FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK IN LOGAN COUNTY, COLORADO

Prepared by the
U.S. Department of Agriculture
Soil Conservation Service
Lakewood, Colorado
in cooperation with the
Colorado Water Conservation Board
Logan County, Colorado
and the
Town of Sterling, Colorado

(April, 1992)

PREFACE

This report includes information on the flood hazard areas along Pawnee Creek between County Road 25 and U.S. Highway 6 in the vicinity of Sterling and Atwood, Colorado.

Because of the potential for flood damages, detailed flood hazard studies have been recognized as an essential item in guiding the use of flood plains. The purpose of this report is to provide adequate mapping and data for implementing flood plain management programs.

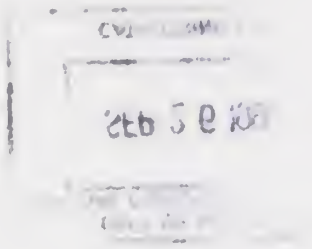
The Pawnee Creek channel along the study reach is not adequate to carry significant flood flows from the large contributing drainage area. Out-of-bank flooding occurs on a regular basis with segments of this flow traveling overland in several directions away from the main channel. The need to establish these locations of overflow and determine their magnitude as well as identify possible flood damage reduction opportunities prompted this study.

Included in the report is information on past floods, the potential for future floods, flooded area maps, water surface profiles, selected cross sections, peak discharge data, and recommendations for reducing potential flood damages.

The Soil Conservation Service conducted the technical studies and prepared the report. These services were carried out in accordance with the Plan of Work of February 1990.

The assistance and cooperation provided by the Colorado Water Conservation Board, Logan County, and the Town of Sterling are appreciated and gratefully acknowledged.

The field survey, hydrologic, hydraulic, and other pertinent data and computations are on file with the U.S. Department of Agriculture, Soil Conservation Service, 655 Parfet Street, Lakewood, Colorado 80215-5517, telephone (303) 236-2900. Additional copies of this report may be obtained from the Soil Conservation Service.



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INTRODUCTION

This flood plain management report was prepared by the U.S. Department of Agriculture, Soil Conservation Service, in cooperation with the Colorado Water Conservation, Logan County, and the Town of Sterling, Colorado. Interpretations of the flood plain management study and recommendations to reduce damages are included; however it is beyond the scope of this report to provide detailed proposals or plans to rectify the flooding problems.

Objectives

The objective of this study is to provide detailed flood plain management information and mapping to Logan County and the town of Sterling for use in implementing flood plain management programs which will minimize potential flood losses. Included in the report are engineering and hydrologic data which will facilitate the development of a flood plain management plan, road and bridge designs, and flood control measures (if needed).

Authority

Section 37-60-106(1)(c), Colorado Revised Statutes, authorizes the Colorado Water Conservation Board "to designate and approve storm or floodwater runoff channels or basins, and to make such designations available to legislative bodies of cities and incorporated towns, to county planning commissions, and to boards of adjustment of cities, incorporated towns, and counties of this state". The board provides assistance to local governments in development and adoption of effective flood plain ordinances. In addition, the board will provide technical assistance to local entities during the performance of flood plain information studies within Colorado. Presently, direct financial assistance for the performance of flood plain studies is no longer available from the board.

Section 30-28-111 C.R.S. for county governments and Section 1-23-301 C.R.S. for municipal governments of the Colorado Revised Statutes, states that cities, incorporated towns, and counties within the study area may provide zoning regulations "...to establish, regulate, restrict, and limit such uses on or along any storm or floodwater runoff channel or basin that has been designated and approved by the Colorado Water Conservation Board, in order to lessen or avoid the hazards to persons and damage to property resulting from the accumulation of storm or floodwaters..."

Therefore, upon official approval of this report by the Colorado Water Conservation Board, the areas described as being inundated by the 100-year flood can be designated as flood hazard areas and their use regulated accordingly by the local governments.

Flood plain management studies are carried out by the Soil Conservation Service as an outgrowth of the recommendations in A Report by the Task Force on Federal Flood Control Policy, House Document No. 465 (89th Congress, August 10, 1966), especially Recommendation 9(c), Regulation of Land Use, which recommended the preparation of preliminary reports for guidance in those areas where assistance is needed before a full flood plain information report can be prepared or where a full report is not scheduled.

Authority for funding flood plain management studies is provided by Section 6 of Public Law 83-566, which authorizes the U.S. Department of Agriculture to cooperate with other federal, state and local agencies to make investigations and surveys of the watersheds and rivers and other waterways as a basis for the development of coordinated programs. In carrying out flood plain management studies, the Soil Conservation Service is being responsive to Executive Order 11988, entitled "Flood Plain Management", and Executive Order 11990, entitled "Protection of Wetlands" (both effective May 24, 1977).

DESCRIPTION OF STUDY AREA

Basin Characteristics

Pawnee Creek drains an area of approximately 645 square miles above U.S. Highway 6 near Atwood, see Fig 1. The basin includes areas in Logan as well as Weld Counties. The mouth of Pawnee Creek is located several miles southwest from Sterling along U.S. Highway 6 and the Burlington/Union Pacific Railroad tracks. The elevation of Pawnee Creek at this location is about 3980 ft above sea level. The elevation of the upper end of the basin is near 5400 ft. The well-known Pawnee Buttes are in the upper reaches of the basin at an elevation of about 5375 ft.

The major tributaries to Pawnee Creek are Raymer Creek, South Pawnee Creek with its tributary Wildhorse Creek, North Pawnee Creek with its tributary Igo Creek, Cottonwood Creek, Horsetail Creek, and Spring Creek. These streams are basically intermittent with some accumulations of live water, particularly in South Pawnee Creek.

The soils in the basin are predominantly loams and clay loams, with sandstone, shale, and siltstone outcroppings. They fit primarily in hydrologic groups "C" and "B". Hydrologic curve numbers are in the range of 77 to 79 with the primary vegetation being native range with some winter wheat and a significant amount of irrigated cropland in the lower part of the basin.

The mean annual precipitation for the basin ranges from 14 to 16 inches. The mean annual precipitation for Sterling, nearest town with weather data, is 14.96 inches with a mean annual temperature of 48.5 degrees Fahrenheit.

Study Limits

The area of interest in this study includes locations where flood waters from Pawnee Creek damage farm lands and county roads along the lower reaches of the basin. Also of concern is Pawnee Creek overflow which inundates portions of the City of Sterling.

Since this basin is so large, the study limit was confined to the lower reach from County Road 29 to U.S. Highway 6. The total study length is about 7.6 miles which includes the main stem of Pawnee Creek and the overflow area between Pawnee Creek and the Riverside Cemetery along U.S. Highway 6. A number of out-of-bank conditions occur with segments of flood waters departing overland away from the main channel. It was attempted herein to track these floodwaters to locations where they combine again and pose a flood threat to the Town of Sterling.

At the time this study was initiated, the flow paths were not all known. As a result of these investigations, it was determined that a segment of flow will move to the vicinity of Atwood. Mapping was not done in this area; therefore, specific details of flow depth, etc. were not made for this segment of flow.

Another significant segment of flow departs from the channel at a location just below County Road 33. The flow moves overland away from the main channel towards the northeast and eventually to the vicinity of the Riverside Cemetery. Water surface profiles were not computed for this reach because of the unpredictable meandering flow pattern through farmland; however, a probable flow path was sketched on the flood plain maps.

Natural and Beneficial Flood Plain Values

The flood plain along Pawnee Creek, within the study limits, generally contains cottonwoods and willows along the channel, irrigated cropland adjacent to the channel, and grasslands interspersed with the cropland. The channel does a considerable amount of meandering which enhances the visual aesthetics and wildlife habitat values in the area.

The flood plain supports a variety of wildlife species such as: cottontail, squirrel, prairie rattlesnake and a variety of birds including the burrowing owl, Swainson's hawk, prairie falcon, meadowlark, horned lark, lark bunting, and pheasant. Notable predators include the great horned owl, bald and golden eagle, coyote, kit fox, badger, and skunk. White-tailed and mule deer and antelope are common to the area.

In the fall and spring, multitudes of migratory birds pass over Logan County.

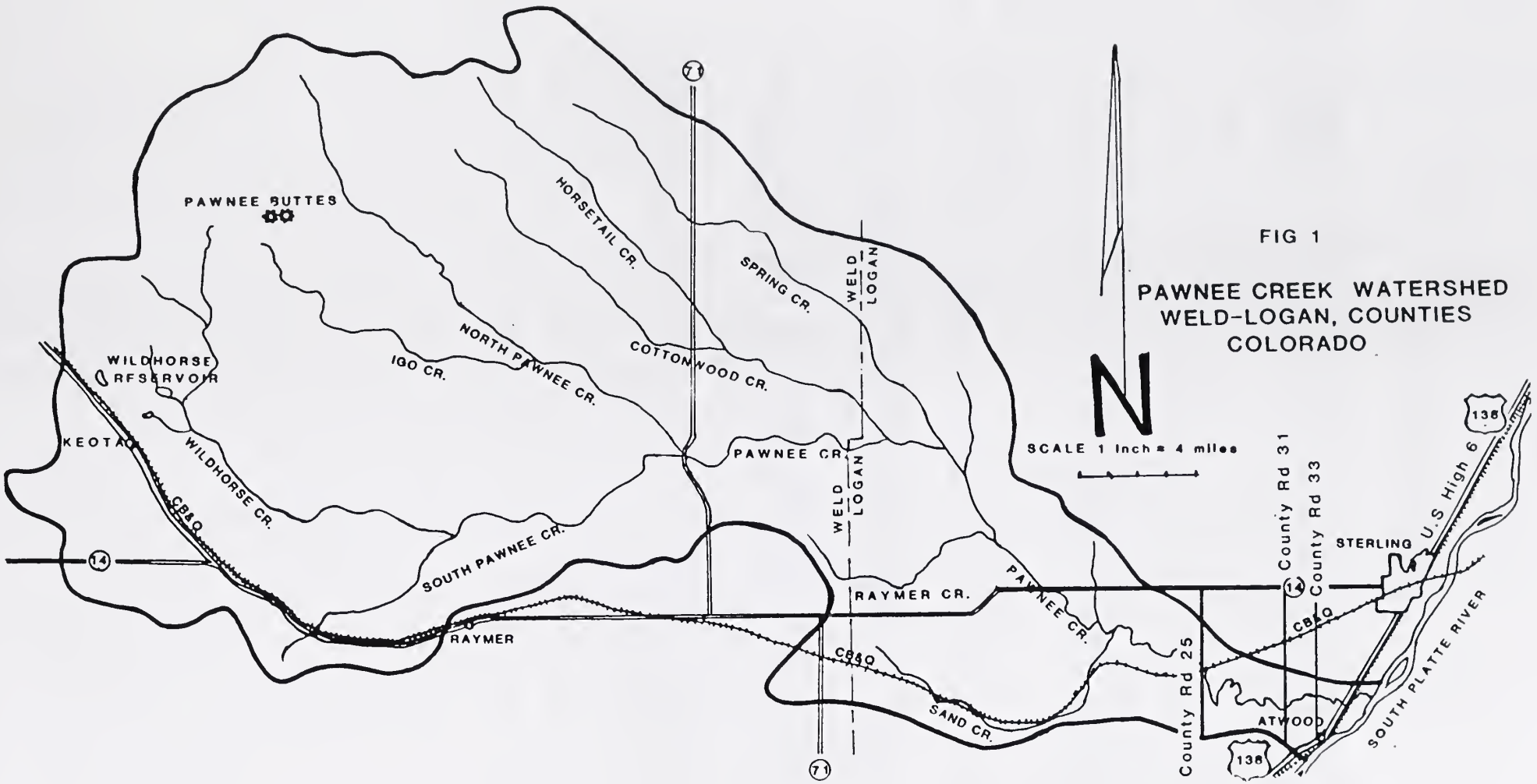


FIG 1

PAWNEE CREEK WATERSHED
WELD-LOGAN, COUNTIES
COLORADO

RELATED FLOOD STUDIES

A number of general flood studies have been made of Pawnee Creek, Sand Creek, and South Platte River in this area. The following is a list of references available:

1. "Flood Plain Information: South Platte River and Pawnee Creek, Sterling, Colorado" prepared by the U.S. Army Corps of Engineers (1978).

2. E.L. Bennett, P.E., a local consulting engineer made studies of Pawnee Creek floods. His work is not published but is on file with the Director of Public Works.

3. Hoskins and Associates (1957) developed a master drainage plan for the City of Sterling. This report is on file with the Director of Public Works.

4. "Flood Plain Information and Drainage Plan for Sand Creek and the Pawnee Creek Overflow at Sterling Colorado, May, 1983, by Resource Consultants Inc.

5. Pre-planning Preliminary Report by the Soil Conservation Service (1973). This was a preliminary investigation into the potential for a watershed project for flood control purposes.

6. Approximate 100-year flood boundaries from Sterling to Atwood, Colorado, South Platte River, Logan County (Sept. 1990).

FLOOD HISTORY

Pawnee Creek and Sand Creek have often been considered together when the topic of flooding has been discussed. This is because Pawnee Creek can overflow into the Sand Creek flood plain at Sterling. For purposes of this study, floods unique to Sand Creek are not included.

Flooding along Pawnee Creek can occur as a result of general rains over the entire basin or from local storms on individual tributaries to Pawnee Creek. An example of local flooding is the fairly recent flood of July 30, 1989. This particular event was not an extreme flood but it did produce about 5000 cfs on Pawnee Creek near Colorado Highway 14. Field observations indicated the major portion of flood waters came from the South Pawnee Creek and Raymer Creek.

The following are accounts of two major floods on Pawnee Creek:

> May 1935 - Huge Pawnee flood damaged the railroad between Sterling and Atwood, perhaps the biggest in many years. This flow swept out several hundred yards of grade on Highway 14, west of Sterling, washed out the approaches to Sterling bridge north of Atwood, and sent a tide flowing over Highway 6 and the bridge and tracks of railroads at the Pawnee bridge.
>
> June 1965 - Flooding occurred June 14 and 15 as the result of heavy rainfall on Pawnee Creek. Considerable damage occurred throughout the lower reaches of the watershed. South of Sterling, near Atwood, flood water overtopped Highway 6 and railroad tracks. Pawnee Creek flood waters also flowed in a northeasterly direction along Highway 6 and inundated portions of Sterling.

Other dates of listed flooding include 1883, 1894, 1914, and 1921.

Pawnee Creek at Union Pacific/ Burlington Northern railroad tracks south of Sterling. Photo courtesy of Colorado Water Conservation Board.

INVESTIGATIONS AND ANALYSIS

Interpretation and Use of Report

A. Frequency and Discharge

The 10-, 25-, 50-, and 100-year flood events are used as the flood frequencies for this flood plain analysis. Thus, the data developed in this report will be suitable, not only for regulation purposes and H.B. 1041 designation, but is also consistent with Federal Insurance Administration flood insurance studies conducted by the Federal Emergency Management Agency.

These various flood events have an average occurrence of once in the number of years as indicated. For example, the 100-year flood occurs, on the average, once in a 100-year period, and has a one percent chance of being equaled or exceeded in any given year.

The particular uses for the various flood events in addition to those stated above are as follows:

10-year, 25-year and 50-year Flood Events

Information regarding these lower frequency floods is especially useful for future engineering studies and land use planning purposes related to minor road systems, minor channel improvements, the location of parks and recreational facilities, agricultural lands, and appurtenant structures. The use of the lower frequency floods may be considered in planning flood prevention projects to protect agricultural areas or other property where risk to life is not a factor.

100-year Flood Event

The 100-year flood event may be used in lieu of lower frequencies for engineering design purposes where greater security from structure failure is desired.

However, the most important use of the 100-year flood event lies in flood plain management and land use planning as set forth in the state statutes. The State of Colorado and the Federal Government considers the 100-year frequency flood as the flood event to be used in designing and protecting structures and dwellings for human occupation. Therefore, all flood plain regulations are based upon the 100-year flood.

B. Flood Elevation

Water surface elevations for the 10-, 25-, 50-, and 100-year floods, as determined at each cross section, may be found in Table 4 "Flood Frequency-Elevation and Discharge Data". The flood profile data (sheets 1-13) show a graphical relationship of water surface elevations along the stream reaches for the given frequencies. Selected typical cross sections from different reaches within the study area are shown on sheets 1 through 6.

The flood profiles may be used in areas where controversy arises over the 100-year flood boundary shown on the flood plain maps. Since the flood profile exhibits give the water surface elevation at a specific point on the reference line, the flood elevations can be surveyed on the ground to alleviate any discrepancies on the base map.

C. Flooded Areas

Flood plain maps, sheets 1 through 6, show the boundary of the 100-year flood plain. The flood plain boundary was plotted using flood contour elevations and stationing from the plotted flood profiles. This was done at elevation intervals compatible with the map contour intervals. Flood contours are shown as wiggly lines at 5 ft intervals perpendicular to the direction of flow.

Hydrology

A table showing peak discharge, location, and frequency was developed for this study. The procedures used in an earlier study on Lonetree Creek (similar drainage to the west) was used.

Two procedures were tested to see which produced the more critical results. Procedure (1) involved the use of the SCS TR-20 Model in conjunction with rainfall depth data from NOAA Atlas for Colorado, areal adjustment of rainfall using NOAA Hydromet 51, and the areal distribution of rainfall to the entire basin using an elliptical storm pattern in NOAA Hydromet 52.

Procedure (2) involved applying a local storm pattern exclusively to individual sub-basins in the lower part of the basin. The elliptical storm pattern was not used for this local storm procedure, but rainfall was assumed to be uniformly distributed and adjusted for areal extent using the procedure in NOAA Atlas. The peak discharges developed by the local storm were used to support the concept that the basin peak discharge for a given frequency cannot be less than that produced by an individual sub-basin. Whichever storm pattern produced the greater peak discharge should be used for planning or design purposes.

The SCS 24 hour Type II rainfall distribution was used to apply a time distribution to rainfall depths for both procedures discussed previously.

Hydrologic parameters necessary for the TR-20 Model were developed from available soils and land use maps. Time of concentration values were based on standard SCS procedures. Precipitation values from NOAA Atlas for Colorado were considered the best reference for depth-frequency data, however its areal adjustment and distribution procedure does not seem appropriate for large drainage areas such as involved in the general basin wide storm analysis for this study. Therefore Hydromet 51 and 52 were used for that purpose, except for the local storm procedure

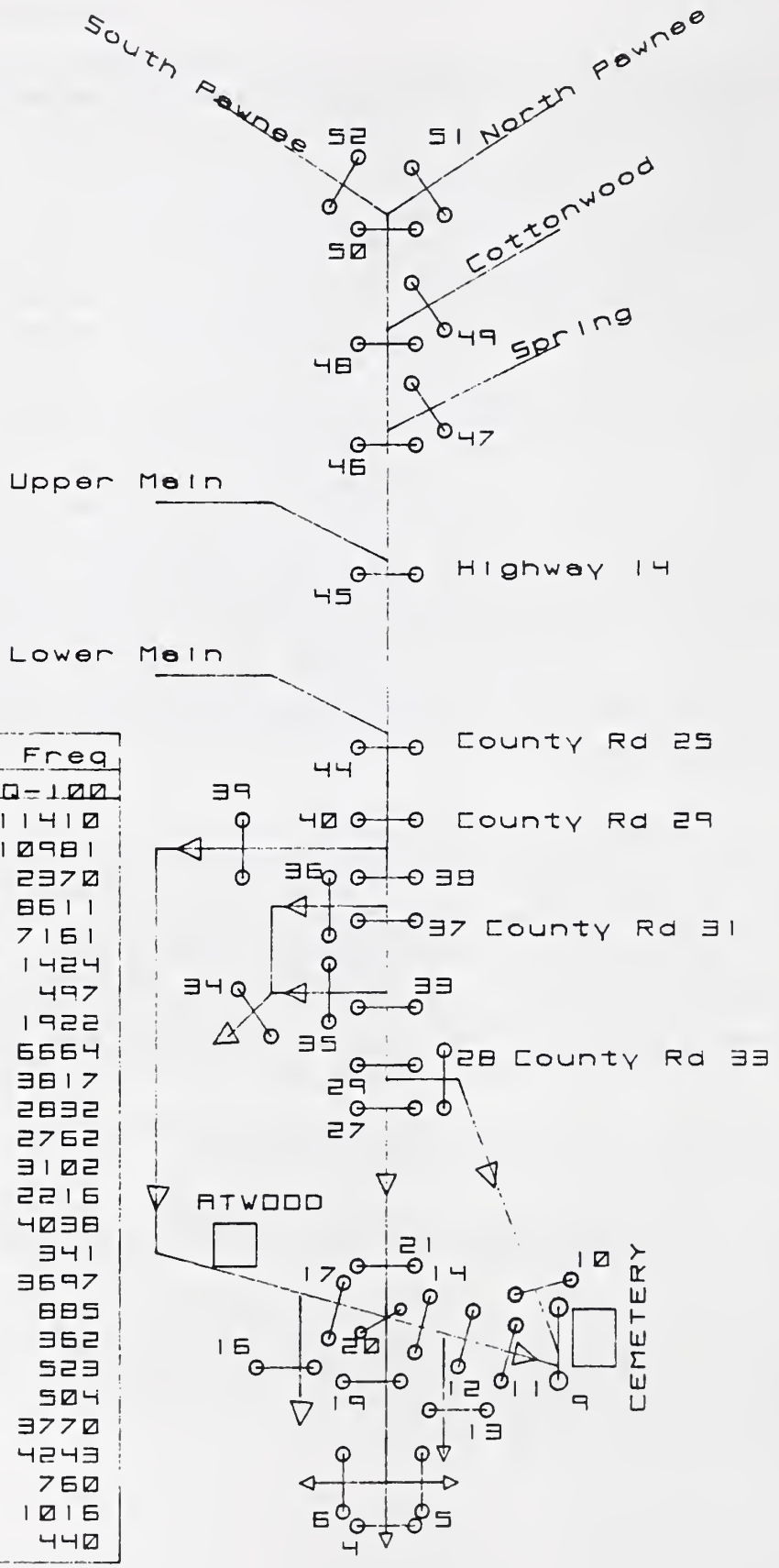
The Modified Att-kin reach routing method was used by the model to move hydrographs through stream reaches.

Figure 2 and included Table 1 show a schematic view of the basin and values of basic parameters used in the TR-20 Model.

Hydraulic analyses were used along with TR-20 to determine the carrying capacity of Pawnee Creek itself and to help define where and how much out-of-channel flow occurs. It was determined that significant out-of-bank division of flow occurs at several locations along the study reach.

Fig 2 PAWNEE CR FLOOD PLAIN MANAGEMENT STUDY

TR20 SCHEMATIC



	CFS - Freq	
Sec	Q-10	Q-100
44	4275	11410
40	4083	10981
39	819	2370
38	3264	8611
37	2945	7161
36	313	1424
35	0	497
34	314	1922
33	2945	6664
28	1396	3817
27	1547	2832
21	1544	2762
20	1705	3102
19	1557	2216
16-17	926	4038
17	162	341
16	764	3697
14	147	885
13	147	362
12	0	523
11	0	504
10	1388	3770
9	1388	4243
6	536	760
5	581	1016
4	440	440

Table 1 TR-20 Schematic Information

Sec ID From	To	Dr Area Sq Mi	CN	Tc Hrs	Reach Information Length-Ft	x	m
52	--	222.36	78	13.13			
51	--	131.82	77	11.97			
50	48				43700	0.18	1.33
49	--	61.65	77	8.71			
48	46				15400	0.05	1.33
47	--	71.63	77	9.77			
46	45				42000	0.10	1.33
45	--	81.69	78	10.94			
45	44				48700	0.18	1.33
44	--	58.35	79	11.34			
44	40				36000	0.18	1.33
38	37				9500	0.18	1.33
33	27				9500	0.18	1.33
27	21				16300	0.10	1.33
39	17				25200	0.10	1.33
34	17				9200	0.18	1.33
28	10				17400	0.18	1.33
12	11				10900	0.18	1.33

A major division of flow occurs between Country Road 31 and the Pawnee Ditch crossing. The Pawnee Creek channel at this location has very limited carrying capacity. A portion of channel overflow moves overland in a southeasterly direction for about 2 miles to U.S. Highway 6 at a location southwest of Atwood. The highway and Burlington Northern Railroad redirect the flow northeast through Atwood and on toward the Pawnee Creek highway and railroad bridges. However, about a mile before the flow reaches the main highway bridge, a restricting ridge causes overflow across the highway and railroad towards the nearby South Platte River. The remainder of this flow continues on to the main highway bridge where it combines with flows from the main channel and adjacent flood plain.

The main highway and railroad bridges on Pawnee Creek and the overflow bridges about 1000 ft further down the highway to the northeast toward Sterling will not accommodate the 100-year flow reaching this point. Therefore, some water will continue to the northeast along the highway beyond the bridges towards the Riverside Cemetery.

Another segment of out-of-bank flow occurs along the main channel just downstream from County Road 33. This segment of flow moves overland away from the main channel towards the northeast and eventually to the vicinity of the Riverside Cemetery. This flow combines with the residual overflow from the main channel highway and railroad bridges. The consolidation occurs at a location along U.S. Highway 6 near the Riverside Cemetery. It appears additional flood water moves across the highway and railroad at this location with some continuing on past the cemetery towards Sterling.

Flows that pass through the highway and railroad bridges on the main stem of Pawnee Creek encounter alluvial fan type topography in the vicinity of a farmstead immediately below the railroad. A three way division of flow occurs here with about 440 cfs remaining in the channel and the balance going out-of-bank splitting to the northeast and the south.

The following table, Figure 2, and Figure 3 show the location and magnitude of flood flows, including their divisions and combining, throughout the study reach.

Location	Discharge - cfs			
	10 yr	25 yr	50 yr	100 yr
Highway 14	4700	7300	9600	12200
County Rd 25	4300	6700	8900	11400

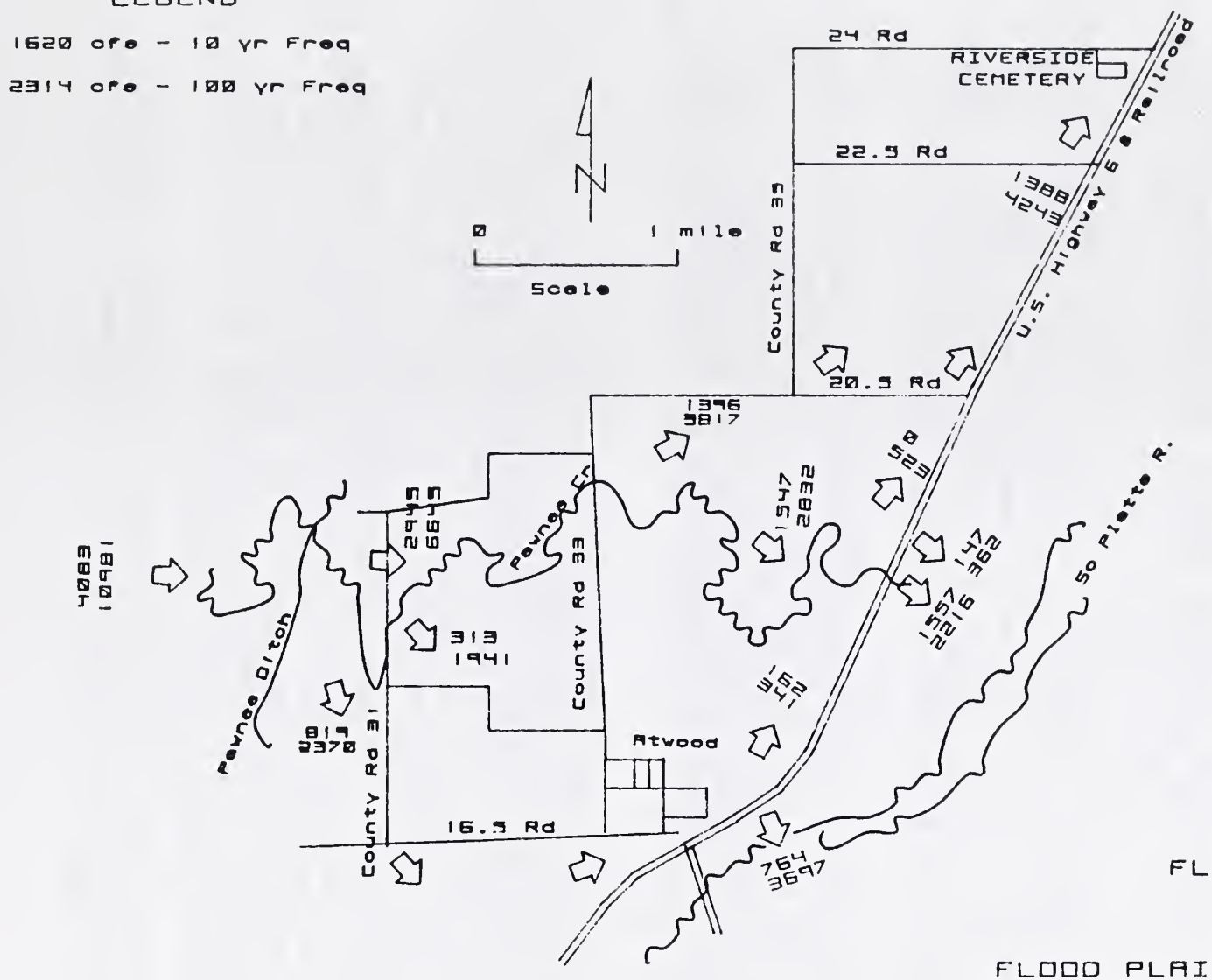


FIG 3

FLOW PATTERN

PAWNEE CR

FLOOD PLAIN MANAGEMENT STUDY

Hydraulics

Hydraulic analyses conducted in this study were done using U.S. Army Corp of Engineers computer model HEC2. The general land slope in the study reach is less than 1 percent, therefore backwater effects from roads, bridges, etc are very significant. In some cases HEC2 was used to develop discharge-elevation rating tables for use in TR20. Water surface profiles were computed for three general reaches.

Reach number one includes a profile of Pawnee Creek from the South Platte River upstream through the Burlington Northern Railroad and U.S. Highway 6 bridges, then continuing on through County Road 33 and 31.

A considerable out of bank division of flow occurs between County Road 31 and the Pawnee Ditch crossing. The Pawnee Creek channel at this location has a very limited carrying capacity. A portion of the out-of-bank flow moves toward the southeast to the vicinity of Atwood. Water surface profiles were not computed for this out-of-bank segment of flow, except along U.S. Highway 6 between Atwood and the main channel, because of the lack of topographic data.

A significant out-of-bank division of flow also occurs just below County Road 33. The out-of-bank flow at this location moves overland away from the main channel towards the northeast and eventually to the vicinity of the Riverside Cemetery. Water surface profiles were not computed for this segment of flow because of the unpredictable meandering flow pattern through farmland; however, a probable flow path was sketched on the flood plain maps.

Alluvial fan type topography exists along Pawnee Creek immediately below U.S. Highway 6 and the railroad. The flow here divides three ways: the main channel, left overbank, and right overbank. Only a profile along the main channel is shown in the included flood profiles. Backwater computations were made, however, for the overbank flow segments for purposes of defining the flood boundaries on included flood plain maps.

A second reach includes a short segment of flow along the railroad and U.S. Highway 6 between the main Pawnee Creek channel and the town of Atwood. The source of this flow is from out-of-bank conditions at the upper end of reach one, discussed previously. A major part of this segment of flow will overflow the highway and railroad near Atwood with the residual moving on to the main channel at U.S. Highway 6.

The third reach is a profile along U.S. Highway 6 and the railroad from the Riverside Cemetery upstream to the bridges on Pawnee Creek.

Discharge values were determined from TR20 analyses which is discussed in the hydrology section of this report. Cross section data was developed from topographic maps with a scale of 1"=400 ft with 5 ft contour intervals. Some supplemental field surveys were made at specific sites. Dimensions of bridges and hydraulic roughness coefficients (n- values) were determined from field investigations.

The following table shows Mannings n-values used in the hydraulic computations:

Section ID		n-value		
From	To	Left Overbank	Right Overbank	Channel
18.1	18.2	.040	.040	.040
18.2	22	.075	.075	.075
22	24	.060	.060	.060
24	29	.100	.110	.110
29	33	.035	.035	.035
33	38	.110	.110	.110
		Atwood Reach		
20.3	17.2	.060	.060	.060
		Cemetery Reach		
7	14	.040	.040	.040

Water surface profiles, typical cross sections, and maps showing the 100 year flood boundaries are shown on included exhibits and flood plain maps. Table 4 shows computed flood elevations at specific cross sections.

Flood boundaries were located on the set of 1990 topographic maps, previously referred to, by transferring flood elevations (at map contour intervals) from plotted profiles (from HEC2) to the maps using stationing along the main channel as the location reference. These points were connected and smoothed to create the map flood boundaries.

The split flow option in HEC2 and the DIVERT and DIVIDE features in TR20 were used to help determine the division of flows that occur throughout the study reach.

Treatment Alternatives

There are a number of possible treatment alternatives for reducing flood damages from Pawnee Creek. However, for purposes of this study investigations were limited to the following:

(1) Flooding under present conditions.

(2) Effects of floodwater retarding structures.

(3) Effects of flood dikes.

The major part of this report attempts to define present condition flooding. There are flood plain maps, flood profiles, tables, a flood history, etc. to provide this information. The following discussion attempts to evaluate the two treatment alternatives.

Floodwater Retarding Structures

Seven potential floodwater retarding structures were considered for purposes of reducing flooding on Pawnee Creek. They are located throughout the basin, see Figure 4. These structures were considered high hazard dams for design purposes, which means the reservoir storage and emergency spillway of each dam must handle the probable maximum flood from the contributing drainage area. The SCS DAMS2 and TR20 computer programs were used to size and analyze the effects of these structures. Table 2 shows structural data for each dam and Table 3 gives a very preliminary approximation of cost. The effects of this alternative can best be illustrated by comparing peak discharge - frequency values for this alternative with no-project conditions at select locations. This comparison is shown in the following table:

Location	Discharge - cfs			
	10 yr	25 yr	50 yr	100 yr
Highway 14	4700	7300	9600	12200
With Dams	600	900	1100	1400
County Rd 25	4300	6700	8900	11400
With Dams	550	700	900	1100

There are other effects, such as economic and environmental, that are not analyzed in this study.

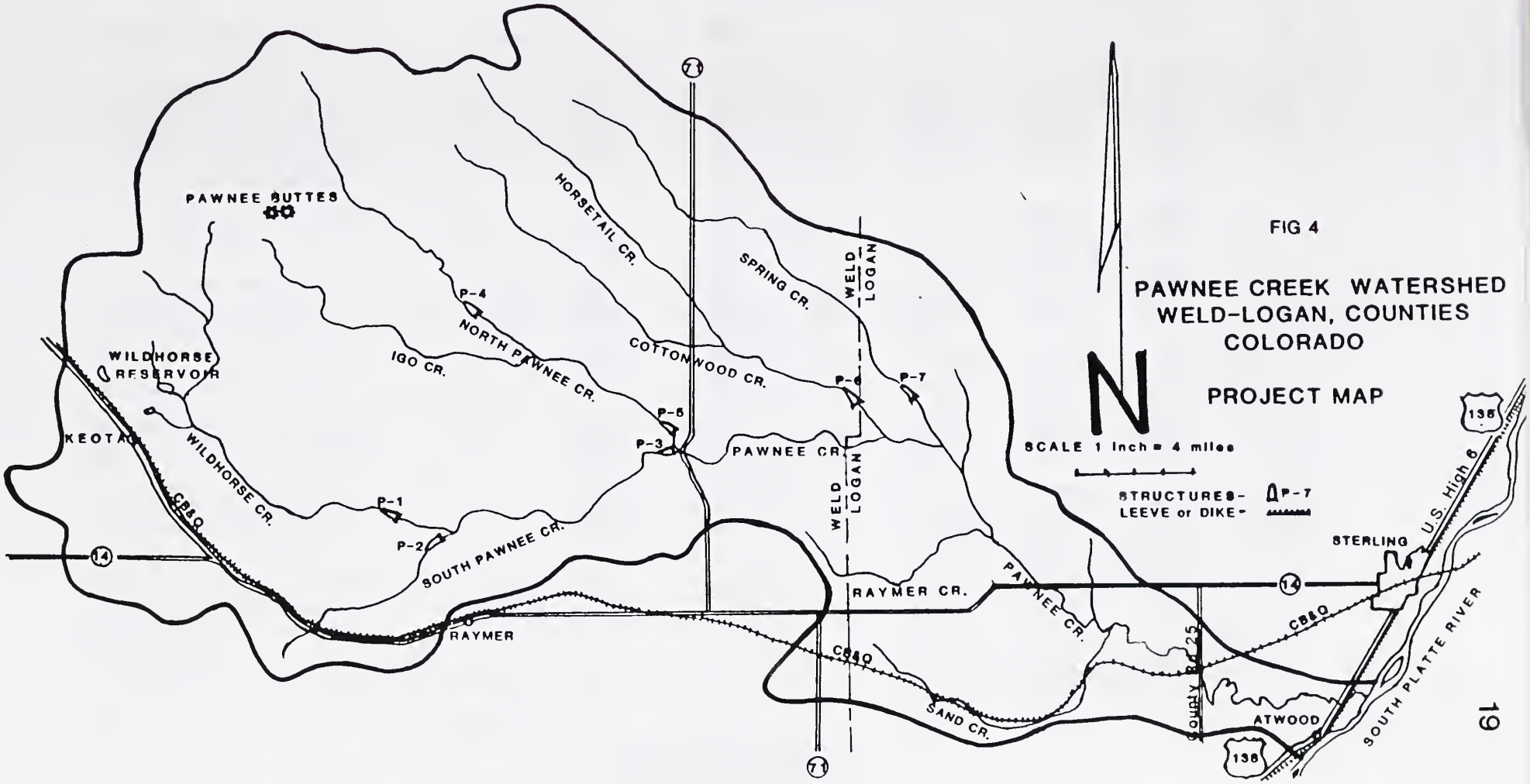


FIG 4

PAWNEE CREEK WATERSHED
WELD-LOGAN, COUNTIES
COLORADO

PROJECT MAP

TABLE 2 STRUCTURAL DATA
PAWNEE CREEK WATERSHED
LOGAN-WELD COUNTIES

Item	Unit	Dam P-1	Dam P-2	Dam P-3	Dam P-4	Dam P-5	Dam P-6	Dam P-7
Class Structure		C	C	C	C	C	C	C
Seismic Zone		I	I	I	I	I	I	I
Uncontrolled Drainage Area	Sq.Mi.	121.4	24.6	76.4	91.3	40.5	61.65	71.63
Controlled Drainage Area	Sq.Mi.	0	0	146.0	0	91.3	0	0
Total Drainage Area	Sq.Mi.	121.4	24.6	222.4	91.3	131.8	61.65	71.63
Runoff Curve No.(1-day,AMCII)		78	78	78	77	77	77	77
Time of Concentration	Hrs	7.5	4.1	11.2	7.0	8.7	8.7	9.7
Elevation Top of Dam	Ft	4739.2	4695.0	4475.4	4705.7	4471.7	4382.7	4342.2
Elevation Crest Emergency Spill	Ft	4723.2	4681.9	4462.9	4690.4	4459.0	4368.0	4329.4
Elevation Crest Pr Spill	Ft	4705.6	4668.3	4447.2	4673.1	4444.3	4349.8	4315.5
Emergency Spill Type		Earth	Earth	Earth	Earth	Earth	Earth	Earth
Emergency Spill Btm Width	Ft	1200	500	800	1000	500	600	800
Emergency Spill Exit Slope	%	>Sc	>Sc	>Sc	>Sc	>Sc	>Sc	>Sc
Maximum Height of Dam	Ft	65.2	55.0	57.4	69.7	45.7	64.7	56.2
Volume of Fill	Cu.Yd.	796307	248481	694901	1122804	694640	680517	674083
Total Storage Capacity	Ac.Ft.	11284	2161	6523	7400	3509	5103	5997
Sediment	Ac.Ft.	3205	658	2044	2440	1075	1643	1910
Floodwater Retarding	Ac.Ft.	8079	1503	4479	4960	2434	3460	4087
Surface Area								
Sediment Pool	Ac.	260	68	175	175	115	135	200
Floodwater Retarding Pool	Ac.	700	160	395	415	250	255	410
Principal Spillway Design								
Rainfall Volume (1-day)	In	3.91	3.91	3.91	3.91	3.91	3.91	3.91
Rainfall Volume (10-day)	In	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Runoff Volume (10-day)	In	1.43	1.67	1.50	1.42	1.54	1.47	1.45
Capacity of Pr Spill	cfs	369	171	256	387	150	270	252
Dimensions of Conduit	In	48	36	42	48	36	42	42
Type of Conduit		R.C.Pipe	R.C.Pipe	R.C.Pipe	R.C.Pipe	R.C.Pipe	R.C.Pipe	R.C.Pipe
Freq Operation of Emerg Spill (Based on 24 Hr Storm)	% Chance	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Emergency Spill Hydrograph								
Rainfall Depth	In	7.05	7.05	7.05	7.05	7.05	7.05	7.05
Runoff Depth	In	4.52	4.52	4.52	4.41	4.41	4.41	4.41
Storm Duration	Hr	6	6	6	6	6	6	6
Velocity of Flow	Ft/Sec	10.4	9.27	9.43	10.32	9.24	10.20	9.25
Max Water Surface Elev	Ft	4730.08	4687.3	4468.6	4697.0	4464.5	4374.4	4335.0
Freeboard Hydrograph								
Rainfall Depth	In	23.30	23.30	23.30	23.30	23.30	23.30	23.30
Runoff Depth	In	20.23	20.23	20.23	20.06	20.06	20.06	20.06
Storm Duration	Hr	24	24	24	24	24	24	24
Max Water Surface Elev	Ft	4739.2	4695.0	4475.4	4705.7	4471.7	4382.7	4342.2
Discharge/Ft Width (Qe/b)	Ac.Ft.	101	49	96	91	81	103	90
Bulk Length	Ft	500	500	500	500	500	500	500
Capacity Equivalents								
Sediment Volume	In	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Floodwater Retarding Volume	In	1.25	1.15	1.10	1.02	1.13	1.05	1.07

Table 3 Floodwater Retarding Structure Costs

Struct ID	Volume of Fill CY	Const Cost $ 1/	Eng Cost $ 2/	Proj Admin $ 3/	Land Rights $ 4/	Total Instal $	O&M Cost $ 5/
P-1	796307	2747259	384616	467034	225000	3823909	13736
P-2	248481	857259	120016	145734	60000	1183010	4286
P-3	694901	2397408	335637	407559	135000	3275605	111987
P-4	1122804	3873674	542314	658525	141000	5215513	19368
P-5	694640	2396508	335511	407406	90000	3229425	11983
P-6	680517	2347784	328690	399123	93000	3168597	11739
P-7	674083	2325586	325582	395350	138000	3184518	11628
Total	4911733	16945479	2372367	2880731	882000	23080577	84727

1/ Const cost is engr est (which is $3.00/cy) + 15% cont = $3.45/cy
2/ 14% of const cost
3/ 17% of const cost
4/ $300. per acre
5/ 0.5% of const cost

Note: These are very preliminary cost estimates; however, they are sufficient to suggest a project of this magnitude may not be cost effective in terms of benefit-cost relationships.

Earth Dike System

A system of dikes to keep the 100-year frequency flood within the Pawnee Creek channel would be impractical. The intent of the dike system proposed herein is to prevent flood waters from encroaching on the Riverside Cemetery and the Town of Sterling. This system of dikes would be installed at three locations, see figure 5, and would continue to allow overflow to occur at several locations along the Pawnee Creek channel as well as along U.S. Highway 6 and the Burlington Railroad. These out-of-bank flows would be restricted from moving to the northeast towards Sterling.

Data pertaining to the three dike segments are shown in the following table:

Location	Earthfill - Length		Concrete - Length	
	(Ft.)	(Cu. Yd.)	(Ft.)	(Cu. Yd.)
West Dike	5350	14500	---	---
East Dike 1/	2400	15340	700	620
South Dike	905	3374	---	---
Total	8655	33214	700	620

1/ East Dike has additional special structure to prevent flow north down highway and railroad.

The West Dike would prevent a segment of out-of-bank flow from moving overland to the northeast towards the Riverside Cemetery and Sterling.

The East Dike would promote more efficient use of the bridges on Pawnee Creek at U.S. Highway 6 and the railroad. The highway and railroad would be used as an emergency spillway to the South Platte River. This dike would prevent out-of-channel flows from following the highway and railroad towards Sterling. The dike would extend some distance below the railroad to prevent out-of-bank flows from encroaching onto a farmstead along the northeast bank.

The South Dike would be near Atwood and would prevent northeast bound flows from following the highway and railroad to combine with the Main Pawnee Creek. These Atwood flows would be pushed over the highway and railroad to join the South Platte River.

The following table shows an estimated cost of the proposed dike system. Figure 5 shows the flow pattern with the proposed dikes in place.

The dike system would prevent flood flows from reaching the Riverside Cemetery along with the associated overflow into Sterling and across the highway and railroad in that vicinity. An additional 2900 cfs, above present conditions, would be forced through the Pawnee Creek highway and railroad bridges (100 yr). Approximately 1400 cfs would overflow the highway and railroad in this vicinity that would not occur under present conditions. There would be an increase in water surface elevation of about 3.1 ft at the Pawnee Creek bridge. An increase of 340 cfs from present conditions would overflow the highway and railroad near Atwood. This would raise the water surface elevation across the railroad near Atwood by very little.

This dike system would benefit the Town of Sterling; however, it should be understood that a tradeoff would be additional flood water discharge and depth along the lower reach of Pawnee Creek to Atwood.

Pawnee Creek Watershed - Dike System Cost

Location	Volume Fill CY	Const Cost $	Eng Cost $	Proj Admin $	Land Right $	Total Instal $	O&M 4/ $
West Dike	14500	70300 1/	9850	11950	12000	104100	700
East Dike	15960 2/	557040 3/	78040	94790	12000	741870	6250
South Dike	3374	12680	1770	2150	5000	21600	200
Total	33834 5/	640020	89660	108890	29000	867570	7150

1/ Includes $16000 for 4 irrigation conduits under the dike
2/ Includes 15340 cu yd earthfill and 620 cu yd of reinforced concrete
3/ Includes $5800 for irrigation conduit, $435240 for concrete wall and $58500 for special structure at highway and railroad
4/ O&M (annual cost assumed to be) 1 percent of construction cost
5/ Includes 620 cu yd of reinforced concrete
Note: Rock rip rap may be needed along the downstream railroad slope at certain locations. Costs for this are not included here.

Further project studies will be needed to evaluate economic feasibility and project effects if this dike system were to be pursued.

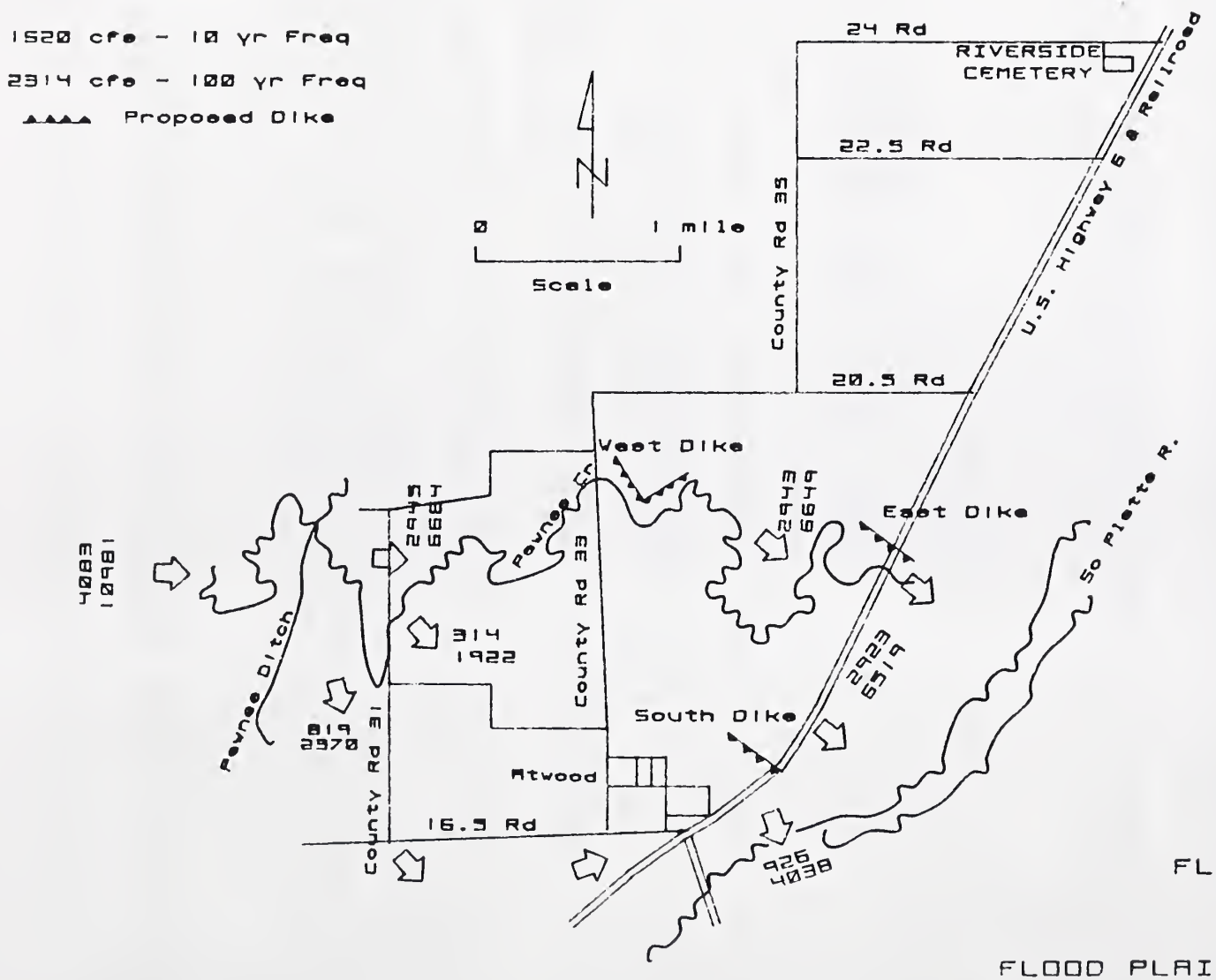


FIG 5

FLOW PATTERN

PAWNEE CR

FLOOD PLAIN MANAGEMENT STUDY

FLOOD PLAIN MANAGEMENT

Potential flood damages to existing development and possible loss of life can be alleviated or lessened through non-structural and structural flood hazard mitigation methods.

Non-structural methods include: local flood plain regulations, land treatment, flood warning and forecasting systems, flood insurance, flood proofing, flood fighting and emergency evacuations.

Local Regulations

The need to minimize property damage due to flooding has been recognized by planners and local community officials. Subdividers and developers are required to submit proposed storm drainage plans to the planning commission for approval. In the past, drainage plans have been prepared singularly or on a plat-by-plat basis. Information contained in this report will be useful in developing a master drainage plan for the study area. This report provides the outline of flood hazard areas on large scale maps specifically for this purpose.

The city may provide zoning regulations "...to establish, regulate, restrict, and limit such uses on or along any storm or floodwater runoff channel or basin, as such storm or floodwater runoff channel or basin has designated and approved by the Colorado Water Conservation Board, in order to lessen or avoid the hazards to persons and damage to property resulting from the accumulation of storm or floodwaters..." as stated in Section 30-28-111 for county governments and Section 31-23-302 for municipal governments of the Colorado Revised Statutes.

Colorado Natural Hazard Area Regulations

In 1974, the Colorado General Assembly passed House Bill 1041, a bill "concerning land use, and providing for identification, designation, and administration of areas and activities of State interest,..." (H.B. 1041, Title 24, Article 65.1, C.R.S., as amended). Areas of State interest include natural hazard areas, or those areas that are "so adverse to past, current, or foreseeable construction or land use as to constitute a significant hazard to public health and safety or to property". Flood plains are natural hazard areas.

With reference to the administration of natural hazard areas, Section 24-65.1-202(2)(a) of the Act provides: Flood plains shall be administered so as to minimize significant hazard to public health and safety or to property; open space activities shall be encouraged; structures shall be designed in terms of use and hazards; disposal sites and systems shall be discouraged which, in time of flooding, would create significant hazards to public health and safety or to property.

The Act further provides that after promulgation of guidelines for land use in natural hazard areas..., the natural hazard areas shall be administered by local government in a manner which is consistent with the guidelines for land use in each of the natural hazard areas.

Colorado Water Conservation Board Designation

Concerning the designation of the flood plain, the Colorado Water Conservation Board is charged with the primary responsibility for:

1. Making recommendations to local governments and the Colorado Land Use Commission.

2. Providing technical assistance to local governments.

The Board's power and duty is...

> ...to devise and formulate methods, means and plans for bringing about the greater utilization of the waters of the state and prevention of flood damages therefrom, and to designate and approve storm or floodwater runoff channels or basins, and to make such designations available to legislative bodies of cities and incorporated towns, to county planning commissions, and to boards of adjustment of cities, incorporated towns, and counties of this state"..

as stated in Section 37-60-106 (1)(c) of the Colorado Revised Statutes.

Upon review and approval of this report, the Colorado Water Conservation Board will designate and approve as flood plain areas those areas inundated by the 100-year flood as described by the floodwater surface elevations and profiles in this report. The use of the designated flood plain areas may then be regulated by the local government.

Model Regulations

Model flood plain regulations have been promulgated by the Colorado Water Conservation Board, with the purpose to promote public health, safety, and general welfare, and minimize flood hazards and losses. The model includes provisions designed to:

1. Promote sound planning and permit only such uses within flood plains that will not endanger life, health, and public safety or property in times of flooding.

2. Protect the public from avoidable financial expenditures for flood control projects, flood relief measures, and the repair and restoration of damaged public facilities.

3. Prevent avoidable interruption of business and commerce.

4. Minimize victimization of unwary home and land purchases.

5. Facilitate the administration of flood hazard areas by establishing requirements that must be met before use or development is permitted.

The Board's model flood plain regulations offer two options for management of the 100-year flood plain. These are the Hazard Area Concept and the Floodway Concept.

The Hazard Area concept defines the areas of the flood plain in which waters of the 100-year flood attain a maximum depth greater than one and one-half feet as a high hazard area, and a depth less than this as a low hazard area.

The Floodway concept defines the channel of a stream and adjacent flood plain areas that must be kept free of development in order to safely pass the 100-year flood with a minimal rise in the water surface elevation. The rise must be no more than one foot to meet federal standards.

Flood Insurance

The National Flood Insurance Act of 1968 (Title XIII of the Housing and Urban development Act, P.L. 90-448) recognized the necessity for flood plain management. This Act makes federally subsidized insurance available to citizens in communities that adopt regulations controlling future developments of their flood plain. Withe respect to encroachment on the flood plain, the regulations require:

1. New residential construction or substantial improvement of existing homes must have the lowest floor level at or above the elevation of the 100-year flood.

2. Non-residential construction must meet the same standard or be flood proofed to that level.

The 1968 Act benefits owners of structures already in the flood-prone areas by providing insurance coverage that had been unavailable through private companies. The Act created a cooperative program of insurance against flood damage by the private flood insurance industry and the federal government.

The amount of coverage available and the premium rate varies considerably depending on property location within the flood plain and the property value. All property owners shown in this study to be within areas subject to flooding should consider the purchase of flood insurance.

Additional information on the Flood Insurance Program is available from local insurance agents or brokers and the:

Federal Emergency Management Agency, Region VIII
Natural and Technological Hazard Division
Building 710
Denver Federal Center
Denver, CO 80225
Telephone: 235-4830

The National Flood Insurance Program used the floodway concept in its rate studies for communities participating in the regular phase of the program.

Flood Warning and Flood Forecasting Systems

The National Oceanic and Atmospheric Administration (NOAA) through its National Weather Service (NWS), maintains year-round surveillance of weather and flood conditions. Daily weather forecasts are issued through the NWS and disseminated by radio and television stations. A general alert to the danger of flash flooding is one of the services provided by the NWS.

The office of the Colorado State Engineer, Division of Water Resources, in cooperation with the National Weather Service, operates a state-wide flood warning system utilizing 78 stream gaging stations that are part of the Colorado satellite linked water resources monitoring network operated by the State Engineer.

Evacuation Plan

An "Emergency Evacuation and Operations Plan" would provide for alerting the public of potential flooding, and coordinating community and county services during an emergency. Plan implementation during the time of an emergency requires cooperation of the general public as well as local officials. This is especially important for flood fighting, evacuation, and rescue operations. Communication is extremely important during flood alerts. Warnings issued through the NWS are disseminated by radio to state and local officials.

RECOMMENDATIONS

The following recommendations are included for consideration in reducing potential flood damages:

1. Carry out periodic maintenance of bridges to preserve hydraulic capacity.

2. Consider dike system alternative presented in this document.

3. Raise a segment of County Road 33 north of Pawnee Creek bridge for purposes of directing out-of-bank flows to the bridge.

4. Rip rap the railroad embankment where overflow to the South Platte River will occur as a result of future flooding.

5. Do detailed study of need for flood proofing around facilities in the flood plain or consider flood insurance.

6. Information and education programs on flood hazards should be made available to the public.

7. The main channels should be maintained to preserve a balance between native vegetation, conveyance capacity, channel stability, and provide wildlife habitat.

GLOSSARY OF TERMS

Channel - A natural or artificial water course of perceptible extent with definite banks to confine and conduct continuously or periodically flowing water. Channel flow is that water which is flowing within the limits of the defined channel.

Flood - Water from a river, stream, water course, lake or other body of standing water, that temporarily overflows the boundaries within which it is ordinarily confined.

Flood Crest - The maximum stage or elevation reached by the waters of a flood at a given location.

Flood Frequency - A means of expressing the probability of flood occurrences as determined from statistical analysis of representative streamflow or rainfall and runoff records. The frequency of a particular stage or discharge is usually expressed as occurring once in a specified number of years. The 10-, 50-, 100-, and 500-year frequency floods have an average frequency of occurrence in the order of once in the number of years indicated.

Flood Hazard Areas - Areas susceptible to flood damage.

Flood Peak - The highest stage or discharge attained during a flood event; also referred to as peak stage or peak discharge.

Flood Plain - The relatively flat or lowland area adjoining a river, stream, watercourse, lake, or other body of water which has been or may be covered temporarily by flood water. For administrative purposes the flood plain may be defined as the area that would be inundated by the 100-year flood.

Left or Right Stream Bank - The left or right bank of the stream looking downstream.

Perched Channel Flow - A condition where the flow elevation in the outer portions of the flood plain is higher than the flow elevation in the main channel. This condition occurs when a secondary channel receives inflow from some location upstream and maintains a flatter slope than the main channel.

Reach - A hydraulic engineering term used to describe longitudinal segments of a stream or river.

Runoff - That part of precipitation, as well as any other flow contributions, which appears in surface streams of either perennial or intermittent form.

Stream - Any natural channel or depression through which water flows whether continuously, or intermittently, including modification of the natural channel or depression.

Structure - Anything constructed or erected, the use of which requires a more or less permanent location on or in the ground. Includes but is not limited to bridges, buildings, canals, dams, ditches, diversions, irrigation systems, pumps, pipelines, railroads, roads, sewage disposal systems, underground conduits, water supply systems and wells.

Valley Cross Section - A plotting of the topography of a stream channel and adjoining landscape as viewed perpendicular to the flow in a downstream direction. The plotting represents a specified location within a designated stream reach.

Water Surface Profile - (This term is synonymous with Flood Profile) - a graph showing the longitudinal relationship of the water surface elevation of a flood event to location along a stream or river.

Watershed - A drainage basin or area which contributes to runoff and transmits it, usually by means of streams and tributaries, to the outlet of the basin.

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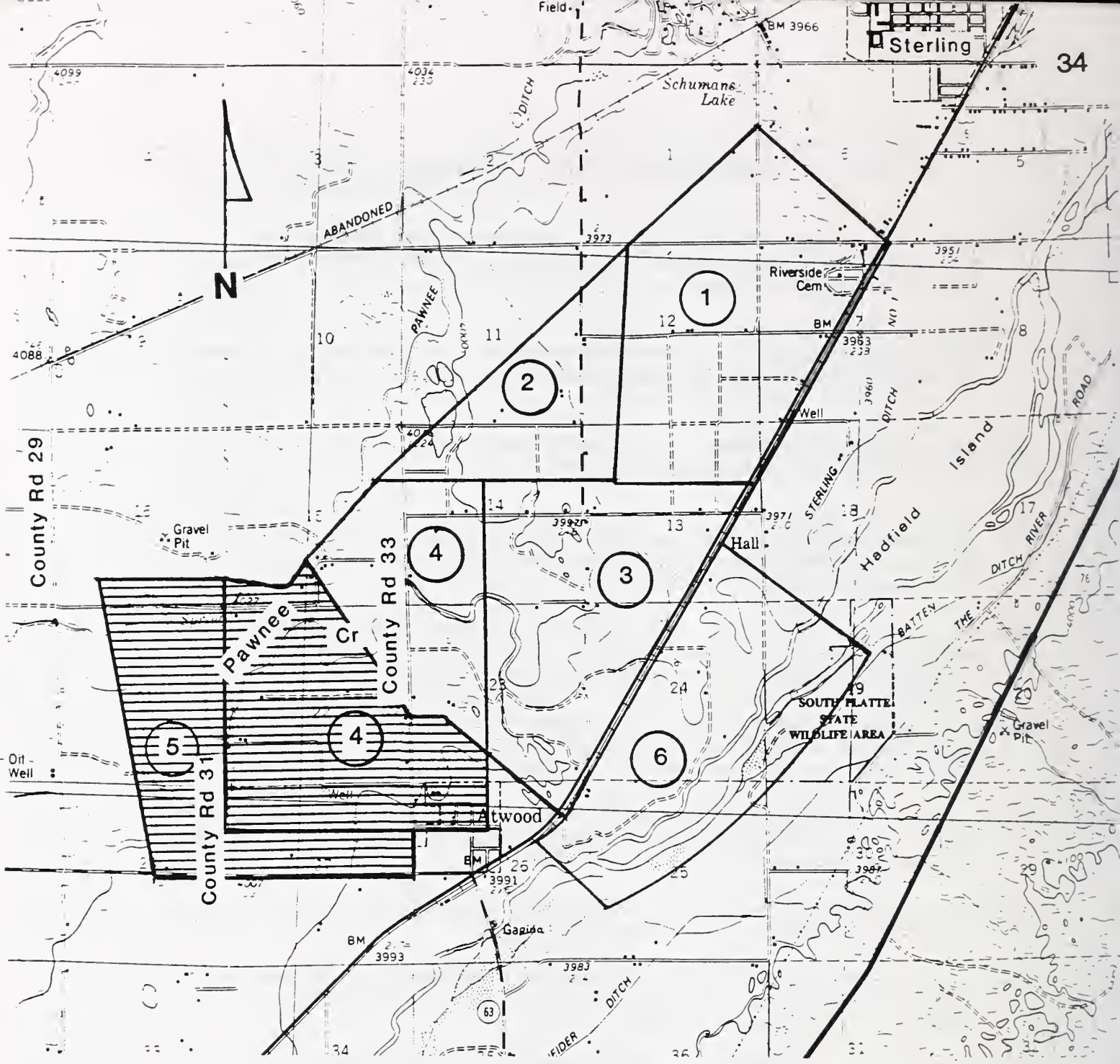

(2) Map Sheet Number

Areas With Only Cross Section Data – No Contours

FIG 6

MAP SHEET INDEX

PAWNEE CREEK

FLOOD PLAN MANAGEMENT STUDY

Match to Sheet 2

Match to Sheet 3

N106,000 N108,000 N110,000 N112,000 N114,000

E 100,000 E 102,000 E 104,000 E 106,000

U.S. Highway 6

Pawnee Creek

Cemetery

3957.15 HV 5

LEGEND

- 100 YEAR FLOOD
- ESTIMATED 100 YEAR FLOOD
- 10 STREAM STATION IN 100 FT FROM LOWER STUDY LIMIT
- 3960 100 YEAR FLOOD ELEV
- CROSS SECTION

TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM 6" C.F.L. VERTICAL AERIAL PHOTOGRAPHY TAKEN MARCH 10, 1990. COORDINATE SYSTEM: IS AN ASSUMED HORIZONTAL DATUM BASE USING THE CENTERLINE OF U.S. HIGHWAY 6 AS THE BASELINE. THE BERING BASE IS THE CENTERLINE OF THE ROADWAY FROM A POINT OPPOSITE THE HISTORICAL MONUMENT ON THE SOUTH-LINE OF SECTION 7, T7N, R52W NORTHEAST ALONG THE ROADWAY CENTERLINE TO THE INTERSECTION OF THE NORTH LINE OF SECTION 7, T7N, R52W ASSUMED BEARING NORTH 30°00'00" EAST. VERTICAL DATUM: BASED ON BENCHMARK G-419, ELEVATION 3987.10' N.G.S. STANDARD MONUMENT LOCATED EAST OF THE INTERSECTION OF HIGHWAY 6 AND HIGHWAY 63.

PREPARED BY: KUCERA WEST, 4690 MONACO PARKWAY, DENVER, COLORADO 80216

FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN AND WELD COUNTIES
COLORADO

SCALE 400 0 400 800 1600 IN FEET

SHEET 1 OF 6

N106,000

N108,000

N110,000

N112,000

N114,000

N116,000

E92,000

E94,000

E96,000

E98,000

Match to Sheet 3

Match to Sheet 1

County Road 35

LEGEND

100 YEAR FLOOD

ESTIMATED 100 YEAR FLOOD

10 STREAM STATION IN 100 FT FROM LOWER STUDY LIMIT

3960 100 YEAR FLOOD ELEV

CROSS SECTION

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FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN AND WELD COUNTIES
COLORADO

SCALE 400 0 400 800 1600 IN FEET

SHEET 2 OF 6

Match to Sheet 4

N98,000 N100,000 N102,000 N104,000

N96,000

E96,000

E98,000

E100,000

E102,000

County Road 3S

U.S. Highway 6

MATCH SHEET 6

Match to Sheet 2

Match to Sheet 1

LEGEND

- 100 YEAR FLOOD
- ESTIMATED 100 YEAR FLOOD
- 10 + STREAM STATION IN 100 FT FROM LOWER STUDY LIMIT
- 3980 100 YEAR FLOOD ELEV
- CROSS SECTION

TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM 6" C.F.L. VERTICAL AERIAL PHOTOGRAPHY TAKEN MARCH 10, 1990. COORDINATE SYSTEM: IS AN ASSUMED HORIZONTAL DATUM BASE USING THE CENTERLINE OF U.S. HIGHWAY 6 AS THE BASELINE. THE BERING BASE IS THE CENTERLINE OF THE ROADWAY FROM A POINT OPPOSITE THE HISTORICAL MONUMENT ON THE SOUTH-LINE OF SECTION 7, T7N, R52W NORTHEAST ALONG THE ROADWAY CENTERLINE TO THE INTERSECTION OF THE NORTH LINE OF SECTION 7, T7N, R52W ASSUMED BEARING NORTH 30°00'00" EAST. VERTICAL DATUM: BASED ON BENCHMARK G-419, ELEVATION 3987.10' N.G.S. STANDARD MONUMENT LOCATED EAST OF THE INTERSECTION OF HIGHWAY 6 AND HIGHWAY 63.

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FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN AND WELD COUNTIES
COLORADO

SCALE 400 0 400 800 1600 FEET

SHEET 3 OF 6

Match to Sheet 5

N 96,000 N 98,000 N 100,000 N 102,000 N104,000

E 88,000 E 90,000 E 92,000 E 94,000

County Road 31

County Road 33

4025 4020 4020 4015 4010 4010 4009 4008 4005

38 37 33 32 31 30 29 28 27

344 336 328 320 312 304 296 288 280 272 264 256 248 240 232 224 216 208

LEGEND

- 100 YEAR FLOOD
- ESTIMATED 100 YEAR FLOOD
- 10 STREAM STATION IN 100 FT FROM LOWER STUDY LIMIT
- 3960 100 YEAR FLOOD ELEV
- CROSS SECTION

TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM 6" C.F.L. VERTICAL AERIAL PHOTOGRAPHY TAKEN MARCH 10, 1990. COORDINATE SYSTEM: IS AN ASSUMED HORIZONTAL DATUM BASE USING THE CENTERLINE OF U.S. HIGHWAY 6 AS THE BASELINE. THE BERING BASE IS THE CENTERLINE OF THE ROADWAY FROM A POINT OPPOSITE THE HISTORICAL MONUMENT ON THE SOUTH-LINE OF SECTION 7, T7N, R52W NORTHEAST ALONG THE ROADWAY CENTERLINE TO THE INTERSECTION OF THE NORTH LINE OF SECTION 7, T7N, R52W ASSUMED BEARING NORTH 30°00'00" EAST. VERTICAL DATUM: BASED ON BENCHMARK G-419, ELEVATION 3987.10' N.G.S. STANDARD MONUMENT LOCATED EAST OF THE INTERSECTION OF HIGHWAY 6 AND HIGHWAY 63.
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FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN AND WELD COUNTIES
COLORADO

400 0 400 800 1600
SCALE IN FEET

SHEET 4 OF 6

Match to Sheet 3

LEGEND

- 100 YEAR FLOOD
- ESTIMATED 100 YEAR FLOOD
- 10 — STREAM STATION IN 100 FT FROM LOWER STUDY LIMIT
- 3960 — 100 YEAR FLOOD ELEV
- CROSS SECTION

TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHOOS FROM 6" C.F.L. VERTICAL AERIAL PHOTOGRAPHY TAKEN MARCH 10, 1990. COORDINATE SYSTEM: IS AN ASSUMEO HORIZONTAL OATUM BASE USING THE CENTERLINE OF U.S. HIGHWAY 6 AS THE BASELINE. THE BERING BASE IS THE CENTERLINE OF THE ROAOWAY FROM A POINT OPPOSITE THE HISTORICAL MONUMENT ON THE SOUTH LINE OF SECTION 7, T7N, R52W NORTHEAST ALONG THE ROADWAY CENTERLINE TO THE INTERSECTION OF THE NORTH LINE OF SECTION 7, T7N, R52W ASSUMEO BEARING NORTH 30°00'00" EAST. VERTICAL OATUM: BASED ON BENCHMARK G-419, ELEVATION 3987.10' N.G.S. STANOARO MONUMENT LOCATEO EAST OF THE INTERSECTION OF HIGHWAY 6 ANO HIGHWAY 63.

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FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN AND WELD COUNTIES
COLORADO

SCALE: 400 0 400 800 1600 IN FEET

SHEET 5 OF 6

LEGEND

- 100 YEAR FLOOD
- ESTIMATED 100 YEAR FLOOD
- 10 STREAM STATION IN 100 FT FROM LOWER STUDY LIMIT
- 3980 100 YEAR FLOOD ELEV
- CROSS SECTION

TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM 6" C.F.L. VERTICAL AERIAL PHOTOGRAPHY TAKEN MARCH 10, 1990. COORDINATE SYSTEM: IS AN ASSUMED HORIZONTAL DATUM BASE USING THE CENTERLINE OF U.S. HIGHWAY 6 AS THE BASELINE. THE BERING BASE IS THE CENTERLINE OF THE ROADWAY FROM A POINT OPPOSITE THE HISTORICAL MONUMENT ON THE SOUTH-LINE OF SECTION 7, T7N, R52W NORTHEAST ALONG THE ROADWAY CENTERLINE TO THE INTERSECTION OF THE NORTH LINE OF SECTION 7, T7N, R52W ASSUMED BEARING NORTH 30°00'00" EAST. VERTICAL DATUM: BASED ON BENCHMARK G-419, ELEVATION 3987.10' N.G.S. STANDARD MONUMENT LOCATED EAST OF THE INTERSECTION OF HIGHWAY 6 AND HIGHWAY 63.

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FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN AND WELD COUNTIES
COLORADO

SCALE 400 0 400 800 1600 IN FEET

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

NOTE: DISCHARGES FOR ALL FREQUENCIES ARE THE SAME BECAUSE OF LIMITED CHANNEL CAPACITY

ELEVATION IN FEET (M.S.L.)

3980
3975
3970
3965
3960
3955

2 LOWER STUDY LIMIT

0 800 1600 2400 3200 4000 4800 5600

FEET UPSTREAM OF LOWER STUDY LIMIT

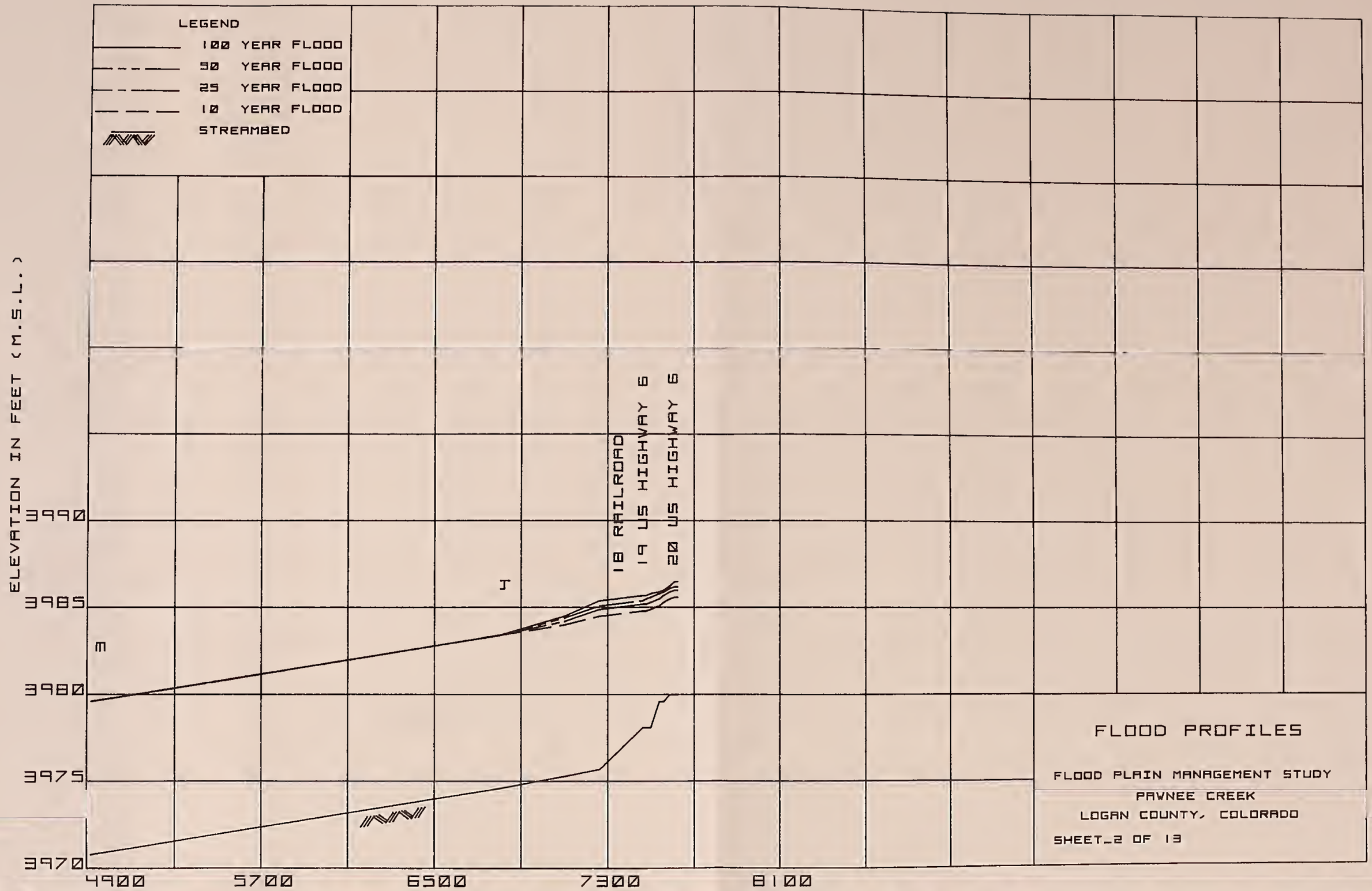
FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 1 OF 13


LEGEND
100 YEAR FLOOD
50 YEAR FLOOD
25 YEAR FLOOD
10 YEAR FLOOD
STREAMBED
ELEVATION IN FEET (M.S.L.)
3990
3985
3980
3975
3970
4900
5700
6500
7300
8100
M
J
18 RAILROAD
19 US HIGHWAY 6
20 US HIGHWAY 6
FEET UPSTREAM OF LOWER STUDY LIMIT
FLOOD PROFILES
FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN COUNTY, COLORADO
SHEET 2 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

ELEVATION IN FEET (M.S.L.)

4000
3995
3990
3985
3980
3975

20 US HIGHWAY 6

22

7600
8400
9200
10000
10800
11600

FEET UPSTREAM OF LOWER STUDY LIMIT

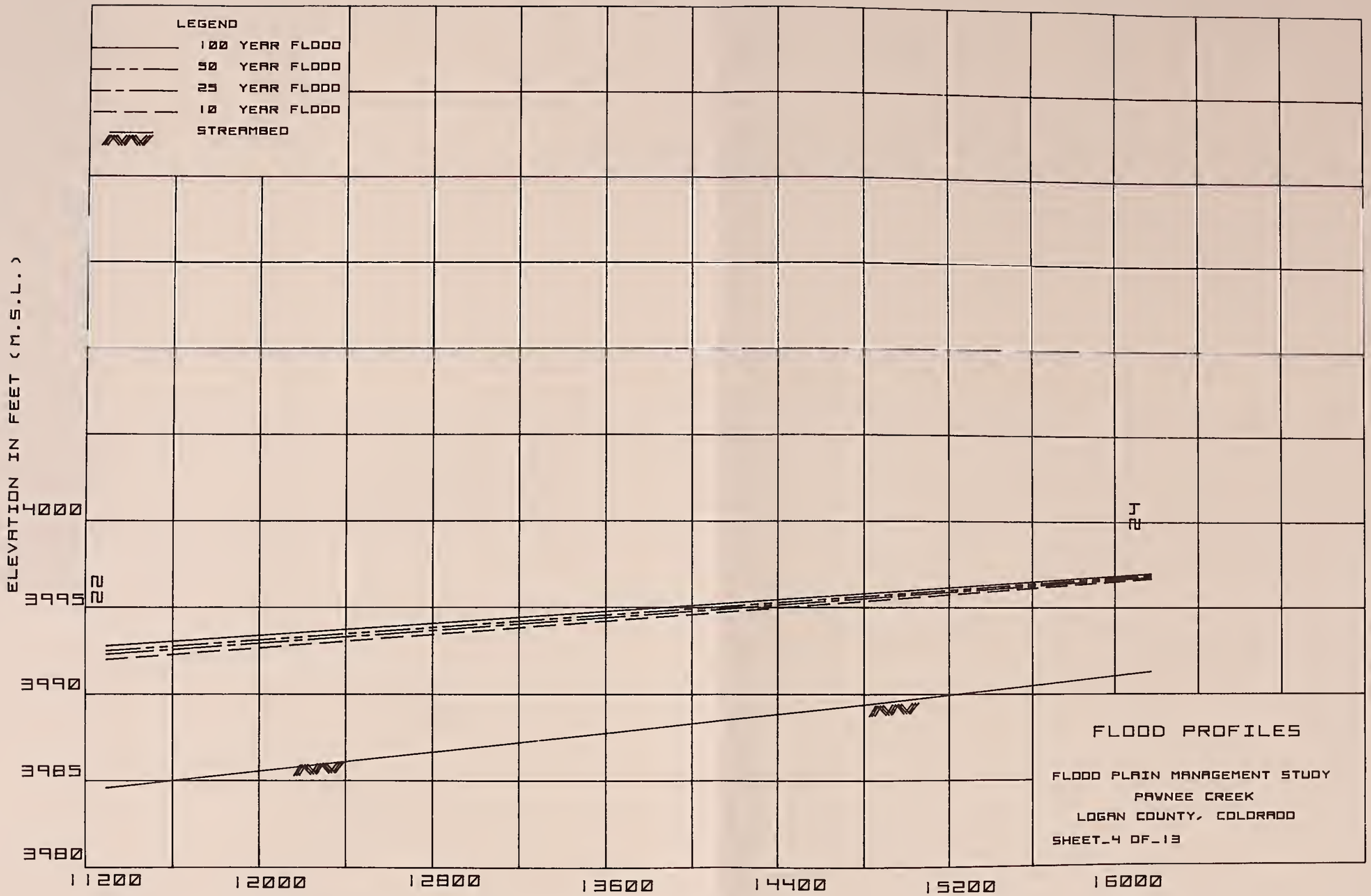
FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 3 OF 13


LEGEND
100 YEAR FLOOD
50 YEAR FLOOD
25 YEAR FLOOD
10 YEAR FLOOD
STREAMBED
ELEVATION IN FEET (M.S.L.)
4000
3995
3990
3985
3980
J2
J2
11200
12000
12800
13600
14400
15200
16000
FEET UPSTREAM OF LOWER STUDY LIMIT
FLOOD PROFILES
FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN COUNTY, COLORADO
SHEET 4 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

ELEVATION IN FEET (M.S.L.)

4010

4005

4000

3995

3990

3985

24

26

27

29

16100 16900 17700 18500 19300 20100 20900 21700

FEET UPSTREAM OF LOWER STUDY LIMIT

FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 5 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

COUNTY ROAD #3

ELEVATION IN FEET (M.S.L.)

4020

4015

4010

4005

4000

3995

3990

22000

22800

23600

24400

25200

26000

26800

27600

FEET UPSTREAM OF LOWER STUDY LIMIT

FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 6 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

37 COUNTY ROAD 31

E3

E2

E1

ELEVATION IN FEET (M.S.L.)

4025

4020

4015

4010

4005

4000

3995

27500

28300

29100

29900

30700

31500

32300

33100

FEET UPSTREAM OF LOWER STUDY LIMIT

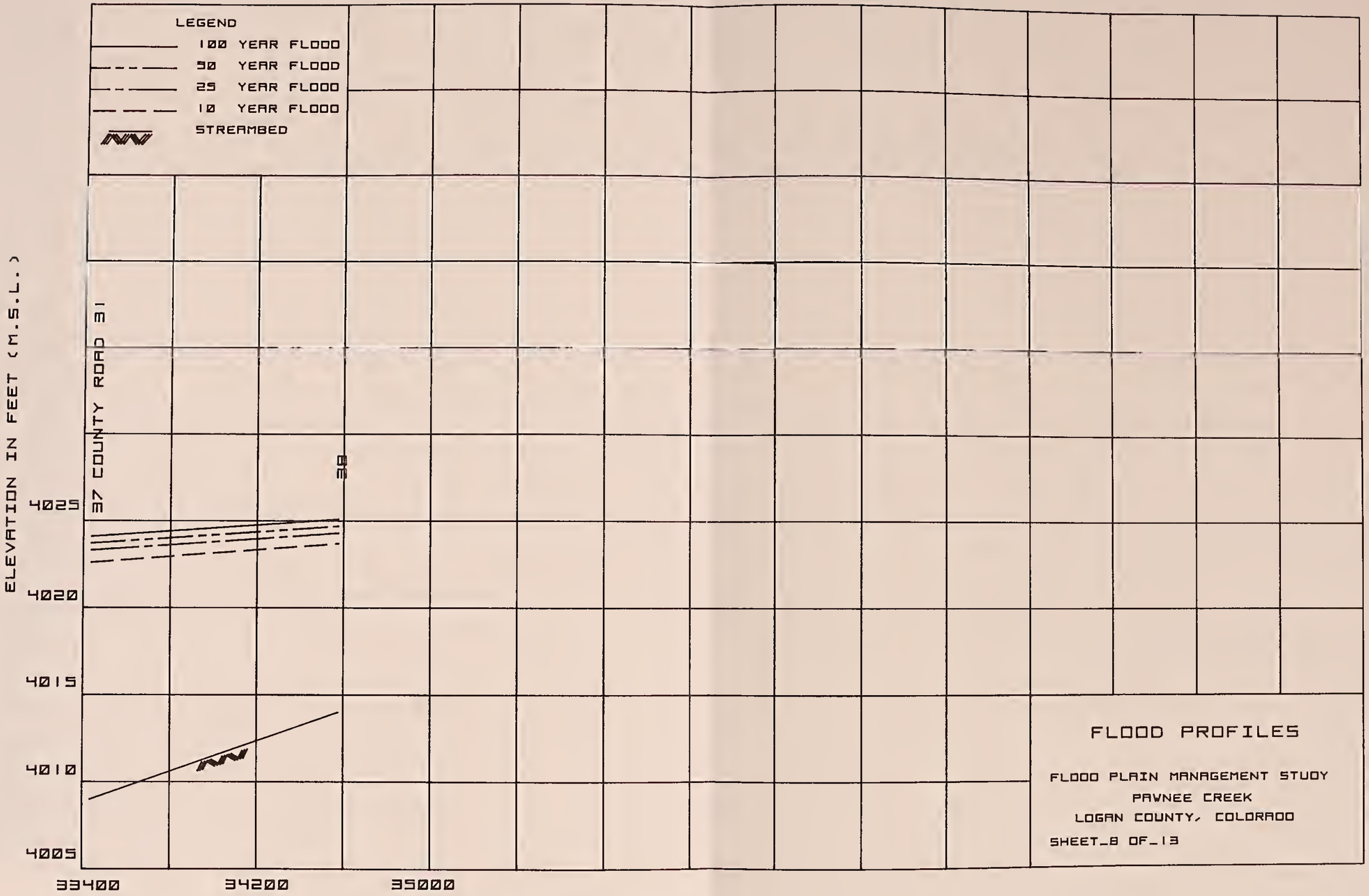
FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 7 OF 13



FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN COUNTY, COLORADO
SHEET 8 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

ELEVATION IN FEET (M.S.L.)

3970

3965

3960

3955

CEMETERY

A

A'

0

800

1600

2400

3200

FEET UPSTREAM OF LOWER STUDY LIMIT

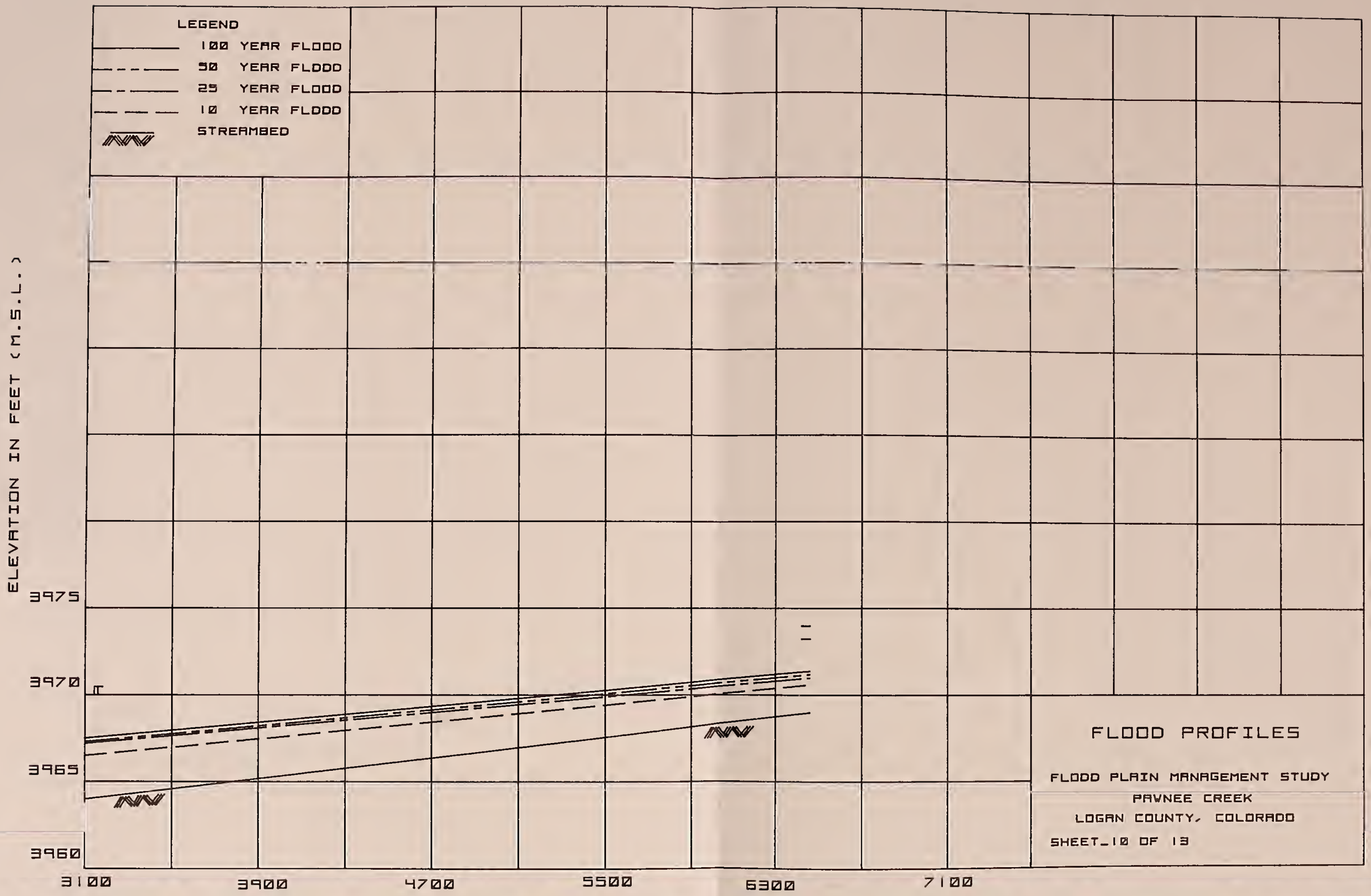
FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 9 OF 13


LEGEND
100 YEAR FLOOD
50 YEAR FLOOD
25 YEAR FLOOD
10 YEAR FLOOD
STREAMBED
ELEVATION IN FEET (M.S.L.)
3975
3970
3965
3960
3100
3900
4700
5500
6300
7100
FEET UPSTREAM OF LOWER STUDY LIMIT
FLOOD PROFILES
FLOOD PLAIN MANAGEMENT STUDY
PAWNEE CREEK
LOGAN COUNTY, COLORADO
SHEET 10 OF 13

LEGEND

100 YEAR FLOOD

90 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

ELEVATION IN FEET (M.S.L.)

3985

3980

3975

3970

3965

6400 7200 8000 8800 9600 10400 11200 12000

FEET UPSTREAM OF LOWER STUDY LIMIT

FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 11 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

ELEVATION IN FEET (M.S.L.)

3990

3985

3980

N

J

12100

12900

13700

FEET UPSTREAM OF LOWER STUDY LIMIT

FLOOD PROFILES

FLOOD PLAIN MANAGEMENT STUDY

PAWNEE CREEK

LOGAN COUNTY, COLORADO

SHEET 12 OF 13

LEGEND

100 YEAR FLOOD

50 YEAR FLOOD

25 YEAR FLOOD

10 YEAR FLOOD

STREAMBED

ELEVATION IN FEET (M.S.L.)

3990

3985

3980

3975

20.3 PAWNEE CR

15

17.1

17.2 NEAR ATWOOD

7600 8400 9200 10000 10800 11600 12400 13200

FEET UPSTREAM OF LOWER STUDY LIMIT

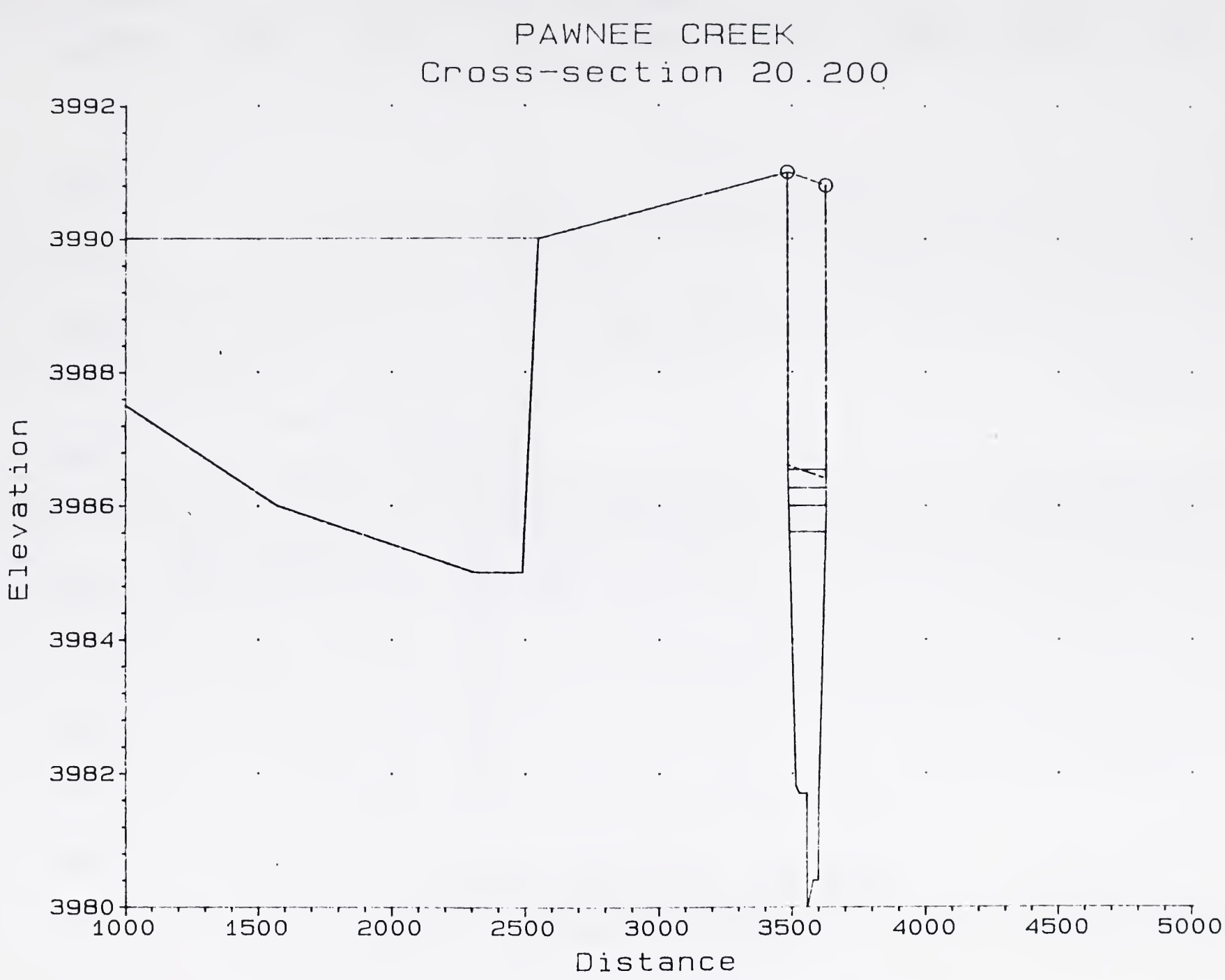
FLOOD PROFILES

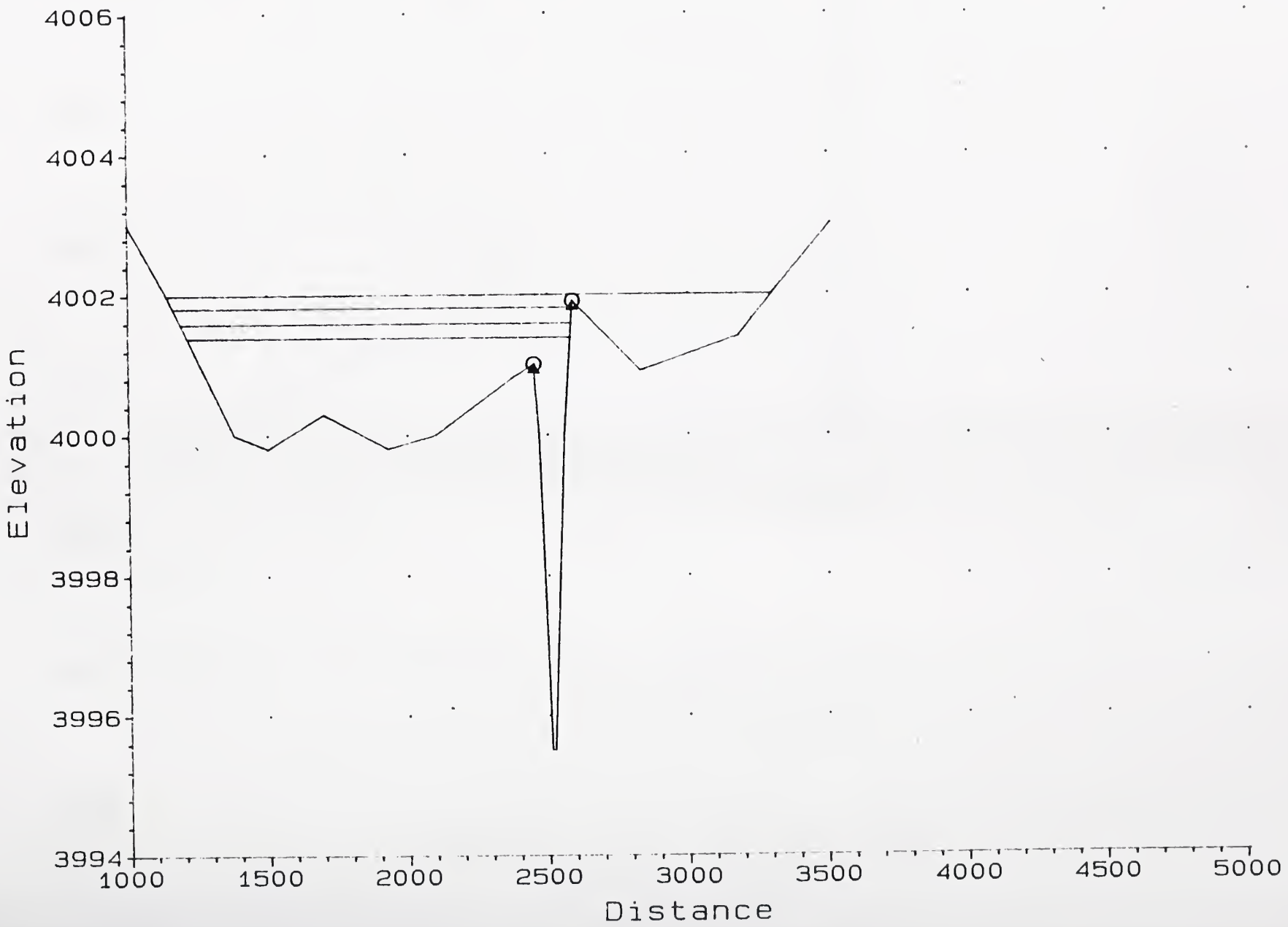
FLOOD PLAIN MANAGEMENT STUDY

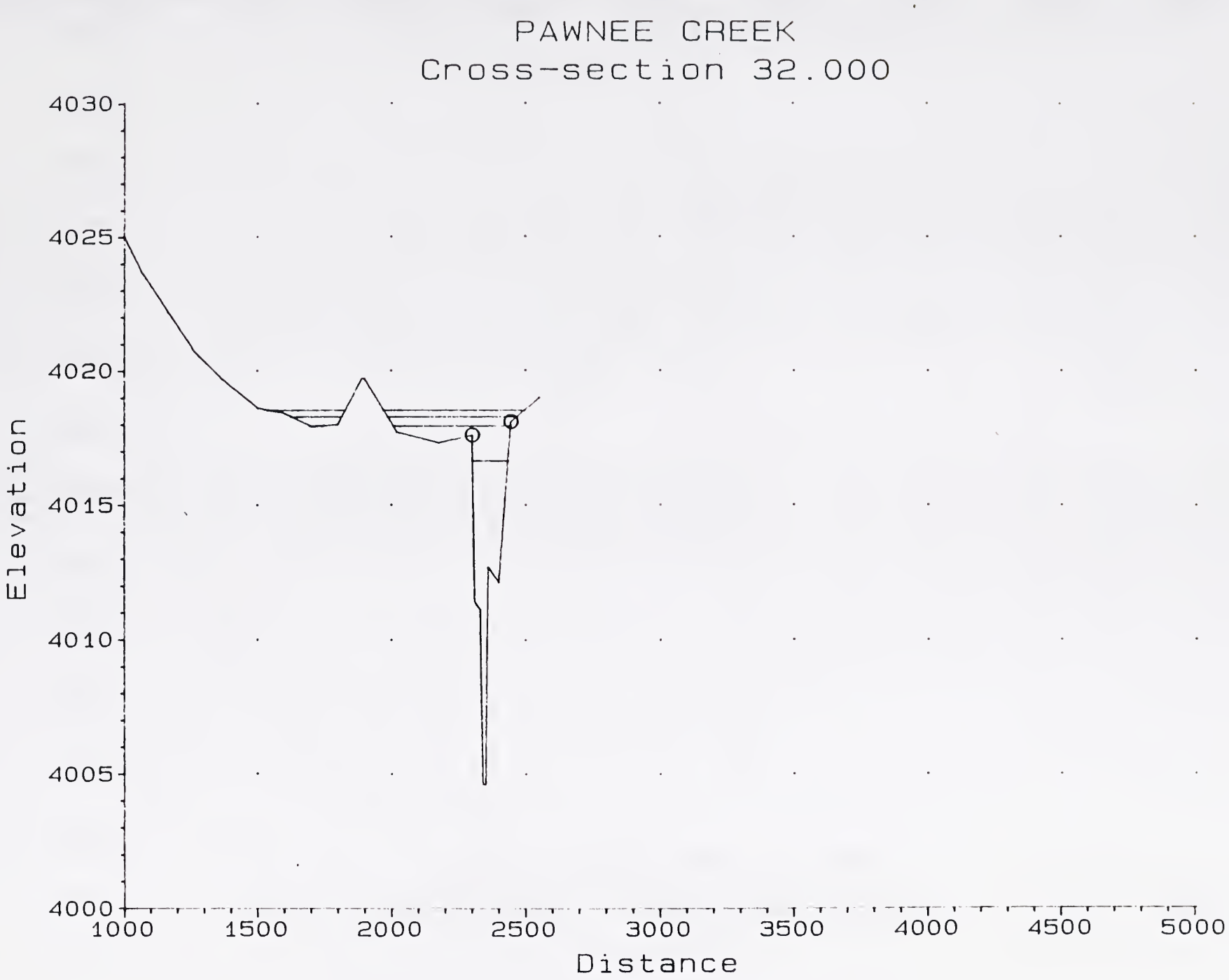
PAWNEE CREEK

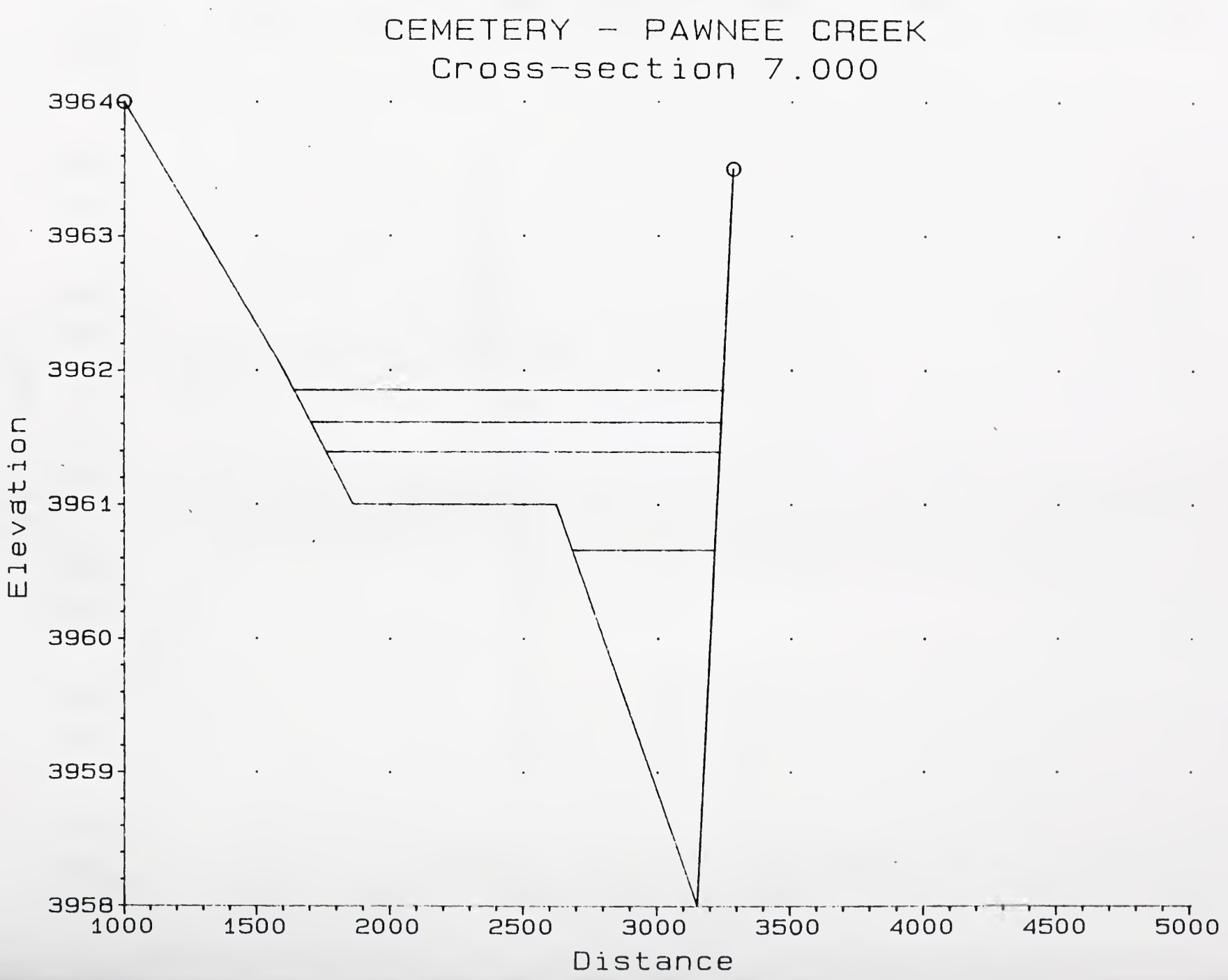
LOGAN COUNTY, COLORADO

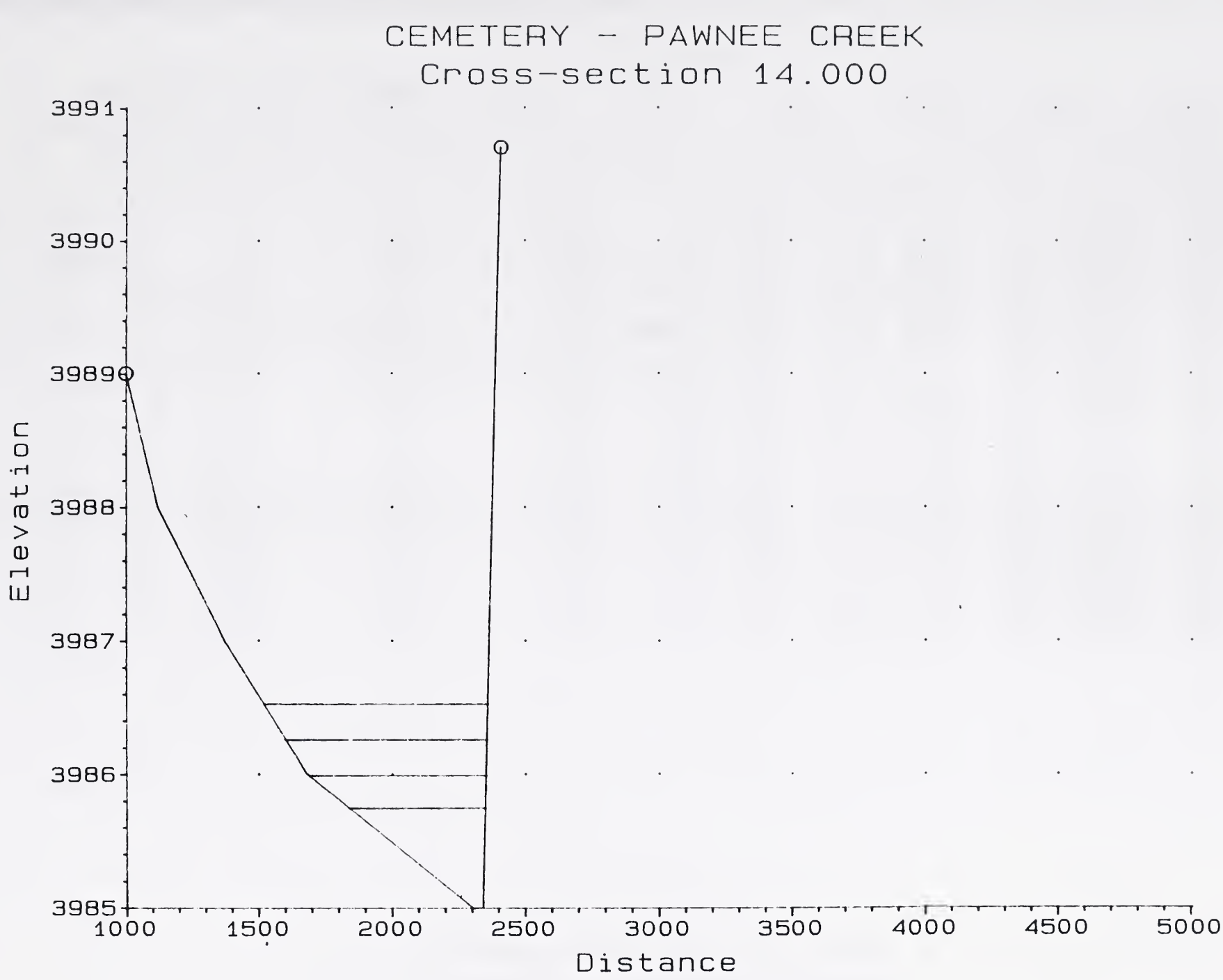
SHEET13 OF 13


PAWNEE CREEK
Cross-section 20.200
3992
3990
3988
3986
3984
3982
3980
Elevation
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance


PAWNEE CREEK
Cross-section 26.000
4006
4004
4002
4000
3998
3996
3994
Elevation
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance


PAWNEE CREEK
Cross-section 32.000
Elevation
4030
4025
4020
4015
4010
4005
4000
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance


CEMETERY - PAWNEE CREEK
Cross-section 7.000
Elevation
3964
3963
3962
3961
3960
3959
3958
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance


CEMETERY - PAWNEE CREEK
Cross-section 14.000
3991
3990
3989
3988
3987
3986
3985
Elevation
1000
1500
2000
2500
3000
3500
4000
4500
5000
Distance

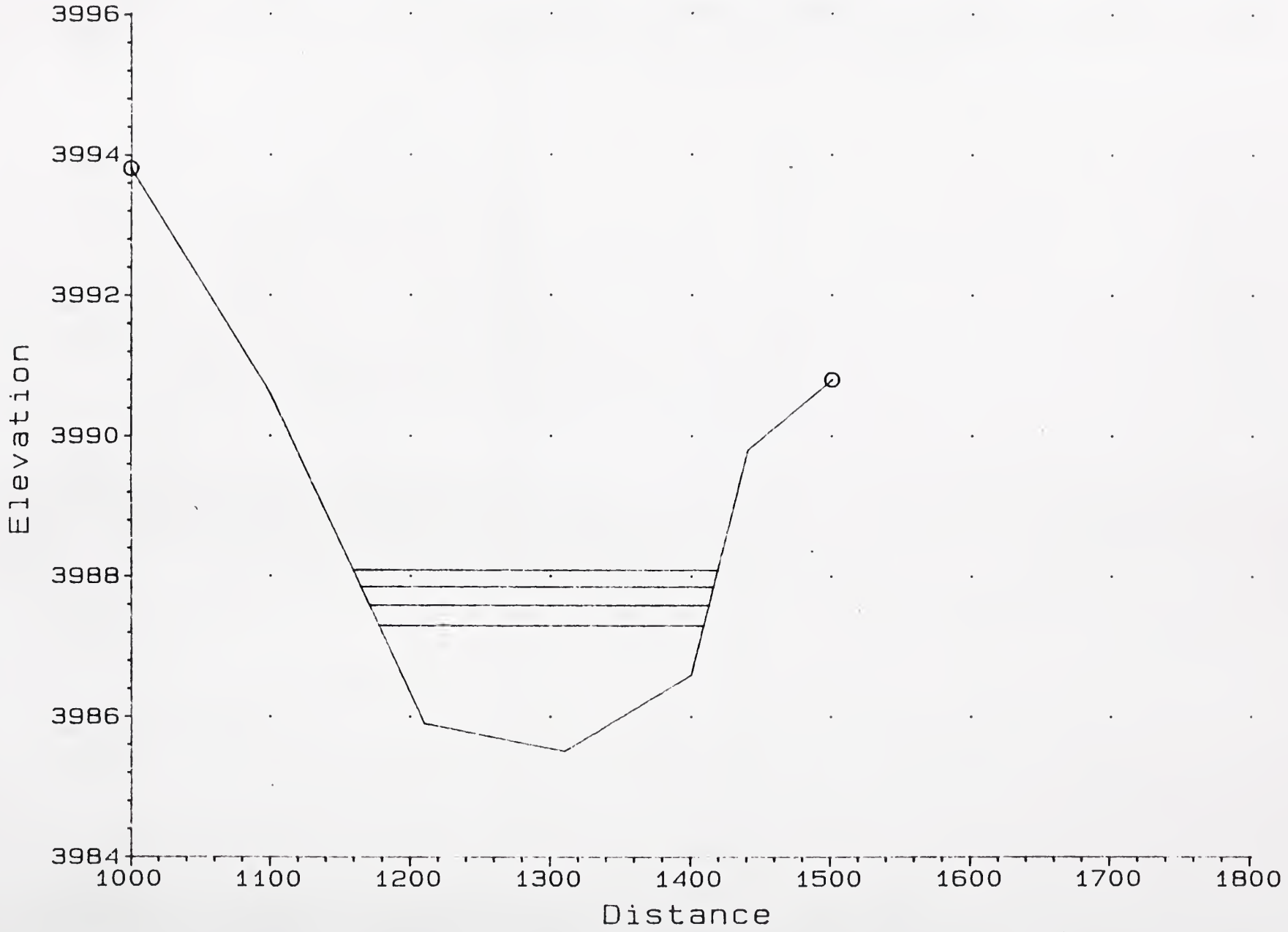

ATWOOD - PAWNEE CREEK
Cross-section 17.100
3996
3994
3992
3990
3988
3986
3984
Elevation
1000
1100
1200
1300
1400
1500
1600
1700
1800
Distance

TABLE 4 FLOOD FREQUENCY - ELEVATION AND DISCHARGE DATA
PROJECT: PAWNEE CREEK DATE: 3/91

X-SEC ID	REACH L	X-SEC STATION	STREAM BTM	10-YEAR FREQ		25-YEAR FREQ		50-YEAR FREQ		100-YEAR FREQ	
	FT	FT	ELEV	ELEV	CFS	ELEV	CFS	ELEV	CFS	ELEV	CFS
2.0	0	0	3964.3	3974.0	440	3974.0	440	3974.0	440	3974.0	440
3.0	4920	4920	3970.8	3979.6	440	3979.6	440	3979.6	440	3979.6	440
4.1	1880	6800	3974.6	3983.4	440	3983.4	440	3983.4	440	3983.4	440
4.2	300	7100	3975.3	3984.0	1557	3984.2	1814	3984.4	2015	3984.5	2216
4.3	165	7265	3975.7	3984.5	1557	3984.9	1814	3985.1	2015	3985.4	2216
18.1	200	7465	3978.1	3984.8	1557	3985.2	1814	3985.4	2015	3985.7	2216
18.2	15	7480	3978.1	3984.8	1557	3985.2	1814	3985.5	2015	3985.7	2216
18.3	20	7500	3978.1	3984.9	1557	3985.3	1814	3985.6	2015	3985.8	2216
19.1	40	7540	3979.6	3985.1	1557	3985.5	1814	3985.8	2015	3985.9	2216
19.2	20	7560	3979.6	3985.3	1557	3985.7	1814	3985.9	2015	3986.0	2216
20.1	30	7590	3980.0	3985.5	1557	3985.9	1814	3986.1	2015	3986.2	2216
20.2	20	7610	3980.0	3985.6	1557	3986.0	1814	3986.2	2015	3986.5	2216
20.3	15	7625	3980.0	3985.6	1705	3986.0	2117	3986.2	2583	3986.5	3102
22.0	3670	11295	3984.6	3992.0	1544	3992.3	1891	3992.5	2300	3992.8	2762
24.0	4880	16175	3991.3	3996.7	1544	3996.8	1891	3996.9	2300	3997.0	2762
26.0	3280	19455	3995.5	4001.4	1544	4001.6	1891	4001.8	2300	4002.0	2762
27-28	1200	20655	3996.4	4005.3	2945	4005.7	4303	4006.0	5434	4006.2	6645
29.0	1400	22055	3887.4	4006.9	2945	4007.4	4303	4007.7	5434	4008.0	6645
30.1	1820	23875	3998.8	4008.1	2945	4008.6	4303	4008.8	5434	4008.9	6645
30.2	20	23895	3998.8	4008.1	2945	4008.7	4303	4008.9	5434	4009.1	6645
30.3	20	23915	3998.8	4008.2	2945	4008.7	4303	4009.1	5434	4009.3	6645
31.0	3660	27575	4003.0	4013.8	2945	4015.5	4303	4016.1	5434	4016.5	6645
32.0	2000	29575	4004.6	4016.6	2945	4017.9	4303	4018.3	5434	4018.5	6645
33-35	1900	31475	4006.0	4019.7	2945	4020.7	4343	4021.2	5638	4021.7	7161
37.1	1940	33415	4009.0	4022.6	3264	4023.2	5086	4023.6	6729	4024.0	8611
37.2	20	33435	4009.0	4022.6	3264	4023.3	5086	4023.7	6729	4024.1	8611
38-39	1140	34575	4014.0	4023.7	4083	4024.3	6439	4024.7	8555	4025.1	10981

TABLE 4 FLOOD FREQUENCY - ELEVATION AND DISCHARGE DATA
PROJECT: PAWNEE CREEK DATE: 3/91

X-SEC ID	REACH L	X-SEC STATION	STREAM BTM	10-YEAR FREQ		25-YEAR FREQ		50-YEAR FREQ		100-YEAR FREQ	
	FT	FT	ELEV	ELEV	CFS	ELEV	CFS	ELEV	CFS	ELEV	CFS
7.0	0	0	3958.0	3960.7	1388	3961.4	2348	3961.6	3210	3961.8	4243
9.0	3100	3100	3964.0	3966.5	1388	3967.2	2348	3967.3	3210	3967.5	4243
11.0	3360	6460	3969.0	3970.6	1110	3971.0	1878	3971.2	2568	3971.4	3374
11.5	2800	9260	3976.0	3976.0	0	3976.3	41	3976.5	215	3976.7	504
12.0	2850	12110	3983.0	3983.0	0	3984.0	41	3984.4	215	3984.8	504
14.0	1640	13750	3985.0	3985.7	147	3986.0	302	3986.2	568	3986.5	885

TABLE 4 FLOOD FREQUENCY - ELEVATION AND DISCHARGE DATA
PROJECT: PAWNEE CREEK DATE: 3/91

X-SEC ID	REACH L	X-SEC STATION	STREAM BTM	10-YEAR FREQ		25-YEAR FREQ		50-YEAR FREQ		100-YEAR FREQ	
	FT	FT	ELEV	ELEV	CFS	ELEV	CFS	ELEV	CFS	ELEV	CFS
20.3	0	7625	3980.0	3985.7	1705	3986.0	2117	3986.2	2583	3986.5	3102
15.0	2200	9825	3985.0	3987.2	162	3987.5	226	3987.7	284	3987.9	341
17.1	2360	12185	3985.5	3987.3	162	3987.6	226	3987.8	284	3988.1	341
16-17.2	940	13125	3987.2	3988.0	926	3988.3	1953	3988.5	2891	3988.7	4038