NEBRASKA NATURAL
RESOURCES COMMISSION

STATE WATER PLAN
PUBLICATION NO. 204-D

PRELIMINARY
REPORT

REPUBLICAN RIVER BASIN PLAN

APPENDIX D

PROJECT INVESTIGATIONS

WAUNETA FLOOD CONTROL PROJECT

AUGUST 1978

STATE OF NEBRASKA

J. James Exon, Governor

NEBRASKA NATURAL RESOURCES COMMISSION

Dayle E. Williamson, Executive Secretary

Report Prepared by the Planning Division
Gayle H. Lewis, Chief

Comprehensive Planning Section
Jerry Wallin, Head
Keith Sheets, Water Resources Planner
Kwonshik Kim, Water Resources Planner
Steve Soberski, Water Resources Planner
Mark Robbins, Draftsman
Michelle Pike, Secretary

Water Quality Section
Tom Pesek, Water Resources Planner

NEBRASKA'S STATE WATER PLAN

REPUBLICAN RIVER BASIN PLAN

APPENDIX D: PROJECT INVESTIGATIONS

WAUNETA
FLOOD CONTROL
PROJECT

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NEBRASKA'S STATE WATER PLAN

Nebraska Revised Statutes § 2-1507 (7) (Supp. 1967) directs the Nebraska Natural Resources Commission to "plan, develop, and encourage the implementing of a comprehensive program of resource development, conservation and utilization for the soil and water resources of this state in cooperation with other local, state and federal agencies and organizations."

Legislative Resolution 5, of the 1967 Legislature, (Reaffirmed by L.R. #72 -- 1969 Session) specifically directed the Nebraska Natural Resources Commission to ". . . prepare a comprehensive water and related land plan for the State of Nebraska, such framework plan to be completed no later than June 30, 1971, and to be known as the State Water Plan." In addition to an analysis and evaluation of the state's water and land resources, the Resolution directed that the State Water Plan include an examination of legal, social, and economic factors associated with resource development.

Nebraska's State Water Plan, as established by the Commission, will consist of the following four sections:

Section 1. The Framework Study - The framework study is based on reconnaissance type investigations and makes use of presently available planning data in formulation of the framework plan. Basic objectives of the study were to assess the present quantity, distribution, quality, and use of Nebraska's water and land resources and to provide a broad, flexible guide to the best uses of these resources to meet current and future needs.

Section 2. Basin Studies - This section will consist of studies of individual river basins. The studies will be made in the detail necessary to identify potential projects, estimate project costs and benefits, suggest the order of development, show the relationship of each project to the state's framework plan, and recommend local action to accelerate resource development.

Section 3. Status Summary - Significant water resource development projects which have been proposed for future development are described in the Status Summary of Potential Projects. It will be updated periodically to reflect new proposals and progress in resource planning. The Status Summary section of the State Water Plan will also include a report summarizing the present status of water resources development in the State.

Section 4. Special Recommendations - This section consists of recommendations for action by the Legislature, Governor, and various units of government to improve the conservation, development, management, and utilization of Nebraska's land and water resources. The recommendations will be prepared as the need for action becomes apparent and are to include a thorough study of the legal, social, and economic aspects of major problems of resources development.

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CHAPTER 1. SUMMARY, CONCLUSIONS, AND SELECTED PLAN

The Village of Wauneta requested aid from the Upper Republican Natural Resources District to control flooding from Frenchman Creek caused by local storms on the tributary areas near Wauneta. The District requested assistance from the Natural Resources Commission in the form of flood control project planning and financial aid from the Resources Development Fund.

Preliminary studies by the Commission determined the cost and effectiveness of different structural alternatives for reducing flooding, including nine dams and a levee. This allowed the district and the village to determine they would prefer a flood protection project including three dams and a levee.

Final investigation of the project was expanded to include hydrologic, economic, and environmental evaluations of non-structural systems as well as the selected flood control structures. A flood plain park that would provide flood control and recreation benefits was acceptable to the project sponsors as an addition to the selected project.

Conclusions

A structural project for reducing flood damages caused by runoff from the uncontrolled area below Enders Dam is technically, economically, and environmentally feasible under the criteria and rules of the Resources Development Fund. It would protect the business and residential section of Wauneta south of Frenchman Creek from floods up to, and including, the 100-year flood. A park located in the part of the flood plain not protected by the levee, if constructed in conjunction with the flood control structures, would provide sufficient recreation benefits to be feasible under the same criteria and rules. This park would also produce some flood control benefits that cannot be quantified.

Selected Plan

The project preferred by the village and the Natural Resources District includes three dams, a levee, and a flood plain park shown on the last foldout map bound at the back of the report. The dams would be earthen embankments with concrete outlets that would eventually drain the reservoirs completely after each rainstorm ("dry" dams). These dams would be located on three tributaries which enter Frenchman Creek from the north between Enders Dam and Wauneta. The levee would be a low earthen embankment located north and west of the business and residential area of Wauneta on the south bank of Frenchman Creek. The park, located east of the stream, would include picnicking, playground, and other recreation facilities that would not obstruct flood flows or add significantly to the amount of damage by flood waters.

CHAPTER 2. INTRODUCTION

The frequent occurrence of minor flooding and the occurrence of several major floods caused the Village of Wauneta to request assistance from the Upper Republican Natural Resources District (NRD).

Background and Authority

In January 1976, the NRD requested that the Natural Resources Commission assist in the development of a special project to provide flood protection for Wauneta.

SPECIAL PROJECT ASSISTANCE

The NRD's request for assistance was referred to the Operations Division. After conferring with NRD personnel and village officials, Commission staff members recommended that the village and the NRD consider constructing dams on a number of small streams tributary to Frenchman Creek to control runoff from the area between Enders Dam and Wauneta. It was also recommended that they apply for special project assistance from the Commission in the investigation. The application by the NRD was approved by the Commission in January 1976.

The village agreed to pay for the aerial photographs required to map the potential structure sites. The NRD contracted with an aerial photographer and the area was flown in April 1976. Elevation control surveys were initiated in July 1976 and topographic mapping of the dam sites was completed by the Commission's Photogrammetry Section in December 1976. Mapping of the village was completed in May 1977.

The Commission's topographic maps and the preliminary 7 1/2 minute quadrangle maps from the U. S. Geological Survey were used to delineate watershed areas and locate nine potential dam sites. Preliminary designs for nine structures were developed, from which preliminary cost estimates and hydrologic characteristics of the dams were determined. Assistance in routing floods through the nine dams was requested from the Comprehensive Planning Section.

BASIN PLANNING STUDY

The Republican River Basin Study, the second in the Basin Planning Section of the State Water Plan, was scheduled to be started by the Comprehensive Planning Section on July 1, 1977. The Wauneta project provided an excellent opportunity to utilize the flood control project planning capability being developed within the section and also start the basin study.

The Soil Conservation Service (SCS) was conducting a river basin survey (formerly Type IV) study of the Republican River Basin with the cooperation of the Commission and the NRD's at the time the special project was requested. The SCS had investigated potential projects to protect Wauneta in the past and further investigation was scheduled for their basin study. To eliminate duplication and facilitate both studies, the Commission and the SCS agreed to cooperate in the investigation of this special project. The SCS provided assistance, training, and supervision in the use of federal watershed project evaluation procedures used by the Comprehensive Planning Section.

Purpose

This study is intended to serve three purposes. It will evaluate the potential for developing a project on Frenchman Creek for the NRD and Wauneta and it will provide information on potential alternatives for the Commission's basin plan and the SCS river basin survey report.

The primary purpose of this investigation is to determine if there is a flood control project with potential for development by the NRD and the village, with or without state and federal aid. The investigation is also intended to determine the eligibility of the project for funding by the Resources Development Fund. The third purpose of the investigation is to determine if any alternatives should be included in the State Water Plan and the SCS Republican River Basin Plan.

Scope

This study was originally intended to investigate the feasibility of a combination of dams on nine tributaries to Frenchman Creek between Enders Dam and Wauneta. The analysis of precipitation and runoff has been concentrated on the area below Enders Reservoir because that structure generally provides a high degree of protection for the village from runoff from the area above the dam. Runoff from the intervening drainage area from short, intense rainstorms has been the principal contributor to the flooding problem since the construction of Enders Dam.

The original intent was to investigate the feasibility of nine dams to protect Wauneta and downstream areas. During the course of the preliminary investigation, it was found that a low levee on the south bank of Frenchman Creek would provide protection from large floods when used in conjunction with several dams. Therefore, the feasibility of a combination of dams and the levee was studied during the preliminary investigation.

At the request of the village and the NRD, final investigations were also conducted by the Commission to determine the feasibility of the selected project. This included technical, economic, and environmental investigations of non-structural alternatives as well as the structural projects.

The preliminary study is sufficiently detailed to show the cost and effectiveness of different alternatives to enable the NRD and the city to select the most effective flood protection measures. The final investigation is sufficiently detailed to show the potential of the selected alternative for funding by the Commission's Resources Development Fund. The data developed for the study will be sufficiently detailed for use by the SCS to determine if further investigation is required for the river basin survey report.

This study is intended to be a part of a comprehensive plan of the Republican River Basin, including Frenchman Creek. This report will become a section of Appendix D to the final report when the basin plan is completed in about four years. It is being printed in preliminary form at this time to make the needed information available to the project sponsors within a reasonable period of time.

Organization

PARTICIPANTS

The village of Wauneta, the Upper Republican NRD, the Natural Resources Commission, and the SCS have all participated in this project. The NRD is sponsoring the project with the cooperation of the village, and they have made application to the Commission for special project assistance and financial aid from the Resources Development Fund. The Commission is providing planning assistance through the special projects assistance program and the basin planning program. The SCS is cooperating in the investigation as part of the cooperative river basin survey study of the basin.

REPORT

The following chapter provides information on the existing situation, including the flooding problem on Frenchman Creek below Enders Dam. Chapter 4 explains the preliminary investigations, and Chapter 5 details the final investigations.

CHAPTER 3. EXISTING SITUATION

The project area, located in southwestern Nebraska bordering the State of Colorado, is part of the Upper Republican NRD (Figure 1). Wauneta is located on Frenchman Creek in the southeastern corner of Chase County, the middle county of the three counties that comprise the Upper Republican NRD. Enders Reservoir is located on Frenchman Creek approximately nine miles west of Wauneta. The project area lies between Wauneta and Enders Dam.

Description of the Project Area

PHYSIOGRAPHY

Chase County is geographically distinguished as part of the Great Plains, located on the eastern edge of the division known as the High Plains. The surface topography is generally that of a plateau, sloping eastward. General surface features have been modified by erosional forces into divides or table lands, separated by shallow valleys of moderate slope.

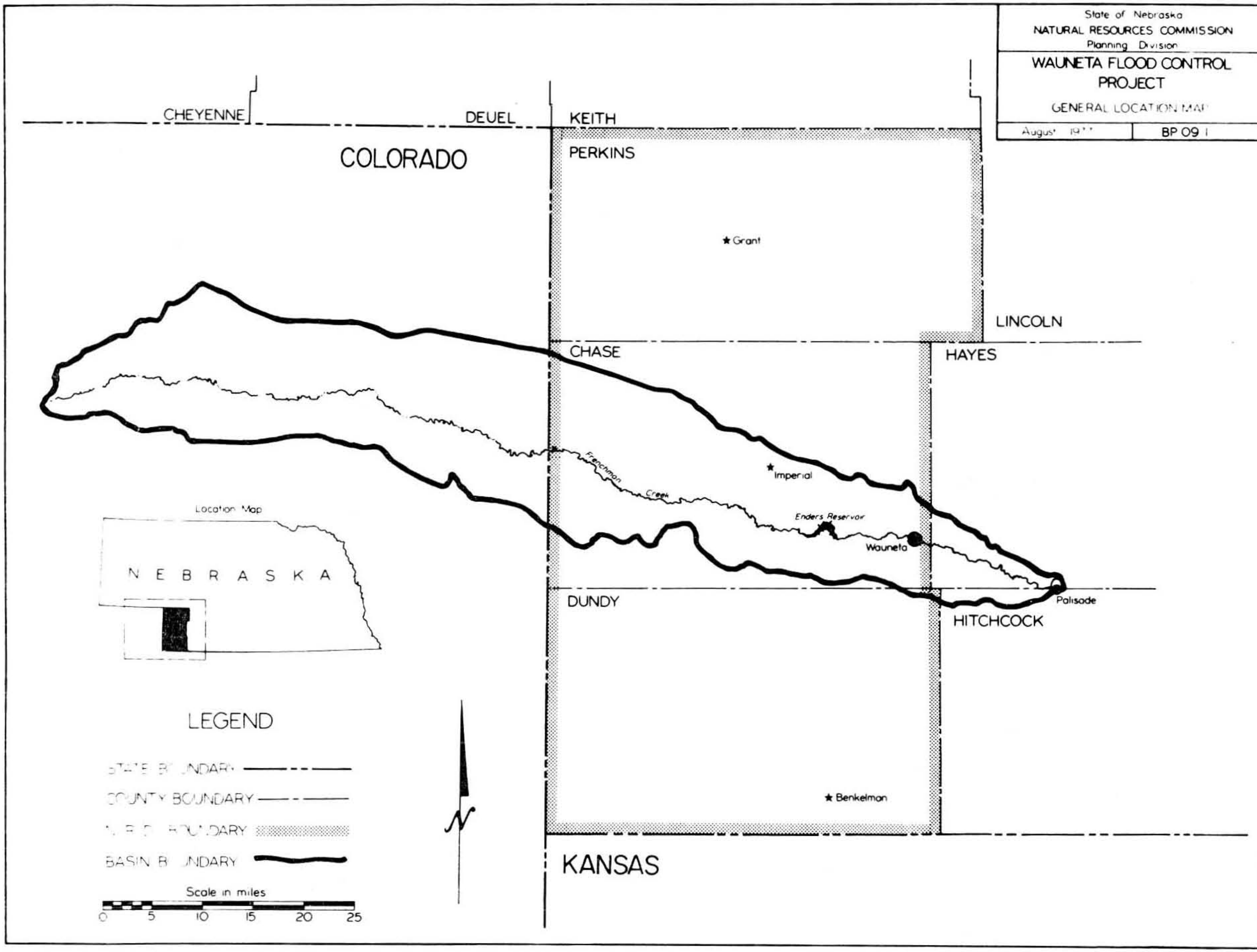
Approximately one-fourth of the county is covered by an extension of the Sandhills region that covers the northcentral portion of Nebraska. This physiographic feature is characterized by a succession of rounded or choppy hills and irregular ridges. The drainage pattern is often poorly defined.

The northwestern and central parts of the county are flat to gently rolling with intermittent stream valleys and shallow depressions. This area has a typical prairie landscape. The eastern part of the county has landscape features that are level to undulating and are remnants of an old loess plain that has been dissected by erosion, resulting in well defined drainage patterns.

CLIMATIC FEATURES

Chase County is located in a region that is characterized by a continental type climate. It experiences a wide range in monthly and annual temperature extremes and generally has cold winters and short, hot summers with uneven rainfall distribution throughout the year. Nearly three-fourths of the mean annual rainfall of approximately 18 inches occurs during the growing season. The summer rainfall is generally of the convectional type in the form of localized thunderstorms, so precipitation patterns can vary considerably within the county during the growing season. This uncertain rainfall distribution combined with the drying southerly winds can produce both localized excesses of rainfall (cloudbursts) and prolonged droughts.

The normal growing season extends for 150 days from mid-May through the third or fourth week of September. The prevailing wind patterns during the growing season are from the south and southwest which,



State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
BP 09 1
CHEYENNE
DEUEL
KEITH
PERKINS
COLORADO
Grant
LINCOLN
CHASE
HAYES
Frenchman Creek
Imperial
Enders Reservoir
Wauneta
Palisade
DUNDY
HITCHCOCK
Location Map
N E B R A S K A
LEGEND
COUNTY BOUNDARY
Benkelmon
KANSAS
Scale in miles
0 5 10 15 20 25

FIG. 1

combined with the high percentage of possible sunshine during this period, results in extremely high evapotranspiration rates. Crop production is directly affected by the stress associated with the summer climatic extremes and agriculture has subsequently adapted through the development of irrigation, primarily with center pivot sprinkler systems.

FRENCHMAN CREEK

Chase County is drained by Frenchman Creek (a major tributary of the Republican River) and its tributaries. Frenchman Creek crosses Chase County in a southeastward course with its valley floor varying in width from one-eighth of a mile in its upper reaches to about one-half mile along its lower reaches. Frenchman Creek and Stinking Water Creek, which joins it just below the study area, both have steady base flows which can be attributed to their origin in the Sandhills area.

DESCRIPTION OF EXISTING DEVELOPMENT

Enders Reservoir is one of five Bureau of Reclamation (USBR) and Corps of Engineers (COE) reservoirs in the Republican River Basin in Nebraska. These projects were constructed to provide flood control, irrigation, fish and wildlife, and recreation in the basin.

Enders Reservoir controls a watershed area of 2,240 square miles. It has 1,707 surface acres and storage capacity of 44,480 acre-feet when the conservation pool is full, plus flood control storage allocation of 30,000 acre-feet. It was constructed as a multipurpose dam to provide storage for irrigation, sediment retention, flood control, and recreational uses. Water from Enders Reservoir is released to Frenchman Creek and diverted to the Culbertson Canal by the Culbertson Diversion Dam near Palisade (Figure 1). The canal serves 22,000 acres in the Frenchman Unit.

Floods on Frenchman Creek

In June of 1940 Wauneta experienced its largest flood up to that date. After three days, the flood waters receded and it was found that 100 homes had received minor to major damage and almost every business in the central business district had received some form of flood related damage.

The flood of June 1956 occurred after the completion of Enders Dam. The intense rainfall of June 16 on the drainage area between Enders Dam and Wauneta caused the major flood that followed.

Average rainfall depths for the storm were calculated at 4.5 inches for the watershed south of Frenchman Creek and 6 inches over the watershed north of Frenchman Creek. Rainfall intensities diminished significantly downstream of Wauneta to 0.84 inches at Palisade, located 22 miles downstream.

Minor flooding has occurred often in Wauneta during the summertime, according to city officials and residents. The area east of the

Wichita Street bridge is flooded frequently, interrupting traffic on the only street connecting the eastern section of the village with the business district and the highway. The flood waters usually deposit silt and debris in the street and the storm sewers, requiring maintenance and repair operations by the city to restore service.

During the irrigation season (June through August) approximately 400 cubic feet per second (cfs) are released from Enders Reservoir to Frenchman Creek for use by the irrigation districts downstream from Wauneta. The residents of Wauneta feel this creates problems for them when localized rainfall between Enders Reservoir and Wauneta contributes a large amount of runoff to the creek, which is already "bank full". Although the amount of water being released during the irrigation season is not significant for the higher frequency storms with discharge rates in the range of 7,000 cfs, it could contribute to the low-frequency flooding that has been causing problems.

The USBR has established a communication system between their McCook office, Enders Reservoir, the National Weather Service, and local observers which, in their opinion, provides adequate warning to discontinue the irrigation releases into Frenchman Creek if there is a possibility of flooding in Wauneta.

CHAPTER 4. PRELIMINARY INVESTIGATIONS

Preliminary investigations were made of the hydrology and economics of nine potential dams as requested. Flood protection by a levee alone was not considered because a project of this type was found to be economically infeasible by the Corps of Engineers in 1956. During the course of these investigations, it became apparent a small levee would combine with the dams to provide extra protection at small cost, so it was added to the alternatives.

Structure Design

The initial request by the Upper Republican NRD was for special project assistance, and the Commission provided surveying, mapping, and preliminary engineering design under this program. Design included location, structure type and size, and construction cost estimates.

DAMS

The watershed between Wauneta and Enders Dam was divided into tributary drainage areas, and suitable sites for nine potential dams were located. These sites are shown on Figure 2.

Preliminary designs for earthfill dams with concrete principal spillways were developed according to standard practices of the SCS. The structures were designed for the 100-year flood with the storage available at the selected site. The preliminary design of the principal spillway and the storage available at each site was used to derive the discharge characteristics for flood frequency analysis. The preliminary design data and profiles from the site maps were used to estimate the cost of construction. The storage capacity, area flooded, and construction cost of the structures are listed in Table 1.

TABLE 1

Storage Capacity, Area Flooded, and Construction Cost of Dams

Dam No.	Flood Storage	Flood Pool	Silt Pool	Estimated Construction Cost	Cost per A.F.1/
	(A.F.)	(acres)	(acres)	($1,000)	($)
1	1135	79	28	177.6	156
2	1346	111	43	130.1	97
3	1809	130	40	180.1	100
4	462	39	15	99.0	214
5	153	18	7	71.2	465
6	100	9	3	91.2	912
7	258	29	10	71.6	278
8	232	25	9	85.8	370
9	567	42	14	153.4	271

1/ A.F. = acre-foot

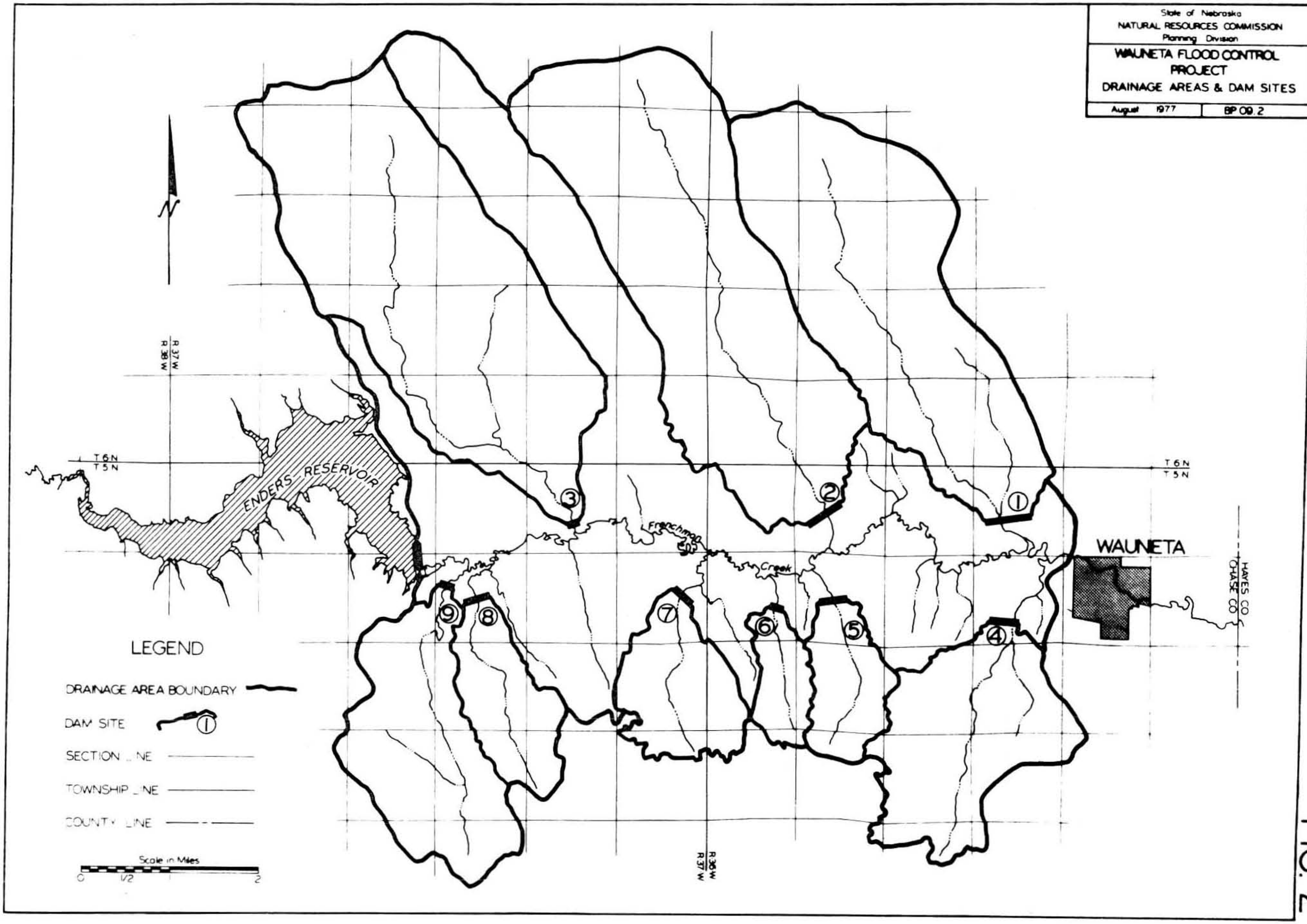

State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
DRAINAGE AREAS & DAM SITES
August 1977
BP 09.2
N
R 37 W
R 38 W
T 6 N
T 5 N
ENDERS RESERVOIR
Frenchman
Creek
WAUNETA
HAYES CO.
CHASE CO.
R 36 W
R 37 W
LEGEND
DRAINAGE AREA BOUNDARY
DAM SITE
SECTION LINE
TOWNSHIP LINE
COUNTY LINE
Scale in Miles
0
1/2
2

FIG. 2

LEVEE

During the course of the hydrological investigations of potential flooding with different combinations of dams, it became apparent that much of the flooding of the business district and surrounding area was very nearly eliminated by only a few dams, but most of the nine were required to eliminate it completely. Several low points on the bank of the river were overtopped by only six to twelve inches, allowing water to reach the flat areas farther from the stream, and causing widespread damage. It appeared that a very low levee would accomplish the same result as five or six dams at a substantially lower cost.

A preliminary design for a levee, including flap gate culverts for internal drainage, was developed and the cost of construction was estimated. The two alternative locations in the northwest section of the village considered in the preliminary stage are shown on Map 1 (attached at the end of the report). For the preliminary design, a top width of 10 feet and side slopes of 3 to 1 were used. The estimated cost of construction was approximately $13,500.

Hydrological Investigations

Two distinctive types of flood damage occur in the Frenchman valley below Enders Dam. One is urban damage to Wauneta and the other is rural damage, including damage to crops and pasture in the flood plain. Consequently, two separate hydrological investigations were conducted. The first investigation was performed to evaluate the urban damage at Wauneta. The area considered as contributing to this flooding was a small watershed (about 59.6 sq. miles) between Enders Dam and Wauneta, shown in Figure 2. The balance of the flood plain from Enders Dam to Palisade was studied in the rural damage investigations.

URBAN FLOOD ANALYSIS

Since very little discharge data is available in the flooded area, rainfall data and a rainfall-runoff model were used to construct flood frequency curves.

The U.S. Department of Commerce Technical Paper No. 40, Rainfall Frequency Atlas of the United States, May 1961, was used to obtain point rainfall data for different return periods. This rainfall data was modified using the appropriate reduction factor given in the bulletin to get average areal rainfall data. The point and areal rainfall data are given in Table 2.

The drainage area above each of the nine dam sites shown in Figure 2 is given in Table 3. Runoff curve numbers shown in Table 3 were estimated for each area from land use data, hydrologic conditions, and hydrologic soil groups. The time of concentration for each area, computed by a method given in Section 4, Hydrology, SCS National Engineering Handbook, is also shown in Table 3.

TABLE 2

Rainfall for Different Return Periods

Return Period	Rainfall 24 Hour Point	Rainfall 24 Hour Areal
(Years)	(Inches)	(Inches)
100	5.31	5.04
50	4.77	4.53
25	4.19	3.98
10	3.56	3.38
5	3.05	2.90
2	2.23	2.12
1	1.73	1.64

TABLE 3

Drainage Area, Curve Number, and Time of Concentration of Dam Sites

Dam No.	Drainage Area	Curve Number	Time of Concentration
	(sq. mi.)		(hours)
1	8.23	73	3.02
2	9.83	73	3.90
3	10.13	76	4.60
4	3.94	70	0.79
5	1.30	70	0.42
6	0.84	70	0.30
7	1.87	73	0.40
8	1.63	75	0.54
9	3.87	75	2.14

According to the McCook office of the USBR, irrigation releases from Enders Reservoir will be stopped whenever a major storm is reported in the area. The time of travel from Enders Dam to Wauneta should be approximately one-third to one-half of the time to peak of the flood from the project area. Therefore, it was assumed that there will be no irrigation releases and base flow, which is normally less than 10 cfs, will be negligible at the peak of any large flood in Frenchman Creek generated by storms on the intervening drainage area.

A schematic diagram of the watershed was prepared to facilitate the use of this data to determine peak flood flows with the Technical Release 20 (TR-20) computer program developed by the SCS. The schematic diagram is shown in Fig. 3.

Flood Frequency Without Dams

The frequency of flooding was analyzed for existing conditions without dams and then with different combinations of dams. To find the frequency of flooding at Wauneta under present conditions, rainfall data in Table 2 and other information in Table 3 and Fig. 3 were processed through the TR-20 computer program. The results are shown in Table 4.

Flood Frequency With Different Combinations of Dams

Flood flow reduction at Wauneta was determined for different combinations of dams by computing the magnitude of the peak discharge at specified frequencies with the TR-20 program. First, an elevation-discharge-storage relationship was developed for all nine dams by use of Figures 4, 5, and 6. This information was then used in the TR-20 program to obtain data on flood frequency with various combinations of dams.

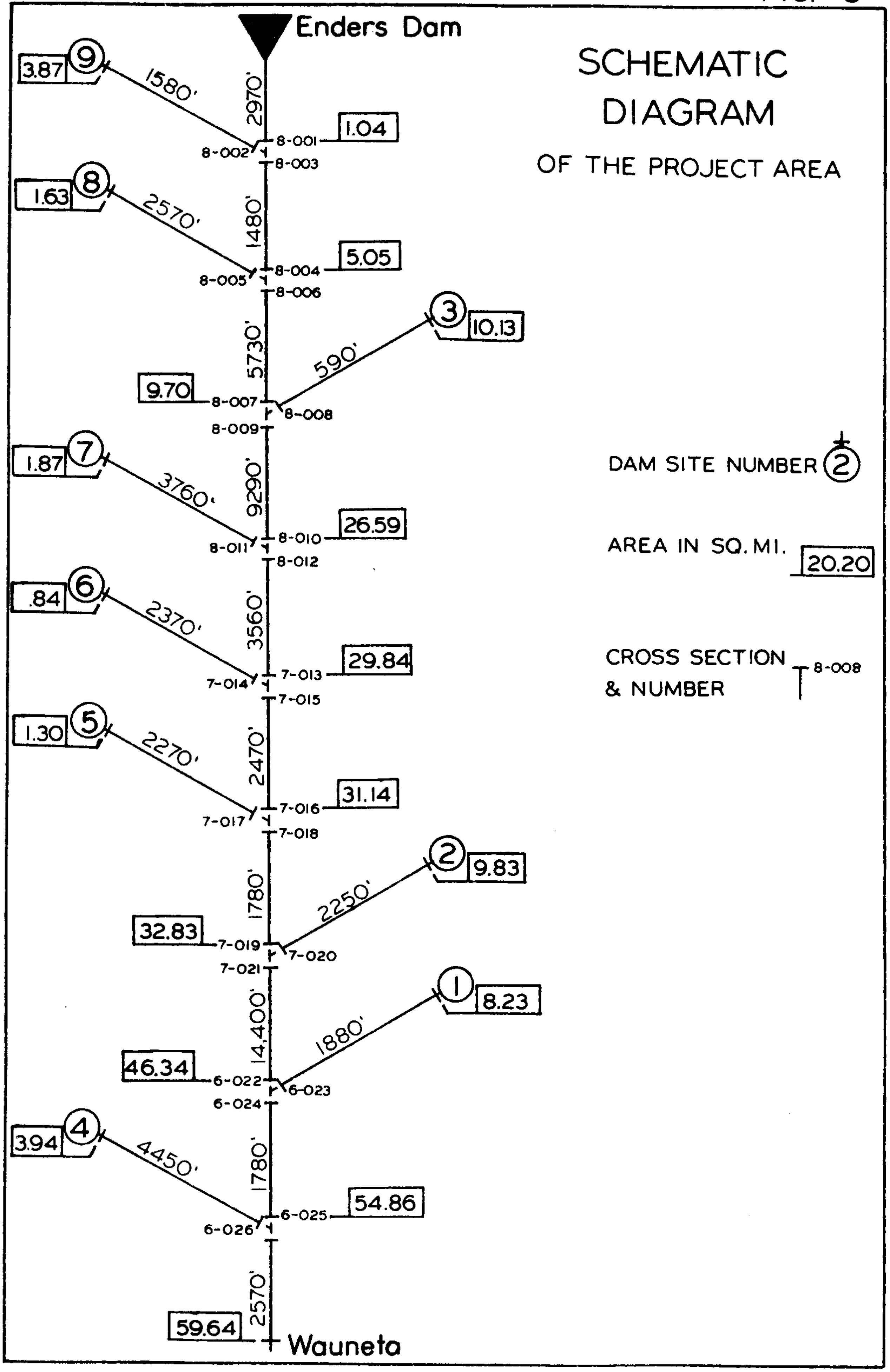
TABLE 4

Estimated Flood Flows at Wauneta

Return Period	No Dams	9 Dams	5 Dams (1+2+3+4+7)	4 Dams (1+2+3+7)	3 Dams (1+2+3)	2 Dams (1+2)
(Years)	(cubic feet per second)					
100	8385	3600	4355	4500	4920	5830
50	6920	2900	3570	3720	4085	4870
25	5410	2290	2850	2960	3235	3880
10	3850	1790	2125	2200	2380	2860
5	2760			1550 1/	1750 1/	2040 1/
2	1260				950 1/	1050 1/

1/ Extrapolated from computed data

FIG. 3



Enders Dam
SCHEMATIC DIAGRAM
OF THE PROJECT AREA
DAM SITE NUMBER 2
AREA IN SQ. MI. 20.20
CROSS SECTION & NUMBER 8-008
3.87 9 1580'
2970'
8-001 1.04
8-002
8-003
1.63 8 2570'
1480'
8-004 5.05
8-005
8-006
3 10.13
590'
5730'
9.70 8-007
8-008
8-009
1.87 7 3760'
9290'
8-010 26.59
8-011
8-012
.84 6 2370'
3560'
7-013 29.84
7-014
7-015
1.30 5 2270'
2470'
7-016 31.14
7-017
7-018
2 9.83
2250'
1780'
32.83 7-019
7-020
7-021
1 8.23
1880'
14,400'
46.34 6-022
6-023
6-024
3.94 4 4450'
1780'
6-025 54.86
6-026
2570'
59.64
Wauneta

FIG. 4

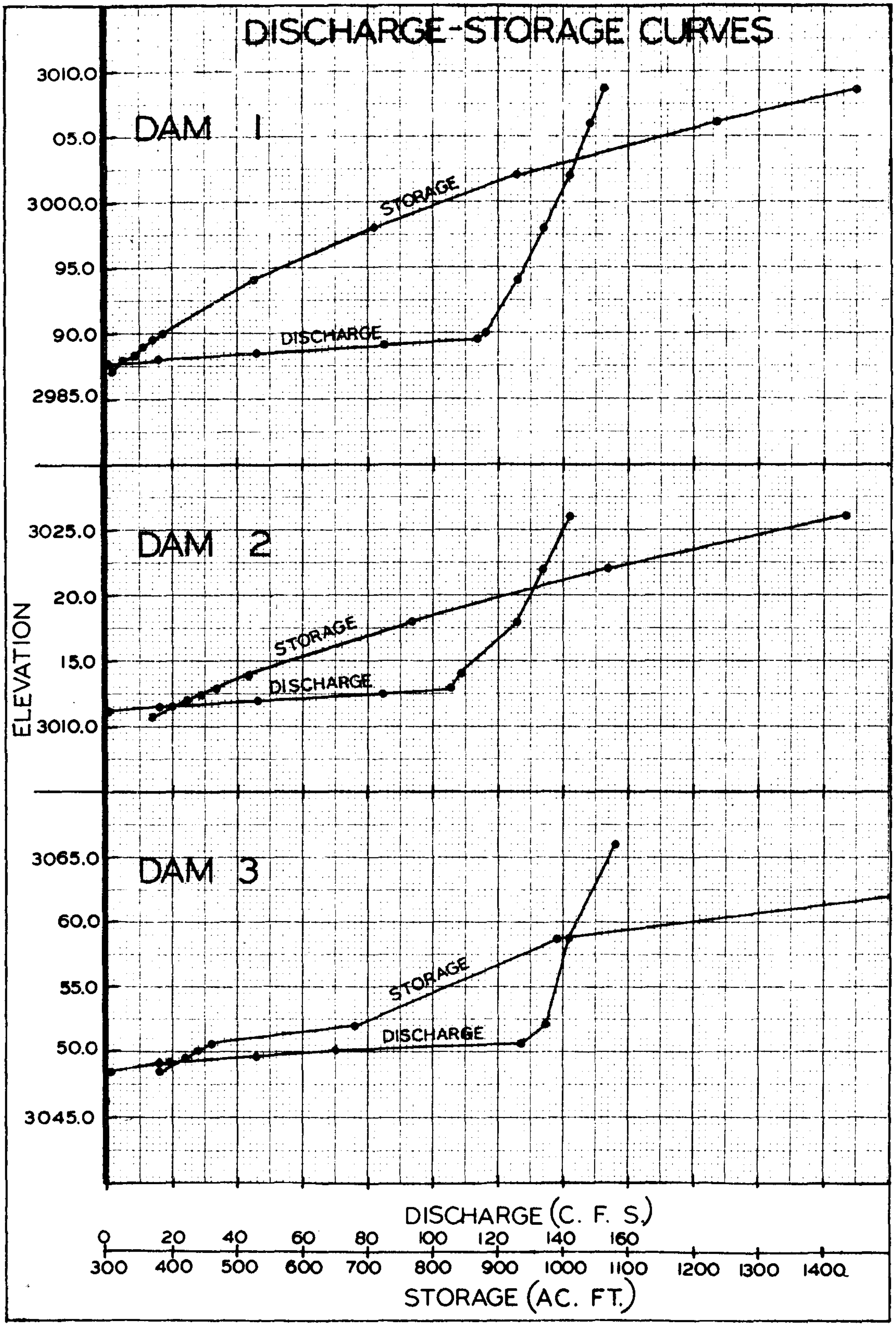
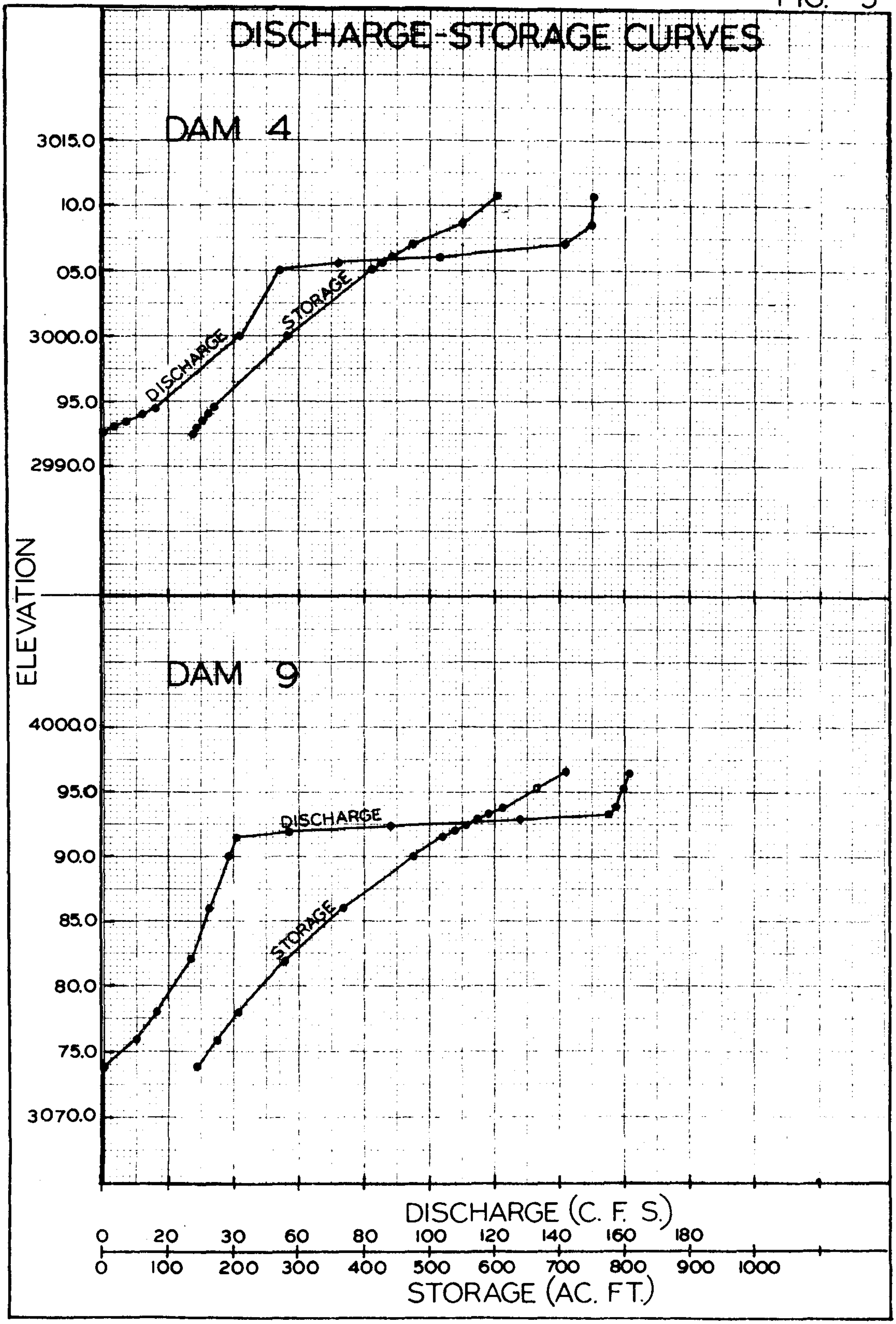
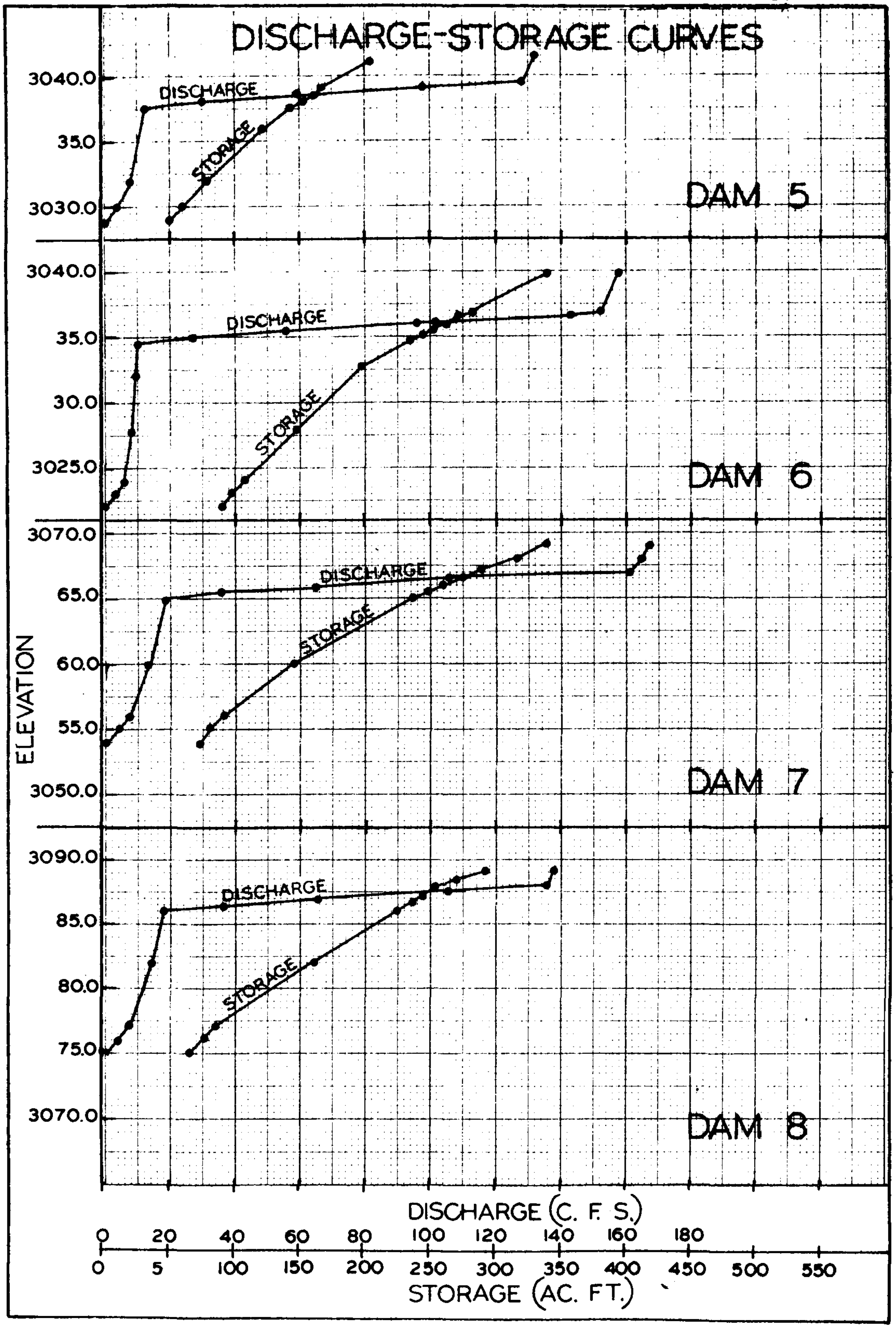

DISCHARGE-STORAGE CURVES
DAM 1
DAM 2
DAM 3
STORAGE
DISCHARGE
ELEVATION
3010.0
05.0
3000.0
95.0
90.0
2985.0
3025.0
20.0
15.0
3010.0
3065.0
60.0
55.0
50.0
3045.0
DISCHARGE (C. F. S.)
0 20 40 60 80 100 120 140 160
300 400 500 600 700 800 900 1000 1100 1200 1300 1400
STORAGE (AC. FT.)

FIG. 5



DISCHARGE-STORAGE CURVES
DAM 4
3015.0
10.0
05.0
3000.0
95.0
2990.0
DISCHARGE
STORAGE
ELEVATION
DAM 9
4000.0
95.0
90.0
85.0
80.0
75.0
3070.0
DISCHARGE
STORAGE
DISCHARGE (C. F. S.)
0 20 30 60 80 100 120 140 160 180
0 100 200 300 400 500 600 700 800 900 1000
STORAGE (AC. FT.)

FIG. 6


DISCHARGE-STORAGE CURVES
DISCHARGE
STORAGE
DAM 5
DAM 6
DAM 7
DAM 8
3040.0
35.0
3030.0
3040.0
35.0
30.0
3025.0
3070.0
65.0
60.0
55.0
3050.0
3090.0
85.0
80.0
75.0
3070.0
ELEVATION
DISCHARGE (C. F. S.)
0 20 40 60 80 100 120 140 160 180
0 5 100 150 200 250 300 350 400 450 500 550
STORAGE (AC. FT.)

Complete hydrological investigation of every possible combination of nine dams would have been very expensive and time-consuming. Determination of the 100-year flood flows for all nine dams showed that the incremental effect of four of the dams would be relatively small, so they were eliminated from further consideration. Flood peak flows shown in Table 4 were computed, or extrapolated from computed data as shown in Fig. 7, for six return periods with 9 dams and with different combinations of as many as 5 dams.

Flood Reduction Effectiveness

The incremental reduction in peak flow and the incremental cost of construction were calculated for comparison. The results are shown in Table 5.

The combination of two dams, 1 and 2, was the most cost effective in reducing peak flows. However, these figures do not include costs other than construction cost or economic benefits derived from flood reduction. Further study was required to determine total costs and potential benefits from different combinations of dams to find the combination with the greatest net economic benefit.

Water Surface Profiles

Water surface profiles were computed at 11 cross-sections in and around Wauneta shown on Map 2. A computer program, WSP-2, developed by the SCS, was used to compute water surface elevations with given peak flow at all the cross-sections.

TABLE 5

Comparison of Flood Reduction and Cost of Various Combinations of Dams

No. of Dams	Dam No's	100-Year Peak Flow	Percent of Existing Peak Flow	Construction Cost	Cost per Percent Reduction
				($1,000)	($1,000)
0		8385	100		
1	1	7490	89	178	16.2
2	1+2	5830	70	308	10.3
	2+3	6640	79	310	14.8
3	1+2+3	4920	59	488	11.9
4	1+2+3+4	4730	56	587	13.3
	1+2+3+7	4500	54	559	12.2
5	1+2+3+4+9	4380	52	740	15.4
	1+2+3+7+9	4145	49	713	14.0
	1+2+3+4+7	4355	52	658	13.7
9		3600	43	1060	18.6

DISCHARGE FREQUENCY CURVES AT WAUNETA

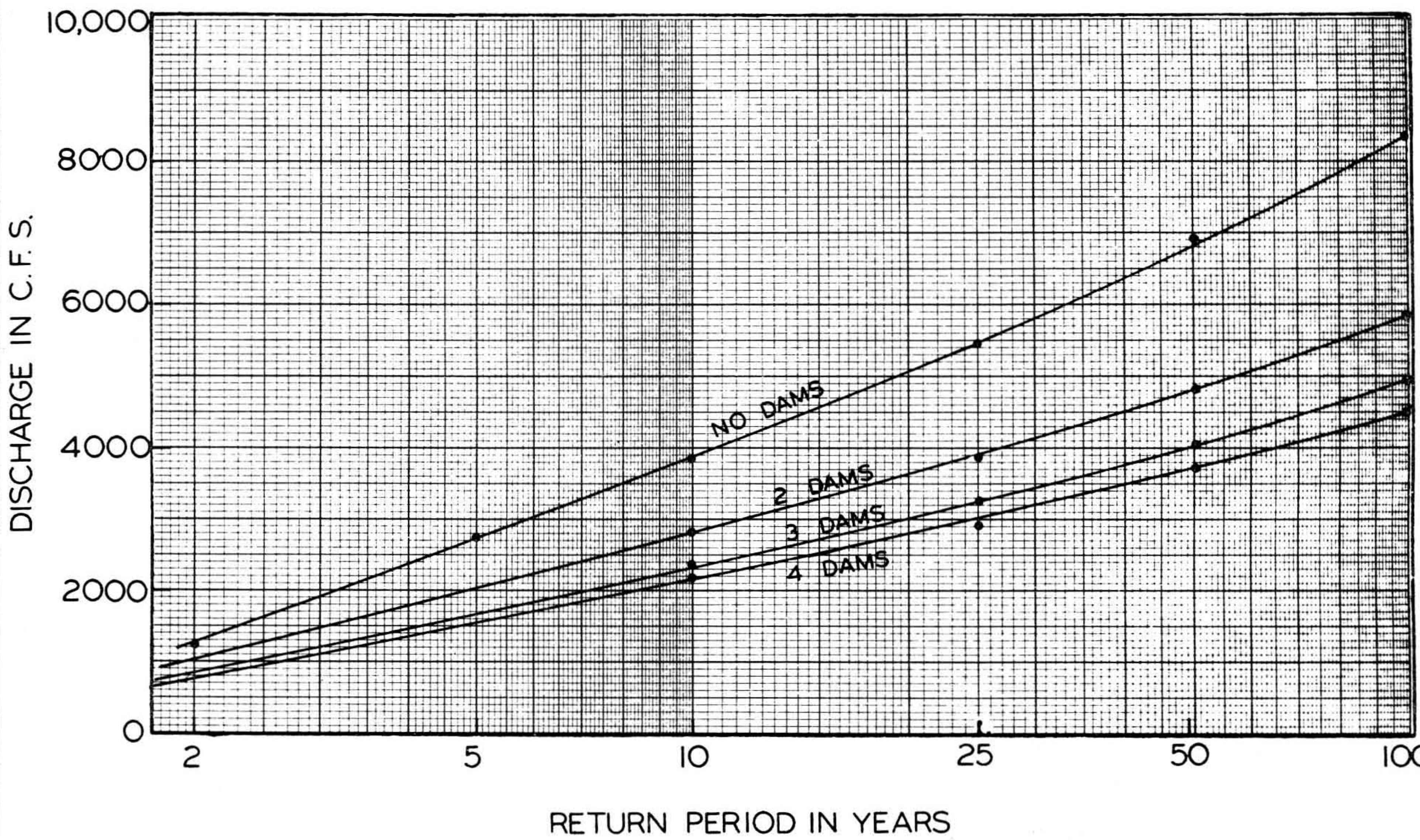


FIG. 7

The roughness coefficients (or "n" values) for the channel were estimated by field survey, an aerial photograph of Wauneta, and a guidebook, Guide for Selecting Roughness Coefficient "n" Values for Channels, SCS, December 1963. The roughness coefficients for the flood plain were obtained by a field survey and a hydraulics textbook, Open-Channel Hydraulics, Ven Te Chow, 1959. Roughness coefficients are given in Table 6.

The initial water surface elevations for different flows were estimated at cross-section 5-002 from the water surface elevation of the 1956 flood. The 1956 flood was a little larger than the 100-year flood. The WSP-2 computer program calculated the other water surface elevations using the assigned "n" values and the estimated water surface elevation at cross-section 5-002. The results are given in Tables 7 and 8.

TABLE 6

Roughness Coefficients at Wauneta

Cross-Section	Left Bank	Channel	Right Bank
5-002	0.10	0.037	0.10
5-003	0.10	0.037	0.07
5-004	0.06	0.030	0.12
5-006	0.07	0.030	0.12
5-007	0.08	0.035	0.10
5-008	0.10	0.040	0.12
5-010	0.10	0.037	0.12
5-011	0.08	0.037	0.07
5-012	0.04	0.035	0.04

TABLE 7

Computed Water Surface Elevations at Wauneta Without Dams

Cross-	Return Period in Years					
Section	100	50	25	10	5	2
	(feet 1/)					
5-002	2932.0	2931.6	2931.3	2930.3	2930.0	2929.5
5-003	2934.1	2933.4	2932.7	2931.6	2931.0	2929.9
5-004	2935.3	2934.5	2933.7	2932.6	2931.9	2930.5
5-005	2935.6	2934.9	2934.05	2932.9	2932.1	2930.5
5-006	2935.7	2934.9	2934.1	2932.9	2932.1	2930.9
5-007	2937.1	2936.4	2935.5	2934.3	2933.5	2931.7
5-008	2940.9	2940.2	2939.3	2937.9	2936.5	2933.9
5-009	2941.3	2940.8	2939.7	2938.2	2936.8	2934.1
5-010	2941.7	2941.2	2940.1	2938.5	2937.0	2934.3
5-011	2942.9	2942.3	2941.5	2939.9	2938.3	2935.2
5-012	2944.0	2943.5	2942.7	2941.3	2939.6	2936.4

1/ Elevations refer to mean sea level datum.

TABLE 8

Computed Water Surface Elevations at Wauneta With 2 and 3 Dams

Cross-Section	2 Dams Return Period 100 yr.	2 Dams Return Period 50 yr.	3 Dams Return Period 100 yr.	3 Dams Return Period 50 yr.
	(feet1/)			
5-002	2931.4	2930.9	2931.0	2930.4
5-003	2932.9	2932.3	2932.4	2931.8
5-004	2934.0	2933.3	2933.4	2932.8
5-005	2934.3	2933.6	2933.7	2933.1
5-006	2934.3	2933.7	2933.8	2933.1
5-007	2935.8	2935.2	2935.2	2934.6
5-008	2939.6	2938.9	2939.0	2938.1
5-009	2940.3	2939.3	2939.4	2938.5
5-010	2940.6	2939.6	2939.7	2938.8
5-011	2941.8	2941.1	2941.1	2940.3
5-012	2943.0	2942.4	2942.5	2941.9

1/ Elevations refer to mean sea level datum.

Area-Flooded Maps

The area flooded in Wauneta during the 1956 flood, mapped by the COE, is shown in Map 2 with the area flooded by the computed 50-year and 100-year floods under existing conditions. Water surface elevations given in Table 8 were plotted in Maps 3 and 4. These maps show the flooded area in Wauneta with 2 dams and 3 dams for the 50- and 100-year floods. These area-flooded maps were used to determine urban damage in Wauneta.

RURAL FLOOD ANALYSIS

The second stage of the hydrological investigation was the study of flooding in the rural area from Enders Dam to Palisade. Since the primary purpose of the preliminary investigation was to determine the potential benefits to Wauneta, a different method of hydrological analysis was used for the rural area.

Flood Frequency in Rural Areas

In the second stage, peak flood flows were obtained or estimated at selected cross-sections in the Frenchman valley from Enders Dam to Palisade. The cross-sections are shown in Map 5.

Flood flows are available at Hamlet (cross-section 3-000) and Palisade (cross-section 1-000) for different return periods from a report by Beckman (Magnitude and Frequency of Floods in Nebraska, USGS, Oct. 1976). These frequency analyses are based on gaging records of flows from the entire drainage area. The entire period of record for the gaging station at Hamlet precedes the construction of Enders Dam, so it was assumed the peak flows developed by the Beckman report reflect conditions without Enders Reservoir. This was checked with, and seemingly supported by, the records in the USGS files.

Peak flows at Wauneta (cross-section 6-000) were determined previously by the rainfall-runoff model of the area below Enders Dam. It was found that discharge frequencies obtained from the two different methods, for different areas, were nearly equal. This would seem to indicate that a flood of any specified frequency could have been generated by rainfall over the whole basin or any part of it above Enders Dam, prior to its construction; or by rainfall on the area below Enders Dam alone. It is impossible to calculate the mathematical probability of the occurrence of either of these types of storms, so it was assumed that the likelihood of either type was equal.

Enders Reservoir has 30,000 acre-feet of storage specifically allocated for flood control, which appeared adequate to provide protection to Wauneta in a 100-year flood of about 8000 cubic feet per second. Therefore, it was assumed that the statisical calculations of flood frequency and average annual damages were valid for floods originating from the area below Enders Dam.

Flood flows at cross-sections 2-000, 4-000, and 5-000 were estimated by linear interpolation. Flood flows at cross-sections 7-000 and 8-000 were determined in the urban flood analysis. Table 9 shows these flood flows.

TABLE 9

Estimated Flood Flows in Frenchman Creek

Cross-Section	Return Period in Years 100	50	25	10	5	2
	(cubic feet per second)					
1-000	6010	4450	3240	2070	1420	770
2-000	6890	5030	3610	2245	1490	765
3-000	7110	5180	3700	2290	1510	760
4-000	7480	5690	4200	2750	1875	910
5-000	7910	6270	4770	3265	2290	1070
6-000	8385	6920	5410	3850	2760	1260
7-000	7650	5160	4855	3500	2300	1100
8-000	5550	4560	3810	2690	1800	950

Water Surface Elevation and Area Flooded

A different method was used to compute water surface elevations and extent of flooding in rural areas. The Manning formula was used to compute discharges at given elevations and stage-discharge tables were compiled for all rural cross-sections. The flooded area in each of the eight reaches was determined from cross-sectional data, stage-discharge tables, and reach lengths. The total area flooded in each reach was computed by multiplying the flood plain length in the reach and the width of the flooding.

Economic Investigations

HISTORICAL INVESTIGATIONS

The COE made a detailed investigation of the June 1956 flood. Field investigations were made to determine the extent and intensities of rainfall in the storm area. High-water marks were tied in to establish flood profiles, slope-area sections were surveyed for computations of flood discharges, and the extent of the flooded area was determined and delineated on flood plain maps. Flood-damage surveys were made of 40 percent of the agricultural areas and 100 percent of the urban areas of Wauneta and Hamlet. A thorough and detailed coverage was made of the transportation, utilities, and communications flood losses. Newspaper accounts and photographs were obtained for the record. All available flood data compiled by the various local interests were obtained for the office files of the COE.

After the COE investigation, the SCS conducted some preliminary economic investigations for the Republican River Basin Study. They have not conducted any further detailed investigations, but they have assisted in this study.

POTENTIAL FLOOD DAMAGE

Urban

Portions of the communities of Wauneta and Hamlet lie within the 100-year flood plain of Frenchman Creek. The damageable property in Hamlet (2 or 3 houses) is negligible compared to the potential total, so only Wauneta was included in the urban flood survey.

Residential. A house-to-house survey was made to determine the location, value and elevation of the 112 houses within the 100-year flood plain. The elevations of a 100-year and a 25-year flood were determined and depth-damage factors developed by the Department of Housing and Urban Development (HUD) were applied to determine damages.

Businesses. A total of 48 business places are in the 100-year flood plain. A survey was made to determine the type of business and the elevation of the buildings. Using the elevations of the 100-year and the 25-year flood, depth-damage factors developed by the COE were applied to arrive at a dollar damage for each type of business. The following table summarizes the results of the urban flood damage survey.

TABLE 10

Total Urban Damages for Present Conditions

Type	100-Year flood	25-Year flood
Residential		
Direct	$217,030	$31,060
Indirect (10% of direct)[1/]	21,703	3,106
Business		
Direct	212,800	76,100
Indirect (15% of direct)[1/]	31,920	11,415
TOTAL	$483,453	$121,681

1/ Based on SCS Guidelines.

Average Annual Damages. The total damage for each storm and the zero damage point (estimated to be at the 10-year storm) were plotted on a graph (Figure 8) according to the probability of the storms. The area under the damage curve was measured to determine the average annual damages. The results, shown on Figure 8, are $17,300 average annual urban damages. The amount of reduction of these damages will be the project benefits for the urban area.

Rural

The rural area of the flood plain considered for the study was from Enders Dam to Palisade.

Crop and Pasture. A strip map (Map 5), showing the type and location of the crops was developed from 1976 aerial photography. A field examination was conducted to verify and correct the strip map.

Considering the crop distribution in the flood plain, the projected yield of future crops, and the prices used for Resources Development Fund projects, a composite damageable value per acre of flood plain was determined. This value, shown on Table 11, is $216.91 per acre.

The damage per acre flooded at different depths was then determined by multiplying the damageable value per acre by a depth-damage factor from the SCS Economics Guide. The results, shown on Table 12, are $27.74 for depths of 0 to 1 foot, $75.48 for depths of 1.1 to 3 feet, and $107.07 for depths of 3.1 feet and over.

FIG. 8

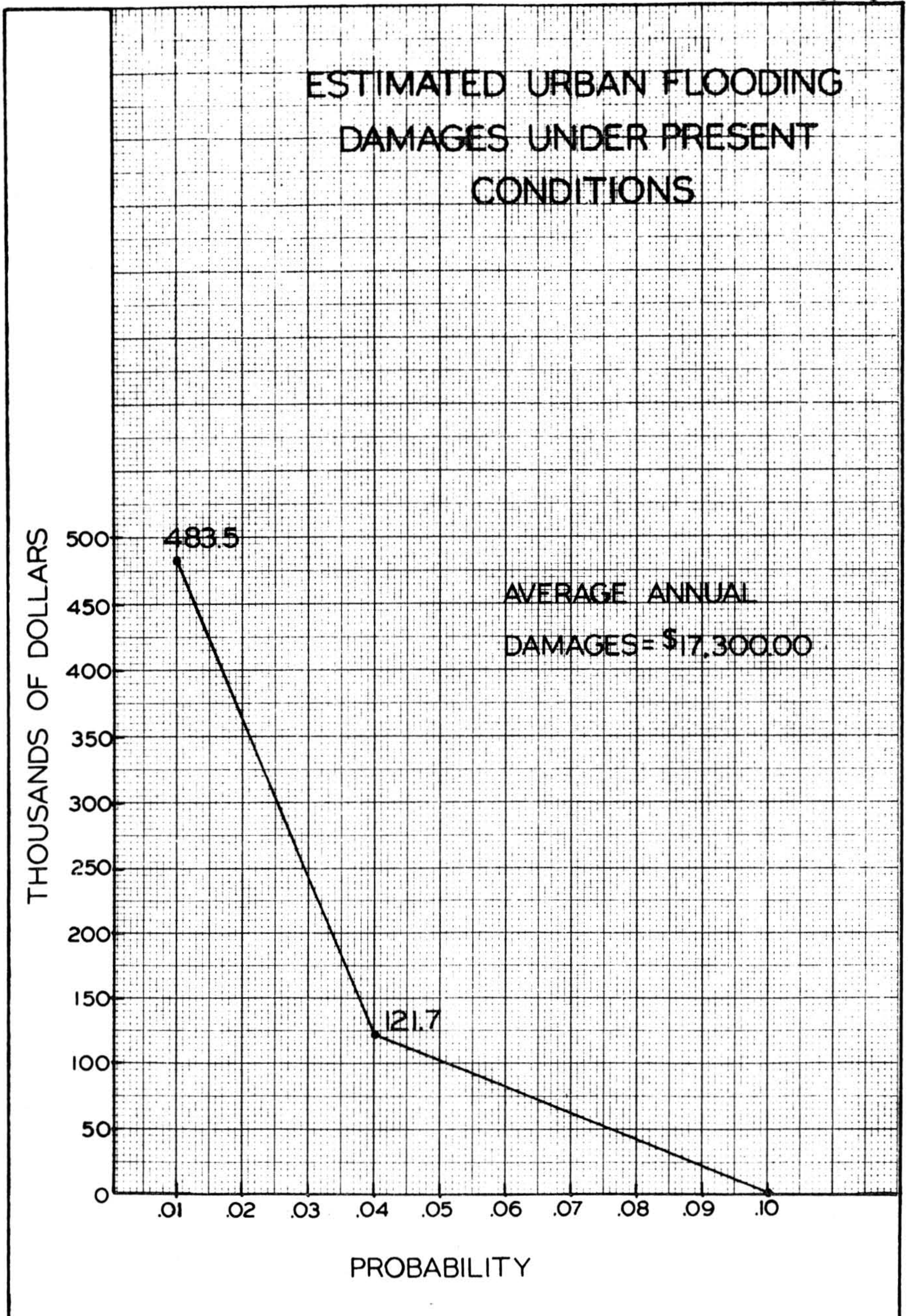

ESTIMATED URBAN FLOODING DAMAGES UNDER PRESENT CONDITIONS
AVERAGE ANNUAL DAMAGES = $17,300.00
483.5
121.7
THOUSANDS OF DOLLARS
500
450
400
350
300
250
200
150
100
50
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
.10
PROBABILITY

TABLE 11

Composite Damageable Value Per Acre of Flood Plain

Flood Plain Crops	Percent of Flood Plain	Yield[1/] Per Acre of Crop	Production Per Flood Plain Acre	Value[2/] Per Unit	Damageable Value
				($)	($/acre)
Corn (Irr.)	46	133 bu.	61.18 bu.	2.40	146.83
Alfalfa (Irr.)	21	5.8 tons	1.22 tons	39.96	48.75
Wheat	17	36 bu.	6.12 bu.	3.29	20.13
Pasture	12	1 A.U.M.	.12 A.U.M.[3/]	10.00	1.20
Misc.	4	--	--	--	--
	100				$216.91

1/ Projected yield for the year 2000 from Great Plains Ag. Pub. #33
2/ 1977 prices developed for the Resources Development Fund
3/ Animal Unit Month

TABLE 12

Composite Crop and Pasture Damage Rate

Crop	Damageable Value[1/]	Net Damage at depth (in feet) 0-1.0		1.1-3.0		3.1 & over	
	($/acre)	(%)	($/acre)	(%)	($/acre)	(%)	($/acre)
Corn	146.83	14.2	20.85	37.2	54.62	55.9	82.08
Alfalfa	48.75	9.0	4.39	31.1	15.16	36.6	17.84
Wheat	20.13	11.9	2.40	27.7	5.58	34.8	7.01
Pasture	1.20	8.1	.10	10.1	.12	11.4	.14
Misc.	--	--	--	--	--	--	--
TOTAL			27.74		75.48		107.07

1/ From Table 11

The discharges necessary to flood to depths from 0 to 3 feet were calculated at each of eight cross-sections. The width of flood plain flooded to different depths and the length of the reach were used to determine the number of acres flooded to those depths. The number of acres were multiplied by the damage per acre flooded to produce the total damage at the calculated discharges and the results were plotted on a graph. The damages caused by the 5, 10, 25, 50, and 100-year floods were then read from the graph.

These damages were plotted on another graph according to the probability of occurrence. Then the area under the curve was measured to determine the average annual damages for present conditions.

These average annual damages for present conditions were checked and expanded by using the computer program Econ-2. The results of the computer calculations, shown on the following table, are $5695.00 average annual crop and pasture damages. The amount of reduction of these damages, calculated by Econ-2, will be the project benefits for crops and pasture.

TABLE 13

Crop and Pasture Damages for Present Conditions

Cross-Section	Average Annual Damage
1-000	$ 990
2-000	360
3-000	130
4-000	1,290
5-000	145
6-000	285
7-000	1,705
8-000	790
TOTAL	$5,695

<u>Other Agricultural Damages</u>. Other agricultural damages such as livestock losses and damage to fences and farm equipment should be included in the study. For the preliminary study, these damages are assumed to be ten percent of direct average annual crop and pasture damages. This value, shown on Table 14, is $570. The amount of reduction of these damages will be project benefits.

<u>Other Damages</u>

Benefits will also occur as a reduction in future damages to roads, bridges, and railroads. Considering the percentages of damages that were listed in the 1956 COE study, these damages are assumed to be twelve percent of direct average annual crop and pasture damages. This value, also shown on Table 14, is $680.

TABLE 14

Total Average Annual Damages
for Present Conditions

URBAN	
Residential and Business[1]	$17,300
RURAL	
Crop and Pasture	$ 5,695
Other Agriculture	570
Indirect[2]	500
OTHER DAMAGES	
Road, Bridge and Railroad	$ 680
Indirect[2]	135
TOTAL	$24,880

1/ Includes indirect damages
2/ Based on SCS Guidelines

PROJECT COSTS

Project costs include construction, land rights, operation, and maintenance costs.

Construction and Land Rights Costs

The construction cost of all nine dams and the levee was estimated from calculated quantities and average prices. The land rights costs were estimated by the use of average costs for the study area. These estimated costs are shown on Table 15.

TABLE 15

Estimated Construction and Land Rights Costs

Structure	Total Const. Cost	Silt Pool	Cost	Flood Pool	Easement Area	Easement Cost	Total Land Costs	Const. & Land Cost[1]
	($)	(acres)	($)	(acres)	(acres)	($)	($)	($)
1	177,600	28	5,600	80	52	2,600	8,200	186,000
2	130,100	43	8,600	111	68	3,400	12,000	142,000
3	180,100	40	8,000	130	90	4,500	12,500	193,000
4	99,000	15	3,000	40	25	1,250	4,250	103,000
5	71,200	8	1,600	18	10	500	2,100	73,000
6	91,200	4	800	9	5	250	1,050	92,000
7	71,600	10	2,000	30	20	1,000	3,000	75,000
8	85,800	10	2,000	25	15	750	2,750	89,000
9	153,400	14	2,800	43	29	1,450	4,250	158,000
Levee	13,500						6,500	20,000

1/ Rounded to nearest thousand dollars

Annual Costs

Annual costs consist of first costs amortized at a specified interest rate over the life of the project plus the annual operation and maintenance costs. For these preliminary estimates, first costs have been annualized over a 50-year period at zero interest to determine the maximum costs that can be justified by the annual benefits, since the Resources Development Fund requires only that the project have a positive rate of return. The annual costs of the structures are displayed in Table 16.

SUMMARY OF PRELIMINARY BENEFITS AND COSTS

Estimated costs and benefits based on preliminary plans are summarized in Table 17. It shows the approximate net benefits for a number of alternatives and the relative efficiency of alternatives in reducing urban damages.

TABLE 16

Estimated Annual Structure Costs

Structure	First Cost	Annualized Cost	Operation and Maintenance Cost[1/]	Total Annual Cost
	(Dollars)			
1	186,000	3,720	1,400	5,120
2	142,000	2,840	1,080	3,920
3	193,000	3,860	1,470	5,330
4	103,000	2,060	770	2,830
5	73,000	1,460	550	2,010
6	92,000	1,840	690	2,530
7	75,000	1,500	560	2,060
8	89,000	1,780	680	2,460
9	158,000	3,160	1,200	4,360
Levee	20,000	400	250	650

1/ Based on SCS Guidelines

TABLE 17

Preliminary Structural Costs and Benefits

Structures	First Cost	Annual[1/] Cost	Rural[2/] and Other Damage	Urban[3/] Damage	Urban Reduction	Total Damage Reduction	Net Benefits
	($)	($)	($)	($)	(%)	($)	($)
None	0	0	7,580	17,300	0	0	0
1+2	328,000	9,040	4/	3,850	78	18,980	9,940
1+2+levee	348,000	9,690	4/	1,870	89	20,960	11,270
1+2+3	521,000	14,370	2,050[5/]	1,400	92	21,430	7,060
1+2+3 +levee	541,000	15,020	4/	880	95	21,950	6,930
1+2+3+7	596,000	16,430	4/	700	96	22,130	5,700
1+2+3+7 +levee	616,000	17,080	4/	540	97	22,290	5,210
1+2+3+4	624.000	17,200	4/	700	96	22,130	4,930
1+2+3+4 +levee	644,000	17,850	4/	540	97	22,290	4,440
1+2+3+7+9	754,000	20,790	4/	300	98	22,530	1,740
1+2+3+4+7	699,000	19,260	4/	300	98	22,530	3,270
All 9	1,111,000	30,620	4/	300	98	22,530	-8,090

1/ Zero interest - 50 Year project life
2/ Average annual damages
3/ Average annual urban damage - Wauneta
4/ Specific data not available - assumed equal to the 3-dam alternative
5/ $1300 remaining crop damages, $750 remaining other damages

CHAPTER 5. FINAL INVESTIGATIONS

After reviewing the results of the preliminary investigation, the sponsors indicated their preference for a project including three dams and the levee. Final investigations, including environmental, technical, and economic analyses, were then conducted to refine and expand on the preliminary results. In addition, several non-structural alternatives were investigated.

Description of the Alternatives

Final investigation of the structural alternatives was limited to three dams and the levee. Investigations of non-structural alternatives were not as detailed.

STRUCTURES

Alternative structural plans were considered in the preliminary stage, so final investigation was restricted to the structures selected by the sponsors.

Dams

The only change in the design of the dams was the substitution of a ported riser to provide "dry dams", which did not change costs significantly. Figure 9 shows a cross-section and profile along the centerline of a typical dam of this type. The general plan of each dam is shown in Maps 6, 7, and 8. Structural data on dams 1, 2, and 3 are given in Tables 18, 19, and 20. Final design of the dams will be done by SCS.

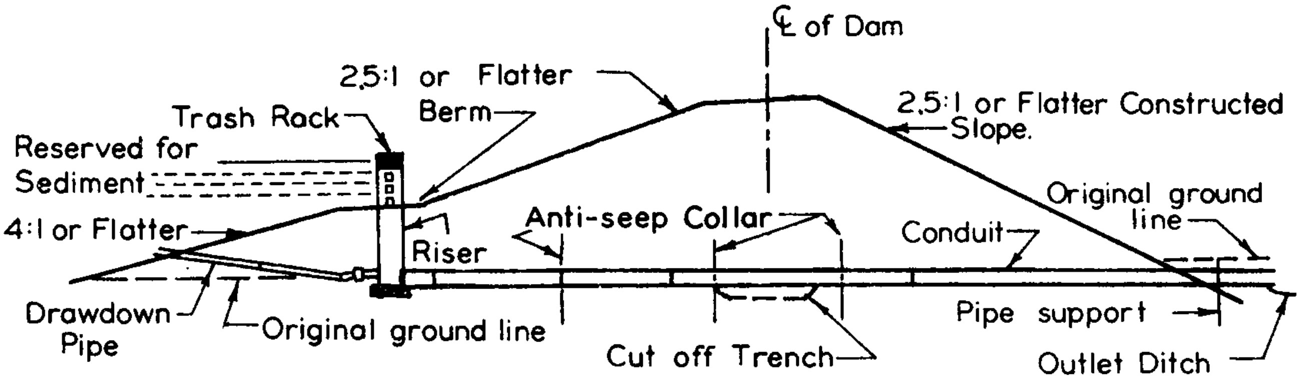
Levee

After a field inspection of the potential levee site, several alternatives for different segments were designed to relieve problems not shown on the original maps. These alternatives are shown on Map 1 with the alternatives considered during preliminary investigations.

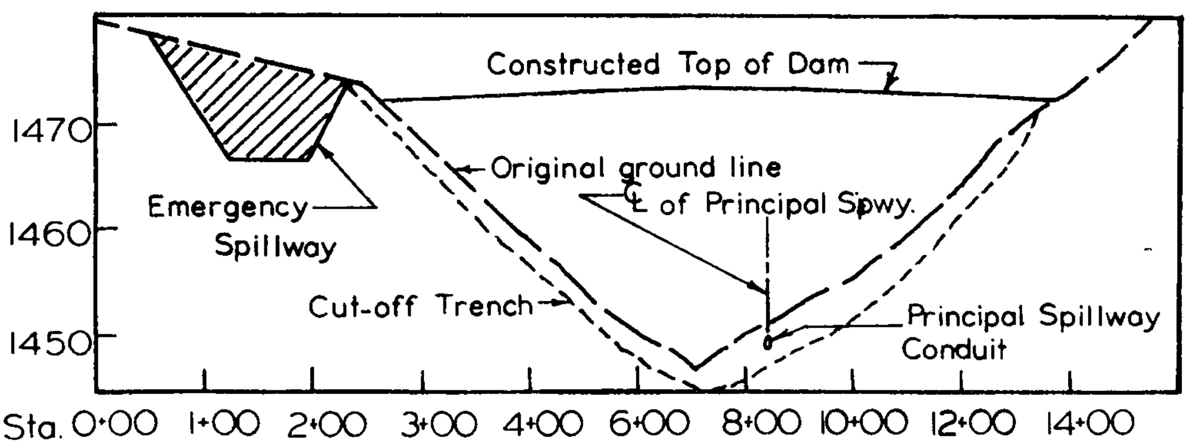
The original location of the west end of the levee is shown with a dashed line in Map 1. The final investigation determined that the residence west of the alley west of Second Street is above flood damage level in the 100-year event, so the levee could be located in the alley.

Three structures between the stream and Arikaree Avenue north of Wichita Street not shown in the preliminary maps made it necessary to investigate two different terminal points at the eastern end of the levee. First, the levee was terminated at a point about 200 feet north of the intersection of Arikaree and Wichita. This ends the levee very near the limit of flooding with 3 dams in operation, and gives very little margin of safety. However, this condition would occur only rarely, and a temporary sandbag closure across Arikaree could provide freeboard if required. Second, a preliminary design of a flood wall from Wichita Street to the end of the levee, between the stream and the structures,

TYPICAL FLOODWATER RETARDING STRUCTURE WITH SINGLE STAGE PORTED RISER



CROSS SECTION OF DAM ON CENTERLINE OF SINGLE STAGE PORTED RISER



PROFILE ON ℄ OF DAM

TABLE 18

Structural Data for Dam 1

ITEM	UNIT	QUALIFIER
Class of Structure		C
Drainage Area	Sq. Mi.	8.23
Controlled Portion	Sq. Mi.	----
Curve No. (1-day) (AMCII)		73.0
TC	HRS.	3.10
Elevation Top of Dam	Ft.	3,014.0
Elevation Crest Emergency Spillway	Ft.	3,009.0
Elevation Crest High Stage Inlet	Ft.	2,987.5
Maximum Height of Dam	Ft.	64.0
Volume of Fill	Cu. Yds.	150,000.0
Total Capacity	Ac. Ft.	1,488.0
Sediment Submerged 1st 50 years	Ac. Ft.	307.0
Sediment Aerated	Ac. Ft.	53.0
Beneficial Use	Ac. Ft.	----
Retarding	Ac. Ft.	1,128.0
Surface Area		
Sediment Pool	Ac.	28.0
Beneficial Use Pool	Ac.	----
Retarding Pool	Ac.	79.0
Principal Spillway		
Rainfall Volume (1-day)	In.	5.20
Rainfall Volume (10-day)	In.	8.45
Runoff Volume (10-day)	In.	3.21
Capacity of High Stage (Max.)	Cfs.	152.0
Frequency operation - Emergency Spillway	% Chance	1.0
Size of conduit	In.	30
Emergency Spillway		
Rainfall Volume (ESH)	In.	9.10
Runoff Volume	In.	5.80
Type		Vegetated Earth
Bottom width	Ft.	200.0
Velocity of Flow (VE)	Ft./Sec.	5.0
Slope of exit channel	Ft./Ft.	0
Maximum water surface elevation	Ft.	3,011.5
Freeboard		
Rainfall Volume (FH) (areal)	In.	23.0
Runoff Volume (FH)	In.	19.09
Maximum Water Surface Elevation	Ft.	3,013.6
Capacity Requirements		
Sediment Volume	In.	0.82
Retarding Volume	In.	3.21

TABLE 19

Structural Data for Dam 2

ITEM	UNIT	QUALIFIER
Class of Structure		C
Drainage Area	Sq. Mi.	9.83
Controlled Portion	Sq. Mi.	0
Curve No. (1-day) (AMCII)		73.0
TC	HRS.	3.2
Elevation Top of Dam	Ft.	3,034.0
Elevation Crest Emergency Spillway	Ft.	3,029.0
Elevation Crest High Stage Inlet	Ft.	3,011.0
Maximum Height of Dam	Ft.	50.0
Volume of Fill	Cu. Yds.	102,400.0
Total Capacity	Ac. Ft.	1,778.0
Sediment Submerged 1st 50 years	Ac. Ft.	367.0
Sediment Aerated	Ac. Ft.	65.0
Beneficial Use	Ac. Ft.	0
Retarding	Ac. Ft.	1,346.0
Surface Area		
Sediment Pool	Ac.	43.0
Beneficial Use Pool	Ac.	----
Retarding Pool	Ac.	110.0
Principal Spillway		
Rainfall Volume (1-day)	In.	5.20
Rainfall Volume (10-day)	In.	8.45
Runoff Volume (10-day)	In.	3.21
Capacity of High Stage (Max.)	Cfs.	148.0
Frequency operation - Emergency Spillway	% Chance	1.0
Size of conduit	In.	30
Emergency Spillway		
Rainfall Volume (ESH)	In.	9.10
Runoff Volume	In.	5.80
Type		Vegetated Earth
Bottom width	Ft.	200.0
Velocity of Flow (VE)	Ft./Sec.	5.6
Slope of exit channel	Ft./Ft.	0.03
Maximum water surface elevation	Ft.	3,031.4
Freeboard		
Rainfall Volume (FH) (areal)	In.	23.0
Runoff Volume (FH)	In.	19.09
Maximum Water Surface Elevation	Ft.	3,033.5
Capacity Requirements		
Sediment Volume	In.	0.82
Retarding Volume	In.	3.21

TABLE 20

Structural Data for Dam 3

ITEM	UNIT	QUALIFIER
Class of Structure		C
Drainage Area	Sq. Mi.	10.13
Controlled Portion	Sq. Mi.	-----
Curve No. (1-day) (AMCII)		76.0
TC	HRS.	4.0
Elevation Top of Dam	Ft.	3,072.0
Elevation Crest Emergency Spillway	Ft.	3,066.0
Elevation Crest High Stage Inlet	Ft.	3,048.5
Maximum Height of Dam	Ft.	57.0
Volume of Fill	Cu. Yds.	147,000.0
Total Capacity	Ac. Ft.	1,837.0
Sediment Submerged 1st 50 years	Ac. Ft.	378.0
Sediment Aerated	Ac. Ft.	67.0
Beneficial Use	Ac. Ft.	-----
Retarding	Ac. Ft.	1,392.0
Surface Area		
Sediment Pool	Ac.	40.0
Beneficial Use Pool	Ac.	----
Retarding Pool	Ac.	130.0
Principal Spillway		
Rainfall Volume (1-day)	In.	5.20
Rainfall Volume (10-day)	In.	8.45
Runoff Volume (10-day)	In.	3.68
Capacity of High Stage (Max.)	Cfs.	156.0
Frequency operation - Emergency Spillway	% Chance	1.0
Size of conduit	In.	30
Emergency Spillway		
Rainfall Volume (ESH)	In.	9.10
Runoff Volume	In.	5.80
Type		Vegetated Earth
Bottom width	Ft.	250.0
Velocity of Flow (VE)	Ft./Sec.	6.5
Slope of exit channel	Ft./Ft.	0.03
Maximum water surface elevation	Ft.	3,068.5
Freeboard		
Rainfall Volume (FH) (areal)	In.	23.0
Runoff Volume (FH)	In.	19.59
Maximum Water Surface Elevation	Ft.	3,071.5
Capacity Requirements		
Sediment Volume	In.	0.82
Retarding Volume	In.	3.68

was developed and the cost was estimated. This structure is difficult to design, and will be extremely difficult to construct, because of the lack of space. It is also extremely difficult to justify economically because the structures it protects are subject to flooding only in rare events, certainly those exceeding the 50-year flood, and possibly those close to the 100-year flood, as shown in Maps 3 and 4.

Final location and details of the levee need not be specified until the final design stage because the levee is so low and the costs will be a minor part of the project costs.

NON-STRUCTURAL ALTERNATIVES

There are several alternative methods of reducing future flood damage that do not involve the construction of dams or levees. These alternatives include evacuation of the flood plain and reconstruction elsewhere, or a program of flood plain zoning and insurance. The development of a flood plain park could be included with any of the alternatives.

Evacuation of the Flood Plain

Flood damages could nearly be eliminated by evacuating all non-essential development from the flood plain. Houses, schools, offices, and businesses could be moved or demolished and replaced at locations not subject to damage by flood waters. Mobile homes could easily be moved. Frame houses could be moved with a little more difficulty if they are structurally sound. Some commercial and industrial structures could also be moved with greater expenditures of energy and funds.

Those buildings whose structural integrity cannot be preserved during moving operations, and those whose current value is too low to justify moving costs, would have to be demolished and replaced with new structures at some location outside the flood plain. A few structures near the edge of the flood plain might not have to be relocated if they could be flood-proofed.

The effects of evacuation would be drastic. The schools, most of the businesses, and about half of the residences in the village are located in the flood plain. The topography of the surrounding area would make it very difficult and expensive, if not impossible, to re-establish the community according to desirable planning concepts. A new location for a central, compact business district would be difficult to find, and residential development would have to spread considerably. The result would be to change the character of the community completely. It would also require extensive investments in streets, lights, sewers, water mains, and other public services. Damage to existing public installations could not be eliminated entirely because the flood plain runs through the middle of the community. Roads, bridges, sewers, power lines and other utilities would still have to be located in the flood plain to connect the two halves of the village.

Flood Plain Zoning and Flood Insurance

Since delineation of the 100-year flood plain by hydrologic analysis is now available, it would be possible to establish flood plain zoning regulations in Wauneta under the Nebraska Flood Plain Management Act.

Under this program the 100-year flood plain would be established as a Commission Floodway and regulation would come under the village's zoning ordinance after all legal and procedural requirements were met. Construction in Commission Floodways is strictly regulated by special permits enforcing minimum state standards.

Future construction of structures for human habitation would be prohibited in the Selected Floodway portion of this zone. Permits would be issued only for non-residential uses that would not adversely affect flood flows. Existing structures in the flood plain would be non-conforming, but exempt, uses. However, they would be subject to severe restrictions on enlargement, alteration, or replacement if damaged more than 50% of their market value.

The village of Wauneta is currently participating in the flood insurance program administered by HUD, which has already designated a flood hazard area in the city. Within this designated area, nationally subsidized flood insurance is available from HUD for all existing insurable development. Future development in the area is possible only if a building permit is issued which conforms to program requirements. No federal funds, such as FHA loans or HUD grants, could be spent for non-insured structures in the designated area.

These programs would reduce future flood damages by preventing the construction of damageable development in the flood plain and gradual elimination of existing non-conforming development as it becomes severely damaged or deteriorates beyond reasonable repair. The insurance program will transfer the cost of flood damage and clean-up from the local residents (and government agencies providing emergency relief) to the federal government.

It is impossible to predict what effects this program would have on the 112 houses and 48 businesses in the 100-year flood plain. It is unlikely that floods would damage many properties more than 50% of their value, so effects would be felt slowly, primarily as the structures age and become infeasible to maintain and impossible to replace. At some future date, the rate of evacuation would probably accelerate, however, as neighborhoods become less and less attractive. As the location of the residences shifted and the business places became older, the location of the business center would probably shift also. If it followed current trends, it would most likely move to a location nearer the highway.

Flood Plain Park

Development of a park in the flood plain could accompany several of the alternatives described in this report. If the facilities included in it were restricted to structures and materials with low potential for flood damage and the area was maintained so the flow of water across the flood plain was not obstructed, flood damages would be reduced.

A park could be developed in conjunction with the evacuation of the flood plain. Land ownership by the village and use of the land for park purposes would preclude future damageable development. However, the park would occupy about one-third of the total area of the village and it might be difficult and expensive to maintain.

A park could also be developed as part of the structural project. The dams and levee will protect the area south and west of the stream from flooding, but the area east of the Wichita Street bridge will still be subject to periodic inundation. Most of the houses in this part of the flood plain have been moved since the 1956 flood, but several still remain and others could possibly be built there in the future. Purchase of the area and conversion to a park would not only control future damages, it would provide some flood control benefits and recreation opportunity.

The park would extend from the site of the old dam south and east along the stream to the sewage pumping plant south of Park Street, as shown in Figure 10. It would include most of the land flooded by the 50-year flood east of the stream.

Development of the park would include purchase of the land, clearing of debris, brush, vacant buildings, and other obstructions to flood flows. The area would be graded to provide drainage and suitable slopes for skating rinks and playing fields. All large, healthy trees would be retained if possible and others would be planted to provide shade in appropriate places.

A paved biking-hiking trail would be constructed along the perimeter of the park near the stream. Picnic tables, fire grates, trash cans and holders, and playground equipment would be placed throughout the park.

A paved driveway and parking area extending south from Wichita Street at the low point east of the bridge would provide drainage of low flows and alleviate some silt deposition in the streets and storm sewers. The area at the end of the parking lot would be graded to drain to the stream. The entire park would be maintained to minimize obstructions to flood flows.

A preliminary plan of the park is shown in Figure 11.

Final Hydrological Investigations

FLOOD ROUTING IN WAUNETA

No further refinement of the preliminary hydrological investigation for Wauneta was required for the final analysis because it provided sufficient information for the final economic analysis.

Hydrologic Effect of the Structural Program

As shown in Table 4, dams 1, 2, and 3 would reduce both 50- and 100-year floods by about 40 percent at Wauneta. They would also lower flood elevations by about 2 feet in Frenchman Creek at Wauneta.

The effect of the proposed levee was also investigated. It was found that the levee would increase water surface elevations by 0.1 to 0.5 feet at Wauneta. This is within the range of precision of the method of computation, so the effects of the levee on flood elevations were considered negligible.

PROPOSED FLOOD PLAIN PARK LOCATION

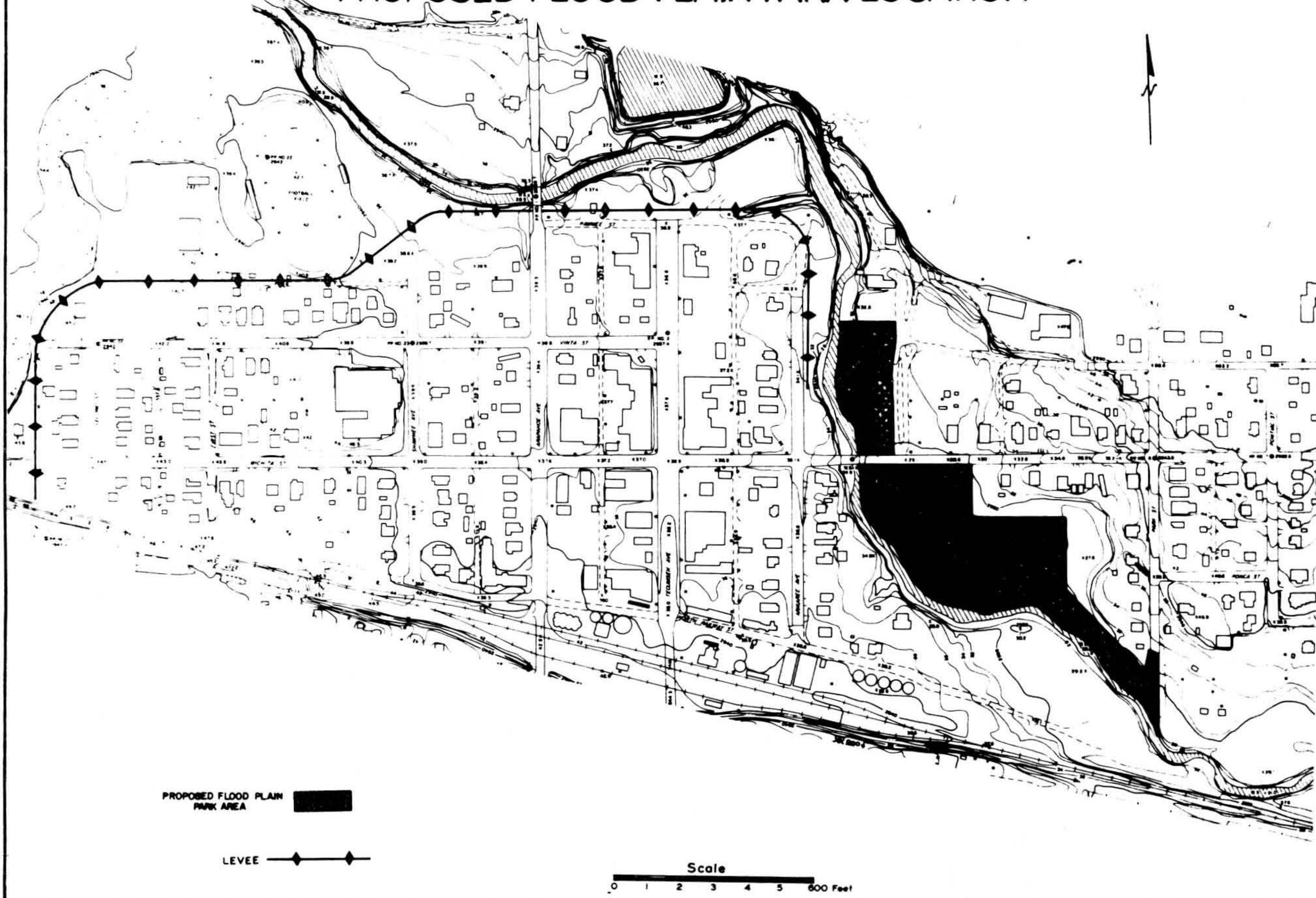
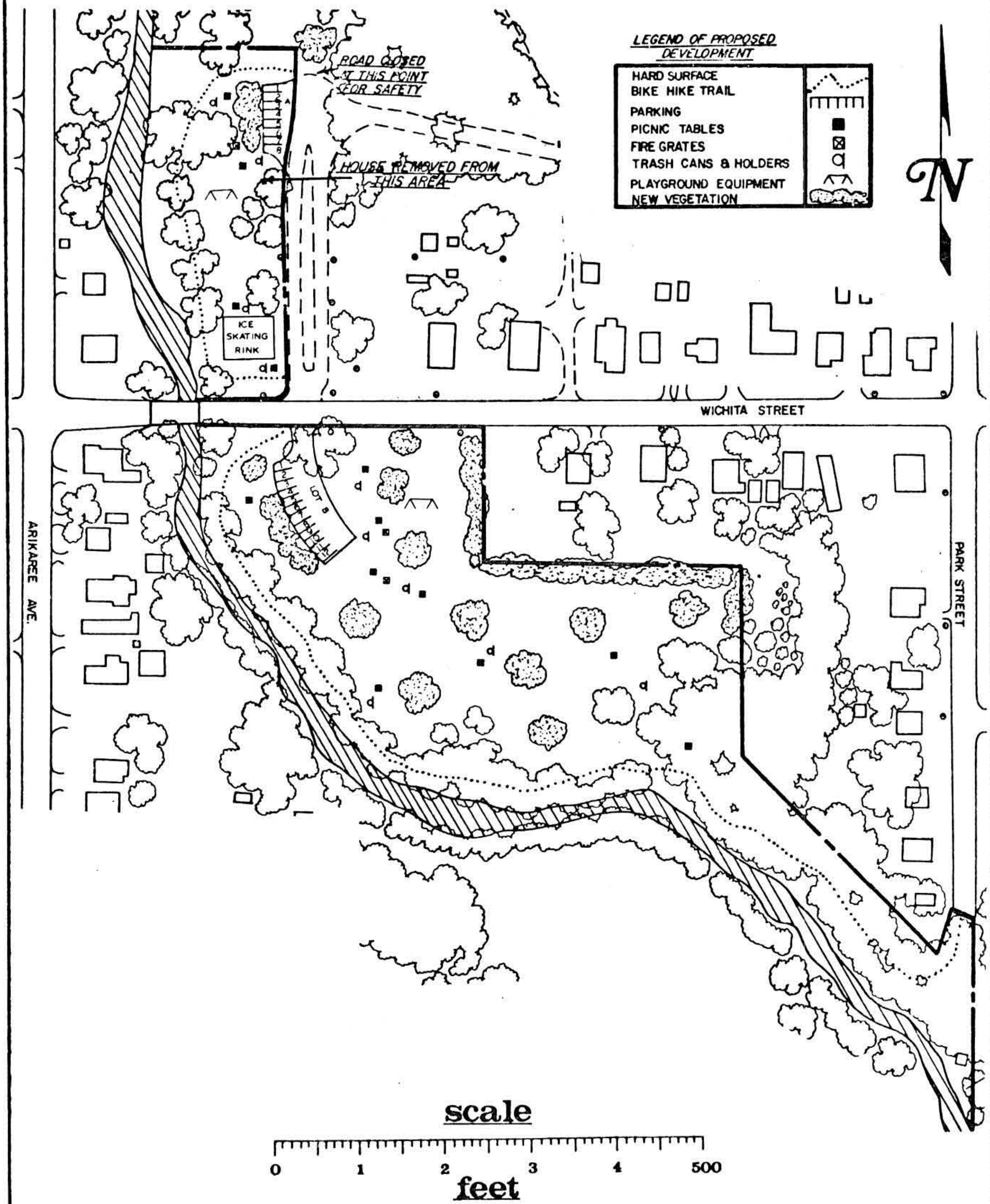


FIG. 10

PROPOSED FLOOD PLAIN PARK



Hydrologic Effects of the Flood Plain Park

The proposed flood plain park would modify the roughness coefficient in that area so it would change the water surface elevations slightly. It was determined that the change was insignificant. However, creation of the park would prevent future development of the flood plain that might obstruct flows and aggravate flood problems in that area.

FLOOD ROUTING IN RURAL AREAS

The preliminary investigation of the rural areas of the Frenchman valley was updated by use of the TR-20 and WSP-2 computer programs.

Frequency of Flooding from Enders Dam to Palisade

In the preliminary hydrological investigation, flood peak flows at cross-sections 2-000, 4-000, and 5-000 were estimated by linear interpolation of the drainage area above each cross-section. For the final investigation, the TR-20 program was employed to determine peak flows at those cross-sections. Parameters in the TR-20 program were adjusted so that computed peak flows would match the known peak flows at cross-sections 1-000, 3-000, and 6-000. Table 21 shows these flood flows.

The selected structural alternative includes three dams and a levee, so the TR-20 program and the previously determined parameters were utilized to estimate the effects of these dams on the peak flows in the Frenchman valley. The results are shown in Table 22.

Water Surface Profiles from Enders Dam to Palisade

The WSP-2 computer program was used to compute water surface elevations and the extent of flooding in rural areas for two different conditions. The first was the existing condition without dams and the second was with three dams. The flooded area for each reach was determined from the flood plain length in the reach (Table 21) and the width of the flooding.

Final Economic Evaluations

ANALYSIS OF FLOOD CONTROL BENEFITS AND COSTS

The final flood control analysis required additional field work to gather more detailed data. Computer programs were also utilized more extensively for the final evaluations.

Structural Alternatives

Final economic evaluation of the structural flood control measures was based on a project consisting of three dams and the levee. Flood control benefits were determined by comparing flood damages with and without the project. Flood control costs are the costs of the structures.

Urban Benefits. Estimates of average annual urban damages were refined by use of the SCS Urban-1 computer program. Additional field work and data processing were required to develop the input to the computer program.

TABLE 21

Flood Flows in Frenchman Creek Under Existing Conditions

Cross-Section	Flood Plain Length	Return Period in Years					
		100	50	25	10	5	2
	(feet)	(cubic feet per second)					
1-000		6010	4450	3240	2070	1420	770
2-000	49000	6970	4990	3630	2260	1500	780
3-000	10800	7110	5180	3700	2290	1510	760
4-000	37200	8090	5970	4390	2940	2160	980
5-000	34000	9030	7140	5450	3880	2800	1290
6-000	12600	8385	6920	5410	3850	2760	1260
7-000	14200	7650	5160	4855	3500	2300	1100
8-000	15000	5550	4560	3810	2690	1800	950

TABLE 22

Flood Flows in Frenchman Creek With Dams 1, 2, and 3

Cross-Section	Return Period in Years					
	100	50	25	10	5	2
	(cubic feet per second)					
1-000	4610	3310	2410	1690	1190	520
2-000	5070	3640	2650	1690	1220	510
3-000	5195	3730	2720	1690	1260	510
4-000	5780	4230	3100	2150	1630	720
5-000	5980	4755	3650	2790	2170	1000
6-000	4920	4085	3235	2380	1750	950
7-000	4350	3750	2800	2000	1500	800
8-000	3500	3100	2300	1400	1100	600

(Residential damage data) The house-to-house survey made for the preliminary investigation was used to determine the value and elevation of the houses within the 100-year flood plain. The elevation at which damage would begin was then calculated from field data and depth-damage factors, developed by HUD, were assigned for each house and its contents.

(Business damage data) In addition to the initial survey made to determine the type of business and the elevation of the buildings, interviews with a number of business people were conducted to get the value of the buildings and contents. An estimate of the damage that would occur at different water depths was also made in the interviews. Using the HUD factors and information from the COE as a guide, depth-damage factors were developed.

(Average annual damage) The SCS Urban-1 program, which computes the average annual flood damage to urban property from the percent damage to buildings and contents at specified water depths, was used in the final economic evaluation. The location of the buildings between cross-sections was assigned by means of stationing along a common base line on Map 2. The damage to each building was computed for specified floods based on its station, elevation, elevation at which damage would begin, value, type of house, and the depth-damage factor determined previously. The results are shown in Table 23.

TABLE 23

Average Annual Urban Damages and Benefits

Cross-Section	Buildings Damaged By 100-year Flood		Average Annual Damage		Benefits
	Without Project	With Project	Without Project	With Project	
	(No.)	(No.)	($)	($)	($)
5-003					
	3	1	575	165	410
5-004					
	5	2	760	170	590
5-007					
	43	0	10,685	0	10,685
5-008					
	36	0	9,780	0	9,780
5-011					
	1	0	30	0	30
5-012					
TOTALS	88	3	21,830	335	21,495

Rural Benefits. A more detailed study of the rural area was necessary for the final economic evaluation. Field investigations were conducted to obtain more detailed data on the cross-sections, and the beginning damage point was lowered on some of the cross-sections to include some pasture land excluded during the preliminary investigation. The SCS computer program Econ-2 was used more extensively for the final study. The same yields, prices, and depth-damage factors used in the preliminary studies were used with the more detailed cross-section data in the Econ-2 program for the final evaluation of crop and pasture damage. The results are shown on Table 24.

Summary of Annual Benefits. Urban and crop and pasture damages constitute the greatest share of annual damages and benefits. Other benefits include indirect, other agriculture, road, bridge, and railroad benefits. These were calculated by the same method used in the preliminary study and added to the benefits from Tables 20 and 21. The total benefits are summarized in Table 25.

Flood Control Costs. Costs assigned to the flood control portion of the project are the costs of the structures, including construction, land, operation, and maintenance costs.

(Construction and Land Rights Costs) The same estimates for construction and land rights costs were used for both the preliminary and the final study. These estimated costs are shown on Table 15.

(Operation and Maintenance Costs) Annual operation and maintenance costs were estimated as a percentage of construction costs. These costs are $1,400 for Dam 1; $1,080 for Dam 2; $1,470 for Dam 3; and $250 for the levee; a total of $4,200 per year for the project.

Non-Structural Alternatives

The non-structural alternatives considered were to do nothing, to evacuate the flood plain, to implement flood plain zoning and to construct a flood plain park.

Do Nothing. This alternative would allow the existing flooding problems, too costly for the individual property owner to solve, to continue without change. The benefits of this alternative would be the costs saved by not building the project. The estimated costs that would be saved over the life of the structural project are $742,600. The costs of this alternative would be the benefits lost by not building the project. The benefits of the structural project are $1,797,840.

Evacuation of the Flood Plain. This alternative would provide for the relocation of the buildings presently in the flood plain. The benefits of this alternative would be nearly equal to the average annual urban flood damages because of the prevention of damage to the buildings, but there would still be some residual damage to streets and utilities which could not be removed. Average annual urban damage is $21,830 under existing conditions.

TABLE 24

Average Annual Crop and Pasture Damages and Benefits

Reach	Average Annual Area Flooded Without Project	Average Annual Area Flooded With Project	Average Annual Damage Without Project	Average Annual Damage With Project	Benefits
	(acres)	(acres)	($)	($)	($)
1	75	35	3,280	1,765	1,515
2	55	30	3,145	1,770	1,375
3	30	15	1,825	930	895
4	160	150	13,270	11,465	1,805
5	90	60	5,530	3,280	2,250
6	5	0	275	0	275
7	40	20	2,450	890	1,560
8	10	5	585	120	465
TOTALS	465	315	30,360	20,220	10,140

TABLE 25

Total Annual Flood Control Benefits

URBAN	
Residential and Business	$21,495
Indirect	2,580
RURAL	
Crop and Pasture	$10,140
Other Agriculture	1,000
Indirect	800
OTHER	
Road, Bridge and Railroad	$ 1,200
Indirect	240
TOTAL	$37,455

The cost of evacuating the flood plain cannot be estimated directly. However, the population and number of buildings to be moved is comparable to that of the town of Niobrara, which was recently evacuated from the flood plain at the head of Lewis and Clark Lake. The total estimated cost of the Niobrara project is approximately 12 million dollars. The prevention of damages of $21,830 per year would have to continue about 500 years to equal that cost.

Flood Plain Zoning and Flood Insurance. Benefits and costs are usually not assigned for these programs. Flood plain zoning will prevent the future growth of damages by preventing damageable development in the flood plain. However, potential increases have not been included in the benefit analysis for the structural project, so the extent of this benefit is not known.

Zoning should lead to the eventual evacuation of the flood plain as the existing buildings age and deteriorate. Moving or demolition could take place gradually over a period of 50 years or more, so reduction in damages will slowly approach the annual total given for the evacuation alternative. The cost of relocation would also be roughly comparable to the cost of the evacuation alternative.

Flood insurance merely transfers the cost of damage from the property owner to the government and the insurance carrier. It reduces damages only as it prevents new construction in the future. The costs of administering the programs would be relatively small.

Flood Plain Park. If all the land in the flood plain were purchased for the development of a park, the cost would be nearly equal to the cost of evacuating the flood plain, and the flood control benefits would also be comparable to that alternative.

The flood control benefits to be derived from a park on the east side of the stream developed in conjunction with the structural project are too small to be determined. Since no flood control benefits have been determined, no costs of developing the park have been assigned to that function.

ANALYSIS OF RECREATION BENEFITS AND COSTS

The proposed guidelines of the Resources Development Fund were used to determine recreation benefits and costs.

Structural Alternatives

No recreation benefits were claimed for the structures. The three dams will be dry under normal conditions, so they are not expected to produce any opportunity for conventional types of recreation. The levee may provide an extension of the hiking-biking trail in the park, but it has not been designed to serve that purpose. Therefore, no recreation benefits or costs have been assigned to it.

Flood Plain Park

The development of a flood plain park in Wauneta along the east side of the river was considered as a separate component of the project.

Recreation Benefits. Tables 26, 27, and 28 show the results of the recreation benefit computations. Included in the tables are a list of the recreation activities, the recreation demand in Wauneta, the net recreation supplied by the project and the final recreation benefits for the project.

TABLE 26

Recreation Demand in Wauneta

Activity	Pop.1/ Partici- pation	Part. Rate	Peak Day Activity Rate	Peak Days	Ave. Party Size	Turn- over Rate	Carrying Capacity Per Unit	Recreation Facility Demand
	(%)		(%)					
Picnicking	58	4.8	60	21	4	2	1	7
Hiking	12	3.8	60	26	2.5	2	12	0.13
Bicycling	26	32.8	60	26	2.5	2	12	2.39
Ice Skating	14	1	60	10	2.5	2	17	0.072
Stream Fishing	19	11.7	30	27	1.5	2.5	2	2.41

1/ Population of Wauneta (the area served) is 730.

TABLE 27

Net Recreation Supplied by the Project

Activity	Recreation Facility Demand	Current Supply	Net Rec. Facility Demand	Project Recreation Facilities	Net Project Facilities
Picnicking	7	8	-1	13	0
Hiking	0.13	0	0.13	.13	0.13
Bicycling	2.39	0	2.39	.21	0.21
Ice Skating	0.072	0	0.072	0.069	0.069
Stream Fishing	2.41	0	2.41	0.35	0.35

TABLE 28

Recreation Benefits

Activity	Net Project Facilities	No. of Parties on Peak Days	Peak Day Use Factor	Peak Day Activity Rate	Activity Days	Recreation Days	Benefits
				(%)			($)
Picnicking	0						0
Hiking	0.13	1.5	130	60	325	162.5	349
Bicycling	0.21	2.5	130	60	542	271	583
Ice Skating	0.069	1.2	50	60	100	50	107
Stream Fishing	0.35	0.7	101.2	30	236	118	254
TOTAL							1,293

Estimated Recreation Costs. The cost of constructing the park and purchasing and installing recreation equipment is estimated to be $30,000. Estimated cost of the land is $10,500. The average annual cost of replacing the recreation facilities and equipment over the 50-year life of the project is estimated to be $250, and annual operation and maintenance costs are estimated to be $150. Total operation, maintenance, and replacement costs over the 47 years after completion of construction will be $18,800. Total estimated recreation costs are $59,300.

SUMMARY OF PROJECT BENEFITS AND COSTS

Benefits

The average annual benefits are $37,455 from flood control and $1,293 from recreation. It was assumed that two dams, 1 and 2, would be constructed in 1978; dam 3 would be constructed in 1979, and the park would be constructed in 1980 because of the timing of potential federal funds. Total benefits, at zero interest, would therefore be $1,797,840 for flood control over the 48-year period the structures would be in operation, and $60,771 for recreation over the 47 years after the park was completed.

Costs

The total cost of the flood control facilities would be $742,600 and the total cost of the recreation facilities would be $59,300. The total project cost would be $801,900.

Rate of Return

The relationship between costs and benefits is expressed as the rate of return on investment. The rate of return is the discount rate at which the net present worth of the project cash flow is zero. It is also the discount rate at which the benefit/cost ratio is equal to one. The project cash flow and the rate of return are shown on Table 29. The rate of return on this project is 5.56 percent.

Environmental Investigations

DESCRIPTION OF THE ENVIRONMENT

A general description of the project area is included in Chapter 3, so this section will concentrate on describing its environmental characteristics.

General Description

The Village of Wauneta (1970 population 738) is situated in the Frenchman Creek valley in southeastern Chase County. Two general landscapes predominate in the project area, which is within the Great Plains physiographic region. The most extensive landscape is the dissected plains area which is marked by occasional canyon-like drainageways. Gentle slopes or ridges are present between the drainageways while benches and terraces parallel them. The second landscape is that of the Frenchman Creek valley which varies from one-eighth to one-half mile in width as it meanders in its southeasterly course.

The area has a continental climate and therefore experiences a wide range of temperature extremes. Precipitation also varies greatly but three-fourths of the mean annual precipitation of approximately 18 inches normally occurs during the growing season. The mean frost-free period is approximately 150 days.

The area lies within the western margin of the mixed prairie vegetation zone. Plants which are characteristic of both the tall-grass prairie to the east and the short-grass plains to the west are present. However, heavy grazing through the years has eliminated some of the more sensitive tall-grass prairie species from many sites. Species characteristic of the sandsage prairie vegetation zone are also present in parts of the project area. Trees are rare with the exception of those along Frenchman Creek and some of its tributaries, farmstead plantings, and those in Wauneta.

Much of the eight-mile reach of the Frenchman valley between Enders Dam and Wauneta is cultivated; irrigated corn and alfalfa are the major crops grown. Native meadows, pasture land, and riparian woodlands are also present in the valley. The uplands are generally in native grass and are used for grazing, but some of the gentler slopes and ridges are farmed; wheat and irrigated corn are the major crops grown.

TABLE 29

Project Cash Flow and Rate of Return

Year	Project Cost					Total Project Value (Gross Benefits)	Incremental Benefit (Cash Flow)
	Feasibility Study, Engineering & Inspection	Capitol Items	Operation & Maintenance Costs	Assoc. Costs	Gross Costs		
1977	500				500		-500
1978		347,500			347,500		-347,500
1979		193,000	4,200		197,200	37,455	-159,745
1980		40,500	4,600		45,100	38,748	-6,352
1981			4,600		4,600	38,748	34,148
1982			4,600		4,600	38,748	34,148
1983			4,600		4,600	38,748	34,148
1984			4,600		4,600	38,748	34,148
1985			4,600		4,600	38,748	34,148
1986			4,600		4,600	38,748	34,148
1987-2026			184,000		184,000	1,549,920	1,365,920
TOTALS	500	581,000	220,400		801,900	1,858,611	1,056,711

Rate of Return = 5.56%

Irrigation development is extensive in the Frenchman valley. Both groundwater and surface water are used. A few center pivot irrigation systems have also been developed in the uplands on the north side of Frenchman Creek.

Soils and Geology

The Keith-Colby soil association extends over the project area. The soils of this association have developed from loess under grassland vegetation. Keith, Richfield, and Kuma soils have developed on the nearly level and gently sloping uplands. These soils generally have a surface layer of dark, grayish-brown, granular, silt loam that ranges from 6 to 20 inches thick. Their subsoils are 12 to 20 inches thick and have weak to moderately blocky structure, and in places are calcareous in the lower part. The underlying substratum is light-gray silt loam that is many feet thick.

Ulysses soils have developed on rolling slopes and Colby soils on steep slopes. Bridgeport soils predominate on the footslopes, canyon floors, and alluvial fans.

The soils in the Frenchman Creek valley have developed in silty and sandy alluvium. Soils of the McCook series predominate. They generally have a surface layer of loam or silt loam approximately 14 inches thick and a silt loam or very fine sandy loam alluvial layer beneath.

Vegetation

The vegetation at each structure site was identified during a field review conducted on November 1, 1977.

The site of dam 1 is native grassland which has been subjected to moderate to heavy grazing. The upland vegetation is composed of herbaceous plants and low shrubs. Buffalograss, hairy grama, side-oats grama, western wheatgrass, little bluestem, and 3-awn grass are the most common grass species. Conspicuous shrubs and shrub-like species include sandhill sage, fringed sage, broom snakeweed, and yucca.

A narrow band of trees occurs along the stream course. The most noteworthy of these are several mature cottonwoods, one of which approaches four feet in diameter. Other trees and woody plants at the site include willow, boxelder, Siberian elm, Russian-olive, American plum, snowberry, skunkbush sumac, and wild grape.

Site 2 is native grassland, similar in composition to site 1, and it too has been heavily grazed. Very little woody vegetation, save a few willows and young cottonwoods, occurs in the drainageway. Annual weeds are abundant near the trees and include Kochia, Russian thistle, and sunflower. Apparently, this part of the site has been used as a wintering area for cattle during recent years. A cornfield, irrigated with a center pivot system, lies immediately downstream from this structure site.

The drainageway where site 3 is located has only a few scattered willows and young cottonwoods above the proposed dam axis. The surrounding upland vegetation is similar to that around site 1 except for a greater occurrence of sandhill sage.

A seldom-used section line roadway bordering the site sustains an array of native grasses and forbs in good condition. Native grass species at this location, including Indiangrass, sand bluestem, and prairie sandreed indicate the natural vegetation potential of the area, because they have been protected from grazing. A large rock outcropping lies on the east side of the roadway.

Riparian woodlands in the Frenchman valley consist primarily of cottonwood, willow, boxelder, green ash, and mulberry. A few black walnut trees of sapling to pole stage are also present just east of Arapahoe Avenue in Wauneta. A number of shrubs and vines are associated with the riparian vegetation of Frenchman Creek. These include indigobush, snowberry, currant, wild grape, and Virginia Creeper. Herbaceous vegetation is limited to a few species of shade tolerant grasses such as wildrye and green muhly, and forbs such as water hemlock and sticktight.

Riparian woodland borders Frenchman Creek along nearly all of its course between Enders Dam and Wauneta. This band is generally less than 50 yards wide but sizable groves of cottonwoods, some up to two to three acres in size, add markedly to the woodland acreage in the valley. The woodland border along Frenchman Creek in Wauneta between Arapahoe Avenue and the sewage pumping station is generally less than 75 feet wide and in some places is nearly nonexistent. Bromegrass, bluegrass, and young willows are conspicuous on the left bank of the stream between Wichita Street and the pumping station.

Fish and Wildlife

In the project area Frenchman Creek is classified as a warmwater stream and supports a limited sport fishery. However, its fishery potential has been adversely affected by habitat reduction due to seasonal dewatering. The most important fish species present are channel catfish, walleye pike, and largemouth bass.

Furbearers inhabiting the stream and its associated woodlands include beaver, muskrat, mink, and raccoon. Coyote, skunk, badger, weasel, and an occassional bobcat are also present in the project area.

Game species present in the project area include white-tailed deer, mule deer, ring-necked pheasant, bobwhite quail, cottontail rabbit, fox, squirrel, and mourning dove.

Overall, the fauna is typical of the eastern High Plains and associated riparian habitat. No endangered species of wildlife have been reported in the area. However, a black-footed ferret was observed in June 1969 near Stratton, approximately 25 miles southeast of the project area. Black-footed ferrets have also been reported near Haigler, Parks, and Benkelman in Dundy County and near Grant in Perkins County during the period from 1969 to 1974. No prairie dog towns were noted during the field review. The bald eagle, classified as a rare species in Nebraska, may occassionally visit the project area.

HYDROLOGY

As shown on Figure 1, Frenchman Creek heads in eastern Colorado and flows in a southeasterly direction to its confluence with the Republican River in eastern Hitchcock County. Above Enders Reservoir the stream largely flows through sand hills, and this accounts for its steady base flow. The construction of Enders Dam by the USBR in 1950, however, has greatly altered the flow of Frenchman Creek below Enders Dam. The 1976 water year discharge rates for Frenchman Creek at two U.S. Geological Survey gaging stations located above and below Enders Dam are shown in Table 30.

The altered flow regime of Frenchman Creek below Enders Dam is especially marked during the period from September through May when Enders Reservoir is being filled and during the period from June through August when stored water is released for conveyance to the Frenchman irrigation project. Frenchman Creek receives significant groundwater discharge below Enders Dam, however, resulting in a stable, although reduced, base flow at Wauneta throughout the year.

Center pivot irrigation development in the upper Frenchman Creek basin during the past 10 years has begun to deplete the stream's base flow. Recent studies have indicated Frenchman Creek may cease to be a perennial stream above Enders Dam if groundwater use for irrigation continues as projected.

The three left bank tributaries of Frenchman Creek between Enders Dam and Wauneta are all intermittent. All were dry at the proposed structure sites during the November 1, 1977 field review. However, about 200 yards below site 1, the tributary received some groundwater discharge resulting in a flow of approximately one cubic foot per second. The three structures will all be designed as "dry dams". Therefore, they will not result in permanent bodies of water and will not markedly affect the hydrologic characteristics of the three tributaries, other than decreasing their peak flows and extending their periods of flow after runoff events.

The Ogallala formation underlies nearly all of the Frenchman Creek basin. It lies near the surface in some places and averages 250 feet in thickness. This formation often yields high capacity wells in the range of 1,000 to 1,500 gallons per minute.

The alluvial deposits of the Frenchman valley also yield significant amounts of water but well yields are often limited by the thickness of saturated material.

SCENIC, ARCHEOLOGICAL, AND HISTORICAL FEATURES

The wooded Frenchman valley meandering through the adjoining hills produces a very pleasant setting, but it is not one of unique significance. Likewise, no significant historical sites have been identified in the project area by the Nebraska State Historical Society.

TABLE 30

Streamflow Characteristics of Frenchman Creek

1976 Water Year

	Frenchman Creek near Imperial (Above Enders Dam)	Frenchman Creek near Enders (Below Enders Dam)
Drainage Area in Square Miles	880	950
Mean Discharge	(C.F.S.)	(C.F.S.)
1976 Water Year	42.8	46.3
October	38.7	0
November	44.9	0.015
December	55.1	0
January	53.6	0
February	47.5	0.47
March	42.8	0.53
April	43.7	1.02
May	46.0	1.94
June	41.4	32.1
July	35.4	268.
August	33.5	344.
September	31.3	0

Source: U. S. Geological Survey Water-Data Report NE-76-1

Several archeological sites have been identified along Frenchman Creek and nearby Stinking Water Creek and two of these are located within the project area near dam 1. During the November 1, 1977 field review, Mr. Walter Fox of Wauneta was contacted regarding these sites. He had accompanied Mr. Metcalf of the Smithsonian Institution during the excavation of these sites several years ago. Mr. Fox identified one as the Fox-Williams Dismal River Culture Site which he positioned as approximately 200 yards southeast of the proposed axis of dam 1. The other site, a Republican Culture Site, is located south of Frenchman Creek.

At the request of the Upper Republican NRD, the Department of Anthropology of the University of Nebraska at Lincoln has made a field inspection of the project area. This field investigation evaluated the project's impact on known archeological resources and checked in a systematic manner for possible unknown resources. The report on this investigation has been provided to the NRD, and it indicates the project would not have any significant adverse effects on any archeological resources.

ENVIRONMENTAL IMPACT OF PROPOSED ACTION

Acquisition Impacts

There should be few or no problems associated with acquisition of the three dam sites. The sites are not suitable for conversion from range to cropland or for irrigation development due to the topography, and they are not favorable as building sites due to their poor accessibility.

No significant problems are expected with acquiring right-of-way for the levee and the flood plain park in Wauneta because the sites are in a flood plain zone not favorable for development and much of the property is now publicly owned.

No dislocation of homes, farmsteads, or displacement of people are involved with this project. An unoccupied house in very poor condition is located within the park site north of Wichita Street.

Construction Impacts

Increases in air, noise, and possibly water pollution can be expected during the construction of this project. The increased air pollution will result from engine exhausts and dust during the earth moving activities. Noise pollution will accompany the tree removal and earth moving activities, which involve the use of machinery. Erosion of exposed areas is possible, especially in the event heavy rains occur during or soon after the construction period. This may result in increased sedimentation of water bodies, especially Frenchman Creek.

The local sponsor will insure erosion prevention practices are followed during the construction period. These practices include scheduled removal of vegetative cover and earth moving activities, construction of temporary sediment basins, and the use of diversions. Vegetative cover will not be removed to any extent greater than necessary. In addition, seeding of exposed areas will be conducted as soon as practical. The seeding will be done according to specifications and fertilizer and mulch will be applied where necessary.

The most significant environmental impacts will be the removal of timber at dam site 1 and within the right-of-way of the levee between Arapahoe Avenue and Wichita Street. Brush, weeds, and trees of poor quality will be cleared from the park site. However, no significant timber resources or habitat areas are involved, so satisfactory mitigation measures can be readily devised. The loss of wildlife associated with this timber removal should be slight due to the timber's low habitat value.

Recreational Development

No recreational development is planned in connection with the dams and reservoirs. The dams are designed to be "dry dams" and, therefore, will not permanently impound water. People can be expected to visit the structures, especially after runoff events, and hike along the levee but these activities will not affect the functioning or condition of the dams and levee.

The flood plain park will be developed for limited recreational activities compatible with the frequency and flood flow capacity in the area. The facilities will include parking areas, playground equipment, picnicking facilities, and hiking and biking trails that are not very susceptible to flood damage.

Inundation Impacts

Because the project involves "dry dams", only temporary inundation will result. Therefore, some of the present vegetation, including willows and cottonwoods, can be expected to persist after the project is completed. In order to reduce potential mosquito habitat, the structures will be designed to drain completely. Likewise, any borrow areas will be self-draining or maintained free of shoreline vegetation. The NRD will be responsible for mosquito control at the reservoir sites should any problems develop as a result of the project.

The reservoirs will also serve as sediment traps for sediment carried by the runoff waters.

Off-Site Impacts

The project will exert little influence on the surrounding area other than their purposes of flood protection for Wauneta and agricultural land in the Frenchman valley and improved recreational opportunities for area residents.

COMPENSATION MEASURES

Some compensation measures involved with this project are necessary to mitigate the loss of woody vegetation and wildlife habitat at dam site 1 and within the right-of-way of the levee. Since no especially valuable timber resources or habitat areas are involved, proper mitigation could be satisfied by:

(1) the establishment of a wildlife planting of approximately one acre in size in the vicinity of dam site 1, and

(2) the planting of 100 trees and shrubs within the flood plain park.

Small wildlife plantings, approximately one-half acre in size, at dam sites 2 and 3 would probably improve upon the existing habitat but these plantings are not required to compensate for losses at the site.

ADVERSE EFFECTS WHICH CANNOT BE AVOIDED OR COMPLETELY COMPENSATED

The removal of timber at the dam sites, within the levee right-of-way, and in the park site cannot be avoided and the habitat cannot be exactly duplicated. However, satisfactory substitutes could be provided by the compensation measures. The loss of wildlife associated with this removal would be minimal. In time, the tree and shrub plantings would provide additional habitat for wildlife.

Increased air and noise pollution and some soil erosion cannot be avoided during the construction phase of the project. However, these can all be kept to a minimum by proper scheduling of work and the application of erosion control practices.

The loss of tax revenue due to the project should be minimal because the structure sites are all relatively small and of low assessed valuation. If easements are obtained on these sites, no tax revenues will be lost. In addition, the levee and the park site are located in a flood hazard area and much of the land is public property so tax revenues should not be affected greatly.

RELATIONSHIP BETWEEN SHORT TERM USE AND LONG TERM PRODUCTIVITY

This project will have few, if any, detrimental effects on either the short term use or long term productivity of the project area. The three dam sites are all located in grazing areas where no change in land use is foreseen. The sites of the levee and the park are not suitable for development due to their location in the flood plain.

The project is beneficial towards short term use and long term productivity in the project area as it will provide protection from flooding for both the community of Wauneta and the agricultural Frenchman valley and improved recreational opportunities for area residents.

IRREVERSIBLE OR IRRETRIEVABLE COMMITMENT OF RESOURCES

During the construction and maintenance phases of the project, limited energy sources, particularly gas and diesel fuel, will be consumed. The riparian woodlands and native grasslands present at the dam sites will be replaced temporarily by water and permanently by sediment.

The capital committed for this project, including labor and materials, is estimated to be $581,000. In addition, average annual operation and maintenance cost of the structural measures will be approximately $4,200 and $400 for the park.

ALTERNATIVES TO THE PROPOSED ACTION

Structural alternatives to the selected project that were considered during these investigations included combinations of nine potential dams and six alternative locations of portions of the levee. Non-structural alternatives included evacuation of the flood plain, flood plain zoning and insurance, and different areas for the flood plain park.

The environmental impacts of this project primarily involve the removal of woody vegetation and associated wildlife habitat at dam site 1 and within the levee's right-of-way between Arapahoe Avenue and Wichita Street in Wauneta. Proper compensation is planned to satisfy these losses. Therefore, the alternatives will differ in their environmental impact relative to the inclusion or exclusion of dam 1 and the levee.

CONSISTENCY WITH OTHER PLANNING

This project is included in the Upper Republican NRD's one- and six-year plan and has been coordinated with the U. S. Department of Agriculture's Republican River Basin Study. It does not conflict with the Report on The Framework Study of Nebraska's State Water Plan.

Map 1


State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
ALTERNATIVE LEVEE LOCATIONS
AUGUST 1978
Scale
0 1 2 3 4 5 600 Feet
N
LEGEND
Preliminary Alternatives
Selected Location
Alternative Flood Wall
FOOTBALL FIELD
PAWNEE ST
VINTA ST
WICHITA ST
SECOND ST
NORTH RAILWAY ST
TECUMSEH AVE
(See Inset)

Map 2


State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
URBAN CROSS SECTIONS AND FLOOD LIMITS UNDER EXISTING CONDITIONS
JULY 1978
0 1 2 3 4 5 600 Feet
N
LEGEND
1956 FLOOD
100 YEAR FLOOD
50 YEAR FLOOD
5-011
5-010
5-009
5-008
5-007
5-006
5-005
5-004
5-003
5-002
PAWNEE ST
VINTA ST
PONCA ST
VALLEY ST
NORTH RAILWAY ST
FOOTBALL FIELD

Map 3

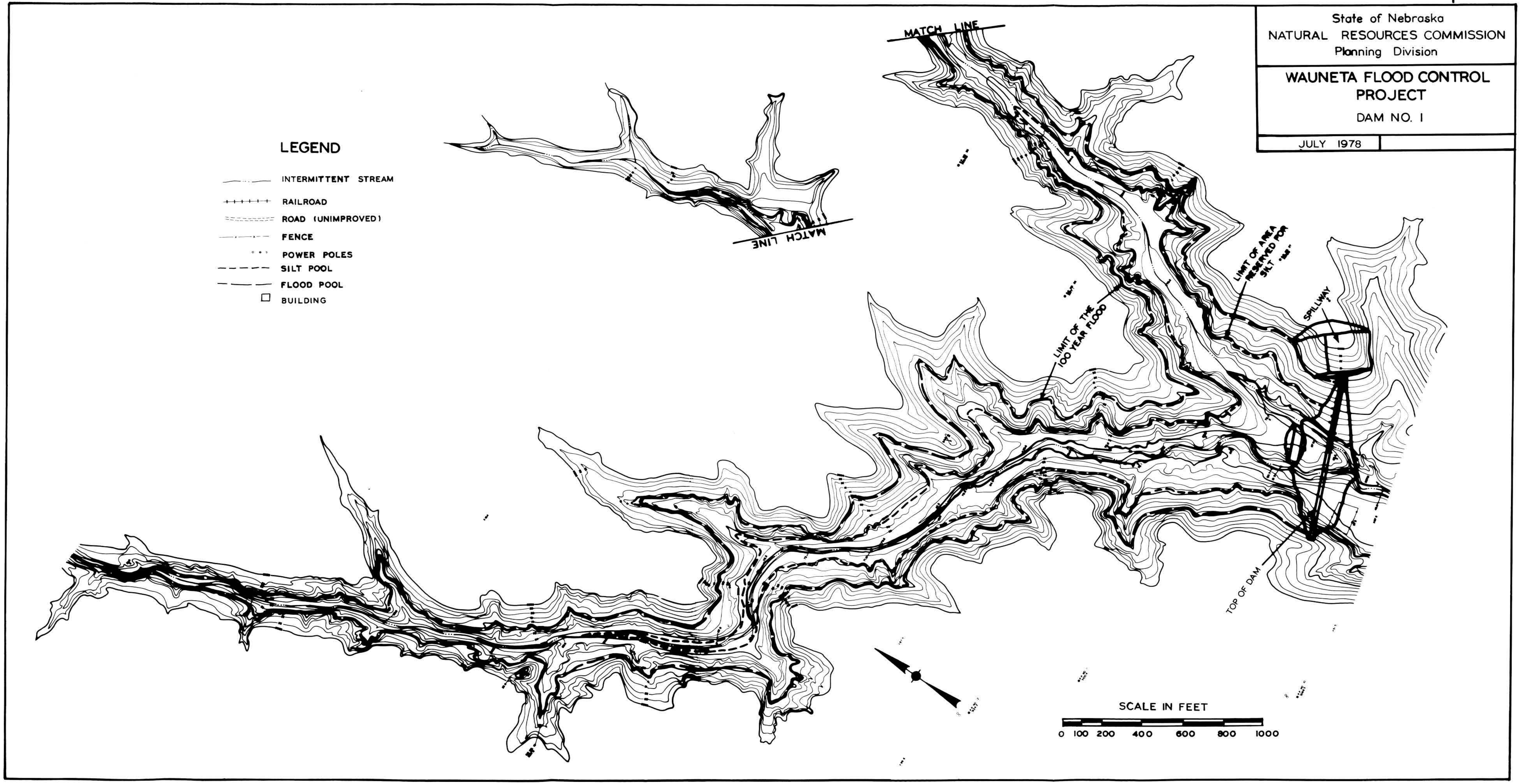

State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
URBAN AREA FLOODED WITH STRUCTURAL ALTERNATIVES - 50 YEAR FLOOD
JULY 1978
Scale
0 1 2 3 4 5 600 Feet
LEGEND
WITH LEVEE
WITHOUT LEVEE
50 Year Flood With 2 Dams
50 Year Flood With 3 Dams
Selected Levee Location
N

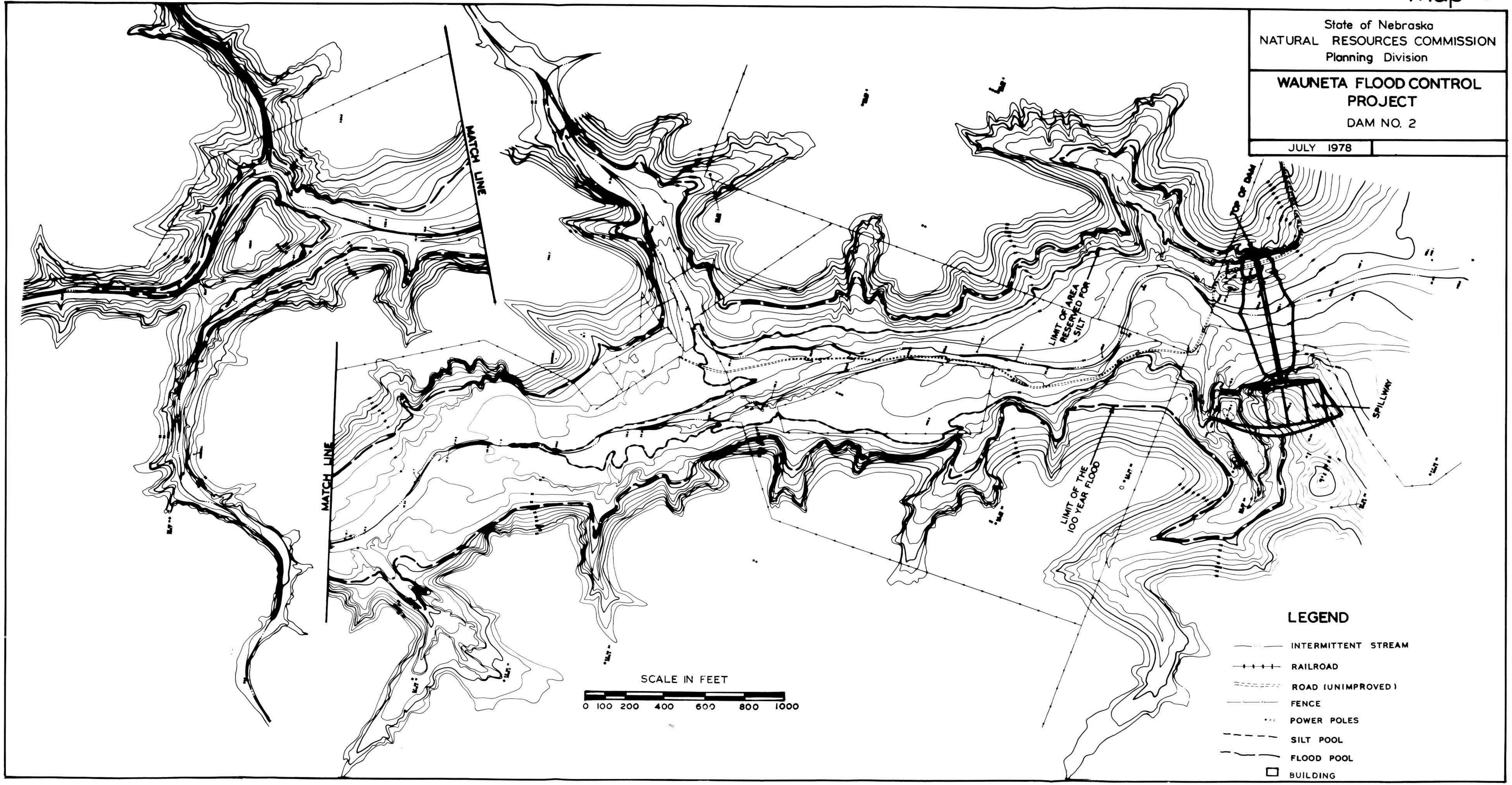

State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
URBAN AREA FLOODED WITH STRUCTURAL ALTERNATIVES— 100 YEAR FLOOD
JULY 1978
Scale
0 1 2 3 4 5 600 Feet
N
LEGEND
WITH LEVEE
WITHOUT LEVEE
100 Year Flood With 2 Dams
100 Year Flood With 3 Dams
Selected Levee Location
FOOTBALL FIELD
PAWNEE ST
VINTA ST
WICHITA ST
PONCA ST
VALLEY ST
SECOND ST
TECUMSEH AVE
NORTH RAILWAY ST

Map 5

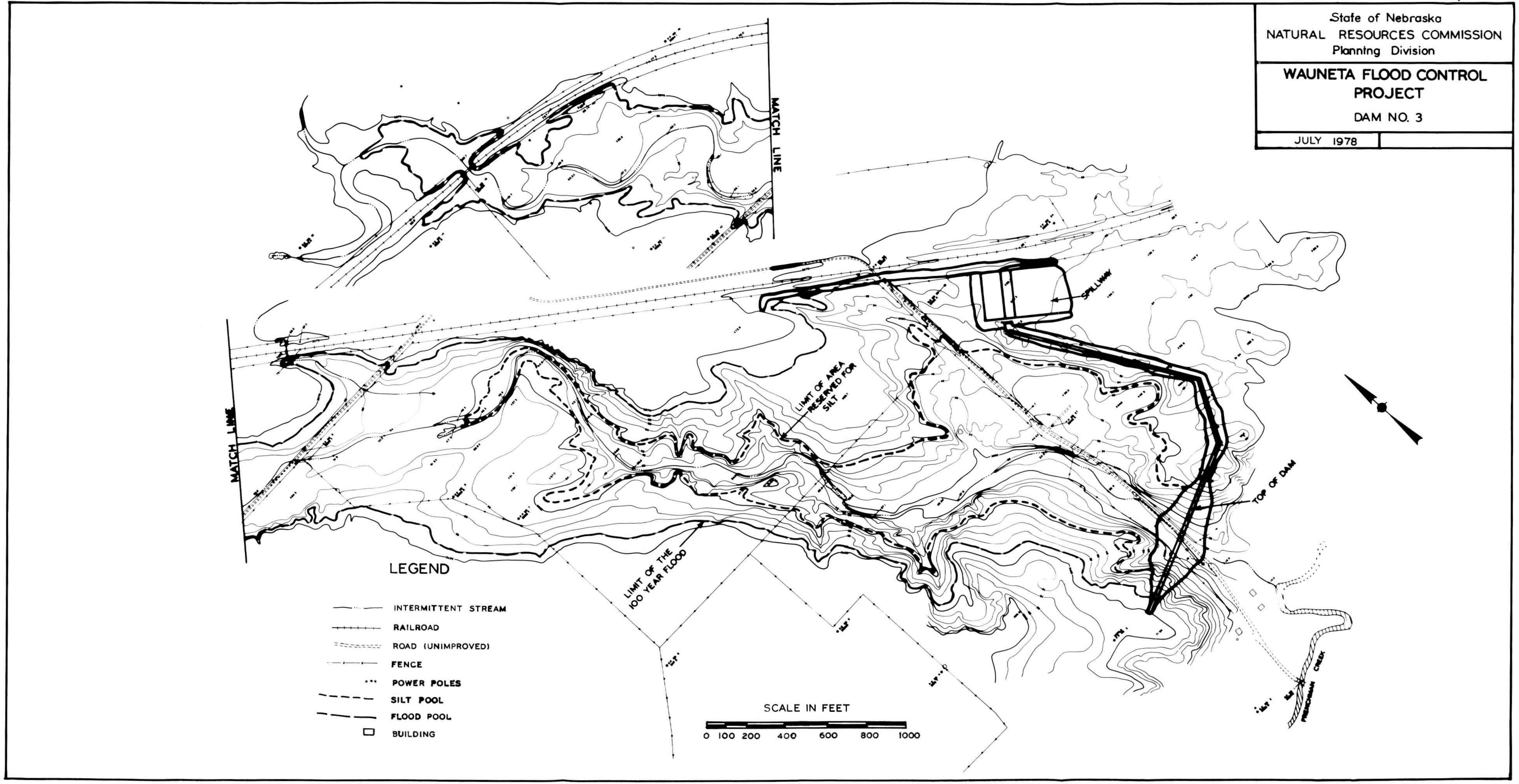
State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
RURAL DAMAGE STUDY AREA
JULY 1978
Enders
Enders Reservoir
Frenchman Creek
Wauneta
Hamlet
Palisade
CHASE CO
HAYES CO
HITCHCOCK CO
8-000
7-000
6-000
5-000
4-000
3-000
2-000
1-000
LEGEND
Railroad
Highway
Cross Section 1-000
Urban Area
Corn
Wheat
Alfalfa
Pasture
SCALE
0 1 2 3 MILES

Map 6

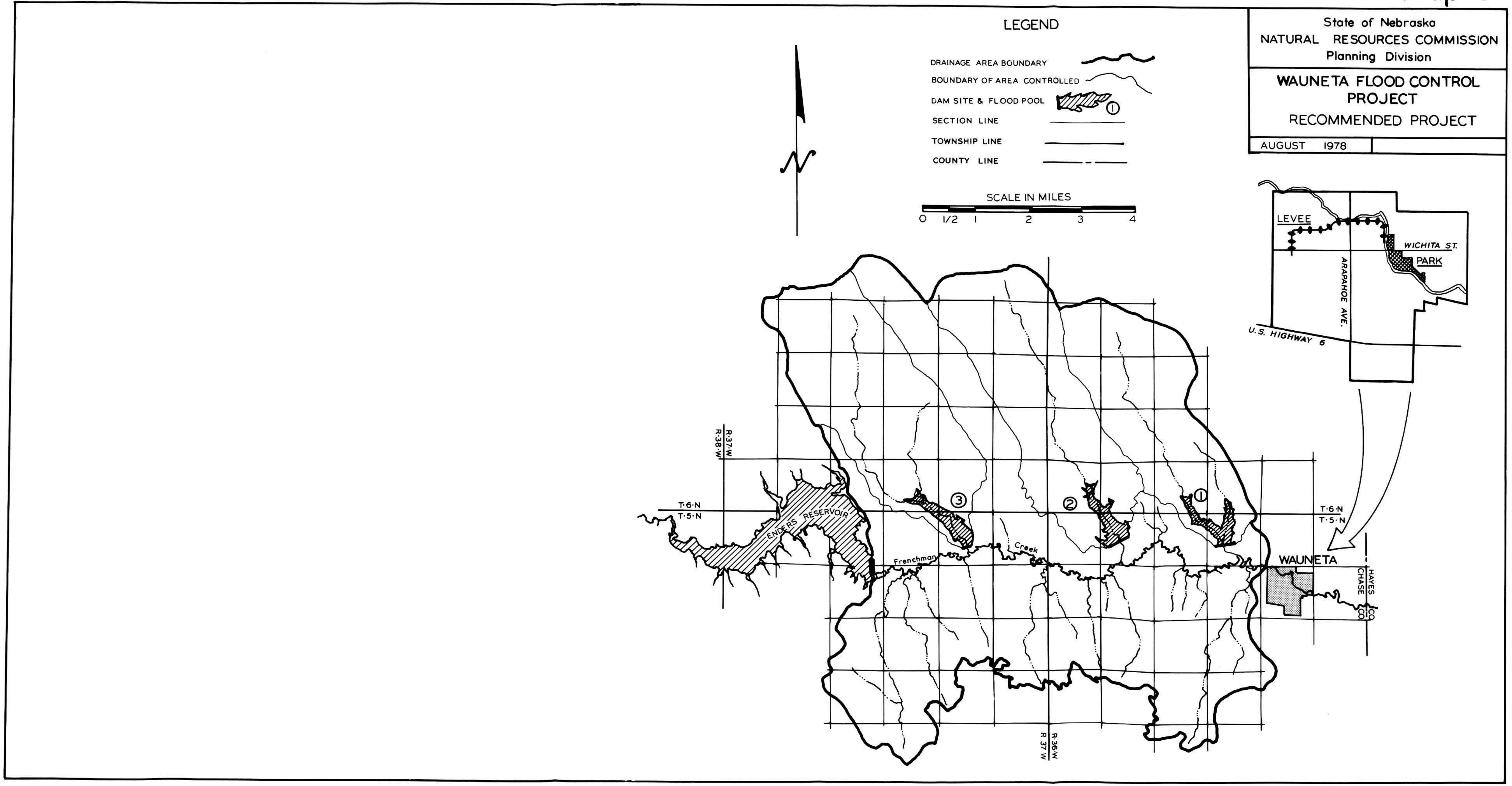

State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
DAM NO. 1
JULY 1978
LEGEND
INTERMITTENT STREAM
RAILROAD
ROAD (UNIMPROVED)
FENCE
POWER POLES
SILT POOL
FLOOD POOL
BUILDING
MATCH LINE
MATCH LINE
LIMIT OF THE 100 YEAR FLOOD
LIMIT OF AREA RESERVED FOR SILT
SPILLWAY
TOP OF DAM
SCALE IN FEET
0 100 200 400 600 800 1000


State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
DAM NO. 2
JULY 1978
MATCH LINE
MATCH LINE
TOP OF DAM
LIMIT OF AREA RESERVED FOR SILT
LIMIT OF THE 100 YEAR FLOOD
SPILLWAY
SCALE IN FEET
0 100 200 400 600 800 1000
LEGEND
INTERMITTENT STREAM
RAILROAD
ROAD (UNIMPROVED)
FENCE
POWER POLES
SILT POOL
FLOOD POOL
BUILDING

Map 8


State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
DAM NO. 3
JULY 1978
MATCH LINE
MATCH LINE
SPILLWAY
LIMIT OF AREA RESERVED FOR SILT
TOP OF DAM
LIMIT OF THE 100 YEAR FLOOD
FRENCHMAN CREEK
LEGEND
INTERMITTENT STREAM
RAILROAD
ROAD (UNIMPROVED)
FENCE
POWER POLES
SILT POOL
FLOOD POOL
BUILDING
SCALE IN FEET
0 100 200 400 600 800 1000

Map 9



State of Nebraska
NATURAL RESOURCES COMMISSION
Planning Division
WAUNETA FLOOD CONTROL PROJECT
RECOMMENDED PROJECT
AUGUST 1978
LEGEND
DRAINAGE AREA BOUNDARY
BOUNDARY OF AREA CONTROLLED
DAM SITE & FLOOD POOL
SECTION LINE
TOWNSHIP LINE
COUNTY LINE
SCALE IN MILES
0 1/2 1 2 3 4
N
LEVEE
WICHITA ST.
PARK
ARAPAHOE AVE.
U.S. HIGHWAY 6
R·37·W
R·38·W
T·6·N
T·5·N
ENDERS RESERVOIR
Frenchman
Creek
WAUNETA
HAYES CO
CHASE CO
R 36W
R 37 W