is defined in chapter 15 of NEH-4 as: 1) the time for runoff to travel from the furthestmost point in the watershed to one point in question, and 2) the time from the end of excess rainfall to the point of inflection of the unit hydrograph.

From equation 4-18, Corp lag can be related to T_p :

$$\text{Corps } T_l = 1.16 T_p$$

When equations 4-18 and 4-22 are combined, the result is:

$$\text{Corps } T_l = 1.16 (0.67) T_c = 0.77 T_c \quad (\text{Eq. 4-23})$$

The following relationship relating Corps lag to T_c , based on equation 4-23, was adopted for this manual:

$$\text{Corps } T_l = 0.8 T_c \quad (\text{Eq. 4-24})$$

4.2 DEVELOPING INPUT DATA FOR NRCS HYDROLOGIC METHOD COMPUTATIONS

The following data is required for NRCS hydrologic method calculations: watershed area and physical characteristics, total rainfall amount, precipitation zone number, and runoff curve number. Sections 4.2.1 through 4.2.4 describe the development of input data. Section 4-3 describes the procedure for NRCS hydrologic method calculations.

4.2.1 Watershed, Geographic Location, Area, and Physical Characteristics

The watershed area and geographic location are determined from topographic maps and field surveys. For large drainage areas it might be necessary to divide the area into subareas to account for major land use changes, obtain analysis results at different points within the watershed area, combine hydrographs from different subareas as applicable, and/or route flows to points of interest. The highest elevation in the watershed (high point) and the elevation of the point of interest (low point) are determined from the map. The watershed length along the longest watercourse and the length to centroid are also read from the map. The centroid is the point in the watershed where approximately 50% of the watershed area is contributing to the watercourse. The length to centroid is measured from the low point of the watershed to the centroid.

4.2.1.1 Basin Factor ($\bar{n}$)

The basin $\bar{n}$ factor is the visually estimated mean of the n values (roughness values from Manning's formula) of all the channels within the basin area. A basin $\bar{n}$ factor can be estimated by comparing characteristics of drainage areas being studied with the characteristics of the drainage areas for which basin $\bar{n}$ factors have been estimated. Typical values of $\bar{n}$ range from 0.015 for areas that are mainly developed and have a large percentage of impervious area, to 0.100 for areas with extensive vegetation including vegetation in watercourses that slows water velocity.

The following descriptions are a guide for estimating the basin $\bar{n}$ factor, based on Plate 21, *Lag Relationships* from *Antelope Valley Streams Los Angeles County, California, Draft Survey Report, Hydrology Part I*, prepared by the U.S. Army Engineer District, Los Angeles Corps of Engineers (USACE, 1976):

$\bar{n} = 0.100$: The drainage area has extensive vegetation, including grass, or is farmed with contoured plowing, and streams that contain a large amount of brush, grass or other vegetation that slows water velocity.

$\bar{n} = 0.050$: Drainage area is quite rugged, with sharp ridges and narrow, steep canyons through which watercourses meander around sharp bends, over large boulders and considerable debris obstruction. The ground cover, excluding small areas of rock outcrops, includes many trees and considerable underbrush. No drainage improvements exist in the area.

$\bar{n} = 0.030$: Drainage area is generally rolling, with rounded ridges and moderate side slopes. Watercourses meander in fairly straight, unimproved channels with some boulders and lodged debris. Ground cover includes scattered brush and grasses. No drainage improvements exist in the area.

$\bar{n} = 0.015$: Drainage area has fairly uniform, gentle slopes with most watercourses either improved or along paved streets. Ground cover consists of some grasses with appreciable areas developed to the extent that a large percentage of the area is impervious.

The following additional references may also be helpful for determining an appropriate basin $\bar{n}$ factor: *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (USGS Water Supply Paper 2339) presents procedures for assigning reliable n values for channels and floodplains. This paper contains some photos, examples, and step-by-step procedures. The procedures can be used in the field. *Open Channel Hydraulics* by Ven Te Chow also provides guidance with tables of n values and photographs.

4.2.2 Rainfall and Precipitation Zone Number

The 6-hour and 24-hour rainfall amounts are taken from the isopluvial maps included in Appendix B. For large watersheds that intersect more than one isopluvial, the engineer may estimate a weighted average rainfall amount for the entire watershed. As described in Section 3.1.3, P_6 for the selected frequency should be between 45% and 65% of P_{24} for the selected frequency. If P_6 is not within 45% to 65% of P_{24} , P_6 should be increased or decreased as necessary to meet this criteria.

The PZN is taken from the map in Appendix C. As with the rainfall amount, the engineer may estimate a weighted average PZN for large watersheds.

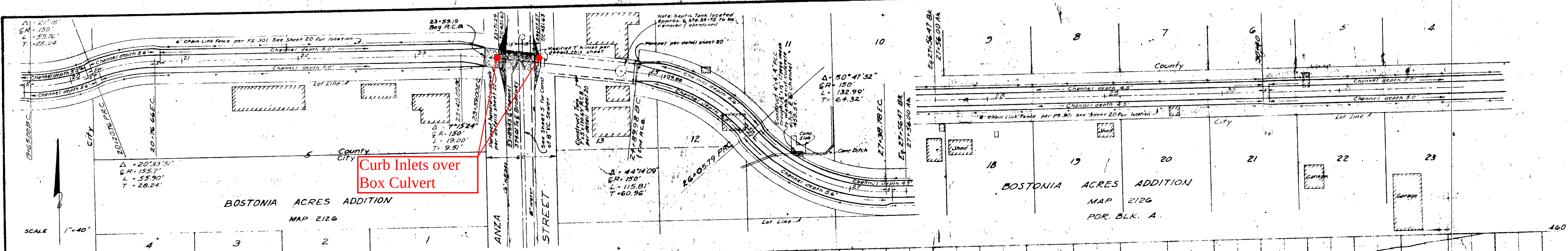
4.2.3 Runoff Curve Number

The step by step procedure for calculating a composite CN is described in Table 4-8. A 2000-scale topographic map, and an NRCS hydrologic ground cover map and NRCS soil group map at the same scale are needed. The NRCS maps are available at the County of San Diego DPWFCS. A sheet of translucent vellum is also needed.

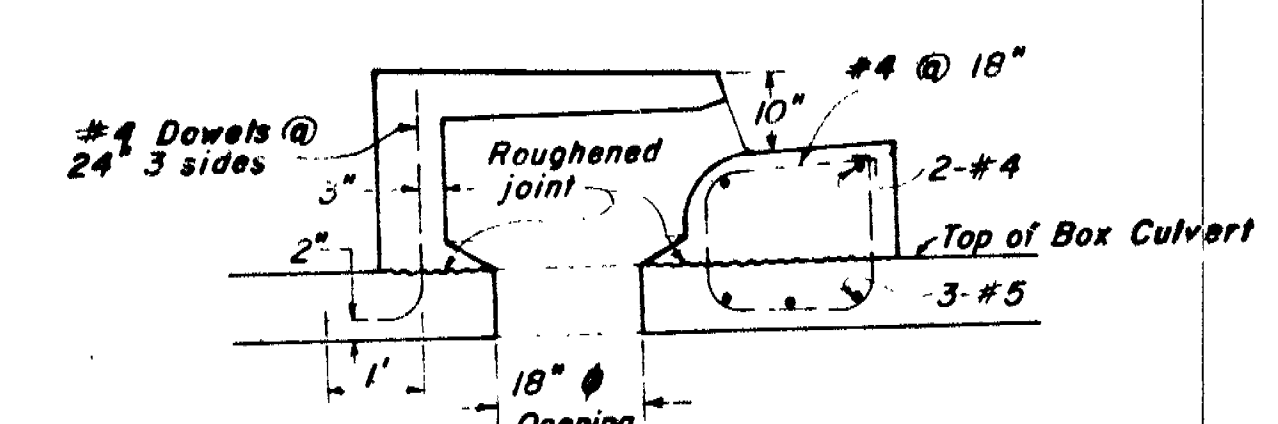
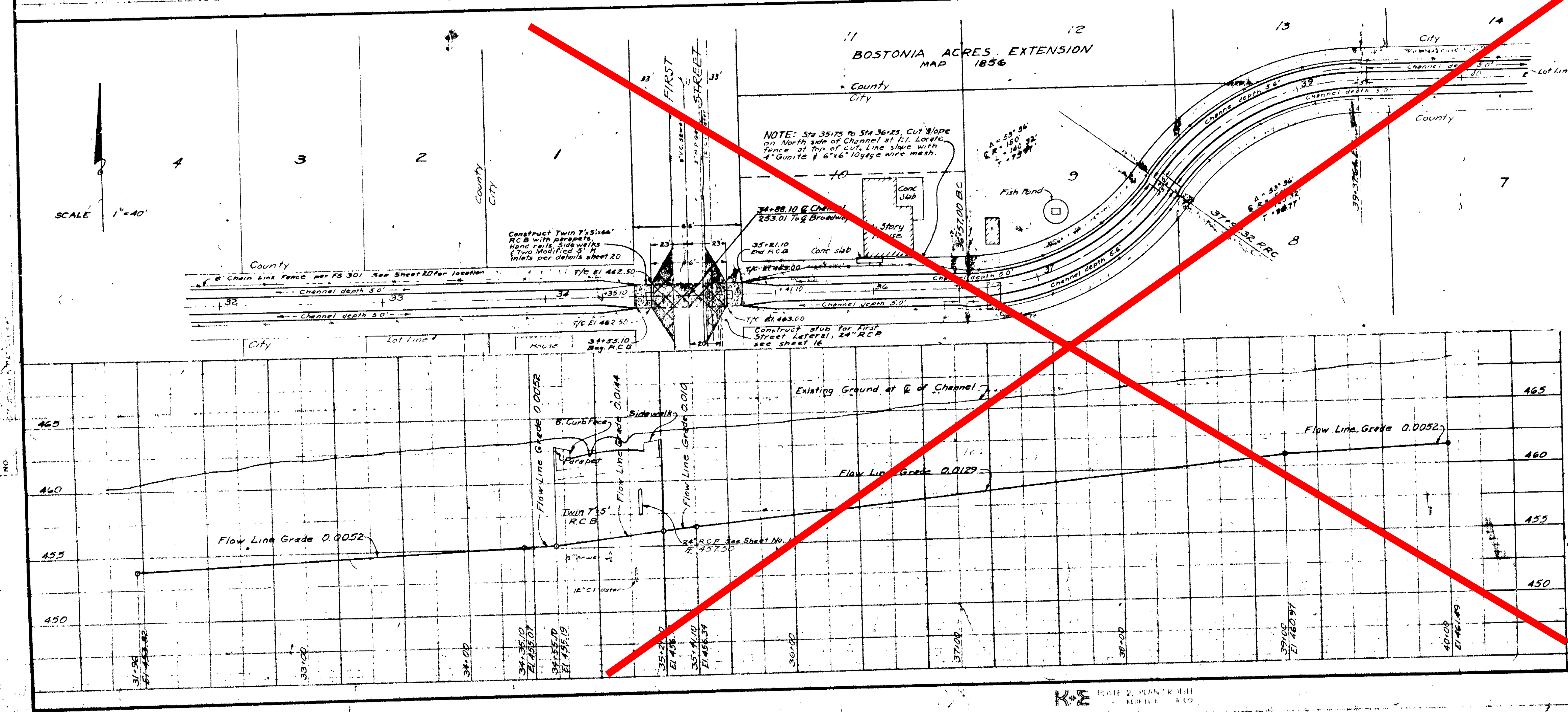
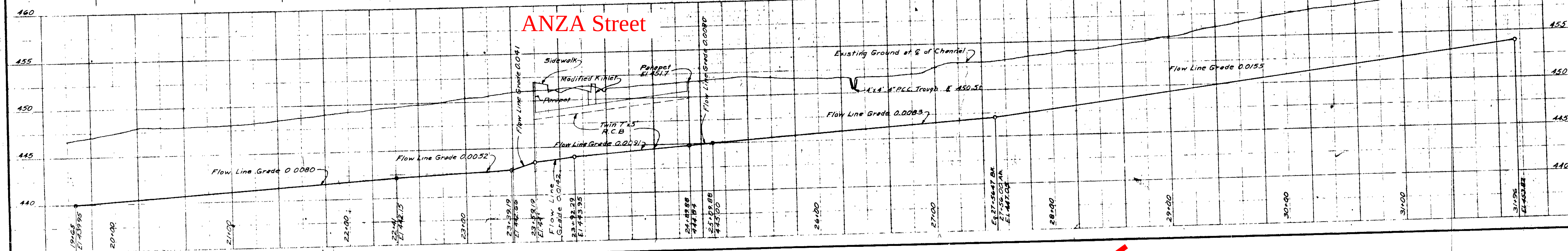
Step 5 of the procedure described in Table 4-8 involves tabulating data for different combinations of land use and soil group within the watershed. Data may be recorded on Worksheet 4-1 (provided in Appendix D). Composite CNs for the drainage area can be calculated by entering the data collected into a table such as the one provided as Worksheet 4-2 (provided in Appendix D) or a spreadsheet set up in a similar format (Worksheet headers presented as Table 4-9).

The composite CN for the total drainage area is then the sum of the composite CNs from column 6 of Worksheet 4-2 or Table 4-9.

ANZA Street



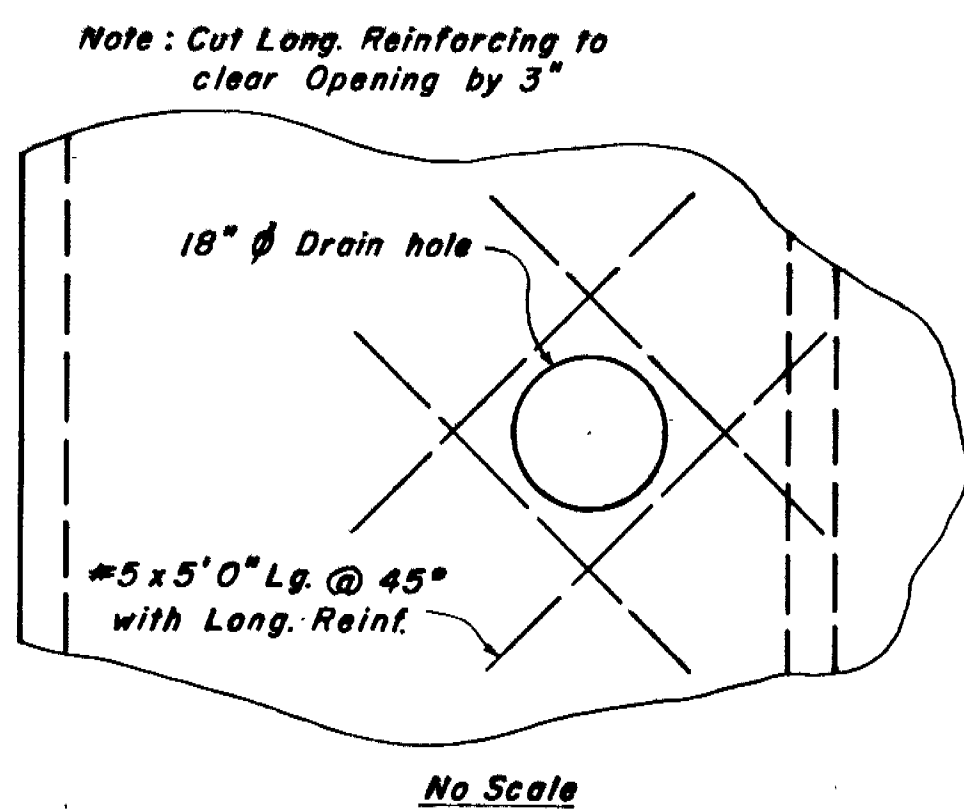
ANZA Street



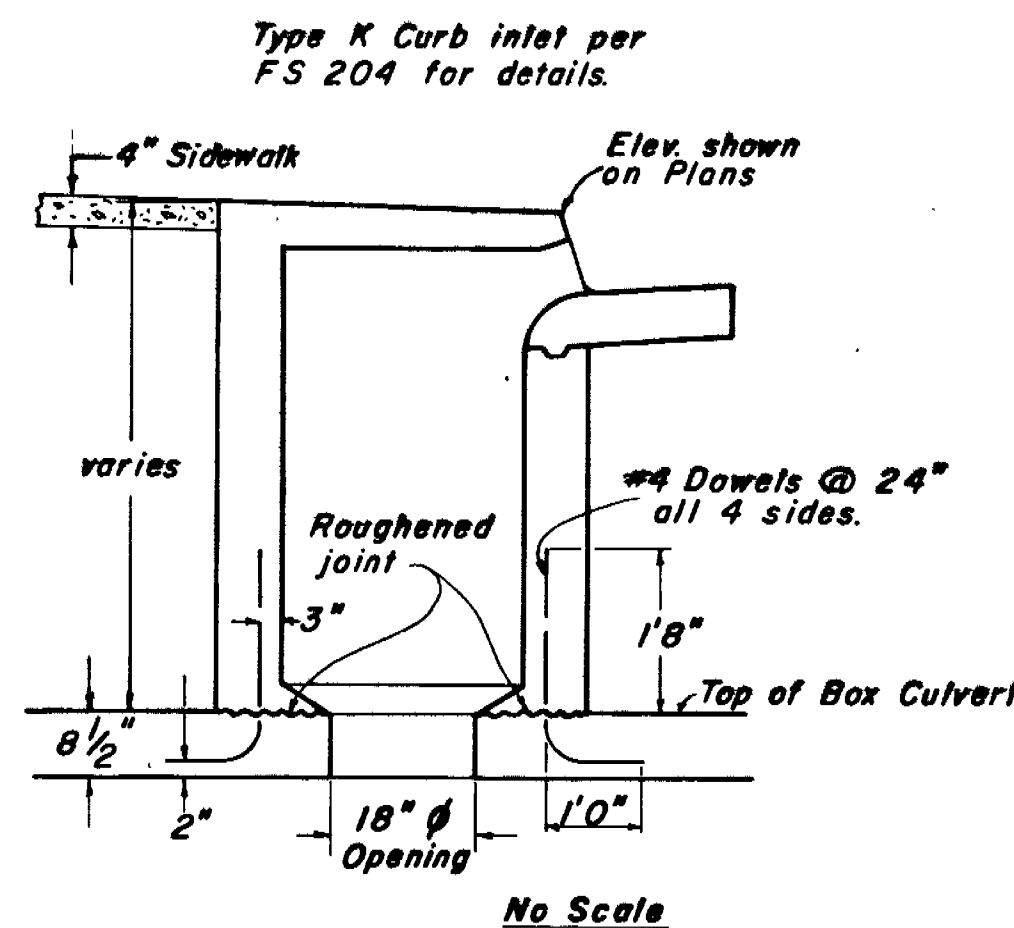
Modified Type K Curb Inlet at Anza Street

BROADWAY CHANNEL			
BROADWAY ET AL 1913 ACT			
AS BUILT	CITY OF EL CAJON ENGINEERING DEPARTMENT		SHEET NO. 18 OF 36 SHEETS
E. R. 1/26/67 ENGINEER OF WORK DATE	J. R. 6/29/65 CITY ENGINEER DATE		ENGINEERING DEPT. JOB NO. 675
HELIX IRRIGATION DISTRICT	CHANGE	BY DATE APPROVAL	DRAWN BY 1/5 CHECKED BY FIELD BOOK 37
NOTE SUBJECT TO REVISION IN NINETY (90) DAYS	CONSTRUCTION RECORD DATE STARTED CONTRACTOR		DATE COMPLETED INSPECTOR

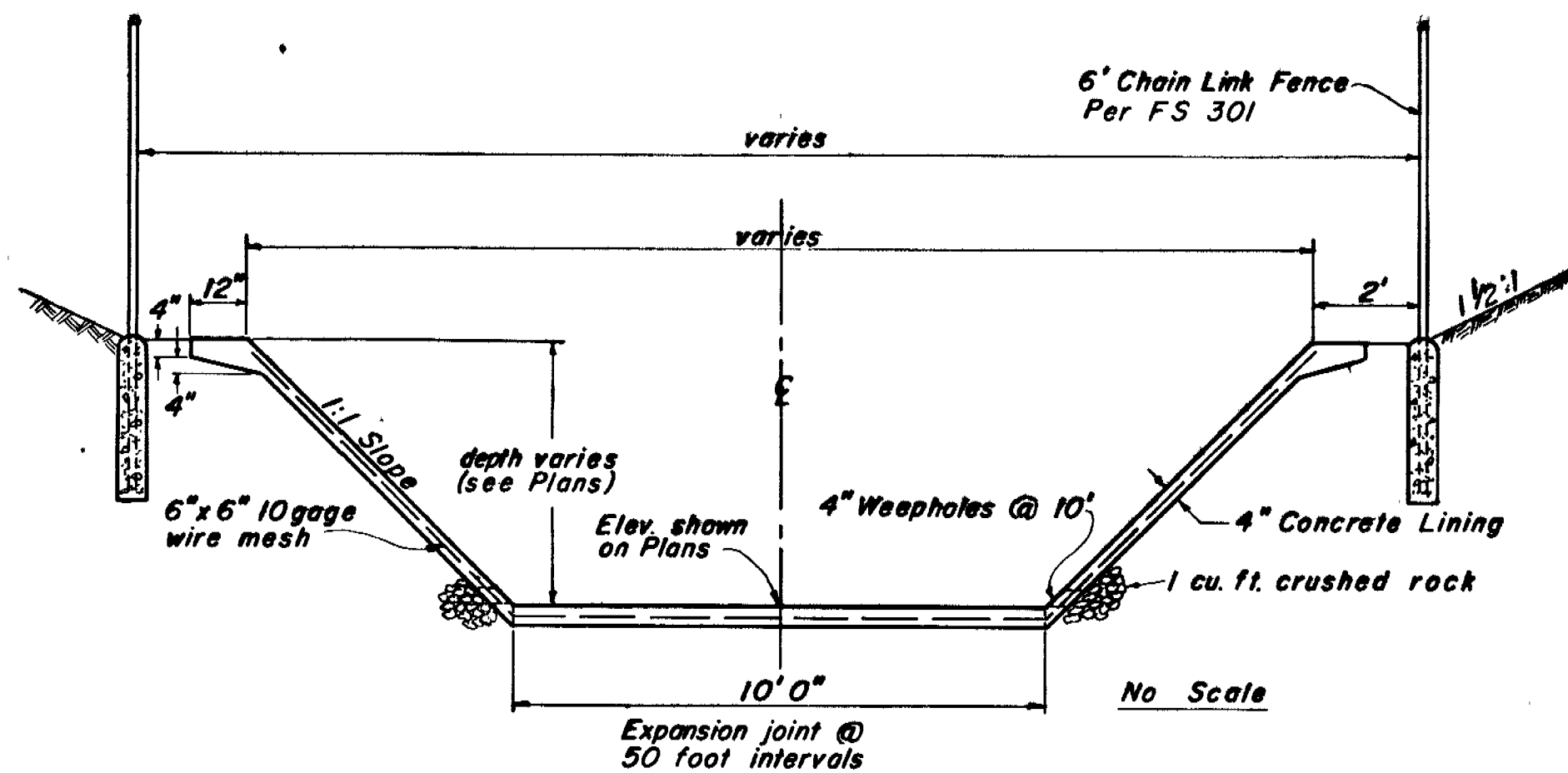
STRUCTURE DETAILS



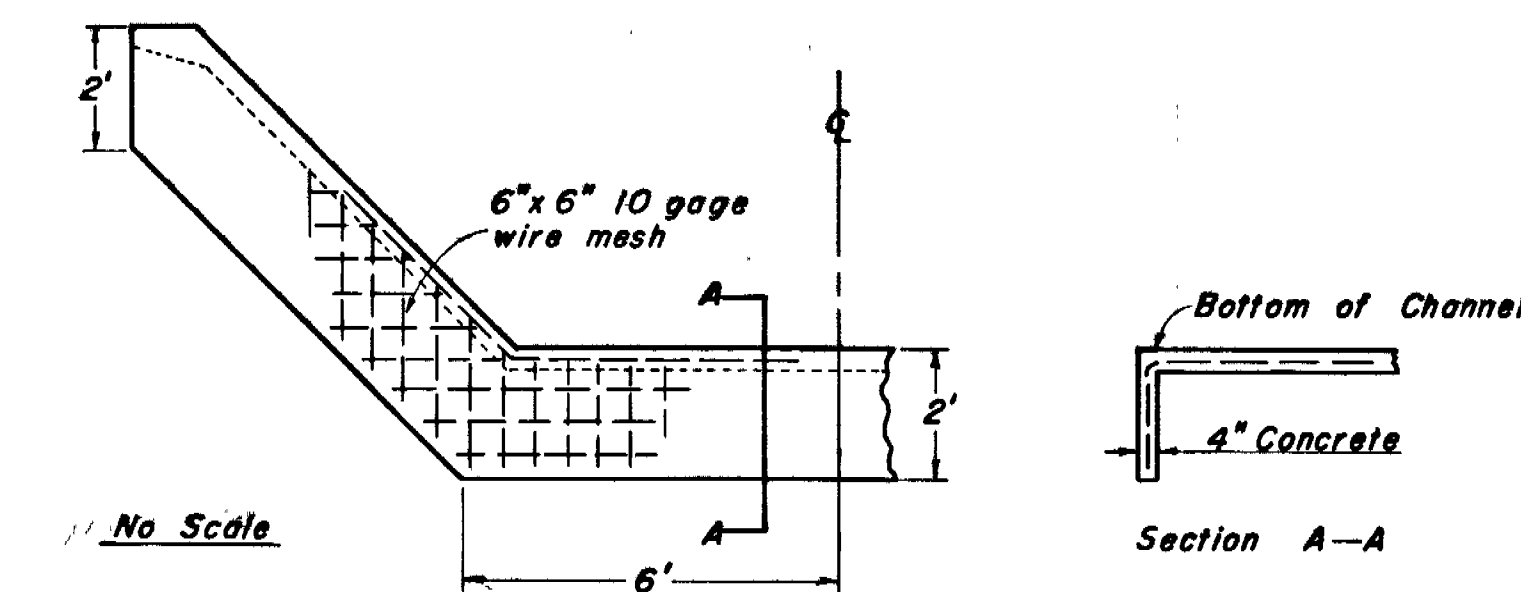
Curb Inlet Drain Hole
Special Reinforcing Diagram



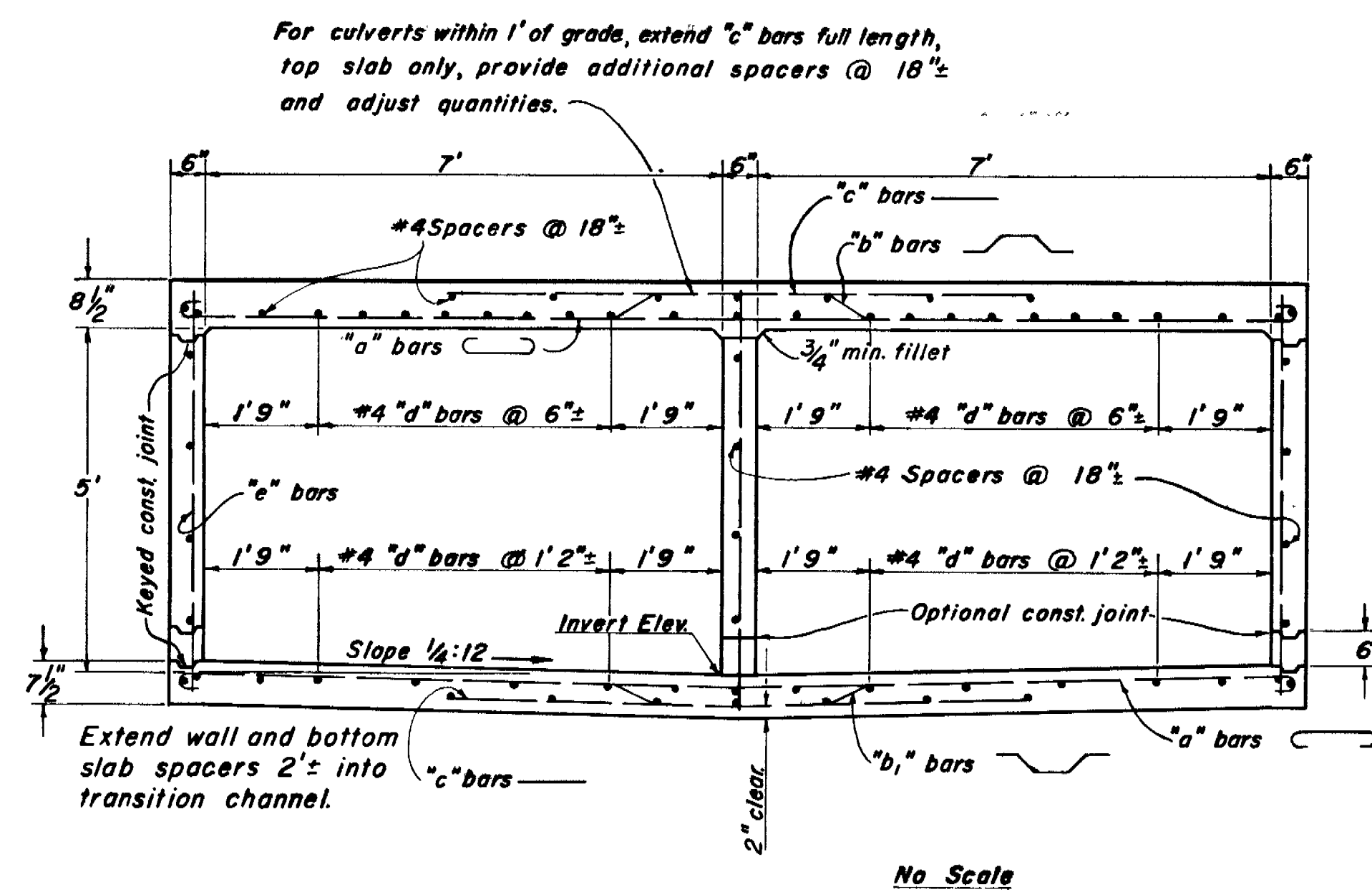
Modified Type K
Curb Inlet



Typical Channel Section

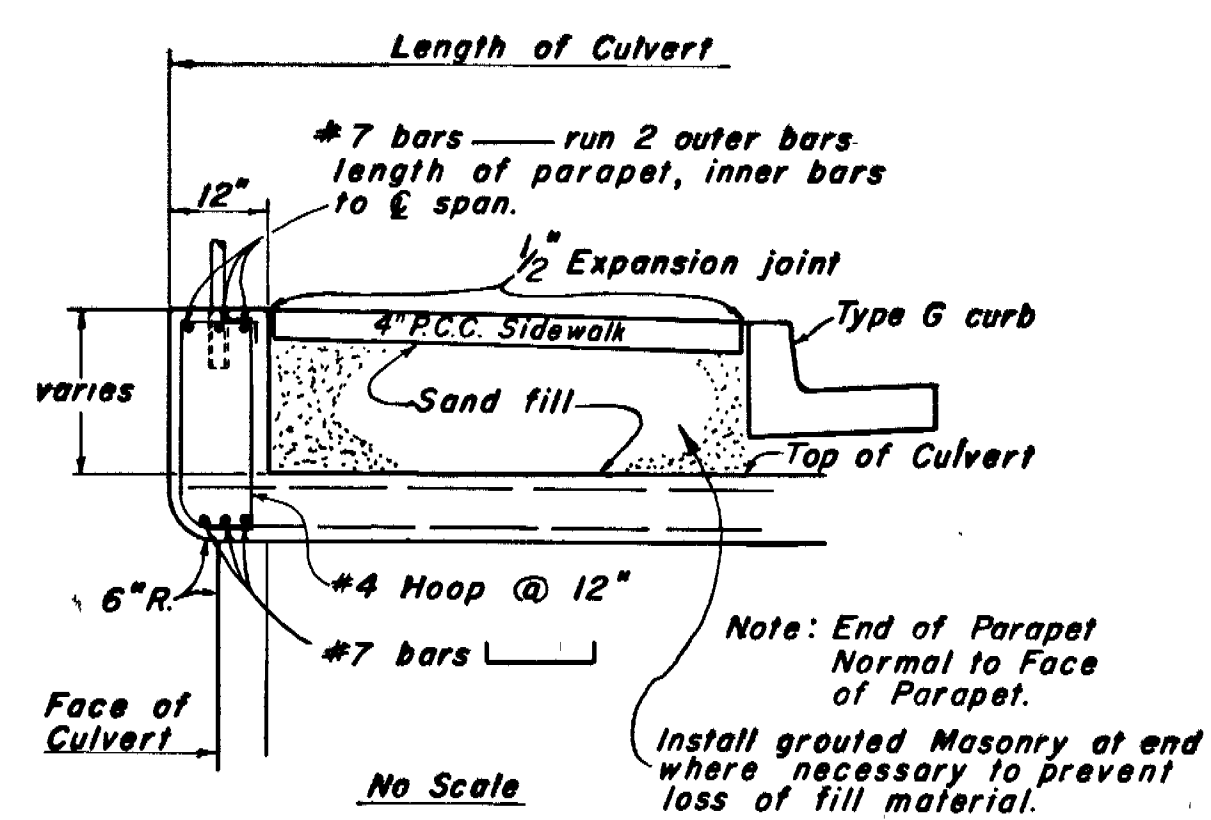


Detail: Cut-off Wall Sta. 47+09

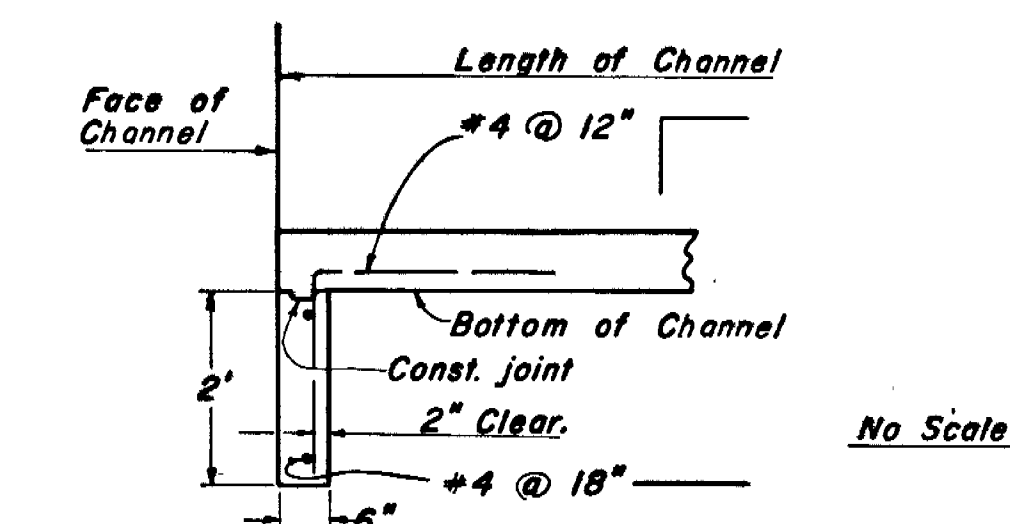


Detail: Double Box Culvert

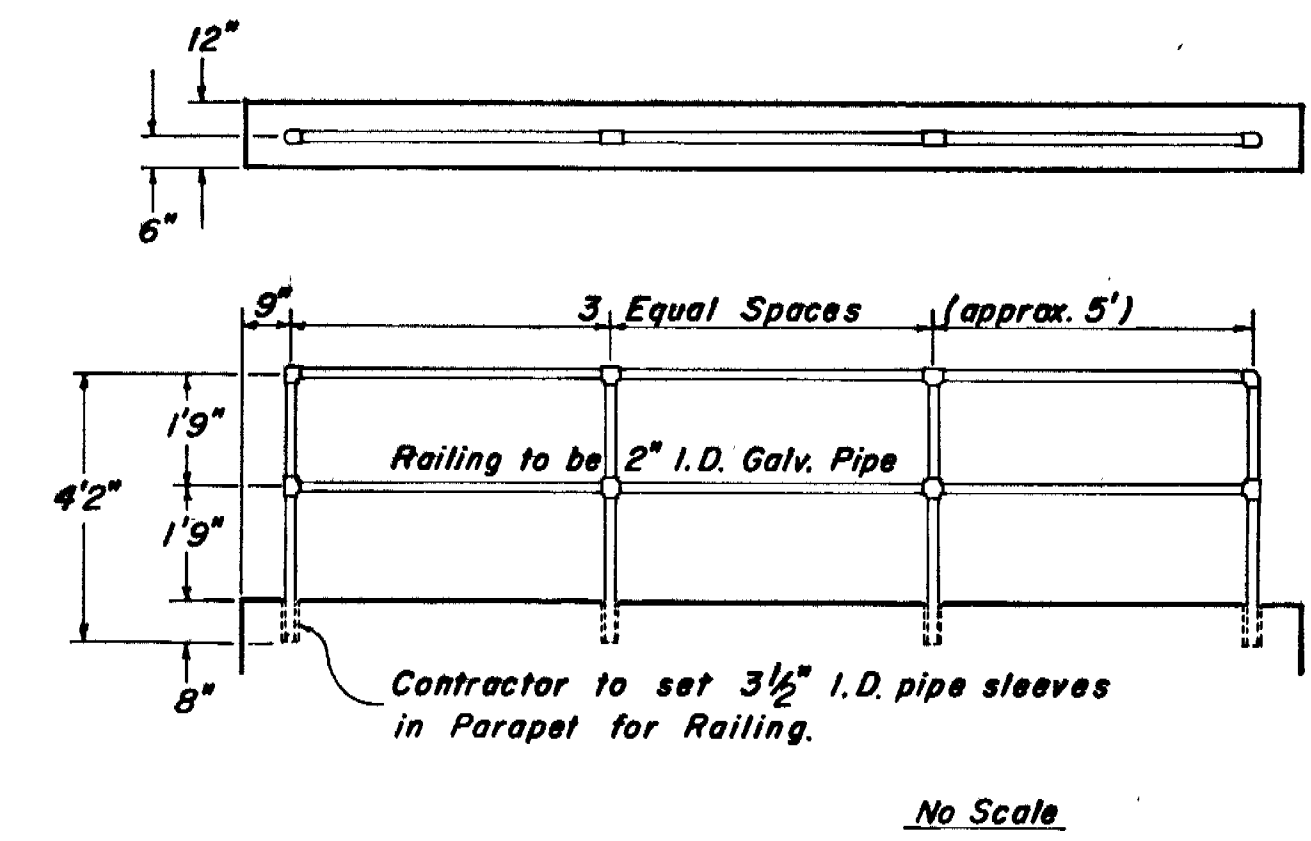
Type of Reinforcing	Size & Spacing	Length
"a" bars	#6 @ 12"	16' 4"
"b" bars	#6 @ 12"	15' 7"
"b" bars	#6 @ 12"	15' 5"
"c" bars	#4 @ 12"	8' 6"
"d" bars Top Slab	#4 @ 6"	Total No. 16
"d" bars Bottom Slab	#4 @ 14"	Total No. 8
"e" bars	#4 @ 18"	
Spacer bars	#4 @ 18"	Total No. 44



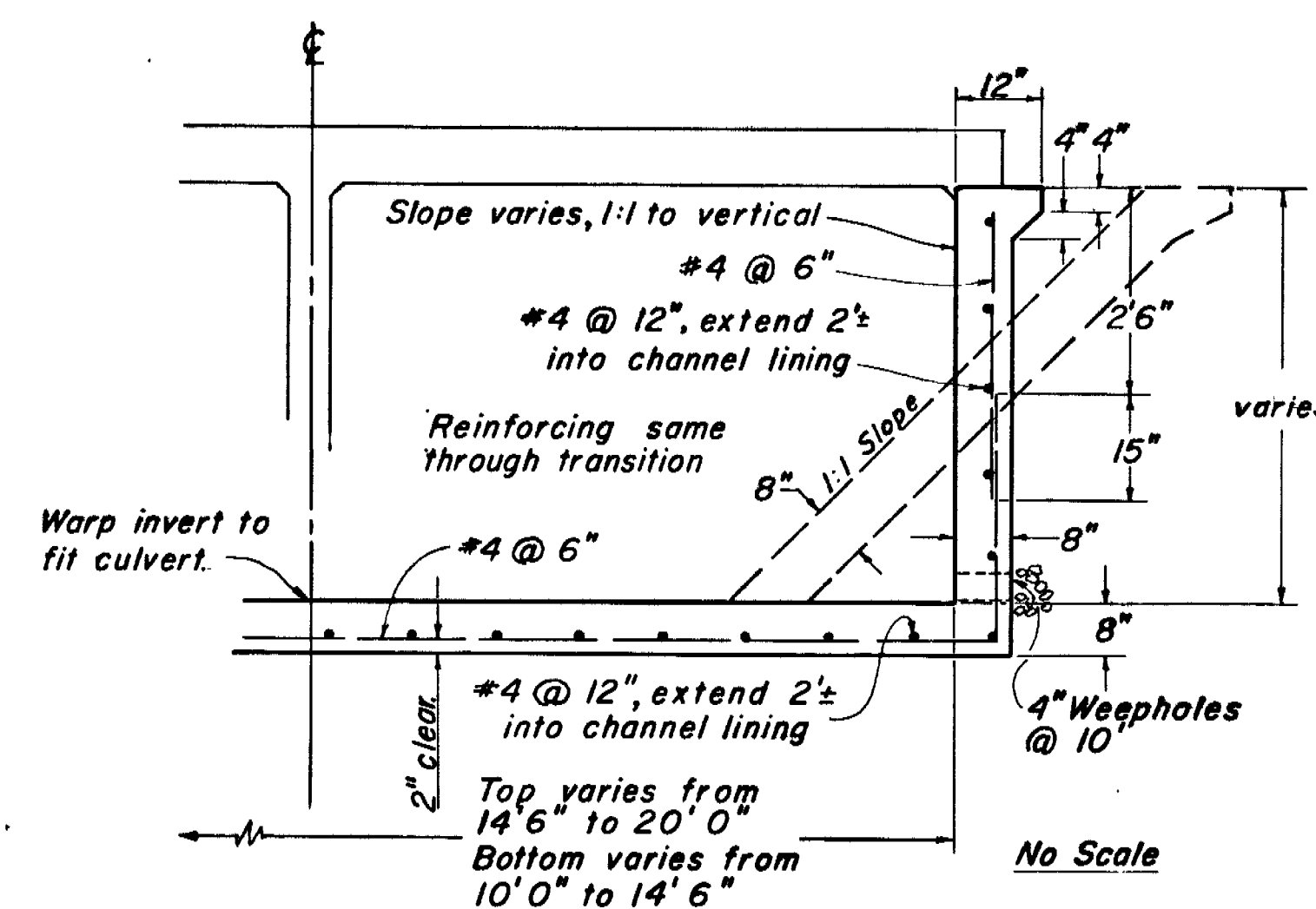
Parapet Detail



Detail: Cut-off Wall Sta. 0+05.79



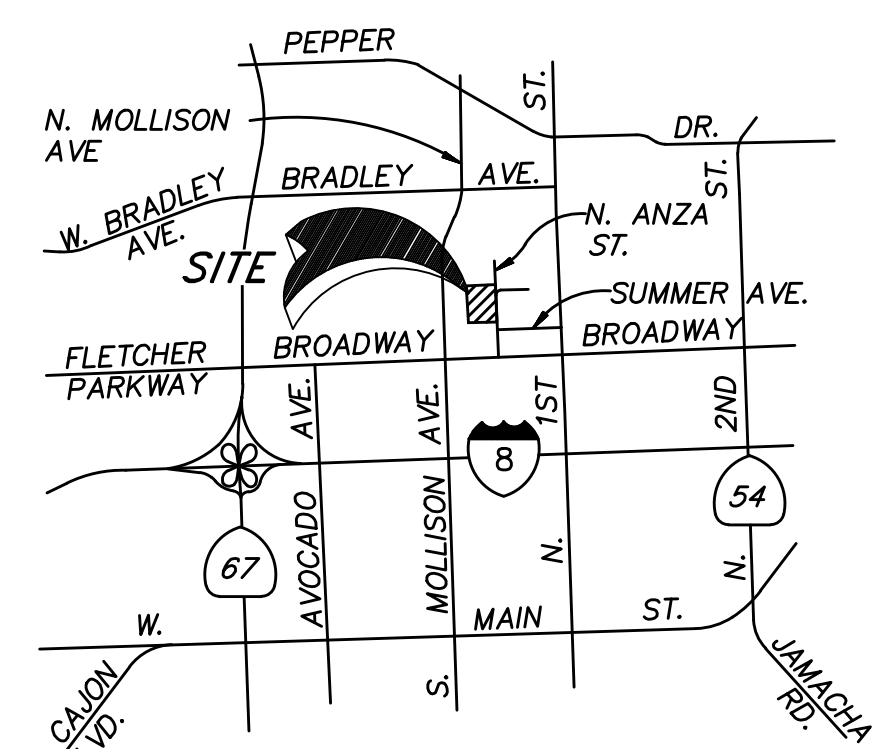
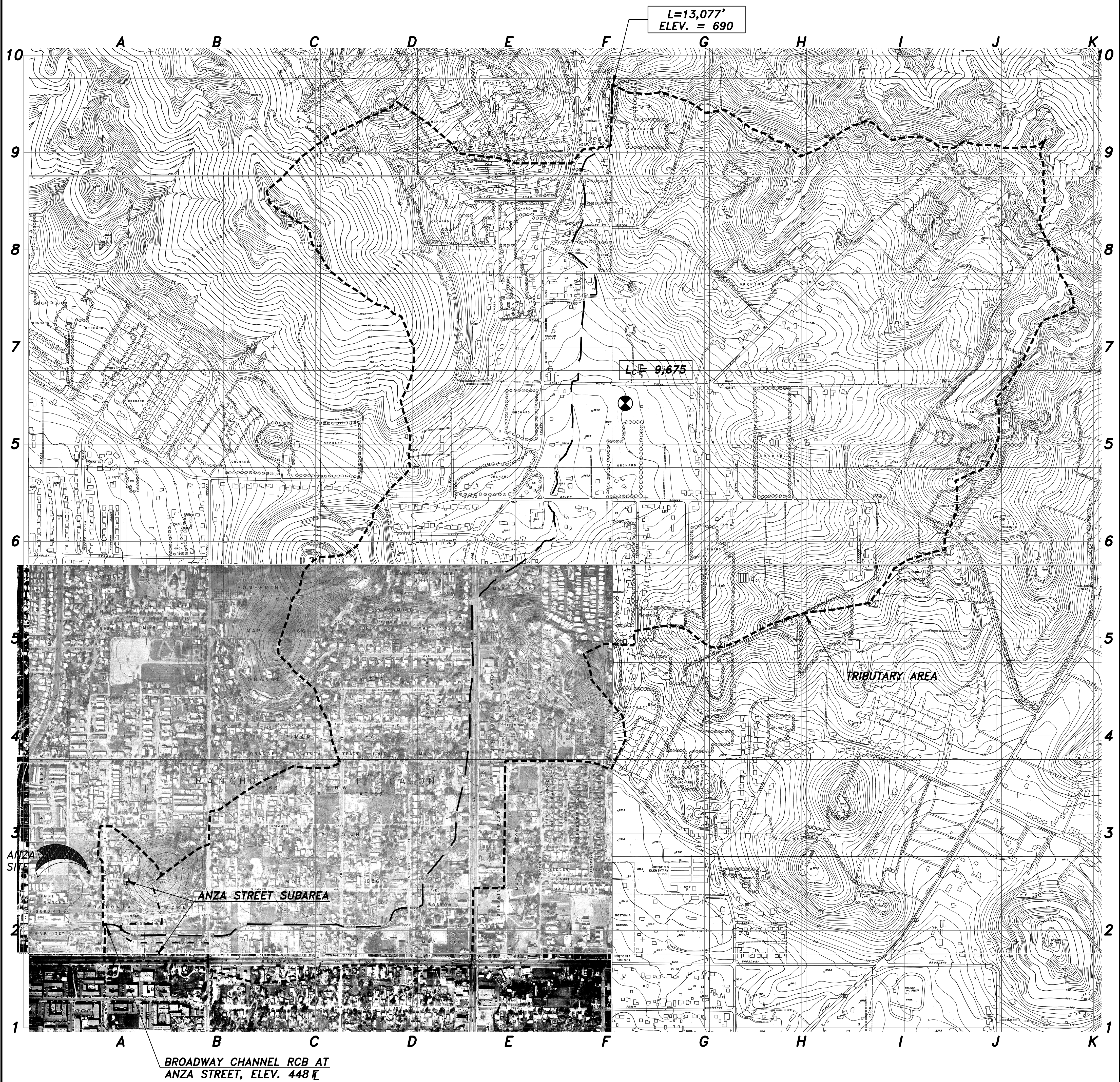
Handrail Detail
BROADWAY CHANNEL



Detail: 20' Channel Transition

AS BUILT		CITY OF EL CAJON ENGINEERING DEPARTMENT		SHEET NO 20 OF 36 SHEETS	
B.B. 1/26/67		J. Haggata 6/29/65		ENGINEERING DEPT. JOB NO. 675	
FIELD OF WORK HELIX IRRIGATION DISTRICT		DESIGNED BY P.S.		DRAWING NO. 3600	
DATE STARTED		DATE COMPLETED		CONTRACTOR	
INSPECTOR		DATE		DATE	

BROADWAY CHANNEL DRAINAGE AREA
TRIBUTARY TO ANZA STREET CULVERT



VICINITY MAP
NOT TO SCALE
THOMAS BROTHERS PG. 1251,
GRID H-3 57TH EDITION

BROADWAY CHANNEL DRAINAGE AREA
TRIBUTARY TO ANZA STREET CULVERT



SB&O INC.
PLANNING ENGINEERING SURVEYING
3990 Ruffin Road, Suite 120
San Diego, Ca. 92123
858-560-1141
858-560-8157 Fax

ALLEN BUTCHER

DATE

Figure 1 is a 10x10 grid map of the Anzac site. The grid is labeled with letters A through K along the top and bottom, and numbers 1 through 10 along the left and right sides. The map shows a distribution of vegetation types represented by different colors: red (open grassland), green (open forest), blue (open woodland), and brown (open shrubland). A dashed line outlines the site boundary. A small inset map in the bottom left corner shows the site's location within the Anzac area.

The map displays a grid with letters A through K along the top and bottom, and numbers 1 through 10 along the left and right sides. The 'BASIN LIMITS' are indicated by a dashed line. The 'ANZA SITE' is marked with a small black dot in the bottom left corner, near the intersection of grid lines A and B, and 1 and 2. The map shows a complex pattern of land use, with a large pink area in the bottom right corner and a large blue area in the top left corner.

PEPPER

N. MOLLISON AVE

W. BRADLEY AVE

BRADLEY AVE

ST.

DR.

N. ANZA ST.

SITE

SUMMER BROADWAY

BROADWAY

FLETCHER PARKWAY

AVOCADO AVE

MOLLISON AVE

1ST

2ND

W. EL CAJON BLVD.

MAIN ST.

JAMACHA RD.

67

8

54

N.

S.

W.

ST.

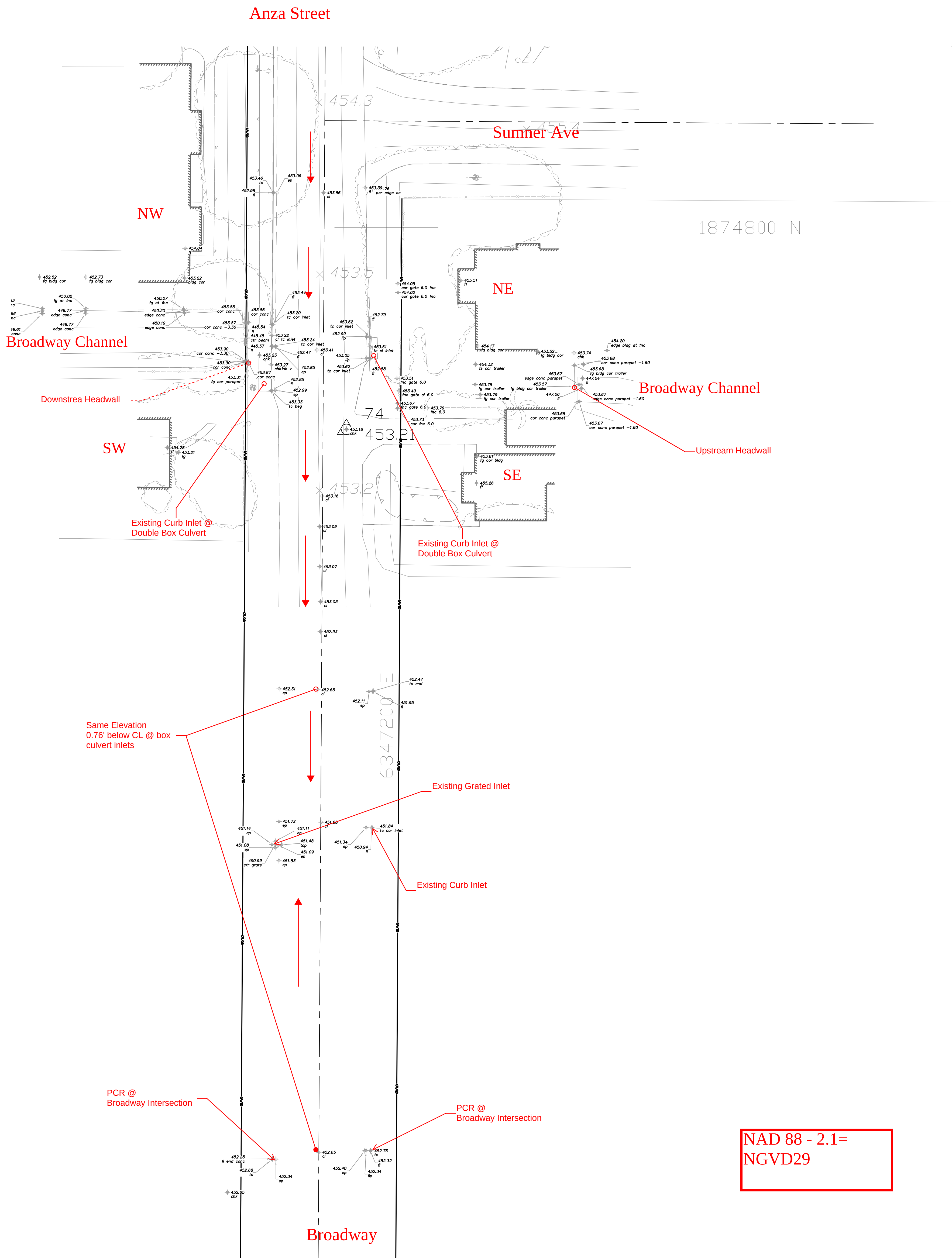
PEPPERCITY MAP

NOT TO SCALE

THOMAS BROTHERS PG. 1251,
GRID H-3 57TH EDITION

ALLEN BUTCHER

DATE _____



Anza Street Field Survey
Broadway Channel
August 2019
JN 73760.66