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CAVE CREEK/CAREFREE

FLOOD DELINEATION STUDY

PRELIMINARY

APPENDIX A

District Copy

FLOOD CONTROL DISTRICT
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	CH ENG		P & PM
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	ADMIN		LMGT
	FINANCE		FILE
	C & O		
	OTHER		

REMARKS

FLOOD CONTROL DISTRICT
APR 04 1990
REMARKS

Registered Professional Engineer (Civil)
CERTIFICATE NO. 20981
STEVEN R. WALKER
ARIZONA, U.S.A.
4-4-90

SUBJECT CAVE CREEK/CAREFREE F/S BY SRW DATE 3-1-90
FCD 88-53 SHEET 1 OF 2
HYDROLOGY PROCEDURE SUMMARY PROJECT NO. RDD 27815.41

MODEL USED : HEC-1, US ARMY COE FLOOD HYDROGRAPH PACKAGE JUN 1, 1988 REVISION.

STORM DURATION : • CAVE CREEK MODEL USES A 24-HR STORM
• OTHER TRIBUTARIES ARE MODELED FOR A 2-HR STORM.

HYETOGRAPH TYPE: SCS TYPE II DISTRIBUTION AS PROVIDED BY FCDMC

FREQUENCIES : 10; 50; 100; AND 500-YR EVENTS ARE MODELED

RAINFALL DEPTHS: DERIVED FROM NOAA PRECIPITATION-FREQUENCY ATLAS - 2 CALCULATIONS WEREMADE: 1 FOR THE "UPPER CAVE CREEK" AREA ABOVE THE COTTONWOOD CONFLUENCE, AND 1 FOR THE BASIN BELOW COTTONWOOD/CAVE CREEK CONFLUENCE. AREAL REDUCTIONS WERE MADE USING DATA FROM HYDRO-40. FOR THE CAVE CREEK MODEL. THE TRIBUTARIES' PRECIP. DEPTHS WERE NOT REDUCED.

MODELING PROCEDURES & ASSUMPTIONS -

1. TWO MODELS WERE USED:
   - 24-HR FOR CAVE CREEK
   - 2-HR FOR TRIBUTARIES.
2. MODELLING PROCEDURES WERE SPECIFIED BY FCDMC (SEE ATTACHMENT)
3. THE MODEL WAS PREPARED BY FCDMC. CH2M HILL STAFF PERFORMED CHECKS OF BASIC PARAMETERS, INCORPORATING CHANGES AS REQUIRED BY FCDMC STUDY CRITERIA, AND SUB BASINS NEED FOR PROPOSED STUDY STREAMS

SUBJECT CAVE CREEK FLS BY SRW DATE 3-1-90
SHEET 2 OF 2
HYDROLOGY PROJECT NO. RDO 27815.141

4. REVISED MODELS WERE RETURNED TO FCDMC FOR REVIEW AND COORDINATION WITH ADWR.

5. FOLLOWING DWR REVIEW FCDMC REVISED THE MODELS AND RETURNED THEM TO CH2M HILL. THE MAJOR REVISIONS TO THE ORIGINAL ARE SUMMARIZED BELOW: —

- LOSS RATE WAS CHANGED TO INITIAL & UNIFORM (PER FCD CRITERIA). PARAMETERS WERE ESTIMATED AS A FUNCTION OF SOIL TYPE. SOIL TYPES WERE DERIVED FROM SCS SOIL SURVEY FOR MARICOPA CO. AND WEIGHTED BY AREA BY CH2M HILL. FCD MODIFIED THESE PARAMETERS TO REFLECT DRY CONDITIONS AND INCREASED COVER DENSITY.

- ALL BASIN AREAS, STREAM LENGTHS, TRAVEL AND LAG TIMES WERE CHECKED BY CH2M HILL. LAG AND ROUTING TRAVEL TIMES WERE RECALCULATED USING THE CH2M HILL "TC" PROGRAM BASED ON OVERLAND FLOW, COLLECTOR AND MAIN CHANNEL VELOCITIES. FCDMC STAFF REVISED THESE VALUES TO REFLECT LOWER VELOCITIES IN BASINS A1-A7 and B1

6. CHANNEL ROUTING USED THE MUSKINGHAM METHOD. "X" = 0.3 K = TRAVEL TIME IN HOURS. TRAVEL TIMES WERE ESTIMATED USING MAIN CHANNEL VELOCITY FR "TC" OUTPUT

7. MAPPING USED FOR WATERSHED DELINEATION WAS USGS 7.5 MIN QUADRANGLES: COOKS MESA, ROVER PEAK, DAISY MTN, NEW RIVER MESA, HUMBOLT MTN, NEW RIVER SE, CAVE CREEK & WILDCAT HILL.

Rcd from FCD
7/16/89

Cave Creek / Care Free Flood Insurance Study - Hydrology

Preferred Hydrologic Methods for the Cave Creek/ Carefree hydrology:

Rainfall :	100 year, 24 hour storm. SCS type II distribution.
Areal Reduction :	NOAA HYDRO-40 (FCD will provide a copy of the report).
Loss Rate :	Green and Ampt as described in the Hydrology Manual (Tables of parameters to be provided) if the version of HEC-1 dated Dec. 5, 1988 is used.
	or Initial and uniform loss rate (tables of parameters to be provided).
Unit Hydrograph :	SCS dimensionless.
Channel Routing :	Normal depth routing where good channel data is available.
	Muskingum for all other routing.
HEC-1 Version:	1988 version preferred, otherwise 1981 version with 1985 modifications.

Submittals for review by the Watershed Management Branch of the Hydrology Division will include the following upon completion:

1. Preliminary plans and maps (separate maps for soil classifications, sub-basin boundaries including the routing reaches).

2. Sample calculations to determine basin parameters for approval prior to the parameter determination for all the subbasins.

3. All calculations to determine basin parameters.

4. HEC-1 model along with the parameters used to prepare the HEC-1 coding. A running model on floppy disk and a schematic drawing of the basins shall accompany the HEC-1 model. The following symbols shall be used to prepare the schematic drawing along with the terminology to be used in the model:

LEGEND

Subarea calculation (SUB)

Combined hydrograph (CO)

Route hydrograph (R, or RO)

Divert hydrograph (D, or DIV)

5. Preliminary and final report and product.

Note: The FCD requests prior notice to when the products will be submitted for review to allow scheduling by reviewer. All efforts will be made to return comments within one week after submittal.

SUBJECT _____ BY _____ DATE _____

SHEET ____ OF ____

PROJECT NO. _____

PRECIPITATION DEPTHS

SUBJECT RAINFALL DISTRIBUTION BY T. MOONEY DATE 7/26/89
CAVE CREEK FIS - MCFCD SHEET 1 OF 8
PROJECT NO. LA027815.H1

OBJECTIVE: TO CALCULATE RAINFALL DISTRIBUTION OVER TWO AREAS OF THE CAVE CREEK WATERSHED. TWO CENTROIDS WERE USED TO LOCATE THE ISOPLUVIALS. ONE IN THE TOWN OF CAVE CREEK, LABELED STUDY AREA, & THE OTHER TO THE NORTH, LABELED WATERSHED AREA. THE "HYDROLOGIC FOR HIGHWAY DRAINAGE IN ARIZONA" MANUAL, ARIZONA HIGHWAY DEPT., BRIDGE DIVISION WAS USED TO DO THE CALCULATIONS. PRECIPITATION MAPS A-D & 1-6 WERE PREPARED BY THE U.S. WEATHER SERVICE FOR THE SOIL CONS. SERV. - MARCH 1967 REVISED BY AHD IN 1970.

SHEET 8 OF 8 IS A SPREADSHEET SHOWING THE RAINFALL DISTRIBUTION PRECIPITATION VALUES OVER THE TWO CENTROIDS.

SUBJECT RAINFALL DISTRIBUTION BY T. MOONEY DATE 7/26/89
MAP VALUES - PRECIP. SHEET 2 OF 8
MCFCD (MAPS A-D, 1-8) PROJECT NO. LA027815.H1

MAP	STUDY CEN.	WATERSHED CEN
A	1.5	1.6
B	1.9	2.2
C	2.0	2.1
D	2.7	3.0
1	2.3	2.45
2	3.2	3.4
3	2.8	2.85
4	3.8	4.1
5	3.1	3.2
6	4.3	4.5
7	3.5	3.6
8	4.8	5.0

SUBJECT RAINFALL DISTRIBUTION BY T. MOONEY DATE 7/26/89
1 HR PRECIPITATION VALUES SHEET 3 OF 8
MCFCD PROJECT NO. CA027815

STUDY AREA

2 year

* BEST FIT 6 hr - 1.52 24 hr = 1.9

100 year

6 hr - 3.48 24 hr 4.81

$Y_2 = -.011 + .942(1.52)^2/1.9$

$Y_2 = 1.13$

$Y_{100} = .494 + .755(3.48)^2/4.81$

$= 2.39$

WATERSHED AREA

2 year

6 hr = 1.6 24 hr = 2.3

100 year

6 hr = 3.59 100 yr = 5.01

$Y_2 = -.011 + .942(1.6)^2/2.3$

$= 1.04$

$Y_{100} = .494 + .755(3.59)^2/5.01$

$= 2.43$

ADDENDUM to "HYDROLOGIC DESIGN FOR HIGHWAY DRAINAGE IN ARIZONA" April 1975

Steps to be used to determine precipitation values for various durations and return periods.

STEP 1. From the precipitation maps in the manual "Hydrologic Design for Highway Drainage in Arizona", determine the precipitation values for the 6 and 24 hour duration storms for return periods of 2, 5, 10, 25, 50 and 100 years. Tabulate these values in Table 1 in the column headed 'Map Values'

TABLE 1

CENTROID OF WATERSHED

Return Period (Years)	Precipitation Values (inches)			
	6 hour duration		24 hour duration	
	Map Value	Corrected Value	Map Value	Corrected Value
2	1.6		2.2	
5	2.1		3.0	
10	2.45		3.4	
25	2.85		4.1	
50	3.2		4.5	
100	3.6		5.0	

NOTE: There is a possibility of making an error while reading the maps because, (1) a site is not easy to locate precisely on a series of 12 maps, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. In order to minimize any errors in reading the maps, these values should be plotted on the diagram "Precipitation Depth versus Return Period" Fig. 1.

CENTROID OF WATERSHED

Project No. _____ Station _____

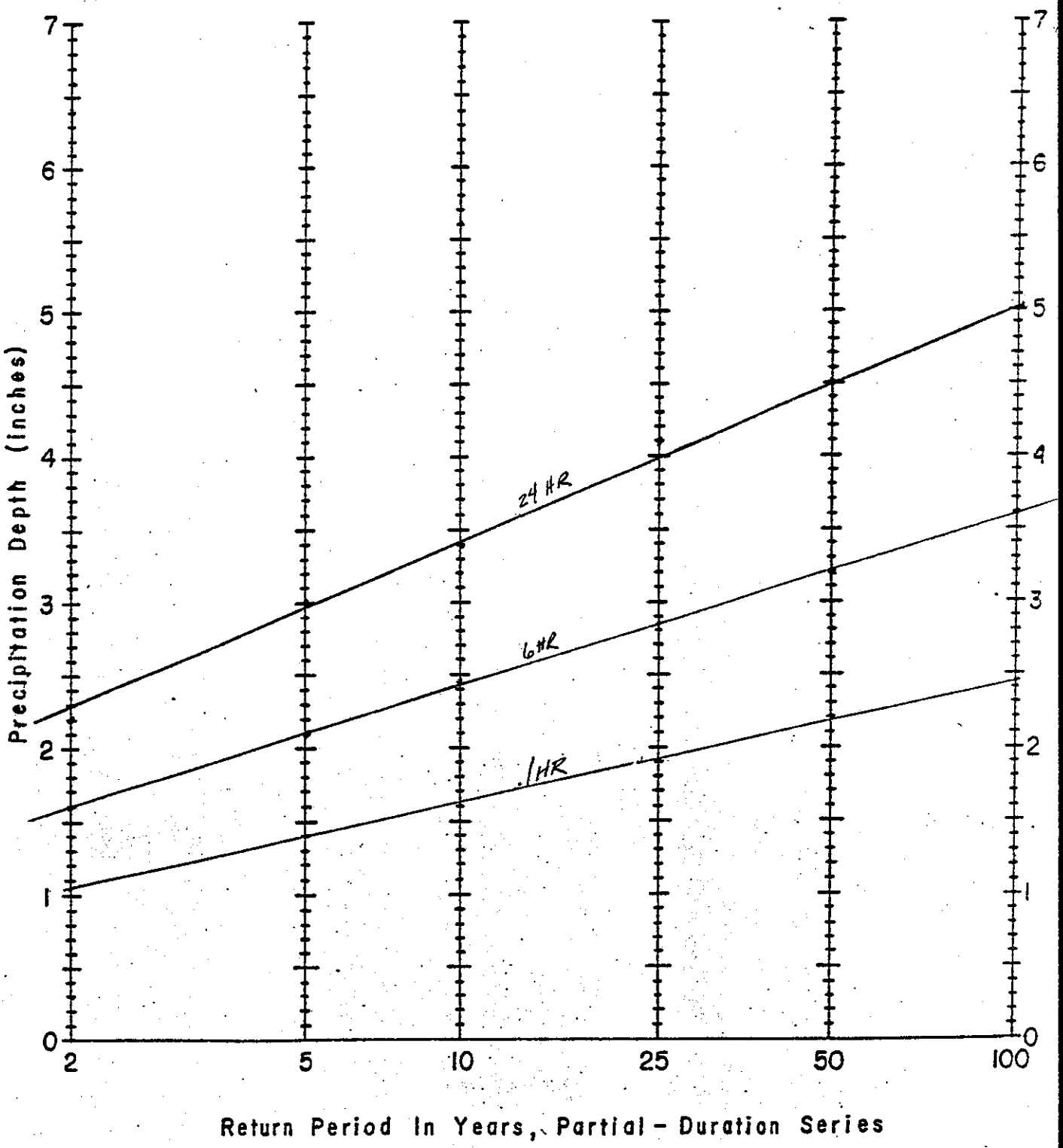

Figure 1 Precipitation Depth Versus Return Period for Partial - Duration Series

ADDENDUM to "HYDROLOGIC DESIGN FOR HIGHWAY DRAINAGE IN ARIZONA" April 1975

Steps to be used to determine precipitation values for various durations and return periods.

STEP 1. From the precipitation maps in the manual "Hydrologic Design for Highway Drainage in Arizona", determine the precipitation values for the 6 and 24 hour duration storms for return periods of 2, 5, 10, 25, 50 and 100 years. Tabulate these values in Table 1 in the column headed 'Map Values'

TABLE 1

CENTROID OF STUDY AREA

Return Period (Years)	Precipitation Values (inches)			
	6 hour duration		24 hour duration	
	Map Value	Corrected Value	Map Value	Corrected Value
2	1.5		1.9	
5	2.0		2.7	
10	2.3		3.2	
25	2.8		3.8	
50	3.1		4.3	
100	3.5		4.8	

NOTE: There is a possibility of making an error while reading the maps because, (1) a site is not easy to locate precisely on a series of 12 maps, (2) there may be some slight registration differences in printing, and (3) precise interpolation between isolines is difficult. In order to minimize any errors in reading the maps, these values should be plotted on the diagram "Precipitation Depth versus Return Period" Fig. 1.

CENTROID OF STUDY AREA

Project No. _____ Station _____

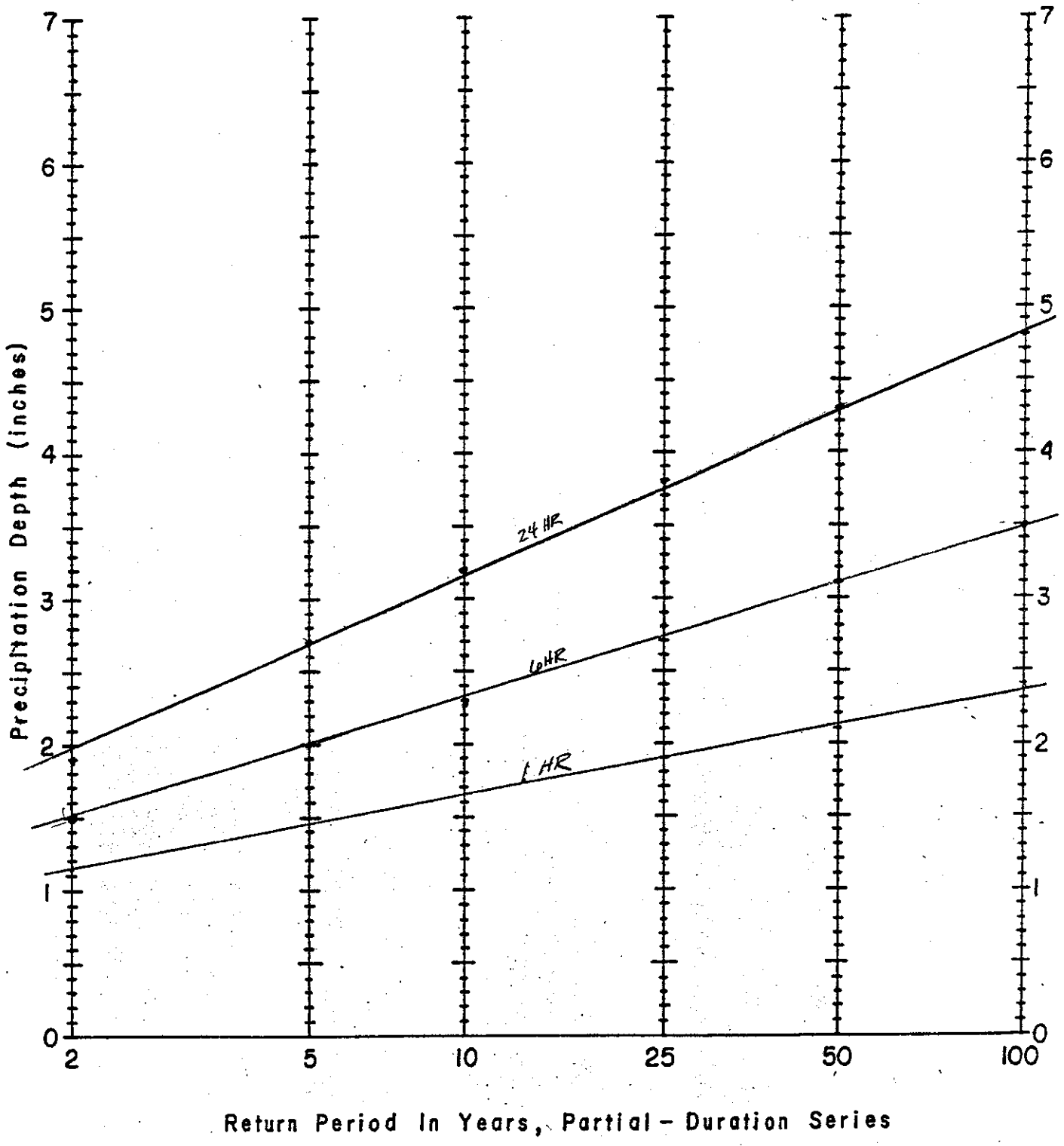

Figure 1 Precipitation Depth Versus Return Period for Partial - Duration Series

LA027815.HI
7/27/89
TWI
8 of 8

STUDY AREA
RAINFALL DISTRIBUTION
PRECIPITATION VALUES

(STEP #9)

DESIGN	1 HOUR	6 HOUR	24 HOUR	2 HOUR	3 HOUR	12 HOUR	5 min	10 min	15 min	20 min	30 min
2 YEAR	1.15	1.51	1.97	1.27	1.35	1.74	0.33	0.52	0.64	0.75	0.91
5 YEAR	1.46	2.05	2.69	1.66	1.80	2.36	0.42	0.66	0.82	0.95	1.15
10 YEAR	1.65	2.32	3.16	1.88	2.03	2.73	0.48	0.74	0.92	1.07	1.30
25 YEAR	1.90	2.72	3.75	2.18	2.37	3.22	0.55	0.86	1.06	1.23	1.50
50 YEAR	2.12	3.10	4.28	2.45	2.68	3.68	0.61	0.95	1.19	1.38	1.67
100 YEAR	2.36	3.48	4.81	2.74	3.00	4.13	0.68	1.06	1.32	1.53	1.86

(STEP # 10)

DESIGN	6.0	9.0	10.5	11.0	11.5	11.75	11.90	11.95	12.0	12.05	12.10	12.25	12.5	13.0	13.5	15.0	18.0
2 YEAR	0.12	0.23	0.31	0.35	0.41	0.53	0.66	0.82	0.99	1.15	1.31	1.44	1.56	1.62	1.66	1.74	1.85
5 YEAR	0.16	0.32	0.45	0.51	0.62	0.77	0.94	1.13	1.35	1.56	1.75	1.92	2.08	2.18	2.24	2.37	2.53
10 YEAR	0.21	0.42	0.56	0.64	0.76	0.93	1.12	1.34	1.58	1.82	2.04	2.23	2.41	2.52	2.60	2.74	2.95
25 YEAR	0.26	0.51	0.69	0.79	0.93	1.12	1.34	1.60	1.88	2.15	2.41	2.63	2.83	2.96	3.06	3.24	3.49
50 YEAR	0.30	0.59	0.80	0.91	1.08	1.30	1.55	1.83	2.14	2.45	2.73	2.98	3.20	3.37	3.48	3.69	3.98
100 YEAR	0.34	0.66	0.91	1.03	1.22	1.47	1.74	2.06	2.41	2.75	3.07	3.34	3.59	3.78	3.90	4.15	4.47

WATERSHED AREA
RAINFALL DISTRIBUTION
PRECIPITATION VALUES

PRECIP. VALUES FOR DURATIONS < 1 HR.

DESIGN	1 HOUR	6 HOUR	24 HOUR	2 HOUR	3 HOUR	12 HOUR	5 min	10 min	15 min	20 min	30 min
2 YEAR	1.15	1.60	2.29	1.30	1.41	1.94	0.33	0.52	0.64	0.75	0.91
5 YEAR	1.40	2.10	2.97	1.64	1.80	2.53	0.41	0.63	0.78	0.91	1.11
10 YEAR	1.62	2.42	3.41	1.89	2.08	2.91	0.47	0.73	0.91	1.05	1.28
25 YEAR	1.92	2.83	4.00	2.23	2.44	3.40	0.56	0.86	1.08	1.25	1.52
50 YEAR	2.18	3.21	4.50	2.53	2.77	3.84	0.63	0.98	1.22	1.42	1.72
100 YEAR	2.43	3.60	5.00	2.83	3.10	4.29	0.70	1.09	1.36	1.58	1.92

(STEP # 10)

DESIGN	6.0	9.0	10.5	11.0	11.5	11.75	11.90	11.95	12.0	12.05	12.10	12.25	12.5	13.0	13.5	15.0	18.0
2 YEAR	0.18	0.35	0.44	0.49	0.57	0.69	0.82	0.98	1.15	1.31	1.47	1.60	1.72	1.80	1.85	1.95	2.11
5 YEAR	0.22	0.44	0.59	0.67	0.79	0.93	1.09	1.28	1.49	1.69	1.88	2.04	2.19	2.30	2.38	2.54	2.75
10 YEAR	0.25	0.50	0.67	0.76	0.90	1.07	1.25	1.47	1.71	1.94	2.16	2.34	2.52	2.65	2.74	2.92	3.16
25 YEAR	0.30	0.59	0.78	0.88	1.04	1.24	1.46	1.72	2.00	2.28	2.54	2.76	2.96	3.12	3.22	3.42	3.70
50 YEAR	0.33	0.65	0.87	0.98	1.16	1.39	1.64	1.93	2.25	2.57	2.86	3.11	3.34	3.52	3.63	3.86	4.17
50 YEAR	0.36	0.70	0.93	1.09	1.29	1.54	1.82	2.15	2.50	2.85	3.18	3.46	3.72	3.91	4.05	4.30	4.64

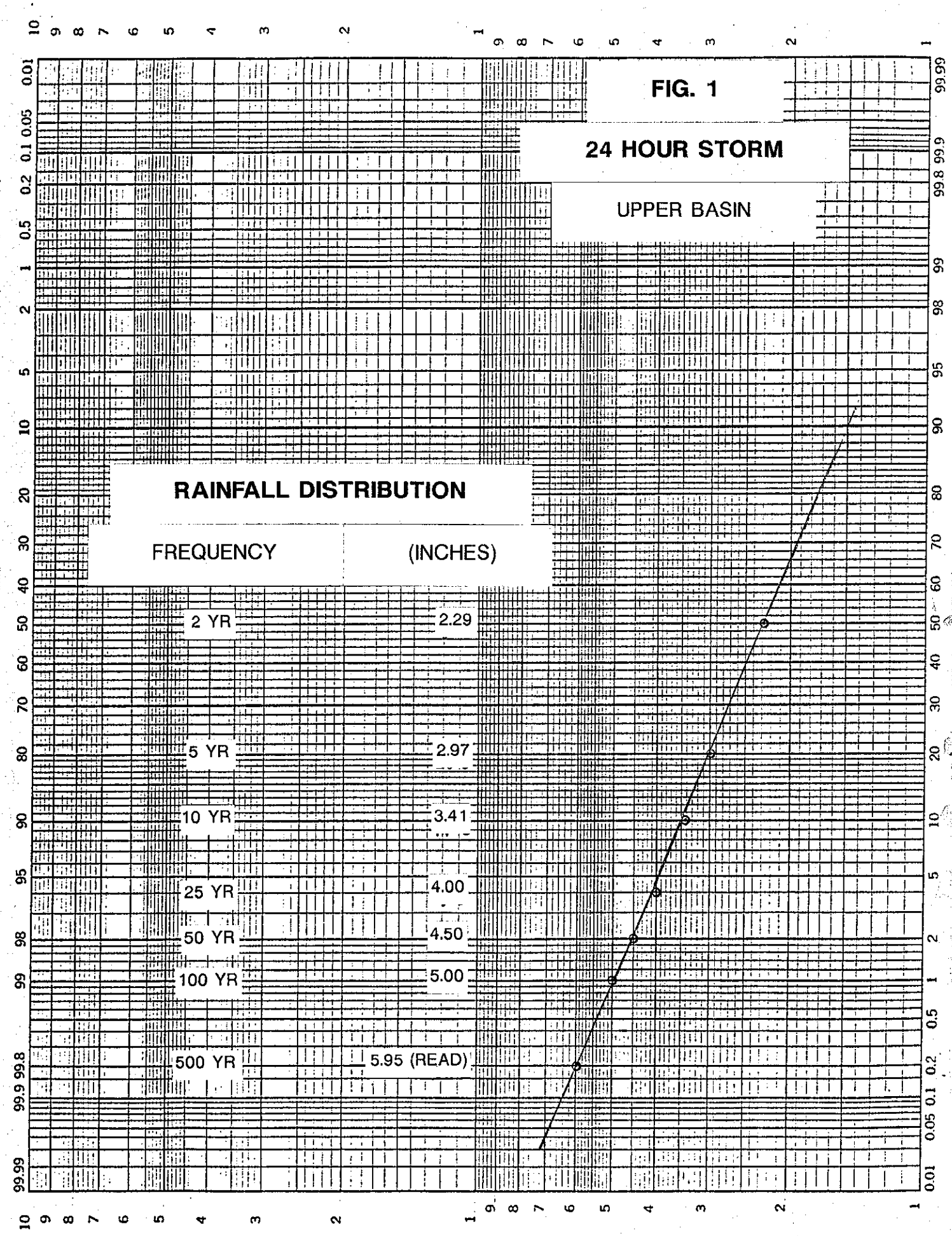
FIG. 1
24 HOUR STORM
UPPER BASIN
RAINFALL DISTRIBUTION
FREQUENCY
(INCHES)
2 YR
2.29
5 YR
2.97
10 YR
3.41
25 YR
4.00
50 YR
4.50
100 YR
5.00
500 YR
5.95 (READ)
PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8040
9-26-89

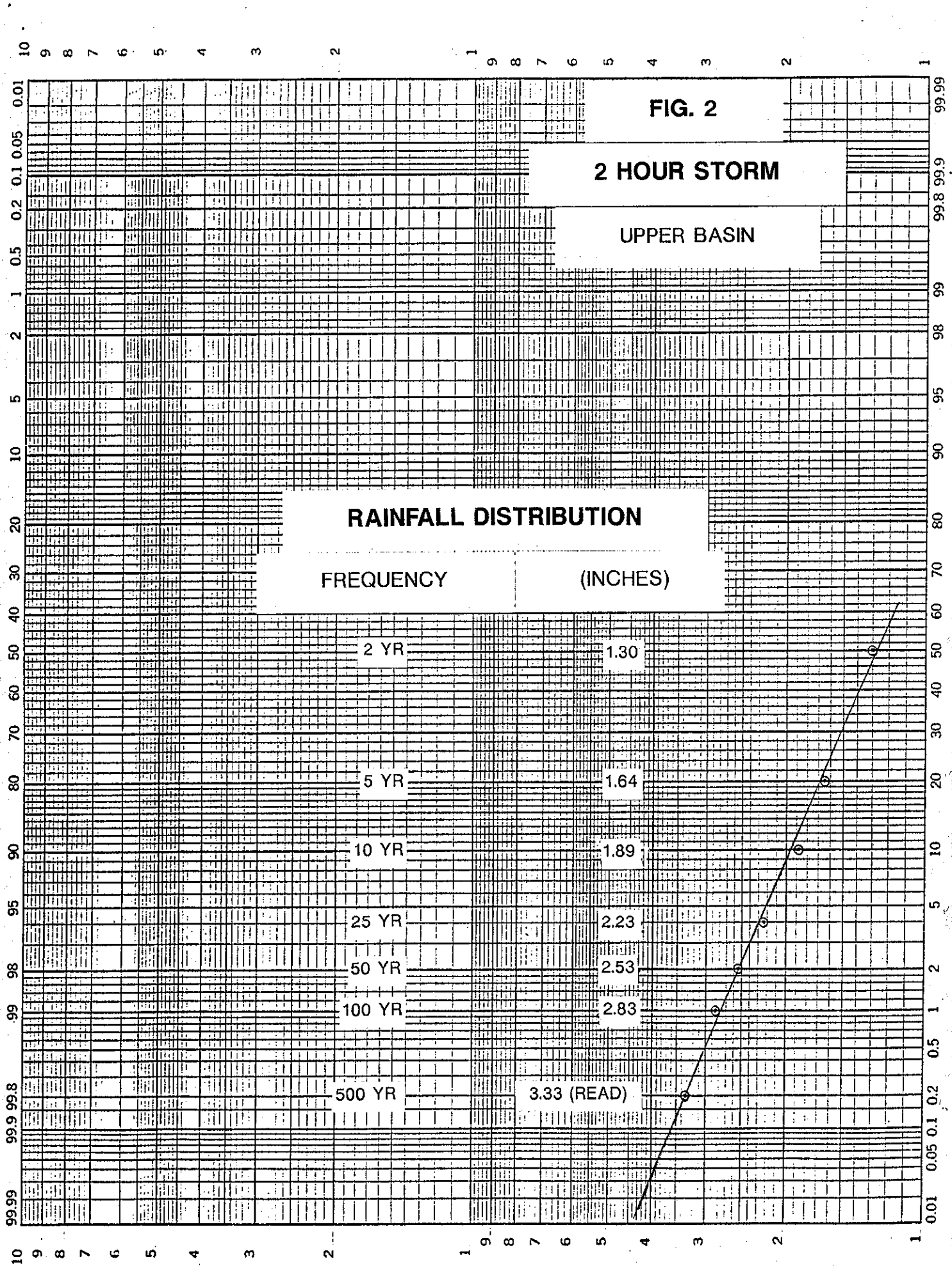
FIG. 2
2 HOUR STORM
UPPER BASIN
RAINFALL DISTRIBUTION
FREQUENCY
(INCHES)
2 YR
1.30
5 YR
1.64
10 YR
1.89
25 YR
2.23
50 YR
2.53
100 YR
2.83
500 YR
3.33 (READ)
PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8040
9-26-89

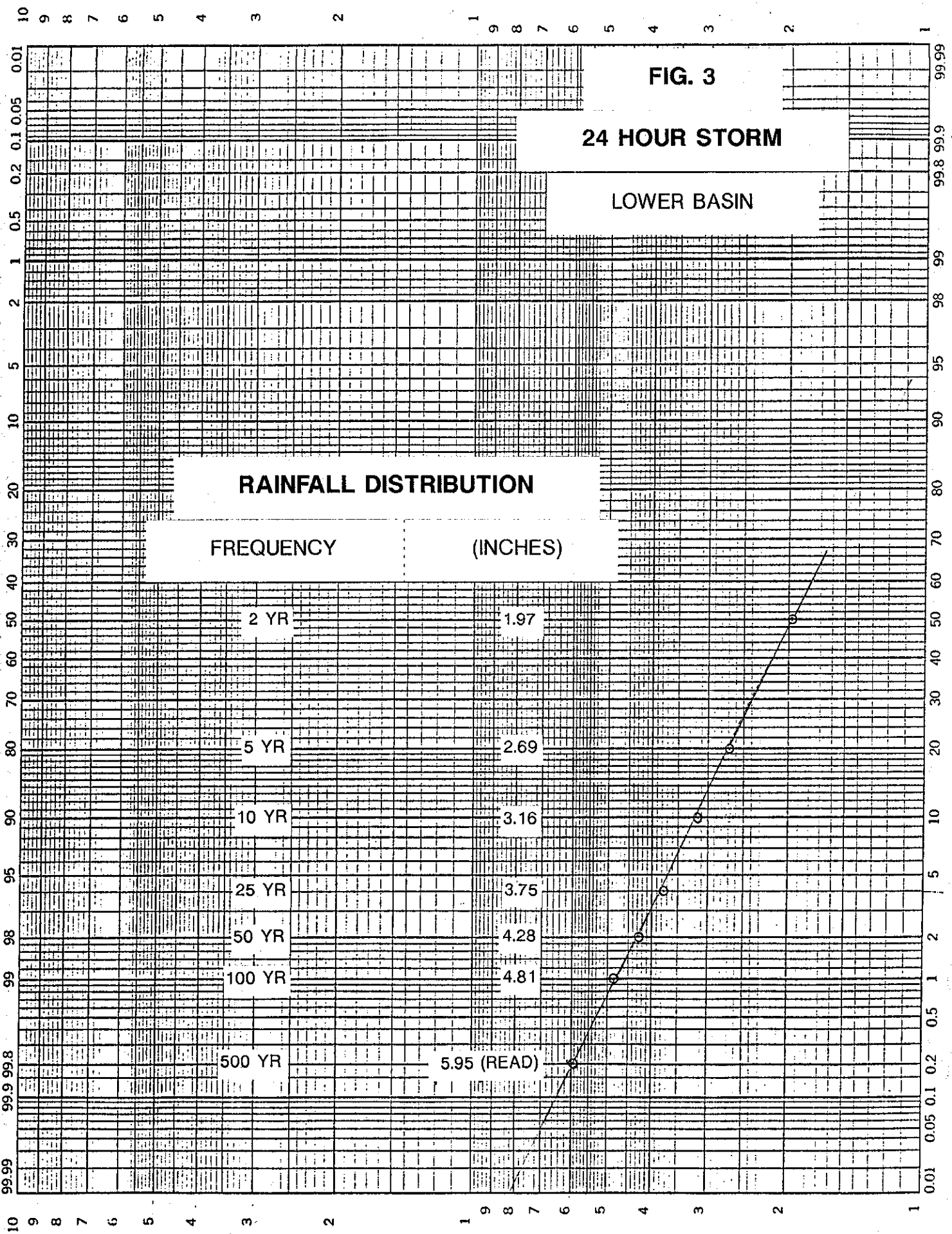
FIG. 3
24 HOUR STORM
LOWER BASIN
RAINFALL DISTRIBUTION
FREQUENCY
(INCHES)
2 YR
1.97
5 YR
2.69
10 YR
3.16
25 YR
3.75
50 YR
4.28
100 YR
4.81
500 YR
5.95 (READ)
PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN USA
46 8040
9-26-89

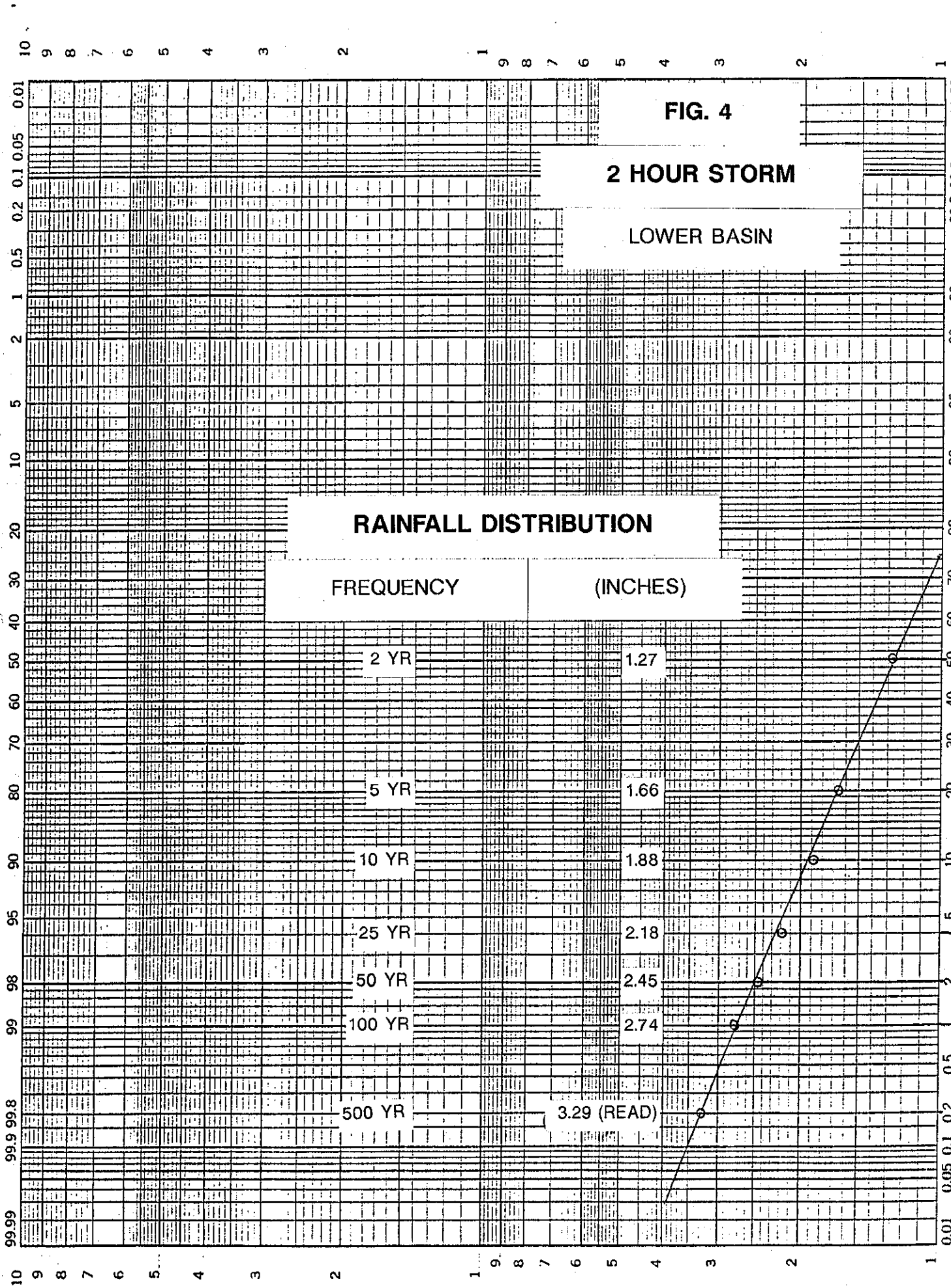
FIG. 4
2 HOUR STORM
LOWER BASIN
RAINFALL DISTRIBUTION
FREQUENCY
(INCHES)
2 YR
1.27
5 YR
1.66
10 YR
1.88
25 YR
2.18
50 YR
2.45
100 YR
2.74
500 YR
3.29 (READ)
PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 8040
9-26-89

SCS TYPE II DISTRIBUTION

2-HOUR DISTRIBUTION

Time Inc.(Hr)	Cumulative ppt
0.00	0.000
0.25	0.039
0.50	0.087
0.75	0.280
1.00	0.791
1.25	0.872
1.50	0.924
1.75	0.967
2.00	1.000

6-HOUR DISTRIBUTION

Time Inc.(Hr)	Cumulative ppt
0.00	0.000
0.25	0.011
0.50	0.022
0.75	0.035
1.00	0.048
1.25	0.062
1.50	0.079
1.75	0.100
2.00	0.125
2.25	0.155
2.50	0.192
2.75	0.339
3.00	0.729
3.25	0.791
3.50	0.830
3.75	0.862
4.00	0.887
4.25	0.908
4.50	0.926
4.75	0.942
5.00	0.956
5.25	0.969
5.50	0.980
5.75	0.990
6.00	1.000

24-HOUR DISTRIBUTION

Time Inc.(Hr)	Cumulative ppt	Time Inc.(Hr)	Cumulative ppt
0.00	0.000	12.00	0.663 } .276
0.25	0.002	12.25	0.707 } .044
0.50	0.005	12.50	0.735
0.75	0.008	12.75	0.758
1.00	0.011	13.00	0.776
1.25	0.014	13.25	0.791
1.50	0.017	13.50	0.804
1.75	0.020	13.75	0.815
2.00	0.023	14.00	0.825
2.25	0.026	14.25	0.834
2.50	0.029	14.50	0.842
2.75	0.032	14.75	0.849
3.00	0.035	15.00	0.856
3.25	0.038	15.25	0.863
3.50	0.041	15.50	0.869
3.75	0.044	15.75	0.875
4.00	0.048	16.00	0.881
4.25	0.052	16.25	0.887
4.50	0.056	16.50	0.893
4.75	0.060	16.75	0.898
5.00	0.064	17.00	0.903
5.25	0.068	17.25	0.908
5.50	0.072	17.50	0.913
5.75	0.076	17.75	0.918
6.00	0.080	18.00	0.922
6.25	0.085	18.25	0.926
6.50	0.090	18.50	0.930
6.75	0.095	18.75	0.934
7.00	0.100	19.00	0.938
7.25	0.105	19.25	0.942 .427
7.50	0.110	19.50	0.946 .450
7.75	0.115	19.75	0.950 .452
8.00	0.120	20.00	0.953
8.25	0.126	20.25	0.956
8.50	0.133	20.50	0.959
8.75	0.140	20.75	0.962
9.00	0.147	21.00	0.965
9.25	0.155	21.25	0.968
9.50	0.163	21.50	0.971
9.75	0.172	21.75	0.974
10.00	0.181	22.00	0.977
10.20	0.191	22.25	0.980
10.50	0.203	22.50	0.983
10.75	0.218	22.75	0.986
11.00	0.236	23.00	0.989
11.25	0.257 }	23.25	0.992
11.50	0.283 } .104	23.50	0.995
11.75	0.387 }	23.75	0.998
		24.00	1.000

From SCS TR-20

DISCREET AREAL REDUCTION VALUES
FROM NOAA CURVES

Square Mile	Ratio
10	.95
20	.92
30	.90
40	.89
50	.88
60	.87
70	.86
80	.86
90	.85
100	.85

SUBJECT _____ BY _____ DATE _____

SHEET ____ OF ____

PROJECT NO. _____

LOSS RATES

SUBJECT MCFCD – CAVE CREEK – PK BY T. MOONEY DATE 8/1/87
HYDROLOGIC SOIL TYPES – SCS SHEET 1 OF 5
PROJECT NO. LA027815.H1

OBJECTIVE: TO CLASSIFY THE DIFFERENT U.S. SOIL CONSERVATION SERVICE (SCS) HYDROLOGIC SOIL TYPES WITHIN THE DRAINAGE BASINS DELINEATED BY MCFCD. THE PURPOSE OF THIS IS TO OBTAIN AN SCS CURVE NO. FOR EACH BASIN.

METHOD: A MYLAR OVERLAY, DIGITIZED USING AUTOCAD & PLOTTED @ 1" = 2000' SCALE, WAS PLACED OVER THE SOILS MAPS. A PERCENTAGE OF EACH HYDRO SOIL TYPE WAS DERIVED FOR EACH BASIN BY VISUALLY SUMMING THE AREAS OF EACH TYPE.

ASSUMPTIONS: THE SOIL SURVEY ONLY EXTENDED TO THE TONTO NATIONAL FOREST BOUNDARY TO THE NORTH. ALL SOILS ABOVE THIS BOUNDARY WERE ASSUMED TO BE SOIL TYPE "D".

REFERENCES: SOIL SURVEY OF AGUILA – CAREFREE AREA, PARTS OF MARICOPA AND PINAL COUNTIES, ARIZONA., U.S. DEPT OF AGRICULTURE, SOIL CONSERVATION SERVICE, APRIL, 1986.

TC
A Program to Estimate Time of Concentration

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INTRODUCTION

Hydrologic flood flow design and analysis methods generally require the estimation of a time parameter. The time parameter most used is the time of concentration, Tc. The time of concentration is the time it takes for flow to reach the basin outlet from the hydraulically most remote point in the watershed (Barfield, et.al). The accuracy of estimating the peak discharge is subject to the accuracy of the estimated time parameter. Bondelid, et al. showed that as much as 75% of the total error in an estimate of the peak discharge can result from errors in the time of concentration estimate.

The program, **TC**, was written to facilitate a more accurate estimate of the time of concentration. By computerizing the hydraulic computations, the hydrologist can incorporate more accurate, more realistic assumptions into a time of concentration estimate.

METHODS OF ESTIMATING TIME OF CONCENTRATION

Over the years, hydrologists have developed numerous methods for estimating time of concentration. McCuen et al. identified and evaluated 13 different methods for estimating time of concentration. These methods can be classified as empirical or velocity based.

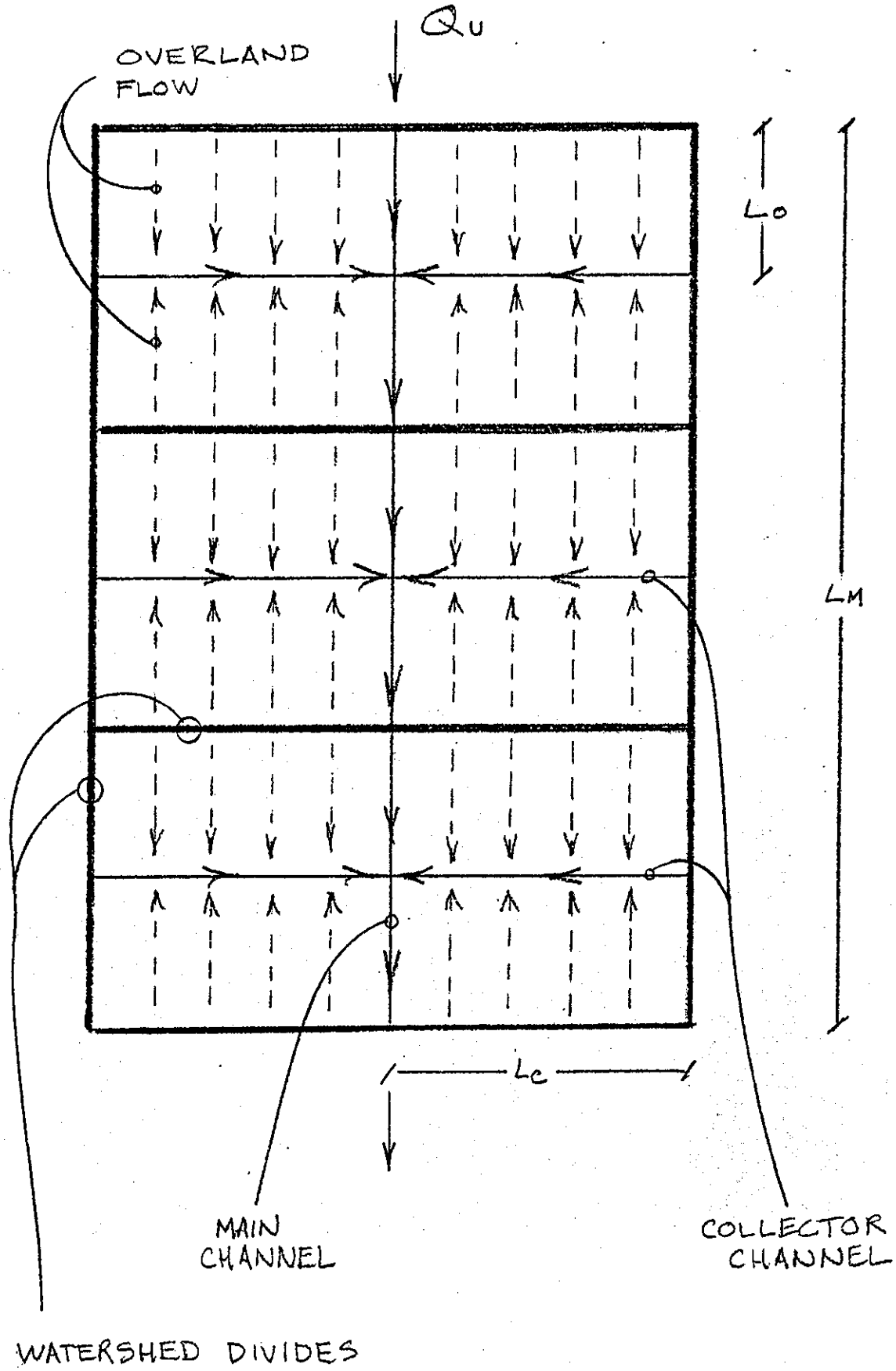
Empirical methods are usually based upon limited data. For example, the popular Kirpich equation is based upon data from seven steeply sloped agricultural watersheds extending in size from 1.25 acres to 112 acres. Therefore, the designer must use caution either for watersheds having characteristics different from those of the watershed used to calibrate the method of for other geographic regions.

Velocity based methods are based upon either the kinematic wave formula or Manning's equation to estimate overland, channel or pipe velocity. For example, the Soil Conservation Service Bulletin TR-55 suggests using a combination of a simplified kinematic wave formula for sheet flow, an empirical method for shallow concentrated flow and Manning's equation for channel flow. Velocity methods require the hydrologist to choose a rainfall intensity. TR-55 utilizes the 2-year rainfall intensity and assumes bank full channel conditions.

SUBJECT FIGURE 1 BY DATE

SHEET OF

BASIN SCHEMATIC PROJECT NO.



McCuen et. al. conclude that a velocity based method is most likely to provide an accurate and unbiased estimate of time of concentration.

ESTIMATION METHOD USED IN PROGRAM TC

The time of concentration estimation program, **TC**, is a velocity based method. Two types of flow regimes are used, overland flow and channel flow. It is generally accepted that overland (sheet) flow should only be considered for at most 300 feet (500 feet for urban) of the most upland areas to a maximum depth of 0.1 foot. Two types of channels are defined, main and collector. Collector channels collect water from the overland flow elements. Main channels collect water from the collector channels (Figure 1).

The user specifies a separate Manning's roughness coefficient, flow length, and slope for a typical sheet flow element, collector and main channel. In addition, the user specifies a side slope and channel bottom width for a typical collector and main channel. The user must also specify total basin area, the flow rate entering the basin from upstream and excess rainfall rate. This last parameter is dependent upon the time of concentration, which in turn is dependent upon the excess rainfall rate. **TC** allows the hydrologist to interactively adjust the excess rainfall rate until it matches the time of concentration.

The flow rate used to compute flow velocity varies along the flow length but not in time (unsteady, uniform). Flow rates vary linearly according to Table 1. The kinematic equation itself is based upon the flow variation listed in Table 1. The Manning equation requires an iterative solution to compute velocity for a specified flow rate. The iterative solution is done for ten points along both the main and collector channel. The time of concentration is calculated by dividing the channel length by the average velocity.

WAVE CELERITY AND AVERAGE FLOW VELOCITY

Time of concentration estimates may be based upon wave celerity or average flow velocity. The wave celerity is the speed at which a flood wave would travel along the water surface. The average flow velocity is the mean velocity of flow. The user must determine whether to base the time of concentration estimate on wave celerity or flow velocity. **TC** calculates time of concentration based on both methods. The user is referred to any standard textbook on open channel hydraulics for further information on wave celerity.

BENEFITS OF USING PROGRAM TC TO ESTIMATE TIME OF CONCENTRATION

There are numerous benefits to using **TC** to estimate time of concentration over other, more approximate methods:

Table 1

Flow Rate Variation

Flow Element	Location	Formula
Overland	Upstream	Q = 0 (cfs)
Overland	Downstream	Q = Lo * Ie (cfs/ft)
Collector	Upstream	Q = 0 (cfs)
Collector	Downstream	Q = 2 * Lc * Lo * Ie (cfs)
Main	Upstream	Q = Qu (cfs)
Main	Downstream	Q = A * Ie + Qu (cfs)

Variable	Units	Definition
A	acres	Basin area
Ie	iph	Excess rainfall intensity
Lo	feet	Typical overland flow length
Ls	feet	Typical collector channel flow length
Q	cfs	Flow rate
Qu	cfs	Flow rate entering basin from upstream

\wsg4\tc.doc

- The velocity method used in **TC** is widely recognized as being the most accurate method for estimating time of concentration. The procedures used in **TC** are not specific to any topography or geographical region.

- The sensitivity of the time of concentration estimate to variations in each hydraulic parameter may be examined. Most lumped parameters do not allow for such an examination. For example, in the TR-55 method, the user cannot vary the roughness coefficient for shallow, concentrated flow.

- The time of concentration estimate is related to excess rainfall rates. This is important because flow velocity increases with flow discharge. **TC** will predict shorter time of concentrations where more intense rainfall rates are experienced. Also, the time of concentration estimate can be tailored to the design event (2-year, 10-year, 100-year, etc.).

- **TC** explicitly manages increasing flow rates from upstream to downstream. Other methods only approximately manage increasing flow rates (by assuming pipe or bank full conditions).

- All input data and a computation summary are listed on a single sheet of computer printout per basin. Flow depth, velocity and flow rates at each element outlet allows the hydrologist to check the reality of the assumed flow conditions.

HOW TO RUN PROGRAM TC

TC may be run interactively or in batch mode. When running interactively, no data files need to be prepared before hand. However, if there are numerous basins to analyze, the user may wish to prepare a data file in advance of executing **TC**. Figure 2 shows a flow chart of program **TC** execution. After each basin is analyzed, program **TC** writes a one page summary of input data and computations to an output file. This output file can be printed and stored with permanent project records.

To execute **TC** in batch mode, the user must first prepare a free-format data file. Figures 3 shows a LOTUS worksheet with contains the required input data. Figure 4 shows the required format for program **TC**. The first line contains the number of basins to analyze. Subsequent lines contain the hydraulic data for each basin basin. The data in Figure 4 is in the same order as in Figure 3, except the first column is omitted.

Sample outputs for the first two basins are shown in Figures 5 and 6.

Figure 2

Flow Chart for Input

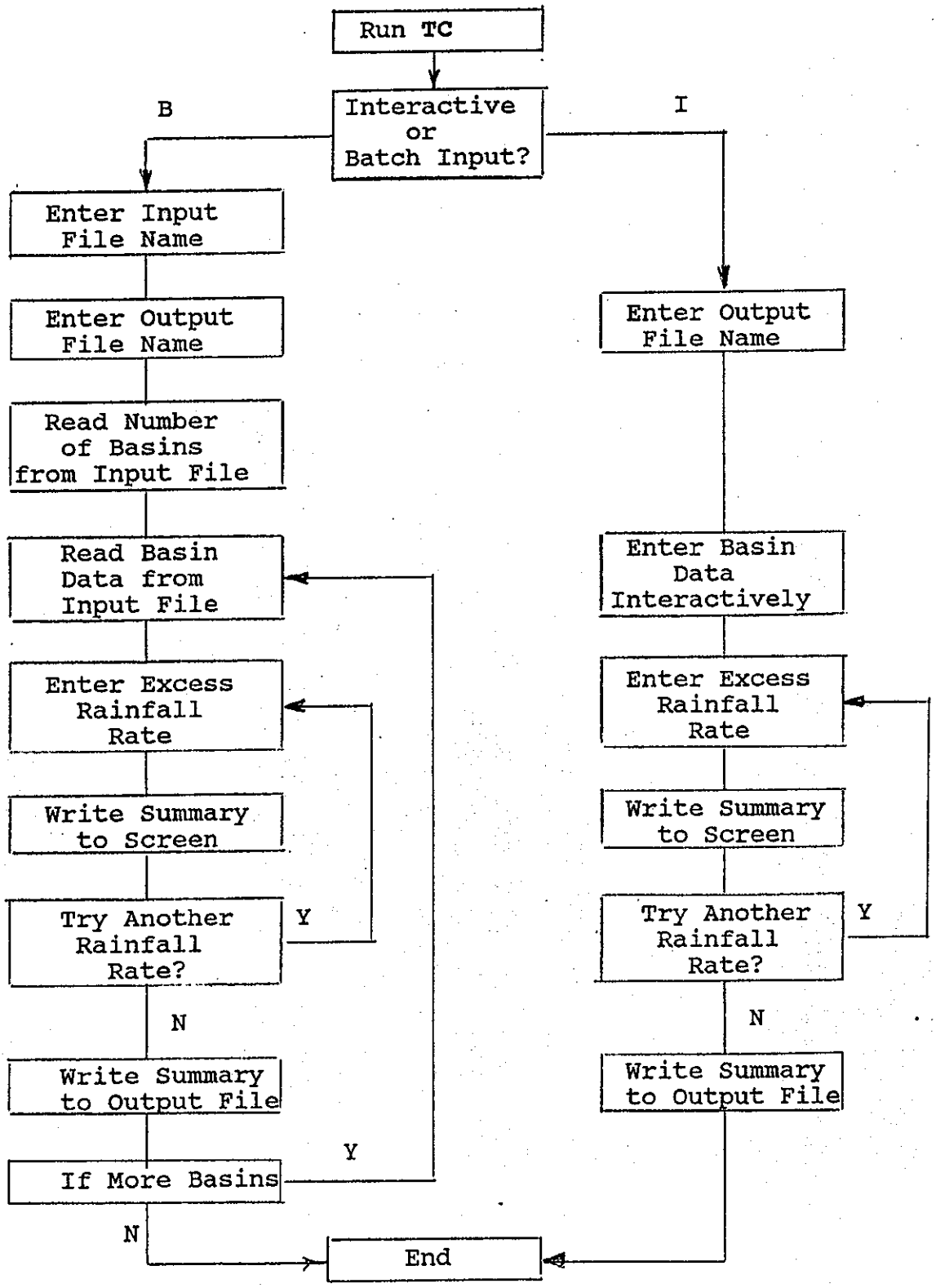


Figure 3

Lotus Worksheet for Sample Basins

SUBJECT: MARICOPA CO
CAVE CREEK/CAREFREE FIS
BASIN CONCENTRATION DATA
BY: WILLIE GONWA/GLO
DATE: SEPTEMBER 27, 1989
PROJECT: LA027815.H1
FILE: TC.WK1

	OVERLAND			COLLECTOR					MAIN						
BASIN	GROUND SLOPE (FT/FT)	MANNING'S n	FLOW LENGTH (FEET)	SIDE SLOPE (FT/FT)	BOTTOM WIDTH (FEET)	CHANNEL SLOPE (FT/FT)	MANNING'S n	CHANNEL LENGTH (FEET)	SIDE SLOPE (FT/FT)	BOTTOM WIDTH (FEET)	CHANNEL SLOPE (FT/FT)	MANNING'S n	CHANNEL LENGTH (FEET)	BASIN AREA (AC-FT)	UPSTREAM FLOW (CFS)	BASIN
A1	0.25	0.1	1000	1	40	0.052	0.065	4500	1	100	0.023	0.050	28000	10081	0	A1
A2	0.27	0.1	1100	1	40	0.051	0.050	9800	1	75	0.021	0.040	19500	6842	0	A2
A3	0.19	0.1	1050	1	40	0.042	0.065	8000	1	100	0.030	0.040	15000	3040	0	A3
A4	0.24	0.1	1600	1	40	0.050	0.065	11400	1	150	0.022	0.040	21000	6700	34000	A4
A5	0.27	0.1	500	1	25	0.167	0.065	3500	1	75	0.044	0.050	19800	2195	0	A5
A6	0.38	0.1	1500	1	40	0.092	0.050	4000	1	100	0.053	0.040	18100	2240	0	A6
A7	0.26	0.1	1500	1	50	0.224	0.065	3900	1	150	0.015	0.040	27600	7437	33000	A7
E1	0.24	0.1	1500	1	25	0.083	0.065	1600	1	250	0.019	0.040	2800	327	34000	E1
B3	0.33	0.1	900	1	25	0.111	0.065	2700	1	75	0.061	0.050	7100	851	0	B3
B2	0.39	0.1	1100	1	25	0.079	0.065	3600	1	75	0.000	0.040	0	198	0	B2
B4	0.28	0.1	950	1	25	0.159	0.065	2300	1	75	0.040	0.050	3700	358	3600	B4
B1	0.23	0.1	800	1	25	0.102	0.065	4900	1	100	0.042	0.045	20700	3910	0	B1
B5	0.30	0.1	550	1	25	0.083	0.065	5200	1	100	0.021	0.050	1600	314	13000	B5
B6	0.28	0.1	1000	1	60	0.083	0.065	12000	1	75	0.000	0.040	0	525	0	B6
B7	0.28	0.1	650	1	25	0.113	0.065	4500	1	100	0.018	0.040	4200	282	14000	B7
E2	0.27	0.1	500	1	25	0.076	0.065	9000	1	75	0.000	0.040	0	320	0	E2
E3	0.27	0.1	1350	1	25	0.169	0.065	6900	1	75	0.041	0.040	7700	269	0	E3
E4	0.12	0.1	700	1	25	0.076	0.065	1700	1	250	0.007	0.040	3000	1312	34000	E4
E5	0.18	0.1	170	1	25	0.000	0.065	0	1	250	0.018	0.040	8300	122	34000	E5
E6A	0.48	0.1	1600	1	40	0.089	0.065	7500	1	0	0.000	0.045	0	640	0	E6A
E6	0.14	0.1	1200	1	40	0.000	0.065	0	1	300	0.018	0.045	1550	122	34000	E6
E7	0.21	0.1	3100	1	40	0.000	0.065	0	1	300	0.036	0.045	1400	237	34000	E7
E8	0.29	0.1	1700	1	40	0.042	0.065	4200	1	0	0.000	0.045	0	230	0	E8
E10	0.10	0.1	1400	1	40	0.021	0.065	11700	1	0	0.000	0.045	0	1382	0	E10
E9	0.07	0.1	2200	1	40	0.000	0.065	0	1	300	0.008	0.045	3000	269	34000	E9
E11	0.23	0.1	1450	1	40	0.000	0.065	0	1	300	0.009	0.045	6000	301	34000	E11
E12	0.04	0.1	1200	1	40	0.037	0.065	5000	1	0	0.000	0.045	0	275	0	E12
E13	0.12	0.1	200	1	0	0.000	0.065	0	1	0	0.000	0.000	0	26	35000	E13
E14	0.53	0.1	900	1	40	0.100	0.065	2000	1	80	0.094	0.050	8800	551	0	E14

Figure 4

Sample Batch Data File for Program TC

29

0.25	0.1	1000	1	40	0.052	0.065	4500	1	100	0.023	0.050	28000	10081	0	A1
0.27	0.1	1100	1	40	0.051	0.050	9800	1	75	0.021	0.040	19500	6842	0	A2
0.19	0.1	1050	1	40	0.042	0.065	8000	1	100	0.030	0.040	15000	3040	0	A3
0.24	0.1	1600	1	40	0.050	0.065	11400	1	150	0.022	0.040	21000	6700	34000	A4
0.27	0.1	500	1	25	0.167	0.065	3500	1	75	0.044	0.050	19800	2195	0	A5
0.38	0.1	1500	1	40	0.092	0.050	4000	1	100	0.053	0.040	18100	2240	0	A6
0.26	0.1	1500	1	50	0.224	0.065	3900	1	150	0.015	0.040	27600	7437	33000	A7
0.24	0.1	1500	1	25	0.083	0.065	1600	1	250	0.019	0.040	2800	327	34000	E1
0.33	0.1	900	1	25	0.111	0.065	2700	1	75	0.061	0.050	7100	851	0	B3
0.39	0.1	1100	1	25	0.079	0.065	3600	1	75	0.000	0.040	0	198	0	B2
0.28	0.1	950	1	25	0.159	0.065	2300	1	75	0.040	0.050	3700	358	3600	B4
0.23	0.1	800	1	25	0.102	0.065	4900	1	100	0.042	0.045	20700	3910	0	B1
0.30	0.1	550	1	25	0.083	0.065	5200	1	100	0.021	0.050	1600	314	13000	B5
0.28	0.1	1000	1	60	0.083	0.065	12000	1	75	0.000	0.040	0	525	0	B6
0.28	0.1	650	1	25	0.113	0.065	4500	1	100	0.018	0.040	4200	282	14000	B7
0.27	0.1	500	1	25	0.076	0.065	9000	1	75	0.000	0.040	0	320	0	E2
0.27	0.1	1350	1	25	0.169	0.065	6900	1	75	0.041	0.040	7700	269	0	E3
0.12	0.1	700	1	25	0.076	0.065	1700	1	250	0.007	0.040	3000	1312	34000	E4
0.18	0.1	170	1	25	0.000	0.065	0	1	250	0.018	0.040	8300	122	34000	E5
0.48	0.1	1600	1	40	0.089	0.065	7500	1	0	0.000	0.045	0	640	0	E6A
0.14	0.1	1200	1	40	0.000	0.065	0	1	300	0.018	0.045	1550	122	34000	E6
0.21	0.1	3100	1	40	0.000	0.065	0	1	300	0.036	0.045	1400	237	34000	E7
0.29	0.1	1700	1	40	0.042	0.065	4200	1	0	0.000	0.045	0	230	0	E8
0.10	0.1	1400	1	40	0.021	0.065	11700	1	0	0.000	0.045	0	1382	0	E10
0.07	0.1	2200	1	40	0.000	0.065	0	1	300	0.008	0.045	3000	269	34000	E9
0.23	0.1	1450	1	40	0.000	0.065	0	1	300	0.009	0.045	6000	301	34000	E11
0.04	0.1	1200	1	40	0.037	0.065	5000	1	0	0.000	0.045	0	275	0	E12
0.12	0.1	200	1	0	0.000	0.065	0	1	0	0.000	0.000	0	26	35000	E13
0.53	0.1	900	1	40	0.100	0.065	2000	1	80	0.094	0.050	8800	551	0	E14

Figure 5

Sample Output for Basin A1

```
*** PROGRAM TO CALCULATE TIME OF CONCENTRATION ***
***   WRITTEN BY WILLIE GONWA, CH2M-HILL/GLO   ***
***        REVISION OCTOBER 4, 1989            ***

**********
********** FOR BASIN :    A1
**********

*** DATA FOR OVERLAND FLOW ELEMENT ***

 SLOPE S (FEET/FOOT) :    0.25000
 ROUGHNESS COEFFICIENT N :    0.10000
 FLOW LENGTH (FEET) :       1000

*** DATA FOR COLLECTOR CHANNEL ***

 SIDESLOPE Z (FEET/FOOT) :    1.00000
 BOTTOM WIDTH W (FEET) :       40.0
 SLOPE S (FEET/FOOT) :    0.05200
 ROUGHNESS COEFFICIENT N :    0.06500
 FLOW LENGTH (FEET) :       4500

*** DATA FOR MAIN CHANNEL ***

 SIDESLOPE Z (FEET/FOOT) :    1.00000
 BOTTOM WIDTH W (FEET) :      100.0
 SLOPE S (FEET/FOOT) :    0.02300
 ROUGHNESS COEFFICIENT N :    0.05000
 FLOW LENGTH (FEET) :      28000

*** END OF FLOW ELEMENTS DATA ***

 TOTAL BASIN AREA (ACRES) :   10081.00
 FLOW FROM UPSTREAM BASIN (CFS) :          0
 EXCESS RAINFALL RATE FOR ESTIMATED BASIN Tc (INCHES/HOUR) :       6.00
```

		OVERLAND FLOW ELEMENT	COLLECTOR CHANNEL	MAIN CHANNEL	TOTAL BASIN
Tc (sec)	BASED ON CW	660	409	961	2030
Tc (hours)	BASED ON CW	0.18	0.11	0.27	0.56
Tc (sec)	BASED ON V	1100	649	1446	3195
Tc (hours)	BASED ON V	0.31	0.18	0.40	0.89
V (fps)	AT OUTLET	1.51	9.91	27.09	
CW (fps)	AT OUTLET	2.52	15.45	39.71	
Y (feet)	AT OUTLET	0.09	2.94	18.95	
Q (cfs)	AT OUTLET	0.1389	1250	60990	

Figure 6

Sample Output for Basin A2

```
*** PROGRAM TO CALCULATE TIME OF CONCENTRATION ***
***   WRITTEN BY WILLIE GONWA, CH2M-HILL/GLO   ***
***        REVISION OCTOBER 4, 1989            ***

**********
********** FOR BASIN :    A2
**********

*** DATA FOR OVERLAND FLOW ELEMENT ***

 SLOPE S (FEET/FOOT) :     0.27000
 ROUGHNESS COEFFICIENT N :    0.10000
 FLOW LENGTH (FEET) :       1100

*** DATA FOR COLLECTOR CHANNEL ***

 SIDESLOPE Z (FEET/FOOT) :    1.00000
 BOTTOM WIDTH W (FEET) :       40.0
 SLOPE S (FEET/FOOT) :     0.05100
 ROUGHNESS COEFFICIENT N :    0.05000
 FLOW LENGTH (FEET) :       9800

*** DATA FOR MAIN CHANNEL ***

 SIDESLOPE Z (FEET/FOOT) :    1.00000
 BOTTOM WIDTH W (FEET) :       75.0
 SLOPE S (FEET/FOOT) :     0.02100
 ROUGHNESS COEFFICIENT N :    0.04000
 FLOW LENGTH (FEET) :      19500

*** END OF FLOW ELEMENTS DATA ***

 TOTAL BASIN AREA (ACRES) :    6842.00
 FLOW FROM UPSTREAM BASIN (CFS) :          0
 EXCESS RAINFALL RATE FOR ESTIMATED BASIN Tc (INCHES/HOUR) :       2.10
```

		OVERLAND FLOW ELEMENT	COLLECTOR CHANNEL	MAIN CHANNEL	TOTAL BASIN
Tc (sec)	BASED ON CW	1039	804	882	2726
Tc (hours)	BASED ON CW	0.29	0.22	0.25	0.76
Tc (sec)	BASED ON V	1732	1287	1369	4389
Tc (hours)	BASED ON V	0.48	0.36	0.38	1.22
V (fps)	AT OUTLET	1.06	10.92	20.18	
CW (fps)	AT OUTLET	1.76	17.25	30.65	
Y (feet)	AT OUTLET	0.05	2.27	8.58	
Q (cfs)	AT OUTLET	0.0535	1048	14488	

DATA SOURCES

The typical flow length, slope, channel width and side slope can be obtained by a trained hydrologist from site visits and topographic mapping. Rainfall depth-duration-frequency curves are published for many areas of the country. The user should investigate local sources (such as the state Department of Transportation or Geological Survey) for such curves. Infiltration rates depend on the soils. U.S. Soil Conservation Service soil surveys are good sources for typical infiltration rates for local soils.

The reader is referred to Barfield et. al., SCS TR-55, and Novotny and Chesters for tabulations of overland flow roughness coefficients. In addition to these publiations, the reader is referred to Chow, and Barnes for estimates of channel roughness coefficients.

FOR MORE INFORMATION

For more information about program **TC** please contact the program's author, Willie Gonwa, at 414-272-2426 or at the address listed above.

REFERENCES

Barfield, B.J., Warner, R.C. and Haan C.T., Applied Hydrology and Sedimentology for Disturbed Areas, Oklahoma Technical Press, Stillwater, OK, 1981

Barnes, H.H., Roughness Characteristics of Natural Channels, U.S. Geological Survey Water-Supply Paper 1849, Washington, D.C., 1967

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Novotny, V. and Chesters, G., Handbook of Nonpoint Pollution Sources and Management, Van Nostrand ReinHold Company, New York, NY, 1981

Soil Conservation Service, Urban Hydrology for Small Watersheds, Technical Release No. 55, Washington, D.C., 1986

SUBJECT: ALLOWABLE NSTEPS FOR GIVEN MUSKINGUM K COEFFICIENTS
BY: WILLIE GONWA/GLO
DATE: SEPTEMBER 27, 1989
PROJECT: LA027815.H1
FILE: MUSKINGM.WK1
TIME INTERVAL (MIN): 5
X COEFFICIENT: 0.3

1 / 2*(1-X)	AVERAGE	1 / 2X
0.71	1.19	1.67

MUSKINGUM K COEFFICIENT	MINIMUM NSTEPS	AVERAGE NSTEPS	MAXIMUM NSTEPS	
0.01	1	0	0	*** DO NOT ROUTE
0.02	1	0	0	*** DO NOT ROUTE
0.05	1	1	0	*** DO NOT ROUTE
0.1	1	1	1	0.06 IS OK
0.2	2	2	3	
0.3	3	3	5	
0.4	3	4	6	
0.5	4	5	8	
0.6	5	6	10	
0.7	6	7	11	
0.8	6	8	13	
0.9	7	9	15	
1.0	8	10	16	
1.2	9	12	20	
1.4	11	14	23	
1.6	12	16	26	
1.8	13	18	30	
2.0	15	20	33	
2.5	19	25	42	
3.0	22	30	50	

NOTE: THE MUSKINGUM K EQUALS THE TRAVEL TIME IN HOURS FOR WATER IN THE MAIN CHANNEL.

0 <= X <= 0.5

SUBJECT CAVE CREEK/CAREFREE FIS BY SRW DATE 3-3-90
FCD 88-53 SHEET 1 OF
HYDRAULICS PROCEDURES SUMMARY PROJECT NO. RDD 27815.H2

MODEL USED: US. COE WATER SURFACE PROFILE MODEL HEC-2
SEPT. 1989 VERSION.

REGIME: ALL PROFILES ARE BASED ON SUBCRITICAL FLOW

FREQUENCIES MODELED: DETAILED STUDY REACHES - 10-, 50-, 100-, & 500-YR
APPROX. STUDY REACHES - 100-YR

FLOODWAY METHOD: METHOD 6 WAS USED FOR INITIAL TRIALS
TARGET EGL RISE WAS VARIED TO OPTIMIZE.
METHOD 1 WAS USED TO SMOOTH & FINAL
DELINEATED FLOODWAYS

UNIQUE PROBLEMS & CONDITIONS:

1. MOST REACHS ARE STEEP. MANY RUNS DEFAULTED TO CRITICAL DEPTH.
2. PORTIONS OF ROWE, GALLOWAY, OCOTILLO, AND GRAPEVINE WASHES HAVE WIDE, BRAIDED, ERODIBLE CHANNELS. CHANNEL BANK STATIONS WERE SET AT THE OUTER LIMITS OF THE BRAIDED AREA TO LIMIT FLOODWAY ENCROACHMENT.
3. NH CARDS WERE USED TO RESTRICT CONVEYANCE IN INEFFECTIVE FLOW AREAS USING N = 99
4. FOR SPLIT FLOW AROUND ISLANDS ON OCOTILLO & GRAPEVINE WASHES, THE HEC-2 SPLIT FLOW (WIER) OPTION WAS USED TO ESTIMATE BREAK OUT FROM MAIN. (DUE TO STEEP SLOPES, DOWNSTREAM WIER DOES NOT CONTROL THE FLOW SPLIT.)

   FOR FINAL PROFILES ENTIRE DISCHARGE WAS ASSUMED TO BE IN THE MAIN CHANNEL AND WAS MODELED IN DETAIL. THE ESTIMATED BREAK OUT DISCHARGE WAS MODELED IN THE THE MINOR CHANNEL FOR THE 100-YR. FLOW

SUBJECT CAVE CREEK F/S BY DAN S. DATE 3-29-90

SHEET ___ OF ___

CULVERT HYDRAULICS PROJECT NO. RDD 27815

CULVERTS ON OCOTILLO TRIB. 3 & 4 AND WILLOW SPRINGS TRIB 5 WERE MODELED USING MANUAL CULVERT COMPUTATIONS. HEC-5 NOMOGRAPHS AND BROADCRESTED WIER EQUATION $Q = CLH^{3/2}$ WERE USED TO DEVELOP RATING CURVES. THE RESULTS WERE INPUT INTO THE HEC-2 MODEL USING X-5 RECORDS AT THE UPSTREAM CROSSING SECTION

SUBJECT WS T5 SEC. 0.69

BY ____ DATE ____

SHEET ____ OF ____

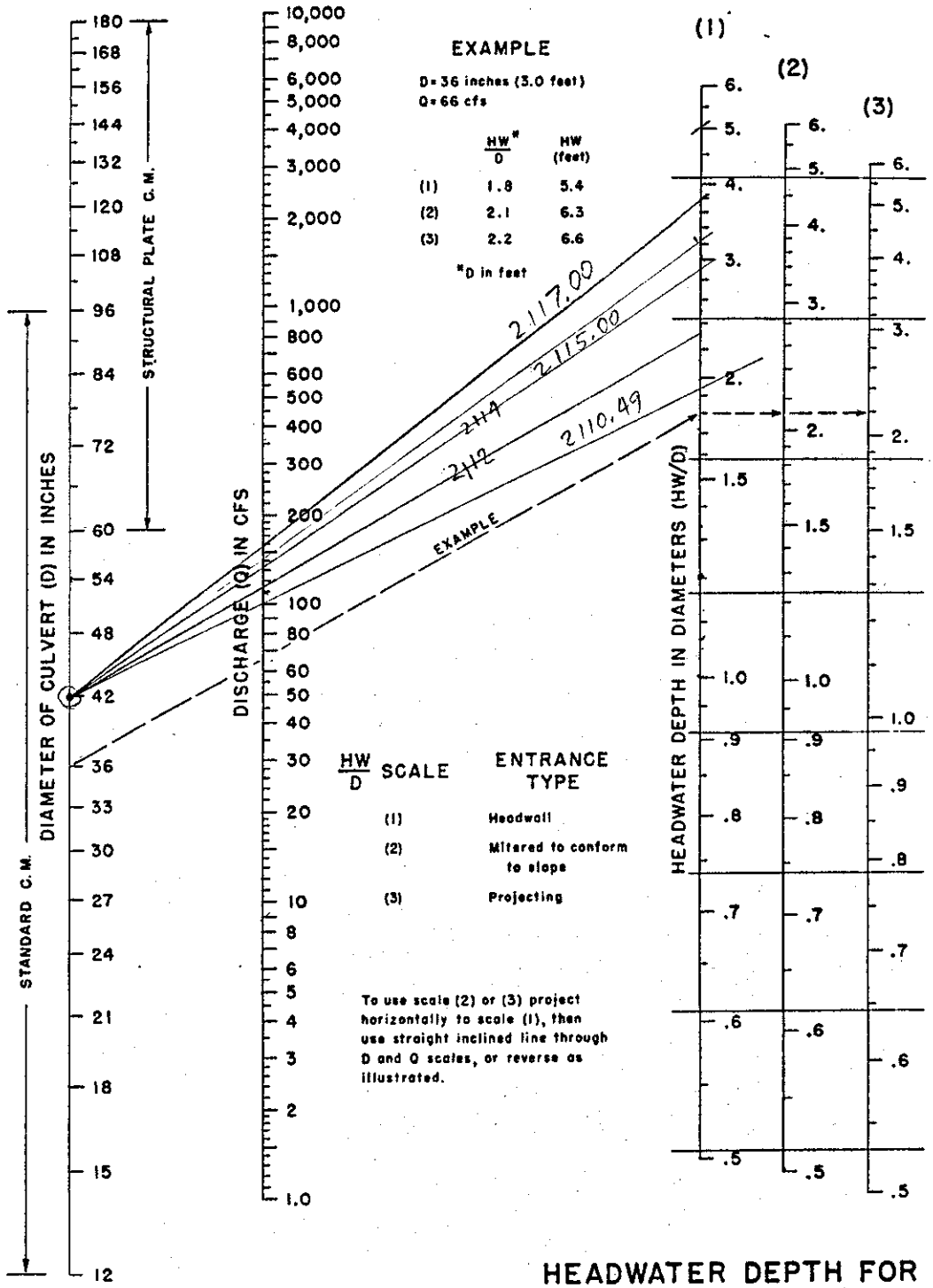
PROJECT NO. ____

3-42" CMP W/ 90° HEADWALL

UPSTRM WSEL	V (fps)	UPSTRM EGL	UPSTRM INVERT	HW	HW/D	PIPE Q (CHART 5)	WIER Q	TOTAL Q
2110.49	7.0	2111.26	2104.5	6.76	1.93	100 (x3)	0	300
2112		2112.76		8.26	2.36	115 (x3)	0	345
2114		2114.76		10.26	2.93	134 (x3)	0	402
2115		2115.76	"	11.26	3.22	141 (x3)	0	423
2115.2		2115.96		11.46	3.27	143 (x3)	3	432
2115.5		2116.26		11.76	3.36	147 (x3)	32	473
2116.0		2116.76		12.26	3.5	150 (x3)	180	630
2117.0		2117.76		13.26	3.79	160 (x3)	625	1105

WST5
SEC 0.69

CHART 5



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

OVERFLOW STAGE TABLE - WILLOW SPR. TRIB.5

Qi = C*l*H^1.5 Q = Σ Qi

C = 3, l = 10

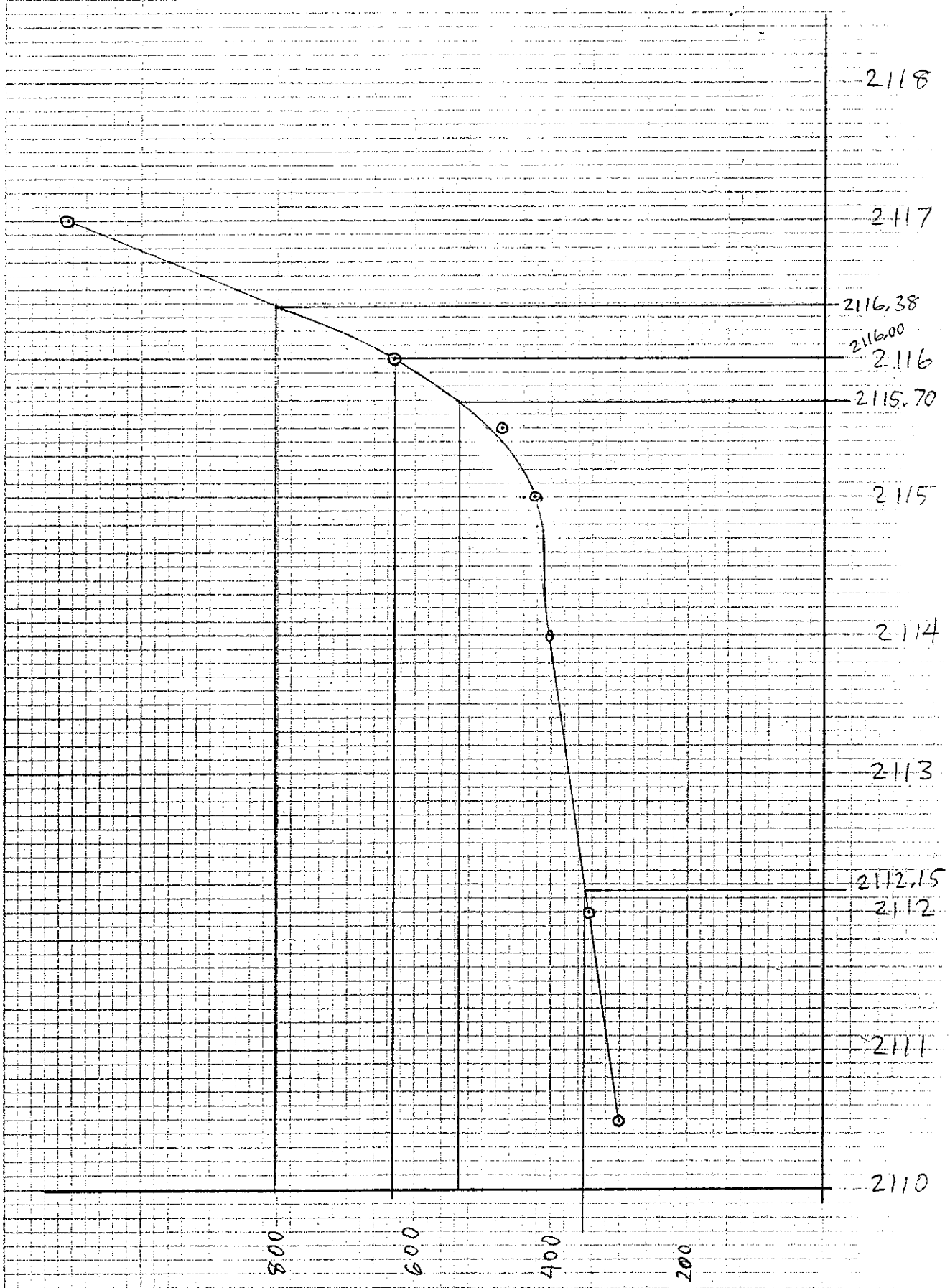
ITER	TRIAL H	overflow Q
1	2116.00	179.44
2	2115.98	170.52
3	2115.96	161.87
4	2115.94	153.54
5	2115.92	145.45
6	2115.90	137.60
7	2115.88	130.03
8	2115.86	122.82
9	2115.84	115.87
10	2115.82	109.10
11	2115.80	102.55
12	2115.78	96.22
13	2115.76	90.16
14	2115.74	84.31
15	2115.72	78.65
16	2115.70	73.21
17	2115.68	68.02
18	2115.66	63.09
19	2115.64	58.37
20	2115.62	53.90
21	2115.60	49.67
22	2115.58	45.68
23	2115.56	41.86
24	2115.54	38.20
25	2115.52	34.70
26	2115.50	31.41
27	2115.48	28.33
28	2115.46	25.41
29	2115.44	22.64
30	2115.42	20.05
31	2115.40	17.69
32	2115.38	15.54
33	2115.36	13.59
34	2115.34	11.78
35	2115.32	10.11
36	2115.30	8.62
37	2115.28	7.23
38	2115.26	5.95
39	2115.24	4.79
40	2115.22	3.79
41	2115.20	2.92
42	2115.18	2.14
43	2115.16	1.47
44	2115.14	.93
45	2115.12	.61
46	2115.10	.38
47	2115.08	.19
48	2115.06	.05
49	2115.04	
50	2115.02	

SUBJECT WST5 SEC. 0.~~64~~ 0.70 RATING CURVE

BY D. STOUGH DATE 4-3-90

SHEET ___ OF ___

PROJECT NO. RDD27815.H3



SUBJECT OCT4 SEC. 0.60 – RATING CURVE BY D. STOUGH DATE

SHEET ___ OF ___ PROJECT NO. RDD 27815.43

5

1-36" CMP W/ 90° HEADWALL

UPSTRM WSEL	V (fps)	UPSTRM EGL	UPSTRM INVERT	HW	HW/D	PIPE Q (CHART 5 HEC5)	WIER Q	TOTAL Q	
2210.04	9.00	2211.30	2208.0	3.30	1.10	40	0	40	(PART FLOW)
2215.60	10.50	2217.31		9.31	3.10	96	7	103	
2215.80		2217.51		9.51	3.17	97	42	139	
2216.00		2217.71		9.71	3.24	98	112	210	
2212.00	9.00	2213.26		5.26	1.75	64	0	64	(PART FLOW)
2214.00	9.00	2215.26		7.26	2.42	80	0	80	(PART FLOW)

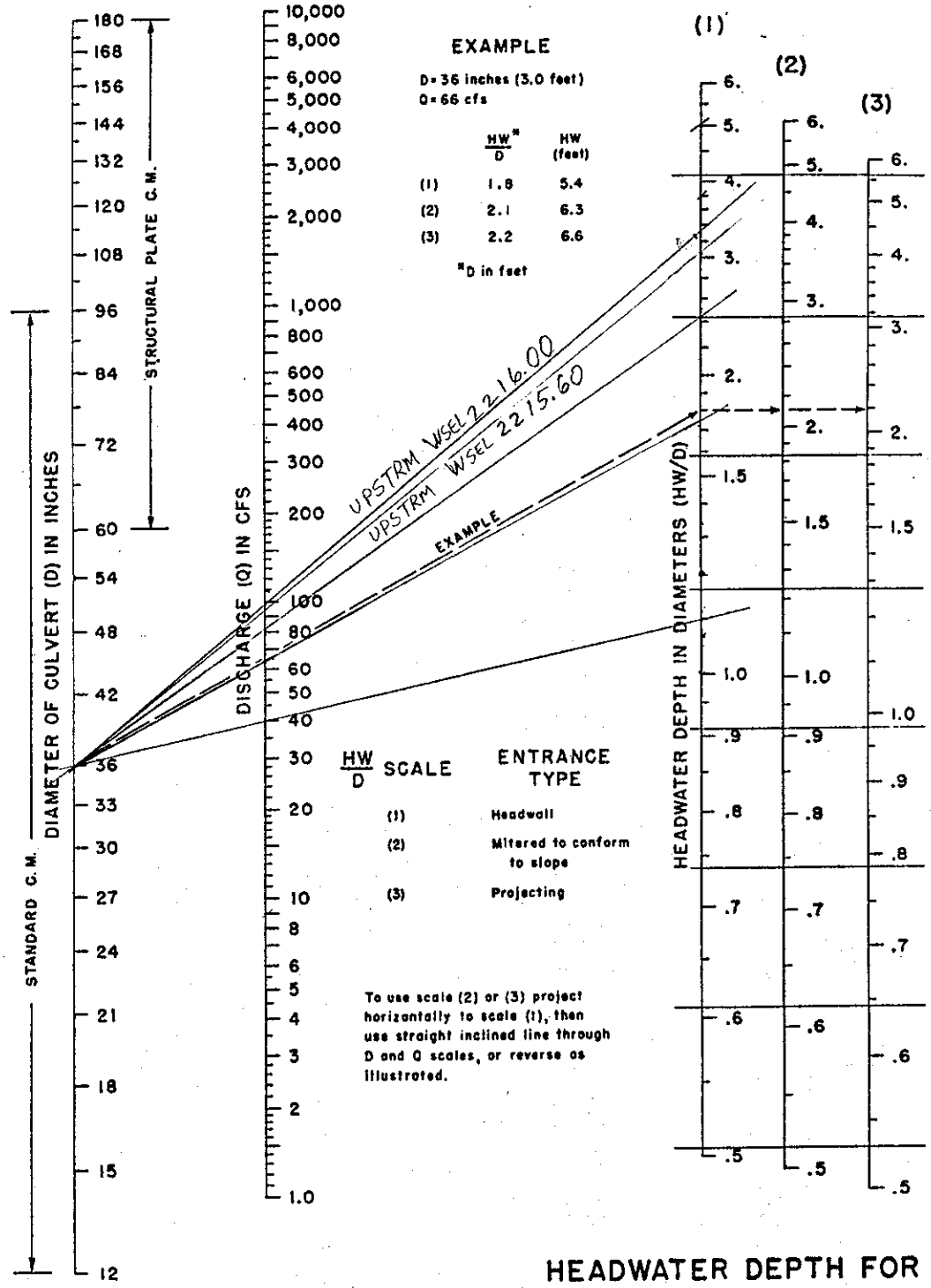
☆ WIER FLOWS TAKEN FROM OCT4WIER.CAL (SPREADSHEET)

$Q_{WIER} = \Sigma Q_i = \Sigma C \cdot L \cdot H_i$ WHERE H_i = UPSTRM WSEL – $EL_{WIER\,i}$ $C = 3$ $L = 10$

FOR EACH PART OF THE WIER

☆☆ CULVERT LENGTH IS TOO SHORT TO BE OUTLET CONTROL (CHART 11 – HEC5)

CHART 5



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

OVERFLOW STAGE TABLE - OCOTILLO TRIB.4 SEC 0.60

Qi = C*L*H^1.5 Q = Σ Qi

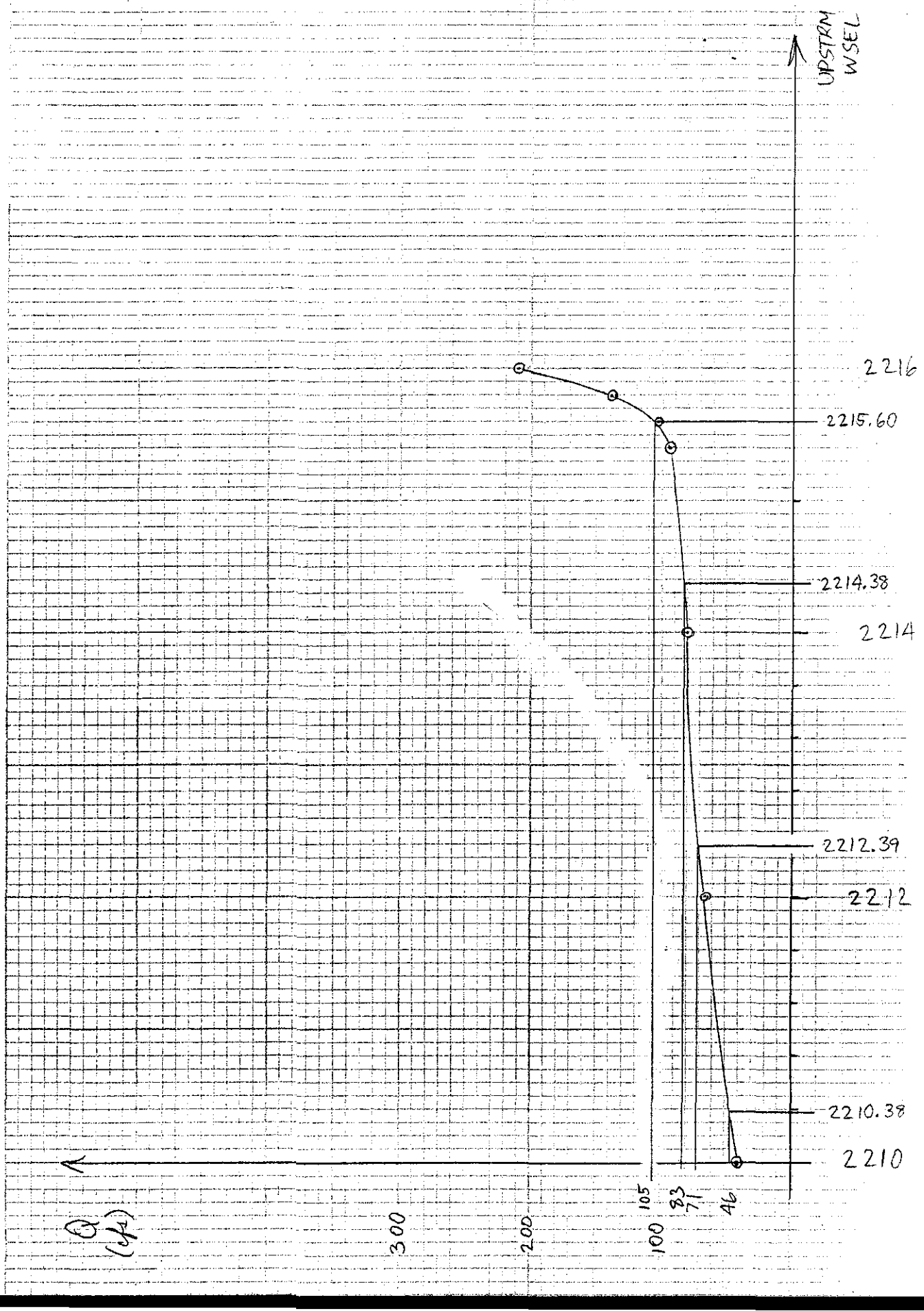
C = 3, L = 10

ITER	TRIAL H	overflow Q
1	2216.00	111.60
2	2215.99	107.42
3	2215.98	103.30
4	2215.97	99.26
5	2215.96	95.30
6	2215.95	91.42
7	2215.94	87.63
8	2215.93	83.91
9	2215.92	80.26
10	2215.91	76.67
11	2215.90	73.15
12	2215.89	69.70
13	2215.88	66.33
14	2215.87	63.04
15	2215.86	59.82
16	2215.85	56.70
17	2215.84	53.68
18	2215.83	50.73
19	2215.82	47.86
20	2215.81	45.07
21	2215.80	42.35
22	2215.79	39.73
23	2215.78	37.21
24	2215.77	34.80
25	2215.76	32.48
26	2215.75	30.26
27	2215.74	28.15
28	2215.73	26.14
29	2215.72	24.21
30	2215.71	22.34
31	2215.70	20.57
32	2215.69	18.89
33	2215.68	17.28
34	2215.67	15.75
35	2215.66	14.31
36	2215.65	12.97
37	2215.64	11.73
38	2215.63	10.54
39	2215.62	9.43
40	2215.61	8.39
41	2215.60	7.42
42	2215.59	6.50
43	2215.58	5.65
44	2215.57	4.88
45	2215.56	4.17
46	2215.55	3.53
47	2215.54	2.98
48	2215.53	2.48
49	2215.52	2.03
50	2215.51	1.62

SUBJECT OCT4 BY D. STOUGH DATE

SEC. 0.60 - RATING CURVE SHEET OF

PROJECT NO. RDD27815.H3



SUBJECT OCT3 SEC. 0.28 - RATING CURVE USING CHART 5 TO FIND Q_{PIPE} BY DATE

SHEET 2 OF 3 PROJECT NO.

UPSTRM WSEL	V (fps)	UPSTRM EGL	UPSTRM INVERT	HW	HW/D	PIPE Q (CHART 5)	WIER Q (cfs)	TOTAL Q (cfs)
2208	4	2208.25	2193.50	14.75	4.92	127	0	127
2208.80		2209.05		15.55	5.18	130	58	188
2209.00		2209.25		15.75	5.25	130	100	230
2209.20		2209.45		15.95	5.32	131	160	291
2209.60		2209.60		16.10	5.37	132	328	460

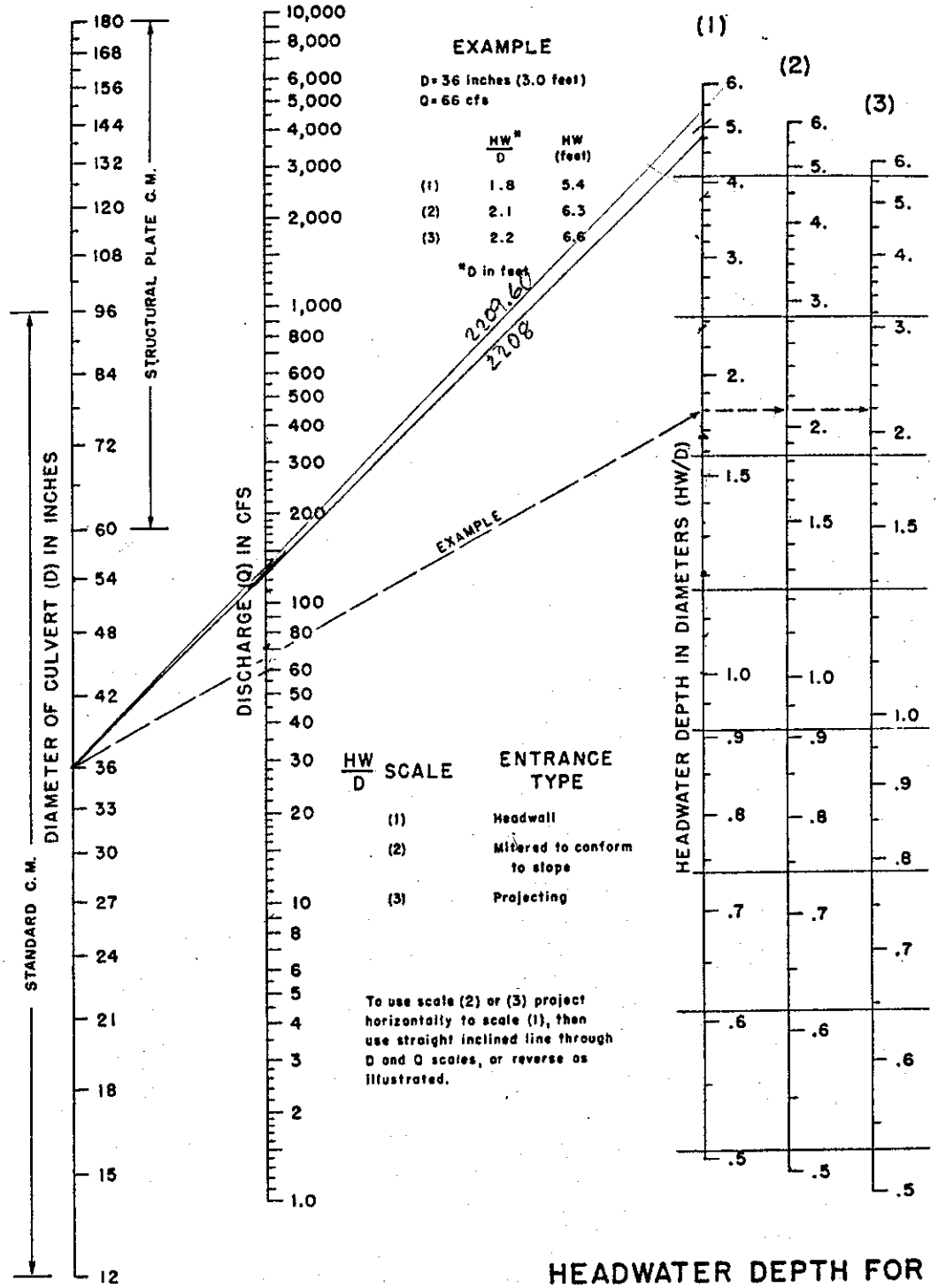
★ WIER FLOWS TAKEN FROM SEC28DN.CAL (SPREADSHEET) WHICH DIVIDES OVERFLOW VOLUME INTO 10' SECTIONS. EACH SECTION ASSUMES A FLAT BROAD CRESTED WIER $\longrightarrow Q = 3.0 \cdot L \cdot H^{3/2}$ (L=10') THE FLOW FOR EACH SECTION IS DETERMINED FOR INCREMENTAL UPSTREAM WSEL'S; THE SUM OF PARTIAL Q'S IS AN APPROX. WIER Q.

★★ DOWNSTREAM CONTROL (CHART 11) DOES NOT APPLY TO SHORT CULVERTS

OCT 3 0.28

3 OF 3

CHART 5



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

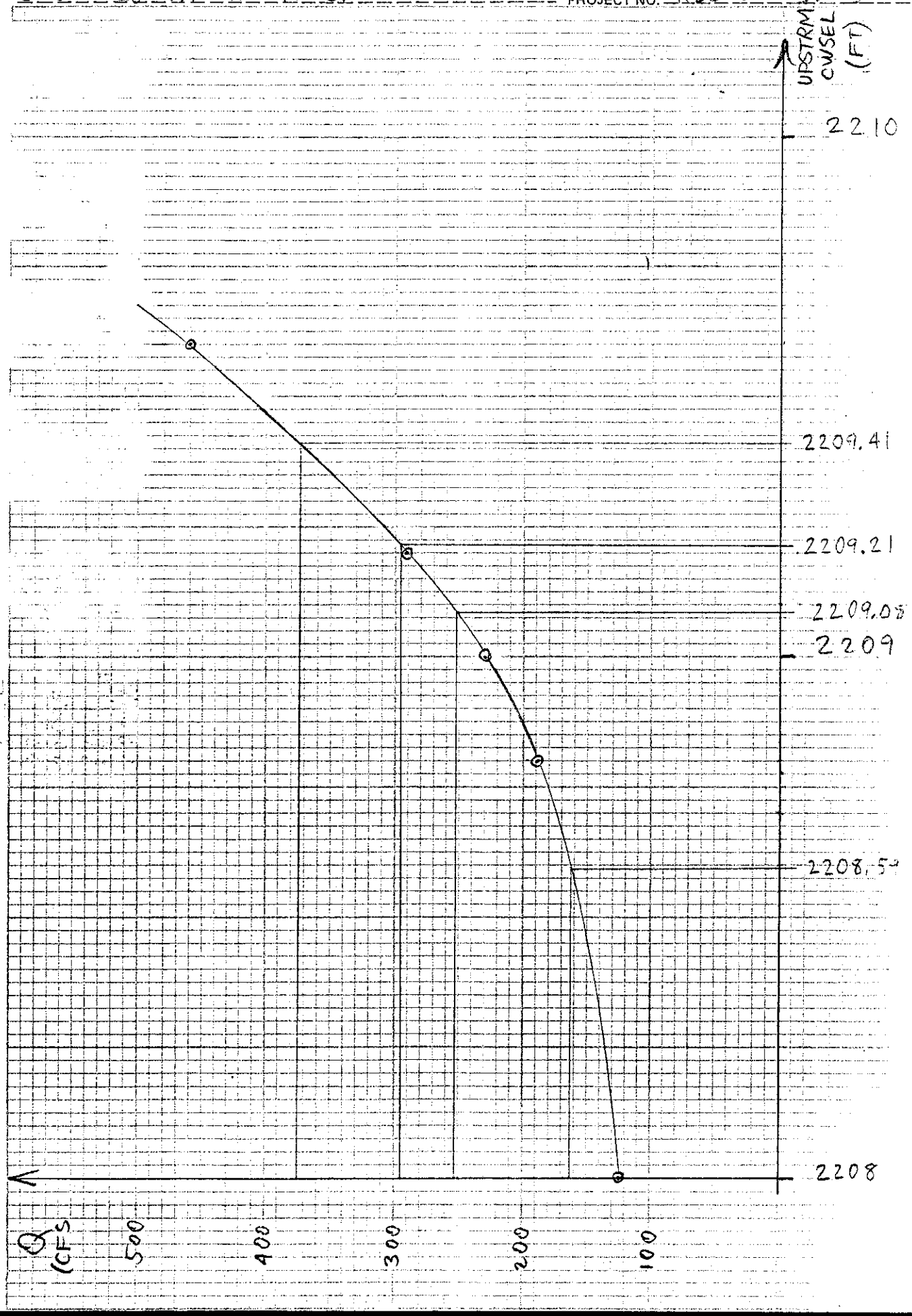
BUREAU OF PUBLIC ROADS JAN. 1963

1 36" CMP

OVERFLOW STAGE TABLE (-0.28)
(500yr Flood Frequenc)

ITER	TRIAL H	overflow Q	TOTAL Q 10yr
1	2209.64	350.13	430.19
2	2209.62	339.48	419.47
3	2209.60	329.01	408.95
4	2209.58	318.78	398.66
5	2209.56	308.77	388.58
6	2209.54	298.91	378.67
7	2209.52	289.22	368.92
8	2209.50	279.70	359.34
9	2209.48	270.35	349.93
10	2209.46	261.20	340.72
11	2209.44	252.24	331.71
12	2209.42	243.52	322.93
13	2209.40	235.10	314.44
14	2209.38	226.89	306.18
15	2209.36	218.83	298.05
16	2209.34	210.89	290.06
17	2209.32	203.11	282.22
18	2209.30	195.47	274.52
19	2209.28	188.00	266.99
20	2209.26	180.70	259.63
21	2209.24	173.62	252.49
22	2209.22	166.70	245.51
23	2209.20	159.91	238.66
24	2209.18	153.26	231.95
25	2209.16	146.75	225.38
26	2209.14	140.38	218.96
27	2209.12	134.18	212.69
28	2209.10	128.15	206.60
29	2209.08	122.33	200.72
30	2209.06	116.71	195.04
31	2209.04	111.23	189.51
32	2209.02	105.91	184.12
33	2209.00	100.78	178.93
34	2208.98	95.84	173.93
35	2208.96	91.04	169.07
36	2208.94	86.37	164.33
37	2208.92	81.85	159.76
38	2208.90	77.53	155.38
39	2208.88	73.32	151.10
40	2208.86	69.21	146.93
41	2208.84	65.20	142.87
42	2208.82	61.31	138.92
43	2208.80	57.54	135.09
44	2208.78	53.90	131.39

SUBJECT MCFCD - CAVE CREEK FIS BY D. STOUGH DATE 4-2-90
RATING CURVE FOR SEC. 0.29 SHEET 1 OF 3
OCOTILLO WASH TRIB. 3 PROJECT NO. RDD 27815.43



SUBJECT OCT 3 SEC. 0.46 RATING CURVE USING CHART 5 FOR Q PIPE

BY D. STOUGH DATE 4-2-91

SHEET ___ OF ___

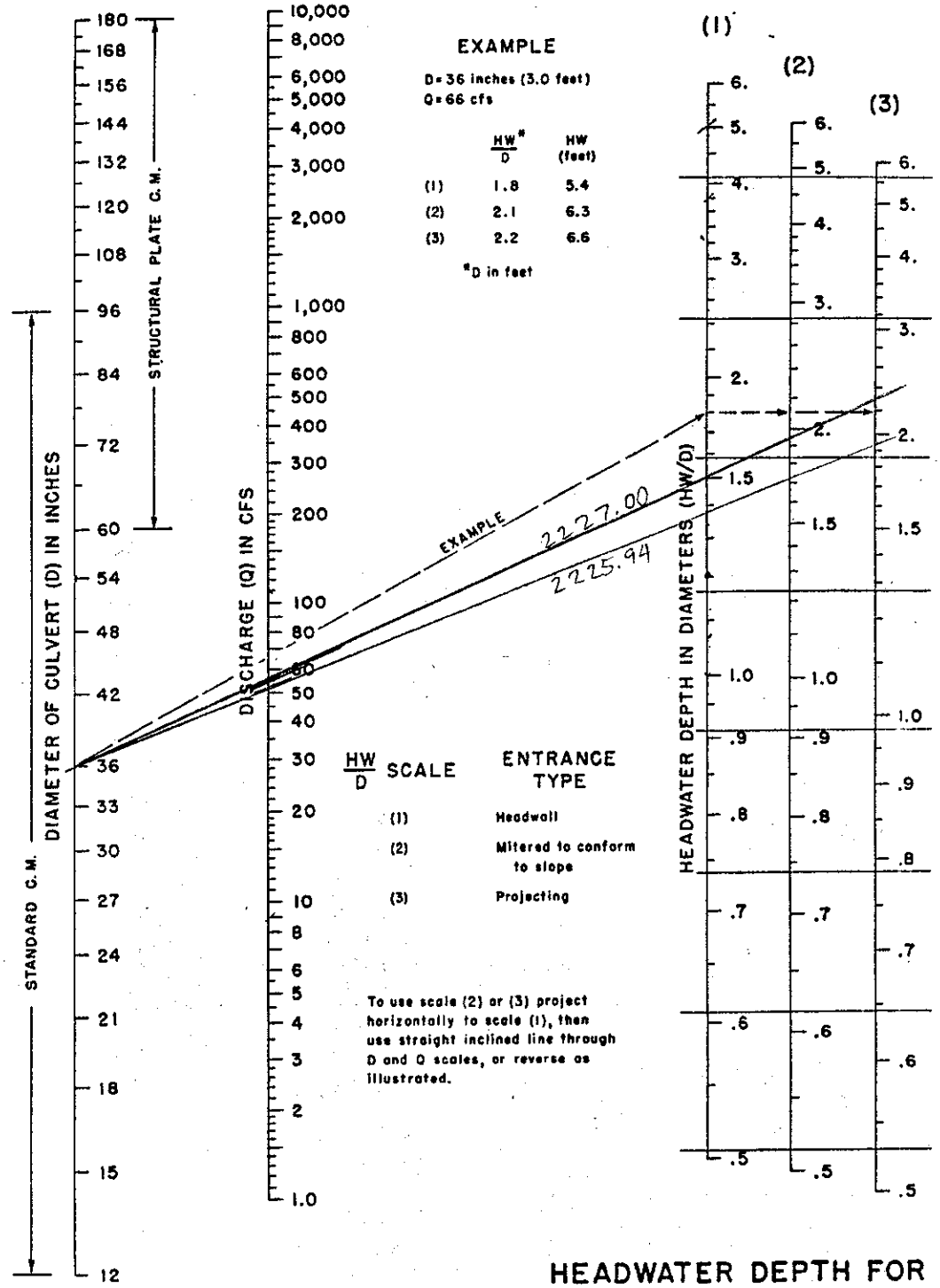
PROJECT NO. RDD 27815.H2

UPSTRM WSEL	V (fps)	UPSTRM EGL	UPSTRM INVERT	HW	HW/D	PIPE Q (CHART 5)	WIER Q	TOTAL Q
2225.94	3.5	2226.13	2220.30	5.83	1.94	52 (x3)	12.61	168.61
2226.20	3.5	2226.19		5.89	1.96	53 (x3)	35.89	194.89
2226.60	3.5	2226.79		6.49	2.16	54 (x3)	99.91	261.91
2226.80	3.5	2226.99		6.69	2.23	55 (x3)	148.22	313.22
2227.00	3.5	2227.19		6.89	2.30	56 (x3)	206.95	374.95

★ NOTE: WIER FLOWS TAKEN FROM SEC46DN.CAL (SPREADSHEET)

★★ DOWNSTREAM CONTROL (CHART 11) DOES NOT APPLY TO THIS SHORT CULVERT

CHART 5



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

OVERFLOW STAGE TABLE 26-0.28)
(10yr Flood Frequency

ITER	TRIAL H	Overflow Q
1	2227.02	213.39
2	2227.00	206.95
3	2226.98	200.60
4	2226.96	194.34
5	2226.94	188.18
6	2226.92	182.12
7	2226.90	176.16
8	2226.88	170.31
9	2226.86	164.58
10	2226.84	158.97
11	2226.82	153.54
12	2226.80	148.22
13	2226.78	142.98
14	2226.76	137.83
15	2226.74	132.76
16	2226.72	127.78
17	2226.70	122.88
18	2226.68	118.08
19	2226.66	113.38
20	2226.64	108.78
21	2226.62	104.29
22	2226.60	99.91
23	2226.58	95.66
24	2226.56	91.58
25	2226.54	87.62
26	2226.52	83.74
27	2226.50	79.94
28	2226.48	76.24
29	2226.46	72.62
30	2226.44	69.11
31	2226.42	65.70
32	2226.40	62.41
33	2226.38	59.26
34	2226.36	56.29
35	2226.34	53.42
36	2226.32	50.65
37	2226.30	48.03
38	2226.28	45.49
39	2226.26	43.00
40	2226.24	40.58
41	2226.22	38.20
42	2226.20	35.89
43	2226.18	33.64
44	2226.16	31.45
45	2226.14	29.33
46	2226.12	27.29
47	2226.10	25.31
48	2226.08	23.42
49	2226.06	21.63
50	2226.04	19.98
51	2226.02	18.41
52	2226.00	16.88
53	2225.98	15.40
54	2225.96	13.98
55	2225.94	12.61

EXAMPLE

9900.00	2228.00	
		-.03
10000.00	2225.40	
		.07
10040.00	2228.00	

$Q = C\,L\,H^{3/2}$

$Q_i = (3.0)(10)(H_i^{3/2})$

$Q = \sum Q_i$

TRIAL WSEL 2226.76
l(xsect) 10.00

SECTION 1 - Wier cross-section

int. sect.	avg.elev	H(trial) (ft)	Q(wier) (cfs)
9905	2227.87	-1.11	
9915	2227.61	-.85	
9925	2227.35	-.59	
9935	2227.09	-.33	
9945	2226.83	-.07	
9955	2226.57	.19	2.48
9965	2226.31	.45	9.06
9975	2226.05	.71	17.95
9985	2225.79	.97	28.66
9995	2225.53	1.23	40.92

SECTION 2

10005	2225.73	1.04	31.59
10015	2226.38	.39	7.17
10025	2227.03	-.27	
10035	2227.68	-.92	
10045	2228.33	-1.57	
10055	2228.98	-2.22	
10065	2229.63	-2.87	
10075	2230.28	-3.52	
10085	2230.93	-4.17	
10095	2231.58	-4.82	

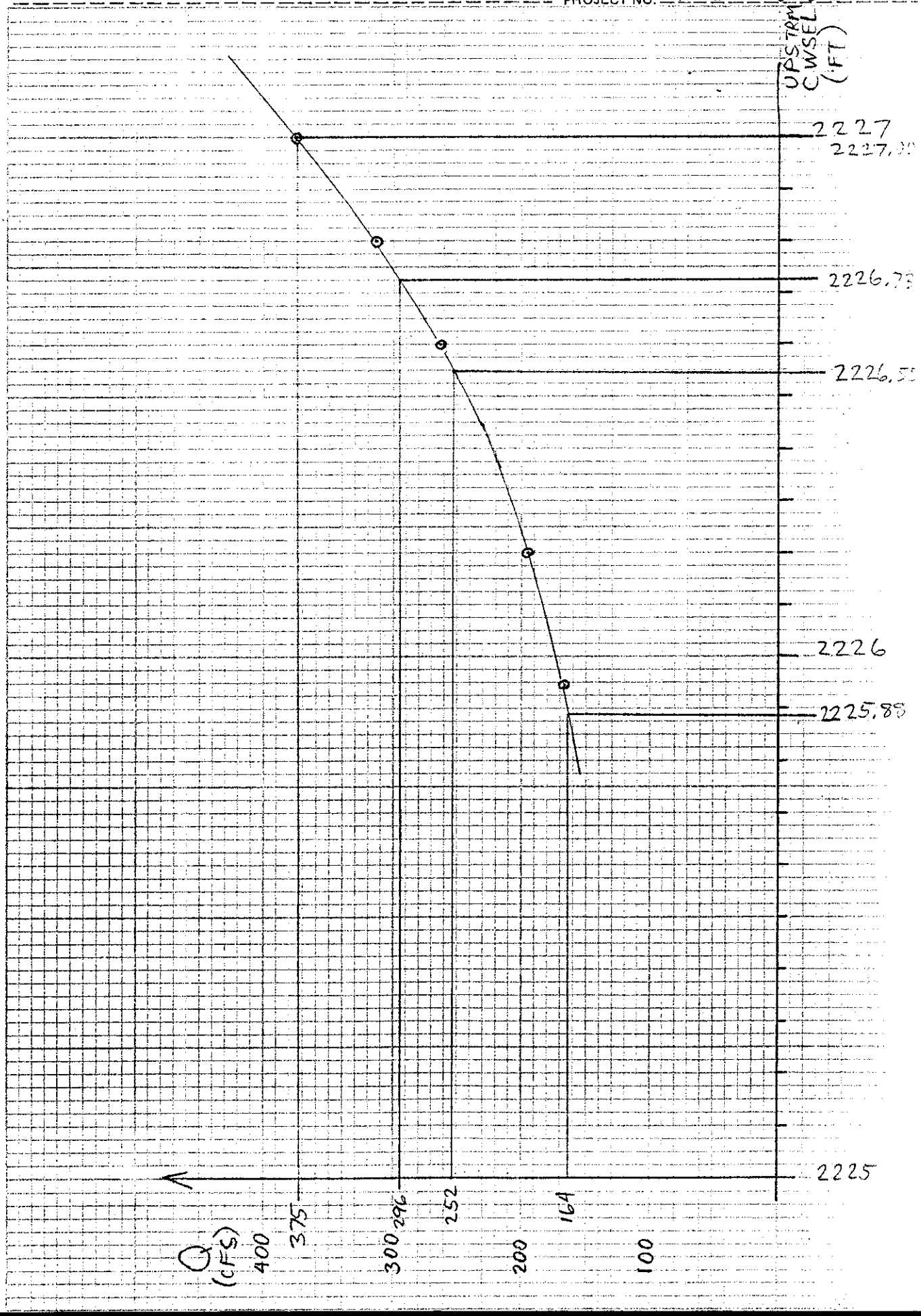
SUM OF OVERFLOW Q-VALUES 137.83
(for trial H)

OVERFLOW STAGE TABLE (sec. 0.26-0.28)
(100yr Flood Frequency Model)

SUBJECT OCT3 SEC. 0.46 RATING CURVE BY D. STOUGH DATE 4-2-9

SHEET ___ OF ___

PROJECT NO. RDD 27815.H3



SUBJECT CAVE CREEK / CAREFREE FIS BY SRW DATE 3-9-90

SHEET 1 OF

WILLOW SPGS TRIB 3A PROJECT NO. RDD 27815.H2

APPROX. METHODS HYDRAULICS. ANALYSIS

OBJECTIVE: ESTIMATE 100-YR FLOOD LIMITS

PROCEDURE: 1. ESTIMATE Q_{100} BASED ON UNIT DISCHARGE (q) FROM HEC-1 SUB-BASIN F2C

2. ESTIMATE D, V, WSE FOR 2 SECTIONS ALONG THE STREAM USING MANNING'S EQ. FOR NORMAL DEPTH.

3. MAP FLOOD LIMITS BY EXTRAPOLATION

ASSUMPTIONS: 1. q (TRIB 3A) ≈ q (TRIB 3)

2. MANNING'S "n" VALUES ARE BASED ON FIELD OBSERVATIONS. "n" = 0.05

3. S_o & GEOMETRY BASED ON 200 SC. 4' CI TOPOGRAPHIC MAPPING DATED 7, 1989

SUBJECT _____ BY SRW DATE _____

SHEET ___ OF ___

PROJECT NO. _____

Q100

Q_{100} (F2C) = 1098 cfs FROM CVCRKA3R.OUT HEC-1

A (F2C) = 0.53 mi²

q (F2C) = 2071.7 cfs/mi

A (TRIB 3A) = 51 AC = 0.08 mi² Q = 165 cfs

A @ sec 2 = 16 AC = 0.025 mi² Q_{100} = 52 cfs

A @ Sec 1 = 42 AC = 0.066 mi² Q_{100} = 138 cfs

SEC 1. (STA 0.169) S_o = 81/300 = 0.027 ft/ft

STA/ ELEV. (looking D.S. L to R)

0/2496 45/2480 62/2472 79/2470.55 89/2472

107/2476 160/2480

WSE = 2472.3

D = 2.1 LSTA = 61.36

A = 28.67 RSTA = 90.35

P_w = 29.27

V = 4.82 ft/s

SEC 2. (STA 0.402) S_o = 24/300 = 0.08 ft/ft

0/2560 35/2552 40/2548 66/2544.8 74/2544

89/2552 120/2560

WSE = 2546.07

A = 8.53 LSTA = 55.7

P = 13.79 RSTA = 67.17

V = 6.1

Federal Emergency Management Agency

Washington, D.C. 20472

Case No.: 90-09-87P

Re: Cave Creek/Carefree Floodplain Study

Community: Maricopa County, Arizona

Additional Data Required to Support a Request for a Flood Insurance Study (FIS)/ Flood Insurance Rate Map (FIRM) Revision

Requestor: Mr. Ron Nevitt

Date: JUN 29 1990

The data described below must be provided before we can process your request for an FIS/FIRM revision.

1. HYDROLOGY:

A. North Tributary of Galloway Wash:

In Table 4, Summary of Peak Discharges listed on page 18 of the report entitled "Final Hydrologic and Hydraulic Report for Cave Creek/Carefree Flood Delineation Study," prepared by CH2M Hill, dated March 1990, the discharges for the North Tributary of Galloway Wash located at concentration point CP63 could not be matched with any discharges in submitted HEC-1 model, or with the discharges used at cross section 320 in the submitted HEC-2 model for this stream. Please provide an explanation for these discrepancies.

B. Willow Springs Wash and Tributaries:

Several of the discharges developed for Willow Springs Wash and its tributaries and shown in Table 4, as referenced above, could not be located in the submitted HEC-1 models for these streams. The River Mile (RM) locations where these discrepancies occur are listed below.

	Stream	Location
1.	Willow Springs Wash	RM 4.95
2.	Willow Springs Wash Tributary 1	RM .98
		RM 2.82
3.	Willow Springs Wash Tributary 2	RM 1.31
4.	Willow Springs Wash Tributary 2A	RM .52
5.	Willow Springs Wash Tributary 4	RM .52
		RM .98
6.	Willow Springs Wash Tributary 5	Above confluence with Willow Springs Wash Tributary 5A

Please provide an explanation to account for these discrepancies.

2. HYDRAULICS:

A. Ocotillo Wash and Tributaries:

The review of contiguous streams revealed tie-in problems with flooding shown on effective FIRM Panel 0805 for Maricopa County, Arizona and Incorporated Areas. According to the distances taken from the annotated FIRM received on May 3, 1990, the base flood elevations (BFEs) for Ocotillo Wash Tributaries 2 and 3 do not match at their confluences with Ocotillo Wash. The specific discrepancies are listed below.

Stream	BFE (feet)
Ocotillo Wash Tributary 2 (new detailed)	2,216
Ocotillo Wash (effective at confluence)	2,226
Ocotillo Wash Tributary 3 (new detailed)	2,163.3
Ocotillo Wash (effective at confluence)	2,168

Please submit an explanation for these discrepancies or a revised HEC-2 hydraulic computer model to resolve these discrepancies. Please note that new BFEs must tie in with the effective BFEs within 0.5 foot.

B. Ocotillo Wash and Rowe Wash - Split Flow Analysis:

As stated in the report entitled "Cave Creek/Carefree Flood Delineation Study, Appendix A," prepared by CH2M Hill, and dated March 1990, the HEC-2 split flow option was used to estimate breakout from the main channel for both Ocotillo Wash and Rowe Wash. The main channels are shown as areas of detailed flooding with BFEs. However, the minor channels are shown as unnumbered Zone A. Please submit these split flow analyses and an explanation of how they were used to determine the BFEs along the main channels of Ocotillo Wash and Rowe Wash and the unnumbered Zone A along the minor channels.

C. Cottonwood Creek:

For many of the streams studied, the slope/area method was used to determine the starting water-surface elevation (SWSEL); however, for

Cottonwood Creek, the SWSEL was taken from the 100-year new BFE on Cave Creek at its confluence with Cottonwood Creek. The common cross section in both HEC-2 models is 37,800. The BFE on Cave Creek at this point is 2,287.84 feet and the SWSEL for Cottonwood Creek is 2,287.92 feet. Since the SWSEL for Cottonwood Creek was taken directly from the Cave Creek profile, it appears that the two creeks have similar watersheds and coincident peaks. Please provide an explanation to support this selection of the SWSEL for Cottonwood Creek.

D. Ineffective Flow Areas:

Several sections of streams were modeled as ineffective flow areas by using a Manning's roughness coefficient of 99 or 999 in the HEC-2 models. These areas are listed below by stream and cross section and the bank (right or left) that was modeled as an area of ineffective flow is identified.

Stream	Cross Section	Ineffective Bank
North Tributary of Galloway Wash	600	Right/Left
Willow Springs Wash	2,780	Left
	3,230	Right
Willow Springs Wash Tributary 1A	440	Right
Flemming Springs Wash	330	Left
Ocotillo Wash	2,850	Right
	2,970	Right
	3,090	Right
Ocotillo Wash Tributary 2	150	Right
Rowe Wash	1,830	Left

Please provide an explanation of why these areas are considered ineffective flow areas.

E. Culverts:

Included in the submitted report entitled "Cave Creek/Carefree Flood Delineation Study, Appendix A," prepared by CH2M Hill and dated March 1990, were analyses of four culverts. These culverts are located on Willow Springs Wash Tributary 5, Ocotillo Wash Tributary 4, and Ocotillo Wash Tributary 3. The analyses assumed inlet control because of the short culvert lengths, 50 to 110 feet. For the Ocotillo Wash Tributary 4 culvert, when the calculated water-surface elevation from the HEC-2 model is used at cross section 580, the cross section located downstream of the culvert, the culvert is submerged. Therefore, the culvert is outlet controlled. Although the other culverts are not submerged and appear to be inlet controlled, there is some concern about the possible high velocities through these culverts which could result in a hydraulic jump just downstream of the culverts. Please provide additional documentation on these culverts, including data on any erosion control measures in place downstream of the culverts, and a new analysis for the Ocotillo Wash Tributary 4 culvert based on outlet control.

3. MAPPING:

A. Ocotillo Wash and Tributaries 2, 3, and 4/Willow Springs Wash Tributary 5:

Delineations for Ocotillo Wash Tributaries 2, 3, and 4 must be shown on the topographic workmap entitled "Cave Creek/Carefree Flood Insurance Study," scale 1:2,400, contour interval 4 feet, prepared by CH2M Hill, Inc., dated March 1990, to tie in with the effective Ocotillo Wash boundaries. Likewise, the delineations for Willow Springs Wash Tributary Wash 5 must be shown on the topographic workmap to tie in with the effective Cave Creek boundaries. Please submit revised delineations on the topographic workmaps for these streams.

B. Ocotillo Wash:

The reach of Ocotillo Wash between cross sections 2.17 and 3.09 splits into two branches. The submitted topographic information, referenced earlier, shows that, at certain cross sections, the ground elevations adjacent to the floodplain shown on the workmap are equal to or less than the BFEs shown on the workmap. The following list includes the BFEs at which the land between the two branches would be flooded, based on the submitted topographic information.

Stream	BFE (feet)
Ocotillo Wash	2,260
	2,310
	2,340
	2,360
	2,380
	2,420

Please submit an explanation of why these areas would not be flooded or revised delineations on the topographic workmaps.

C. Distances Between Map Cross Sections and the HEC-2 Model

Our review of the submitted HEC-2 hydraulic computer models and the submitted topographic workmaps, referenced earlier, revealed that the distances between some cross sections in the HEC-2 hydraulic computer model do not match the distances measured between the same cross sections on the workmaps. The specific streams and cross sections at which these differences occur are shown below.

Stream	Between Cross Sections	Distance in Feet HEC-2 Model	Distance in Feet Map
Cave Creek	36.4 and 36.49	480	400
	36.49 and 36.52	160	200
	36.96 and 37.01	260	300
	37.12 and 37.20	420	370

Stream	Between Cross Sections	Distance in Feet HEC-2 Model	Map
Cottonwood Creek	.51 and .57	320	380
	.79 and .87	420	360
	1.14 and 1.23	480	540
	2.07 and 2.12	260	320
	2.12 and 2.19	370	310
	2.30 and 2.40	530	460
	2.85 and 2.91	320	360
	3.32 and 3.41	480	400
	4.17 and 4.26	480	600
Cottonwood Creek Tributary 1	.44 and .56	630	700
Cottonwood Creek Tributary 2	.10 and .15	260	300
North Tributary Galloway Wash	3.21 and 3.26	260	310
Rowe Wash	3.88 and 3.94	320	280
	3.94 and 3.98	210	260
Ocotillo Wash	2.26 and 2.31	260	220
	2.4 and 2.47	370	320
	2.97 and 3.09	635	690
	3.74 and 3.83	480	380
Ocotillo Wash Tributary 2	.42 and .48	320	380
Ocotillo Wash Tributary 3	.16 and .24	285	450
	.24 and .26	240	100
	.26 and .28	50	80
	1.12 and 1.19	370	430
Willow Springs Wash Tributary 1	1.88 and 1.96	420	370
	2.48 and 2.57	480	410
	2.89 and 2.98	480	420
	2.98 and 3.07	480	53
Willow Springs Wash Tributary 2	.54 and .66	630	700
	.74 and .82	420	490

Stream	Between Cross Sections	Distance in Feet HEC-2 Model	Map
Willow Springs Wash Tributary 5	.11 and .20	480	420
	.41 and .51	530	460
	.65 and .69	240	200
	.92 and .99	370	450
	1.57 and 1.66	480	420
	1.92 and 2.04	630	560

D. Floodway Widths:

There were also discrepancies between floodway widths listed in the HEC-2 hydraulic computer models and the floodway widths on the topographic workmap. The specific streams and cross sections at which these differences occur are shown below.

Stream	Cross Section	Width HEC-2 Model	Map
Cave Creek	35.59	435	410
	37.47	323	300
	38.79	204	190-14
Cottonwood Creek	1.40	113	100-13
Cottonwood Creek Tributary 1	.18	44	60-16
	.56	67	90
Cottonwood Creek Tributary 2	.15	30	60
	.22	20	40 20
Grapevine Wash	.11	317	300 17
	.29	261	300
	.57	216	250
North Tributary Galloway Wash	2.14	255	240 15
	2.26	295	250
	2.46	331	310
Rowe Wash	2.25	309	280
	2.51	348	330-18
Ocotillo Wash	2.47	141	110 31
	2.97	339	310 29
	3.09	203	140
	3.17	114	80
Ocotillo Wash Tributary 1A	.02	105	40 16
	.69	46	30 16
Ocotillo Wash Tributary 2	.23	26	10 16
	.31	34	20 14

Stream	Cross Section	Width HEC-2 Model	Width Map
Ocotillo Wash	.16	54	30
Tributary 3	.24	55	40 15
	.57	33	20 13
	1.19	47	30 17
	1.3	52	30
Willow Springs Wash	2.36	96	80 16
Willow Springs Wash	.98	57	40 17
Tributary 1	1.38	75	60 15
	1.45	104	70
	1.65	44	30 14
Willow Springs Wash Tributary 2A	.10	49	30 19

Please revise the HEC-2 models, the workmaps, or both, to resolve the discrepancies outlined in Items 3(C) and (D) shown above.

4. ELEVATION REFERENCE MARKS:

The following elevation reference marks are not shown on the workmaps: 1, 3, 5, 7, 8, 13, and 14. Please provide these reference marks on the workmaps or an explanation as to why they are not shown.

CH2M HILL
Engineers
Planners
Economists
Scientists

October 1, 1990

RDD27815.H2

Ms. Jan Farmer
Hydrology
Flood Control District of Maricopa County
3335 W. Durango Street
Phoenix, AZ 85009

Dear Jan:

Subject: Cave Creek/Carefree Hydrology
FCD Contract No. 88-53
ADWR Comments

The following summarizes CH2M HILL's action regarding the review comments you forwarded from ADWR in your letter of July 31, 1990. In addition, attached please find a draft response letter to FEMA regarding review comments from FEMA's technical evaluation contractor, Michael Baker, Jr., Inc., on the Flood Insurance Study revision for Cave Creek/Carefree.

1. Figure 3 has been revised so that the discharges for Subareas A-4, A-7, E-1, and E-4 correspond with the HEC-1 output.

2. ADWR noted that hydrologic routings for the following stream reaches were not included in the HEC-1 model:

   a. Node 1 to Node 2.
   b. Node 2 to Node 3 (Subarea 5).
   c. Node 3 to Node 10.
   d. Node 25 to 26.
   e. Node 26 to 27.
   f. Node 33 to 29.
   g. Node 63 to 71.
   h. Node 50 to 51.
   i. Node 52 to 71b.

   For each of these stream reaches, the reach length is so short that the travel time of the flood wave through the reach would be shorter than the

computational time increment used to generate the input hydrograph. Routing would at best result in pure translation of the hydrograph, and at worst introduce an additional source of error. Therefore, Muskingum routings were not performed for these reaches, and pure translation was assumed.

Comment cards were added to the HEC-1 control deck where routings were not performed in order to clarify this assumption.

3. Subareas F1a, F1b, and F1 were combined in the Cave Creek HEC-1 model only. These subareas were modeled separately in the tributary watershed HEC-1 model. Peak discharge values used in hydraulic modeling for streams within Subareas F1a, F1b, and F1 were determined from the tributary watershed HEC-1 model.

4. There is no Node 34. Thus, it was not shown on Figure 2.

Please do not hesitate to call me at 966-8188 if you have any further questions regarding this matter.

Sincerely,

CH2M HILL

Steven R. Walker, P.E.
Project Manager

Engineers
Planners
Economists
Scientists

October 1, 1990

RDD27815.H2

Ms. Jan Farmer
Hydrology
Flood Control District of Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

Dear Ms. Farmer:

Subject: Cave Creek/Carefree Floodplain Study
Maricopa County, Arizona
Case Number: 90-09-87P

In his letter of June 29, 1990, to Mr. Ron Nevitt of the Flood Control District of Maricopa County, Mr. John Matticks of FEMA requested additional data for the above-referenced project. Our responses to the comments made in that letter are outlined below. These responses were discussed with and approved by Ms. Michelle Monday of Michael Baker, Jr., Inc., during a phone conversation on September 21, 1990. Our responses parallel the structure of your letter dated June 29, 1990.

1. HYDROLOGY

A. North Tributary of Galloway Wash

Peak discharges listed in Table 4, "Summary of Peak Discharges," and used on QT records in the HEC-2 model were revised to conform with the HEC-1 output. Floodplain delineations were revised accordingly. Some of the subbasins listed in Table 4 required further subdivision from those computed in the HEC-1 model. For these concentration points, peak discharge rates were interpolated by considering peak discharge rates per unit area. These concentration points are noted with footnotes in Table 4. A copy of the revised Table 4 is attached.

B. Willow Springs Wash and Tributaries

Peak discharges listed in Table 4 were revised to conform with HEC-1 output as described above. QT records in the HEC-2 model and floodplain delineations were revised accordingly.

2. HYDRAULICS

A. Ocotillo Wash and Tributaries

Tie-in lines from the new flood study to the existing floodplain boundaries will be drawn on the plan sheets. HEC-2 profiles used the upstream-most cross section of the existing Flood Insurance Study (FIS) prepared by HTA as the starting water surface elevation (WSE), rather than the Base Flood Elevation (BFE) shown on the Flood Insurance Rate Maps (FIRM). We have provided the HTA work maps from the existing FIS. Because the starting WSE used HTA cross section data, the distances listed in annotated FIRM differ from HEC-2 channel distances. Copies of the revised work maps an attached.

B. Ocotillo Wash and Rowe Wash--Split Flow Analyses

Split flow HEC-2 runs for Ocotillo and Rowe Washes have been provided for review. Computations for the main channels reflect the entire peak discharge. HEC-2 split flow analyses of the main channels were used to determine the peak flow rates in the break out channels only. Floodplain delineations along the break out channels are based on WSE determined by separate HEC-2 modeling of the break out channels. No BFEs for the break out channels were determined per instructions from the Flood Control District of Maricopa County.

C. Cottonwood Creek

The starting WSE for Cottonwood Creek was based on the 100-year BFE at the confluence with Cave Creek as a conservative assumption. Further analysis indicates that due to the steepness of Cottonwood Creek, the starting WSE method used does not affect the WSE upstream of the starting cross section.

D. Ineffective Flow Areas

Several sections of streams were modeled as ineffective flow areas by using a Manning's roughness coefficient of 99 or 999. The ineffective flow areas included reaches with rapid channel expansions (greater than 4:1) or contractions (greater than 1:1), or topographic lows in the overbank area caused by minor tributary confluences. Comment cards were added to the HEC-2 card deck explaining the reason for ineffective flow. In two cases, Willow Springs Wash, Section 3230, and Ocotillo Wash Tributary 2, Section 150, ineffective flow areas were found to be unjustified and were removed or modified. Computation sheets for each ineffective flow reach are attached.

E. Culverts

Rating curves for each of the culverts on Willow Springs Wash Tributary 5, Ocotillo Wash Tributary 4, and Ocotillo Wash Tributary 3 were revised and are attached. New X5 records based on the rating curves were inserted in the HEC-2 card deck and the profiles adjusted accordingly. All of the culverts are submerged by flow over the roadway or operate under outlet control at the regulatory flow rate. Therefore, no hydraulic jumps will form. In addition, outlet velocities do not exceed the range of channel velocities experienced in the reaches near the culverts. Therefore, no excessive erosion is likely. Computation sheets are attached.

3. MAPPING

A. Ocotillo Wash and Tributaries 2, 3, and 4; Willow Springs Wash Tributary 5

Floodplain delineations for these streams which tie in with the effective floodplain boundaries have been added to the plan sheets.

B. Ocotillo Wash

The reach of Ocotillo Wash between Sections 2.17 and 3.09 experiences split flow during the regulatory flood. The main channel is mapped assuming the entire regulatory flood is conveyed. The overflow channel was mapped using HEC-2 as per instructions from the Flood Control

District of Maricopa County as described above. Where ground elevations between the overflow channels and the main channel are less than the BFE, the floodplain delineations have been modified.

C. Distances Between Map Cross Sections and the HEC-2 Model

The distances in the HEC-2 models have been modified to conform with the map distances.

D. Floodway Widths

Floodway widths have been modified to conform within 5 percent of the widths listed in the HEC-2 output.

ELEVATION REFERENCE MARKS

Certain elevation reference marks were not shown on the workmaps due to the limited extent of the workmaps. Where reference marks could not be plotted, a legal description for the reference mark is provided in the legend of the workmap.

Please do not hesitate to call me at (602)966-8188 if you should have any further questions regarding this matter.

Sincerely,

CH2M HILL

Steven R. Walker, P.E.
Project Manager

SUBJECT CULVERTS — SEF — DATE 10-1-80

SHEET 1 OF 19

RESPONSE TO FEMA: — PROJECT NO. RDD2781.5

① HEADWATER CHANGES FOR Q100 ONLY AT OCOTILLO WASH TRIBUTARY = SECTION #600.

WAS:	NOW
2214.38	2215.17

② ALL CULVERTS ARE OUTLET CONTROLLED, OUTLET VELOCITIES ARE LESS THAN VELOCITIES IN SECTION DOWNSTREAM

③ EVALUATING CULVERT SCOUR IS NOT OF SCOPE OF WORK NOR IS IT COMPATIBLE W/ USE OF HEC2.

ENTIRE CHANNEL IS ALLUVIAL & SUBJECT TO EROSION DURING HIGH VELOCITY FLOODING. OUTLET VELOCITIES ARE NOT OUTSIDE THE RANGE OF VELOCITIES EXPERIENCED IN ALLUVIAL REACHES.

④ NO HYDRAULIC JUMPS

X5 RECORDS

A. EXISTING	WSE Q_{10}	Q_{50}	Q_{100}	Q_{500}	Q Q_{10}	Q_{50}	Q_{100}	Q_{500}
OCT #3 -280	2208.59	2209.08	2209.21	2209.41	164	252	296	375
#3 -460	2225.88	2226.55	2226.73	2227.00	164	252	296	375
OCT #4 -600	2210.38	2212.39	2214.38	2215.60	46	71	83	105
WST #5 -700	2112.15	2115.70	2116.0	2116.38	352	536	631	804
B. REVISED								
X5 → OCT #3 -280	2208.64	2209.1	2209.23	2209.44				
#3 -460	2225.76*	2226.48	2226.7	2226.93				
OCT #4 -600	2210.1*	2213.22*	2215.3*	2215.68				
WST #5 -700	2113.05*	2115.83	2116.04	2116.40				

Q's SAME

X5 RECORDS

** [illegible]

SUBJECT ((JEF DATE 9-18-90

CH2M HILL

FEMA RESPONSE MEMO SHEET 2 OF 19

CULVERT HYDRAULICS PROJECT NO. RDD 27815.42

PROCEDURE:

1. RECOMPUTE CULVERT/WEIR RATING CURVES BASED ON OUTLET CONTROL - INLET CONTROL WHICHEVER MOST CONSERVATIVE. CULVERT DESIGN SHEET NEEDED FOR EACH CULVERT
2. DETERMINE OUTLET VELOCITY
3. DETERMINE CONJUGATE DEPTH FOR HYDRAULIC JUMP & COMPARE OUTLET FROUDE # TO TAILWATER FROUDE #

REFERENCES

1. H.D.S. #2 DESIGN CHARTS FOR OPEN CHANNEL FLOW
2. H.D.S #5 HYDRAULIC DESIGN OF WATERWAY CULVERTS
3.

OUTLET VELOCITIES

WATERCOURSE NAME	CULVERT STN HEC2 (XSECTION #)	TW DEPTH HEC-2 D/S (FT)	CULVERT DIAM. (FT)	Q_{100} (CFS)	WEIR OVER ROADWAY AT Q_{100}
OCOTILLO TRIB #3	280	1.92* (260)	1 - 3' CMP	296	YES
	460	1.38 (450)	3 - 3' CMP	296	YES
OCOTILLO TRIB #4	600	3.32* (580)	1 - 3' CMP	83	NO
WILLOW SPRING TRIB #5	700	3.66 (690)	3 - 3.5' CMP	631	YES

	CULVERT SUBMERGED?	SUBMERGED OUTLET VELOCITY = Q/A (FT/S)	MAX Q THRU PIPE	NORMAL DEPTH AT Q_{MAX} IN PIPE	HEC2 VELOCITY AT SECTION DOWNSTREAM (FT/S)	OUTLET VELOCITY ~ Q_{MAX} IN PIPE
OCT #3						
XS #280	NO (TW)	-	131	2.2'	8.15*	10.4
XS #460	NO (TW)	-			3.38	3.5
OCT #4						
XS #600	YES	2.94 FT/S F =			10.4*	
WST #5						
XS #700	YES	7.32 FT/S F =			9.02	

* CRITICAL DEPTH ASSUMED

SUBJECT ((JEF DATE 9-18-90
FEMA RESPONSE MEMO SHEET 2 OF 19
CULVERT HYDRAULICS PROJECT NO. 2DD 27815

DATA SUMMARY

A. OCT TRIB #3

(1) CROSS SECTION # 280

1 - 36" CMP
S_o = 0.041 FT/FT } FROM TOPO
L = 60 FT

Q_{100} = 29.6
K_e = 0.5 CMP W/ HEADWALL
h_o = 3 FT

OUTLET ELEVATION = 2191.0 = INLET EL − (S_o · L)
TW = 1.92 FT
EL$_i$ = 2193.5

(2) CROSS SECTION # 460

3 - 36" CMP Q_{100} = 29.6
S_o = .01 - ASSUME, TOPO INCONCLUSIVE; HEC2 S_o = 0.0
L = 50' - FROM TOPO K_e = 0.5, CMP W/ HEADWALL
TW = 1.38 h_o = 3 FT
EL$_{OUT}$ = 2220.3 = EL$_{OUT}$

B. OCT TRIB #4

(1) CROSS SECTION # 600

1 - 36" CMP Q_{100} = 83
S_o = 0.046 FT/FT } FROM TOPO
L = 75'

TW = 3.32
EL$_{IN}$ = 2208.0 EL$_{OUT}$ = 2204.5
K_e = 0.5 CMP
ROAD EL = 2215.4

C. WILLOW SPRINGS TRIB #5 - SECTION 700

3 - 42" CMP Q_{100} = 631 CFS
S_o = 0.032 } FROM TOPO
L = 75'
K_e = 0.5
TW = 3.66' = h_o
EL$_{IN}$ = 2104.5
EL$_{OUT}$ = 2102.1

SUBJECT ((JEF DATE 9-18-90

FEMA RESPONSE MEMO SHEET 4 OF 19

CULVERT HYDRAULICS PROJECT NO. 600 27815.H2

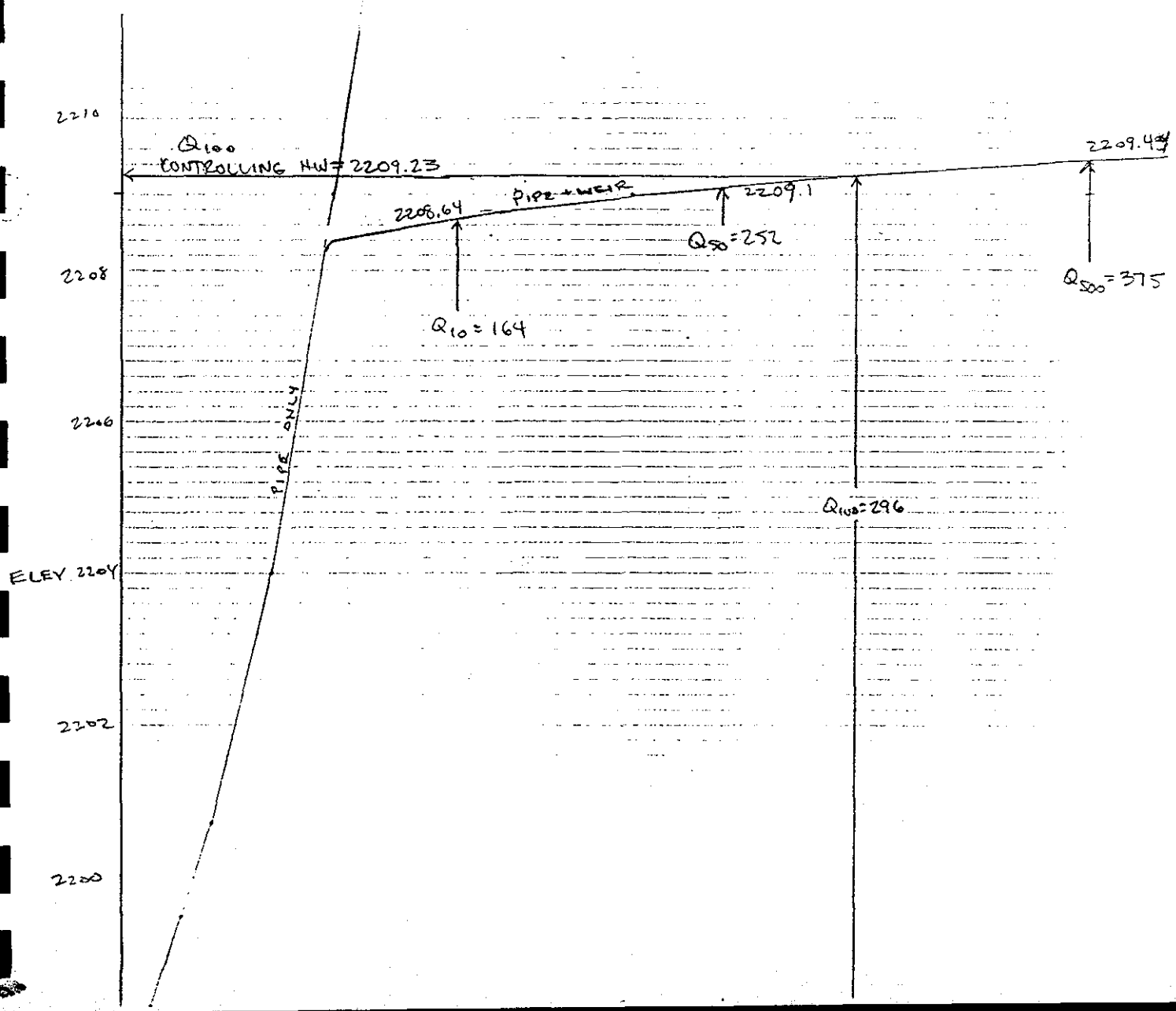
OUTLET CONTROL RATING CURVES

1. OCT TRIB #3 - CHART 6, TS #5 SECTION 280

Q_{PIPE}	H	$H + h_o - EL_o$	INLET HW	$HW - EL_i$	EL -	Q_{WEIR}
20	0.4	2194.4	2.1	2195.6	2203.8	55
30	0.9	2194.9	2.7	2196.2	9.0	101
40	1.6	2195.6	3.3	2196.8	9.2	160
50	2.5	2196.5	4.1	2197.6	9.4	235
60	3.6	2197.6	4.8	2198.3	9.6	320
70	5.0	2199.0	6.0	2199.5	9.64	350
80	6.5	2200.5	7.2	2200.7		
100	10.0	2204.0	9.9	2203.4		
120	15.0	2209.0	13.5	2207.0		
140	20.0	2214.0	16.8	2210.3		

INLET CONTROL

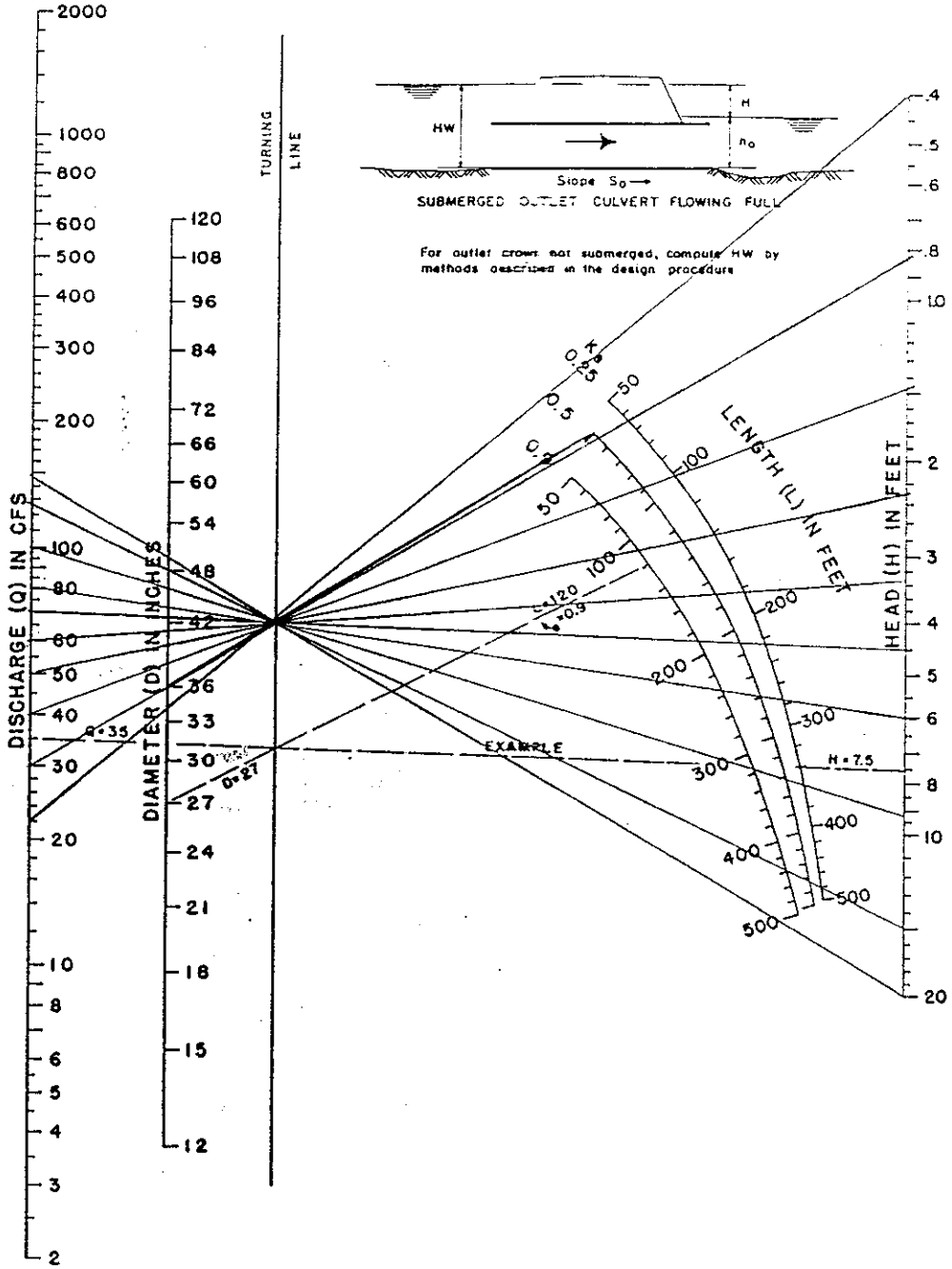
OUTLET CONTROL



OCT 3 - SEC 280.

SHEET 5 - 19

CHART 6

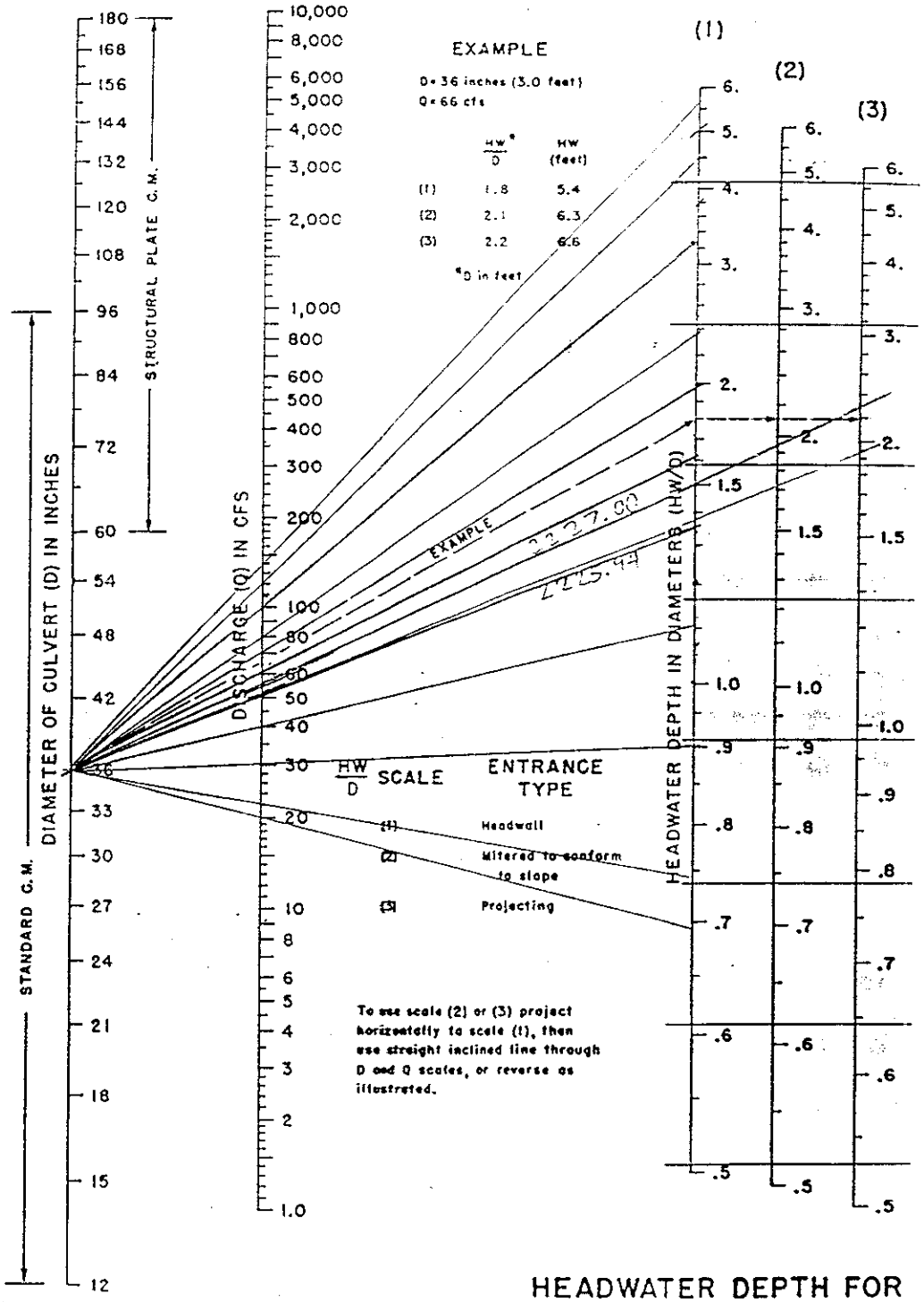


HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

SHEET 6-19

CHART 5



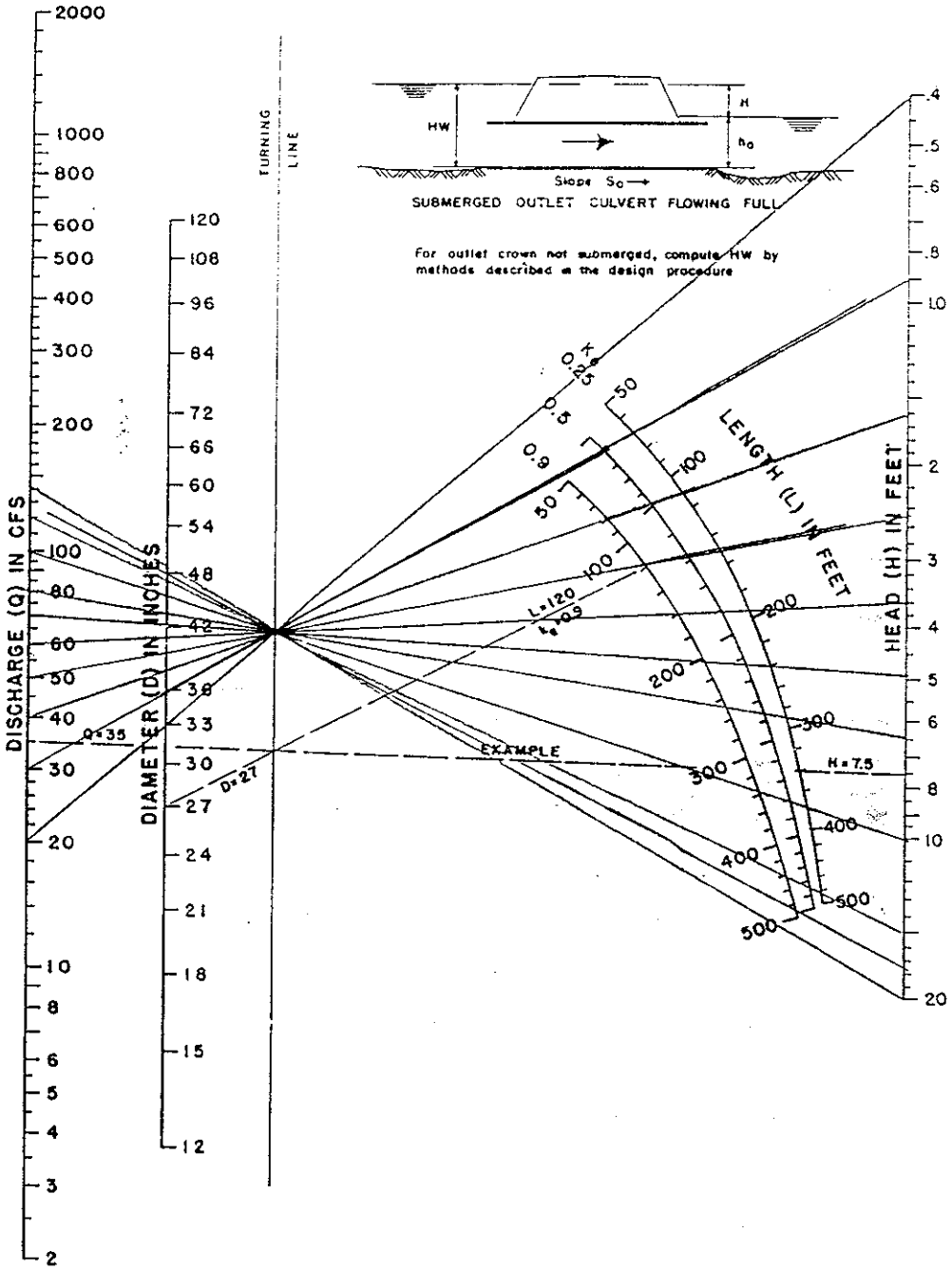
HEADWATER DEPTH FOR
C. M. PIPE CULVERTS
WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

OCT 3 - #280

SHEET 7-19

CHART 6



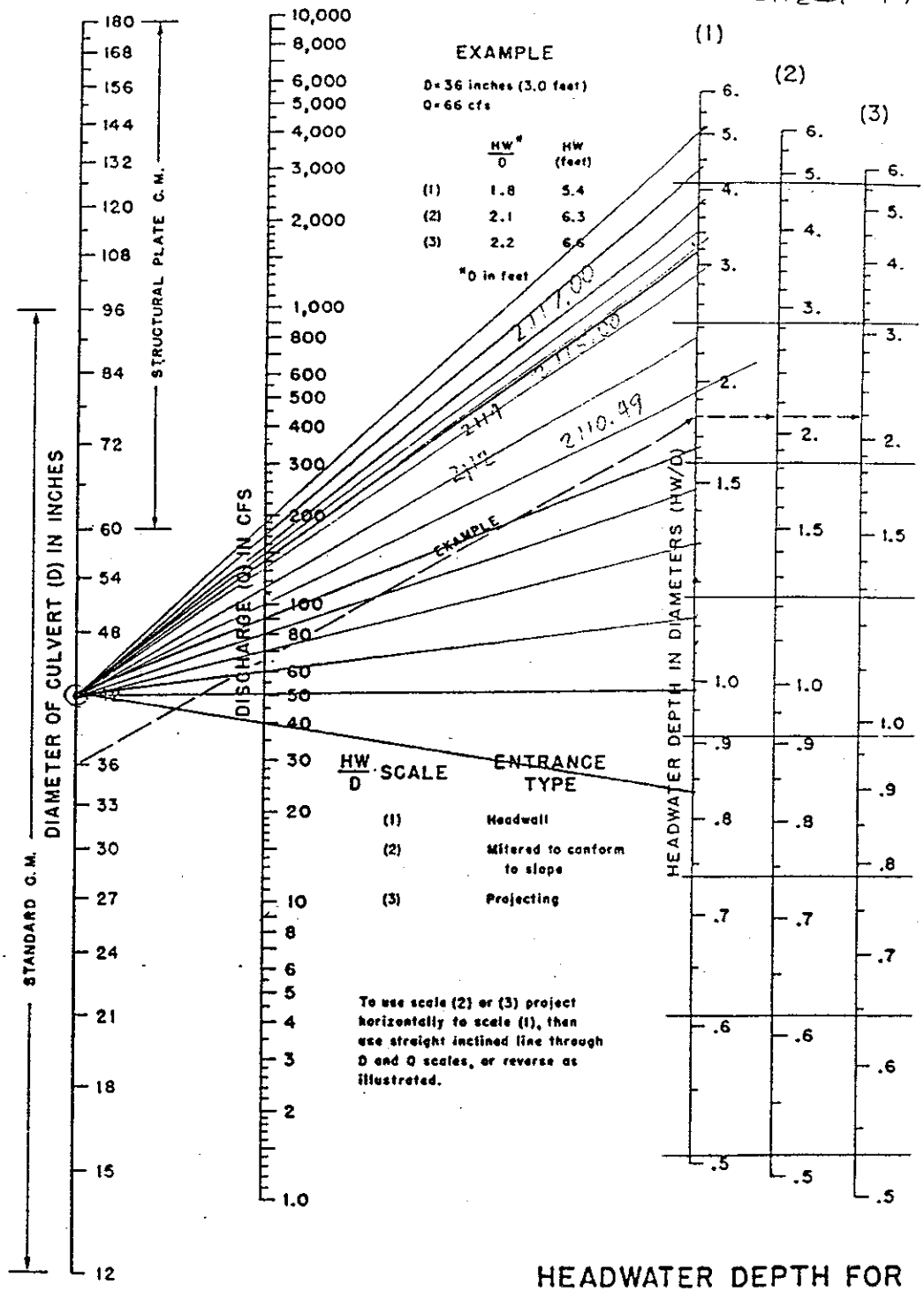
HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

WST5
SEC 0.69

CHART 5

SHEET 17-19



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

OVERFLOW STAGE TABLE - WIDOW SPR. TRIB.5 L = 85 WST #5

Q = C*l*H^1.5 Q = Σ Qi SHEET 18 -19

C = 3, l = 10

ITER	TRIAL H	overflow Q
1	2116.00	179.44
2	2115.98	170.52
3	2115.96	161.87
4	2115.94	153.54
5	2115.92	145.45
6	2115.90	137.60
7	2115.88	130.03
8	2115.86	122.82
9	2115.84	115.87
10	2115.82	109.10
11	2115.80	102.55
12	2115.78	96.22
13	2115.76	90.16
14	2115.74	84.31
15	2115.72	78.65
16	2115.70	73.21
17	2115.68	68.02
18	2115.66	63.09
19	2115.64	58.37
20	2115.62	53.90
21	2115.60	49.67
22	2115.58	45.68
23	2115.56	41.86
24	2115.54	38.20
25	2115.52	34.70
26	2115.50	31.41
27	2115.48	28.33
28	2115.46	25.41
29	2115.44	22.64
30	2115.42	20.05
31	2115.40	17.69
32	2115.38	15.54
33	2115.36	13.59
34	2115.34	11.78
35	2115.32	10.11
36	2115.30	8.62
37	2115.28	7.23
38	2115.26	5.95
39	2115.24	4.79
40	2115.22	3.79
41	2115.20	2.92
42	2115.18	2.14
43	2115.16	1.47
44	2115.14	.93
45	2115.12	.61
46	2115.10	.38
47	2115.08	.19
48	2115.06	.05
9	2115.04	
50	2115.02	

SUMMARY / RESULTS

① OCT TRIB #3 SECTION 280

a) ACTUALLY AT OUTLET CONTROL

b) CONTROLLING HEADWATER = 2209.23 (VS. 2209.21 USED IN HEC

c) OUTLET VELOCITY, ASSUME FLOWING FULL = $\frac{Q}{A} = \frac{122 \text{ cfs}}{28.3 \text{ ft}^2} = 4.31$ FT

d) F AT OUTLET = $\frac{V}{\sqrt{gd}} = 0.43$ SUPERCRITICAL DEPTH

CRITICAL DEPTH ASSUME DOWNSTREAM (F = 1), NO HYDRAULIC JUMP

② OCT TRIB #3 - SECTION 460

a) ACTS W/ OUTLET CONTROL

b) CONTROLLING HEADWATER = 2226.67 (VS. 2226.73 IN HEC2)

c) OUTLET VELOCITY, ASSUME FLOWING FULL = $\frac{Q}{A}$ = 2.12 FT/S

d) F AT OUTLET = $\frac{V}{\sqrt{gd}} = 0.22$ SUBCRITICAL, NO JUMP

③ OCT TRIB #4 SECTION 600

a) ACTS W/ OUTLET CONTROL

b) CONTROLLING HEADWATER = 2215.17 (VS. 2214.38 IN HEC2)

c) OUTLET VELOCITY = $\frac{Q}{A}$ = 2.93 FT/S SUBCRITICAL, NO JUMP

④ WSP TRIB #5

a) ACTS W/ OUTLET CONTROL AT Q100

b) CONTROLLING HEADWATER = 2116.04 (VS 2216.0 IN HEC2)

c) OUTLET VELOCITY = $\frac{Q}{A}$ = 3.68 FT/S (SUBCRITICAL, NO JUMP)

Federal Emergency Management Agency

Washington, D.C. 20472

(202) 646-3458

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

IN REPLY REFER TO:
65-POST

Mr. Ron Nevitt
Flood Control District of
Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

Date: MAY 8 1991
Case Number: 90-09-87P
Re: Cave Creek/Carefree
Floodplain Study
Community: Maricopa County,
Arizona

Dear Mr. Nevitt:

This is in regard to the data submitted in support of your request for a revision to the Flood Insurance Rate Map and/or Flood Boundary and Floodway Map for the referenced community. Our previous letter regarding your request stated that we would inform you in writing if we needed additional data to complete our evaluation. The enclosed list describes the data we need. A representative of Michael Baker, Jr., Inc. (MBJ), our Technical Evaluation Contractor, will call you to discuss the requested data.

We have suspended processing of your request pending our receipt of the requested data. After we receive the requested data, we will continue our evaluation. If we need additional data to complete our evaluation, we will inform you in writing.

When you write to us about your request, please include the case number (shown above) in your letter. If you have any questions about the status of your request, please call MBJ, at (703) 838-0400, and ask for the Revisions Coordinator for your state.

Sincerely,

William R. Locke

William R. Locke
Chief, Risk Studies Division
Federal Insurance Administration

Enclosure

cc: The Honorable Dave Dennison
Mayor, City of Carefree
The Honorable Jacky Davis
Mayor, City of Cave Creek
The Honorable James Bruner
Chairman, Maricopa County Board
of Supervisors
Ms. Jan Opstein
Flood Control District of
Maricopa County

FLOOD CONTROL DISTRICT
RECEIVED
MAY 13 1991
JMD
ICC RGN

Federal Emergency Management Agency

Washington, D.C. 20472

Case No.: 90-09-87P

Re: Cave Creek/Carefree
Floodplain Study

Community: Maricopa County,
Arizona

Additional Data Required to Support a Request
for a Flood Insurance Study (FIS)/
Flood Insurance Rate Map (FIRM) Revision

Requestor: Mr. Ron Nevitt

Date: MAY 8 1991

Community: Maricopa County, Arizona
Cave Creek/Carefree

The data listed below must be provided before we can process your request for an FIS/FIRM revision.

I. HYDROLOGY

As we mentioned in our June 29, 1990, letter, and discussed in a April 26, 1991, telephone conversation, we could not locate several of the discharges developed for Willow Springs Wash and its tributaries, as shown in Table 4, Summary of Peak Discharges, on Page 18 of the report entitled "Final Hydrologic and Hydraulic Report for Cave Creek/Carefree Flood Delineation Study," prepared by CH2M Hill, dated March 1990, in the submitted HEC-1 models for these streams. The River Mile (RM) locations where these discrepancies occur are listed below.

Stream	Location
Willow Springs Wash	RM 4.95
Willow Springs Wash, Tributary 1	RM 0.98
	RM 2.82
Willow Springs Wash, Tributary 2	RM 1.31
Willow Springs Wash, Tributary 2A	RM 0.52
Willow Springs Wash, Tributary 4	RM 0.52
	RM 0.98
Willow Springs Wash, Tributary 5	Above confluence with Willow Springs Wash, Tributary 5A

As discussed in our April 26, 1991, telephone conversation, these discharges were developed using discharge per weighted area

calculations. Please submit the supporting calculations for these discharges.

II. HYDRAULICS

A. Ocotillo Wash—Split Flow Analysis

We have reviewed the split flow analyses submitted with your letter dated February 13, 1991, as we requested in our June 29 letter. Several HEC-2 hydraulic computer models were used in those analyses to determine the flood hazards for this area. First, a HEC-2 model (identified as "split flow"), which included the split flow option based on weir flow, was developed to calculate the 100-year discharge of 2,132 cubic feet per second (cfs) in the west braid of Ocotillo Wash. A separate HEC-2 model (identified as "West Braid") was then run for the west braid of Ocotillo Wash, based on the discharges calculated in the "split flow" model. However, this west braid run did not include the entire reach of the braided area. A third HEC-2 model (identified as "Main Channel") was prepared for the main channel of Ocotillo Wash to include the total discharge. This discharge varies from 1,714 cfs to 4,047 cfs. The BFEs from this run do not reflect the flow that splits into the west braid of Ocotillo Wash.

As discussed in our April 26, 1991, telephone conversation, our review of the submitted models revealed the following three concerns:

1. The first concern regarding the "split flow" HEC-2 hydraulic model is whether it is more appropriate to use the weir flow or normal depth option in calculating the flow splitting into the west braid of Ocotillo Wash. Since the split in flow appears to be caused by natural high ground, it is unclear why the split was established assuming weirs at the two reaches where flow splits from the main channel. As explained during the April 26, 1991, telephone conversation, the upstream weir was based on a ridge located where the flow splits. Please explain in writing the use of the weir flow option, including the reason for choosing this method and the impact of using the weir flow option instead of the normal depth option.

2. The second concern, which was also discussed in the April 26, 1991, telephone conversation, is that the "West Braid" HEC-2 model does not include the entire reach of the braided area. Only cross sections 1710 through 2850 are modeled. It is unclear how the floodplain was delineated for the upstream reach and why the west braid of Ocotillo Wash is shown on the work map as Zone A, because the discharge is basically divided equally between the main channel and the west braid. Please explain how the approximate floodplain was delineated and why one side of Ocotillo Wash is shown with detailed information and the other side is shown as approximate.

3. The third concern is that the BFEs for the main channel were based on the total discharge varying from 1,714 to 4,047 cfs, including the flow in the west braid of Ocotillo Wash. These BFEs differ by as much as 1.8 feet from those developed in the "split flow" HEC-2 hydraulic computer model. The BFEs should reflect the existing conditions and be based on the "split flow" HEC-2 hydraulic model, which accounts for 2,132 cfs being diverted to the west braid. The use of the total discharge in the main channel is a conservative approach. In the April 26, 1991, telephone conversation, we discussed some reasons for this modeling approach, including field observations of cutting and scour in the main channel. This modeling approach reflects the assumption that future floods will cause the main channel to be further cut and therefore, contain most of the discharge. Since this conservative approach is based on future conditions and may affect property owners along the east braid, please provide documentation explaining why this conservative approach was used, including erosion rates if available.

Also, because of the instability of the highly erosive alluvial soils in the area of high ground between the main channel and the west braid of Ocotillo Wash, we will place the following note on the FIRM: "Floodplain subject to significant hazards because of channel migration and stream bed and bank erosion."

B. Floodway Surcharges

Our review of the newly submitted HEC-2 hydraulic computer models revealed that there are two cross sections that have surcharges greater than 1.0 foot. At all cross sections, the differences in elevation between the encroached and natural conditions must be less than or equal to 1.0 foot. The specific streams and cross sections at which the surcharges are greater than 1.0 foot are listed below.

Stream	Cross Section	Difference in Water-Surface Elevation (feet)
Cottonwood Creek	940	1.2
Ocotillo Wash	3090	1.1

Please revise the HEC-2 hydraulic models so that all cross sections have surcharges of 1.0 foot or less, and make any necessary revisions to the profiles and work maps.

C. Culverts

Our review of the newly submitted culvert calculations raised the following three concerns that should be addressed:

1. The submitted report does not describe the derivation of the outlet velocities. Please explain how the outlet velocities were derived.

2. In the HEC-2 model for Willow Springs Wash Tributary 5, reference is made to a 40- by 27-inch corrugated metal pipe arch culvert. However, this culvert is not modeled. Please explain this discrepancy.

3. According to the Willow Springs Wash Tributary 5 HEC-2 hydraulic model, submitted with the February 13, 1991, letter, the cross section downstream of the culvert is 690, with a depth of 3.5 feet. Please provide revised culvert calculations for Willow Springs Wash Tributary 5, based on the tailwater equal to 3.5 feet, instead of the previously used 3.66 feet.

III. MAPPING

A. Ocotillo Wash

Our review of the HEC-2 hydraulic computer models and topographic work map entitled "Cave Creek/Carefree Flood Insurance Study," scale 1:2,400, contour interval 4 feet, prepared by CH2M Hill, Inc., dated March 1990, and submitted with your February 13, 1991, letter, revealed that all but one discrepancy in distances between cross sections had been corrected. The specific stream and cross sections at which there is a discrepancy between the HEC-2 model and the topographic work map is listed below.

Stream	Between Cross Sections	Distance in Feet HEC-2 Model	Map
Ocotillo Wash	.16 and .24	285	450

B. Floodway Widths

Some discrepancies between the floodway widths listed in the HEC-2 hydraulic computer models and those shown on the previously referenced topographic work map were not resolved in the February 13, 1991, submittal. The specific streams and cross sections at which these differences occur are listed below.

Stream	Cross Sections	Width HEC-2 Model	Map
Ocotillo Wash	2.97	670	335
Ocotillo Wash, Tributary 3	1.19	60	45

Please revise the HEC-2 models, the work maps, or both, to resolve these discrepancies.

Engineers
Planners
Economists
Scientists

August 23, 1991

PHX27815.AM

Ms. Jan Opstein
Flood Control District of Maricopa County
3335 W. Durango Street
Phoenix, Arizona 85009

Dear Ms. Opstein:

Subject: Cave Creek/Carefree Flood Insurance Study

This letter follows our meeting of August 1, 1991 and presents the information and modifications to the project deliverables requested by the Federal Emergency Management Agency in their letter dated May 8, 1991. The following paragraphs summarize the requested information:

I. HYDROLOGY

The stream reaches referred to in the May 8, 1991 letter were modeled using discharges estimated by assuming a unit discharge for each subbasin as estimated using the HEC-1 model. The discharge per unit area was then used to estimate discharges for channel reaches in the watershed. The supporting calculations are shown in Table 1.

CH2M HILL Phoenix Office, 1620 West Fountainhead Parkway, Suite 550, P.O. Box 28440 Tempe, Arizona 85285-8440 602.966.8188

Table 1

Stream	Section	Subarea	Total Subarea (sq.mi.)	Partial Area (sq.mi.)	Fraction	Q(HEC-1)	Q(HEC-2)
WS	4.95	D2	0.32	0.16	0.50	420	210
			0.32	0.16	0.50	626	313
			0.32	0.16	0.50	724	362
			0.32	0.16	0.50	896	449
WST1 uses PC 32+0.58*		F1 from sec.	0.98 to 1.52				
WST1	0.98	PC 32	0.84			543	
			0.84			820	
			0.84			962	
			0.84			1,215	
		F1	0.82	0.48	0.58	525	848
			0.82	0.48	0.58	787	1,277
			0.82	0.48	0.58	921	1,497
			0.82	0.48	0.58	1,168	1,894
WST1	2.82	F1B	0.56	0.25	0.45	358	160
			0.56	0.25	0.45	537	240
			0.56	0.25	0.45	629	281
			0.56	0.25	0.45	794	354
WST2	1.31	F2B	0.43	0.22	0.50	511	256
			0.43	0.22	0.50	762	240
			0.43	0.22	0.50	891	281
			0.43	0.22	0.50	1,114	354
WST2A	0.52	F2A	0.29	0.19	0.67	345	231
			0.29	0.19	0.67	514	344
			0.29	0.19	0.67	601	403
			0.29	0.19	0.67	752	504
WST4	0.52	F2D	0.23	0.16	0.69	180	124
			0.23	0.16	0.69	271	187
			0.23	0.16	0.69	318	219
			0.23	0.16	0.69	402	277
WST4	0.98	F2D	0.23	0.10	0.42	180	76
			0.23	0.10	0.42	271	114
			0.23	0.10	0.42	318	134
			0.23	0.10	0.42	402	169
WST5	0.92	F3	0.89	0.42	0.47	352	165
			0.89	0.42	0.47	536	252
			0.89	0.42	0.47	631	297
			0.89	0.42	0.47	804	378

II. HYDRAULICS

A. Ocotillo Wash Foot Flow Analysis

The first concern listed by FEMA regards the "split flow."

1. FEMA's reviewer questioned whether the weir flow or the normal depth option for calculating the flow distribution at the two areas of channel bifurcation was most appropriate. Based on detailed field investigations by our staff as well as Flood Control District staff and evaluations of stereoscopic aerial photographs, it was our conclusion that the predominant flow direction was in the east or main braid at both split locations. As depth of flow increases to above the crest of the ridge separating the east and west braids, flow begins to leave the main channel into the west braid. The angle of this flow over the divide will vary depending on the depth, however, it was our conclusion that the component of velocity in that direction would be low. Using normal depth to estimate the magnitude of the split would therefore not be appropriate. It is our opinion that modeling the flow as a broad-crested weir with a relatively high weir coefficient more accurately represents the actual flow characteristics. Although arguments could be made for using either method, the field and photographic evidence appeared to indicate that the predominant flow direction was within the main or west braid and that the use of the normal depth option for estimating the flow split would underestimate the magnitude and severity of flooding in the main braid.

2. The second concern described in FEMA's letter regards the length of the reach modeled by the west braid HEC-2 model. On Ocotillo Wash two separate reaches of divided flow were investigated. The upstream split occurs between Section 3.09 and 3.17 at that location; a minor amount of flow is diverted from the main braid. This flow re-enters the main stream at approximately Section 2.65. Between cross-sections 2.72 and 3.17, the hydraulic characteristics of the diverted west braid were modeled by approximate methods as directed by FCDMC. Based on our conversations with FEMA and FCDMC, these calculations have been revised. New 100-year flood-prone areas have been estimated using Manning's equation for normal depth. These calculations and a portion of Sheet 13 showing the cross-section locations are attached.

Cross-sections 1.71 through 2.85 were used in the west braid model to evaluate the flooding conditions downstream of the lower flow split which occurs between cross-sections 2.72 and 2.78. Although the flow split model predicts that during large events relatively equal flow would occur in either braid, field investigations and examination of stereographic aerial photography led to the conclusion that the primary flow channel is indeed the eastern or main braid. This conclusion is supported by evidence of recent and historic scour, highwater marks, and anecdotal evidence. It was our conclusion that as this channel continues to scour, all flow could be contained in or diverted to the main braid. The channel banks are composed of unconsolidated alluvial fill materials and are subject to significant episodes of scour and deposition. Because of these conditions, we were directed by the Flood Control District to use a conservative assumption that represented the probable worse case for each braid. We therefore modeled the main stream assuming no flow diversion occurred at the split and modeled the west braid assuming that the portion of flow indicated by the split flow analysis was conveyed by the west braid.

B. Floodway Surcharges

The profiles and work maps for Cottonwood Creek and Ocotillo Wash sections referenced in the letter have been revised. The revised work products are attached.

C. Culvert Calculations for Willow Springs Wash Tributary 5

As we discussed, the hydraulic computations for these culverts have been revised. The 40-inch by 27-inch cmp arch culvert had been omitted from the original model. It has been added and new computations revised. Federal Highway Administration Model HY8 was used to revise the calculations and to estimate outlet velocities. The results were used to revise the HEC-2 model. Calculations and documentation are attached.

II. MAPPING

The sections of Ocotillo Wash referred to in the May 8th letter have been revised to address the discrepancies indicated. Revised HEC2 outputs, revised maps, and profiles are attached.

Jan, I believe these items will respond to each of FEMA's comments and allow for finalization of the above-referenced project. If you have any questions or comments, please call me.

Sincerely,

CH2M HILL

Steven R. Walker
Project Manager

Attachments

OCOTILLO WEST BRAID
HYDRAULIC COMPUTATION

Section 2.65 through 3.09

PHXC17.104.51

CROSS-SECTIONAL ANALYSIS

X-SECT.BAS/V.1

Preparer: D.STOUGH
Job#: PHX27815.AM
Date: 08-19-1991

ct: CAVE CREEK FIS
Section Description: XS-1

	STA(ft)	ELEV(ft)	MANNINGS n (to Next #)
1	705.00	2349.50	.045
2	755.00	2349.00	.04
3	810.00	2345.00	.04
4	850.00	2347.00	.04
5	878.00	2344.50	.04
6	905.00	2345.50	.045
7	935.00	2345.50	.04
8	950.00	2344.00	.04
9	970.00	2345.50	.045
10	985.00	2345.50	.04
11	995.00	2344.00	.04
12	1010.00	2344.00	.04
13	1030.00	2345.00	.045
14	1125.00	2347.50	-

hannel Slope = 0.0276 ft./ft.

.E. = 2347.40 ft.
epth = 3.40 ft.
el Slope = 0.0276 ft./ft.

NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
BANK	777.0								
		0.040	206.59	128.27	10573.7	1756.63	8.50	1.18	128.0
IGHT BANK	905.0								
		0.045	57.00	30.00	2895.0	480.95	8.44	1.08	30.0
	935.0								
		0.040	92.75	35.13	6599.3	1096.35	11.82	1.28	35.0
	970.0								
		0.045	28.50	15.00	1447.5	240.48	8.44	1.08	15.0
	985.0								
		0.040	135.50	45.14	10503.0	1744.89	12.88	1.31	45.0
	1030.0								
		0.045	109.43	91.23	4090.6	679.59	6.21	1.00	91.2
	1121.2								
s:			629.76	344.76	36109.1	5998.89	9.53	1.24	344.2

S = 2347.10 ft.
= 3.10 ft.
nel Slope = 0.0276 ft./ft.

NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
FT BANK	781.1								
		0.040	168.83	124.13	7720.1	1282.56	7.60	1.15	123.9
BANK	905.0								
		0.045	48.00	30.00	2174.4	361.24	7.53	1.05	30.0
	935.0								
		0.040	82.25	35.13	5402.4	897.52	10.91	1.25	35.0

	985.0								
		0.040	68.00	45.14	3328.4	552.96	8.13	1.17	45.0
	1030.0								
		0.045	15.39	34.21	299.1	49.69	3.23	0.85	34.2
	1064.2								
			---	---	---	---	---	---	---
S:			190.56	232.66	7046.5	1170.66	6.14	1.20	232.2

= 2345.80 ft.
= 1.80 ft.
hannel Slope = 0.0276 ft./ft.

NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
EFT BANK	799.0								
		0.040	10.80	27.05	218.2	36.25	3.36	0.93	27.0
	826.0								
ANK	863.4								
		0.040	31.07	41.64	952.0	158.15	5.09	1.04	41.6
BANK	905.0								
		0.045	9.00	30.00	133.6	22.19	2.47	0.79	30.0
	935.0								
		0.040	36.75	35.13	1410.8	234.38	6.38	1.10	35.0
	970.0								
		0.045	4.50	15.00	66.8	11.10	2.47	0.79	15.0
	985.0								
		0.040	63.50	45.14	2970.0	493.41	7.77	1.15	45.0
	1030.0								
		0.045	12.16	30.41	218.6	36.31	2.99	0.83	30.4
	1060.4								
			---	---	---	---	---	---	---
OTALS:			167.79	224.37	5969.8	991.78	5.91	1.20	224.0

I.S.E. = 2345.87 ft.
epth = 1.87 ft.
el Slope = 0.0276 ft./ft.

NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
BANK	798.0								
		0.040	12.78	29.42	272.9	45.34	3.55	0.95	29.4
ANK	827.4								
	862.7								
		0.040	34.01	42.42	1093.0	181.59	5.34	1.05	42.3
IGHT BANK	905.0								
		0.045	11.10	30.00	189.5	31.49	2.84	0.82	30.0
	935.0								
		0.040	39.20	35.13	1571.2	261.02	6.66	1.11	35.0
	970.0								
		0.045	5.55	15.00	94.8	15.74	2.84	0.82	15.0
	985.0								
		0.040	66.66	45.14	3219.8	534.92	8.03	1.16	45.0
	1030.0								
		0.045	14.38	33.08	273.4	45.42	3.16	0.84	33.1
	1063.1								
			---	---	---	---	---	---	---
S:			183.68	230.19	6714.6	1115.51	6.07	1.20	229.8

CROSS-SECTIONAL ANALYSIS

X-SECT.BAS/V.1

Preparer: D.STOUGH
Job#: PHX27815.AM
Date: 08-19-1991

Project: CAVE CREEK FIS
Cross Section Description: XS-2

	STA(ft)	ELEV(ft)	MANNINGS n (to Next #)
1	925.00	2370.50	.055
2	940.00	2366.50	.055
3	980.00	2367.00	.035
4	1000.00	2364.00	.035
5	1010.00	2364.50	.035
6	1025.00	2368.00	.055
7	1040.00	2371.00	.055
8	1090.00	2372.00	-

Channel Slope = 0.0296 ft./ft.

RATING CURVE

WSE(ft)	D(ft)	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
2364.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.0
2364.50	0.50	3.33	13.38	56.2	9.66	2.90	1.02	13.3
2365.00	1.00	11.37	18.95	344.2	59.22	5.21	1.18	18.8
2365.50	1.50	22.14	24.53	880.6	151.50	6.84	1.26	24.3
2366.00	2.00	35.65	30.10	1699.4	292.38	8.20	1.32	29.8
2366.50	2.50	51.90	35.67	2837.6	488.20	9.41	1.37	35.2
2367.00	3.00	81.36	83.18	4443.4	764.48	9.40	1.67	82.6
2367.50	3.50	123.66	87.32	7131.9	1227.02	9.92	1.46	86.6
2368.00	4.00	167.97	91.46	10545.0	1814.22	10.80	1.40	90.6
2368.50	4.50	214.38	95.95	14931.6	2568.94	11.98	1.41	95.0
2369.00	5.00	262.97	100.44	19998.8	3440.72	13.08	1.42	99.4
2369.50	5.50	313.75	104.93	25732.4	4427.16	14.11	1.43	103.8
2370.00	6.00	366.72	109.42	32123.9	5526.81	15.07	1.44	108.1
2370.50	6.50	421.88	113.91	39168.8	6738.86	15.97	1.45	112.5

RATING CURVE

WSE(ft)	D(ft)	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
2367.00	3.00	81.36	83.18	4443.4	764.48	9.40	1.67	82.6
2367.05	3.05	85.51	83.60	4676.9	804.65	9.41	1.63	83.0
2367.10	3.10	89.67	84.01	4918.8	846.27	9.44	1.60	83.4
2367.15	3.15	93.83	84.42	5167.7	889.08	9.48	1.58	83.8
2367.20	3.20	98.04	84.84	5425.7	933.47	9.52	1.56	84.2
2367.25	3.25	102.26	85.25	5691.5	979.20	9.58	1.53	84.6
2367.30	3.30	106.50	85.67	5964.9	1026.25	9.64	1.52	85.0
2367.35	3.35	110.77	86.08	6246.0	1074.60	9.70	1.50	85.4
2367.40	3.40	115.03	86.49	6533.0	1123.99	9.77	1.49	85.8
2367.45	3.45	119.34	86.91	6828.8	1174.88	9.85	1.47	86.2
2367.50	3.50	123.66	87.32	7131.9	1227.02	9.92	1.46	86.6

W.S.E. = 2367.37 ft.
Depth = 3.37 ft.

nnel Slope = 0.0296 ft./ft.

NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
LEFT BANK	936.7								
		0.055	26.22	43.38	507.9	87.39	3.33	0.75	43.3
HT BANK	980.0								
		0.035	86.26	42.87	5852.6	1006.91	11.67	1.44	42.3
	1022.3								
TOTALS:			112.48	86.25	6360.5	1094.30	9.73	1.50	85.6

CROSS-SECTIONAL ANALYSIS

X-SECT.BAS/V.1

Preparer: D.STOUGH
Job#: PHX27815.AM
Date: 08-19-1991

Project: CAVE CREEK FIS
Cross Section Description: XS-3

NO.	STA(ft)	ELEV(ft)	MANNINGS n (to Next #)
1	750.00	2395.00	.045
2	850.00	2392.00	.045
3	910.00	2392.00	.045
4	925.00	2392.00	.035
5	985.00	2388.00	.035
6	1005.00	2388.00	.035
7	1025.00	2390.50	.045
8	1050.00	2392.00	.045
9	1110.00	2395.00	-

Channel Slope = 0.0445 ft./ft.

RATING CURVE

W.S.E.(ft)	D(ft)	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
2388.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.0
2388.50	0.50	12.88	31.55	301.6	63.62	4.94	1.36	31.5
2389.00	1.00	31.50	43.10	1088.1	229.54	7.29	1.50	43.0
2389.50	1.50	55.88	54.64	2414.3	509.30	9.11	1.59	54.5
2390.00	2.00	86.00	66.19	4359.3	919.59	10.69	1.65	66.0
2390.50	2.50	121.88	77.74	7001.9	1477.06	12.12	1.70	77.5
2391.00	3.00	164.58	93.60	10662.1	2249.16	13.67	1.81	93.3
2391.50	3.50	215.21	109.47	15205.7	3207.65	14.90	1.87	109.2
2392.00	4.00	273.75	125.33	20735.1	4374.07	15.98	1.90	125.0

RATING CURVE

W.S.E.(ft)	D(ft)	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
2390.00	2.00	86.00	66.19	4359.3	919.59	10.69	1.65	66.0
2390.05	2.05	89.33	67.35	4591.1	968.50	10.84	1.66	67.2
2390.10	2.10	92.72	68.50	4830.0	1018.89	10.99	1.66	68.3
2390.15	2.15	96.15	69.65	5074.8	1070.54	11.13	1.67	69.4
2390.20	2.20	99.66	70.81	5328.1	1123.96	11.28	1.67	70.6
2390.25	2.25	103.22	71.96	5588.6	1178.91	11.42	1.68	71.8
2390.30	2.30	106.84	73.12	5856.5	1235.43	11.56	1.68	72.9
2390.35	2.35	110.52	74.28	6131.9	1293.52	11.70	1.69	74.1
2390.40	2.40	114.23	75.43	6413.3	1352.90	11.84	1.69	75.2
2390.45	2.45	118.03	76.58	6703.8	1414.17	11.98	1.70	76.3
2390.50	2.50	121.88	77.74	7001.9	1477.06	12.12	1.70	77.5

W.S.E. = 2390.19 ft.
Depth = 2.19 ft.
Channel Slope = 0.0445 ft./ft.

NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
LEFT BANK	952.2								
		0.035	98.95	70.58	5276.8	1113.15	11.25	1.67	70.4
RIGHT BANK	1022.5								
TOTALS:			98.95	70.58	5276.8	1113.15	11.25	1.67	70.4

CROSS-SECTIONAL ANALYSIS

X-SECT.BAS/V.1

Preparer: D.STOUGH
Job#: PHX27815.AM
Date: 08-19-1991

Project: CAVE CREEK FIS
Cross Section Description: XS-4

NO.	STA(ft)	ELEV(ft)	MANNINGS n (to Next #)
1	925.00	2407.00	.05
2	960.00	2406.50	.03
3	995.00	2404.00	.03
4	1005.00	2404.00	.03
5	1030.00	2409.00	.05
6	1070.00	2410.00	-

Channel Slope = 0.0410 ft./ft.

W.S.E. = 2406.50 ft.
Depth = 2.50 ft.
Channel Slope = 0.0410 ft./ft.

	NOTES	STA-ft	MAN.n	AREA-sf	WT.P-ft	CONV(K)	Q-(cfs)	V-fps	Fr.#	TW(ft)
LEFT BANK		960.0								
			0.030	84.38	57.84	5390.4	1091.47	12.94	1.88	57.5
RIGHT BANK		1017.5								
TOTALS:				84.38	57.84	5390.4	1091.47	12.94	1.88	57.5

OVERFLOW STAGE TABLE (-0.28)
(500yr Flood Frequency)

OCT #3-280
SHEET 8-19

ITER	TRIAL H	overflow Q	TOTAL Q 100yr
1	2209.64	350.13	430.19
2	2209.62	339.48	419.47
3	2209.60	329.01	408.95
4	2209.58	318.78	398.66
5	2209.56	308.77	388.58
6	2209.54	298.91	378.67
7	2209.52	289.22	368.92
8	2209.50	279.70	359.34
9	2209.48	270.35	349.93
10	2209.46	261.20	340.72
11	2209.44	252.24	331.71
12	2209.42	243.52	322.93
13	2209.40	235.10	314.44
14	2209.38	226.89	306.18
15	2209.36	218.83	298.05
16	2209.34	210.89	290.06
17	2209.32	203.11	282.22
18	2209.30	195.47	274.52
19	2209.28	188.00	266.99
20	2209.26	180.70	259.63
21	2209.24	173.62	252.49
22	2209.22	166.70	245.51
23	2209.20	159.91	238.66
24	2209.18	153.26	231.95
25	2209.16	146.75	225.38
26	2209.14	140.38	218.96
27	2209.12	134.18	212.69
28	2209.10	128.15	206.60
29	2209.08	122.33	200.72
30	2209.06	116.71	195.04
31	2209.04	111.23	189.51
32	2209.02	105.91	184.12
33	2209.00	100.78	178.93
34	2208.98	95.84	173.93
35	2208.96	91.04	169.07
36	2208.94	86.37	164.33
37	2208.92	81.85	159.76
38	2208.90	77.53	155.38
39	2208.88	73.32	151.10
40	2208.86	69.21	146.93
41	2208.84	65.20	142.87
42	2208.82	61.31	138.92
43	2208.80	57.54	135.09
44	2208.78	53.90	131.39

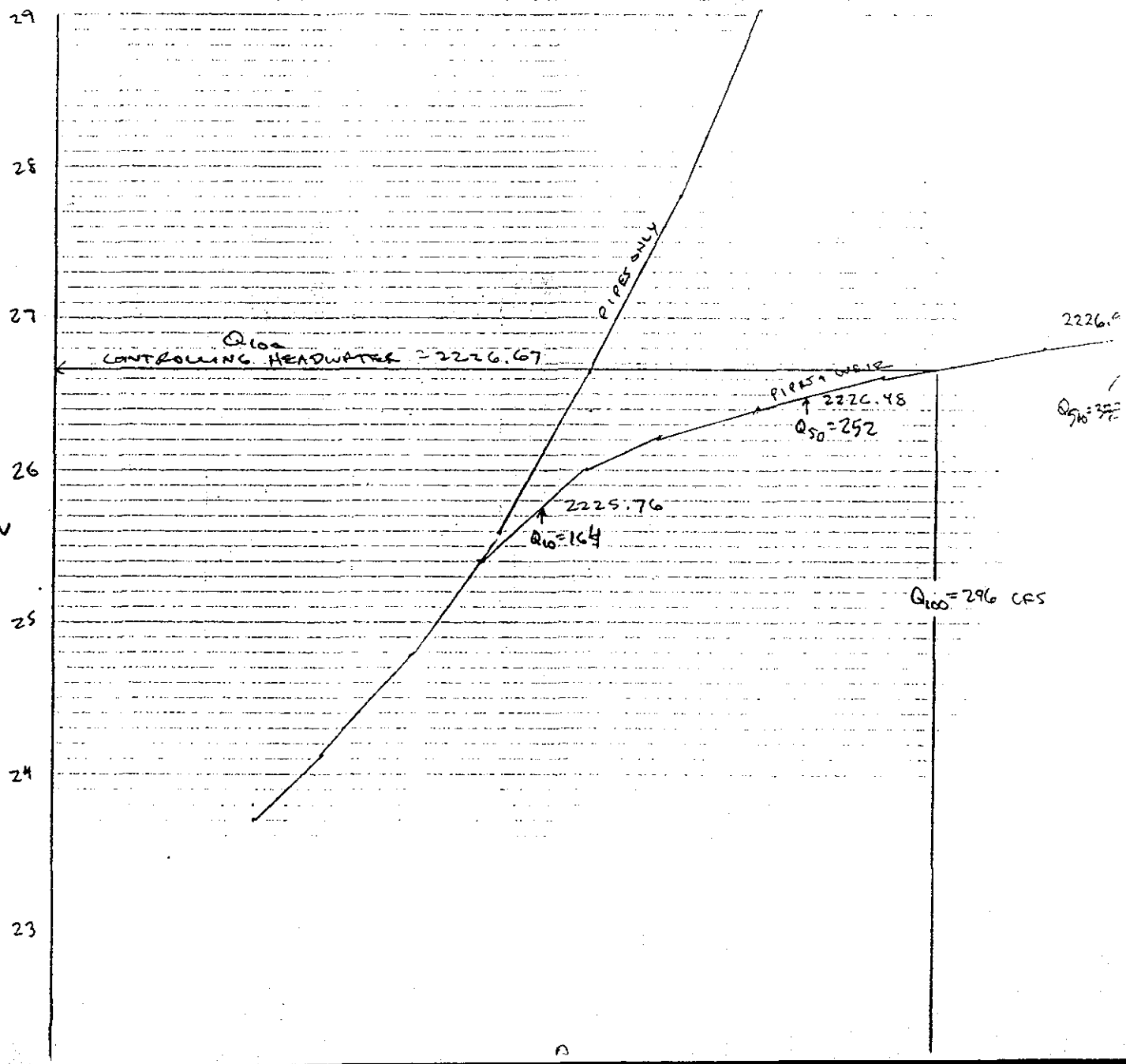
SUBJECT ((JEF DATE 9-19-90

FEMA RESPONSE MEMO SHEET 9 OF 9

CULVERT HYDRAULICS PROJECT NO. R0D27815.H2

2. OCT TRIB #3 SECTION 460

$Q_{0.85}$	H	$H+h_o+EL_o$		INLET HW	$HW+EL_i$	EL	Q_{weir}
(32)66	0.4	2223.7	OUTLET CONTROL	2.25	2222.55	2025.4	0
(30)90	0.82	24.12		2.7	23.8	26.0	7
(48)120	1.48	24.78		3.3	23.6	26.2	36
(50)150	2.3	25.6		4.1	24.4	26.4	62
(60)180	3.35	26.65		4.8	25.1	26.6	100
(70)210	4.5	27.8		6.0	26.3	26.8	148
(80)240	6.0	29.3		7.2	27.5	27.0	207
(100)300	9.2	32.5		9.9	30.2		
(128)384	15.0	38.3		13.2	33.5		
(148)444	20.0	2243.3		18.0	2238.3		



OVERFLOW STAGE TABLE 26-0.28
(10yr Flood Frequency)

OCT # 3 - 460
SHEET 10 - 19

ITER	TRIAL H	Overflow Q
1	2227.02	213.39
2	2227.00	206.95
3	2226.98	200.60
4	2226.96	194.34
5	2226.94	188.18
6	2226.92	182.12
7	2226.90	176.16
8	2226.88	170.31
9	2226.86	164.58
10	2226.84	158.97
11	2226.82	153.54
12	2226.80	148.22
13	2226.78	142.98
14	2226.76	137.83 < EXAMPLE
15	2226.74	132.76
16	2226.72	127.78
17	2226.70	122.88
18	2226.68	118.08
19	2226.66	113.38
20	2226.64	108.78
21	2226.62	104.29
22	2226.60	99.91
23	2226.58	95.66
24	2226.56	91.58
25	2226.54	87.62
26	2226.52	83.74
27	2226.50	79.94
28	2226.48	76.24
29	2226.46	72.62
30	2226.44	69.11
31	2226.42	65.70
32	2226.40	62.41
33	2226.38	59.26
34	2226.36	56.29
35	2226.34	53.42
36	2226.32	50.65
37	2226.30	48.03
38	2226.28	45.49
39	2226.26	43.00
40	2226.24	40.58
41	2226.22	38.20
42	2226.20	35.89
43	2226.18	33.64
44	2226.16	31.45
45	2226.14	29.33
46	2226.12	27.29
47	2226.10	25.31
48	2226.08	23.42
49	2226.06	21.63
50	2226.04	19.98
51	2226.02	18.41
52	2226.00	16.88
53	2225.98	15.40
54	2225.96	13.98
55	2225.94	12.61

SUBJECT FEMA RESPONSE MEMO
CULVERT HYDRAULICS

BY JEF DATE 9-19-90
SHEET 11 OF 19
PROJECT NO. RDD 27815.H2

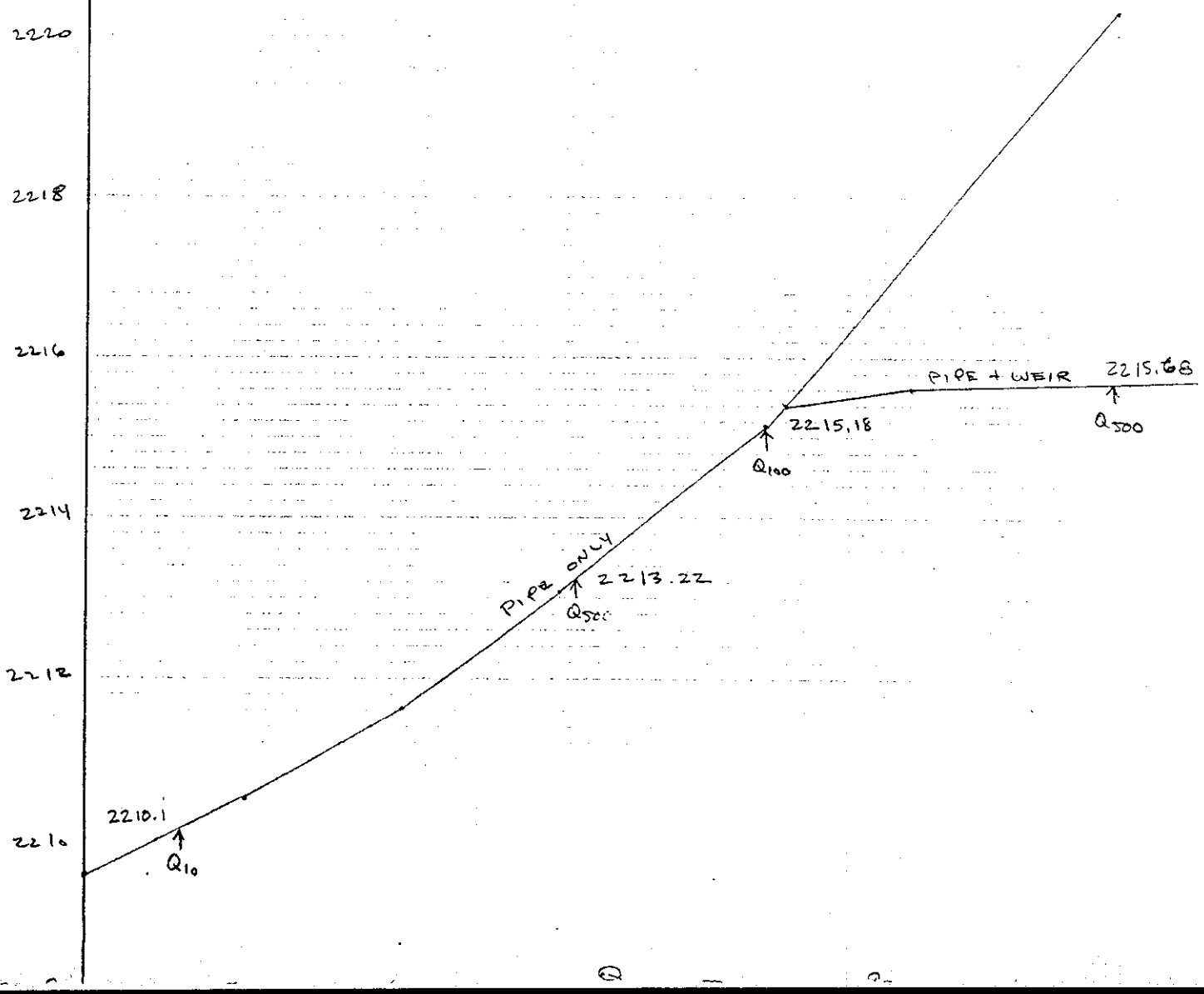
(3) OCT TRIB #4 SECTION 600

Q_{PIPE}	H	$H + h_o + EL_o$	INLET HW	$HW + EL_{IN}$	EL	Q_{WEIR}
83	7.3	2215.17	2.41	2210.41	2215.4	0
70	5.2	2213.07	OUTLET CONTROL 1.75	9.75	15.6	7
60	3.75	2211.62	1.61	9.61	15.8	42
50	2.6	10.47	1.35	9.35	16.0	112
40	1.68	9.55	1.1	INLET CONTROL 9.1		
30	1.0	8.87	0.9	8.9		
20	0.44	8.31	0.71	8.71		
105	12.5	2220.32				

ROADWAY IS NOT OVERTOPPED 'TIL Q500

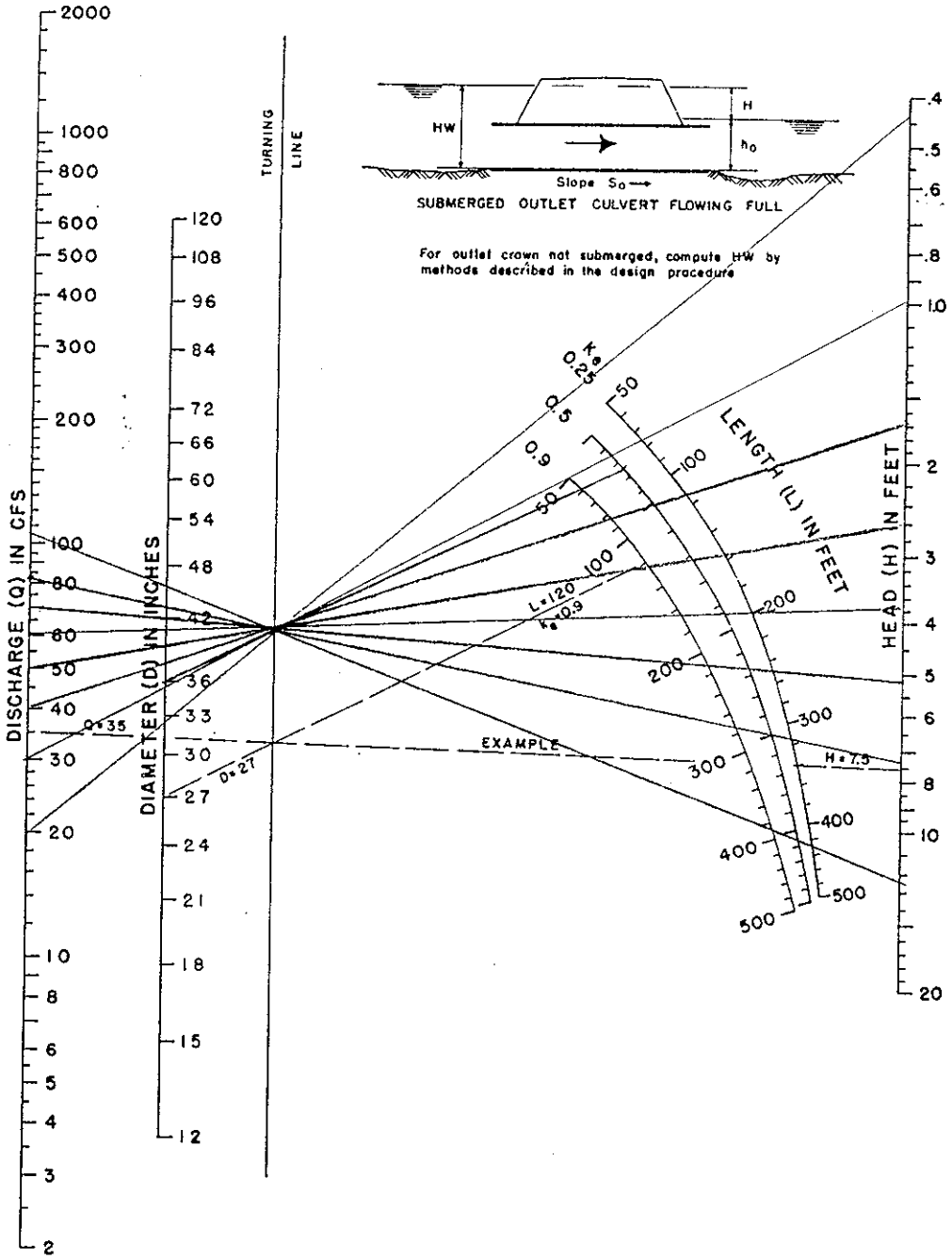
Q_{100} CONTROLLING HW = 2215.17

OUTLET CONTROL



OCT TRIB 4
SEC. 600
SHEET 12 - 19

CHART 6



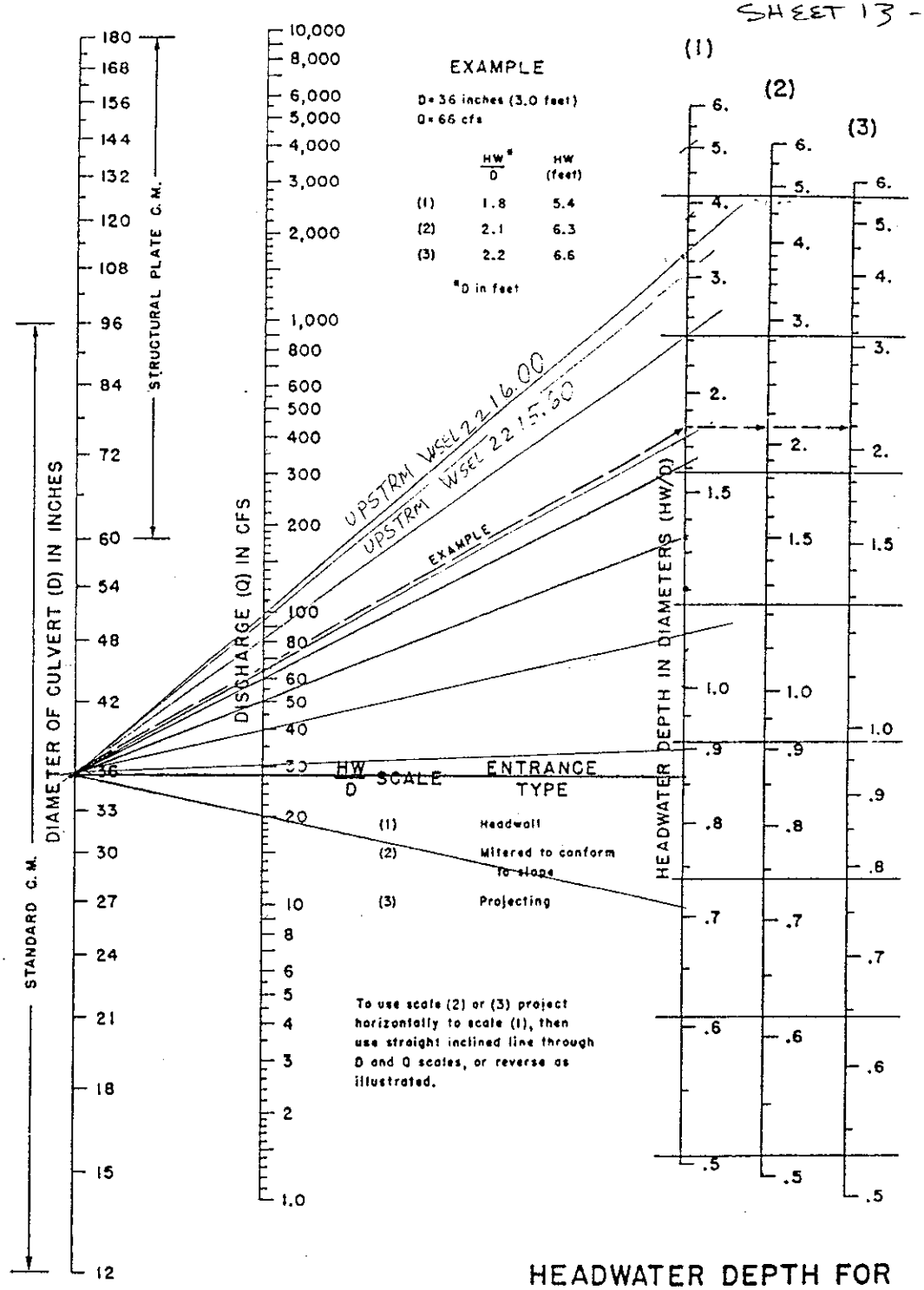
HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963

OCT 4

CHART 5

SHEET 13-19



HEADWATER DEPTH FOR C. M. PIPE CULVERTS WITH INLET CONTROL

BUREAU OF PUBLIC ROADS JAN. 1963

VERFLOW STAGE TABLE - O(TILLO TRIB.4 SEC 0.60(OCT # 4-600

Qi = C*L*H^1.5 Q = Σ Qi

C = 3, L = 10 SHEET 14-19

TER	TRIAL H	overflow Q
1	2216.00	111.60
2	2215.99	107.42
3	2215.98	103.30
4	2215.97	99.26
5	2215.96	95.30
6	2215.95	91.42
7	2215.94	87.63
8	2215.93	83.91
9	2215.92	80.26
10	2215.91	76.67
11	2215.90	73.15
12	2215.89	69.70
13	2215.88	66.33
14	2215.87	63.04
15	2215.86	59.82
16	2215.85	56.70
17	2215.84	53.68
18	2215.83	50.73
19	2215.82	47.86
20	2215.81	45.07
21	2215.80	42.35
22	2215.79	39.73
23	2215.78	37.21
24	2215.77	34.80
25	2215.76	32.48
26	2215.75	30.26
27	2215.74	28.15
28	2215.73	26.14
29	2215.72	24.21
30	2215.71	22.34
31	2215.70	20.57
32	2215.69	18.89
33	2215.68	17.28
34	2215.67	15.75
35	2215.66	14.31
36	2215.65	12.97
37	2215.64	11.73
38	2215.63	10.54
39	2215.62	9.43
40	2215.61	8.39
41	2215.60	7.42
42	2215.59	6.50
43	2215.58	5.65
44	2215.57	4.88
45	2215.56	4.17
46	2215.55	3.53
47	2215.54	2.98
48	2215.53	2.48
49	2215.52	2.03
50	2215.51	1.62

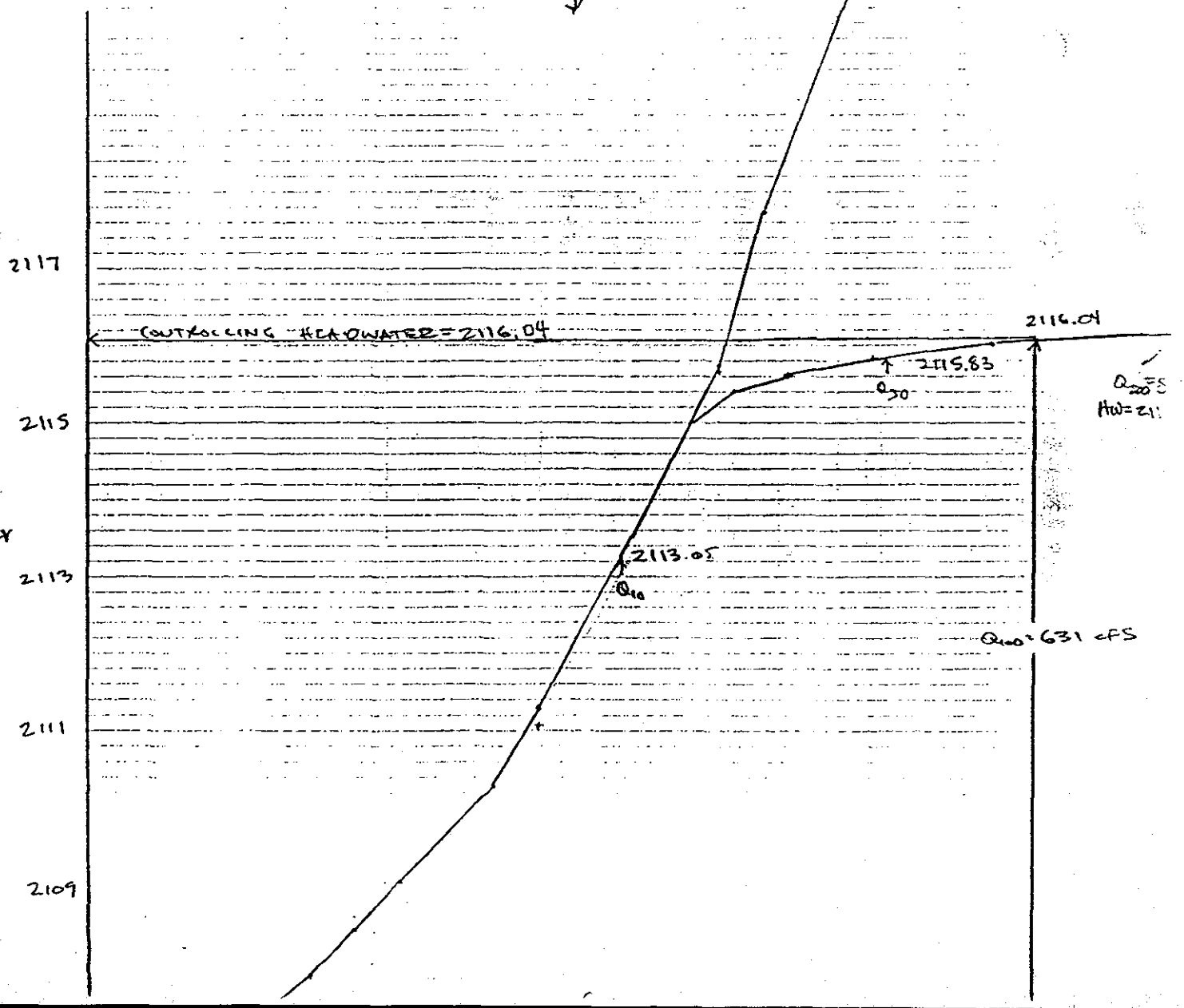
SUBJECT FEMA RESPONSE MEMO
CULVERT HYDRAULICS

BY JEF DATE 9-19-90
SHEET 15 OF 19
PROJECT NO. 400 27815

4. WILLOW SPRINGS TRIB #5 SECTION 700

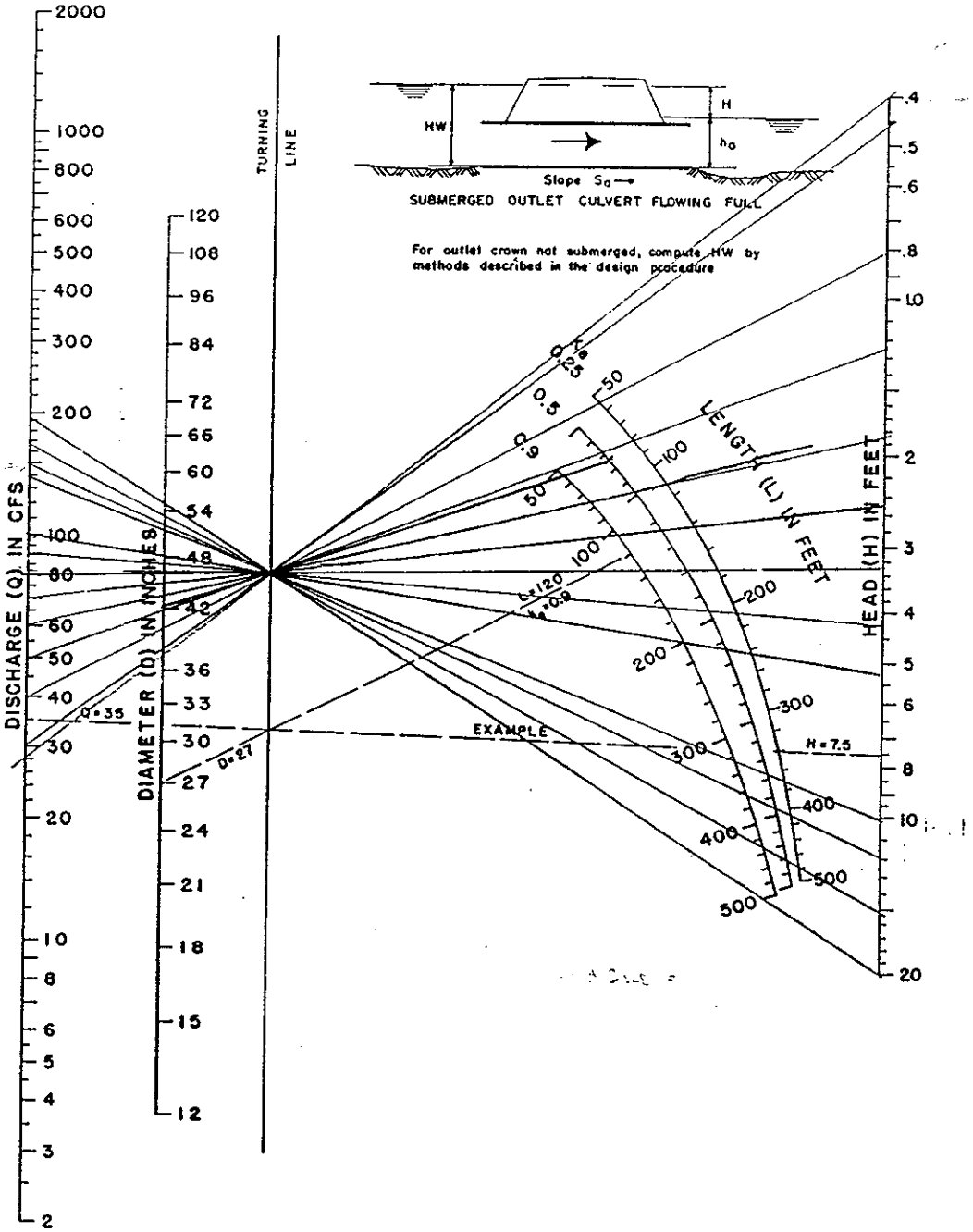
$Q_{p.ft}$	#	$H+h_o+EL_o$	INLET HW	HW+EL$_i$	EL − Q_{WSIR}	
(89)2t	0.4	2106.16			2115	0
120(40)	0.8	6.56	2.94	2107.4	15.4	18
150(50)	1.25	7.01	3.35	7.85	15.6	50
180(60)	1.8	7.56	3.92	8.42	15.8	103
210(70)	2.5	8.26	4.55	9.05	2116.0	170
240(80)	3.3	9.06	5.25	9.75	16.2	352
270(90)	4.2	9.96	5.78	10.28		
300(100)	5.3	11.06	6.03	11.33		
420(140)	10	15.76	outlet 11.2	15.70		
450(150)	12	17.76	control 11.9	16.40		
510(170)	15	20.76	15.4	19.9		
570(190)	20	25.76	17.5	22.0		

INLET CONTROL



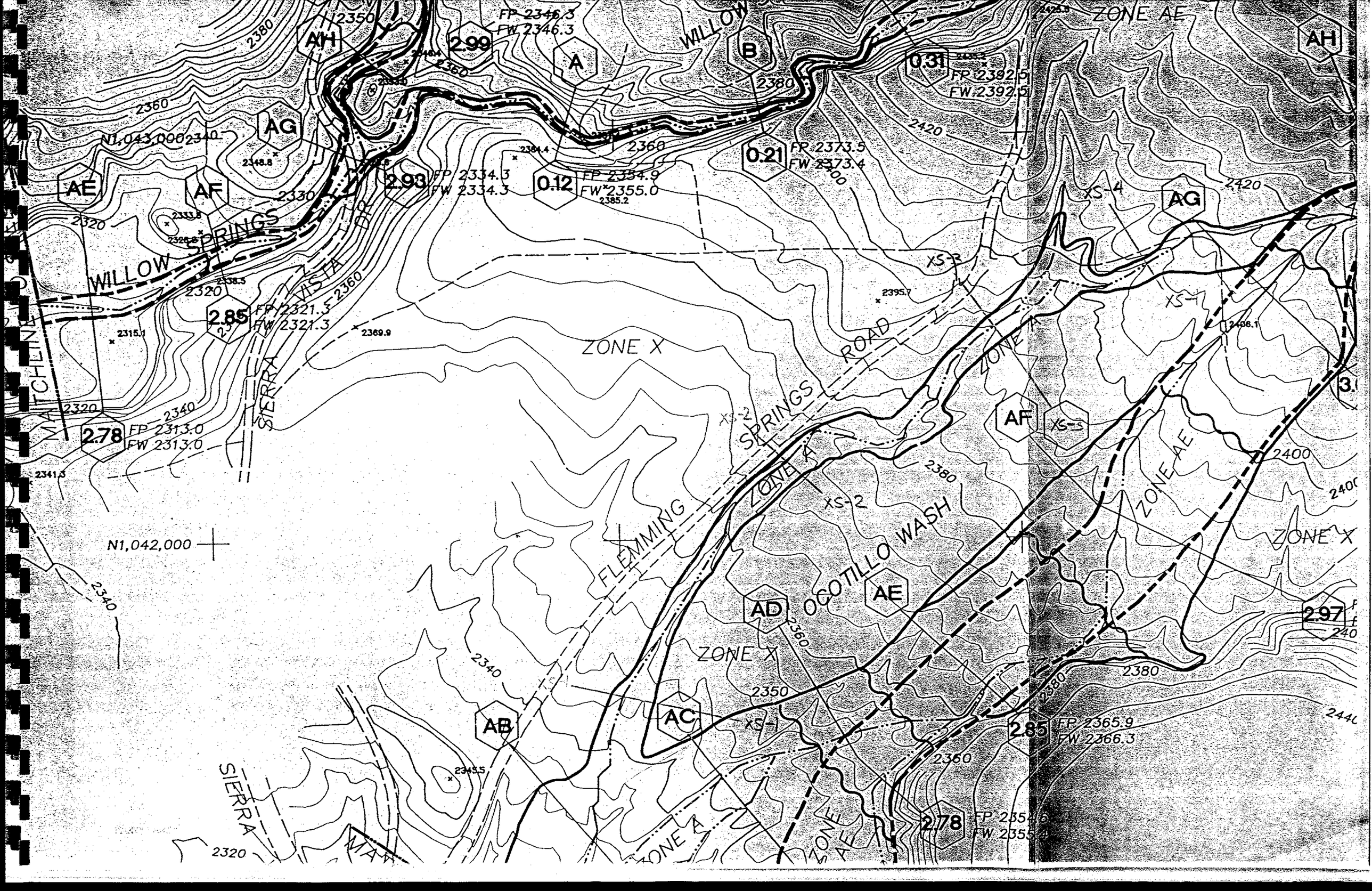
OCT TRIB 4
SEC. 600
SHEET 16-19

CHART 6



HEAD FOR
STANDARD
C. M. PIPE CULVERTS
FLOWING FULL
n = 0.024

BUREAU OF PUBLIC ROADS JAN. 1963


ZONE AE
AH
2.99
FP 2346.3
FW 2346.3
A
WILLOW
B
0.31
FP 2392.5
FW 2392.5
AG
N1,043,000
AE
AF
2.93
FP 2334.3
FW 2334.3
0.12
FP 2354.9
FW 2355.0
0.21
FP 2373.5
FW 2373.4
XS-4
WILLOW SPRINGS
SIERRA VISTA DR
2.85
FP 2321.5
FW 2321.3
ZONE X
XS-3
ROAD
SPRINGS
ZONE A
XS-2
FLEMMING
OCOTILLO WASH
AD
AC
XS-1
2.85
FP 2365.9
FW 2366.3
2.78
FP 2354.6
FW 2355.4
2.97
2.78
FP 2313.0
FW 2313.0
N1,042,000
MATCHLINE
SIERRA
ZONE AE

WILLOW SPRINGS TRIBUTARY 5
CULVERT COMPUTATION

CURRENT DATE: 06-17-1991
CURRENT TIME: 14:28:50

FILE DATE: 06-17-1991
FILE NAME: WST5

****
********** FHWA CULVERT ANALYSIS **********
********** HY-8, VERSION 3.2 **********
****

CULV #	SITE DATA: INLET ELEV. (FT)	SITE DATA: OUTLET ELEV. (FT)	SITE DATA: CULVERT LENGTH (FT)	CULVERT SHAPE, MATERIAL, INLET: BARRELS SHAPE MATERIAL	SPAN (FT)	RISE (FT)	MANNING n	INLET TYPE
1	2104.50	2102.10	50.06	3 CSP	3.50	3.50	.024	CONVENTIONAL
2	2104.50	2102.10	50.06	1 CMPA	3.50	2.42	.025	CONVENTIONAL
3								
4								
5								
6								

****

SUMMARY OF CULVERT FLOWS (CFS) FILE: WST5 DATE: 06-17-1991

ELEV (FT)	TOTAL	1	2	3	4	5	6	ROADWAY	ITR
2104.50	0	0	0	0	0	0	0	0	0
2106.60	100	76	24	0	0	0	0	0	4
2107.93	200	158	42	0	0	0	0	0	4
2109.55	300	244	56	0	0	0	0	0	4
2111.80	400	330	71	0	0	0	0	0	4
2114.69	500	413	86	0	0	0	0	0	4
2117.41	600	476	100	0	0	0	0	23	6
2117.61	631	481	100	0	0	0	0	50	4
2118.36	800	496	100	0	0	0	0	203	3
2118.71	900	502	100	0	0	0	0	297	3
2119.03	1000	500	100	0	0	0	0	398	3
2117.10	568	470	98	0	0	0	0	OVERTOPPING	

****

SUMMARY OF ITERATIVE SOLUTION ERRORS FILE: WST5 DATE: 06-17-1991

HEAD ELEV(FT)	HEAD ERROR(FT)	TOTAL FLOW(CFS)	FLOW ERROR(CFS)	% FLOW ERROR
2104.50	0.00	0	0	0.00
2106.60	0.00	100	-0	-0.02
2107.93	0.00	200	-0	-0.01
2109.55	0.00	300	-0	-0.03
2111.80	0.01	400	-0	-0.08
2114.69	-0.00	500	0	0.02
2117.41	-0.01	600	1	0.16
2117.61	-0.00	631	1	0.12
2118.36	-0.00	800	1	0.10
2118.71	-0.00	900	1	0.15
2119.03	-0.00	1000	2	0.15

****

<1> TOLERANCE (FT) = 0.010 <2> TOLERANCE (%) = 1.000

****

CURRENT DATE: 06-17-1991 FILE DATE: 06-17-1991
CURRENT TIME: 14:28:50 FILE NAME: WST5

****
********** CULVERT # 1 **********
****

PERFORMANCE CURVE FOR 3 BARREL(S)

Q (cfs)	HWE (ft)	TWE (ft)	ICH (ft)	OCH (ft)	FLOW TYPE	CCE (ft)	FCE (ft)	TCE (ft)	VO (fps)
0	2104.50	2102.10	0.00	-2.40	0-NF	0.00	2104.50	0.00	0.00
76	2106.61	2102.30	2.11	0.39	6-FF	0.00	0.00	0.00	9.94
158	2107.93	2104.20	3.43	1.69	6-FF	0.00	0.00	0.00	11.41
244	2109.55	2104.60	5.05	3.62	6-FF	0.00	0.00	0.00	12.69
330	2111.79	2104.85	7.29	6.17	6-FF	0.00	0.00	0.00	14.08
413	2114.68	2105.00	10.18	9.33	4-FF	0.00	0.00	0.00	14.32
476	2117.41	2105.20	12.91	12.03	4-FF	0.00	0.00	0.00	16.50
481	2117.61	2105.60	13.11	12.22	4-FF	0.00	0.00	0.00	16.65
496	2118.36	2106.10	13.86	13.46	4-FF	0.00	0.00	0.00	17.19
502	2118.71	2106.60	14.12	14.21	4-FF	0.00	0.00	0.00	17.38
500	2119.05	2107.00	14.06	14.55	4-FF	0.00	0.00	0.00	17.33

El. inlet face invert 2104.50 ft El. outlet invert 2102.10 ft
El. inlet throat invert 0.00 ft El. inlet crest 0.00 ft

****

***** SITE DATA ***** CULVERT INVERT **********

INLET STATION (FT)	690.00
INLET ELEVATION (FT)	2104.50
OUTLET STATION (FT)	740.00
OUTLET ELEVATION (FT)	2102.10
NUMBER OF BARRELS	3.00
SLOPE (V-FT/H-FT)	0.0480
CULVERT LENGTH ALONG SLOPE (FT)	50.06

***** CULVERT DATA SUMMARY **********

BARREL SHAPE	CIRCULAR
BARREL DIAMETER	3.50 FT
BARREL MATERIAL	CORRUGATED STEEL
BARREL MANNING'S N	0.024
INLET TYPE	CONVENTIONAL
INLET EDGE AND WALL	SQUARE EDGE WITH HEADWALL
INLET DEPRESSION	NONE

****

CURRENT DATE: 06-17-1991
CURRENT TIME: 14:28:50

FILE DATE: 06-17-1991
FILE NAME: WST5

****
********** CULVERT # 2 **********
****

PERFORMANCE CURVE FOR 1 BARREL(S)

Q (cfs)	HWE (ft)	TWE (ft)	ICH (ft)	OCH (ft)	FLOW TYPE	CCE (ft)	FCE (ft)	TCE (ft)	VO (fps)
0	2104.50	2102.10	0.00	-2.40	0-NF	0.00	2104.50	0.00	0.00
24	2106.60	2102.30	2.10	0.15	6-FF	0.00	0.00	0.00	9.30
42	2107.92	2104.20	3.42	1.84	6-FF	0.00	0.00	0.00	10.44
56	2109.55	2104.60	5.05	3.94	4-FF	0.00	0.00	0.00	8.28
71	2111.79	2104.85	7.29	6.48	4-FF	0.00	0.00	0.00	10.46
86	2114.69	2105.00	10.19	9.66	4-FF	0.00	0.00	0.00	12.79
100	2117.41	2105.20	12.91	12.91	4-FF	0.00	0.00	0.00	15.36
100	2117.86	2105.60	12.95	13.36	4-FF	0.00	0.00	0.00	15.38
100	2118.39	2106.10	12.97	13.89	4-FF	0.00	0.00	0.00	15.40
100	2118.86	2106.60	12.95	14.36	4-FF	0.00	0.00	0.00	15.39
100	2119.26	2107.00	12.95	14.76	4-FF	0.00	0.00	0.00	15.39

El. inlet face invert 2104.50 ft El. outlet invert 2102.10 ft
El. inlet throat invert 0.00 ft El. inlet crest 0.00 ft

****

***** SITE DATA ***** CULVERT INVERT **********

INLET STATION (FT)	690.00
INLET ELEVATION (FT)	2104.50
OUTLET STATION (FT)	740.00
OUTLET ELEVATION (FT)	2102.10
NUMBER OF BARRELS	1.00
SLOPE (V-FT/H-FT)	0.0480
CULVERT LENGTH ALONG SLOPE (FT)	50.06

***** CULVERT DATA SUMMARY **********

BARREL SHAPE	PIPE ARCH
BARREL SPAN	42.00 FT
BARREL RISE	29.00 FT
BARREL MATERIAL	STEEL OR ALUMINUM
BARREL MANNING'S N	0.025
INLET TYPE	CONVENTIONAL
INLET EDGE AND WALL	PROJECTING
INLET DEPRESSION	NONE

****

CURRENT DATE: 06-17-1991
CURRENT TIME: 14:28:50

FILE DATE: 06-17-1991
FILE NAME: WST5

****
********** TAILWATER **********
****
****

TAILWATER RATING CURVE

FLOW(CFS)	W.S.E.(FT)
0	2102.10
100	2102.30
200	2104.20
300	2104.60
400	2104.85
500	2105.00
600	2105.20
631	2105.60
800	2106.10
900	2106.60
1000	2107.00

****
********** ROADWAY OVERTOPPING DATA **********
****

ROADWAY SURFACE	GRAVEL
EMBANKMENT TOP WIDTH (FT)	30.00
CREST LENGTH (FT)	50.00
OVERTOPPING CREST ELEVATION (FT)	2117.10

****

Engineers
Planners
Economists
Scientists

FLOOD CONTROL DISTRICT
RECEIVED
SEP 2 3 199

September 25, 1991

PHX27815.AM

Ms. Jan Opstein
Flood Control District of Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

Dear Ms. Opstein:

Subject: Cave Creek/Carefree FIS

As you requested, I have prepared a brief summary of the results of the hydraulic analysis of the culverts in the study reaches of this project. Following discussions with FEMA's review contractor. I identified an error in the velocity calculations for Ocotillo Wash Tributary 4 (OCT. 4). The velocity shown in the October 1, 1990, letter for this culvert was 2.94 ft/s. The corrected velocity is 11.7 ft/s.

I believe the attached discussion and summary table will provide the information requested by the review contractor.

If you have any questions, please give me a call.

Sincerely,

CH2M HILL

Steven R. Walker, P.E.
Project Manager

Attachment

PHXC16.164.51

Culvert Hydraulics

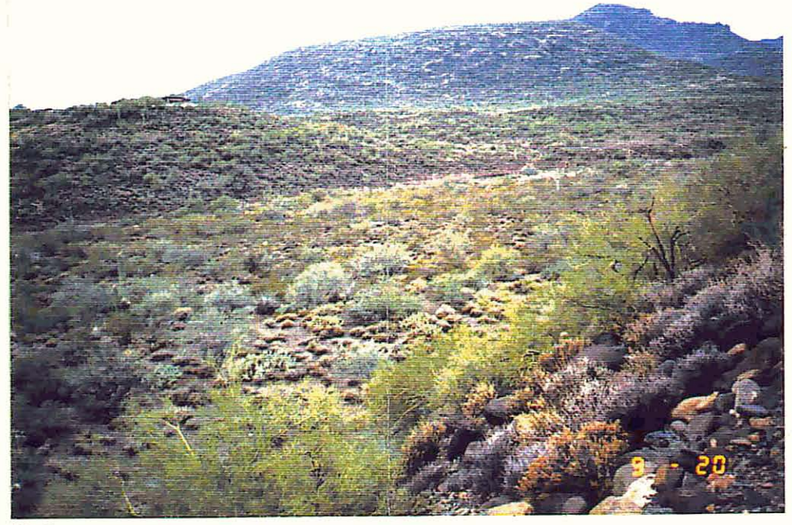
The hydraulic computations for the culverts in the study area were initially prepared using manual calculations. As described in the letter to Jan Farmer dated October 1, 1990, the calculations followed the procedure described in *Hydraulic Engineering Circular No. 5* entitled "Hydraulic Design of Highway Culverts." The calculations for the culvert at Section 700 of Willow Springs Tributary 5 were subsequently revised using the FHWA Culvert Analysis computer program HY-8. The computations were submitted in a letter dated August 23, 1991.

Outlet velocities were estimated for each culvert. For culverts flowing full under outlet control conditions velocity was estimated using the equation $V = Q/A$. Velocities for culverts under inlet control were estimated using normal depth or tailwater depth, which ever was higher. The attached table summarizes the results of the computations.

Culvert Summary								
Stream	**Cross-section**	**Culvert Description**	**Q_{100} (cfs)**	**Q_{100} Pipe (cfs)**	**Q_{100} Weir (cfs)**	**Is Outlet Submerged**	**Outlet Velocity (ft/s)**	**100-yr. WSE**
OCT. 3	280 460	1 - 3' CMP 3 - 3' CMP	296 296	131 180	165 116	No No	10.4 3.5	2209.23 2226.67
OCT. 4	600	1 - 3' CMP	83	83	0	Yes	11.7	2215.17
WST. 5	700	3 - 3.5' CMP 1-29" x 42" CMPA	631	481 100	50	Yes Yes	16.65 15.36	2117.61 2117.61

Ph 1

Section 34.70, Upstrm, N_{CH} = 0.05, N_{OB} = 0.07



Ph 2

Section 35.37, Upstrm, N_{CH} = 0.045, N_{OB} = 0.055

Ph 3

Section 35.37, Dnstrm, N_{CH} = 0.06, N_{OB} = 0.06

Ph 4

Section 35.37, Dnstrm, N_{CH} = 0.06, N_{OB} = 0.06

Ph 5

Section 36.33, Dnstrm, N_{CH} = 0.08, N_{OB} = 0.065

Ph 6

Section 36.33, Upstrm, N_{CH} = 0.08, N_{OB} = 0.065

MCFCD
CAVE CREEK - FIS

CAVE CREEK

PHOTO DATE: 10-4-89 (ROLLS 1,2)
PROJECT: LAO27815.H2

Ph 41

Section 2.35, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.045

Ph 42

Section 2.70, Upstrm, N_{CH} = 0.035, N_{OB} = 0.05

Ph 43

Section 2.95, Upstrm, N_{CH} = 0.04, N_{OB} = 0.045

Ph 44

Section 3.08, Dnstrm, N_{CH} = 0.045, N_{OB} = 0.06

Ph 45

Section 3.30, Upstrm, N_{CH} = 0.04, N_{OB} = 0.055

Ph 46

Section 3.55, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.055

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH

PHOTO DATE: 10-9-89 (ROLLS 6,7)
PROJECT: LAO27815.H2

Ph 35

Section 1.70, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.045

Ph 36

Section 1.75, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045
Narrows

Ph 37

Section 1.75, Dnstrm, N_{CH} = 0.025, N_{OB} = 0.045
Narrows

Ph 38

Section 1.85, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045

Ph 39

Section 1.93, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045
at Confluence Trib. 2 / Trib. 3

Ph 40

Section 2.35, Upstrm, N_{CH} = 0.03, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH

PHOTO DATE: 10-9-89 (ROLL 6)
PROJECT: LAO27815.H2

Ph 15

Section 0.00, Upstrm, N_{CH} = 0.03, N_{OB} = 0.05
Confluence Cottonwood Wash/Cave Creek

Ph 16

Section 0.30, Upstrm, N_{CH} = 0.03, N_{OB} = 0.05

Ph 17

Section 0.88, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 18

Section 0.88, Upstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 19

Section 1.40, Upstrm, N_{CH} = 0.045, N_{OB} = 0.065

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CAVE CREEK - FIS

COTTONWOOD WASH

PHOTO DATE: 10-4-89 (ROLL 2)
PROJECT: LAO27815.H2

Ph 91

Section 0.29, Upstrm, N_{CH} = 0.032, N_{OB} = 0.04

Ph 92

Section 0.29, Dnstrm, N_{CH} = 0.032, N_{OB} = 0.04

Ph 93

Section 0.54, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 94

Section 0.54, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
TRIBUTARY 1A

PHOTO DATE: 10-5-89 (ROLLS 4,5)
PROJECT: LAO27815.H2

Ph 12

Section 37.65, Upstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 13

Section 37.65, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 14

Section 38.70, Dnstrm, N_{CH} = 0.06, N_{OB} = 0.065

Ph 7

Section 36.60, Upstrm, N_{CH} = 0.08, N_{OB} = 0.065

Ph 8

Section 36.60, Dnstrm, N_{CH} = 0.08, N_{OB} = 0.065

Ph 9

Section 36.95, Upstrm, N_{CH} = 0.08, N_{OB} = 0.065
Dnstrm Constriction /Upstrm Ineffective Flow

Ph 10

Section 37.40, Upstrm, N_{CH} = 0.035, N_{OB} = 0.065
Gauging Station

Ph 11

Section 37.40, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.065

MCFCD
CAVE CREEK - FIS

CAVE CREEK

PHOTO DATE: 10-4-89 (ROLL 2)
PROJECT: LAO27815.H2

Ph 20

Section 0.70, Upstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 21

Section 0.70, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 22

Section 0.70, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.065

Ph 23

Section 0.90, Upstrm, N_{CH} = 0.03, N_{OB} = 0.05

Ph 24

Section 0.90, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.05

Ph 25

Section 1.90, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.05

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 1

PHOTO DATE: 10-4-89 (ROLLS 1,2)
PROJECT: LAO27815.H2

Ph 47

Section 3.81, Upstrm, N_{CH} = 0.04, N_{OB} = 0.055

Ph 48

Section 3.93, Upstrm, N_{CH} = 0.04, N_{OB} = 0.055

Ph 135

Section 3.04, Dnstrm, Nch = 0.04, Nob = 0.05

Ph 136

Section 3.04, Upstrm, Nch = 0.04, Nob = 0.05

Ph 137

Section 3.60, Upstrm, Nch = 0.048, Nob = 0.055

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 1

PHOTO DATE: 12-29-89 (ROLL 9)
PROJECT : RDD27815.H2

Ph 26

Section 2.10, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.04

Ph 27

Section 2.10, Upstrm, N_{CH} = 0.03, N_{OB} = 0.04

Ph 28

Section 2.17, Upstrm, N_{CH} = 0.035, N_{OB} = 0.04
Nick-Point

Ph 29

Section 2.30, Upstrm, N_{CH} = 0.03, N_{OB} = 0.04

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH

TRIBUTARY 1

PHOTO DATE: 10-4-89 (ROLL 3)
PROJECT: LAO27815.H2

Ph 30

Section, 0.00, Upstrm, N_{CH} = 0.03, N_{OB} = 0.04
at Confluence Trib. 2 / Trib. 3

Ph 31

Section 0.10, Upstrm, N_{CH} = 0.03, N_{OB} = 0.04

Ph 32

Section 0.30, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.04

Ph 33

Section 0.10, Upstrm, N_{CH} = 0.045, N_{OB} = 0.05
TRIBUTARY 2A

Ph 34

Section 0.40, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.05
TRIBUTARY 2A

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 2 & 2A

PHOTO DATE: 10-6-89 (ROLL 6)
PROJECT: LAO27815.H2

Ph 138

Section -0.02, Upstrm. Nch = 0.03, Nob = 0.04
(Below Confluence; at Spur-X Rd.)

Ph 139

Section 0.20 Dnstrm. Nch = 0.028, Nob = 0.045
Confluence w/ Minor Stream. River Lt.

Ph 140

Section 0.20, Upstrm. Nch = 0.035, Nob = 0.045

Ph 141

Section 0.33, Upstrm. Nch = 0.045, Nob = 0.055

Ph 142

Section 0.60, Upstrm. Nch = 0.05, Nob = 0.06

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 1A

PHOTO DATE: 12-29-89 (ROLL 9)
PROJECT : 100027815.H2

Ph 49

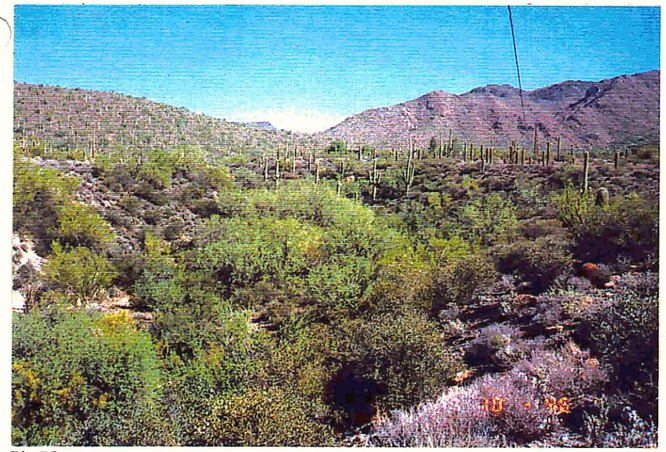
Section 0.00, Upstrm, N_{CH} = 0.04, N_{OB} = 0.05

Ph 50

Section 0.13, Upstrm N_{CH} = 0.04, N_{OB} = 0.05
Dip Crossing
Lower Part Passes Through Incised Rock

Ph 51

Section 0.35, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.05

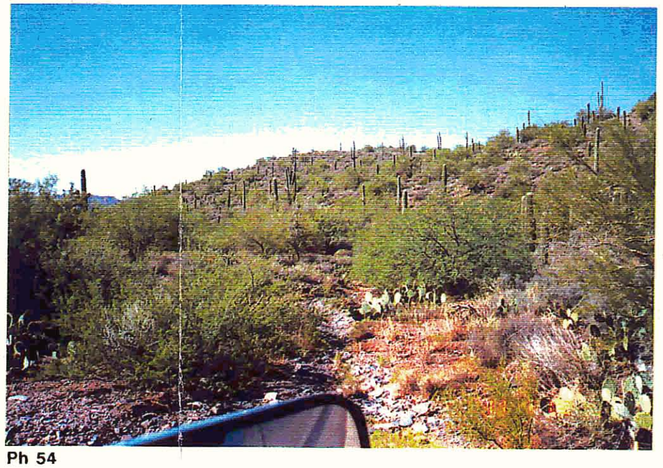


Ph 52

Section 0.35, Upstrm, N_{CH} = 0.04, N_{OB} = 0.05

Ph 53

Section 0.64, Upstrm, N_{CH} = 0.04, N_{OB} = 0.05



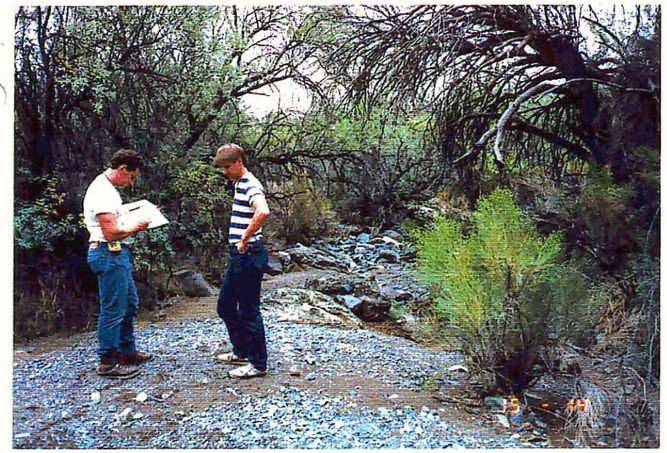
Ph 54

Section 1.13, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.05

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 4

PHOTO DATE: 10-9-89 (ROLLS 6,7)
PROJECT: LAO27815.H2



Ph 55

Section 0.00, Upstrm, N_{CH} = 0.05, N_{OB} = 0.06

Ph 56

Section 0.21, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.05

Ph 57

Section 0.46, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.05

Ph 58

Section 0.69, Upstrm, Culverts

Ph 59

Section 0.69, Upstrm, Culverts

Ph 60

Section 0.79, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045
Dnstrm Culverts Visible

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 5

PHOTO DATE: 10-4-89 (ROLL 3)
PROJECT: LAO27815.H2

Ph 61

Section 0.80, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 62

Section 0.89, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 63

Section 0.89, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 64

Section 1.04, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 65

Section 1.15, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

WILLOW SPRINGS WASH
TRIBUTARY 5

PHOTO DATE: 10-4-89 (ROLL 3)
PROJECT: LAO27815.H2

Ph 149

Section 0.47. ACROSS. Nch = 0.045. Nob = 0.06

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CAVE CREEK - FIS

FLEMING SPRINGS WASH
TRIBUTARY 1

PHOTO DATE: 12-29-89 (ROLL 9)
PROJECT : E0027815.N2

Ph 143

Section 0.01, Dnstrm. Nch = 0.038, Nob = 0.055
CONFLUENCE W/ WST3: 24" CMP, 12' RCP
ROAD IS 1.0' ABOVE CROWN

Ph 144

Section 0.24, UPstrm. Nch = 0.045, Nob = 0.055

Ph 145

Section 0.33, Dnstrm. Nch = 0.045, Nob = 0.06

Ph 146

Section 0.33, UPstrm. Nch = 0.045, Nob = 0.06
30" CMP CULVERT (RD. IS 3.0' ABOVE CROWN)

Ph 147

Section 0.33, UPstrm. Nch = 0.045, Nob = 0.06

Ph 148

Section 0.47, Dnstrm. Nch = 0.045, Nob = 0.06

MCFCD
CAVE CREEK - FIS

FLEMING SPRINGS WASH
TRIBUTARY 1

PHOTO DATE: 12-29-89 (ROLL 9)
PROJECT : [illegible]27815.H2

Ph 66

Section 1.60, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 67

Section 1.60, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 68

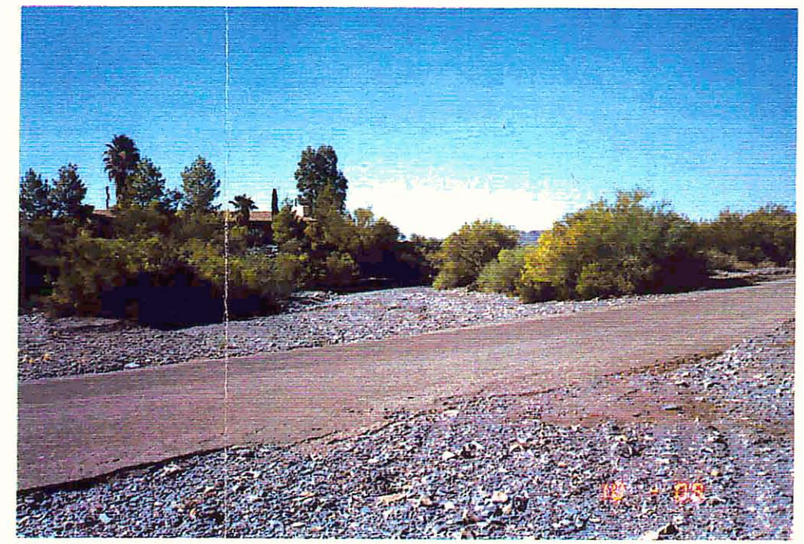
Section 1.75, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 69

Section 1.75, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 70

Section 1.88, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045



Ph 71

Section 1.88, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
MAIN

PHOTO DATE: 10-5-89 (ROLL 3)
PROJECT: LAO27815.H2

Ph 72

Section 2.08, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045
Ineffective Flow Area

Ph 73

Section 2.10, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045
East Braid Above Confluence

Ph 74

Section 2.10, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045
East Braid Above Confluence

Ph 75

Section 2.10, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045
Below Confluence

Ph 76

Section 2.50, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045
East Braid

Ph 77

Section 2.83, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045
East Braid

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
MAIN

PHOTO DATE: 10-5-89 (ROLLS 3,4,5)
PROJECT: LAO27815.H2

Ph 78

Section 2.83, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 79

Section 3.00, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.05
Upper West Braid

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
MAIN

PHOTO DATE: 10-6-89 (ROLL 6)
PROJECT: LAO27815.H2

Ph 80

Section 2.10, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 81

Section 2.20, Upstrm, N_{CH} = 0.04, N_{OB} = 0.045
Right Bank

Ph 82

Section 2.20, Upstrm, N_{CH} = 0.04, N_{OB} = 0.045
Left Bank

Ph 83

Section 2.20, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.045
Left Bank

Ph 84

Section 2.20, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.045
Across Section

Ph 85

Section 2.50, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.055

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
LOWER WEST BRAID

PHOTO DATE: 10-5-89 (ROLLS 4,6)
PROJECT: LAO27815.H2

Ph 86

Section 2.50, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.055
East Braid

Ph 87

Section 2.82, Dnstrm, N_{CH} = 0.03, N_{OB} = 0.05
West Side at Biforkation

Ph 88

Section 0.00, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045
at Confluence Main/Trib. 1

Ph 89

Section 0.73, Upstrm, N_{CH} = 0.04, N_{OB} = 0.045

Ph 90

Section 0.73, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
LOWER WEST BRAID & TRIB.1

PHOTO DATE: 10-6-89 (ROLL 6)
PROJECT: LAO27815.H2

Ph 95

Section 0.00, Upstrm, N_{CH} = 0.04, N_{OB} = 0.05 at Confluence Main/Trib. 2

Ph 96

Section 0.34, Upstrm, N_{CH} = 0.045, N_{OB} = 0.045

Ph 97

Section 0.34, Dnstrm, N_{CH} = 0.045, N_{OB} = 0.045

Ph 98

Section 0.34, Dnstrm, N_{CH} = 0.045, N_{OB} = 0.045 Well Shack

Ph 99

Section 0.60, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.04

Ph 100

Section 0.60, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
TRIBUTARY 2

PHOTO DATE: 10-5-89 (ROLLS 3,4)
PROJECT: LAO27815.H2

Ph 101

Section 0.47, Dnstrm, N_{CH} = 0.055, N_{OB} = 0.055

Ph 102

Section 0.47, Dnstrm, N_{CH} = 0.055, N_{OB} = 0.055

Ph 103

Section 0.47, Upstrm from Crossing

Ph 104

Section 0.68, Dnstrm Culvert

Ph 105

Section 0.86, Dnstrm, N_{CH} = 0.045, N_{OB} = 0.055

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
TRIBUTARY 3

PHOTO DATE: 10-5-89 (ROLL 5)
PROJECT: LAO27815.H2

Ph 106

Section 0.00, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 107

Section 0.28, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045

Ph 108

Section 0.55, Upstrm, N_{CH} = 0.04, N_{OB} = 0.05

Ph 109

Section 0.55, Dnstrm, N_{CH} = 0.04, N_{OB} = 0.05

Ph 110

Section 0.59, Upstrm, N_{CH} = 0.04, N_{OB} = 0.05

36" CMP Culvert w/90 Degree Headwall

Ph 111

Section 0.60, Dnstrm

36" CMP Culvert w/90 Degree Headwall

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
TRIBUTARY 4

PHOTO DATE: 10-6-89 (ROLL 5)
PROJECT: LAO27815.H2

Ph 112

Section 0.84, Dnstrm, N_{CH} = 0.045, N_{OB} = 0.045
Second Road Crossing

Ph 113

Section 0.84, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045
Second Road Crossing

Ph 114

Section 0.89, Dnstrm, N_{CH} = 0.025, N_{OB} = 0.045
First Road Crossing

Ph 115

Section 0.89, Upstrm, N_{CH} = 0.045, N_{OB} = 0.045
First Road Crossing

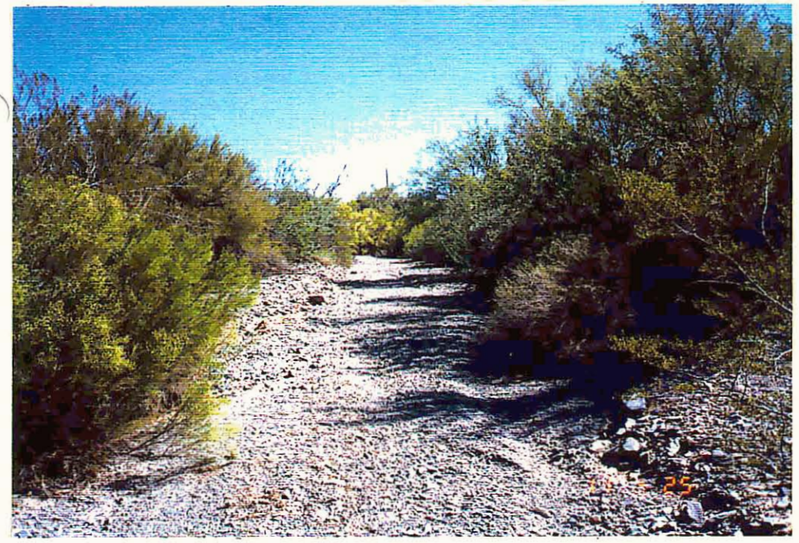
Ph 116

Section 1.12, Dnstrm, N_{CH} = 0.045, N_{OB} = 0.045

MCFCD
CAVE CREEK - FIS

OCOTILLO WASH
TRIBUTARY 4

PHOTO DATE: 10-6-89 (ROLL 5)
PROJECT: LAO27815.H2

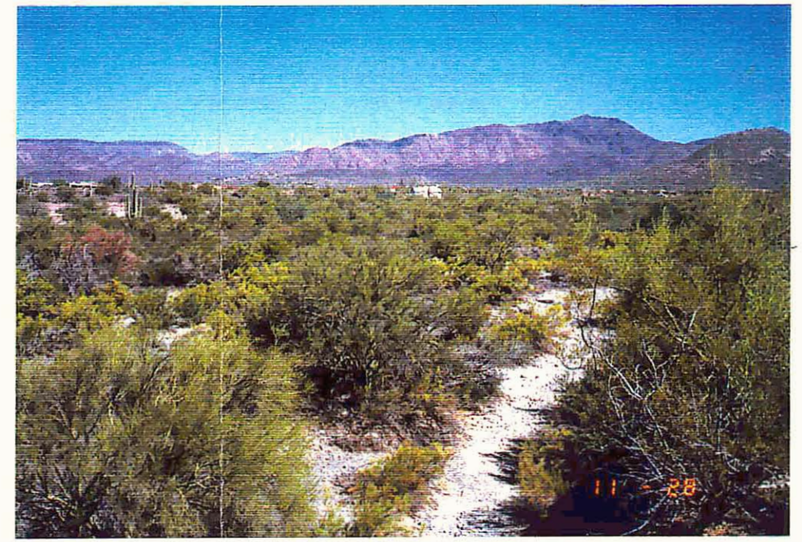


Ph 117

Section 1.10, Dnstrm, N_{CH} = 0.025, N_{OB} = 0.045

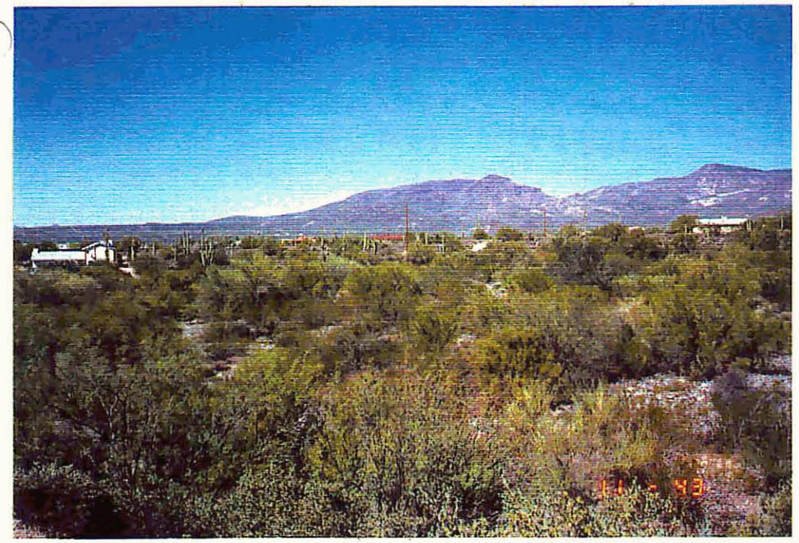
Ph 118

Section 1.10, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045



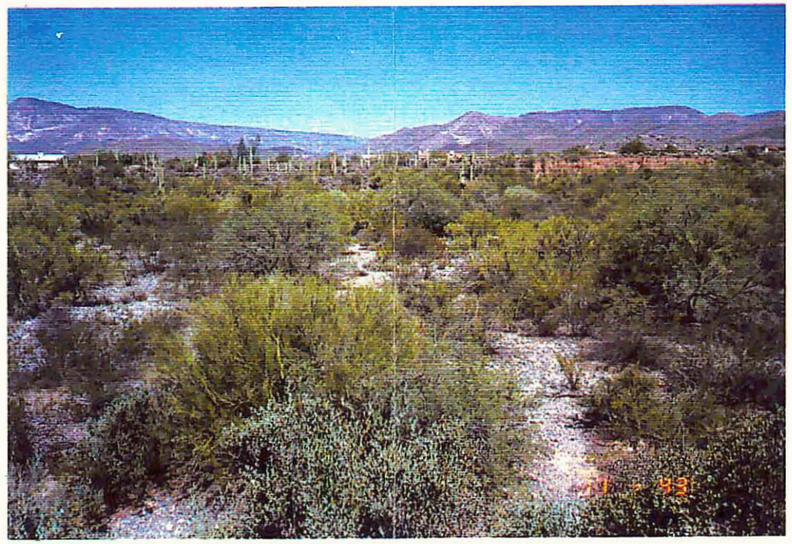
Ph 119

Section 1.15, Upstrm, N_{CH} = 0.035, N_{OB} = 0.045
All 3 Braids



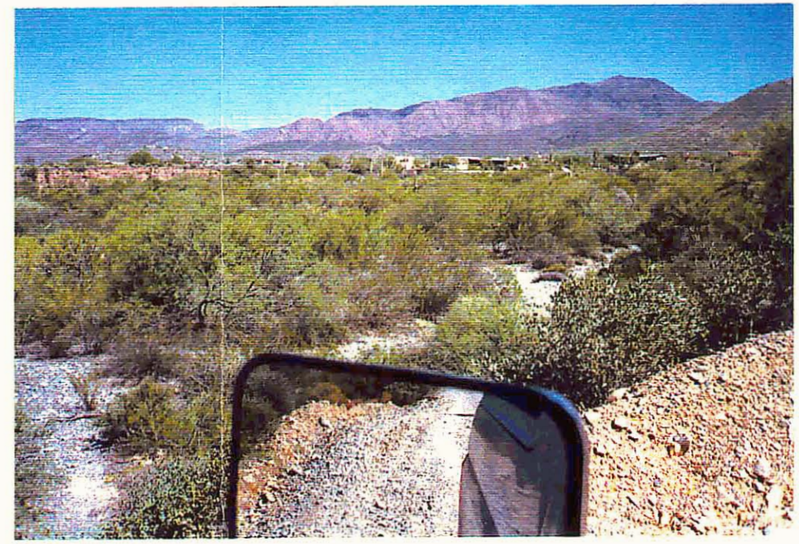
Ph 120

Section 1.34, Dnstrm, N_{CH} = 0.032, N_{OB} = 0.05



Ph 121

Section 1.34, Across, N_{CH} = 0.032, N_{OB} = 0.05



Ph 122

Section 1.34, Upstrm, N_{CH} = 0.032, N_{OB} = 0.05

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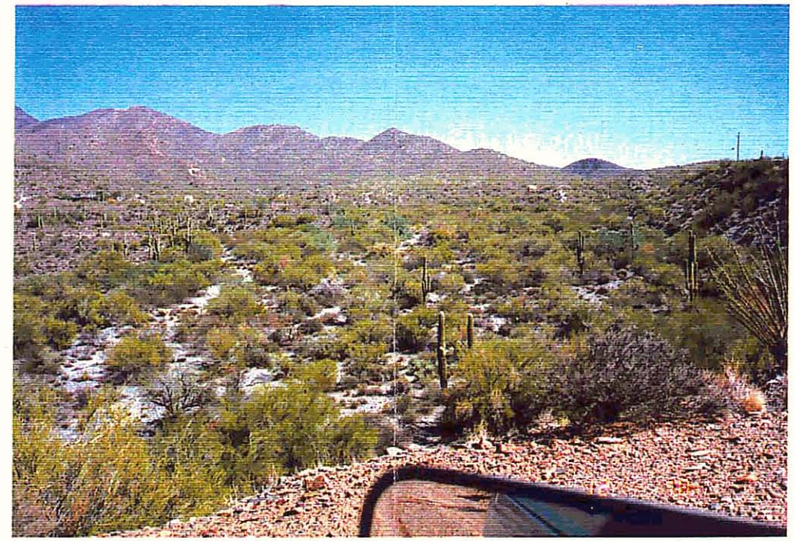
CAVE CREEK - FIS

ROWE WASH
MAIN

PHOTO DATE: 10-9-89 (ROLL 7)
PROJECT: LAO27815.H2

Ph 123

Section 1.90, Dnstrm, N_{CH} = 0.035, N_{OB} = 0.05

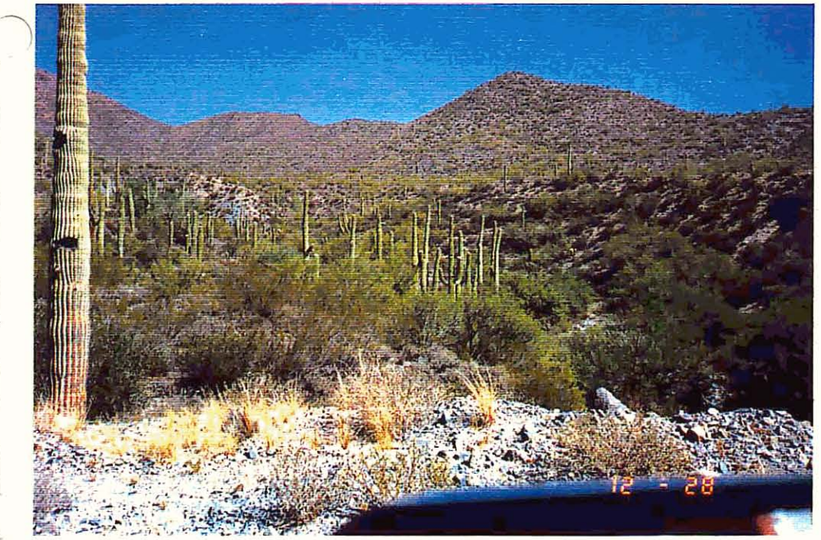


Ph 124

Section 2.35, Upstrm, N_{CH} = 0.035, N_{OB} = 0.05
Grapevine/Rowe Confluence

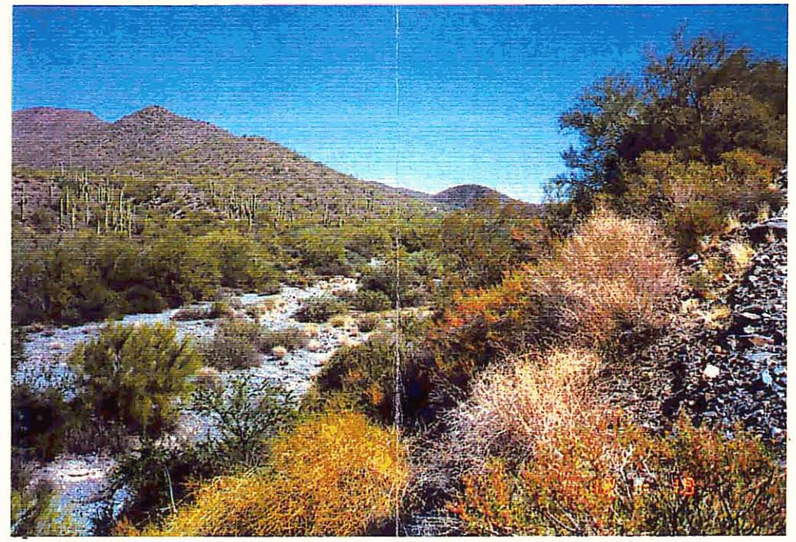
Ph 125

Section 3.04, Upstrm, N_{CH} = 0.035, N_{OB} = 0.05



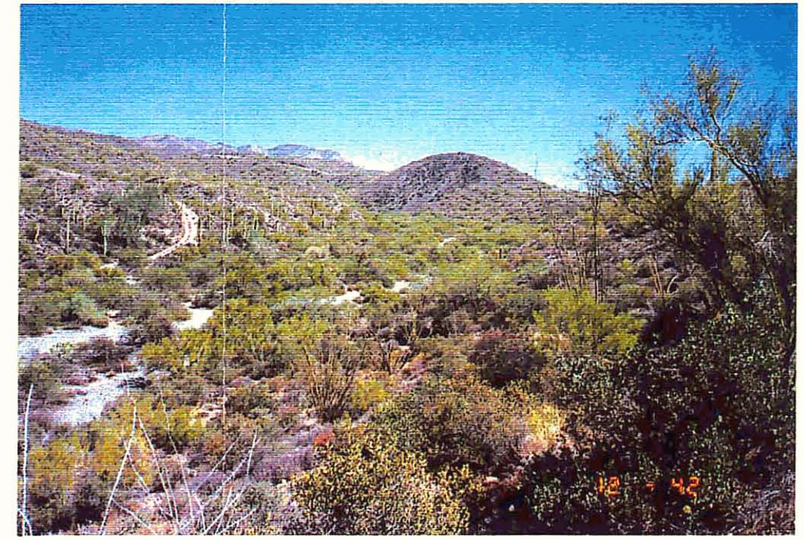
Ph 126

Section 3.05, Upstrm, N_{CH} = 0.045, N_{OB} = 0.05
Rowe Trib. 1/Main Confluence



Ph 127

Section 0.33, Upstrm, N_{CH} = 0.03, N_{OB} = 0.05
Grapevine Wash



Ph 128

Section 1.00, Upstrm, N_{CH} = 0.03, N_{OB} = 0.05
Grapevine Wash

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CAVE CREEK - FIS

ROWE WASH
MAIN & GRAPEVINE WASH

PHOTO DATE: 10-9-89 (ROLL 7)
PROJECT: LAO27815.H2

Ph 129

Section 0.35, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045

Ph 130

Section 0.35, Dnstrm, N_{CH} = 0.025, N_{OB} = 0.045

Ph 131

Section 2.00, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045

Ph 132

Section 2.50, Upstrm, N_{CH} = 0.025, N_{OB} = 0.045

Ph 133

Section 2.50, Dnstrm, N_{CH} = 0.025, N_{OB} = 0.045

Ph 134

Section 3.38, Dnstrm, N_{CH} = 0.025, N_{OB} = 0.045
Upstrm Limit

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GALLOWAY WASH
NORTH TRIBUTARY

PHOTO DATE: 10-9-89 (ROLLS 7,8)
PROJECT: LAO27815.H2