RAINSTORMS OF THE IMPERIAL VALLEY
INVITED LECTURE
AMERICAN SOCIETY OF CIVIL ENGINERS
JUNE 6, 1996
IMPERIAL VALLEY

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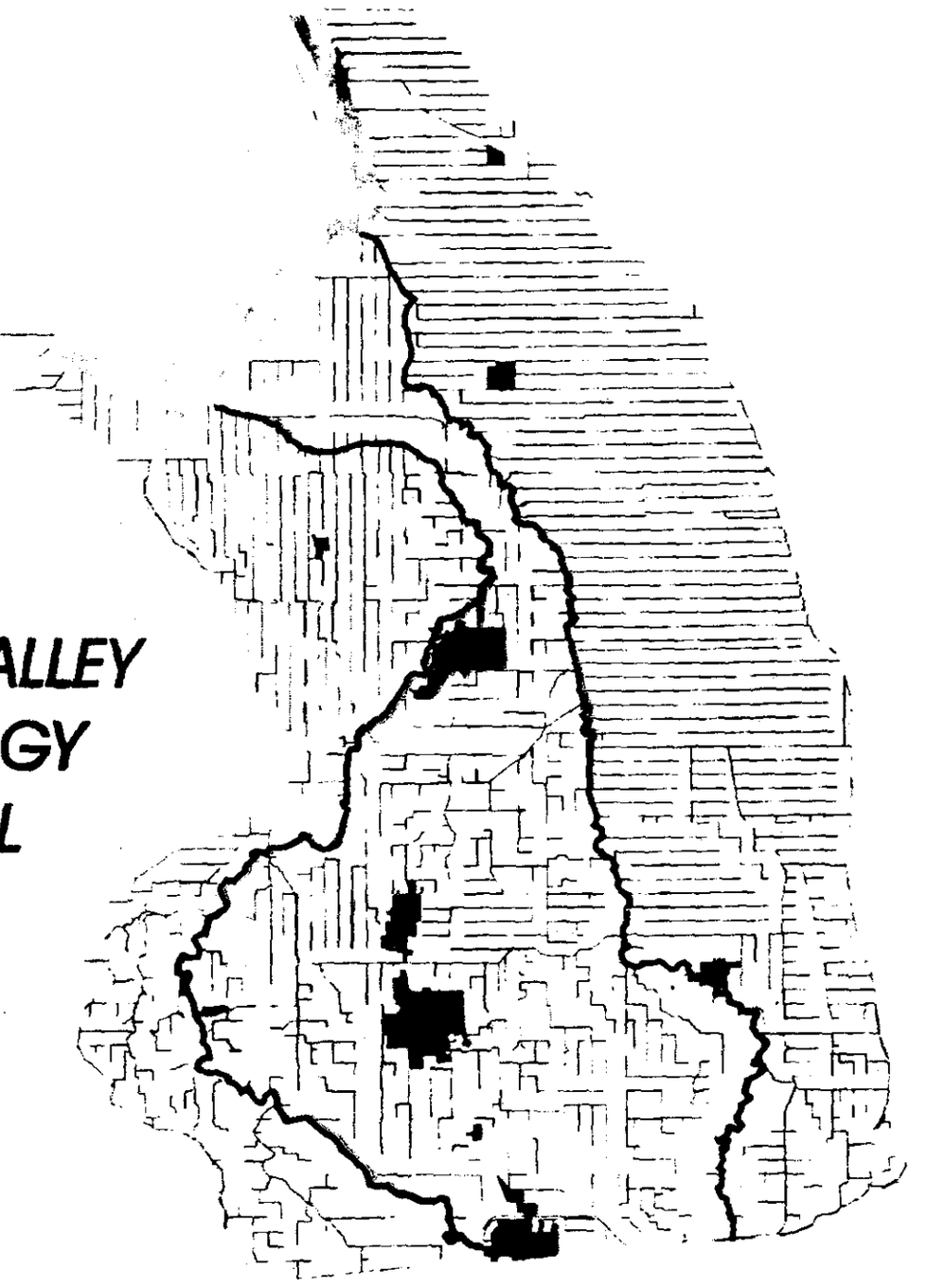
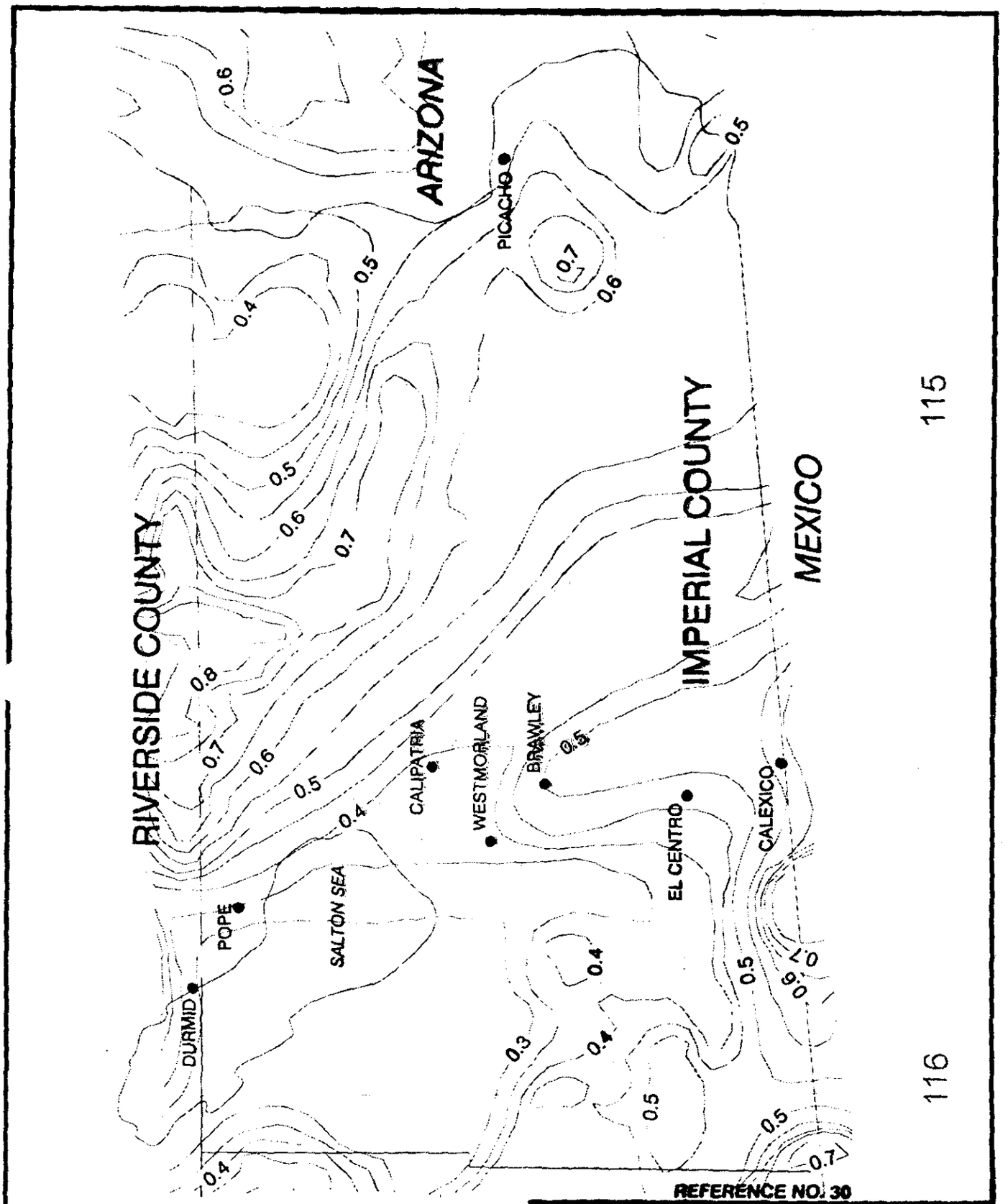
June, 1996

IMPERIAL IRRIGATION DISTRICT



IMPERIAL VALLEY HYDROLOGY MANUAL

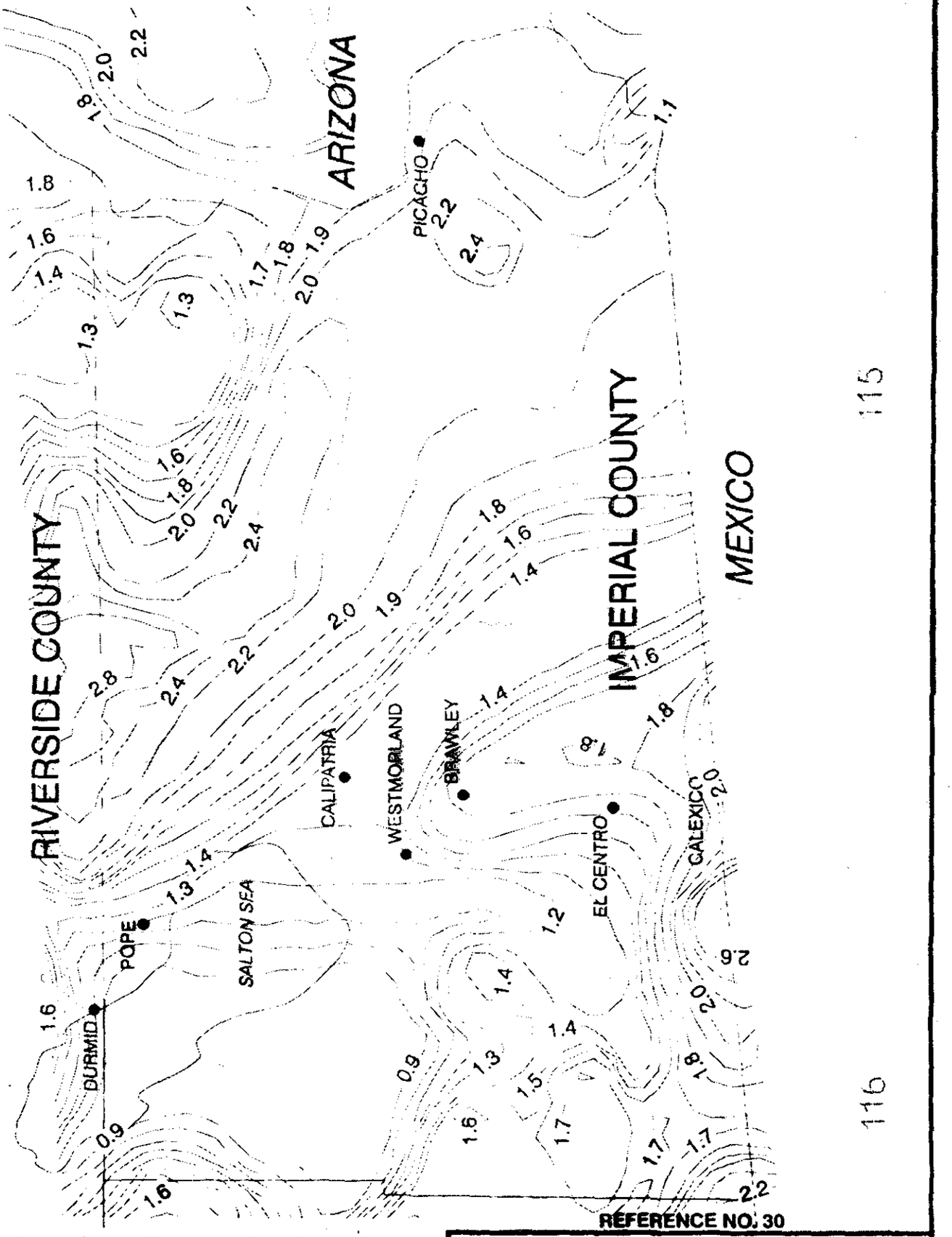
September, 1995



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

2-YEAR, 1-HOUR PRECIPITATION

FIGURE B-1

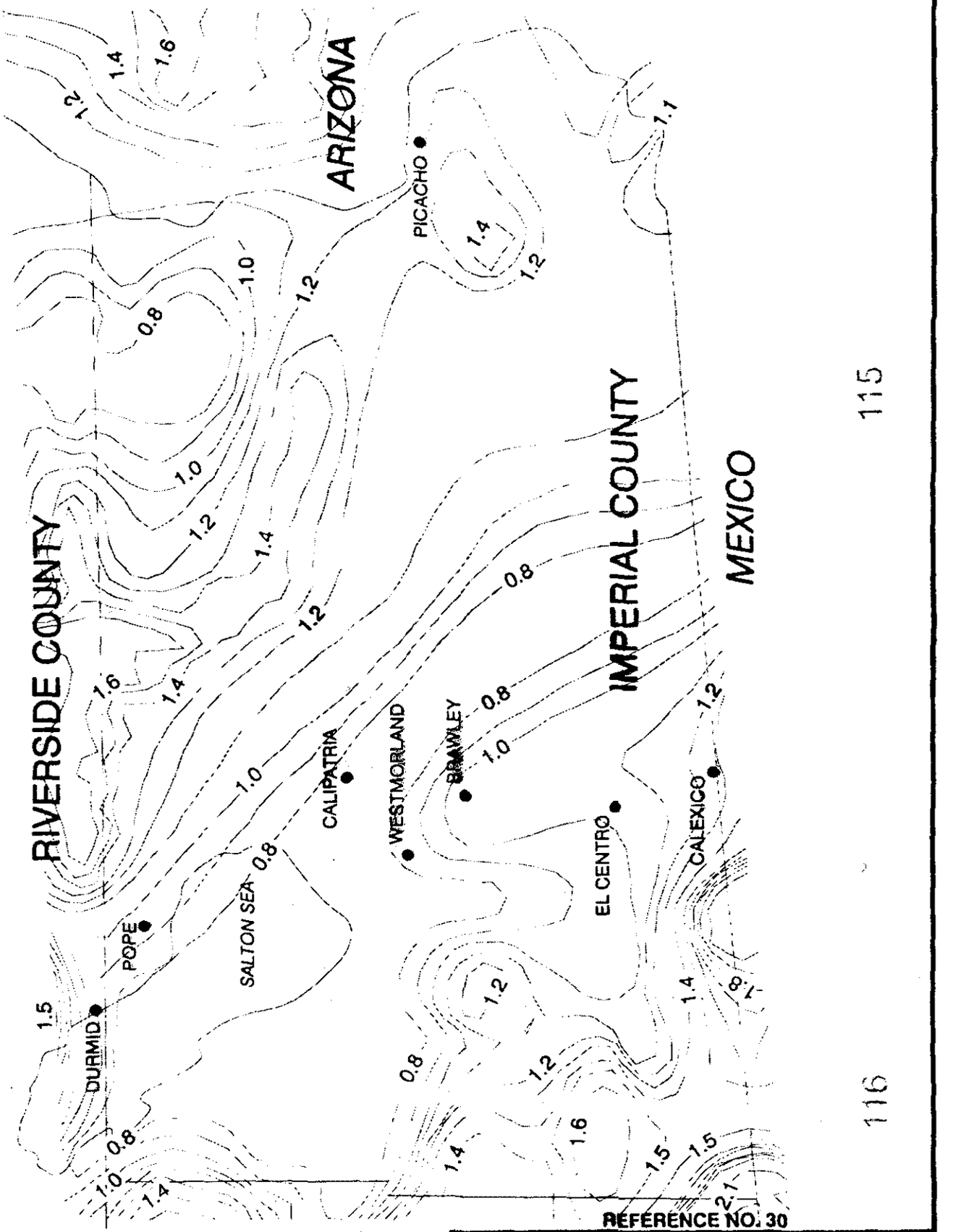


IMPERIAL IRRIGATION DISTRICT

HYDROLOGY MANUAL

100-YEAR, 1-HOUR PRECIPITATION

FIGURE B



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

2-YEAR, 24-HOUR PRECIPITATION

FIGURE B-2

REFERENCE NO. 30

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

100-YEAR, 24-HOUR PRECIPITATION

Residential Landscaping (Lawn, Shrubs, etc.) - The pervious portions of commercial establishments, single and multiple family dwellings, trailer parks and schools where the predominant land cover is lawn, shrubbery and trees.

Row Crops - Lettuce, tomatoes, beets, tulips or any field crop planted in rows far enough apart that most of the soil surface is exposed to rainfall impact throughout the growing season. At plowing, planting and harvest times it is equivalent to fallow.

Small Grain - Wheat, oats, barley, flax, etc. planted in rows close enough that the soil surface is not exposed except during planting and shortly thereafter.

Legumes - Alfalfa, sweetclover, timothy, etc. and combinations are either planted in close rows or broadcast.

Fallow - Fallow land is land plowed but not yet seeded or tilled.

Woodland - grass - Areas with open cover or broadleaf or coniferous trees usually live oak and pines, with the intervening ground space occupied by annual grasses or weeds. The trees may occur singly or in small clumps. Canopy density, the amount of ground surface shaded at high noon, is from 20 to 50 percent.

Woodland - Areas on which coniferous or broadleaf trees predominate. The canopy density is at least 50 percent. Open areas may have a cover of annual or perennial grasses or of brush. Herbaceous plant cover under the trees is usually sparse because of leaf or needle litter accumulation.

Chaparral - Land on which the principal vegetation consists of evergreen shrubs with board, hard, stiff leaves such as manzonita, ceanothus and scrub oak. The brush cover is usually dense or moderately dense. Diffusely branched evergreen shrubs with fine needle-like leaves, such as chamise and redchank, with dense high growth are also included in this soil cover.

Annual Grass - Land on which the principal vegetation consists of annual grasses and weeds such as annual bromes, wild barley, soft chess, ryegrass and filaree.

Irrigated Pasture - Irrigated land planted to perennial grasses and legumes for production of forage and which is cultivated only to establish or renew the stand of plants. Dry land pasture is considered as annual grass.

Meadow - Land areas with seasonally high water table, such as seasonal wetlands. Principal vegetation consists of sod-forming grasses interspersed with other plants.

Orchard (Deciduous) - Land planted to such deciduous trees as apples, apricots, pears, walnuts, and almonds.

Orchard (Evergreen) - Land planted to evergreen trees which include citrus and avocados and coniferous plantings.

REFERENCE NO. 3

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

SCS COVER TYPE DESCRIPTIONS

FIGURE C-1

Curve [1] Numbers of Hydrologic Soil-Cover Complexes for Pervious Areas-AMC II

Cover Type (3)	Quality of Cover (2)	Soil Group A	B	C	D
NATURAL COVERS -					
Barren (Ref. No. 21) (Rockland, eroded and graded land)		78	86	91	93
Chaparral, Broadleaf (Ref. No. 21) (Manzonita, ceanothus and scrub oak)	Poor	53	70	80	85
	Fair	40	63	75	81
	Good	31	57	71	78
Chaparral, Narrowleaf (Ref. No. 21) (Chamise and Redskank)	Poor	71	82	88	91
	Fair	55	72	81	86
Grass, Annual or Perennial	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadows or Seasonal Wetlands (Ref. No. 21) (Areas with seasonally high water table, principal vegetation is sod forming grass)	Poor	63	77	85	88
	Fair	51	70	80	84
	Good	30	58	72	78
Open Brush (Ref. No. 21) (Soft wood shrubs-buckwheat, sage, etc.)	Poor	62	76	84	88
	Fair	46	66	77	83
	Good	41	63	75	81
Woodland (4) (Coniferous or broadleaf trees predominate. Canopy density is at least 50 percent)	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Woodland, Grass (Coniferous or broadleaf trees with canopy density from 20 to 50 percent)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
URBAN COVERS -					
Residential or Commercial Landscaping (Lawns, shrubs, etc.)	Good	39	61	74	80
Turf (Irrigated and mowed grass)	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80

REFERENCE NO. 32 UNLESS NOTED

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

CURVE NUMBERS FOR PERVIOUS AREAS

FIGURE C-2 (1 of 3)

Curve [1] Numbers of Hydrologic Soil-Cover Complexes for Pervious Areas-AMC II

Cover Type (3)	Quality of Cover (2)	Soil Group A	B	C	D
AGRICULTURAL COVERS -					
Fallow (Bare Soil)		77	86	91	94
Close Seeded (alfalfa, sweetclover, timothy, etc.)	Poor	66	77	85	89
	Good	58	72	81	85
Contoured	Poor	64	75	83	85
	Good	55	69	78	83
Countoured and Terraced	Poor	63	73	80	83
	Good	51	67	76	80
Orchards, Evergreen (Ref. No. 2) (Citrus, avacodos, etc.)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Pasture (Grassland or range, continuous forage for grazing)	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Contoured	Poor	47	67	81	88
	Fair	25	59	75	83
	Good	6	35	70	79
Row Crops (Straight row, non-contoured)	Poor	72	81	88	91
	Good	67	78	85	89
Contoured	Poor	70	79	84	88
	Good	65	75	82	86
Contoured and Terraced	Poor	66	74	80	82
	Good	62	71	78	81
Small Grain (Straight row, non-contoured))	Poor	65	76	84	88
	Good	63	75	83	87
Contoured	Poor	63	74	82	85
	Good	61	73	81	84
Contoured and Terraced	Poor	61	72	79	82
Grapes, New Orchards (4), and Decidious Orchards (Ref. No. 33)	Poor	62	76	84	88
	Fair	46	67	78	83
	Good	37	60	73	79

REFERENCE NO. 3 UNLESS NOTED

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

CURVE NUMBERS FOR PERVIOUS AREAS

FIGURE C-2 (2 of 3)

Notes:

1. Average runoff condition, Ia = 0.2(S)

2. Poor: Heavily grazed, regularly burned areas, or areas of high burn potential. Less than 50 percent of the ground surface is protected by plant cover or brush and tree canopy.

   Fair: Moderate cover with 50 percent to 75 percent of the ground surface protected. In wood areas the woods are grazed but not burned, and some forest litter covers the soil.

   Good: Heavy or dense cover with more than 75 percent of the ground surface protected. In wooded areas the woods are protected from grazing, litter and brush adequately cover soil.

3. See Figure C-1 for definition of cover types.

4. Based on 25% by vines or trees.

REFERENCE NO. 3

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

CURVE NUMBERS FOR PERVIOUS AREAS

FIGURE C-2

ACTUAL IMPERVIOUS COVER

Land Use	Range-Percent	Recommended Value For Average Conditions-Percent (1)
Natural or Agriculture	0-0	0
Public Park	10 - 25	15
School	30 - 50	40
Single Family Residential: (2)		
2.5 acre lots	5 - 15	10
1 acre lots	10 - 25	20
2-3 DU/acre	20 - 40	30
3-5 DU/acre	30 - 50	40
5-8 DU/acre	35 - 55	50
8-10 DU/acre	50 - 70	60
More than 10 DU/acre	65 - 90	80
Multiple Family Residential:		
Condominiums	45 - 70	65
Apartments	65 - 90	80
Mobile Home Parks	65 - 85	75
Commercial, Downtown Business or Industrial	80 - 100	90

Notes:

(1) Recommended values are based on average conditions which may not apply to a particular study. The percentage may vary greatly even on comparable study sized lots due to differences in the dwelling size, improvements, etc. Landscape practices should also be considered as it is common in some areas to use ornamental gravels underlain by impervious plastic materials in place of lawns and shrubs. A field investigation of a study area shall always be made, and a review of aerial photos, where available, may assist in estimating the percentage of impervious cover in developed areas.

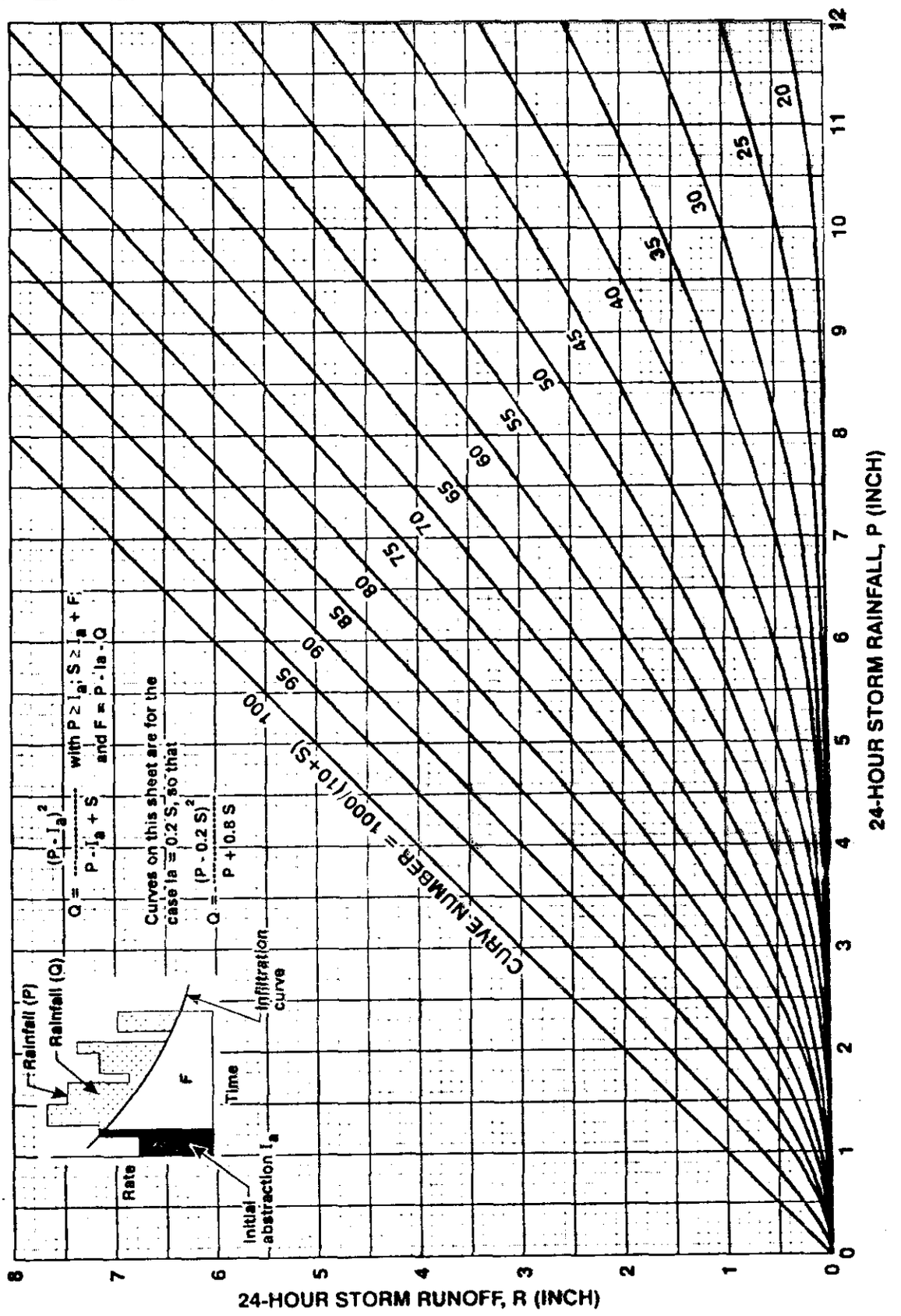
(2) For typical equestrian subdivisions increase impervious area 5% over the values recommended in the table above.

REFERENCE NO. 3

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

ACTUAL IMPERVIOUS COVER FOR DEVELOPED AREAS

FIGURE C-3

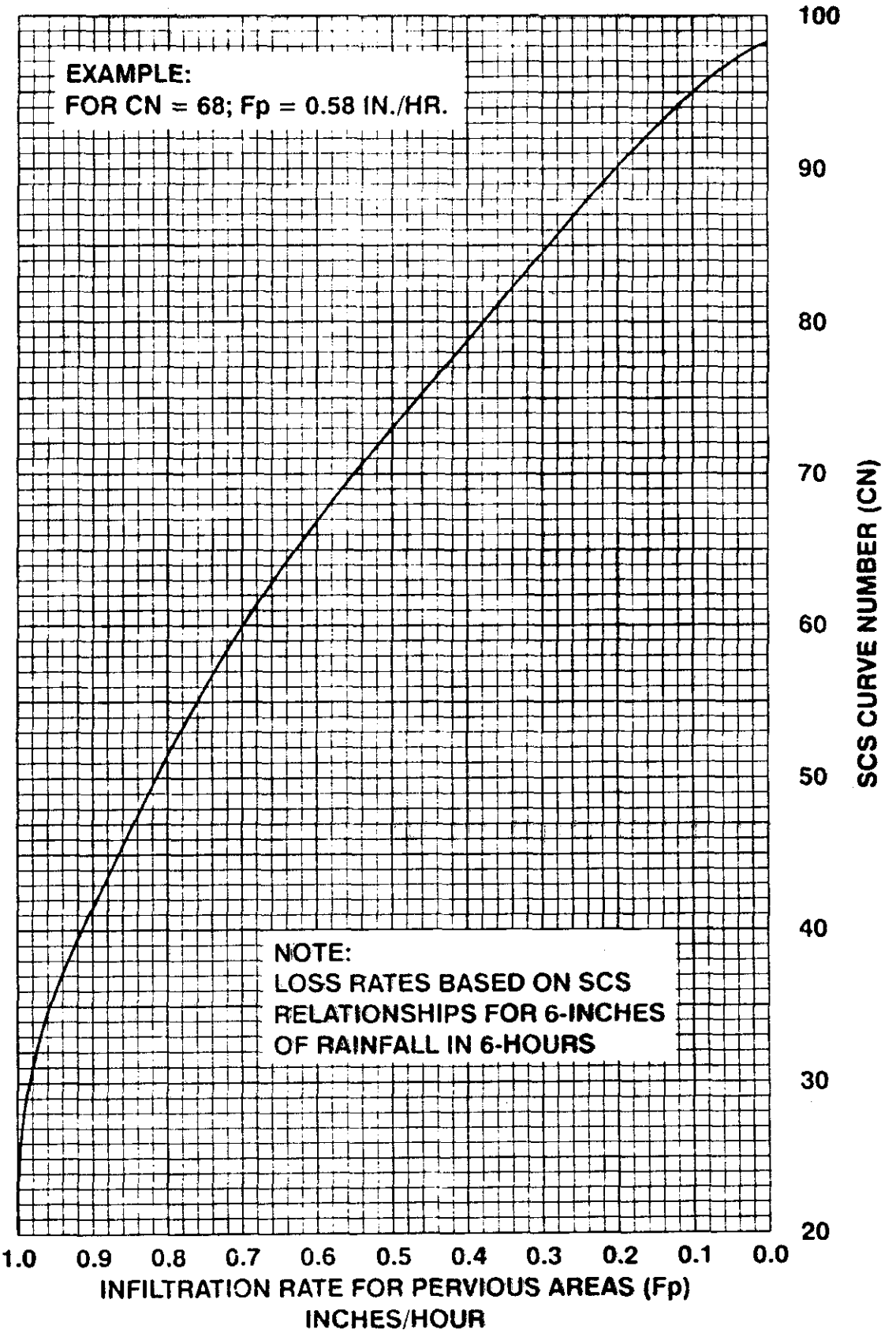


REFERENCE NO. 3

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

SCS 24-HOUR STORM RAINFALL-RUNOFF RELATIONSHIPS

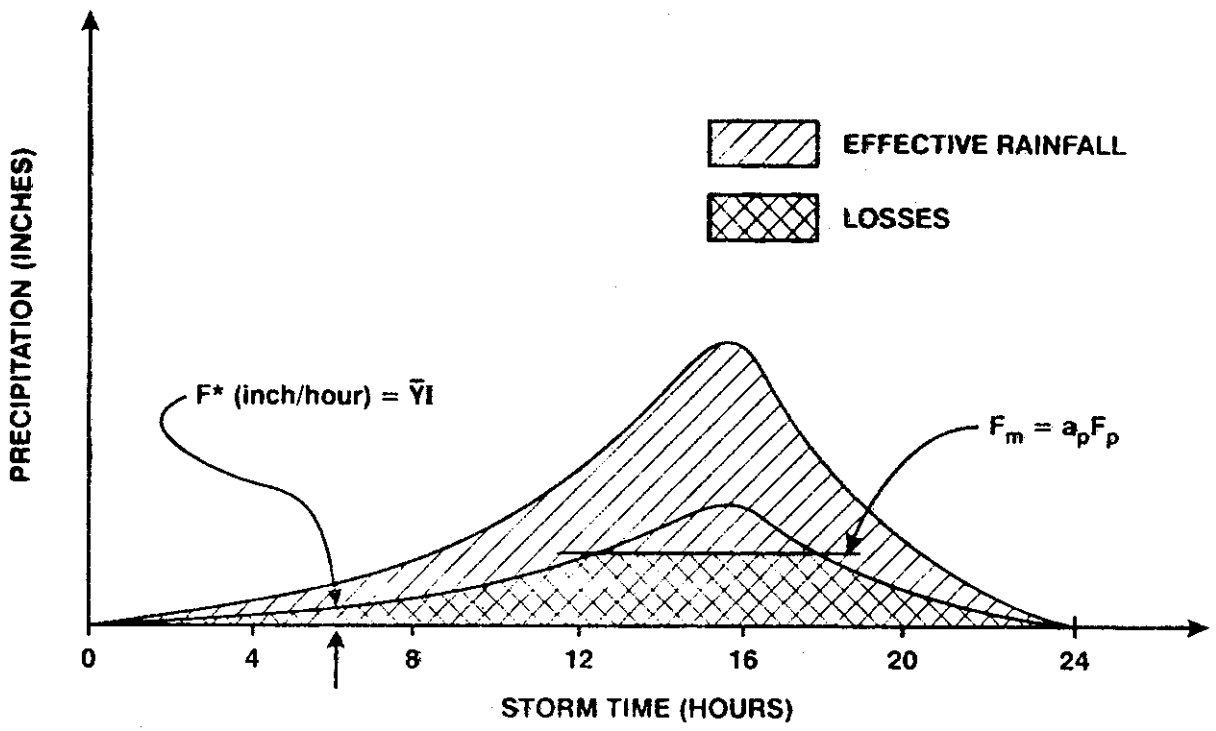
FIGURE C-1



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

INFILTRATION RATE FOR PERVIOUS AREAS VERSUS SCS CURVE NUMBERS

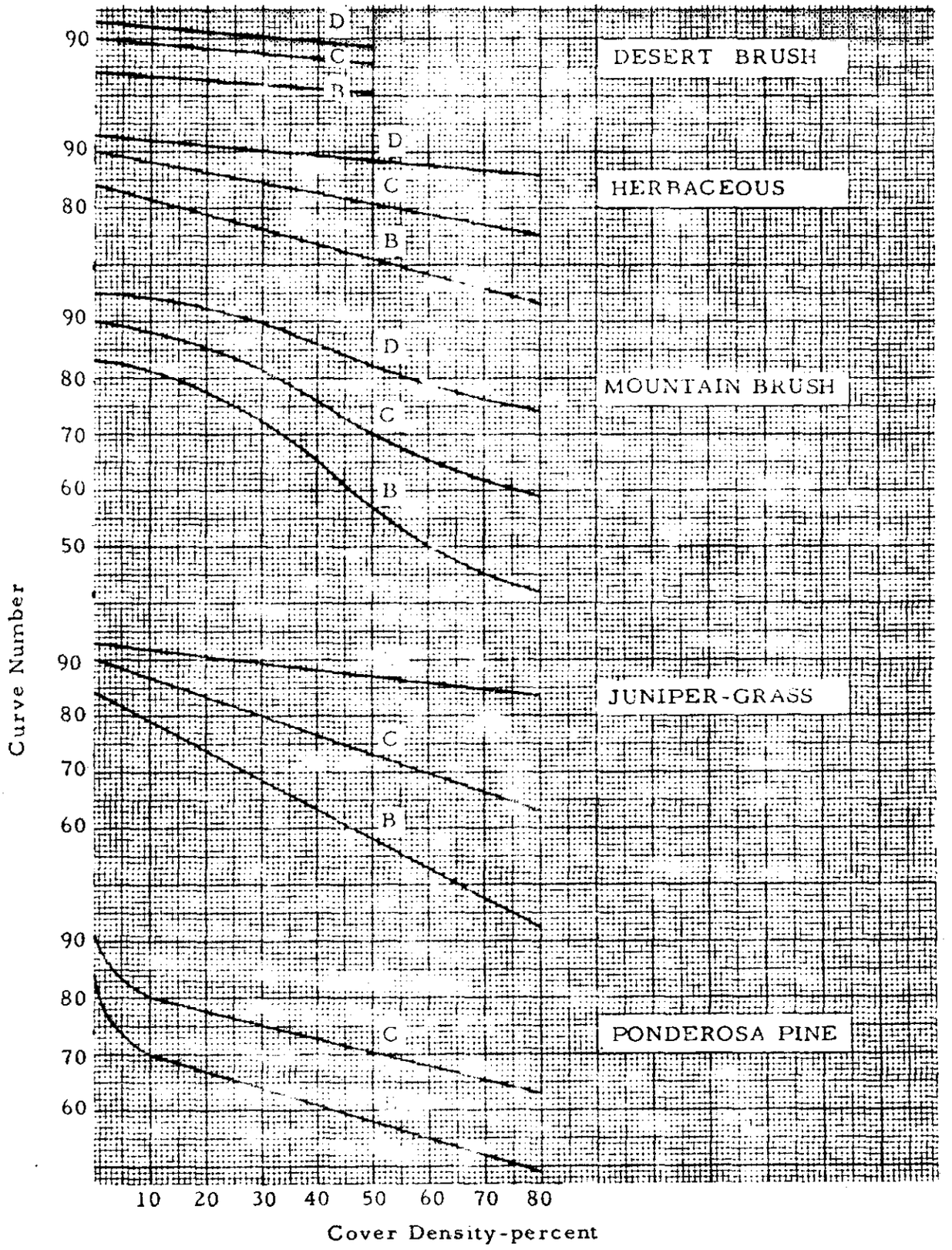
FIGURE C-5



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DESIGN STORM LOSS FUNCTION

FIGURE C-6

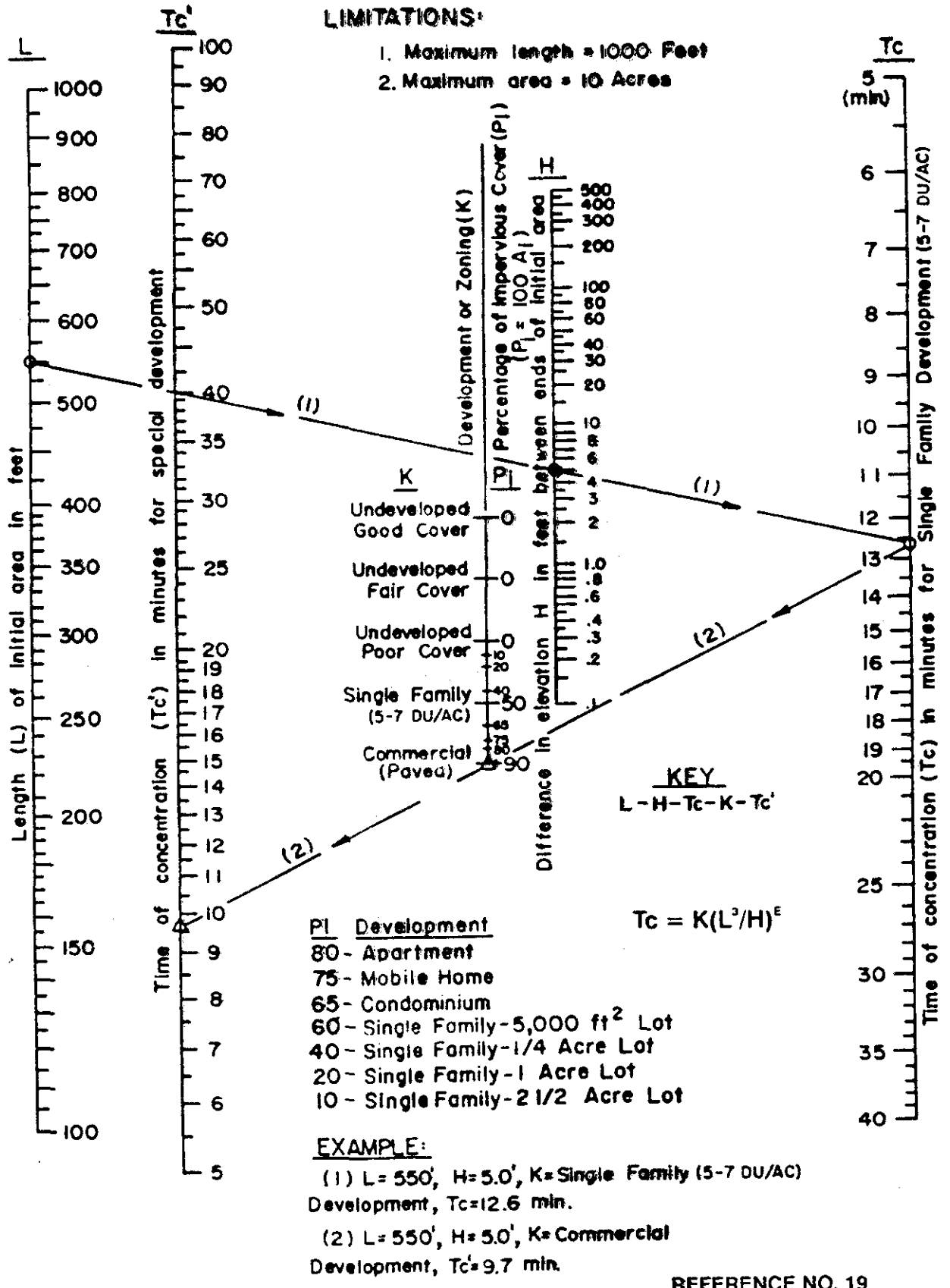


REFERENCE NO. 25

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

HYDROLOGIC SOIL COVER COMPLEXES AND ASSOCIATED CURVE NUMBERS

FIGURE C

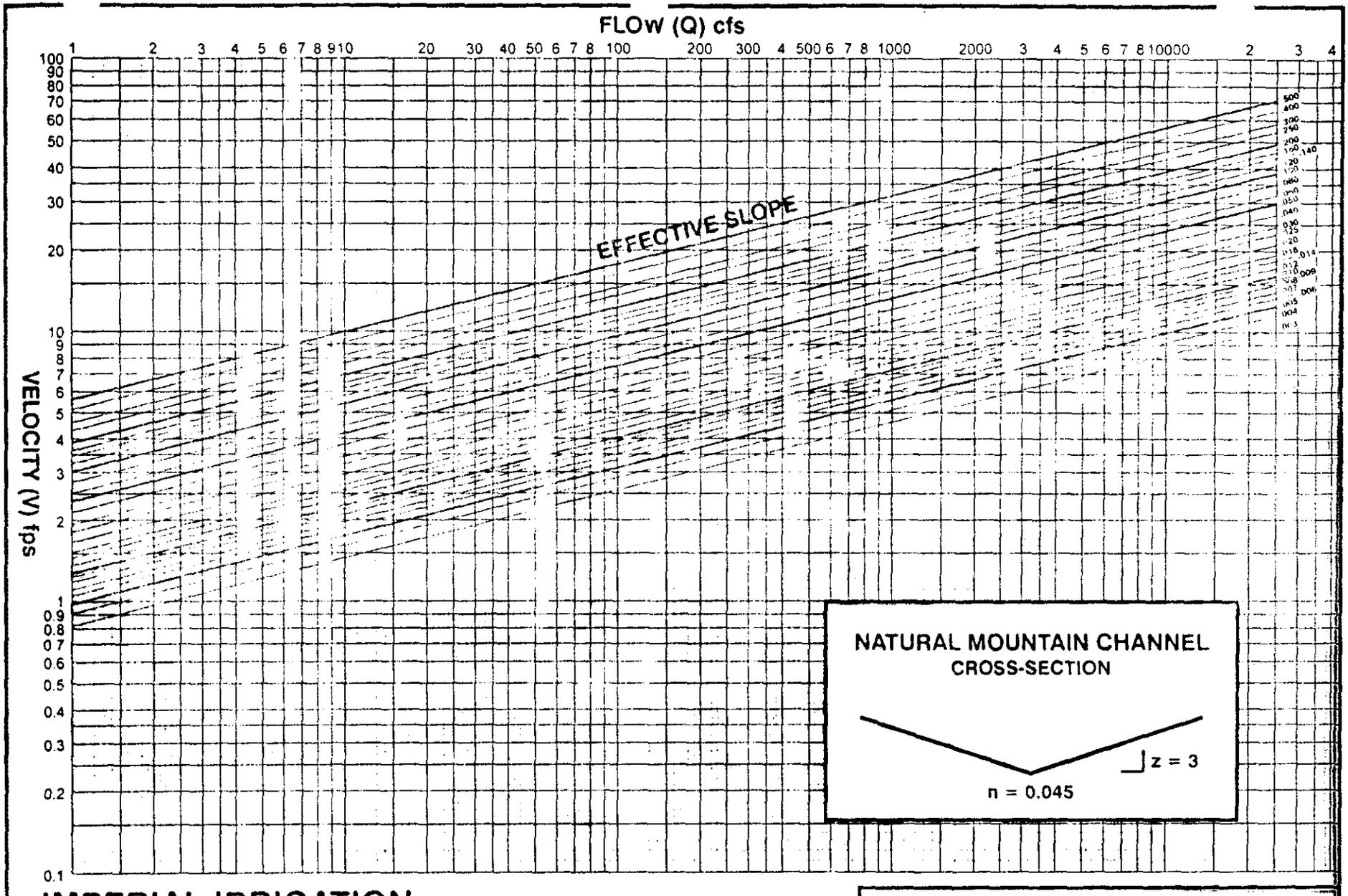


REFERENCE NO. 19

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

TIME OF CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA

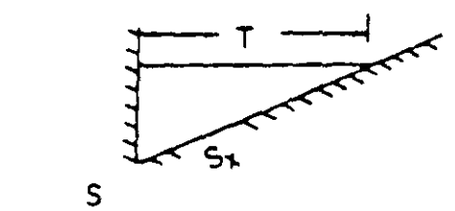
FIGURE D-1



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

VELOCITY-DISCHARGE-SLOPE RELATIONSHIPS NATURAL MOUNTAIN CHANNELS

FIGURE D-2



$$Q = \frac{0.56}{n} S_x^{1.67} S^{0.5} T^{2.67}$$

EXAMPLE: GIVEN:

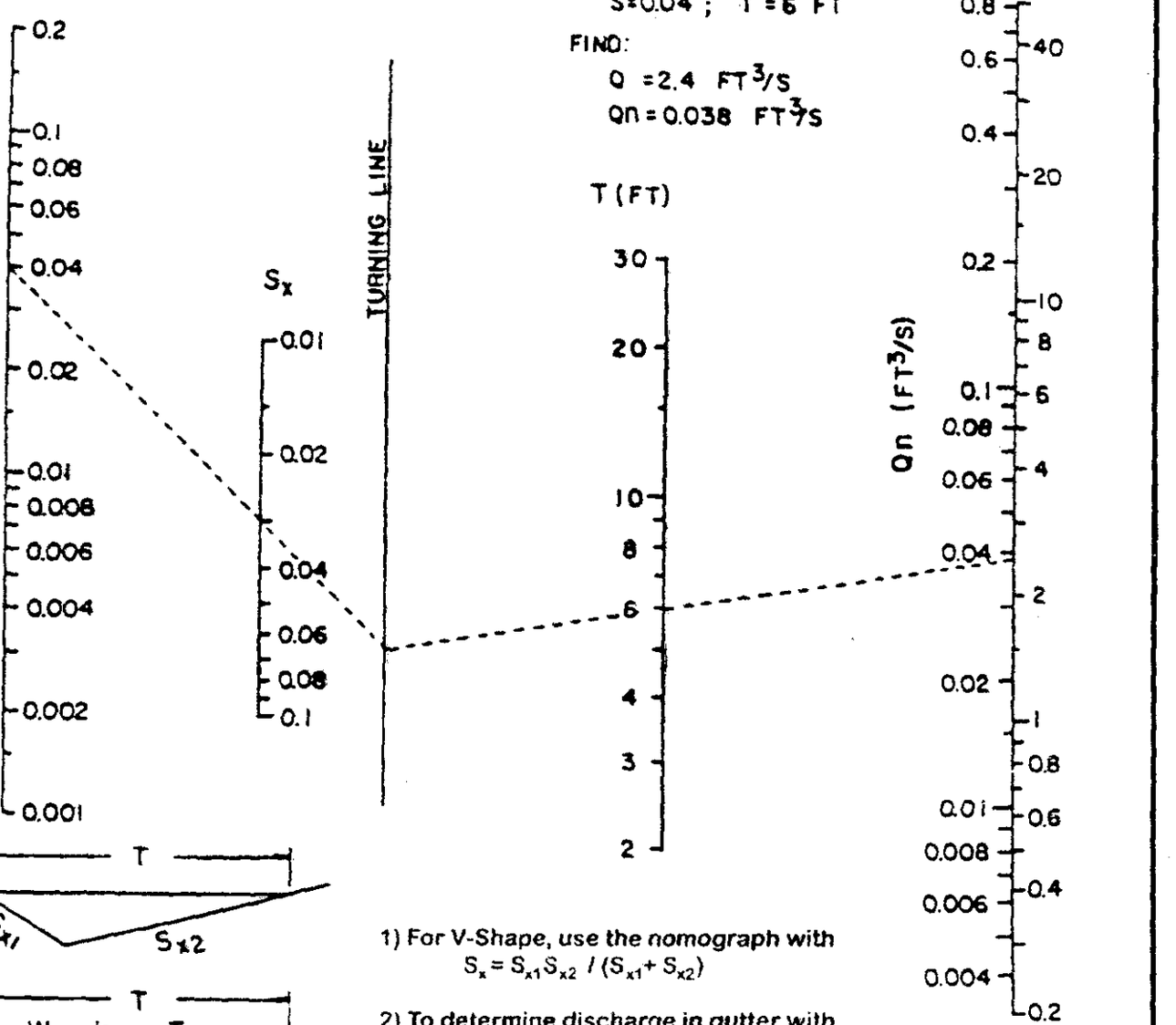
$n = 0.016$; $S_x = 0.03$

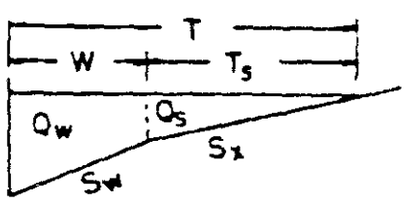
$S = 0.04$; $T = 6$ FT

FIND:

$Q = 2.4$ FT^3/S

$Qn = 0.038$ FT^3/S





1) For V-Shape, use the nomograph with $S_x = S_{x1} S_{x2} / (S_{x1} + S_{x2})$

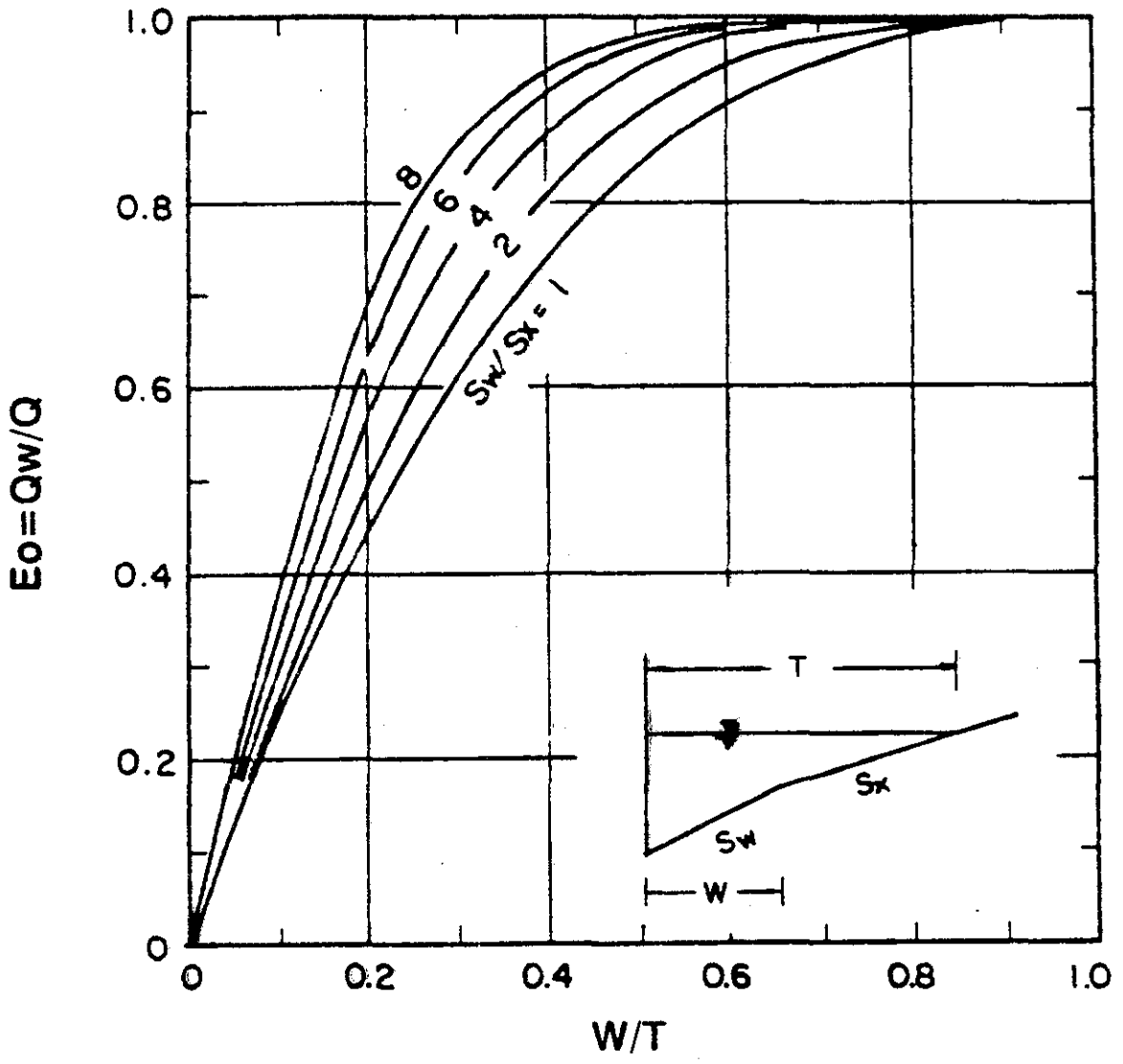
2) To determine discharge in gutter with composite cross slopes, find Q_s using T_s and S_x. Then, use Figure D-2b to find E_o. The total discharge is $Q = Q_s / (1 - E_o)$, and $Q_w = Q - Q_s$.

Ref: CalTrans Hydraulic Design Manual

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

FLOW IN TRIANGULAR GUTTER SECTIONS

FIGURE D-3a

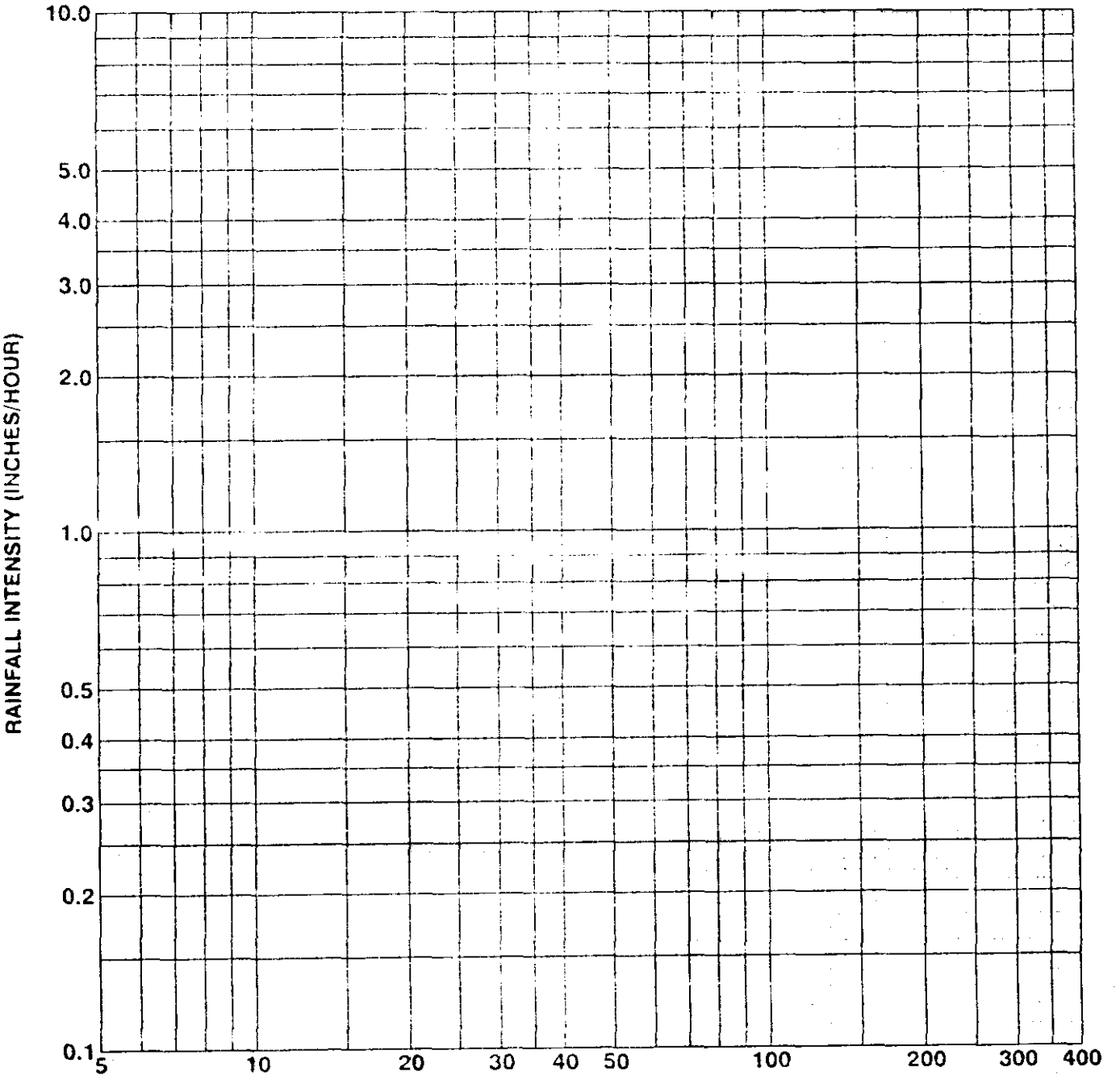


Ref: CalTrans Hydraulic Design Manual

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

RATIO OF FRONTAL FLOW TO TOTAL GUTTER FLOW

FIGURE D-3b



DESIGN STORM FREQUENCY = _____YEARS

PROJECT LOCATION: _____

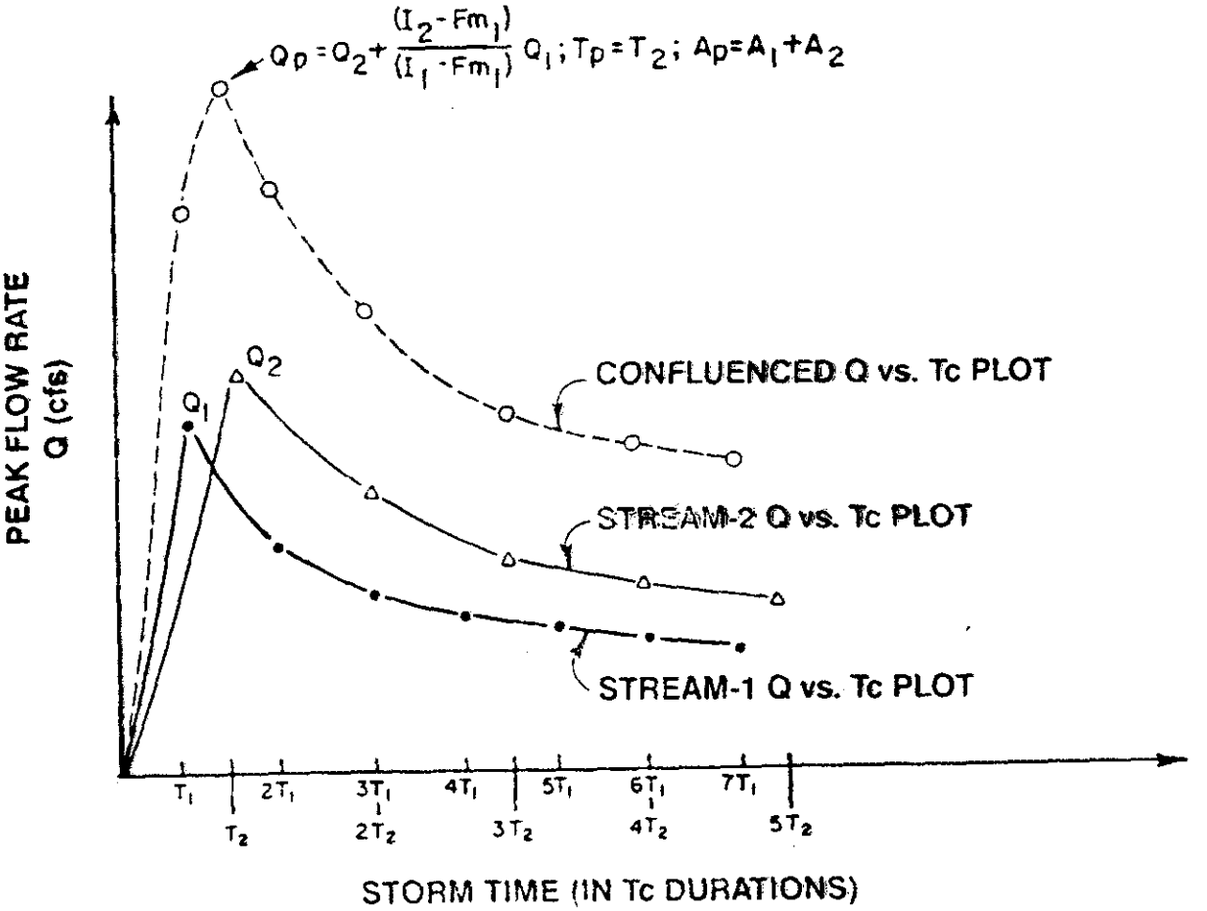
_____

_____

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

INTENSITY-DURATION CURVES CALCULATION SHEET

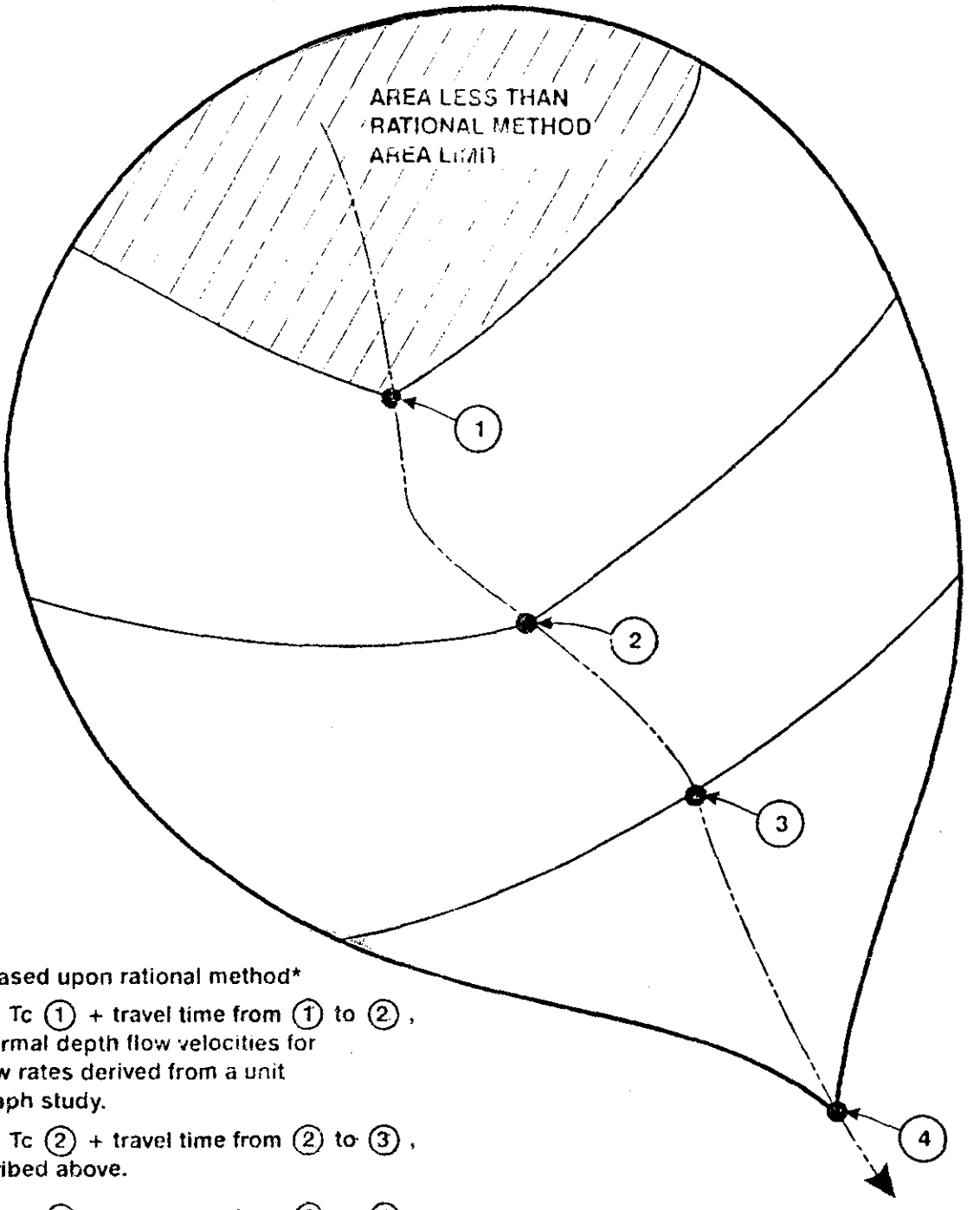
FIGURE D-4



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

RATIONAL METHOD CONFLUENCE ANALYSIS (FOR I GREATER THAN Fp)

FIGURE D-5

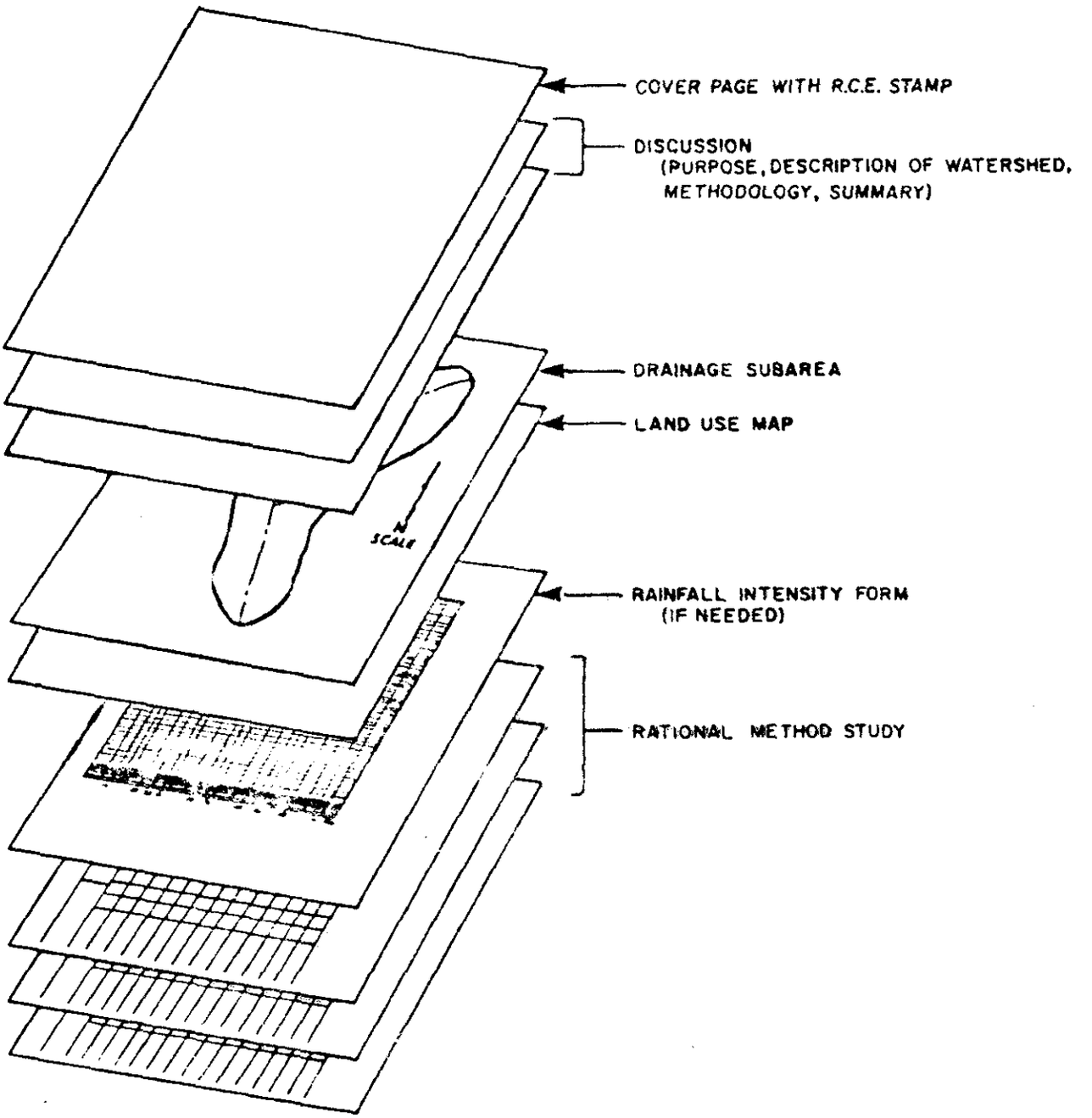


1. Tc (1) based upon rational method*
2. Tc (2) = Tc (1) + travel time from (1) to (2), using normal depth flow velocities for peak flow rates derived from a unit hydrograph study.
3. Tc (3) = Tc (2) + travel time from (2) to (3), as described above.
4. Tc (4) = Tc (3) + travel time from (3) to (4), as described above.
5. In general, reach lengths should be chosen such that:
   travel time < 3 minutes for Tc < 30 minutes
   travel time < 5 minutes for Tc < 60 minutes
   travel time < 10 minutes for Tc > 60 minutes

* Tc (1) corresponds, in general, to the longest watercourse Tc value.

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

TIME OF CONCENTRATION Tc CALCULATIONS FOR UNIT HYDROGRAPH STUDIES



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

TYPICAL REPORT FORMAT FOR RATIONAL METHOD STUDY

FIGURE

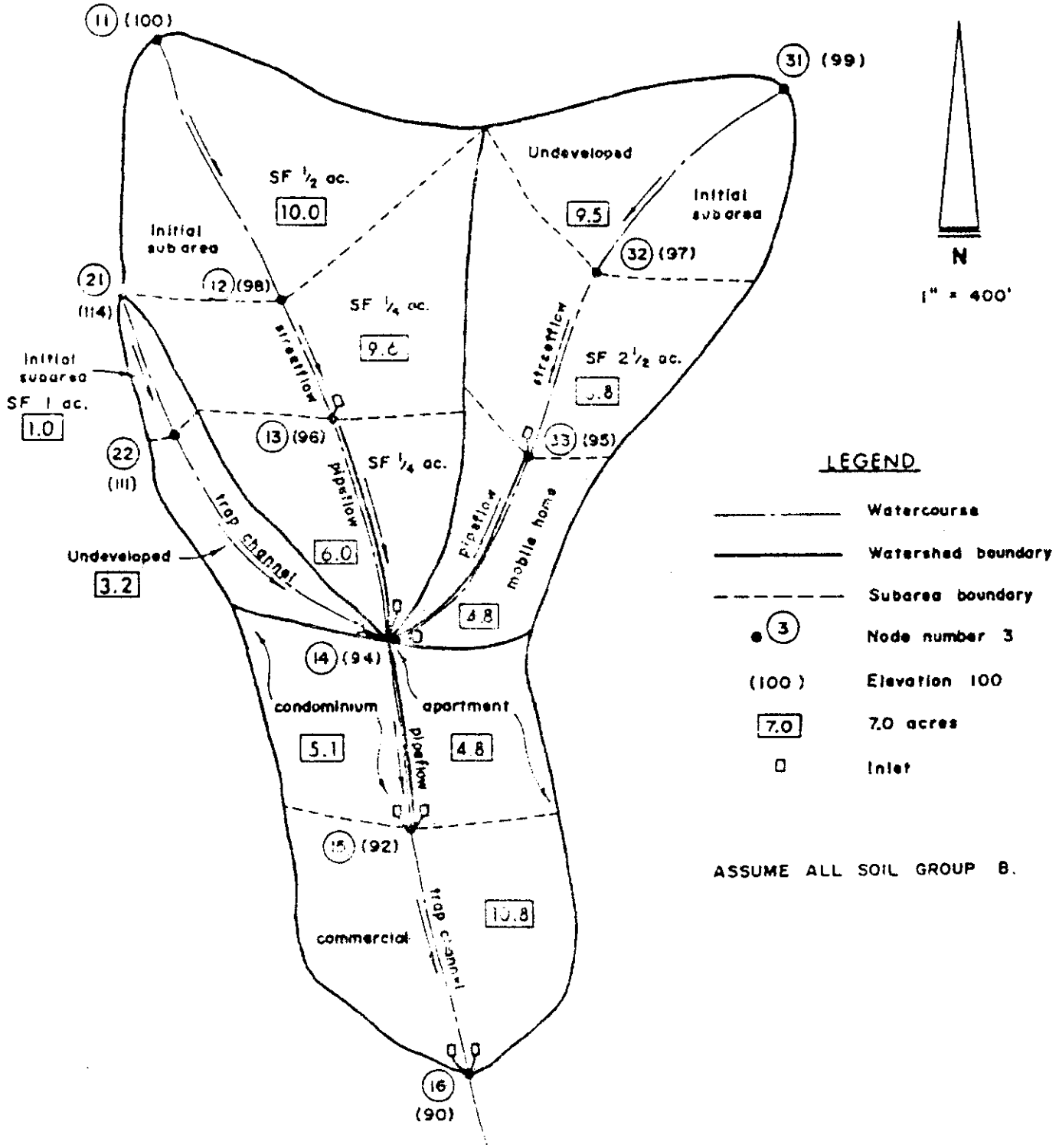
RATIONA ETHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

Study Name:

Calc'd By: ______ Dat ______
Chk'd By: ______ Date: ______
Page ____ of ____

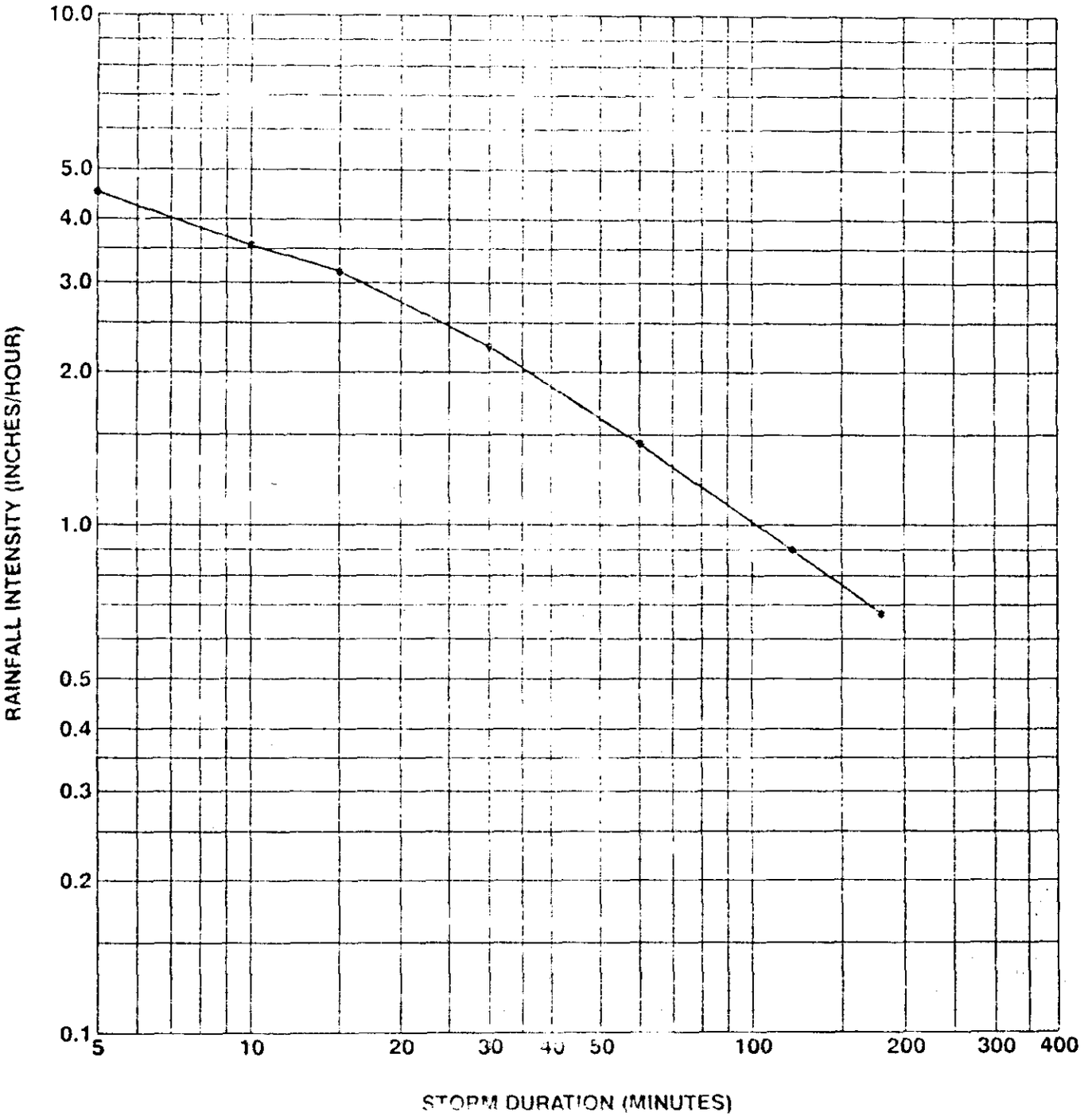
Concentration Point	Area (Acres)		Soil Type	Dev. Type	Tt min.	T min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
	Subarea	Total												

FIGURE D-8



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 1
DRAINAGE SYSTEM



DESIGN STORM FREQUENCY = 100 YEARS

PROJECT LOCATION: Example

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 1
INTENSITY-DURATION CURVES
CALCULATION SHEET

RATION. METHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

Study Name: Example Problem 1
100-Year Storm Event

Calc'd By: _____ Date: _____
Chk'd By: _____ Date: _____
Page 1 of 2

Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	T min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
12.0	10.0	10.0	B	SF(1/2)		21.0	1.84	0.48	0.48	12.2	800	0.0025	---	Initial Subarea
					2.4						350	0.0057	2.6	44 ft. Street Dn = 0.5'
13.0	9.6	19.6	B	SF(1/4)		23.4	1.73	0.41	0.45	22.6				
					2.1						650	0.0031	5.3	30' RCP Dn = 2.0'
14.0	6.0	25.6	B	SF(1/4)		25.5	1.65	0.41	0.44	27.7				
														Stream Summary
14.0		25.6				25.5				27.7				
											400	0.0075	---	Initial Subarea
22.0	1.0	1.0	B	SF(1)		13.7	2.38	0.55	0.55	1.6				
					3.1						850	0.0200	4.6	B = 0.5', Z = 2.0 n = 0.015, Dn = 0.3'
14.0	3.2	4.2	B	UNDEV. (GRASS)		16.8	2.10	0.57	0.56	5.6				
														Stream Summary
14.0		4.2				16.8				5.6				
											750	0.0027	---	Initial Subarea
32.0	9.5	9.5	B	UNDEV. (GRASS)		32.6	1.41	0.57	0.57	7.2				
					5.1						550	0.0036	1.9	44 ft. Street Dn = 0.5'
33.0	8.8	18.3	B	SF (2 1/2)		37.7	1.30	0.62	0.59	11.6				
					3.0						700	0.0014	3.4	27" RCP n = 0.013, Dn = 1.8'
14.0	4.8	23.1	B	MH		41.2	1.23	0.17	0.50	15.1				
														Stream Summary
14.0		23.1				41.2				15.1				
14.0	Q1 = 27.7 + (5.8) (1.65 - 0.56 / 2.10 - 0.56) + (15.1) (25.5 / 41.2) (1.65 - 0.50 / 1.23 - 0.50) = 46.4													
	Q2 = (27.7) (16.8 / 25.5) (2.10 - 0.44 / 1.65 - 0.44) + 5.8 + (15.1) (16.8 / 41.2) (2.10 - 0.50 / 1.23 - 0.50) = 44.8													Confluence Analysis for pt.# 14.0
	Q3 = (27.7) (1.23 - 0.44 / 1.65 - 0.44) + (5.8) (1.23 - 0.56 / 2.10 - 0.56) + 15.1 = 35.9													
	Ap = 25.6 + 4.2 + (25.5 / 41.2) 23.1													Confluence Results
	= 44.1													

RATIONAL METHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

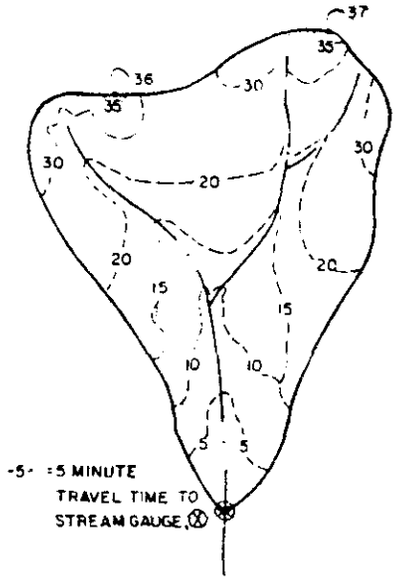
Study Name: Example Problem 1
100-Year Storm Event

Calc'd By: _____ Date: _____
Chk'd By: _____ Date: _____
Page 2 of 2

Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	T min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
15.0	5.1	49.2	B	Condo	1.3	26.8	1.59	0.24	0.45	50.6	550	0.00[illegible]8	[illegible]	39" RCP, D=2.5', n=0.013
											---			Addition of Subarea
15.0	4.8	40.4*	B	Apt.		18.2*	1.60	0.14	0.41	58.3				
					2.2						700	0.0[illegible]29	5.4	D = 2.0', Z = 2.0
16.0	10.8	51.2	B	Comm.		20.3	1.88	0.07	0.34	71.2				n = 0.015, Dr = 1.0
											---			Addition of Subarea
16.0		51.2				20.3				71.2				

*Shortest Tc provided maximum peak flow rate.

Q (cfs)	Tc (min)	Fm (in/hr)	Ae (Ac)
58.3	18.2	0.41	40.4
56.9	26.8	0.42	54.0
43.7	42.6	0.43	62.8



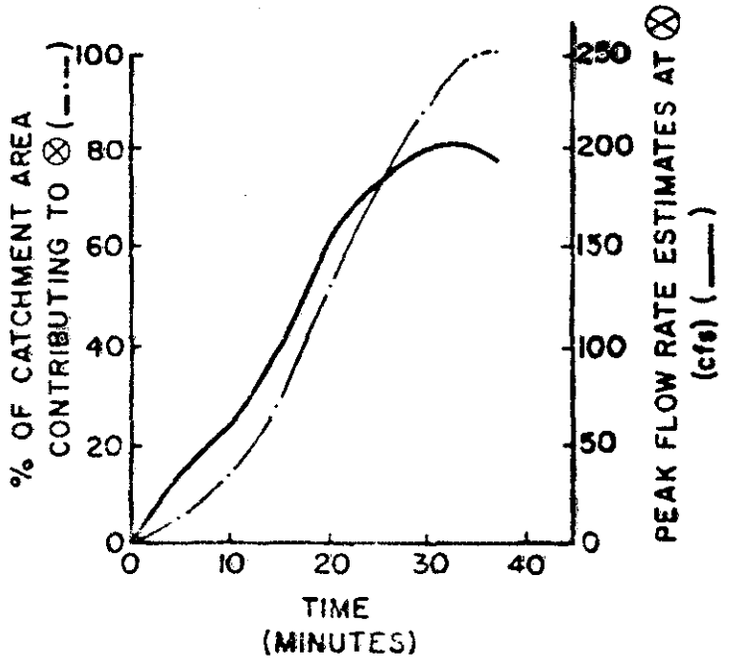
TIME AREA DIAGRAM

NOTE:
Runoff arrival times to the stream gauge are determined by normal depth flow velocities corresponding to peak flow conditions.

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 2
CATCHMENT TRAVEL TIME TO ⊗

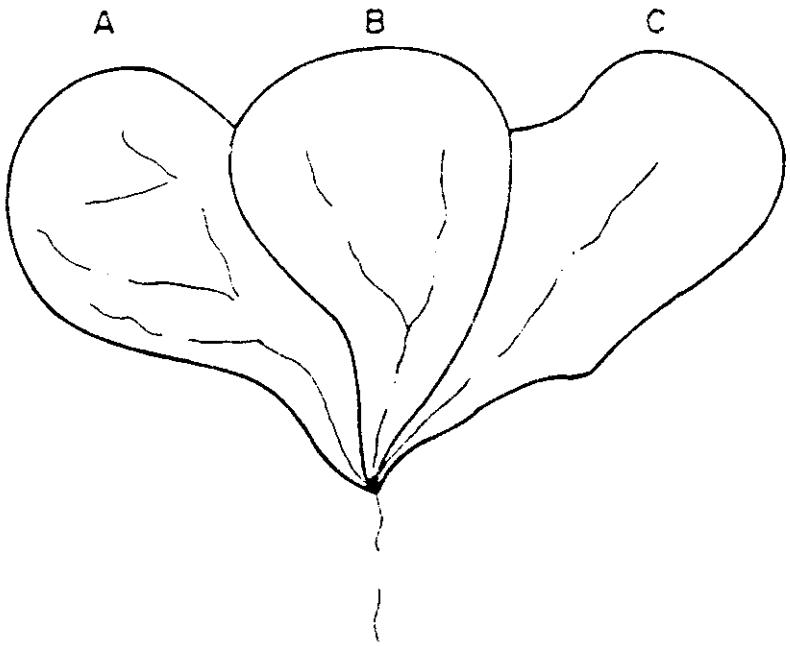
FIGURE D-12



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 2
TIME-AREA DIAGRAM AT ⊗

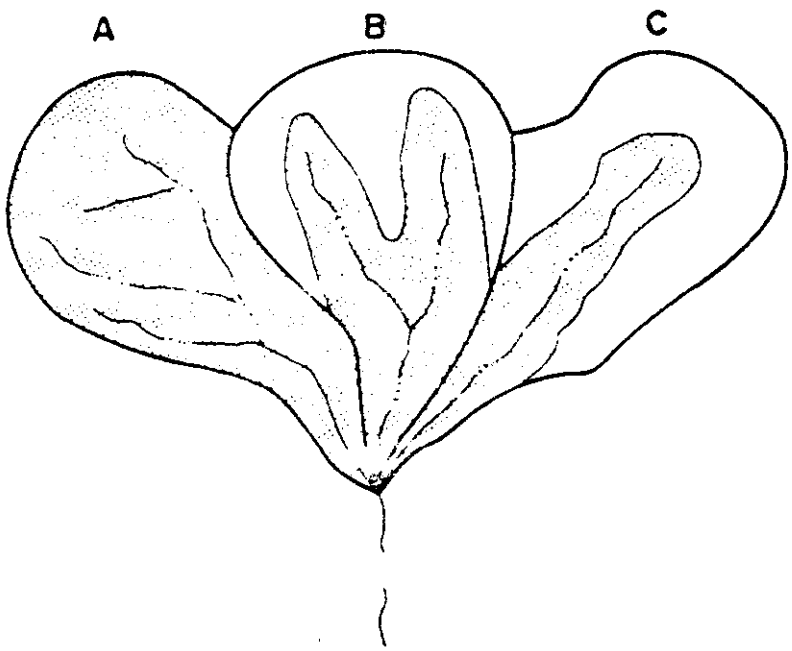
FIGURE D-1



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

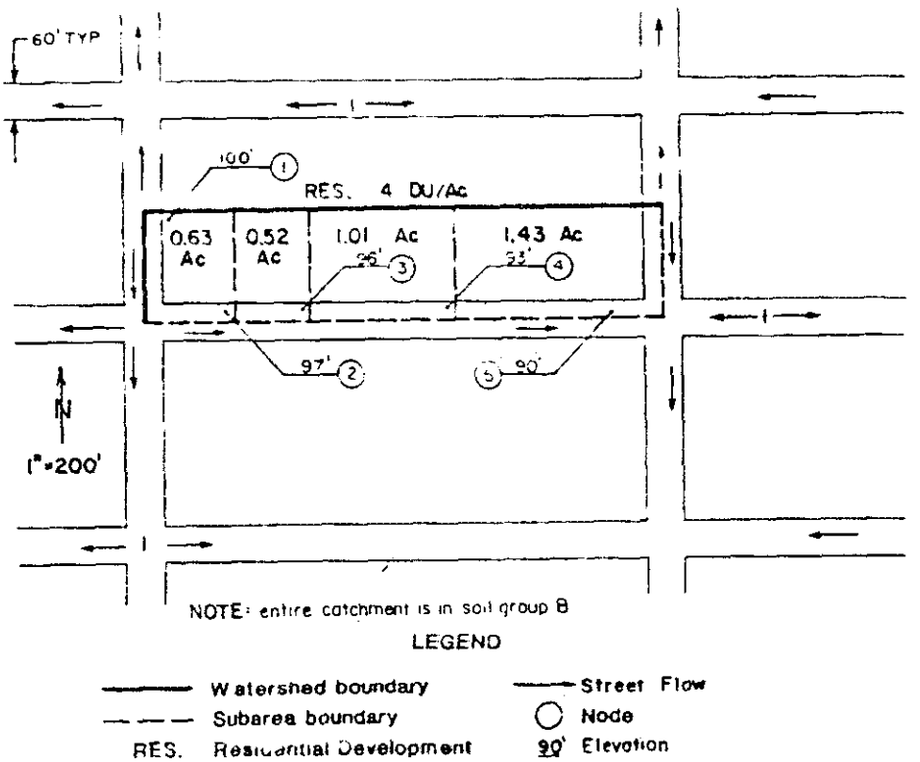
EXAMPLE PROBLEM 2
CONFLUENCE SCHEMATIC

FIGURE D-13



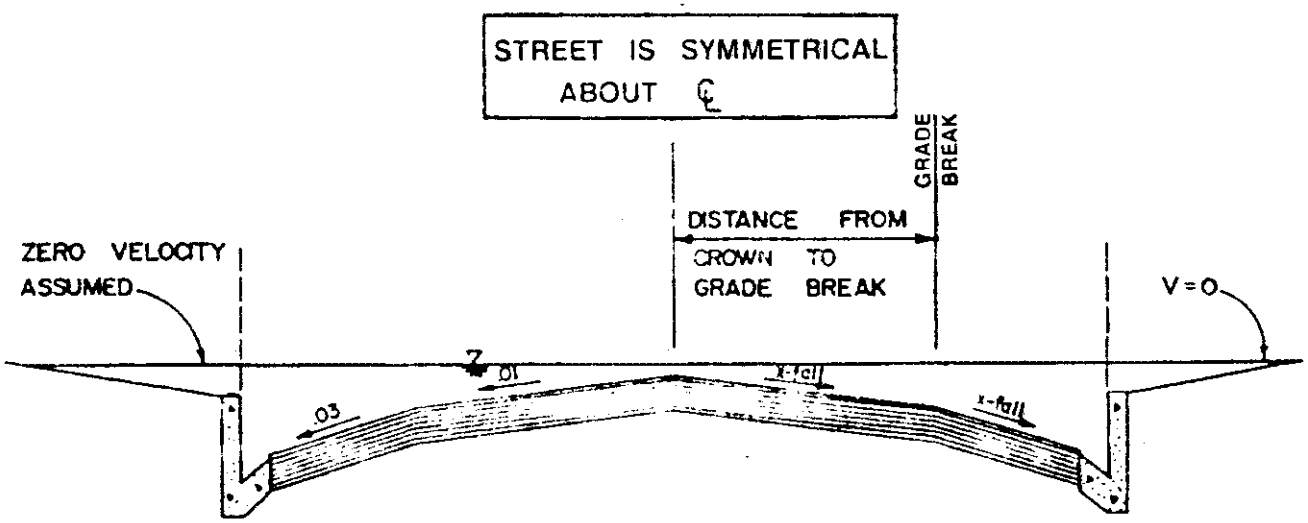
IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

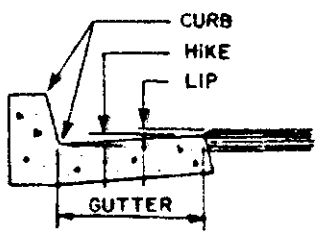
EXAMPLE PROBLEM 2
ESTIMATED EFFECTIVE AREA
FOR Tc OF 30 MINUTES



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3 SCHEMATIC



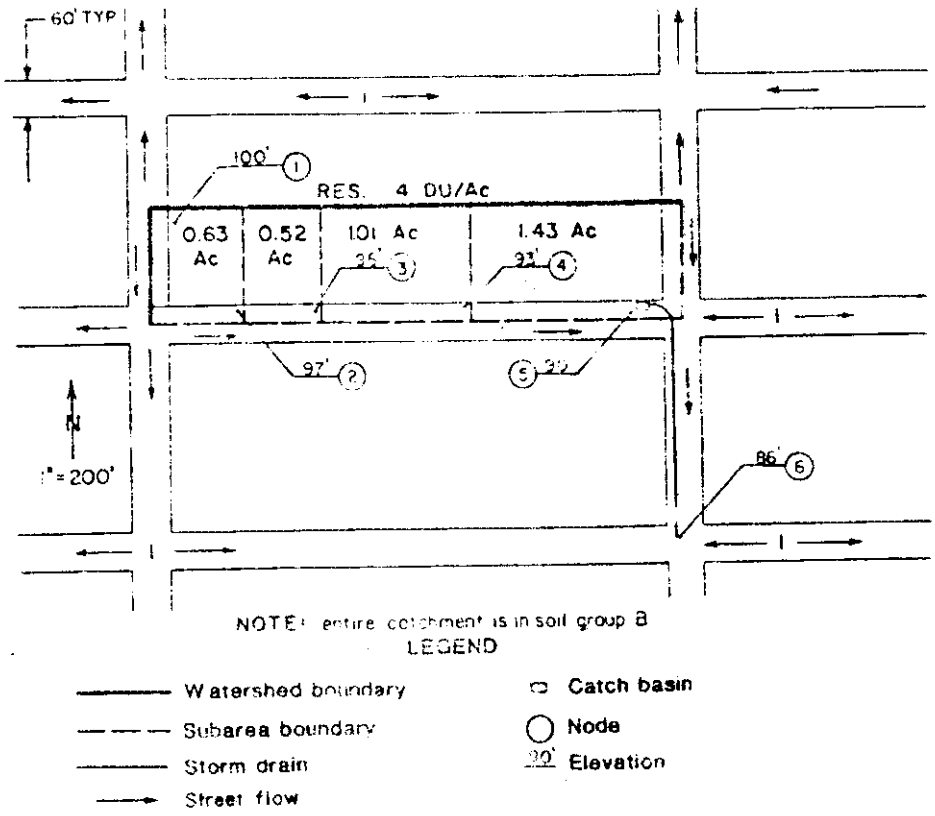


ASSUMED VALUES:

	6" CURB	8" CURB
Curb	6.0"	8.0"
Gutter	1.5'	2.0'
Hike	0.125'	0.167'
Lip	0.03125'	0.03125'
Manning's n	0.015	0.015

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

STREETFLOW HYDRAULIC DATA FOR EXAMPLE PROBLEM 3



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEMS 4 & 5 SCHEMATIC

FIGURE D-17

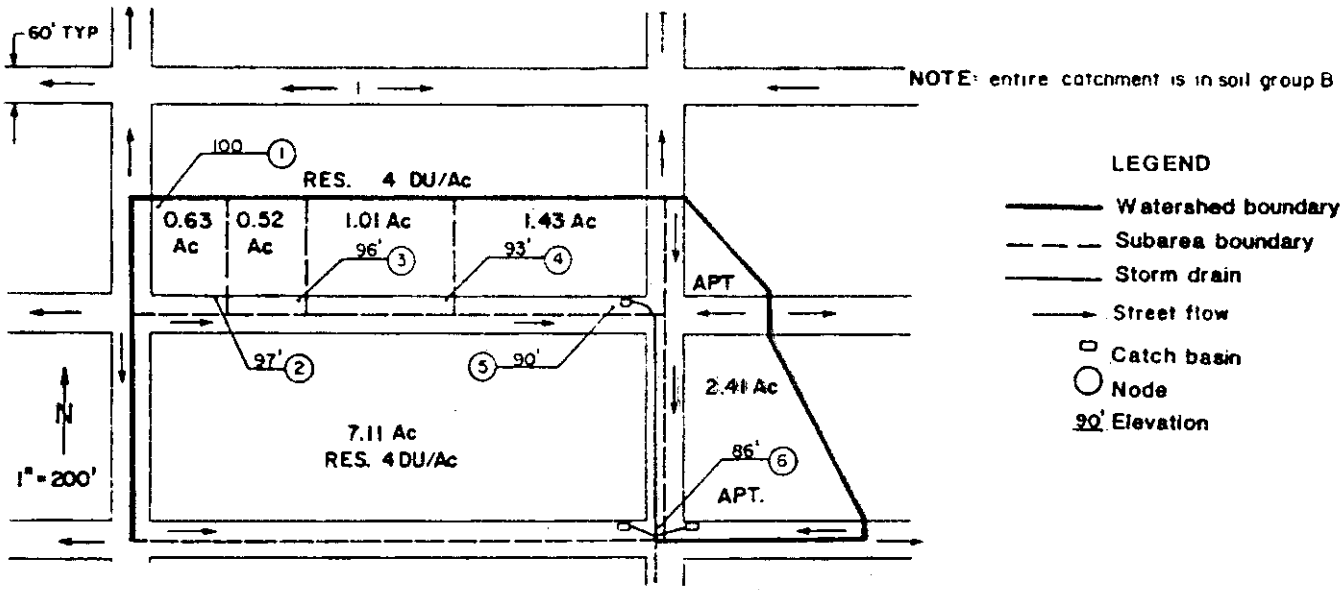
RATIONAL METHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

Study Name: Example Problems 3 & 4
100-Year Storm Event

Calc'd By: _____ **Date:** _____
Chk'd By: _____ **Date:** _____
Page ___ **of** ___

	Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	Tc min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
Example Problem #3	2.00	0.63	0.63	B	4d/AC	---	7.9	3.30	0.45	0.449	1.6	200	0.0150	---	Initial Subarea
						.9						130	0.0077	2.3	40 ft. Street Dn = 0.37'
	3.00	0.52	1.15	B	4d/AC	1.2	8.8	3.09	0.45	0.449	2.7	240	0.0125	3.3	40 ft. Street Dn = 0.41'
	4.00	1.01	2.16	B	4d/AC	1.3	10.0	2.86	0.45	0.449	4.7	270	0.0111	3.5	40 ft. Street Dn = 0.49'
	5.00	1.43	3.59	B	4d/AC	1.1	11.3	2.67	0.45	0.449	7.2	410	0.0098	6.2	18" RCP Dn 0.93'
Example Problem #4	6.00														

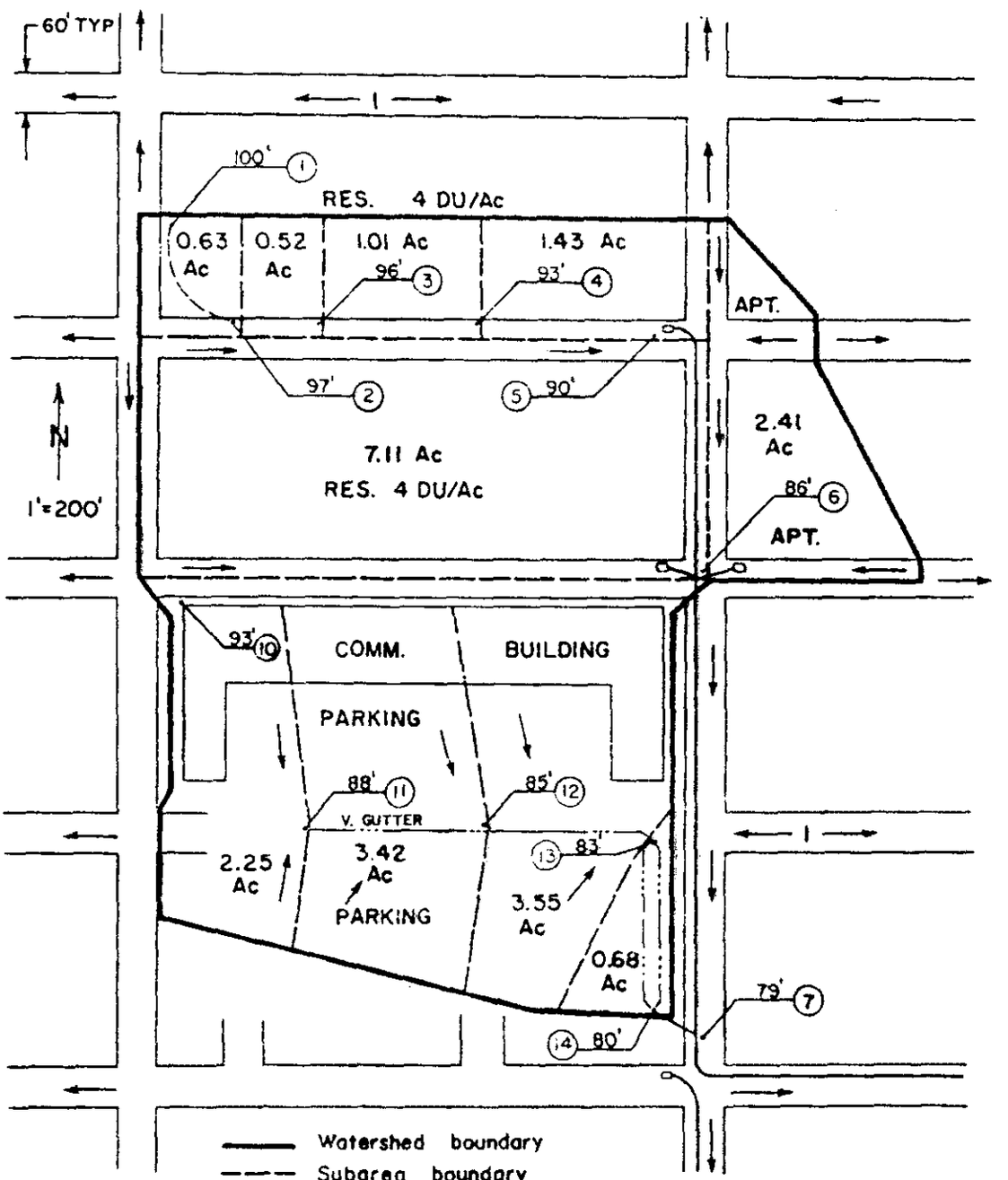
FIGURE D-17a



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

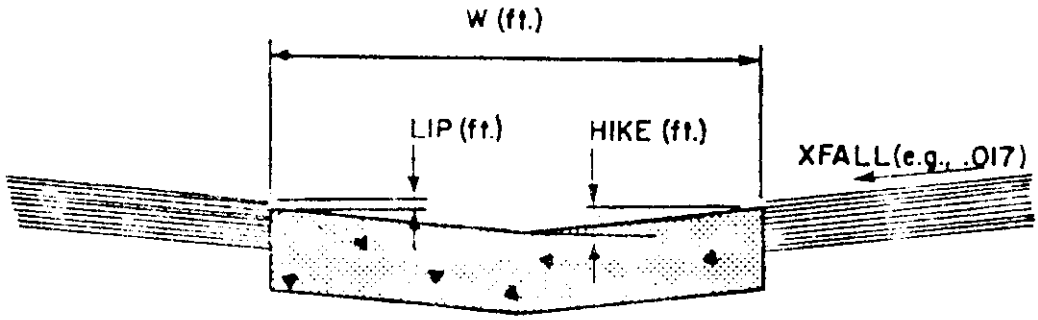
EXAMPLE PROBLEM 6 SCHEMATIC

FIGURE D-19

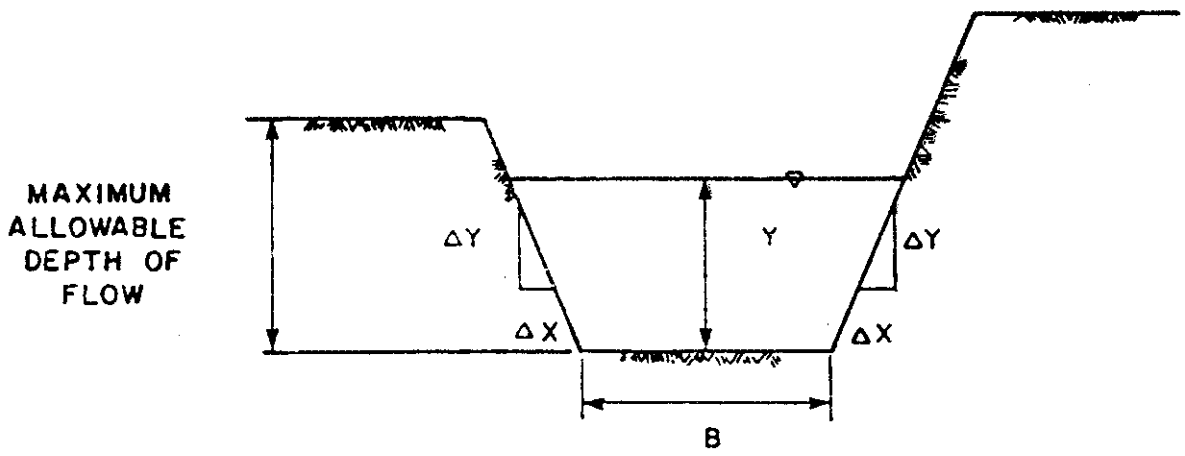


IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 7 SCHEMATIC



V – Gutter



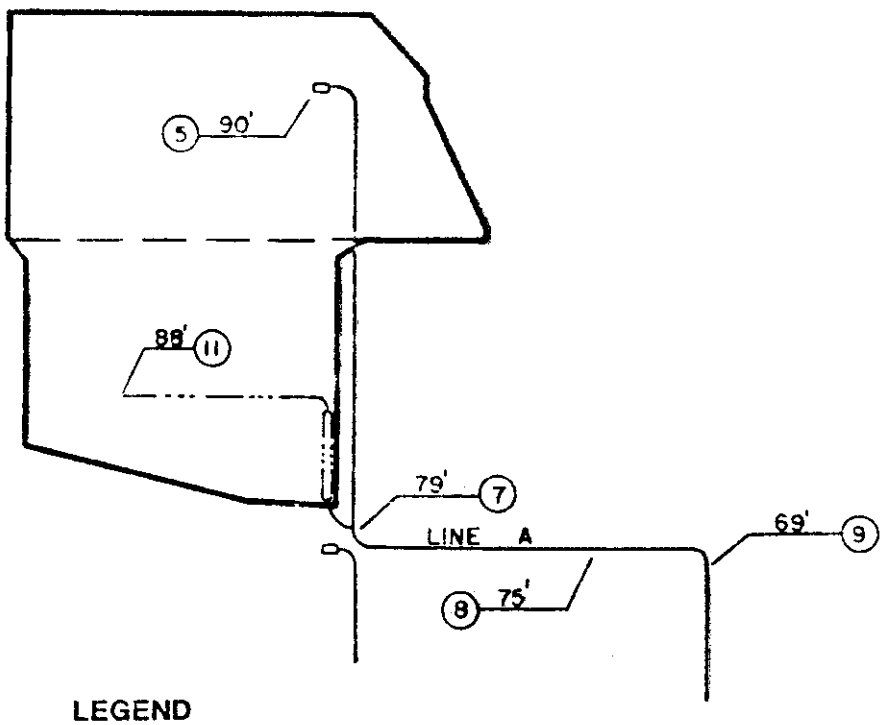
$Z = \Delta X / \Delta Y$

Trapezoidal Channel

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DATA REQUIREMENTS FOR TRAVELTIME CALCULATIONS EXAMPLE PROBLEM 7

FIGURE D-



LEGEND

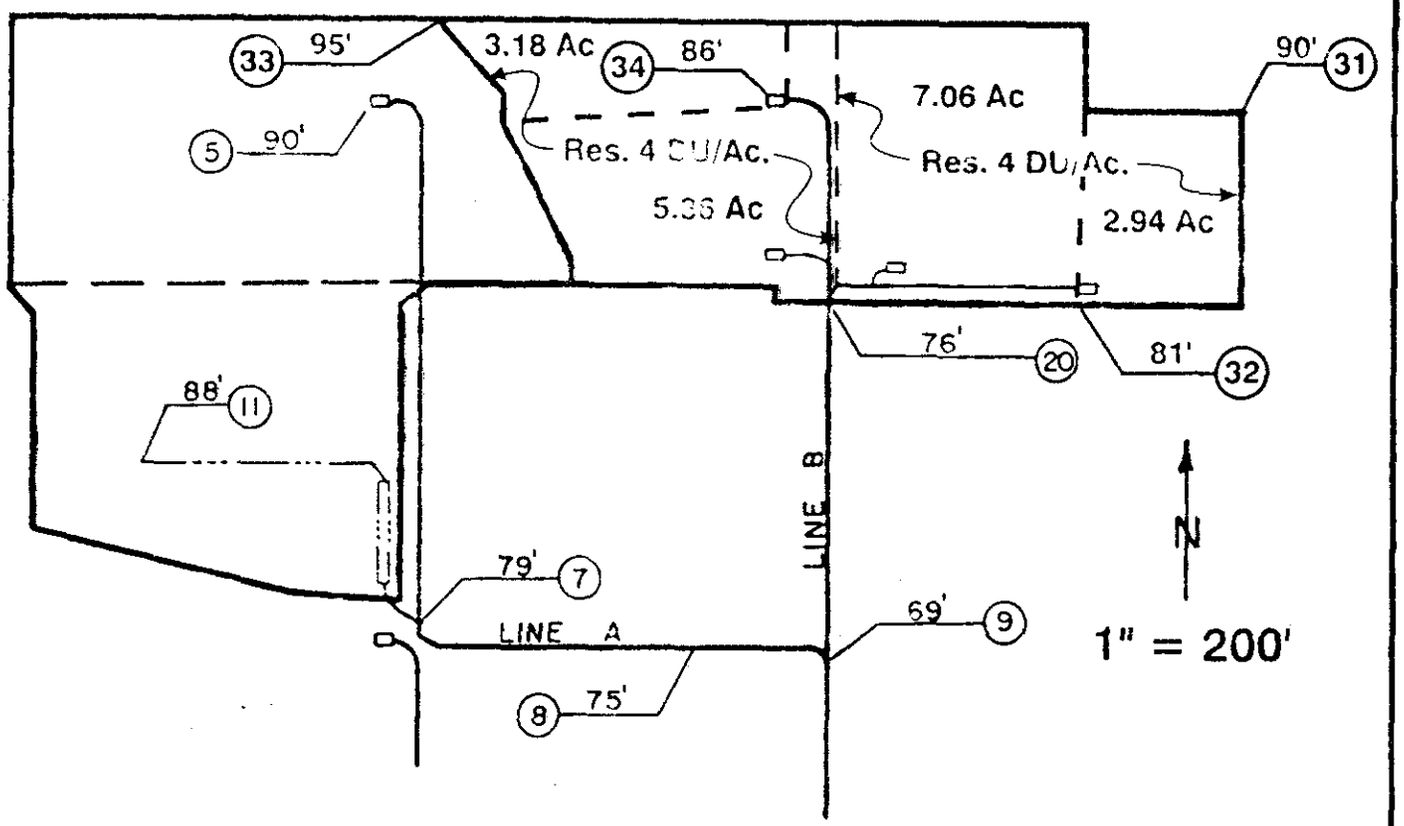
- Watershed boundary
- Subarea boundary
- Storm drain
- Catch basin
- Node
- 90 Elevation

See Figure D-19 for Land Use

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 8
SCHEMATIC

FIGURE D-21



Watershed boundary

Subarea boundary

Storm drain

Catch basin

Node

90' Elevation

A' Effective Area

IMPERIAL IRRIGATION DISTRICT

HYDROLOGY MANUAL

EXAMPLE PROBLEM 9
SCHEMATIC

FIGURE D-22

RATIONAL METHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

Study Name: Example Problems 5,6,7,8 & 9
100-Year Storm Event

Calc'd By: _____ Date: _____
Chk'd By: _____ Date: _____
Page 1 of 3

	Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	Tc min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
Example Problem #3	2.00	0.63	0.63	B	4d/AC	---	7.9	3.30	0.45	0.449	1.6	200	0.0150	---	Initial Subarea
	3.00	0.52	1.15	B	4d/AC	.9	8.8	3.09	0.45	0.449	2.7	130	0.0077	2.3	40 ft. Street Dn = 0.37'
	4.00	1.01	2.16	B	4d/AC	1.2	10.0	2.86	0.45	0.449	4.7	240	0.0125	3.3	40 ft. Street Dn = 0.41'
	5.00	1.43	3.59	B	4d/AC	1.3	11.3	2.67	0.45	0.449	7.2	270	0.0111	3.5	40 ft. Street Dn = 0.49'
Exam. Prob. #5	6.00					1.1						410	0.0[illegible]08	8.2	24" RCP Dn = 0.[illegible]'
Exam. Prob. #6	6.00	7.11 2.41	13.11	B B	4d/AC Com.		12.4	2.52	0.45 0.15	0.394	25.1				Add Subarea
Example Problem #7	7.00					1.4						705	0.0099	8.5	27" RCP Dn = 1.56'
	7.00		13.11				13.8	2.37			25.1				For Confluence
	1[illegible]0	2.25	2.25	B	Com.	---	8.7	3.12	0.07	0.075	6.2	4[illegible]0	0.0109	---	Initial Subarea
	12.00	3.42	5.67	B	Com.	1.5	10.2	2.83	0.07	0.075	14.1	275	0.0109	3.0	4 ft. Gutter Dn = 0.37'
	13.00	3.55	9.22	B	Com.	1.5	11.7	2.61	0.07	0.075	21.1	260	0.0077	2.9	4 ft. Gutter Dn = 0.45'
	14.00	0.68	9.90	B	Com.	0.5	12.2	2.55	0.07	0.075	22.0	245	0.0122	7.8	B = 1.0', Z = 1.0 n = 0.015, Dn = 1.22'
	7.00					0.2						85	0.0118	8.6	Add Subarea 24" RCP, Dn = 1.52'

Confluence Analysis 7.00

Peak FLow Rate = 46.4
Time of Concentration (min.) = 12.4
Mean Values: Fp = 0.748 (in/hr); Ap = 0.331; Fm = 0.248 (in/hr)
Effective Area = 21.65 (Acres); Total Area = 23.01 (Acres)

Q (cfs)	Tc (min)	Fp (avg)	Ap (avg)	Fm (avg)	I (in/hr)	Ae (Acres)
45.70	13.80	0.748	0.34	0.257	2.37	23.010
46.37	12.37	0.748	0.33	0.248	2.53	21.652

Largest Confluence Q = 46.4

FIGURE D-22a

RATIONAL METHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

Study Name: Example Problems 5,6,7,8 & 9
100-Year Storm Event

Calc'd By: _____ Date: _____
Chk'd By: _____ Date: _____
Page 2 of 3

Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	Tc min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
Example Problem #8					1.2						620	0.0065	8.3	36" RCP; Dn = 2.2'
8.00					0.4						300	0.0200	12.9	30" RCP Dn = 1.73'
9.00														
9.00					---						250	0.0360	---	Initial Subarea
32.00	2.94	2.94	B	4d/AC		7.3	3.47	0.45	0.449	8.0				
					0.5						250	0.0200	8.4	18" RCP Dn = 0.79'
Example Problem #9 20.00					---									Add Subarea
20.00	7.06	10.00	B	4d/AC	---	7.8	3.34	0.45	0.449	26.0				
20.00		10.00			---	7.8	3.34			26.0				For Confluence
34.00	3.18	3.18	B	4d/AC	---	9.3	3.07	0.45	0.449	7.5	350	0.0257	---	Initial Subarea
					0.4						250	0.0400	10.7	18" RCP; Dn = 0
20.00	5.36	8.54	B	4d/AC	---	9.3	3.00	0.45	0.449	19.6				Add'l Subare

Confluence Analysis 20.00

Peak Flow Rate = 44.5
Time of Concentration (min.) = 7.8
Mean Values: Fp = 0.748 (in/hr); Ap = 0.600; Fm = 0.419 (in/hr)
Effective Area = 17.14 (Acres); Total Area = 18.54 (Acres)

Q (cfs)	Tc (min)	Fp (avg)	Ap (avg)	Fm (avg)	I (in/hr)	Ae (Acres)
44.55	7.79	0.748	0.60	0.449	3.34	17.142
42.52	9.31	0.748	0.60	0.449	3.00	18.540

Largest Confluence Q = 44.5

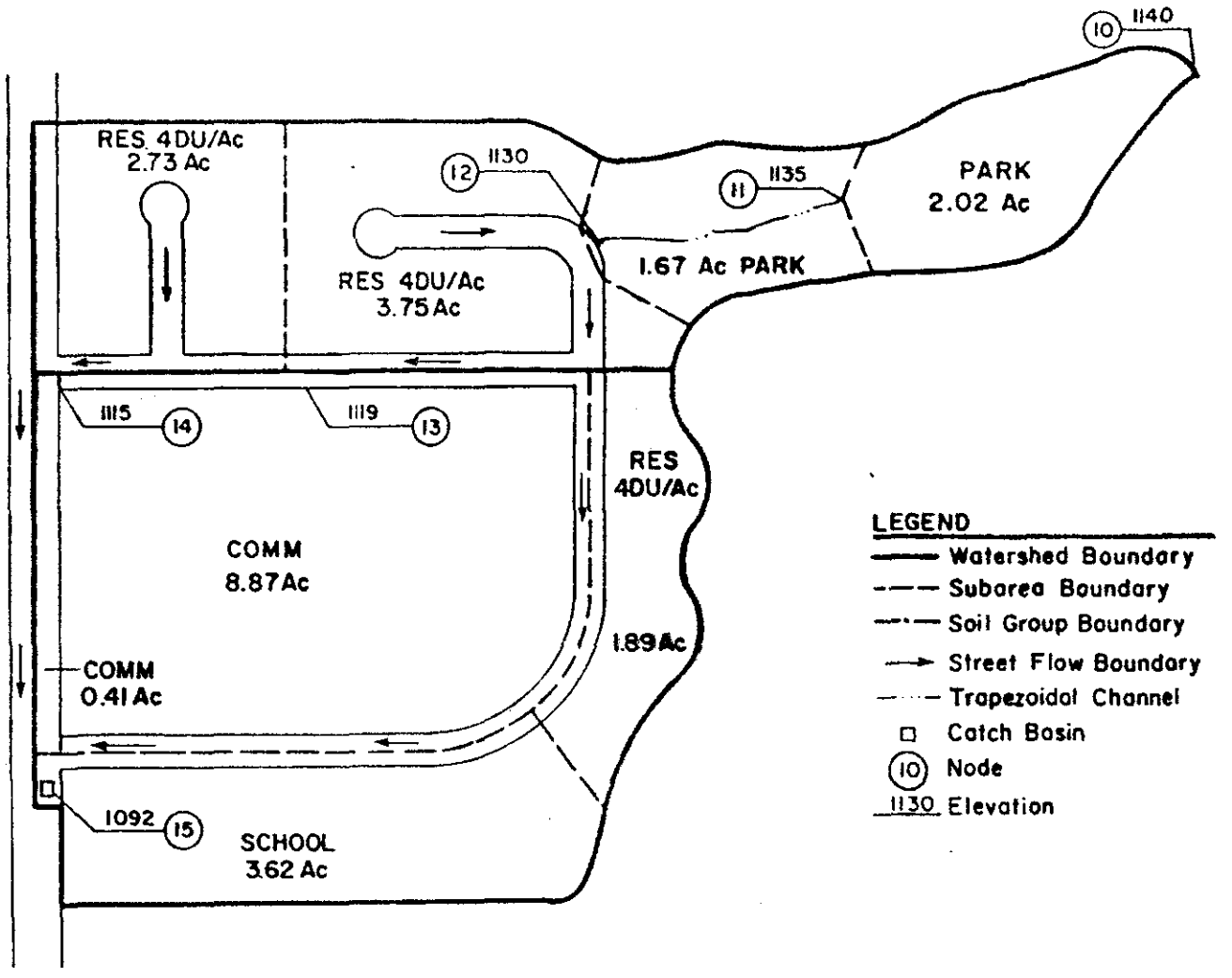
9.00					0.5						375	0.0187	12.4	30" RCP Dn = 1.72'

FIGURE 3.3

RATIONAL METHOD STUDY FORM Imperial Irrigation District Hydrology Manual	Study Name: Example Problems 5,6,7,8 & 9 100-Year Storm Event	Calc'd By: _____ Da... Chk'd By: _____ Date: Page 3 of 3

Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	Tc min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
9.00														Confluenced with Main-Stream Q (cfs) Tc (min) Fp (avg) Ap (avg) Fm (avg) I (in/hr) Ae (Acres) 83.35 8.29 0.748 0.49 0.363 3.21 29.963 83.66 9.82 0.748 0.48 0.358 2.90 33.726 79.24 14.00 0.748 0.46 0.341 2.35 40.192 76.26 15.44 0.748 0.46 0.342 2.21 41.550 Total Area = 41.550
9.00		33.7				9.8				83.7				Stream Summary

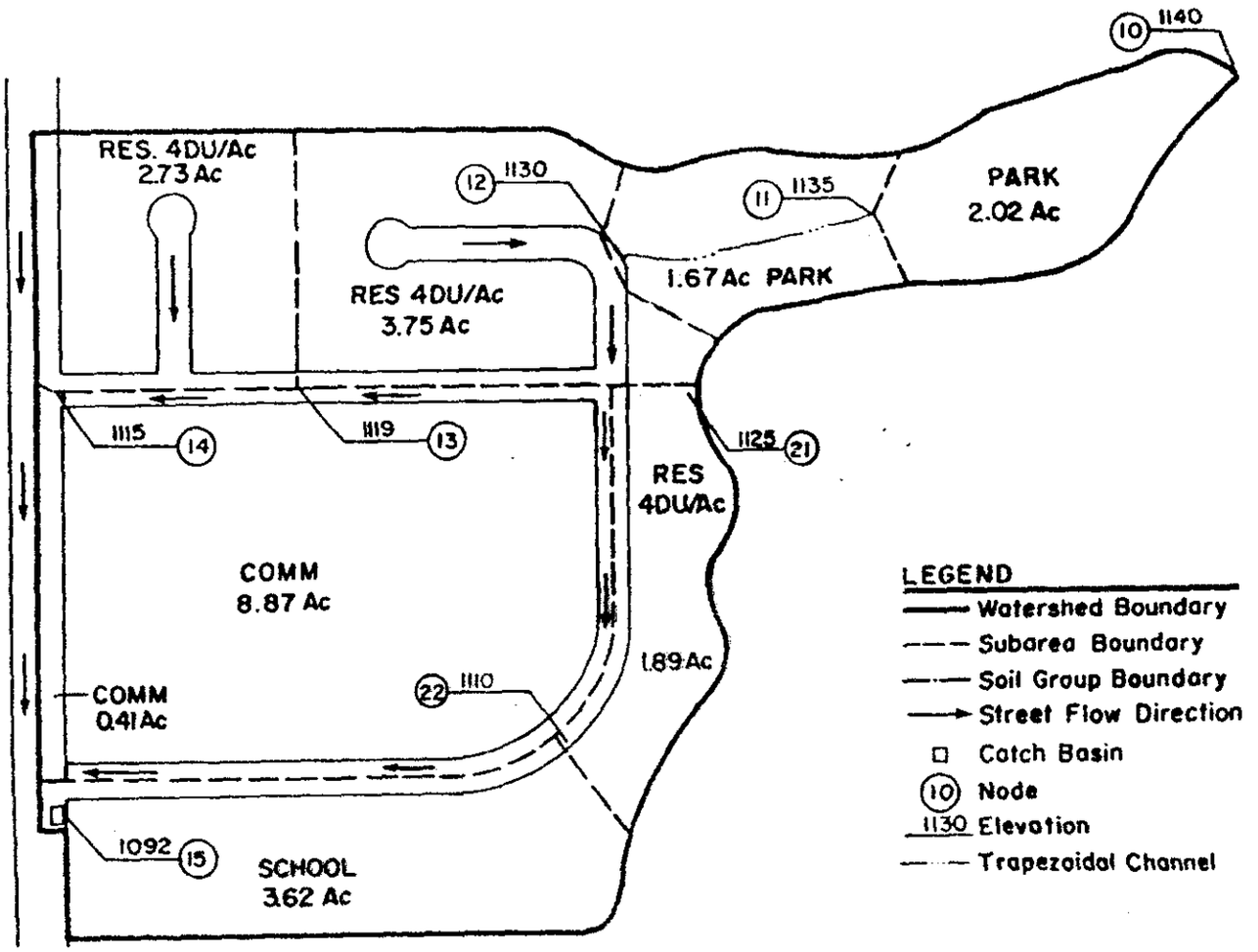
FIGURE C 22a



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 10 SCHEMATIC

FIGURE D-23



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 11 SCHEMATIC

FIGURE D-21

RATIONAL METHOD STUDY FORM Imperial Irrigation District Hydrology Manual	Study Name: Example Problems 10 & 11 100-Year Storm Event	Calc'd By: _____ Date: _____ Chk'd By: _____ Date: _____ Page 1 of 2

Concentration Point	Area (Acres)		Soil Type	Dev. Type	Tt min.	Tc min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
	Subarea	Total												
11.00	2.02	2.02	B	Park	---	15.1	2.24	0.64	0.636	2.9	530	0.0094	---	Initial Subarea
					2.5						380	0.0132	2.5	B = 1.0', Z = 3.0 n = 0.030, Dn = 0.48'
12.00	1.67	3.69	B	Park		17.6	2.04	0.64	0.636	4.7				
					2.3						620	0.0177	4.4	Add Subarea 40 ft. St., Dn = 0.52'
13.00	3.75	7.44	B	4d/AC		19.9	1.90	0.45	0.542	9.1				
					1.5						330	0.0121	3.6	40 ft. Street Dn = 0.60'
14.00	2.73	10.17	B	4d/AC		21.5	1.82	0.45	0.517	11.9				
					1.3						550	0.0418	6.9	40 ft. Street Dn = 0.49'
15.00	0.41	10.58	B	Com.		22.8	1.75	0.07	0.500	11.9				
Example Problem #10														
	8.87		B	Com.				0.07						
15.00	3.62		B	Sch.				0.45						
														Add Subarea
15.00	1.89	24.96	B	4d/AC		22.8	1.75	0.45	0.337	31.7				
														Stream Summary
15.00		24.96				22.8				31.7				

FIGURE D-24a

RATIONAL METHOD STUDY FORM
Imperial Irrigation District
Hydrology Manual

Study Name: Example Problems 10 & 11
100-Year Storm Event

Calc'd By: _____ **Date:** _____
Chk'd By: _____ **Date:** _____
Page 2 **of** 2

Concentration Point	Area (Acres) Subarea	Area (Acres) Total	Soil Type	Dev. Type	Tt min.	Tc min.	I in/hr	Fm in/hr	Fm avg.	Q Total	Flow path Length ft.	Slope ft./ft.	V ft./sec.	Hydraulics and Notes
11.00	2.02	2.02	B	Park	---	15.1	2.24	0.64	0.636	2.9	530	0.0094	---	Initial Subarea
					2.5						380	0.0132	2.5	B = 1.0', Z = 3.0 n = 0.030, Dn = 0.48'
12.00	1.67	3.69	B	Park		17.6	2.04	0.64	0.636	4.7				
					2.3						620	0.0177	4.4	Add Subarea 40 ft. St., Dn = 0.52'
13.00	3.75	7.44	B	4d/AC		19.9	1.90	0.45	0.542	9.1				
					1.5						330	0.0121	3.6	40 ft. Street Dn = 0.60'
14.00	2.73	10.17	B	4d/AC		21.5	1.82	0.45	0.517	11.9				
					1.3						550	0.0418	6.9	40 ft. Street Dn = 0.49'
15.00	0.41	10.58	B	Com.		22.8	1.75	0.07	0.500	11.9				
														For Confluence
15.00		10.58				22.8	1.75			11.9				
					---						560	0.0268	---	Initial Subarea
22.00	1.89	1.89	B	4d/AC		10.7	2.76	0.45	0.443	3.9				
					1.9						630	0.0286	5.5	40 ft. Street Dn = 0.57'
	8.87		B	Com.				0.07						
15.00	3.62	14.38	B	Sch.		12.6	2.50	0.45	0.218	29.5				

Example Problem #11

Confluence Analysis 15.00

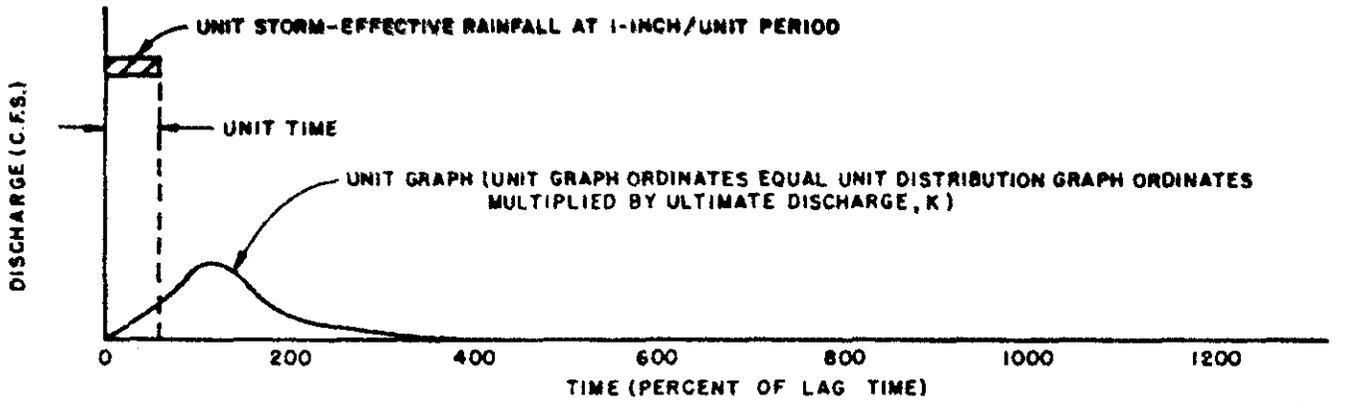
Peak FLow Rate = 40.1
Time of Concentration (min.) = 12.6
Mean Values: Fp = 0.748 (in/hr); Ap = 0.400; Fm = 0.299 (in/hr)
Effective Area = 20.22 (Acres); Total Area = 24.96 (Acres)

Q (cfs)	Tc (min)	Fp (avg)	Ap (avg)	Fm (avg)	I (in/hr)	Ae (Acres)
31.74	22.82	0.748	0.45	0.337	1.75	24.960
40.06	12.59	0.748	0.40	0.299	2.50	20.215

Largest Confluence Q = 40.1

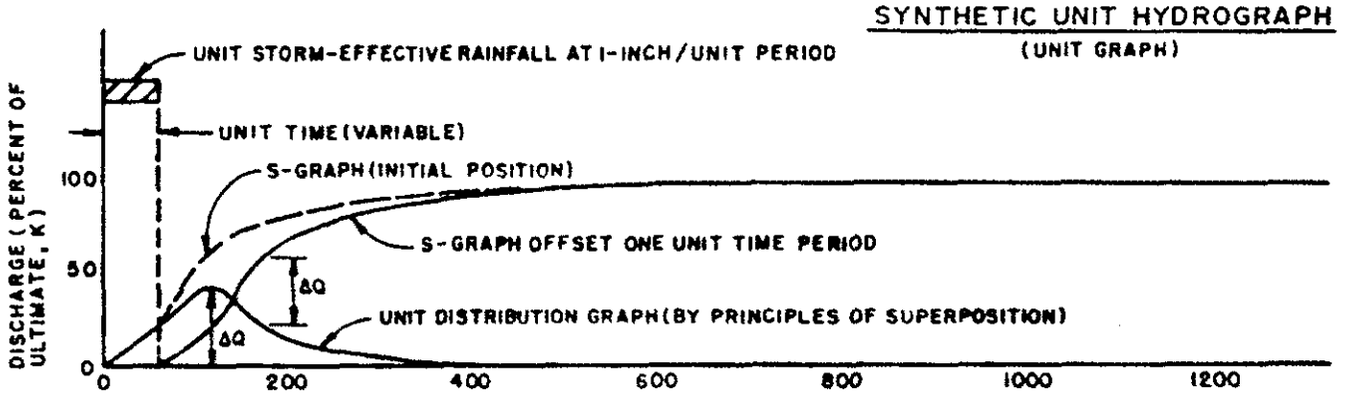
15.00		20.21				12.6				40.1				Stream Summary

FIGURE D-24a

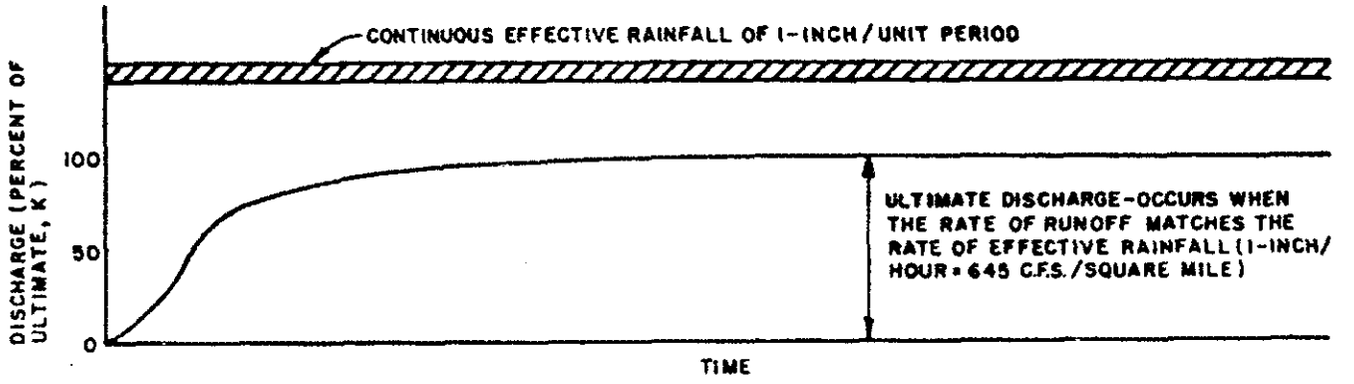


SYNTHETIC UNIT HYDROGRAPH

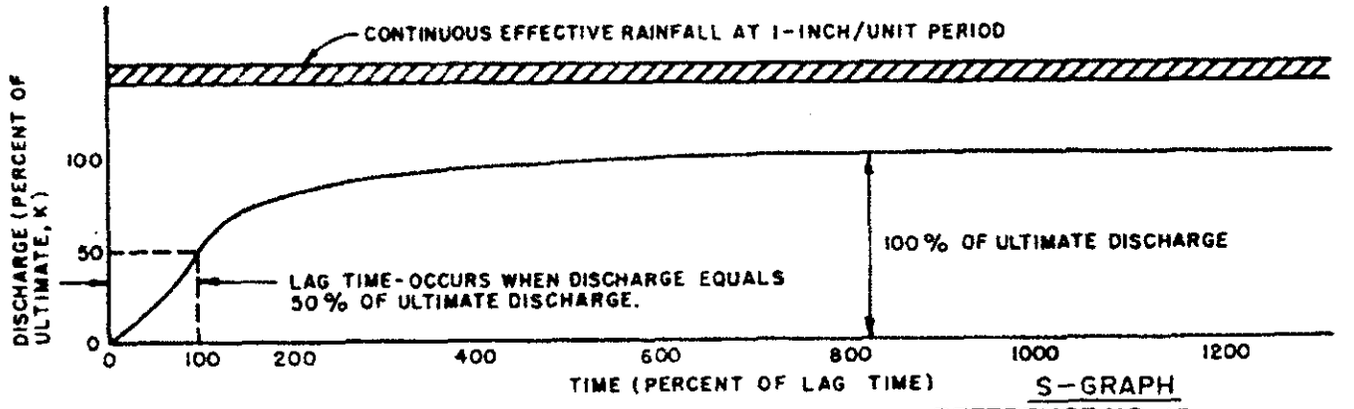
(UNIT GRAPH)



UNIT DISTRIBUTION GRAPH



SUMMATION HYDROGRAPH



S-GRAPH

REFERENCE NO. 15

IMPERIAL IRRIGATION DISTRICT

HYDROLOGY MANUAL

DERIVATION OF A SYNTHETIC UNIT HYDROGRAPH

FIGURE E-1

$\bar{n}$ = 0.015

1. Drainage area has fairly uniform, gentle slopes
2. Most watercourses either improved or along paved streets
3. Groundcover consists of some grasses - large % of area impervious
4. Main water course improved channel or conduit

$\bar{n}$ = 0.020

1. Drainage area has some graded and non-uniform, gentle slopes
2. Over half of the area watercourses are improved or paved streets
3. Groundcover consists of equal amount of grasses and impervious area
4. Main watercourse is partly improved channel or conduit and partly greenbelt (see $\bar{n}$ = 0.025)

$\bar{n}$ = 0.025

1. Drainage area is generally rolling with gentle side slopes
2. Some drainage improvements in the area - streets and canals
3. Groundcover consists mostly of scattered brush and grass and small % impervious
4. Main watercourse is straight channels which are turfed or with stony beds and weeds on earth bank (greenbelt type)

$\bar{n}$ = 0.030

1. Drainage area is generally rolling with rounded ridges and moderate side slopes
2. No drainage improvements exist in the area
3. Groundcover includes scattered brush and grasses
4. Watercourses meander in fairly straight, unimproved channels with some boulders and lodged debris

$\bar{n}$ = 0.040

1. Drainage area is composed of steep upper canyons with moderate slopes in lower canyons
2. No drainage improvements exist in the area
3. Groundcover is mixed brush and trees with grasses in lower canyons
4. Watercourses have moderate bends and are moderately impeded by boulders and debris with meandering courses

$\bar{n}$ = 0.050

1. Drainage area is quite rugged with sharp ridges and steep canyons
2. No drainage improvements exist in the area
3. Groundcover, excluding small areas of rock outcrops, includes many trees and considerable underbrush
4. Watercourses meander around sharp bends, over large boulders and considerable debris obstruction

$\bar{n}$ = 0.200

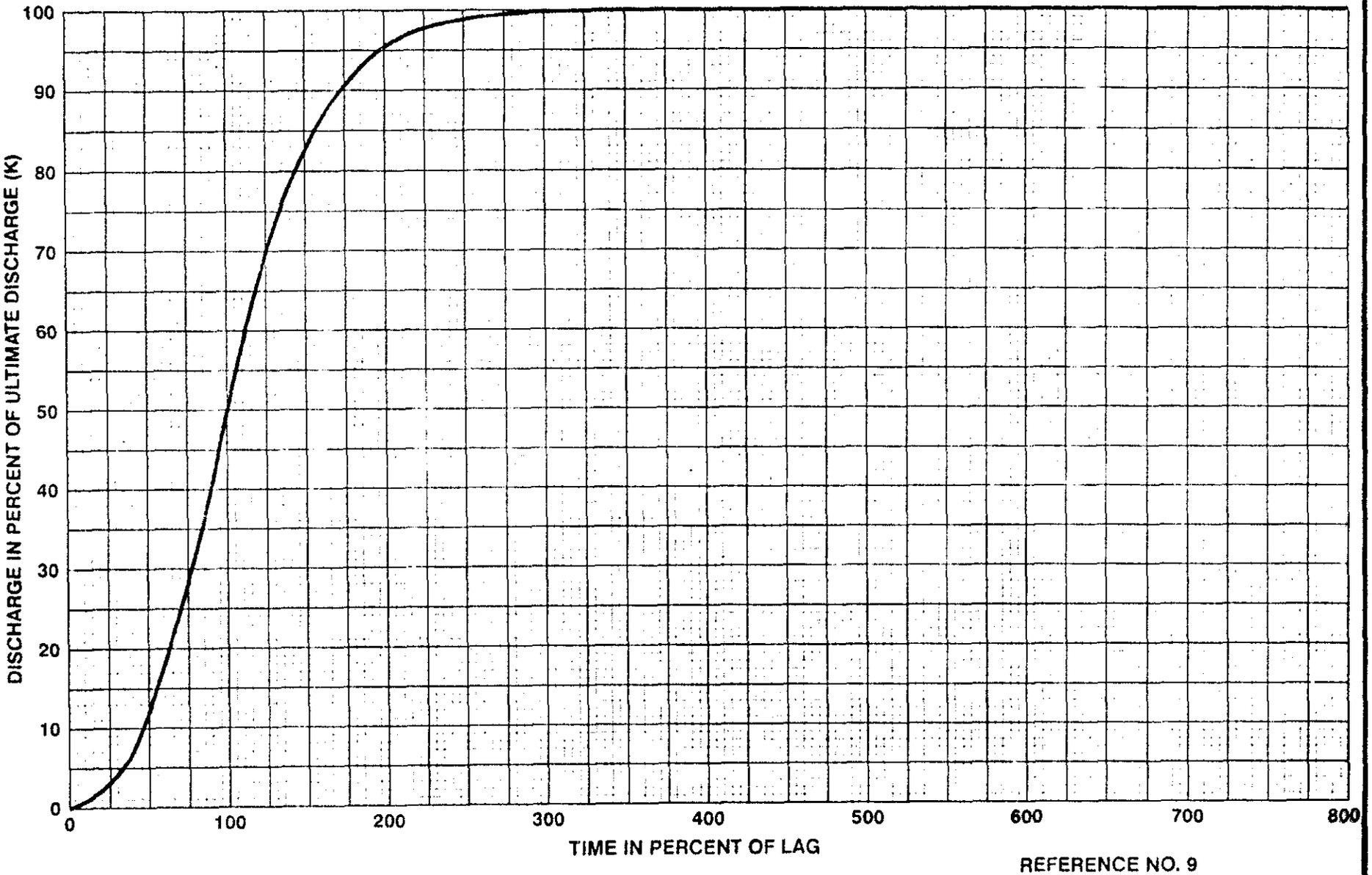
1. Drainage area has comparatively uniform slopes
2. No drainage improvements exist in the area
3. Groundcover consists of cultivated crops or substantial growths of grass and fairly dense small shrubs, cacti, or similar vegetation
4. Surface characteristics are such that channelization does not occur

REFERENCE NOS. 8, 9

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

BASIN FACTOR DESCRIPTIONS

FIGURE E-2

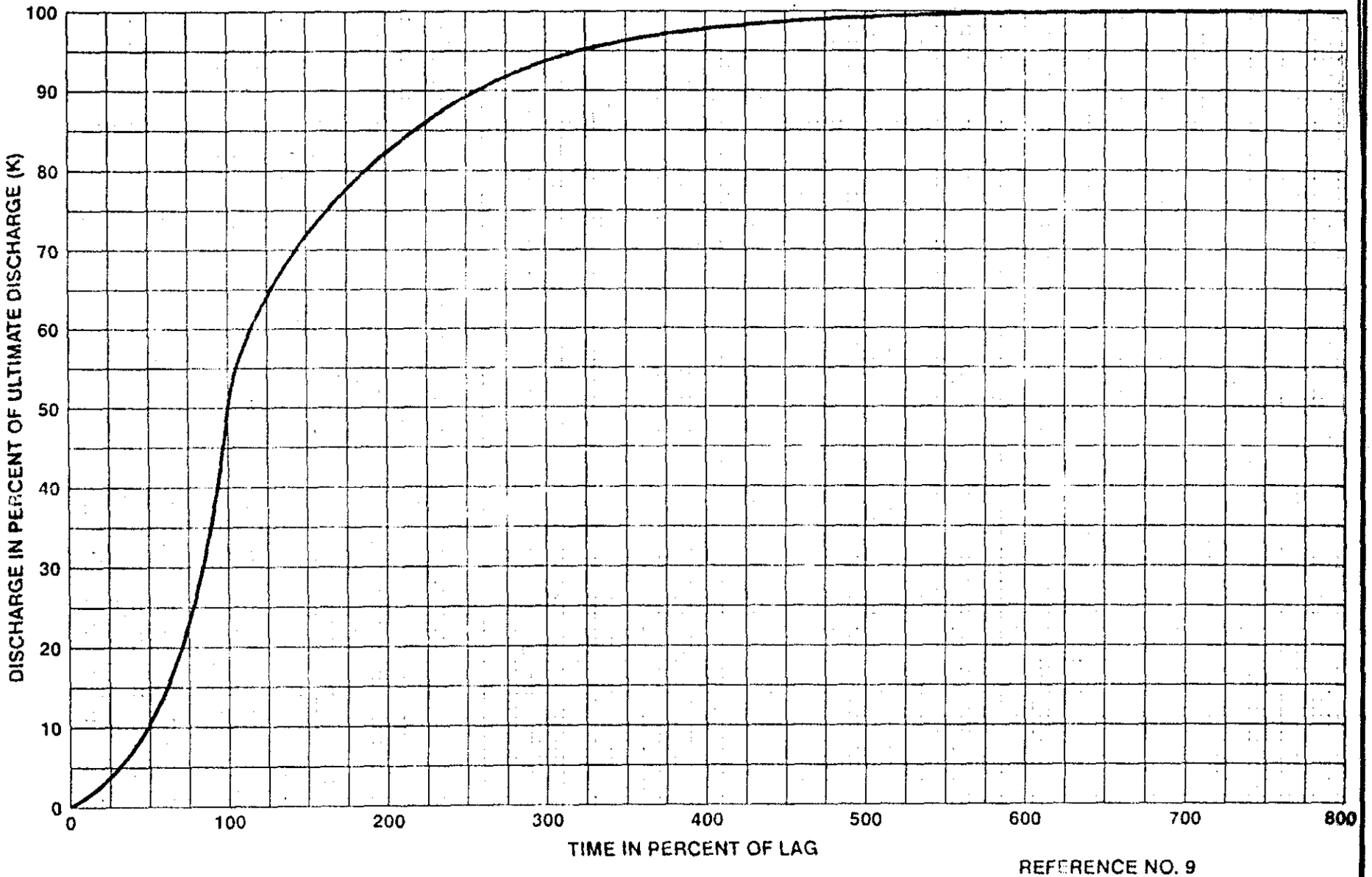


REFERENCE NO. 9

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

S-GRAPH FOR VALLEY: DEVELOPED

FIGURE E-3a

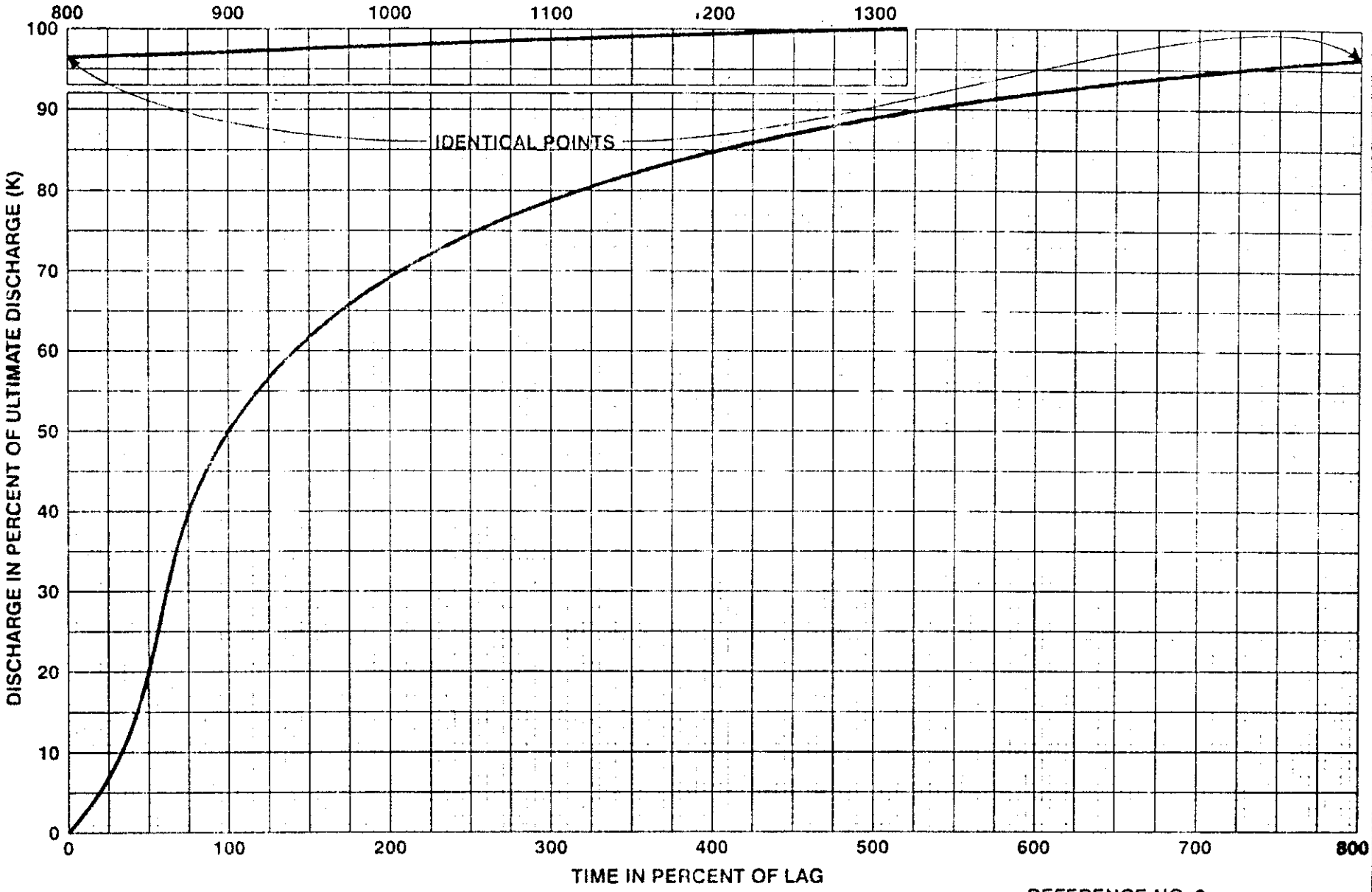


REFERENCE NO. 9

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

S-GRAPH FOR FOOTHILL AREAS

FIGURE E-3b

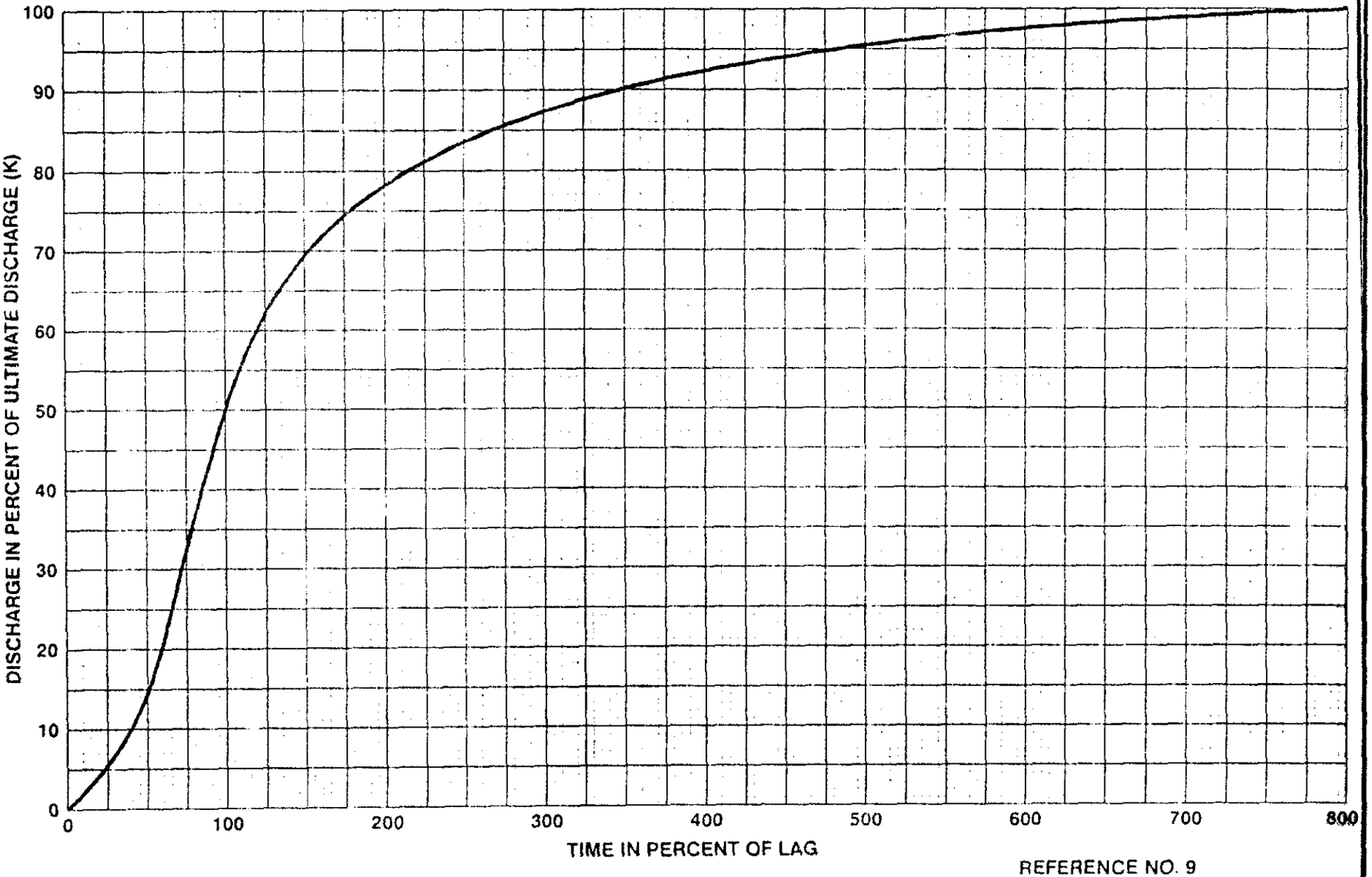


REFERENCE NO. 9

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

S-GRAPH FOR MOUNTAIN AREAS

FIGURE E-3c

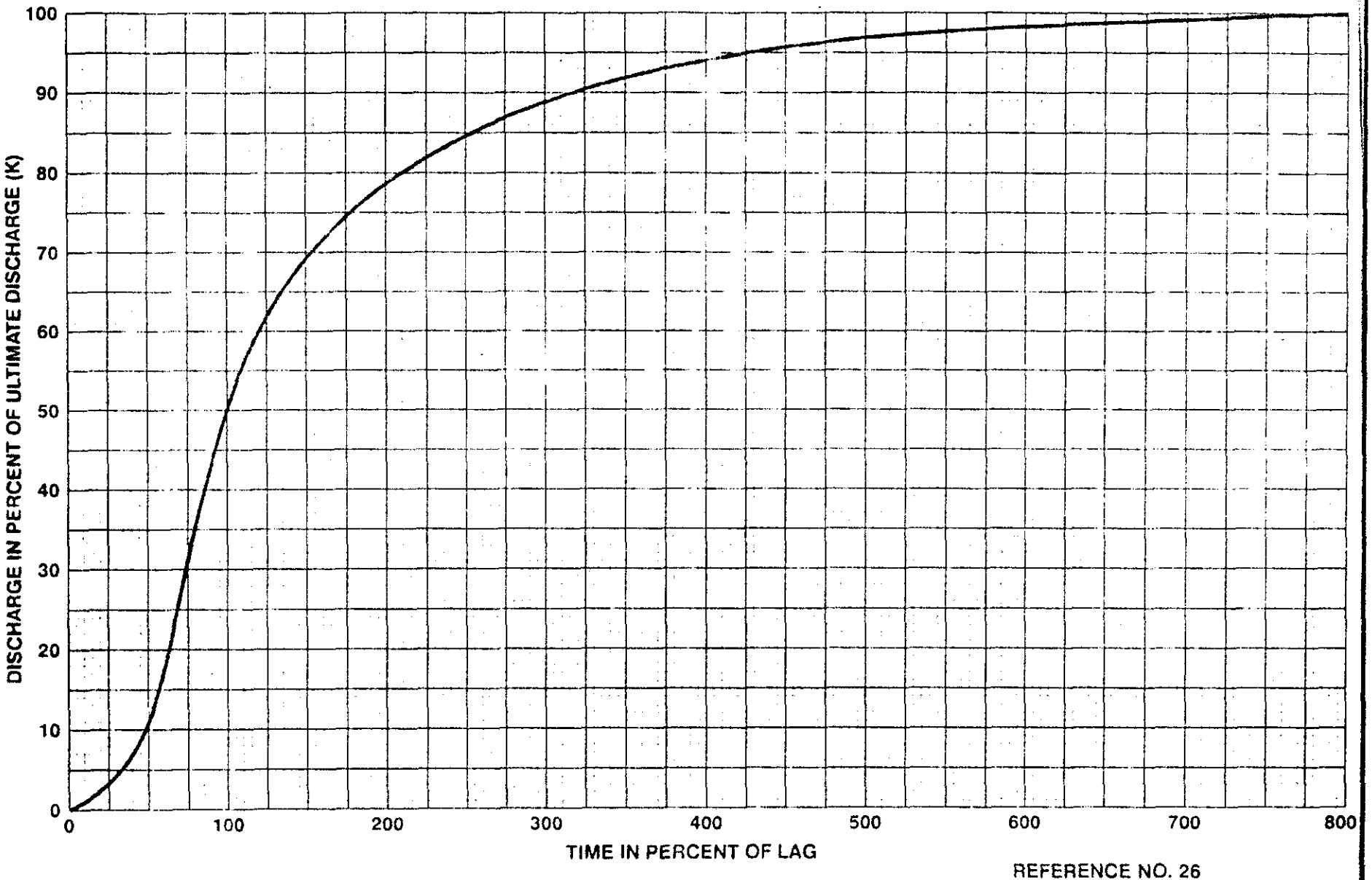


REFERENCE NO. 9

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

S-GRAPH FOR VALLEY: UNDEVELOPED

FIGURE E-3d

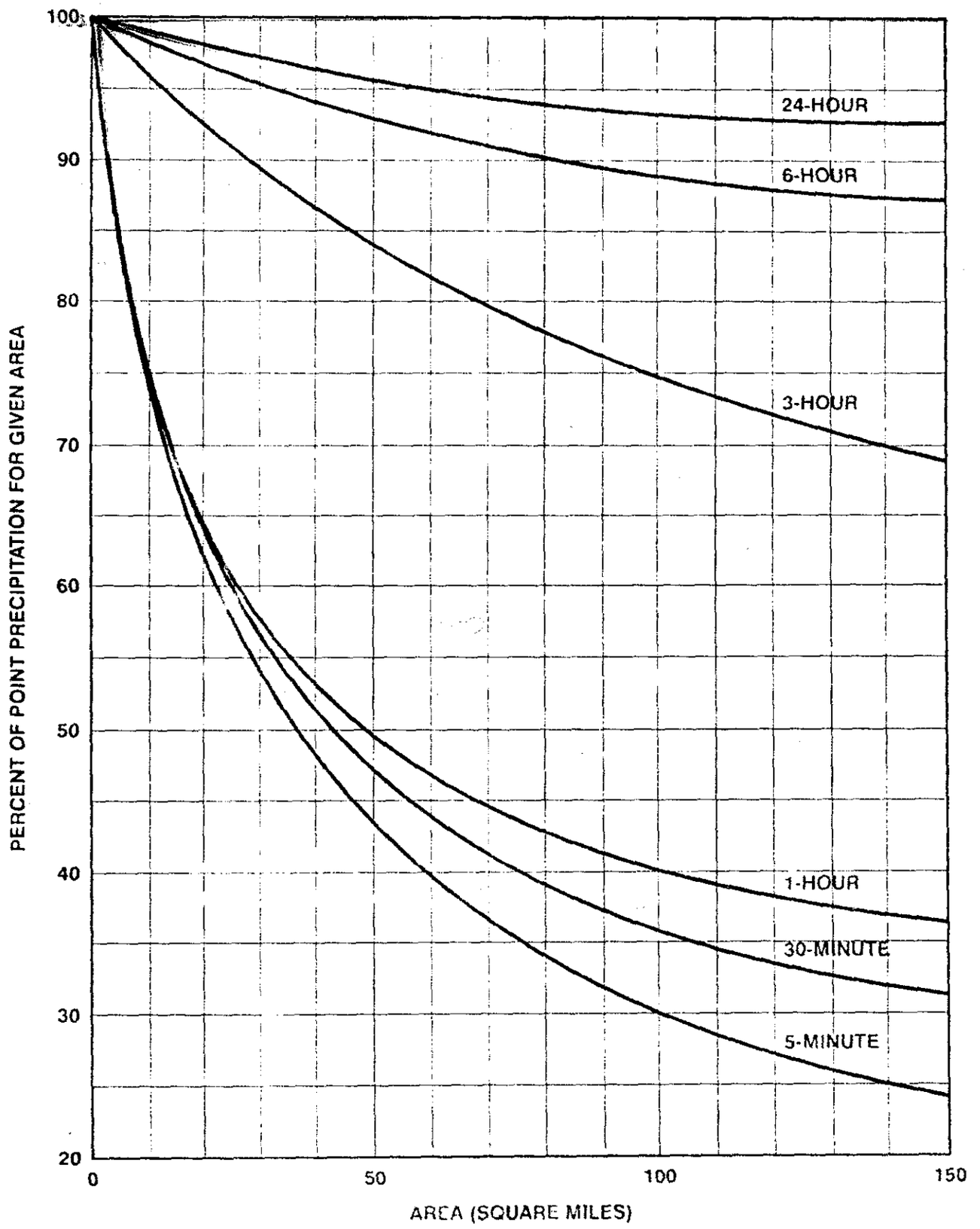


REFERENCE NO. 26

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

S-GRAPH FOR DESERT AREAS

FIGURE E-3e

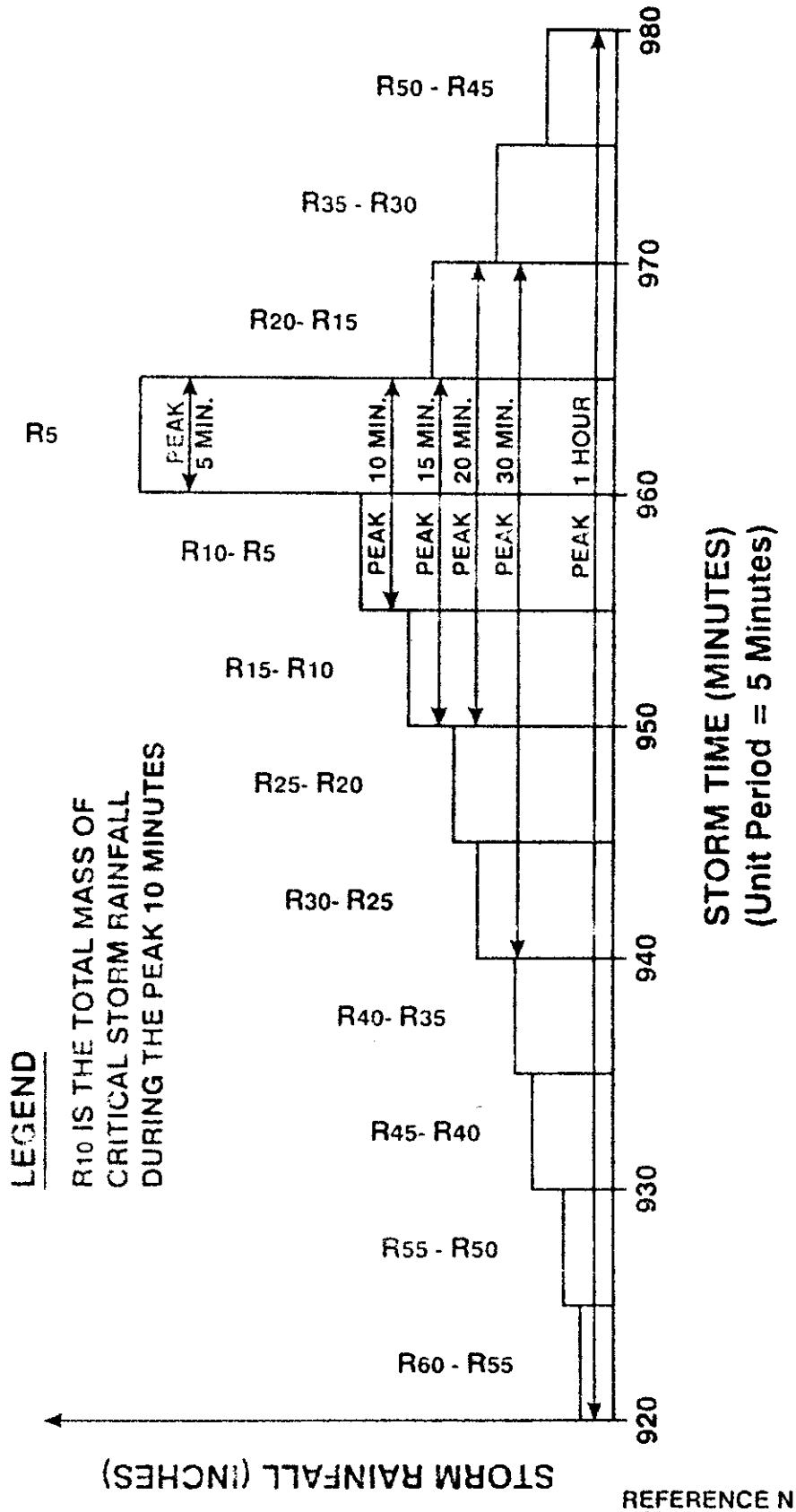


REFERENCE NO. 10

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DESIGN STORM DEPTH AREA CURVES

FIGURE E-4

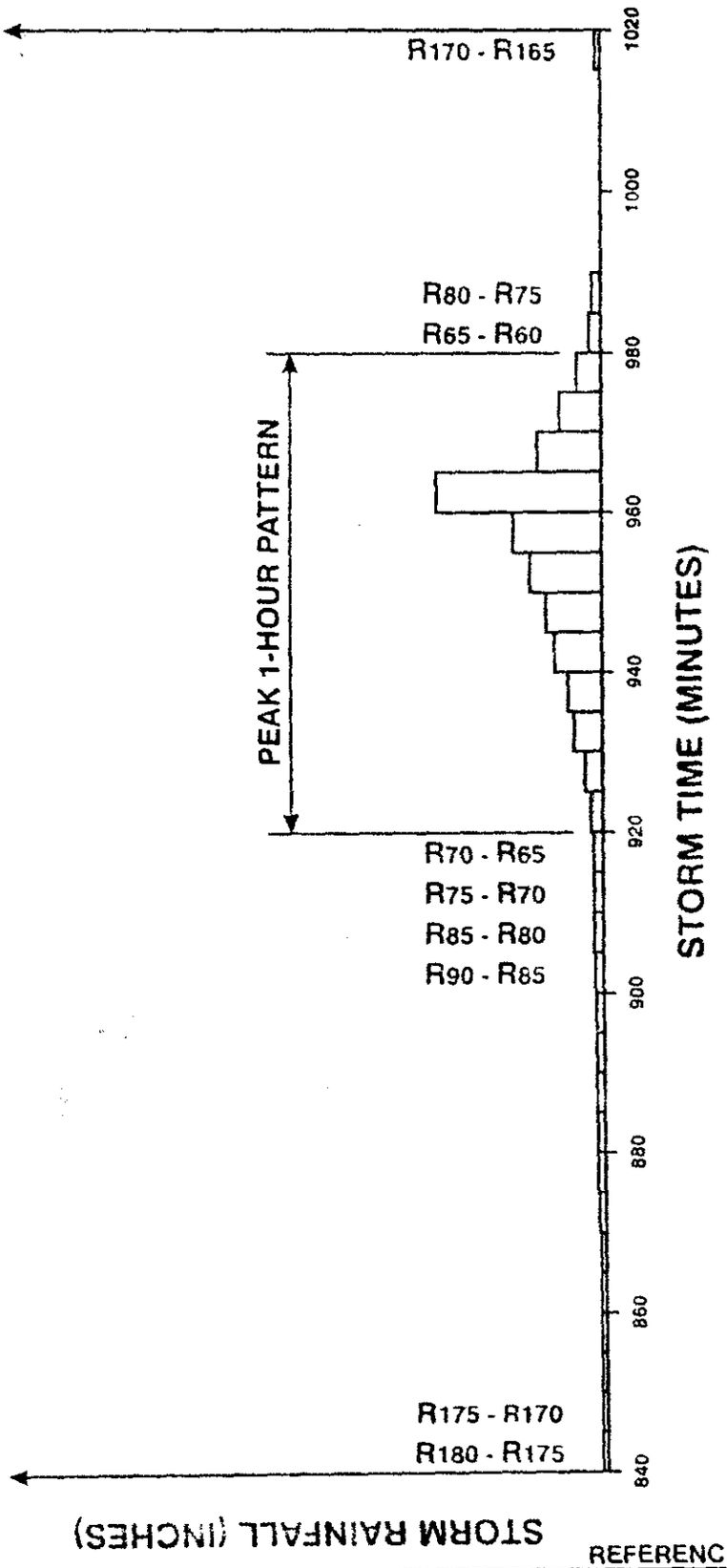


REFERENCE NO. 10

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DESIGN CRITICAL STORM PEAK 1-HOUR PATTERN

FIGURE E-5a

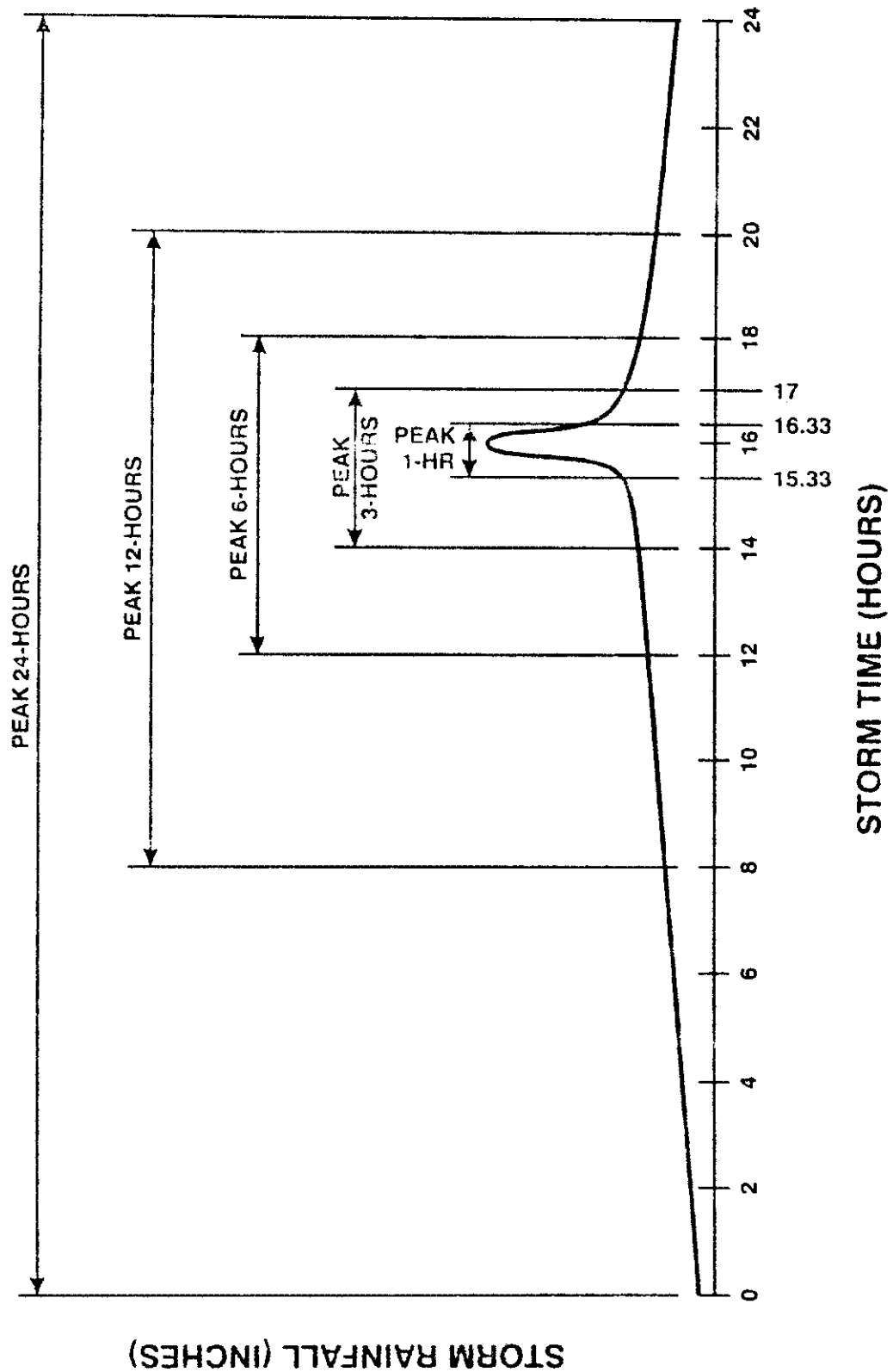


REFERENCE NO. 10

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DESIGN CRITICAL STORM
PEAK 3-HOUR PATTERN

FIGURE E-5b

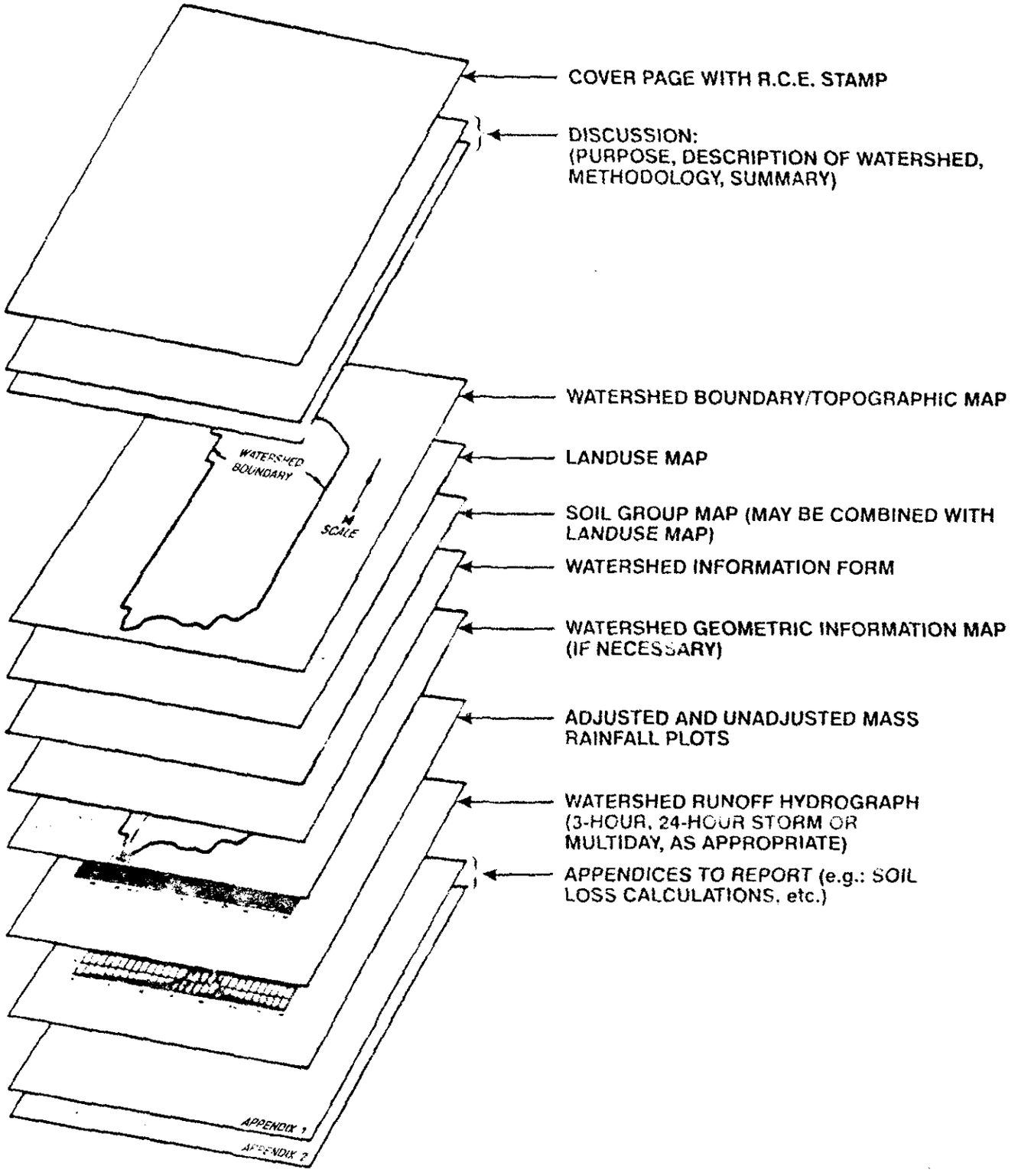


REFERENCE NO. 10

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DESIGN CRITICAL STORM PEAK 24-HOUR PATTERN

FIGURE E-5c



REFERENCE NO. 10

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

TYPICAL REPORT FORMAT FOR UNIT HYDROGRAPH STUDY

FIGURE E-6

PROJECT: _____ **DATE:**

_____

ENGINEER: _____

---

1. Enter the design storm return frequency **(years)** _____

2. Enter catchment lag **(hours)** _____

3. Enter the catchment area **(acres)** _____

4. Enter baseflow **(cfs/square mile)** _____

5. Enter S-Graph proportions **(decimal)**

   Valley: Developed _____
   Foothill _____
   Mountain _____
   Valley: Undeveloped _____
   Desert _____

6. Enter maximum loss rate, F_m **(inch/hour)** _____

7. Enter low loss fraction, $\bar{Y}$ **(decimal)** _____

8. Enter watershed area-averaged 5-minute point rainfall **(inches)*** _____

   Enter watershed area-averaged 30-minute point rainfall **(inches)*** _____

   Enter watershed area-averaged 1-hour point rainfall **(inches)*** _____

   Enter watershed area-averaged 3-hour point rainfall **(inches)*** _____

   Enter watershed area-averaged 6-hour point rainfall **(inches)*** _____

   Enter watershed area-averaged 24-hour point rainfall **(inches)*** _____

9. Enter 24-hour storm unit interval **(minutes)** _____

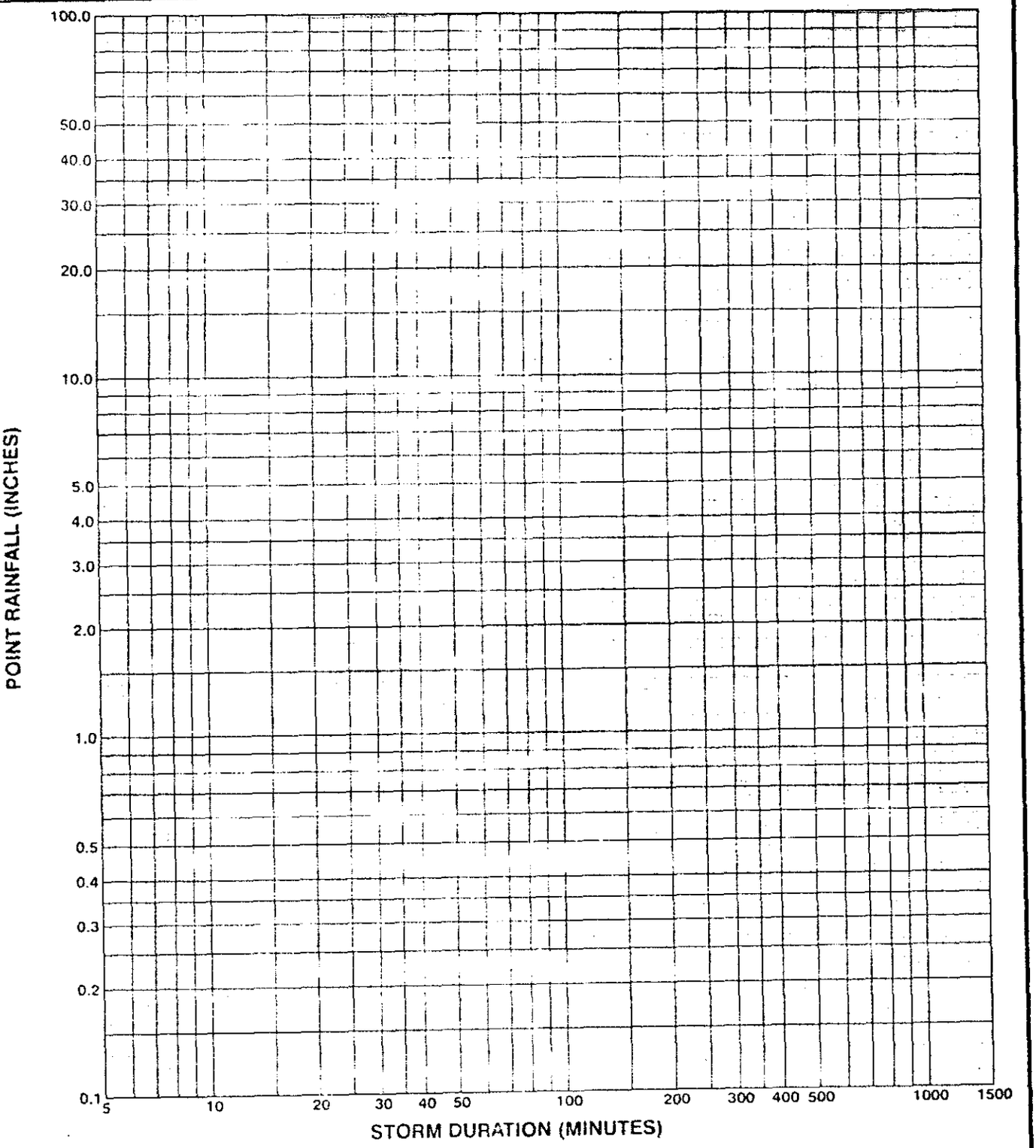
*Note: enter values unadjusted by depth-area factors

REFERENCE NO. 10

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

WATERSHED INFORMATION FORM

FIGURE E-7



PROJECT LOCATION: _____

NOTES: _____

IMPERIAL IRRIGATION DISTRICT

HYDROLOGY MANUAL

AREA-AVERAGED MASS RAINFALL PLOTTING SHEET

FIGURE E-8

IMPERIAL IRRIGATION DISTRICT HYDROLOGY MANUAL	SYNTHETIC UNIT HYDROGRAPH METHOD Flood Hydrograph Calculation Form	SHEET____OF____

Project:_____ By:_____ Date:_____ Chk'd:_____ Date:_____

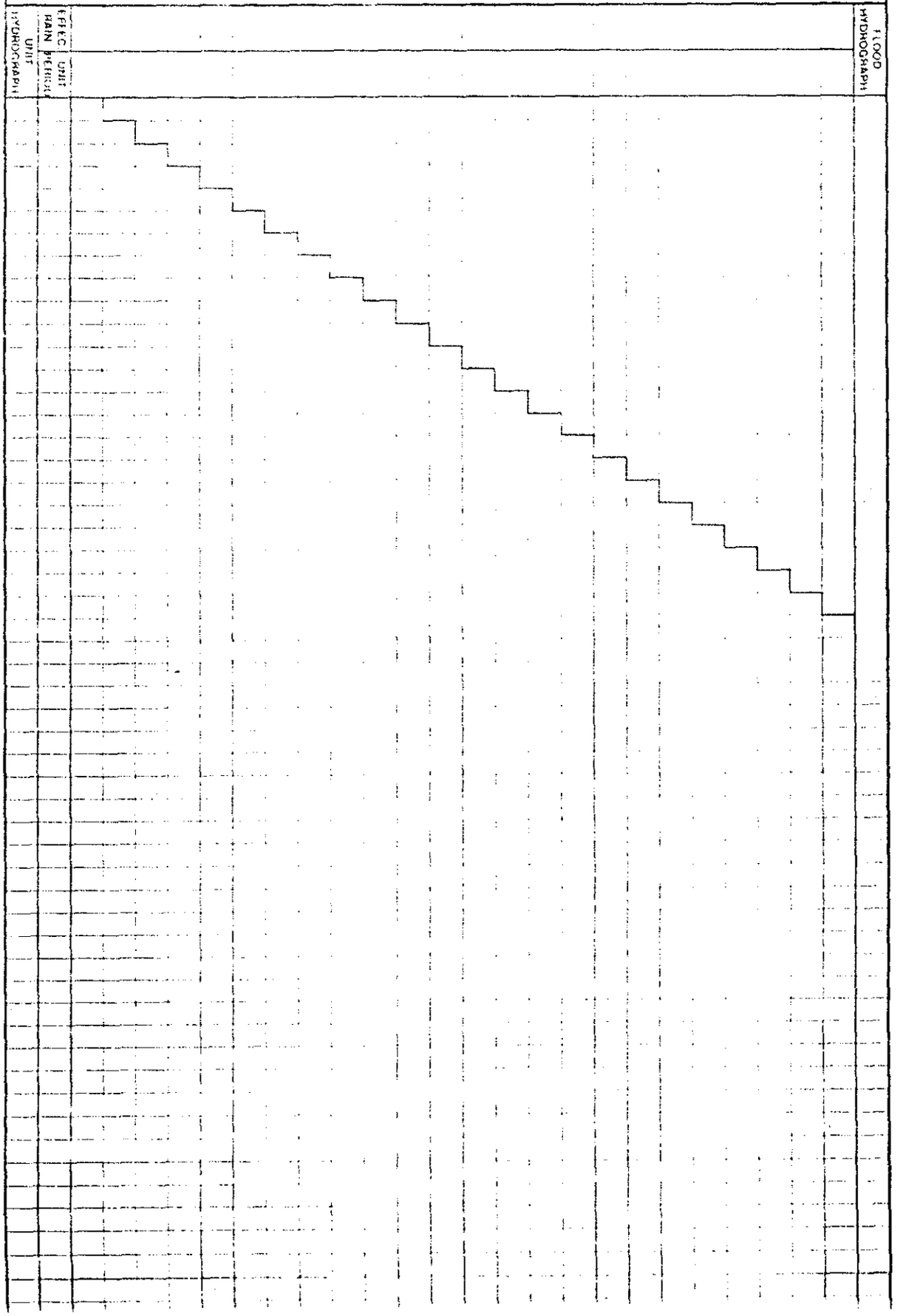
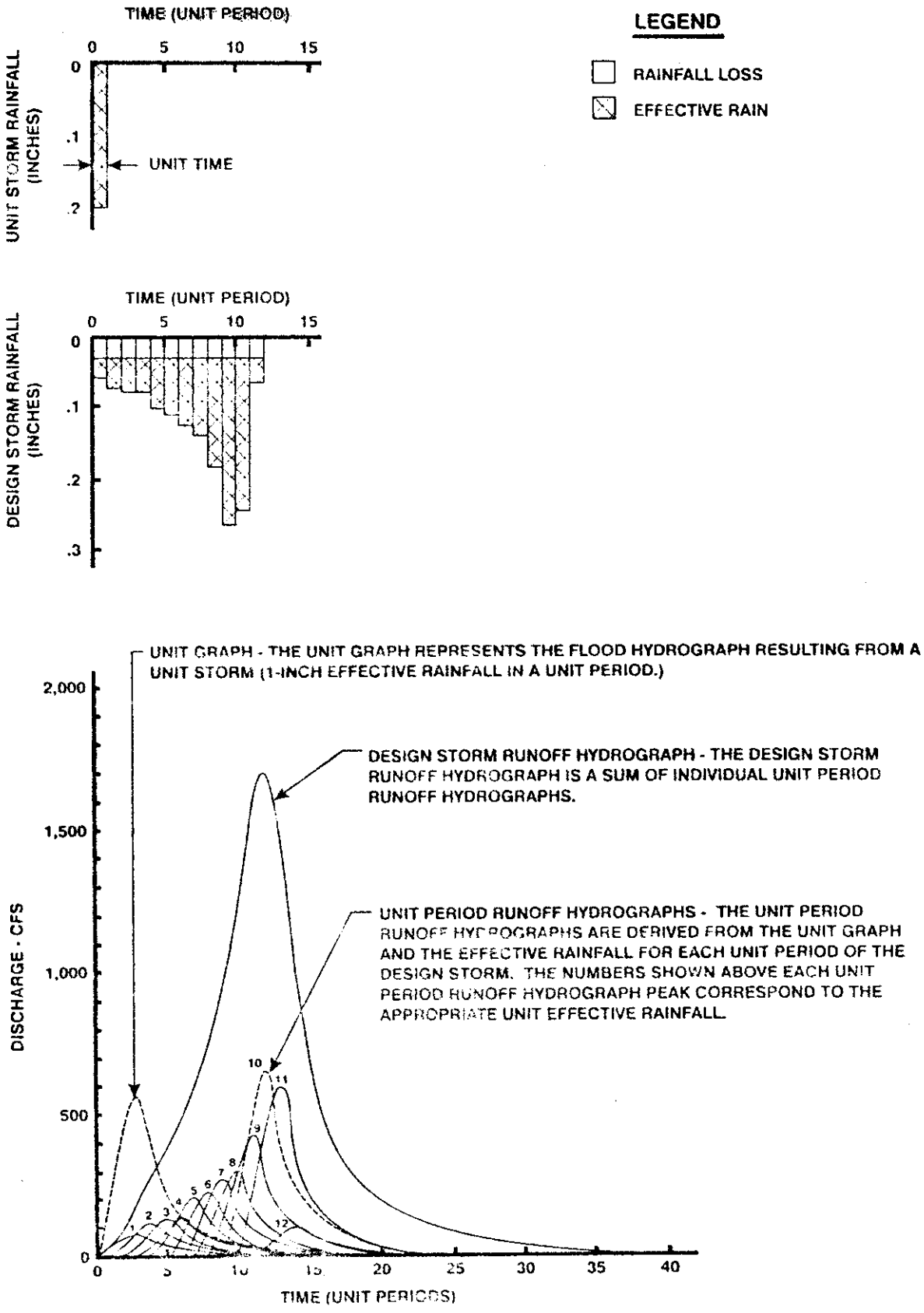


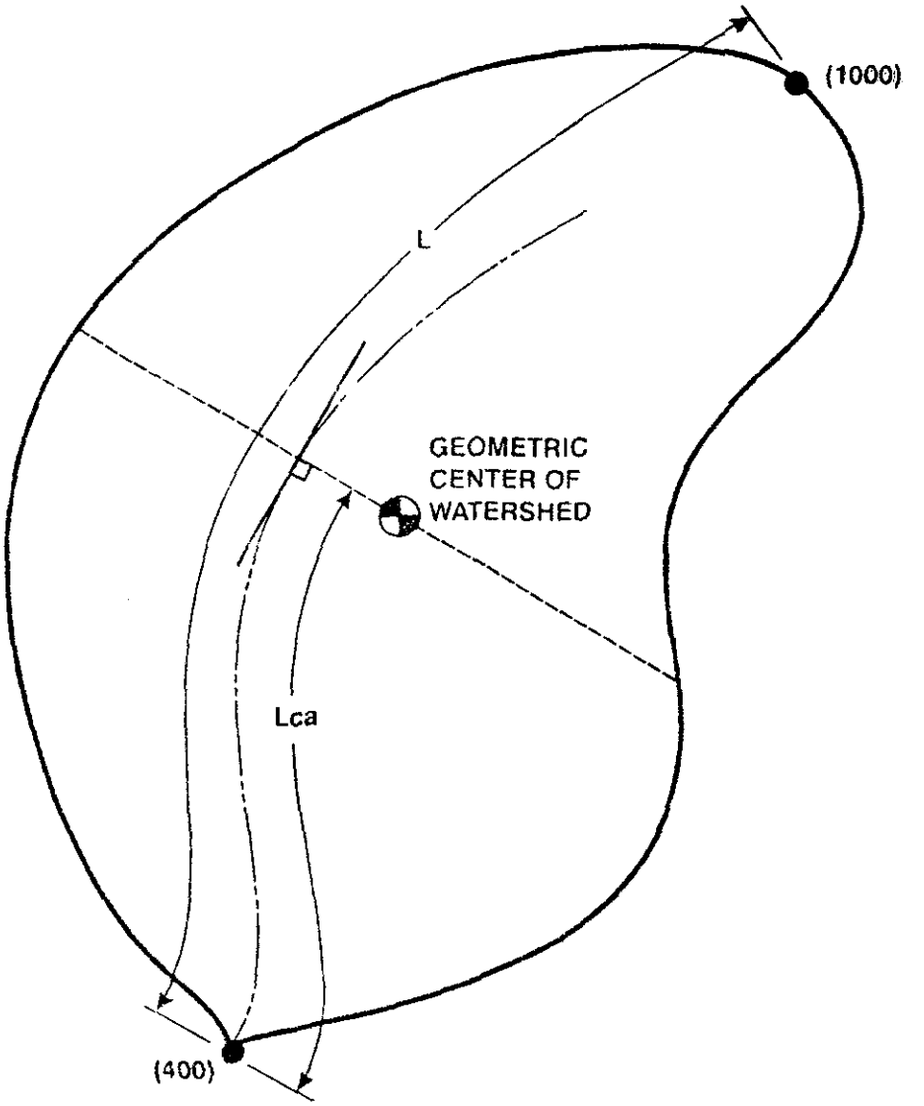
FIGURE E



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

DERIVATION OF A RUNOFF HYDROGRAPH

FIGURE E-10



L = 6.7 (LENGTH OF LONGEST WATERCOURSE IN MILES)

Lca = 3.2 (LENGTH ALONG LONGEST WATERCOURSE, MEASURED UPSTREAM TO A POINT OPPOSITE CENTER OF AREA IN MILES)

$\bar{n}$ = 0.040 (BY VISUAL INSPECTION)

m = 0.38 (m IS A CALIBRATION COEFFICIENT)

s = (1000 - 400) / 6.7
= 89.6 FT./MILE

$$\text{LAG (HOURS)} = 24\bar{n}\,[(L \cdot Lca) / s^{0.5}]^{m}$$
$$= 24\,(0.040)\,[(6.7 \cdot 3.2) / (89.6)^{0.5}]^{0.38}$$
$$= \underline{1.31 \text{ HOURS}}$$

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 1
APPLICATION OF
LAG EQUATION

FIGURE E-11

PROJECT: Example Problem **DATE:**

ENGINEER:

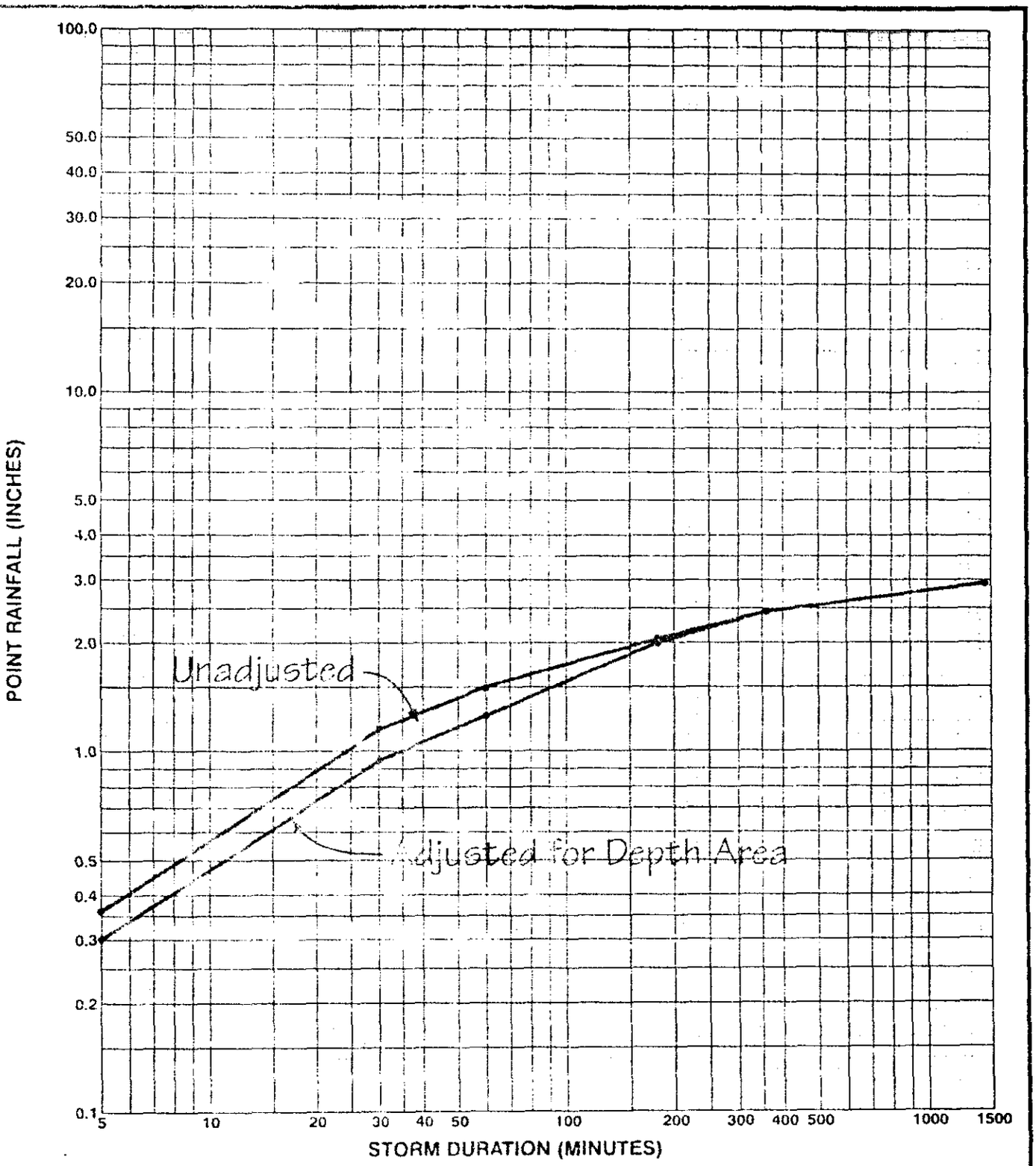
1.	Enter the design storm return frequency **(years)**	100
2.	Enter catchment lag **(hours)**	0.75
3.	Enter the catchment area **(acres)**	3200
4.	Enter baseflow **(cfs/square mile)**	0
5.	Enter S-Graph proportions **(decimal)**	
	Valley: Developed	1.0
	Foothill	0
	Mountain	0
	Valley: Undeveloped	0
	Desert	0
6.	Enter maximum loss rate, F_m **(inch/hour)**	0.28
7.	Enter low loss fraction, $\bar{Y}$ **(decimal)**	0.40
8.	Enter watershed area-averaged 5-minute point rainfall **(inches)***	0.37
	Enter watershed area-averaged 30-minute point rainfall **(inches)***	1.13
	Enter watershed area-averaged 1-hour point rainfall **(inches)***	1.49
	Enter watershed area-averaged 3-hour point rainfall **(inches)***	2.04
	Enter watershed area-averaged 6-hour point rainfall **(inches)***	2.43
	Enter watershed area-averaged 24-hour point rainfall **(inches)***	2.99
9.	Enter 24-hour storm unit interval **(minutes)**	5

*Note: enter values unadjusted by depth-area factors

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
WATERSHED
INFORMATION FORM

FIGURE E-12



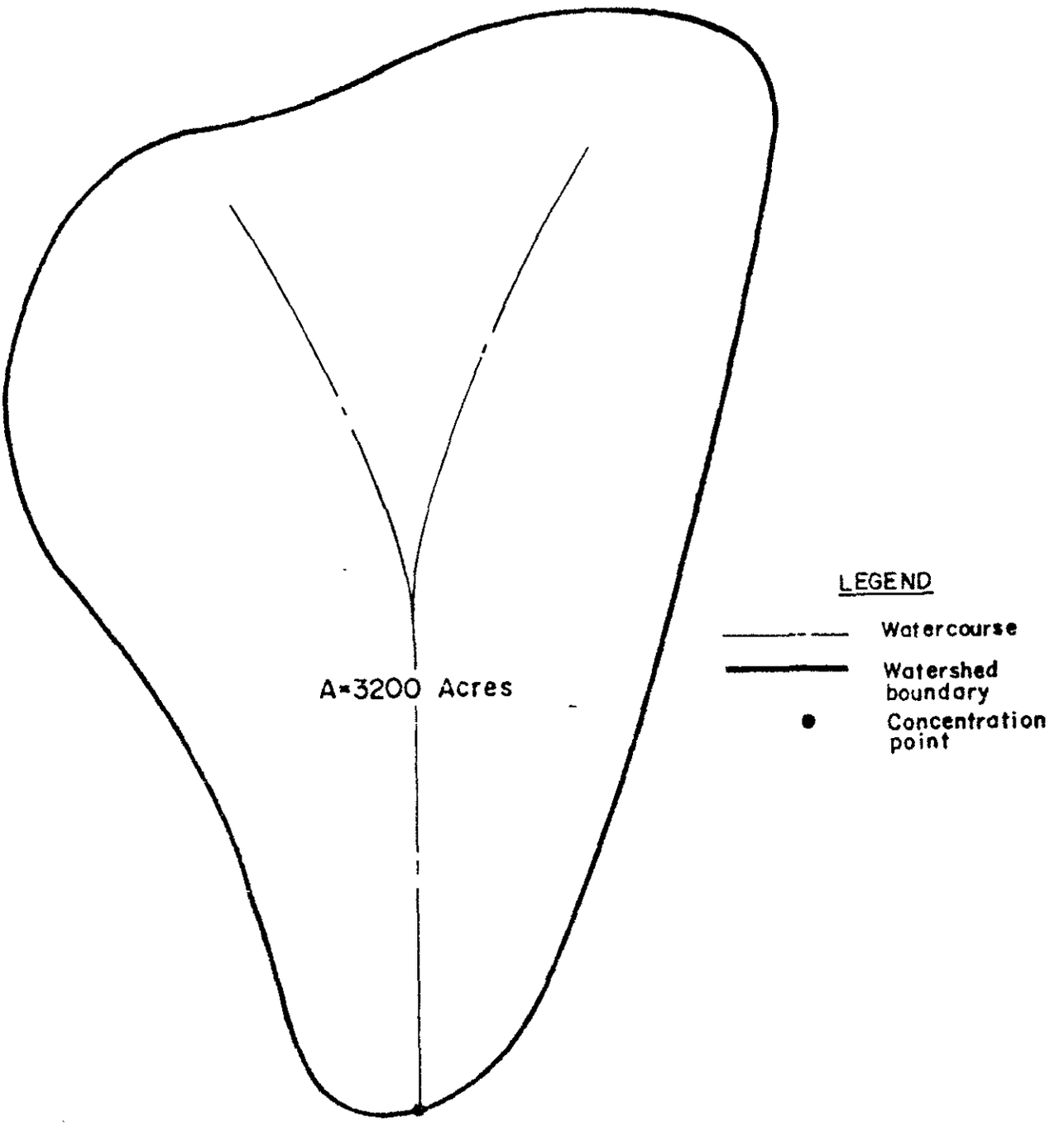
PROJECT LOCATION: Example Problem

NOTES: Adjusted Rainfall: 5-min. = 0.31, 30-min. = 0.95
1-hr. = 1.25, 3-hr. = 2.00, 6-hr. = 2.41, 24-hr. = 2.98

IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
AREA-AVERAGED MASS RAINFALL PLOTTING SHEET

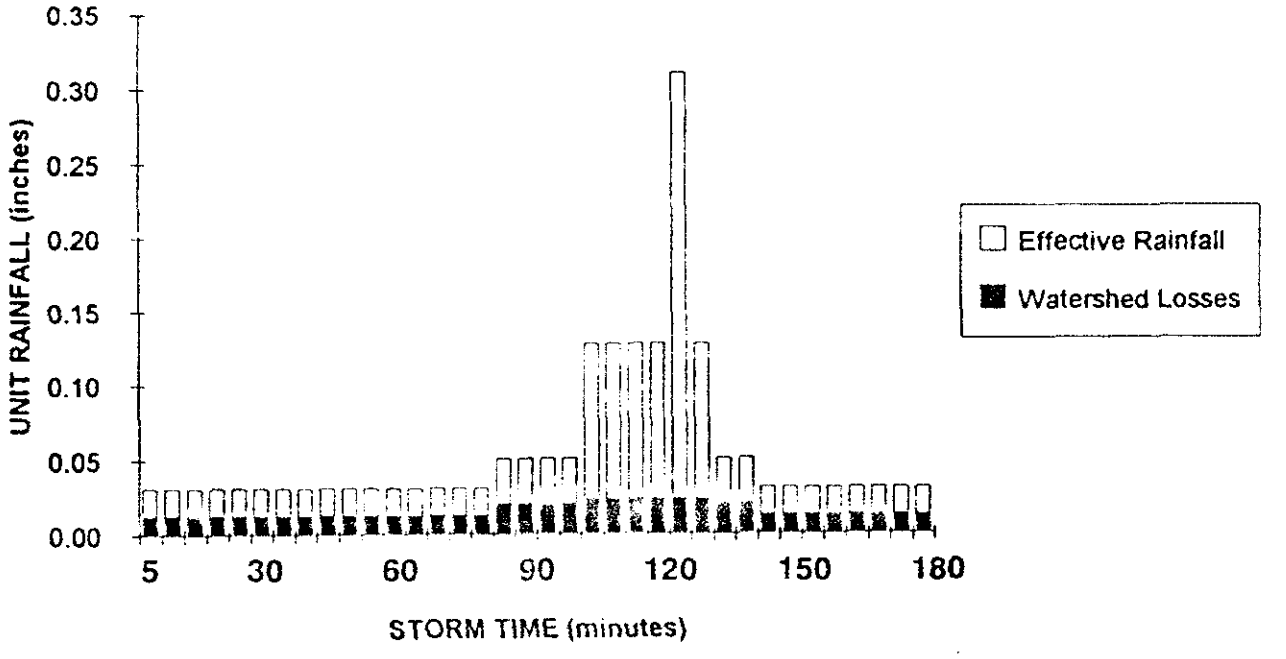
FIGURE E-13



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
WATERSHED BOUNDARY

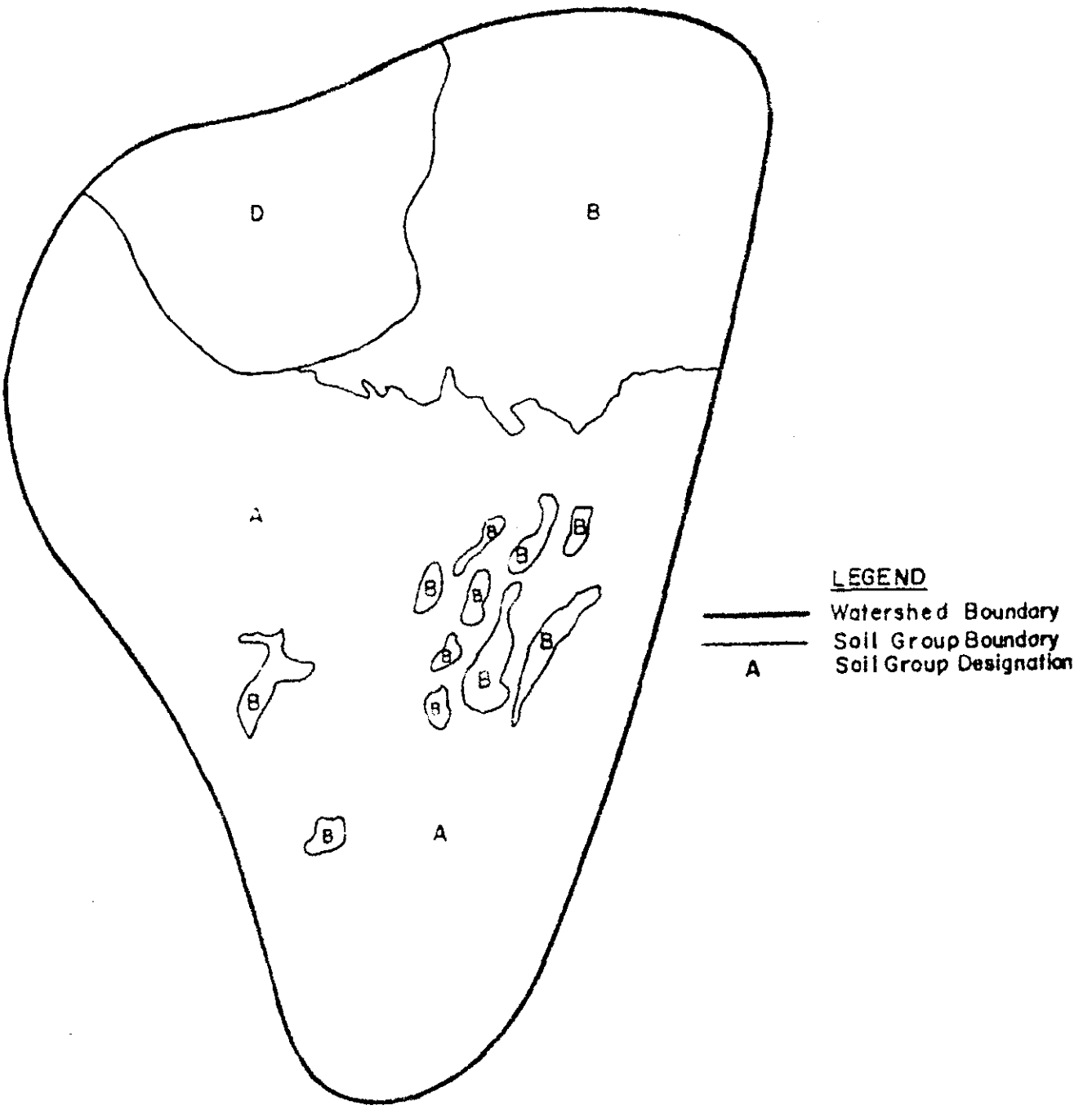
FIGURE E-14



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
SYNTHETIC 3-HOUR
CRITICAL STORM

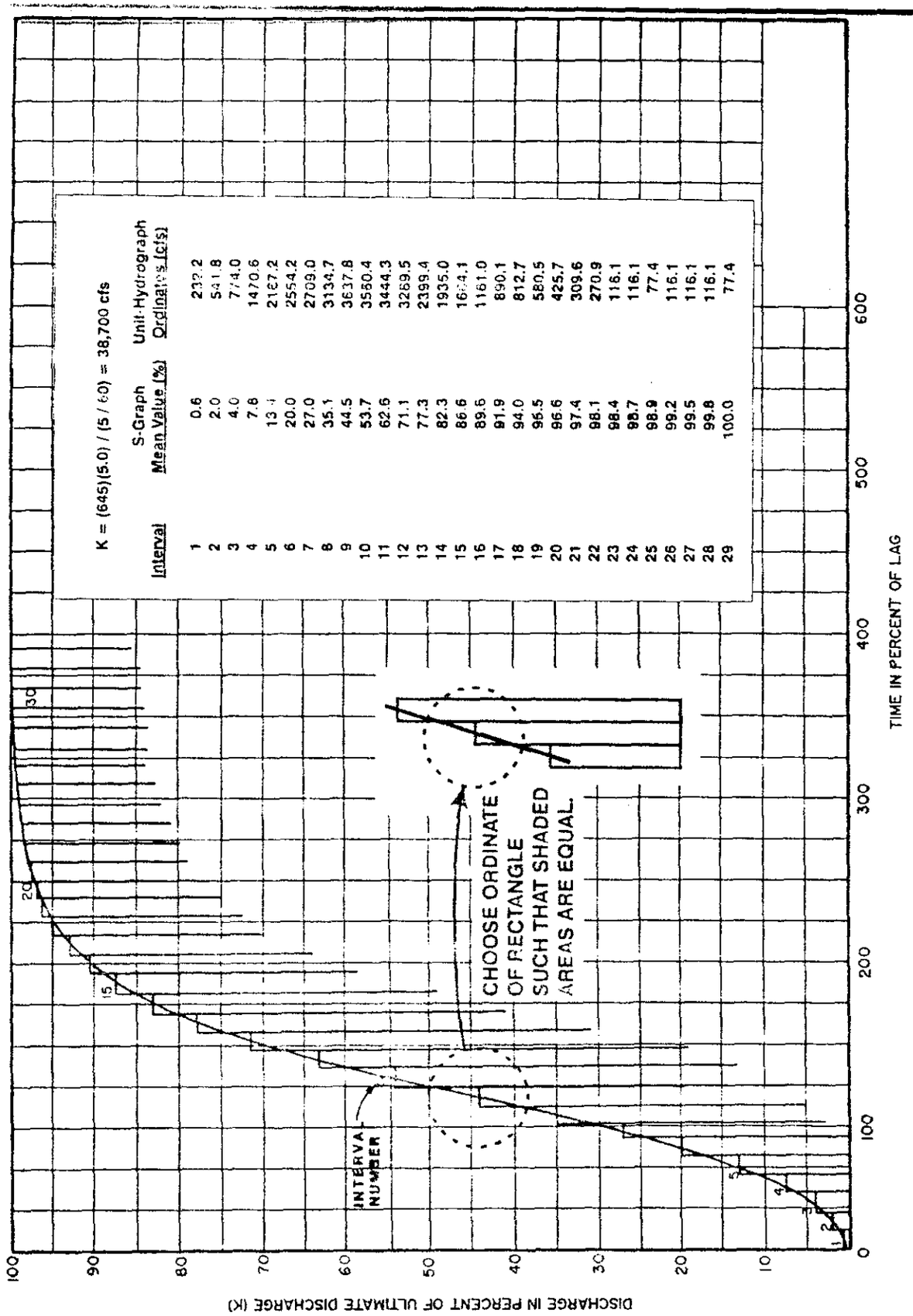
FIGURE E-15



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
WATERSHED-LOSS DETERMINATION
INFORMATION MAP

FIGURE E-16

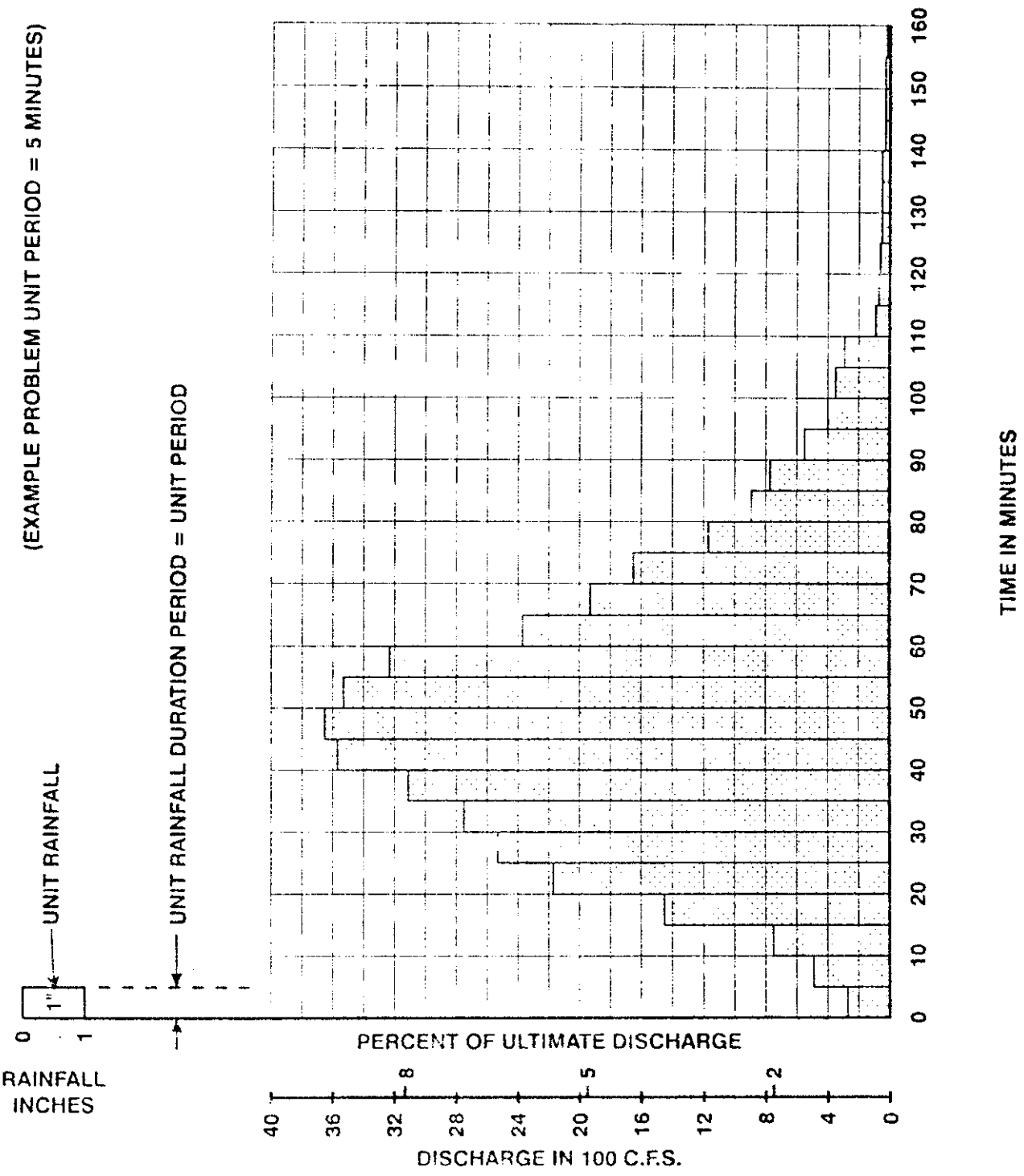


IMPERIAL IRRIGATION DISTRICT

HYDROLOGY MANUAL

EXAMPLE PROBLEM 3 S-GRAPH FOR VALLEY: DEVELOPED

FIGURE E-17

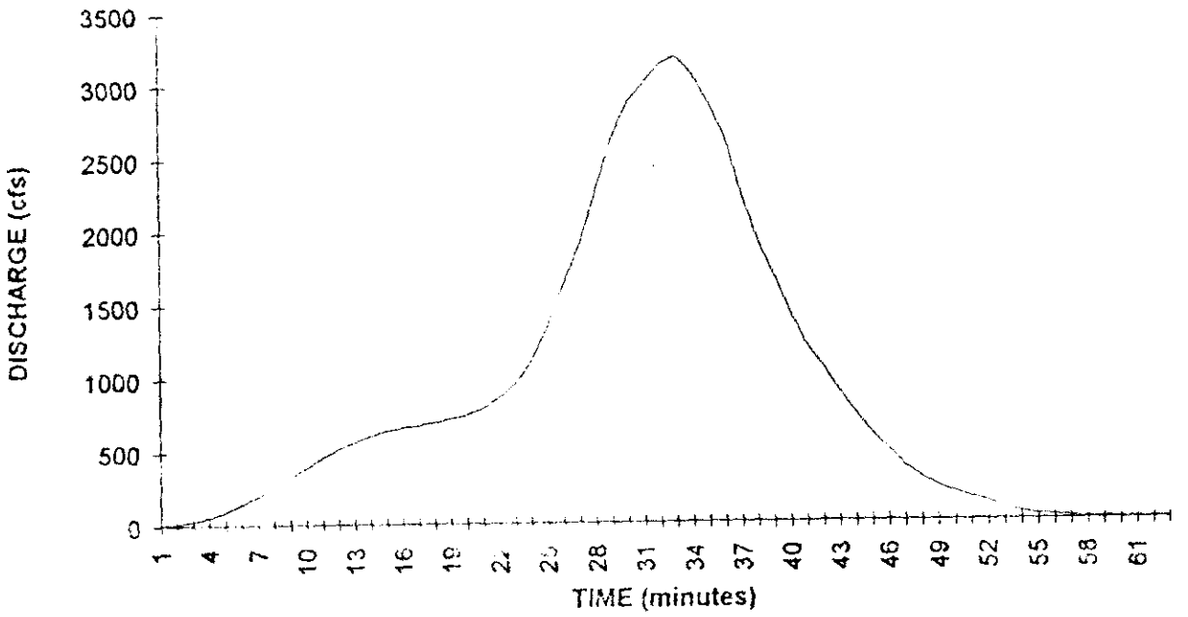


IMPERIAL IRRIGATION DISTRICT

HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
UNIT DISTRIBUTION GRAPH

FIGURE E-19



IMPERIAL IRRIGATION DISTRICT
HYDROLOGY MANUAL

EXAMPLE PROBLEM 3
HYDROGRAPH

FIGURE E-