2383

SULPHUR CREEK BASIN

Hydrologic Investigation

Rio Blanco County, Colorado

Meeker Area

March 1992

Colorado Department of Natural Resources

Colorado Water Conservation Board

Flood Control and Floodplain Management Section

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PURPOSE FOR THE STUDY

The Sulphur Creek Hydrology Study was performed by the Colorado Water Conservation Board (CWCB) to address a number of concerns which have been expressed by officials for the Town of Meeker, Colorado. These concerns resulted from findings in the preliminary design phase for the "Sulphur Creek Flood Control Project" at Meeker, Colorado. At the request of the officials in Meeker and Rio Blanco County, Colorado, the CWCB initiated the evaluation of the Sulphur Creek Basin hydrology on January 2, 1992.

SCOPE OF INVESTIGATION

An investigation was proposed that would review existing, related basin studies; evaluate the hydrologic parameters for the basin; and select an applicable hydrologic analysis procedure/method. No stream gage records exist for Sulphur Creek. Therefore, the investigation should be performed under a regional analysis or a synthetic rainfall-runoff model procedure/method. In addition, the basin is a rural, agricultural one; therefore, the USDA Soil Conservation Service TR-20 Computer Program for Project Formulation was determined to be an applicable model for use given the basin conditions in Rio Blanco County, Colorado.

DESCRIPTION OF STUDY BASIN

The Sulphur Creek drainage basin extends about 10 miles north of Meeker; averages about 3 miles in width; and is 22.2 square miles in area. It rises from 6800 feet at the town's north boundary to elevations above 8000 feet at the upper end of the watershed. The ground cover is primarily sage and oak brush with some aspen, juniper and pinon at higher elevations. There is also some crop and grazing land in the valleys. Cover conditions range from good in the upper reaches of the watershed to fair-poor in the lower reaches. Sulphur Creek has one major tributary, Four Mile Gulch, which drains about one-fourth of the basin.

Local residents have experienced overbank flooding from Sulphur Creek on a number of occasions. For the Town of Meeker stream reach, the natural drainage path flowed diagonally through the Town before it was realigned along Second Street in the early 1900's. Local residents have stated that the 1896, 1918, 1937 and 1957 flood events were the result of excess precipitation or thunderstorms in the hills north of the Town.

The soil types in the basin area vary from rock outcrops to sandy loams. The hydrologic classifications are B's, C's and D's. Each sub-basin has a varying percentage of soil types and classifications. In Table No. 1, the curve numbers are presented for the sub-basin soil types and vegetative cover conditions. Percentages were computed for each sub-basin and are presented in Table 2. A weighted CN value was computed for each sub-basin.

RELATED HYDROLOGY STUDIES

A number of hydrologic studies have been performed for the Sulphur Creek Basin. These studies were completed using methodologies which may have been applicable at the time they were performed. The methods and input parameters used for those studies were reviewed in the CWCB's 1992 investigation. After the previous studies had been examined, it was determined that a new hydrologic study was justified.

The following reports are known to exist for the basin.

- "Sulphur Creek Hydrology" dated November 21, 1969 by USDA - Soil Conservation Service, Meeker Area Office.
- "Hydrology For Flood Plain Information Report, White River, Sulphur Creek, Sanderson Heights, Meeker Colorado" dated August, 1976 by Merrick and Company.
- "Draft Hydrology, Sulphur Creek Basin" dated April, 1977 by Merrick and Company. Note: Same values published in Floodplain Information Report dated June, 1978.

Copies of these reports are presented in the Technical Addendum for the CWCB's March, 1992 Sulphur Creek hydrologic report.

Table 2-2a.—Runoff curve numbers for urban areas[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type and hydrologic condition	Average percent impervious area[2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.)[3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only)[4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation)[5]		77	86	91	94
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

[1]Average runoff condition, and $I_a = 0.2S$.
[2]The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
[3]CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open-space cover type.
[4]Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
[5]Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4, based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2d.—Runoff curve numbers for arid and semiarid rangelands[1]

Cover description		Curve numbers for hydrologic soil group—			
Cover type	Hydrologic condition[2]	A[3]	B	C	D
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both; grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[1]Average runoff condition, and $I_a = 0.2S$. For range in humid regions, use table 2-2c.
[2]*Poor:* <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: >70% ground cover.
[3]Curve numbers for group A have been developed only for desert shrub.

Source: SCS TR55 Manual

Table 2
Hydrologic Sub basin CN Determinations

Sub-basin I

Index No.	% of basin	Soil Name	Hydrologic Soil Group	CN
51	30	Merged-Redthayne-Dollard	B	50
80	8	Shawa loam	B	50
91	0	Torriorthents - (Rock Outcrop)	D	91
48	2	Kobar Silty Clay loam	C	67
45	60	Jerry Thornburgh-Rhone	C	67
			Weighted Average	**61**

Sub-basin II

Index No.	% of basin	Soil Name	Hydrologic Soil Group	CN
48	4	Kobar Silty Clay	C	73
80	10	Shawa loam	B	58
10	29	Blazon	D	80
51	25	Mergel-Redthayne-Dollard	B	58
45	30	Jerry-Thornburgh-Rhone	C	73
91	2	Torriorthents-(Rock Outcrop)	D	80
			Weighted Average	**71**

Sub-basin III

Index No.	% of basin	Soil Name	Hydrologic Soil Group	CN
48	9	Kobar Silty Clay	C	79
10	50	Blazon	D	85
51	18	Mergel-Redthayne-Dollard	B	67
61	4	Patent loam	C	79
45	19	Jerry-Thornburgh -Rhone	C	79
			Weighted Average	**80**

Sub-basin IV

Index No.	% of basin	Soil Name	Hydrologic Soil Group	CN
10	5	Blazon	D	82
45	47	Jerry-Thornburgh-Rhone	C	76
51	40	Mergel-Redthayne-Dollard	B	64
82	2	Silas loam	B	64
91	6	Torreorthents-(Rock Outcrop)	D	91
			Weighted Average	**73**

Sub-basin V

Index No.	% of basin	Soil Name	Hydrologic Soil Group	CN
51	39	Mergel-Redthayne-Dollard	B	59
10	11	Blazon	D	78
48	14	Kobar Silty Clay	C	71
31,49	12	Ballard-Kobar Silty Clay	C	71
45	12	Jerry-Thornburgh-Rhone	C	71
107,108	12	Zoltary Clay	C	71
			Weighted Average	**66**

Sub-basin VI

Index No.	% of basin	Soil Name	Hydrologic Soil Group	CN
47,48	15	Kobar Silty Clay	C	63
91		Torriorthents	D	91
61,63	18	Patent loam	C	63
10	40	Blazon	D	70
45,31		Jerry loam, Bollard Clay		
33	17	Fordle loam	C	63
Urban	10	Development (1/3 Acre lots comm, - gravel)	C	83
			Weighted Average	**68**

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BASIN MAP

The drainage basin was divided into six sub-basins for the hydrologic analysis for the Sulphur Creek Basin. The sub-basins were determined by their respective drainage characteristics and runoff patterns. USGS quad sheets for the basins were used for making these determinations. The basin drainage and its sub-basins are shown in Exhibit No. 1. The drainage areas for each sub-basin are presented in Table III.

TABLE III
SULPHUR CREEK BASIN
SUB-BASIN DRAINAGE AREAS

Sub-Basin No.	Drainage Area
I	6.3
II	7.1
III	2.9
IV	1.1
V	3.4
VI	1.4

FIELD REVIEWS

Field inspections were conducted by the CWCB staff in consultation with the USDA Soil Conservation Service, Meeker, Colorado area office. During these field inspections the vegetative cover was studied; drainage patterns noted; grazing habits noted; and channel and valley cross sections obtained. These basin characteristics were essential parameters for the development of a hydrologic rainfall-runoff model.

HYDROLOGIC ANALYSIS

Following a review of rainfall-runoff models and regional methods, the CWCB selected the USDA, SCS computer program TR-20 which was run on an in-house PC for the analysis. The hydrologic analysis was undertaken to determine peak discharges for the 10, 25, 50, and 100-year flood frequencies.

The TR-20 model computer routes runoff hydrographs for selected sub-basins at designated design points. These design points were placed at locations which were representative for the basin runoff patterns. The 7.5 Minute Quadrangle Maps at a scale of 1:24,000 were used to complement the field data for developing the input data for the determination of the runoff patterns and characteristics and sub-basin hydrographs.

The rainfall values which were used were obtained from the "Precipitation-Frequency Atlas of the Western United States", NOAA ATLAS 2, Volume III for a 24 hour storm event. The May-October precipitation values were used for the analysis. These values were selected because the values are representative of a summer rainfall event which has been the history of flood events for the basin. The rainfall values are shown in Table IV. The Type II storm distribution was used for the analysis.

TABLE IV
SULPHUR CREEK BASIN
RAINFALL VALUES
for
May - October
(in inches)

10-year	1.7*
25-year	2.0
50-year	2.2
100-year	2.4

* Note: Value adjusted for consistences of input data.

The model input determinations for the Sulphur Creek Basin include:

- Soil Classification

  Source: Soil Survey of Rio Blanco County Area Colorado, USDA Soil Conservation Service dated May, 1982

- Vegetative Cover and Condition

  Source: Urban Hydrology for Small Watersheds, TR 55 dated June, 1986, Tables 2-2a and 2-2d

- Times of Concentration (TC)

  Source: Urban Hydrology for Small Water sheds, TR 55 dated June, 1986, worksheet 3

- Hydraulic analysis

  Source: Flowmaster PC Program for Open Channels and Field Surveys

  - Rating Curves
  - Manning's "N" Roughness Values
  - Average Velocity
  - Cross sectional conveyance

- Curve Numbers (CN) for the Sub-Basin

  Source: See Table 2

- Frequency rainfall values

  Source: NOAA Atlas 2" Precipitation-Frequency Atlas of the Western United States Volume III - Colorado

- Sub-basin characteristics

  Source: See Exhibit 1

These values which were used for the analysis are presented on the basin schematic for the Sulphur Creek Basin as shown on Exhibit No. 2.

The input data and summary output Tables for the TR-20 computer run for the 100-year flood event are presented in Exhibit No. 3. The TR-20 runs for the 10-, 25-, and 50-year are presented in the Technical Addendum for the Sulphur Creek Basin Hydrology Analysis dated March, 1992.

FINDINGS OF STUDY

A detailed hydrologic investigation was performed for the Sulphur Creek Basin. The investigation analyzed past flood events and their runoff characteristics; reviewed existing flood-related studies and projects for the basin; evaluated the basin hydrologic parameters

and runoff characteristics; selected a hydrology model which was applicable for basin conditions; and computed flood frequency discharge values.

The rainfall values that were used for the analyses were as published in the National Weather Service NOAA Atlas with no station adjustments. The 10-year rainfall value was adjusted to develop homogeneity among the rainfall runoff value. The value was adjusted from 1.6 inches to 1.7 inches as presented in Table IV.

The discharge values of the 1992 CWCB hydrology study have been compared to the regional curves for the USDA SCS Garfield County Study. When considering the watershed hydrologic characteristics, the 1992 values appear to be reasonable and acceptable (See Exhibit 5). A comparison of the March 1992 values with other studies show that the values are also reasonable. This comparison is presented in Table V.

TABLE V
STUDY COMPARISON
for
Sulphur Creek Basin Hydrology

Flood Frequency (in years)	SCS 1969 (in cfs)	Merrick 1976 (in cfs)	Merrick 1978 (in cfs)	CWCB 1992 (in cfs)
10-year	351	148	820	345
25-year	439	xx	xx	690
50-year	615	297	1510	975
100-year	xx	513	1850	1325

The 500-year discharge was determined by the extension of the frequency discharge log plot curve as shown in Exhibit 4. No detention ponds or reservoirs were determined to be applicable for the analysis.

RECOMMENDATION

The CWCB staff recommends that the flood discharge values as presented in Table

VI be used for flood control and floodplain management activities for the Sulphur Creek Basin. This recommendation is based on the findings of the detailed investigation using 1991 basin conditions and the USDA-SCS TR 20 rainfall-runoff model.

TABLE VI
SULPHUR CREEK BASIN
1991 HYDROLOGIC CONDITIONS
FLOOD DISCHARGES
(in cubic feet per second)

FLOOD FREQUENCY	Discharge
10-year	345
25-year	690
50-year	975
100-year	1325
500-year	2450

It was discovered that the 1969, 1976, and 1977/1978 hydrologic studies previously listed were performed under criteria/procedures which cannot be re-constituted. However, these respective criteria/procedures may have been state-of-the-art at the time of study. A summary of the review of those studies is listed below:

- For the 1969 study, a study procedure was used by the SCS which has been replaced by their TR-55 procedure. It is recommended this method not be used for homogeneous basins which are larger than 5 square miles. The Sulphur Creek Basin is 22.2 square miles.

- For the August, 1976 study, a hybrid procedure was used which included portions of a Bureau of Reclamation procedure and basin parameters from the SCS's 1969 study. It is difficult to determine how the frequency values were computed.

- The June, 1978 study was prepared in draft form in April, 1977. There is some comparability of the study procedure described in that draft to the SCS TR 20 model. However, a number of the input parameters are referenced to the 1969 study. Some changes were made after the April, 1977 draft. Those changes appear in the floodplain study itself. No final hydrology report could be located. Since the final report can not be retrieved, it is difficult to determine the study procedure.

Due to the confusion that exists among the previous hydrologic studies, the CWCB finds that its 1992 values are the most representative of 1991 basin conditions. During the current CWCB evaluation, it became clear that the study findings presented in the 1978 report do not adequately represent 1991 basin conditions. It also became clear that a new hydrology study was warranted for the Sulphur Creek Basin.

The CWCB 1992 study did not incorporate any of the previous study assumptions or parameters without a complete review. At a March 17, 1992 meeting, the CWCB findings were presented to the Town of Meeker and Rio Blanco County, Colorado. The local officials comments were, "The CWCB study parameters and findings are representative of past runoff conditions and events." The CWCB study findings appear to best address the concerns of state and local officials and to present flood discharges which are reasonable for the Sulphur Creek Basin.

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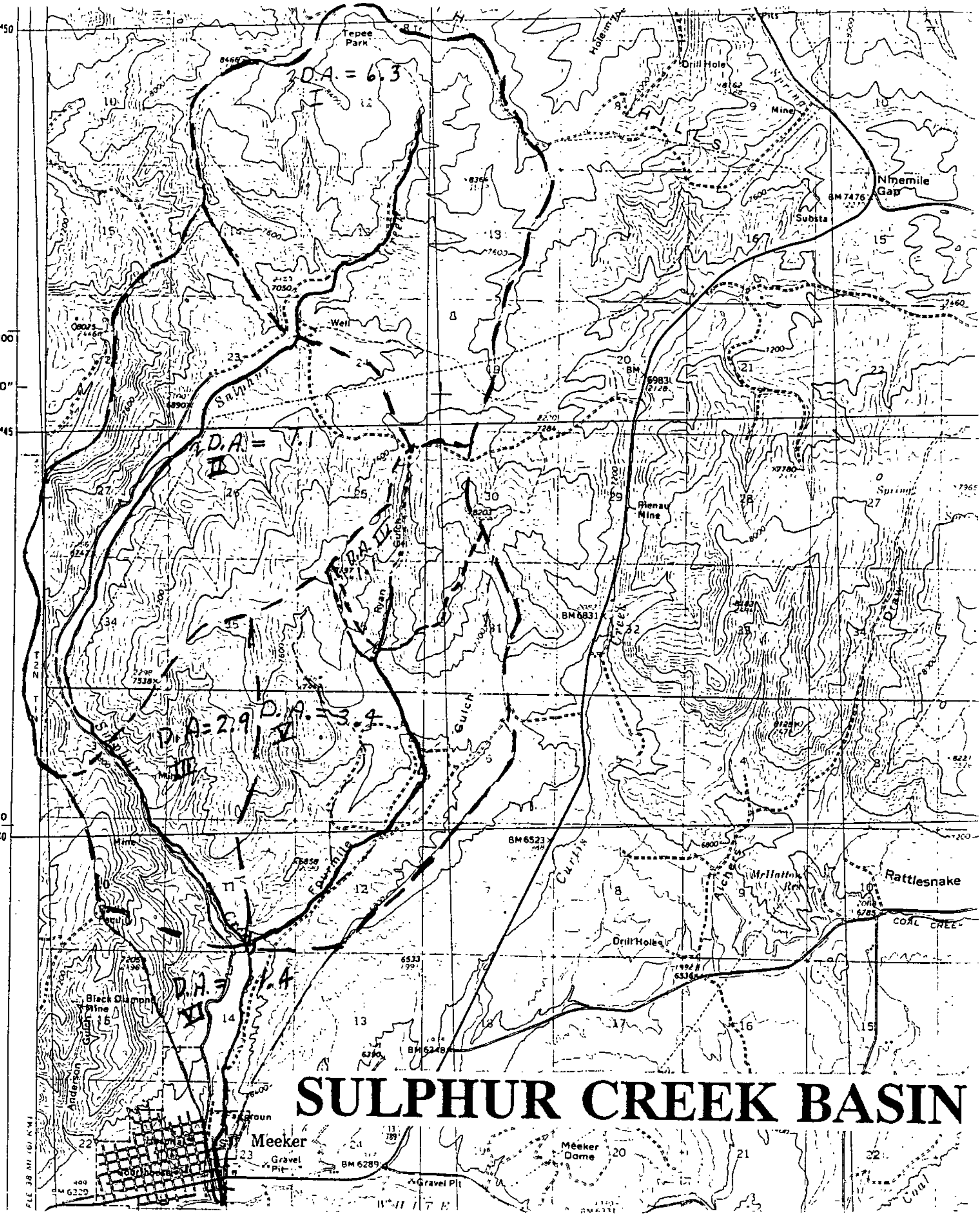
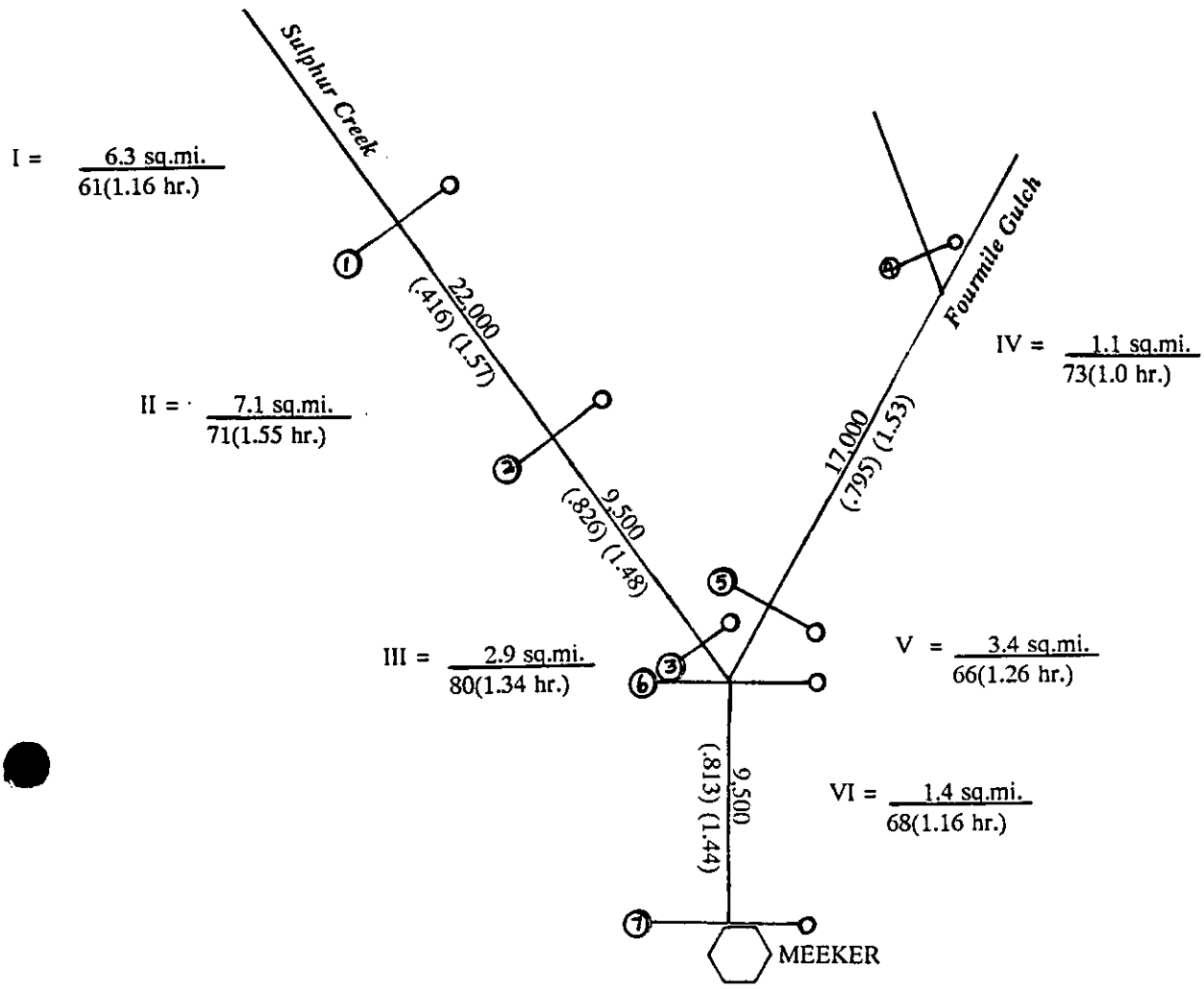


SULPHUR CREEK BASIN

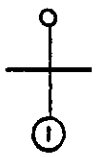
EXHIBIT NO. 1

BASIN SCHEMATIC



LEGEND

I = Sub-basin Number



Cross Section Number
(at downstream end of reach)

9,400 / (.04)(1.33) — Reach Length - Feet / (End area Coeff.x)(Exponent M)

1.20 / 75(.33) — Drainage Area - Square Miles / Runoff Curve Number (Time of Concentration-Hours)

EXHIBIT NO. 2

TR 20

COMPUTER

PROGRAM

EXHIBIT NO. 3

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**********80-80 LIST OF INPUT DATA FOR TR-20 HYDROLOGY**********

JOB TR-20                                                SUMMARY
TITLE 999 SULPHUR CREEK AT MEEKER, COLORADO
TITLE     DRAINAGE BASIN HYDROLOGY
 2 XSECTN   002          1.0
 8                       0.0          0.0          0.0
 8                       1.0          70.0         26.0
 8                       2.0          221.0        54.0
 8                       4.0          706.0        116.0
 8                       6.0          1409.0       186.0
 9 ENDTBL
 2 XSECTN   003          1.0
 8                       0.0          0.0          0.0
 8                       1.0          48.0         16.0
 8                       2.0          153.0        34.0
 8                       4.0          498.0        76.0
 8                       6.0          1016.0       126.0
 8                       8.0          1714.0       184.0
 9 ENDTBL
 2 XSECTN   005          1.0
 8                       0.0          0.0          0.0
 8                       1.0          55.0         16.0
 8                       2.0          174.0        34.0
 8                       3.0          346.0        54.0
 8                       4.0          567.0        76.0
 8                       5.0          837.0        100.0
 8                       6.0          1156.0       126.0
 9 ENDTBL
 2 XSECTN   007          1.0
 8                       0.0          0.0          0.0
 8                       1.0          155.0        36.0
 8                       2.0          364.0        74.0
 8                       3.0          716.0        114.0
 8                       4.0          1158.0       156.0
 8                       6.0          2290.0       246.0
 8                       8.0          3738.0       344.0
 9 ENDTBL
 6 RUNOFF  1 001        7 6.3          61.0         1.16         1     1 1 1
 6 REACH   3 002   7    5 22200.0                                 1   1 1 1 1
 6 RUNOFF  1 002        6 7.1          71.0         1.55         1     1 1 1
 6 ADDHYD  4 002   5 6 7                                        1   1 1 1 1
 6 REACH   3 003   7    5 9500.0                                  1   1 1 1 1
 6 RUNOFF  1 003        6 2.9          80.0         1.34         1     1 1 1
 6 ADDHYD  4 003   5 6 7                                        1 1 1 1 1 1
 6 SAVMOV  5 003   7    1
 6 RUNOFF  1 004        7 1.1          73.0         1.00         1     1 1 1
 6 REACH   3 005   7    5 17000.0                                 1   1 1 1 1
 6 RUNOFF  1 005        6 3.4          66.0         1.26         1     1 1 1
 6 ADDHYD  4 005   5 6 7                                        1 1 1 1 1 1
 6 SAVMOV  5 006   7    5
 6 SAVMOV  5 006   1    6
 6 ADDHYD  4 006   5 6 7                                        1 1 1 1 1 1
 6 REACH   3 007   7    5 9500.0                                  1   1 1 1 1
 6 RUNOFF  1 007        6 1.4          68.0         1.16         1     1 1 1
 6 ADDHYD  4 007   5 6 7                                        1 1 1 1 1 1
   ENDATA
 7 INCREM  6              .20
 7 COMPUT  7 001   007    0.0          2.4          1.0          2 2  01   01
   ENDCMP  1
   ENDJOB  2


**********END OF 80-80 LIST**********
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SUMMARY TABLE 1 - SELECTED RESULTS OF STANDARD AND EXECUTIVE CONTROL INSTRUCTIONS IN THE ORDER PERFORMED
(A STAR(*) AFTER THE PEAK DISCHARGE TIME AND RATE (CFS) VALUES INDICATES A FLAT TOP HYDROGRAPH
A QUESTION MARK(?) INDICATES A HYDROGRAPH WITH PEAK AS LAST POINT.)

SECTION/ STRUCTURE ID		STANDARD CONTROL OPERATION	DRAINAGE AREA (SQ MI)	RAIN TABLE #	ANTEC MOIST COND	MAIN TIME INCREM (HR)	PRECIPITATION			RUNOFF AMOUNT (IN)	PEAK DISCHARGE			
							BEGIN (HR)	AMOUNT (IN)	DURATION (HR)		ELEVATION (FT)	TIME (HR)	RATE (CFS)	RATE (CSM)
ALTERNATE 1 STORM 1														
XSECTION	1	RUNOFF	6.30	2	2	.20	.0	2.40	24.00	.17	---	13.04	139.15	22.1
XSECTION	2	REACH	6.30	2	2	.20	.0	2.40	24.00	.17	1.15	14.33	92.23	14.6
XSECTION	2	RUNOFF	7.10	2	2	.20	.0	2.40	24.00	.44	---	13.05	582.45	82.0
XSECTION	2	ADDHYD	13.40	2	2	.20	.0	2.40	24.00	.31	3.70	13.12	632.99	47.2
XSECTION	3	REACH	13.40	2	2	.20	.0	2.40	24.00	.31	4.40	13.47	602.30	44.9
XSECTION	3	RUNOFF	2.90	2	2	.20	.0	2.40	24.00	.82	---	12.80	593.78	204.8
XSECTION	3	ADDHYD	16.30	2	2	.20	.0	2.40	24.00	.40	6.08	13.11	1042.60	64.0
XSECTION	4	RUNOFF	1.10	2	2	.20	.0	2.40	24.00	.51	---	12.60	151.50	137.7
XSECTION	5	REACH	1.10	2	2	.20	.0	2.40	24.00	.51	1.39	13.20	101.61	92.4
XSECTION	5	RUNOFF	3.40	2	2	.20	.0	2.40	24.00	.29	---	12.93	170.67	50.2
XSECTION	5	ADDHYD	4.50	2	2	.20	.0	2.40	24.00	.34	2.55	13.03	268.21	59.6
XSECTION	6	ADDHYD	20.80	2	2	.20	.0	2.40	24.00	.39	---	13.09	1314.05	63.2
XSECTION	7	REACH	20.80	2	2	.20	.0	2.40	24.00	.39	4.17	13.46	1256.63	60.4
XSECTION	7	RUNOFF	1.40	2	2	.20	.0	2.40	24.00	.34	---	12.82	98.04	70.0
XSECTION	7	ADDHYD	22.20	2	2	.20	.0	2.40	24.00	.39	4.29	13.44	1322.72	59.6

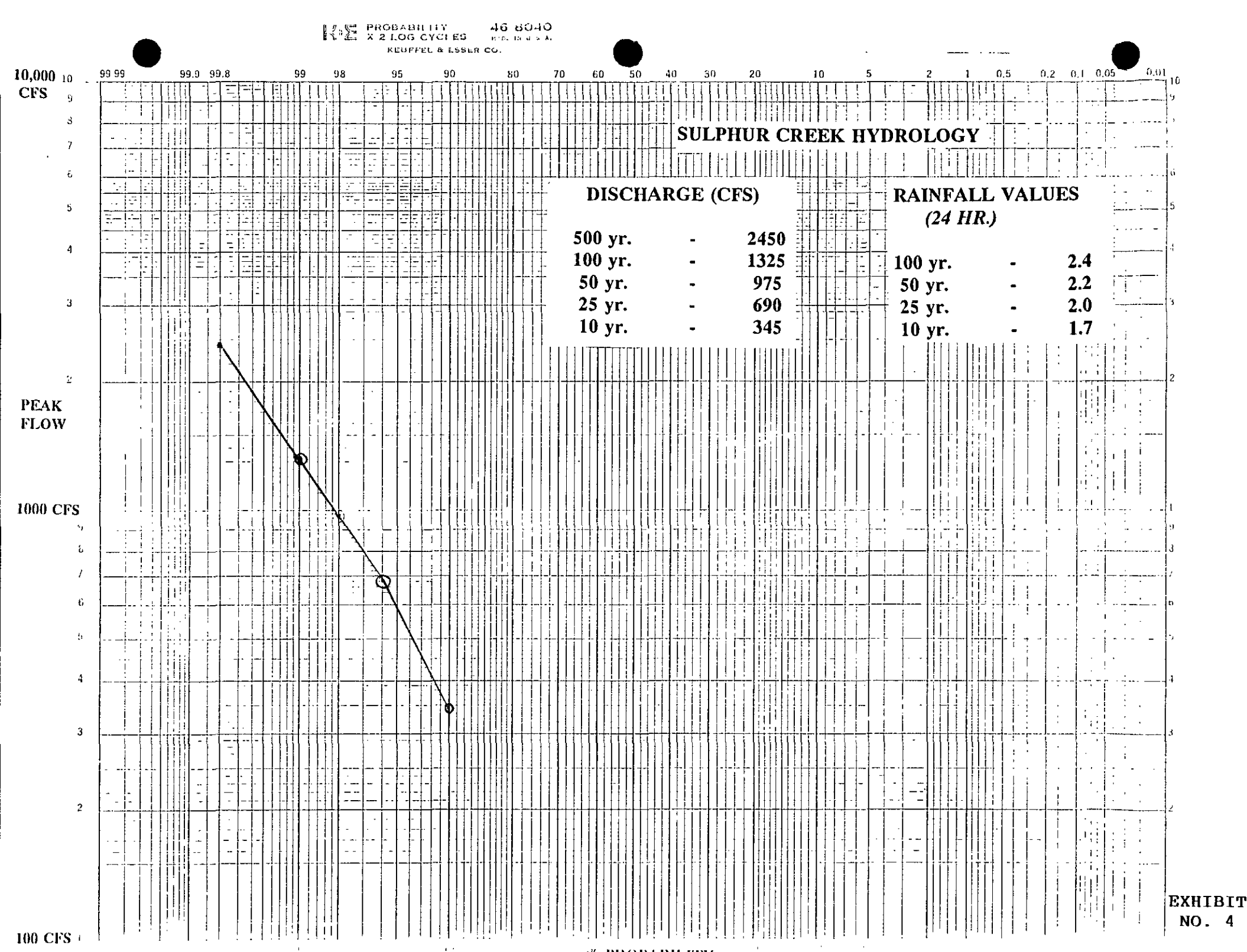
SUMMARY TABLE 2 - SELECTED MODIFIED ATT-KIN REACH ROUTINGS IN ORDER OF STANDARD EXECUTIVE CONTROL INSTRUCTIONS
(A STAR(*) AFTER VOLUME ABOVE BASE(IN) INDICATES A HYDROGRAPH TRUNCATED AT A VALUE EXCEEDING BASE + 10% OF PEAK
A QUESTION MARK(?) AFTER COEFF.(C) INDICATES PARAMETERS OUTSIDE ACCEPTABLE LIMITS, SEE PREVIOUS WARNINGS)

		HYDROGRAPH INFORMATION							ROUTING PARAMETERS									PEAK
		INFLOW		OUTFLOW		OUTFLOW+ INTERV. AREA						Q AND A EQUATION						TRAVEL TIME
XSEC ID	REACH LENGTH (FT)	PEAK (CFS)	TIME (HR)	PEAK (CFS)	TIME (HR)	PEAK (CFS)	TIME (HR)	BASE-FLOW (CFS)	VOLUME ABOVE BASE (IN)	MAIN TIME INCR (HR)	ITER-ATION #	COEFF (X)	POWER (M)	LENGTH FACTOR (K*)	PEAK RATIO O/I (Q*)	S/Q @PEAK (K) (SEC)	ATT-KIN COEFF (C)	STOR-AGE (HR)	KINE-MATIC (HR)
ALTERNATE 1 STORM 1																		
2	22200	139	13.0	92	14.4	629	13.2	0	.17	.20	1	.416	1.57	.205	.664	4085	.16	1.40	1.22
3	9500	629	13.2	599	13.4	1037	13.2	0	.31	.20	1	.826	1.48	.027	.952	918	.56	.20	.26
5	17000	151	12.6	102	13.2	268	13.0	0	.51	.20	1	.795	1.53	.248	.671	2281	.27	.60	.68
7	9500	1304	13.0	1253	13.4	1321	13.4	0	.39	.20	1	.813	1.44	.029	.961	855	.59	.40	.24

SUMMARY TABLE 3 - DISCHARGE (CFS) AT XSECTIONS AND STRUCTURES FOR ALL STORMS AND ALTERNATES

XSECTION/ STRUCTURE ID		DRAINAGE AREA (SQ MI)	STORM NUMBERS..... 1
XSECTION 1		6.30	
ALTERNATE	1		139.15
XSECTION 2		13.40	
ALTERNATE	1		632.99
XSECTION 3		16.30	
ALTERNATE	1		1042.60
XSECTION 4		1.10	
ALTERNATE	1		151.50
XSECTION 5		4.50	
ALTERNATE	1		268.21
XSECTION 6		20.80	
ALTERNATE	1		1314.05
XSECTION 7		22.20	
ALTERNATE	1		1322.72

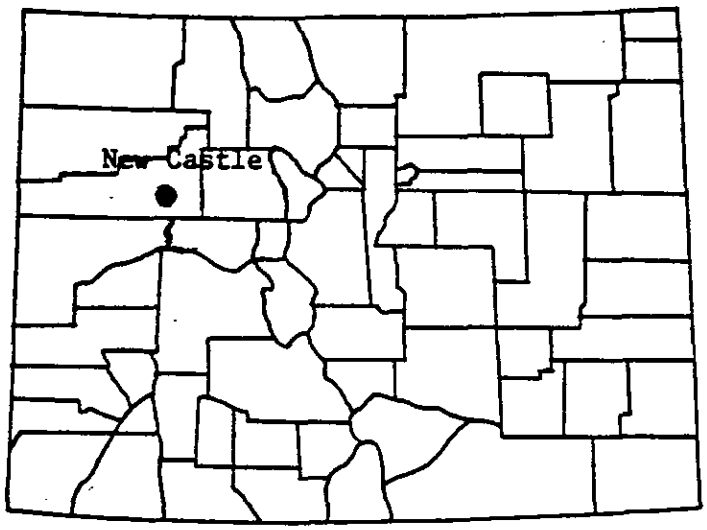
MAIN - UNEXPECTED RECORD FOUND(IGNORED))))


K&E PROBABILITY 46 8040
X 2 LOG CYCLES
KEUFFEL & ESSER CO.
10,000 CFS
1000 CFS
100 CFS
PEAK FLOW
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
SULPHUR CREEK HYDROLOGY
DISCHARGE (CFS)
500 yr. - 2450
100 yr. - 1325
50 yr. - 975
25 yr. - 690
10 yr. - 345
RAINFALL VALUES
(24 HR.)
100 yr. - 2.4
50 yr. - 2.2
25 yr. - 2.0
10 yr. - 1.7
EXHIBIT NO. 4

FLOOD PLAIN MANAGEMENT STUDY

COLORADO RIVER TRIBUTARIES

PORCUPINE CREEK, BEAVER CREEK, MAMM CREEK, DRY HOLLOW CREEK, DIVIDE CREEK, GARFIELD CREEK, ALKALI CREEK, SOUTH CANYON CREEK, CANYON CREEK, ELK CREEK

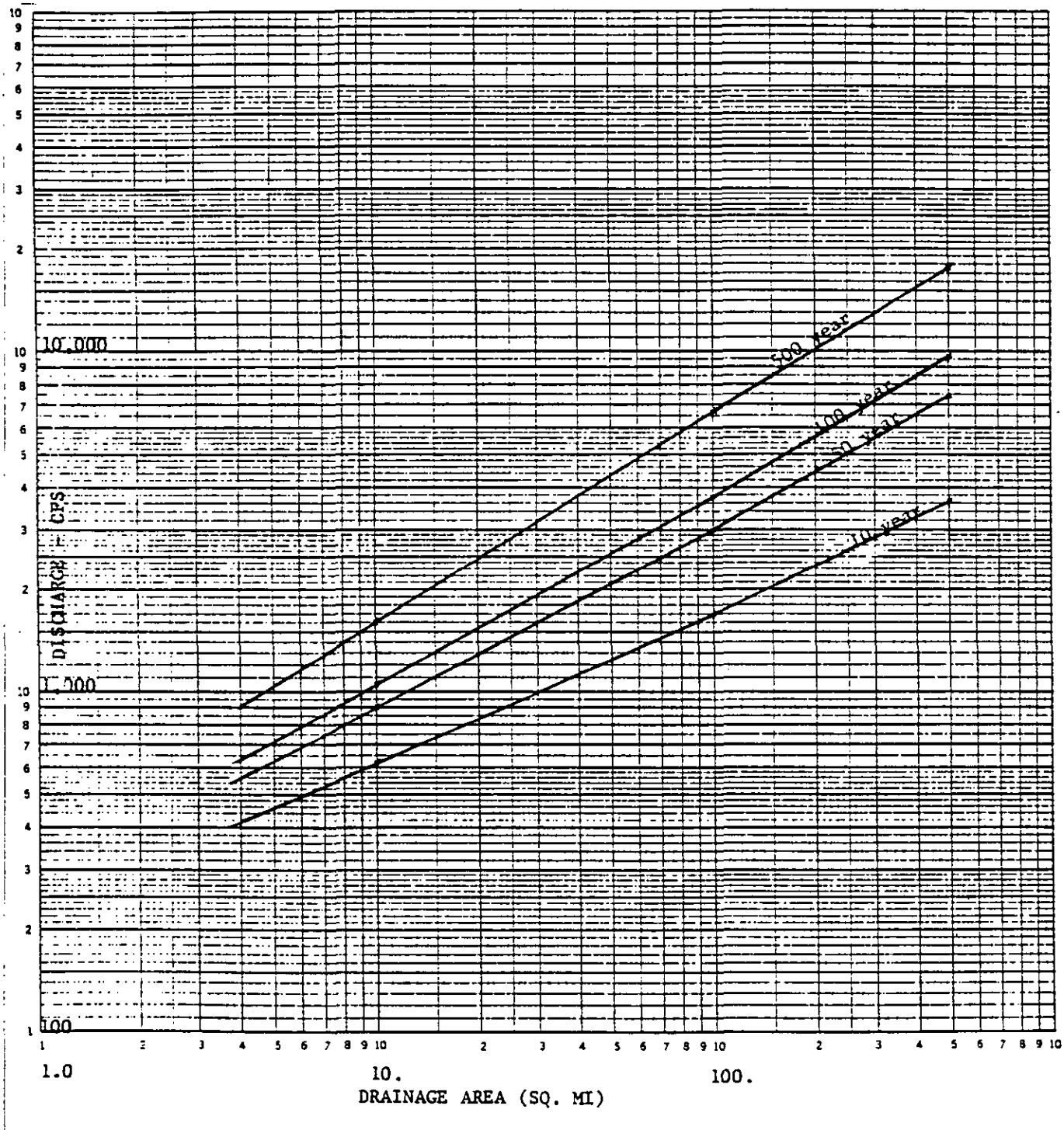


Prepared by the
U.S. Department of Agriculture
Soil Conservation Service
Denver, Colorado
in cooperation with the
Colorado Water Conservation Board
Town of New Castle
and Garfield County, Colorado
July 1986

EXHIBIT NO. 5

DISCHARGE-FREQUENCY-DRAINAGE AREA RELATIONSHIP FOR COLORADO RIVER TRIBUTARIES IN THE VICINITY OF DEBEQUE TO GLENWOOD SPR. COLORADO

Ref: Soil Conservation Service, Denver, Co.



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