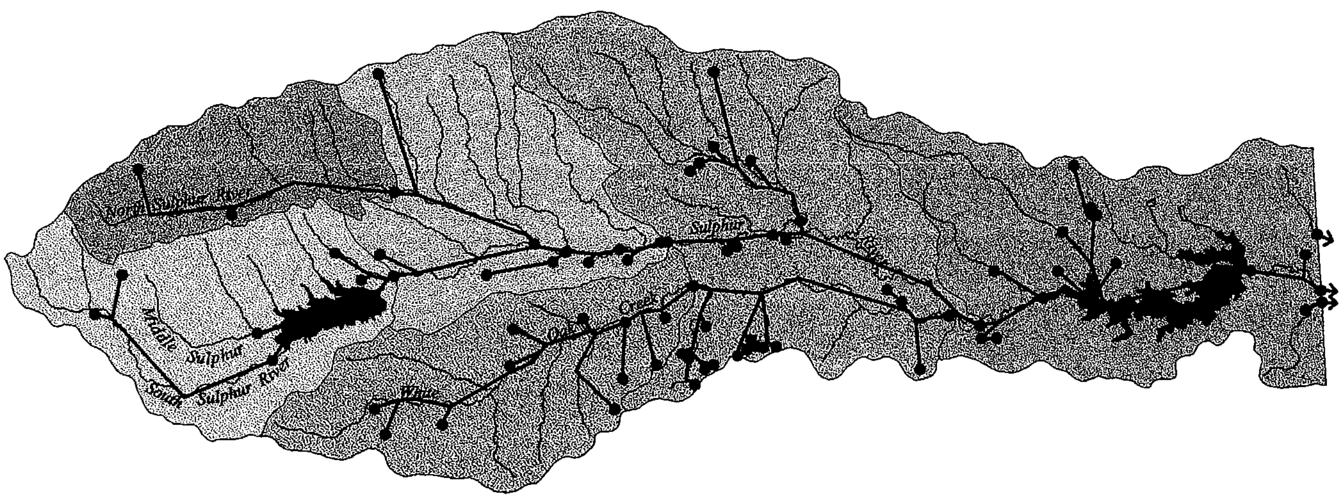
TNRCC Contract No. 9880059300

FINAL REPORT

Water Availability Modeling
for the
Sulphur River Basin



prepared for:

Texas Natural Resource Conservation Commission
Austin, Texas

June 1999

prepared by:

R. J. Brandes Company
Austin, Texas

TABLE OF CONTENTS

TABLE OF CONTENTS, continued

TABLE OF CONTENTS, continued

LIST OF TABLES

LIST OF TABLES, continued

LIST OF TABLES, continued

LIST OF FIGURES

Page

LIST OF FIGURES, continued

Page

LIST OF APPENDICES

EXECUTIVE SUMMARY

OVERVIEW

Pursuant to Senate Bill 1 passed by the 75th Texas Legislature, the Texas Natural Resource Conservation Commission (TNRCC) must develop or acquire new reservoir/river basin simulation models in order to determine available water in accordance with the Texas Water Code. Under Contract No. 9880059300 with TNRCC, R. J. Brandes Company (RJBCO) of Austin, Texas has performed these water availability analyses for the Sulphur River Basin. Specifically, naturalized streamflows have been developed for the Sulphur River Basin, and the Texas A&M Water Rights Analysis Package (WRAP, 1996, 1998) has been applied to model and determine available water in the basin in accordance with the requirements of Senate Bill 1.

The water availability analyses being undertaken by the TNRCC pursuant to the requirements of Senate Bill 1 are intended to provide useful information that will assist existing water rights holders, prospective water rights applicants, regional water supply planning entities, and state water and environmental regulatory agencies in determining the quantities of water that are likely to be available for use throughout a river basin under varying climatic and hydrologic conditions. This process necessarily includes consideration and application of the Prior Appropriation Doctrine as it dictates the priorities (based on permit application dates) by which limited water supplies must be allocated among existing water rights within a basin during low-flow or drought periods when authorized water demands may exceed available water supplies.

As stated in Senate Bill 1, the following specific information is to be developed by the TNRCC through water availability analyses for each river basin in the state, excluding the Rio Grande[1]:

1. For all holders of existing permits, certified filings, and certificates of adjudication, the projected amount of water that would be available during the drought of record and when flows are at 75 percent of normal and at 50 percent of normal.

2. For each regional water planning group created under Section 16.053 as amended by Senate Bill 1, the projected amount of water that would be available if cancellation procedures were instigated under Subchapter E, Chapter 11 of the Texas Water Code.

[1] Water rights in the Middle and Lower Rio Grande Basins in Texas are not subject to the Prior Appropriation Doctrine, but rather are founded on and regulated in accordance with the decision of the Thirteenth Court of Civil Appeals in "State of Texas, et al. vs. Hidalgo County Water Control and Improvement District No. 18, et al.", 1969; and therefore, the Rio Grande Basin has been excluded from the Senate Bill 1 water availability analyses. However, there are other efforts underway involving water availability modeling in the Rio Grande Basin above and below Fort Quitman.

3. In coordination with the Texas Parks and Wildlife Department, the potential impact of reusing municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries.

The TNRCC, working with the Texas Water Development Board (TWDB) and the Texas Parks and Wildlife Department (TPWD) and with assistance from outside consultants, has developed specific procedures and criteria for undertaking the water availability analyses pursuant to the requirements of Senate Bill 1, with consideration of the Prior Appropriation Doctrine, the Texas Water Code, and the water management and regulatory policies of the TNRCC. The basic procedures applied in analyzing water availability in any particular river basin involve simulating on a monthly basis the ability of individual water rights to satisfy their authorized diversions or storage quantities in accordance with the Prior Appropriation Doctrine under hydrologic conditions characterized by historical, but naturalized streamflows. By taking into consideration a wide range of naturally occurring streamflow conditions, the results from these analyses provide a meaningful indication of the extent to which water will be available for specific water rights in the foreseeable future.

For performing the actual water availability calculations, the TNRCC has adopted the Texas A&M WRAP model (Wurbs and Dunn, 1996). The simulation routines in this model balance available water in terms of streamflows at specified control points against specified demands that reflect the authorized diversions and storage amounts of existing water rights. The WRAP model incorporates the Prior Appropriation Doctrine and has been applied to a number of Texas river basins to simulate water availability for a wide variety of different types of water rights. To better address the specific requirements of the water availability analyses as required by Senate Bill 1, the TNRCC has engaged the author of the WRAP model from Texas A&M (Dr. Ralph Wurbs) to make a number of useful modifications (Wurbs, 1998, 1999). The resulting model is also referred to as WRAP-SIM.

Naturalized streamflows must be used in the water availability analyses so that the diversion and storage amounts for individual water rights can be satisfied at any prescribed levels without double accounting for their effects in the baseline (historical) streamflows. Naturalized streamflows represent historical streamflow conditions, including typical wet, dry, and normal flow periods, without the influence of man's historical activities as they relate to water rights and water use. In essence, naturalized streamflows exclude the effects of historical diversions, return flows, and reservoir storage and evaporation.

The process of determining water availability for existing and future water rights in the Sulphur River Basin has encompassed several sequential steps, with the output from one task providing the input to subsequent tasks. The initial effort involved the compilation and organization of all available data describing and pertaining to existing water rights, historical gaged streamflows, historical reservoir operations, historical surface water diversions, historical return flows, and historical rainfall and reservoir evaporation. In addition, information contained in previous water resources studies and in the files and records of such agencies as the TNRCC, TWDB, U. S. Geological Survey, U. S. Department of Agriculture Natural Resources Conservation Service, and the U. S. Army Corps of Engineers also has been compiled, reviewed and examined.

Development of the naturalized streamflow data base for the basin probably has been the most important activity in the overall process. This has involved adjusting historical measured streamflows at gage locations for the effects of historical diversions, return flows, and reservoir storage and evaporation, and developing continuous sets of monthly naturalized streamflow records for the desired analysis period. For the Sulphur River Basin, this analysis period extends from 1940 through 1996. The WRAP model has been used to perform the actual analyses of water availability by simulating monthly streamflows throughout the basin for the 1940-1996 hydrologic period in response to specified diversions, reservoir storage, and special conditions for each water right. The principal results derived from these simulations have included the monthly quantities of water that would be available for diversion and/or storage by individual water rights over the 1940-1996 hydrologic period, with all senior water rights fully honored to the extent that water is available. These quantities, in essence, provide a measure of water availability for each water right, taking into consideration actual hydrologic conditions as they have occurred over the last 50 years or so and the higher priorities of other water rights. By examining these results for the drought-of-record and for 50-percent and 75-percent of normal streamflow conditions as they have occurred during the 1940-1996 hydrologic period, under various assumptions regarding water rights cancellations and reuse of wastewater effluent, the specific information required by Senate Bill 1 has been developed.

The water availability results presented in the final report for the Sulphur River Basin represent only a partial summary of the complete sets of output generated with the WRAP model for all existing water rights. The report contains specific information regarding water availability with respect to diversion and storage by certain selected water rights that includes the largest in the basin and also some characterized by special features. Summaries of projected unappropriated water and regulated (actual) streamflows at selected locations within the basin also are provided. Complete water availability summaries for all existing water rights in the Sulphur River Basin under various drought conditions and assumptions regarding cancellation and reuse are available from the TNRCC.

SULPHUR RIVER BASIN

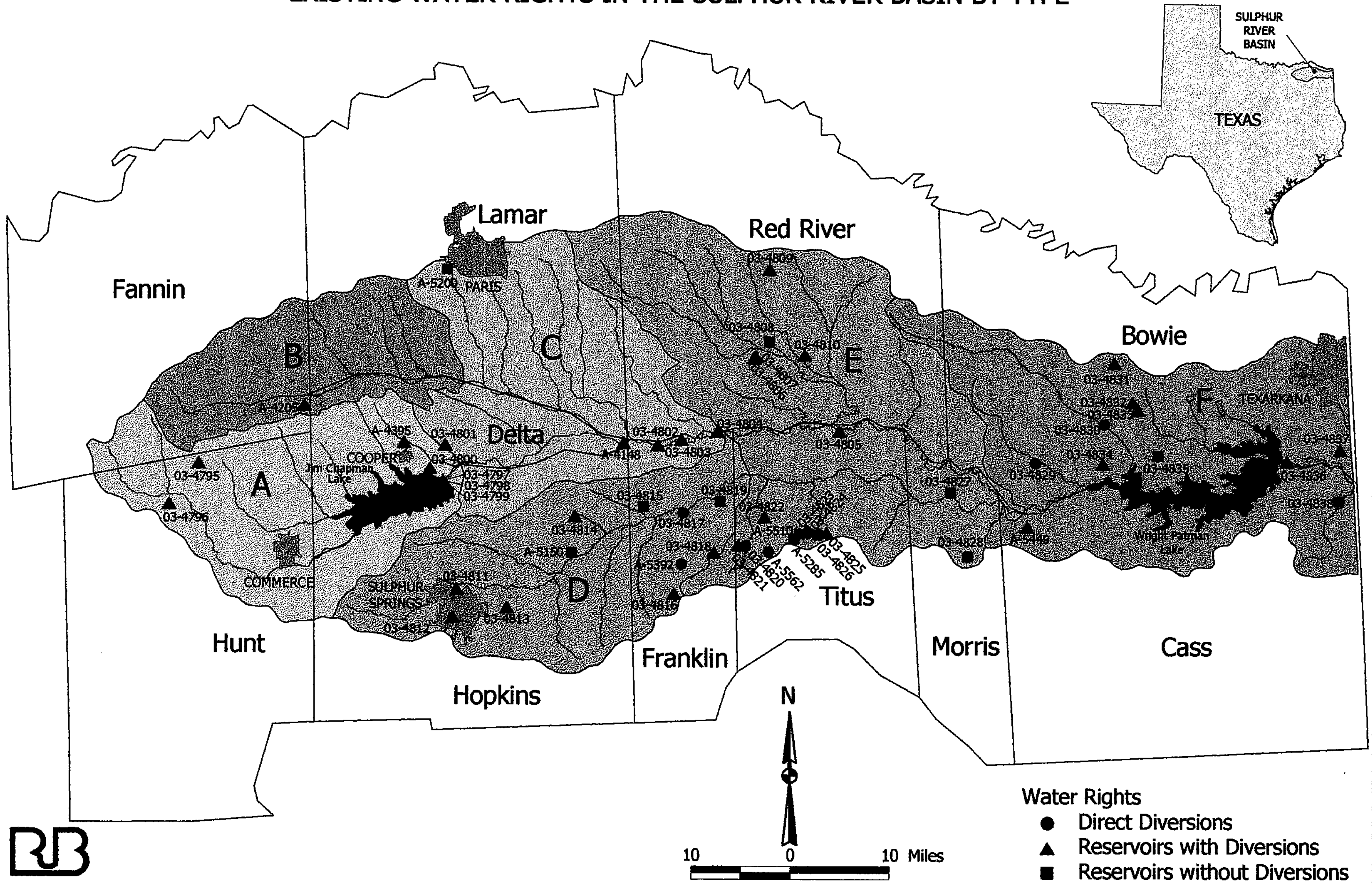
The Sulphur River Basin lies within 11 counties (Bowie, Cass, Delta, Fannin, Franklin, Hopkins, Hunt, Lamar, Morris, Red River, and Titus) in northeast Texas and drains an area of approximately 3,600 square miles within Texas. From the eastern state line of Texas, the Sulphur River flows into Arkansas and eventually joins with the Red River, a tributary of the Mississippi River. A general location map of the Sulphur River Basin showing counties and existing water rights within the basin is presented in Figure ES-1.

The South and North Sulphur Rivers originate in southern Fannin County and flow eastward 50 to 60 miles to their confluence on the boundary of eastern Delta and Lamar Counties. In the late 1920's, the U. S. Army Corps of Engineers initiated extensive channelization of these streams, particularly the North Sulphur River, for flood control purposes, and the confluence of the rectified channels was moved some distance west of where the natural confluence existed. This confluence forms the Sulphur River, which flows eastward an additional 75 miles to the Texas-Arkansas state line. White Oak Creek is the largest tributary of the Sulphur River, and it drains about 500 square miles in the southern part of the basin, including the city of Sulphur Springs. Ground elevations in the basin range from about 700 feet above sea level at the headwaters down to about 190 feet at the state line.

The climate of the basin is classified as humid subtropical. Rainfall is high, and average annual precipitation ranges from approximately 40 inches in the western portion of the basin to approximately 47 inches at the state line. The Sulphur River Basin is largely rural in nature and lies in the Coastal Plain geographic province. Overall relief is low. The western part of the basin lies in the Blackland Prairie belt and generally is comprised of open rolling prairies with small tracts of woodlands. Pasture and cropland are the predominant land uses. The eastern part of the basin lies in the Forested Coastal Plain and is typically forested, with a smaller amount of cropland and pasture. Since the 1940's, land use has changed from primarily cropland (mostly cotton) to a predominance of pasture land.

The total population of the basin increased from about 154,000 in 1980 to around 162,000 in 1990. By 2050, the basin population is projected to increase to 196,000 (TWDB, 1997). The largest cities are Texarkana, Sulphur Springs, Commerce, and New Boston. The city of Paris lies on the divide between the Sulphur and Red River Basins. Water for Paris is supplied from the Red River Basin.

FIGURE ES-1
EXISTING WATER RIGHTS IN THE SULPHUR RIVER BASIN BY TYPE



The Sulphur River Basin is a prolific water resource, primarily because of the high annual rainfall. Average runoff is estimated to range from about 14 inches per year (750 acre-feet per square mile) in the eastern portion of the basin to about 10 inches per year (550 acre-feet per square mile) at the headwaters. Surface water resources supply more than 91 percent of the water used for all purposes in the basin, with groundwater supplying the remainder.

Wright Patman Lake (formerly Lake Texarkana), covering approximately 20,000 acres and located on the Sulphur River about seven miles upstream of the state line, and Jim Chapman Lake (formerly Cooper Lake), covering about 19,000 acres and located on the South Sulphur River near the city of Cooper, are the two largest reservoirs within the basin. These reservoirs are owned and operated by the U. S. Army Corps of Engineers, and they provide water supply, flood control, and recreational benefits. Several other minor impoundments exist on tributaries, the most significant of which is Lake Sulphur Springs. There are 29 impoundments in the Sulphur River Basin with authorized storage capacity greater than 200 acre-feet. The total authorized storage capacity of these impoundments is about 750,000 acre-feet; however, Wright Patman Lake, Jim Chapman Lake, and Lake Sulphur Springs comprise approximately 95 percent of this total capacity.

There are 54 separate existing water rights located within the Sulphur River Basin. The locations of these water rights are identified on the map in Figure ES-1, and they are listed with general descriptive information, including permittee name and authorized diversion amounts, in Table ES-1. The total of the authorized diversions for these water rights is approximately 380,000 acre-feet per year as shown in the following table. Approximately 49 percent of the total authorized diversion volume is for municipal use, and 44 percent is for industrial purposes. The remainder is for irrigation and other (fish and wildlife) uses.

SULPHUR RIVER BASIN DIVERSION RIGHTS BY USE CATEGORY

USE CATEGORY	NUMBER OF RIGHTS	AUTHORIZED DIVERSION acre-feet/year
Municipal	15*	185,057
Industrial	9*	165,875
Irrigation	23	26,635
Mining	0	0
Recreation	9	0
Other	1	863
TOTAL	- -	378,430

* Note: Three water rights include both municipal and industrial uses.

TABLE ES-1

EXISTING WATER RIGHTS IN THE SULPHUR RIVER BASIN (8/7/98)

Water Right Identification No.[1]	Amend-ments	WRAP Control Point No.	County	Permittee's Name	Stream	Type of Use[2]	Diversion Amount Ac-Ft/Yr	Irrigation Acreage Acres	Reservoir Capacity Ac-Ft	Oldest Priority Date	Facility
03- 004838		F40	Cass	INTERNATIONAL PAPER CO.	GRASSY CRK	7				17-Nov-75	SUPERVISOR'S CLUB RESERVOIR
03- 004837		F50	Bowie	LEON S KENNEDY JR	CRUTCHERS CRK	3	80	157	550	30-Jun-62	KENNEDY LAKE
03- 004836		F60	Bowie	CITY OF TEXARKANA	SULPHUR RIVER	1	45,000		386,900	5-Mar-51	WRIGHT PATMAN LAKE
03- 004836		F60	Bowie	CITY OF TEXARKANA	SULPHUR RIVER	2	135,000			17-Feb-57	WRIGHT PATMAN LAKE
03- 004835		F70	Bowie	JERRY D PRATHER ET UX	UNNAMED TRIB MOSS CRK	7			78	31-Dec-48	
03- 004833		F80, F81	Bowie	H C PRANGE JR	UNNAMED TRIB RICE CRK	2	8		14	31-Jan-56	
03- 004832	A	F90	Bowie	CITY OF NEW BOSTON	HOLLY BR	1	325		8	29-Aug-44	
03- 004831	A	F100	Bowie	CITY OF NEW BOSTON	UNNAMED TRIB RICE CRK	1	31		259	30-Jun-14	
03- 004830		F110	Bowie	WILLIAM E JOHNSON JR ET AL	UNNAMED TRIB	3	378	501		30-Apr-40	
03- 004834		F120	Bowie	WILLIAM E JOHNSON JR ET AL	BROOKS CRK	3	39	66	15	30-Apr-40	
03- 004829		F140	Bowie	WILLIAM E JOHNSON JR ET AL	EDS CRK	3	4	16		30-Apr-40	
A- 005449		F150	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8	863		504	18-Feb-93	ON-CHAN RESERVOIR
A- 005449		F151	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8	436		436	18-Feb-93	OFF-CHAN RES - CELL #1
A- 005449		F151	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8	195		195	18-Feb-93	OFF-CHAN RES - CELL #2
A- 005449		F151	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8	232		232	18-Feb-93	OFF-CHAN RES - CELL #3
03- 004828		E30	Morris	GLASS CLUB LAKE INC	UNNAMED TRIB VILLAGE CRK	7			500	29-Jan-73	
03- 004827		E40, E50	Morris	BROVENTURE COMPANY INC	MURPHY BR	7			1,455	18-Oct-74	
03- 004825		E60	Titus	ROBERT CROOKS ET AL	E PINEY CRK	3	20	7	30	31-Dec-63	
03- 004826		E70	Titus	ELLIS-KELLY LAKE CLUB	E PINEY CRK	7				8-Jan-73	
03- 004823		E80	Titus	ARDELIA GAUNTT	UNNAMED TRIB PINEY CRK	3	22	16	24	1-Jun-65	
03- 004824		E90	Titus	WALTER W LEE	UNNAMED TRIB PINEY CRK	3	7	4		1-Jun-65	
A- 005285		E110	Titus	TEXAS UTIL MINING CO/TU SVCS	UNNAMED TRIB PINEY CRK	2			190	20-Feb-90	MONTICELLO B-2 MINING AREA
A- 005510		E100	Titus	TEXAS UTIL MINING CO/TU SVCS	UNNAMED TRIB	4			172	3-Jan-95	MONTICELLO B-2 MINE, POND L-1
03- 004822		E120	Titus	JOHN E & BERNICE BALDWIN	UNNAMED TRIB MCCULLOUGH CRK	3	100	58	196	31-Jul-67	
03- 004821		E130	Titus	ANNA PEARL LEWIS	UNNAMED TRIB RIPLEY CRK	2	1		1	31-Dec-53	
03- 004820		E160	Titus	BILLY J MAXTON	RIPLEY CRK	3	22	22		31-Dec-64	
A- 005562		E140, E150, E170	Titus	TEXAS UTILITIES MINING CO	UNNAMED TRIBS RIPLEY/DORSEY CRKS	2	125			19-Nov-96	MONTICELLO-WINFIELD N. LIGNITE MINE
03- 004819		D20	Franklin	DDC PROPERTIES LTD	LICK CRK	7			2,360	18-Mar-74	LAKE ROMAL
03- 004818		D30	Franklin	ROBERT W CAMPBELL ET AL	UNNAMED TRIB CAMPBELL CRK	3	11	21	24	31-Dec-64	
03- 004817		D40	Franklin	HANS WEISS ET UX	BEAR PEN CRK	3	333	200		30-Jun-64	
A- 005392		D50	Franklin	PAUL A PIEFER ET UX	TOWN BR	3	341	207		6-Dec-91	
03- 004816		D60	Franklin	CITY OF MOUNT VERNON	DENTON CRK	1	400		434	1-Mar-76	
03- 004815		D70	Franklin	CHARLES HELM & LEWIS HELM	UNNAMED TRIB MITCHELL CRK	7			760	28-Mar-76	
03- 004814		D80	Hopkins	JERRY N JORDAN TRUSTEE ET AL	UNNAMED TRIB WOLFPEN CRK	3	30	12	26	16-Jul-59	
A- 005150		D90	Hopkins	LARRY MILES ET AL	UNNAMED TRIB	1			269	28-Jul-87	
03- 004813		D100	Hopkins	SULPHUR SPGS COUNTRY CLUB	UNNAMED TRIB ROCK CRK	3	113	75		15-Dec-75	
03- 004812		D110	Hopkins	CITY OF SULPHUR SPRINGS	UNNAMED TRIB WHITE OAK CRK	1	408		408	1-Dec-75	LAKE COLEMAN

TABLE ES-1, CONT'D

EXISTING WATER RIGHTS IN THE SULPHUR RIVER BASIN (8/7/98)

Water Right Identification No.[1]	Amend-ments	WRAP Control Point No.	County	Permittee's Name	Stream	Type of Use[2]	Diversion Amount Ac-Ft/Yr	Irrigation Acreage Acres	Reservoir Capacity Ac-Ft	Oldest Priority Date	Facility
03- 004811		D120	Hopkins	SULPHUR SPRINGS WATER DIST	WHITE OAK CRK	1	9,800		17,838	24-Jul-51	LAKE SULPHUR SPRINGS
03- 004810		E190	Red River	PERRY R BASS INC	SAND BR	3	200	106	200	4-Apr-60	MAGIC VALLEY LAKE
03- 004809		E200	Red River	RED RIVER COUNTY WCID 1	LANGFORD CRK	1	1,120		1,225	20-Jan-64	LANGFORD CR LAKE
03- 004809		E200	Red River	RED RIVER COUNTY WCID 1	LANGFORD CRK	2	1			20-Jan-64	
03- 004808		E210	Red River	RED RIVER COUNTRY CLUB	PICKETT CRK	7			670	6-Jan-75	SOUTH LAKE
03- 004806		E230	Red River	MARY MARGARET VAUGHAN	BARNARD DRAW	3	8	8		22-Sep-69	
03- 004807		E220	Red River	MARY MARGARET VAUGHAN	BARNARD DRAW	3	22	22		22-Sep-69	
03- 004805		E240, E250, E260, E270	Titus	E P LAND & CATTLE CO INC	UNNAMED TRIB SULPHUR RIVER	3	3,000	1,500	2,063	5-Jan-81	
03- 004804		C20, C21	Red River	TEXAS UTILITIES ELECTRIC CO	SULPHUR RIVER	2	10,000		7,100	5-Mar-52	RIVERCREST STEAM ELEC. STA.
03- 004803		C30, C40	Franklin	HELMUT HERMANN ET AL	UNNAMED TRIB SULPHUR RIVER	3	1,900	750	328	19-Jun-78	TERRY LAKE
03- 004802		C50	Red River	ALEXANDER FRICK ET AL	UNNAMED TRIB SULPHUR RIVER	3	278	94	300	31-Dec-55	
A- 004148		C70, C71	Delta	SARA M DUNHAM TRUST	OLD CHANNEL S SULPHUR RIVER	3	3,500	1,924	3,875	14-Sep-81	
A- 004148	A	C80, C81	Delta	SARA M DUNHAM TRUST	OLD CHANNEL S SULPHUR RIVER	3	5,500	3,162	3,623	7-Nov-84	
A- 004148	B	C60, C61	Delta	SARA M DUNHAM TRUST	SULPHUR R & S SULPHUR RIVER	3	11,312	13,511	2,925	11-Apr-97	
A- 005200		C100	Lamar	GORDON COUNTRY CLUB	COTTONWOOD BR	7			394	1-Nov-88	
A- 004205		B20	Fannin	CITY OF PECAN GAP	UNNAMED TRIB SULPHUR RIVER	1	102		152	26-Apr-82	
03- 004801		C110	Delta	DELTA COUNTRY CLUB INC	UNNAMED TRIB BRUSHY CRK	3	5	1		2-Jul-79	
03- 004800		A20	Delta	CITY OF COOPER	CEDAR CRK	1	273		164	3-Jan-77	
A- 004395		A30	Delta	CITY OF COOPER	BIG CRK	1	1,518		4,890	6-Sep-83	
03- 004799		A40	Delta	CITY OF IRVING	S SULPHUR RIVER	1	44,820		114,265	19-Nov-65	JIM CHAPMAN LAKE
03- 004799		A40	Delta	CITY OF IRVING	S SULPHUR RIVER	2	9,180			19-Nov-65	JIM CHAPMAN LAKE
03- 004798		A40	Delta	NORTH TEXAS MWD	S SULPHUR RIVER	1	54,000		114,265	19-Nov-65	JIM CHAPMAN LAKE
03- 004797	B	A40	Delta	SULPHUR RIVER M W D	S SULPHUR RIVER	1	26,960		81,470	19-Nov-65	JIM CHAPMAN LAKE
03- 004797	B	A40	Delta	SULPHUR RIVER M W D	S SULPHUR RIVER	2	11,560			19-Nov-65	JIM CHAPMAN LAKE
03- 004797	A	A40	Delta	CITY OF COMMERCE	S SULPHUR RIVER	1				19-Nov-65	JIM CHAPMAN LAKE
03- 004797	A	A40	Delta	CITY OF COMMERCE	S SULPHUR RIVER	2				19-Nov-65	JIM CHAPMAN LAKE
03- 004795		A70	Hunt	CITY OF WOLFE CITY	E FRK TURKEY CRK	1	300		855	31-Dec-25	
03- 004796		A80	Hunt	WEBB HILL COUNTRY CLUB	UNNAMED TRIB S SULPHUR RIVER	3	80	80	60	11-Mar-68	

[1] Water Right ID Number: 03 = Certificate of Adjudication in Basin 03 (Sulphur Basin)
A = Application Number associated with Water Right Permit

[2] Type of use:
1 = Municipal
2 = Industrial
3 = Irrigation
7 = Recreation
8 = Other

The TWDB has summarized historical water use and made future water use projections for the Sulphur River Basin. Total water used within the basin increased by over 50 percent from 1980 to 1990. This significant increase is attributable to the large increase in manufacturing water use during this decade. Water used for manufacturing purposes now accounts for about 70 percent of all water used within the basin. Currently, surface water resources supply over 90 percent of the water used for all purposes in the basin, with groundwater supplying the balance.

A summary of historical water use and future demand projections from the TWDB is presented in the following table. Water exported from the Sulphur River Basin to other basins is not included in these totals. However, water imported from other basins is included.

SULPHUR RIVER BASIN HISTORICAL WATER USE
AND FUTURE DEMAND PROJECTIONS
(acre-feet/year)

USE CATEGORY	1980	1990	2000 (projected)	2050 (projected)
Municipal	28,063	25,770	29,286	28,621
Manufacturing	45,120	88,281	87,627	93,844
Steam Electric	1,947	1,494	1,500	5,000
Mining	1,328	1,155	1,725	1,202
Irrigation	1,775	2,066	2,044	1,933
Livestock	6,459	9,540	9,934	9,934
TOTAL	84,692	128,306	132,116	140,534

The most recent water planning studies of the Sulphur River Basin have been conducted by the TWDB, in coordination with the Texas Parks and Wildlife Department and the TNRCC, as part of preparing the statewide water plan titled "Water For Texas" (1997). In this effort, the TWDB evaluated existing surface and ground water supplies, examined historical water use and projected future water demands by various use categories, quantified potential future water needs both within and outside the basin, and identified prospective surface-water development projects, including major reservoirs, that could be implemented to satisfy future water demands while considering environmental flow needs. On the Sulphur River just upstream of the White Oak Creek confluence, the TWDB 1997 plan includes as a recommended new project Marvin Nichols I Reservoir, with a maximum conservation storage capacity of 1,369,717 acre-feet and an annual supply of 560,151. George Parkhouse II Reservoir, with a maximum conservation storage capacity of 243,617 acre-feet and an annual supply of 134,232 acre-feet, also is recommended.

This project is located on the North Sulphur River. Both of these projects are proposed as supplemental water supplies to meet local needs and the projected water demands in the Dallas-Fort Worth metroplex area.

NATURALIZED STREAMFLOWS

Knowing the amount and distribution of naturalized streamflows throughout the Sulphur River Basin is fundamental to the analysis of water availability for existing water rights as required by Senate Bill 1 and to the determination of unappropriated water when considering water availability for new water rights. By definition, naturalized streamflows represent historical streamflow conditions, including typical wet, dry, and normal flow periods, without the influence of man's activities as they relate to water rights and water use. For example, the construction and operation of reservoirs, the diversion of surface waters, and the discharge of return flows are all activities related to water rights and water use that have had an impact on historical streamflows. In the determination of naturalized streamflows, the historical effects of these types of activities on streamflows must be removed from those portions of the historical streamflow records when such activities actually occurred. The resulting historical trace of naturalized streamflows then represents streamflow conditions uninfluenced by man's water rights or water use activities.

When performing water availability analyses, the potential effects of all existing water rights within a basin, i. e., diversions and reservoir storage, must be considered and accounted for in accordance with their individual water rights priorities. Similarly, the effects of any anticipated return flows also must be factored into the analyses. In essence, for purposes of the water availability analyses, the historical record of naturalized streamflows is readjusted to reflect the anticipated future effects of man's water rights and water use activities, taking into account the potential effects of these activities over the entire period of record of naturalized streamflows. By design, this period should be long enough to encompass a broad range of historical hydrologic conditions so that the availability of water for specific water rights and uses can be meaningfully evaluated. Typically, this would encompass a period on the order of 50 years, with complete monthly records of streamflow data, including the drought of record. For many parts of Texas, including streams in the Sulphur River Basin, the drought of record corresponds to the severe drought that occurred during the early to mid 1950's. The analysis period used in this study extends from 1940 through 1996.

The general equation that has been used for calculating monthly naturalized streamflows at selected locations where historical streamflow data are available within the Sulphur River Basin is as follows:

NATURALIZED STREAMFLOW	=	HISTORICAL STREAMFLOW
	+	DIVERSIONS
	-	RETURN FLOWS
	+	RESERVOIR DEPLETIONS

Because historical measured or deduced streamflow data normally provide the basis for the streamflow naturalization process, the locations where naturalized streamflows are determined are coincident with the locations on watercourses where such historical data are available. These locations, of course, typically are where U. S. Geological Survey (USGS) streamflow gaging stations are, or have been, in operation. However, they also can be at other locations where historical streamflows can be calculated or deduced, such as at reservoirs, based on other related historical data. For the Sulphur River Basin, monthly naturalized streamflows for the period 1940-1996 have been determined at the downstream end of each of the colored subwatersheds that are identified with the letters A through F on the map of the basin in Figure ES-1.

A summary of statistical parameters describing the six different sets (one at the downstream end of each subwatershed) of naturalized streamflows developed in this study for the Sulphur River Basin is presented in Table ES-2. As indicated by the mean values, these streamflows range from a few hundred thousand acre-feet per year in the upper part of the basin (Subwatersheds A and B) and for White Oak Creek (Subwatershed D) up to 2.5 million acre-feet per year at the state line for Subwatershed F. Even the minimum annual value of the naturalized streamflows at the state line exceeds 500,000 acre-feet per year.

WRAP WATER RIGHTS ANALYSIS MODEL

The basic WRAP model is described in the report titled "Water Rights Analysis Package (WRAP), Model Description and Users Manual", as published in October 1996, by the Texas Water Resources Institute at Texas A&M. The WRAP program is coded in FORTRAN and is operational in DOS or Windows operating systems on desktop personal computers. The WRAP model is in the public domain and is available upon request from Texas Water Resources Institute at Texas A&M. The TNRCC is responsible for distributing versions of the WRAP model, including data files, as developed in this study for the Sulphur River Basin.

The WRAP model simulates the allocation of prescribed amounts of water within a river basin to individual water rights, i. e., diversions and storage, subject to the Prior Appropriation Doctrine as it is applied for water rights administration in Texas. WRAP utilizes a network of control points with interconnected links to describe flow paths and the locations of inflows, diversions, reservoirs, and return flows. Simulations are performed sequentially in time using time series of various input data.

TABLE ES-2
MONTHLY NATURALIZED STREAMFLOW STATISTICS BY SUBWATERSHED FOR THE PERIOD 1940-1996 FOR THE SULPHUR RIVER BASIN

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
SUBWATERSHED A, SOUTH SULPHUR RIVER													
MEAN	22,051	33,719	38,039	41,560	53,504	29,020	9,175	2,068	8,883	15,863	28,054	29,944	311,881
MIN	0	37	10	34	6	6	0	0	0	0	0	0	51,794
MAX	102,558	160,465	138,015	259,718	233,227	172,596	63,140	19,666	77,697	128,074	156,814	195,267	835,592
MEDIAN	12,904	21,868	28,199	23,028	30,314	16,782	2,150	316	996	2,876	8,166	19,174	305,289
STD DEV	23,836	37,150	37,945	52,403	56,717	35,672	14,987	3,627	19,202	28,389	43,073	37,685	154,650
SUBWATERSHED B, NORTH SULPHUR RIVER													
MEAN	10,475	16,694	20,853	24,231	30,185	16,888	5,931	1,320	5,873	12,328	14,524	15,968	175,270
MIN	5	21	270	181	157	31	0	0	0	0	0	0	24,283
MAX	72,069	82,363	75,180	179,508	151,320	106,586	53,606	9,821	34,793	109,731	83,644	93,902	485,924
MEDIAN	3,467	9,951	16,369	11,310	16,496	5,959	2,020	210	661	2,540	4,185	11,015	176,324
STD DEV	14,139	20,433	19,172	34,943	33,587	23,927	10,286	2,138	10,013	22,609	21,495	21,135	92,306
SUBWATERSHED C, SULPHUR RIVER NEAR TALCO													
MEAN	67,300	104,042	113,453	117,598	170,086	87,304	30,899	6,725	23,794	50,108	80,475	100,739	952,524
MIN	9	154	728	756	1,196	85	0	0	0	0	0	0	151,932
MAX	265,638	479,680	446,010	618,861	757,998	420,365	236,454	61,428	188,814	431,803	405,784	679,015	2,438,464
MEDIAN	46,611	68,878	85,334	61,753	99,851	43,196	9,307	1,144	4,404	7,664	28,667	59,243	897,031
STD DEV	70,157	112,206	114,566	137,373	182,472	106,396	53,263	12,757	45,792	88,658	111,642	133,411	486,142
SUBWATERSHED D, WHITE OAK CREEK NEAR TALCO													
MEAN	33,661	44,841	49,799	51,792	60,503	26,600	14,988	3,432	5,887	17,254	32,556	45,751	387,065
MIN	82	170	631	260	307	0	0	0	0	0	0	0	63,958
MAX	198,424	228,289	301,552	238,952	261,382	156,985	230,767	56,215	63,356	239,547	177,515	244,775	1,125,841
MEDIAN	22,107	29,098	40,028	35,624	38,314	10,819	3,617	751	1,602	1,755	13,819	22,389	349,365
STD DEV	40,475	48,458	54,714	58,243	63,498	37,482	35,590	8,688	11,973	39,776	47,961	54,537	211,552
SUBWATERSHED E, SULPHUR RIVER BELOW WHITE OAK CREEK													
MEAN	158,058	223,311	258,266	265,028	340,201	165,285	61,338	15,100	39,067	81,331	155,468	221,237	1,983,691
MIN	587	3,725	7,734	5,053	1,504	127	57	16	16	1	35	1,080	392,305
MAX	470,029	1,009,121	1,145,365	1,219,267	1,348,394	690,895	511,310	194,393	481,900	540,855	829,601	1,150,861	4,849,145
MEDIAN	113,227	152,921	169,104	187,087	238,844	73,163	16,818	5,525	10,940	16,045	63,279	141,878	1,871,985
STD DEV	143,202	214,364	240,371	287,168	324,341	186,571	96,498	31,644	81,128	128,573	220,037	260,582	944,901
SUBWATERSHED F, SULPHUR RIVER AT STATE LINE													
MEAN	203,675	282,782	334,168	341,454	427,797	206,349	73,686	19,046	46,571	92,488	189,350	280,903	2,498,269
MIN	587	3,725	10,454	5,053	1,504	127	69	16	22	1	35	1,853	516,674
MAX	607,297	1,288,167	1,531,416	1,812,128	1,713,725	839,467	557,531	255,610	675,299	540,855	1,049,055	1,331,974	6,145,262
MEDIAN	156,062	215,615	240,774	238,701	294,721	94,732	17,286	5,862	11,605	21,804	83,906	150,265	2,323,767
STD DEV	182,855	265,594	310,361	381,993	408,237	235,377	113,370	41,152	104,459	141,234	273,605	326,333	1,211,324

Typically, monthly values are specified for inflows, reservoir net evaporation rates, and water demands subject to prescribed water rights conditions and reservoir system operating rules.

Results from the WRAP model include monthly time series data for: diversions, storage amounts, reliability, and shortages for each water right; naturalized flow, regulated flow, and remaining unappropriated water at each control point; reservoir contents and evaporation; and summary tables by control point, water right, water right group, reservoir, and the entire river basin. These results are displayed and stored in tabular form. This is contrasted with the TNRCC's former water availability models, which could output the following: baseflow (BA), naturalized baseflow; diversions (DI), simulated diversions from a stream (S) or a reservoir (R) for water rights; unappropriated water (EX), the total runoff (naturalized storm runoff plus baseflow) remaining after simulated upstream diversions have been taken out and after simulated priority release for downstream rights included in the model have been taken out; outflow (OU), the total runoff remaining after the simulated upstream diversions and the simulated diversions for a subwatershed have been taken out, but before the simulated priority releases for downstream rights have been taken out; priority releases (PR), simulated releases of inflow to satisfy downstream senior water rights (Updated Trinity Model runs only); reservoir contents (RC), the simulated contents of any reservoir; reservoir evaporation (RE), simulated evaporation from any reservoir; storm runoff (SR), naturalized storm runoff; total runoff (TR), storm runoff plus baseflow, which is also known as naturalized flow; and total inflow (TI), the cumulative sum from the basin of the total runoff remaining after simulated upstream diversions have been taken out, but before simulated diversions for the subwatershed have been taken out and before priority releases for simulated downstream water rights have been taken out.

The WRAP model previously has been applied to simulate simplified water rights systems in several basins in Texas, including the Brazos, San Jacinto and Lavaca Basins. Because of the model's general capabilities for describing hydrologic and water resource system features in Texas and its inclusion of the Prior Appropriation Doctrine, the TNRCC adopted the WRAP model as the basic water rights simulation tool for performing the water availability analyses pursuant to the requirements of Senate Bill 1.

Although the basic WRAP model in its original form does provide the fundamental framework for structuring water availability models of Texas river basins, there are several additional routines that have been incorporated into the WRAP program that have enhanced its capabilities for performing the required water availability analyses. These program modifications have been made, for the most part, by Dr. Ralph Wurbs of Texas A&M under contract to the TNRCC. The version of WRAP used for this water availability analysis is known as the February 1999 version (Wurbs, 1999). This version of WRAP was the best available at the time of modeling for the Sulphur River Basin.

Control points used with the WRAP model provide a mechanism to describe the locational configuration of a river basin. Control points are specified in the input data to indicate the location of streamflow information, reservoirs, water rights diversions, return flows, imports, and other system features. The computations performed by the WRAP model are based on knowing which of the other control points are located downstream of each control point. Essentially any configuration of stream tributaries, reservoirs, and within-basin or interbasin conveyance facilities can be modeled. Each water right can be assigned a separate control point, or alternatively, water rights can be aggregated such that the water rights assigned to a given control point include all water rights located between that control point and the next adjacent control point. Multiple water rights at the same control point all have access, in priority order, to the streamflow available at the control point.

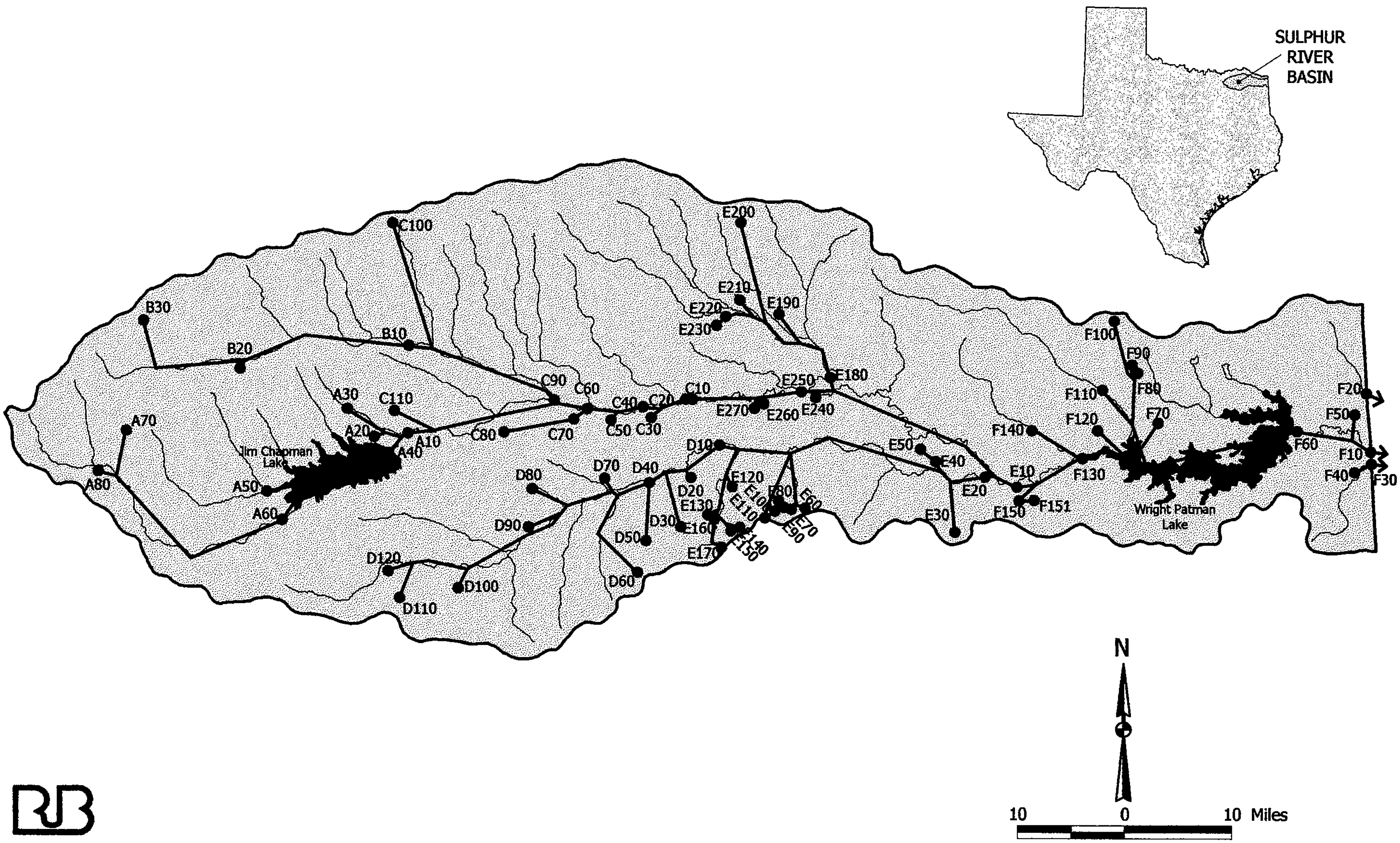
Naturalized streamflows are provided as input for all control points, and the WRAP model computes unappropriated and regulated streamflows and other quantities related to specific water rights at each control point. The WRAP model limits water available to a water right at a control point to the lesser of unappropriated flows at the control point or unappropriated flows at downstream control points.

For the WRAP model of the Sulphur River Basin, control points have been assigned at the location of all existing water rights. In some cases, multiple water rights have been specified at a single control point, such as the water rights for North Texas Municipal Water District, the City of Irving, and the Sulphur River Municipal Water District at Jim Chapman Lake. Additional control points have been assigned at the downstream ends of each of the six subwatersheds where the known naturalized streamflows are specified in the model, at the end points of water quality segments defined by the TNRCC, at the confluence of certain streams, at the locations where return flows are discharged into the basin from facilities unrelated to a specific water right (such as groundwater-based municipal wastewater discharges), and at other special locations. The locations of all of the control points specified in the WRAP model of the Sulphur River Basin are shown on the map in Figure ES-2, together with their connecting links. In all, there are 82 control points that have been defined for structuring the WRAP model of the Sulphur River Basin.

WATER AVAILABILITY ANALYSES

The TNRCC has defined eight specific scenarios for evaluating water availability in each of the basins in Texas, including the Sulphur River Basin. These various scenarios are referred to as "Runs", and the WRAP output from these runs is intended to address directly the requirements for water availability information as specified in Senate Bill 1. Basically, the eight different runs are characterized by different combinations of input conditions for: (1) the diversion amounts

FIGURE ES-2
CONTROL POINTS AND LINKS USED IN THE SULPHUR RIVER BASIN WRAP MODEL



specified for water rights; (2) the area-capacity relationships specified for reservoirs; (3) the quantities specified for return flows corresponding to different assumed levels of reuse; and (4) diversions and/or storage associated with term water rights permits.

It should be noted that the simulated water availability results from the WRAP model for each of these runs are described and summarized only in general terms in the final report for the Sulphur River Basin. Information for selected water rights and specific locations is presented as examples to demonstrate the general condition of the Sulphur River Basin with regard to overall water availability and to illustrate the types of water rights output that has been generated with the WRAP model. More detailed results from the WRAP water availability analyses for all of the individual water rights, including plots of water availability and reliability, are available from the TNRCC.

Reuse Runs

Three different simulations of water availability with the WRAP model have been made to address the potential effects of different levels of reuse of return flows. The first of these, Run 1, is considered the baseline simulation for water availability in the Sulphur River Basin. It includes fully authorized diversions for all water rights, authorized area-capacity relationships for all reservoirs as they were originally permitted, no term water rights permits, and return flows based on simulated diversions times current return flow factors, i. e., no reuse beyond what is reflected in historical return flows as reported for the last five years. The results from Run 1 provide a baseline against which the results from all other runs have been compared for the Senate Bill 1 scenarios.

Runs 2 and 3 incorporate exactly the same input conditions as Run 1, except that Run 2 assumes that 50 percent of the return flows are reused and Run 3 assumes that all of the return flows are reused (zero return flow condition). Hence, in general, the results from Run 1 should reflect more water available than either Run 2 or Run 3, and the results from Run 2 should reflect more water available than Run 3.

Cancellation Runs

Various simulations have been made with the WRAP model to provide information regarding the potential water availability impacts of canceling water rights pursuant to the provisions of Subchapter E, Chapter 11 of the Texas Water Code. Under this section of the Water Code, the TNRCC has the authority to cancel a permit, certified filing or certificate of adjudication if the water authorized to be appropriated is not beneficially used during the last ten years. Hence, those water rights in the Sulphur River Basin that have not been used in the last ten years according to TNRCC and TWDB records have been identified and simulated as cancelled for purposes of these analyses.

It should be noted that under the TNRCC-specified criteria for identifying water rights that should be simulated as cancelled for purposes of these analyses, the diversion rights for Jim Chapman Lake (Water Rights 4797, 4798, and 4799) have been simulated as cancelled because of non-use during the last ten years, but the reservoir storage has been left in place in the WRAP model since the reservoir has been constructed and does indeed exist. The only reason that water has not been diverted from the reservoir during the last ten years is because there has not been an immediate need and the pumping and transmission facilities have not been in place. Caution should be used in interpreting the results of model Runs 4, 5, and 6. Just because these runs show what appears to be additional water, that does not mean that the TNRCC could, or would, actually cancel water rights that were simulated in these runs as cancelled.

Four different runs have been made for purposes of investigating water rights cancellation. For current reuse conditions, two runs have been made. One, Run 4, incorporates fully authorized diversions in the WRAP model, except for those water rights subject to cancellation (diversions for these have been set equal to zero). The other, Run 5, has all diversions set equal to the maximum annual use reported during the last ten years, which, by definition, also includes zero diversions for those water rights subject to cancellation. Runs 6 and 7 correspond to Runs 4 and 5 directly, except that 100-percent reuse of all return flows is assumed (zero return flow amounts). For all four of these runs, the authorized area-capacity relationships for all reservoirs have been used, and all term water rights permits have been excluded.

Current Conditions Run

The final simulation that has been made with the WRAP model for purposes of evaluating water availability in the Sulphur River Basin is Run 8, which corresponds to current conditions. This means that the annual diversion amounts for all water rights have been set equal to the maximum annual use reported during the last ten years, the area-capacity relationships for all major reservoirs have been assumed to correspond to year-2000 sedimentation conditions, all return flows have been based on current conditions without any additional reuse, and all term water rights permits have been fully accounted for.

WATER AVAILABILITY MODEL RESULTS

The simulated results from the WRAP model for the various input conditions corresponding to the eight runs provide an indication of water availability for each water right in the Sulphur River Basin. All of these simulations have encompassed actual monthly hydrologic conditions for the 1940 through 1996 period. The basic results from the different runs with regard to water availability consist of monthly values of simulated diversions and simulated end-of-month reservoir storage for each of the water rights in the basin. Also of importance are the simulated quantities of monthly unappropriated streamflows and monthly regulated streamflows at various locations throughout the Sulphur River Basin. The unappropriated streamflows, of course, provide an indication of the water available for future water resource development projects, while the regulated streamflows reflect the actual levels of flow that can be expected in the streams under the various scenarios of diversions, reservoir storage, return flows, and term permits.

To illustrate the variations in water availability among large and different types of water rights in the Sulphur River Basin for the different simulation runs, several individual water rights have been selected for graphically displaying the model results. For describing the simulated quantities of unappropriated water and regulated flows corresponding to the different runs, model results have been plotted for locations at the downstream end of each of the subwatersheds defined in this study and at the mouth of selected major tributaries. Examples of these types of presentations are contained in Figure ES-3 for diversions, in Figure ES-4 for reservoir storage, and in Figure ES-5 for streamflows.

A summary of the results from the eight runs with regard to the amount and reliability of simulated diversions for each water right is presented in Table ES-3. This table lists the water rights with authorized diversions in the Sulphur River Basin, and indicates their respective water right numbers and types of use, i. e., municipal, industrial, irrigation, or other. For each of the eight runs, the authorized annual diversion amount for each water right and type of use is listed, along with the simulated mean annual shortage amount, the percent of the total months analyzed (57 years x 12 = 684 months) for which the authorized diversion was satisfied, and the percent of the total authorized diversion amount over the entire 1940-1996 analysis period that was actually diverted. Although these results do not provide a complete picture of when and how much water is available for each water right, the two percentage quantities in the table do provide an indication of the reliability with which water can be diverted. At 100 percent, the fully authorized annual diversion of a particular water right is satisfied in every month. A zero value would mean that water is never available.

FIGURE ES-3
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

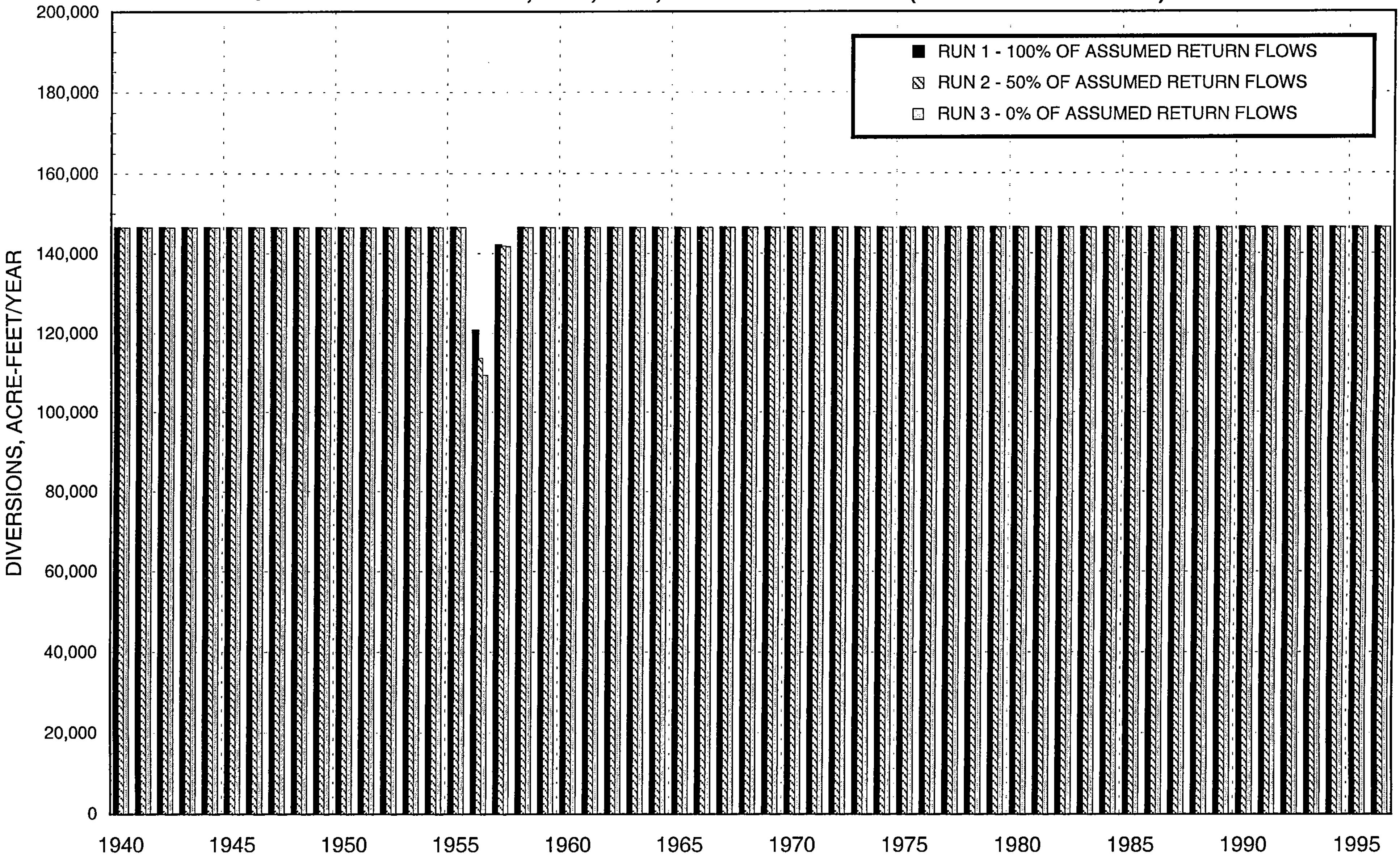


FIGURE ES-4
MONTHLY RESERVOIR STORAGE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

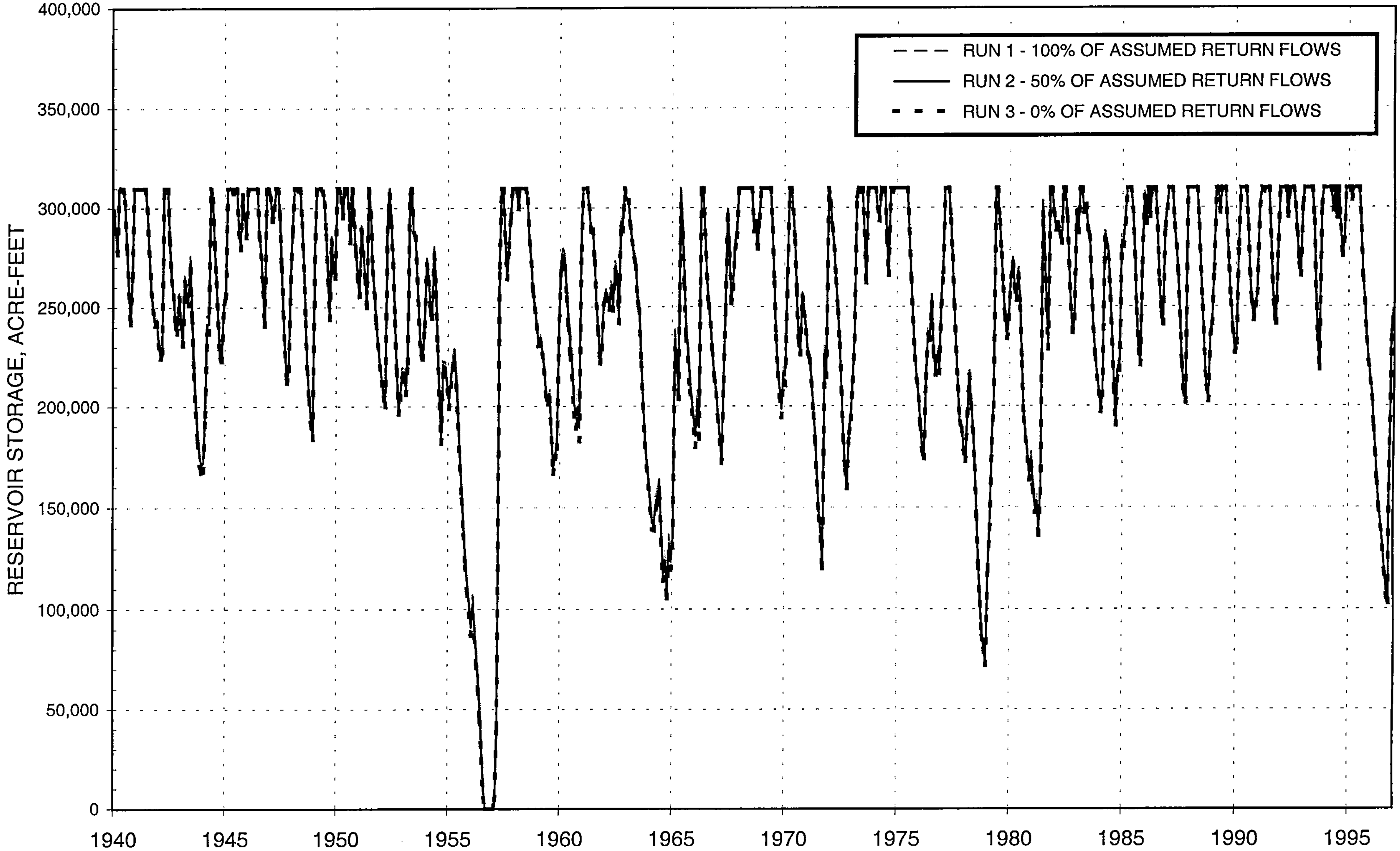


FIGURE ES-5
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

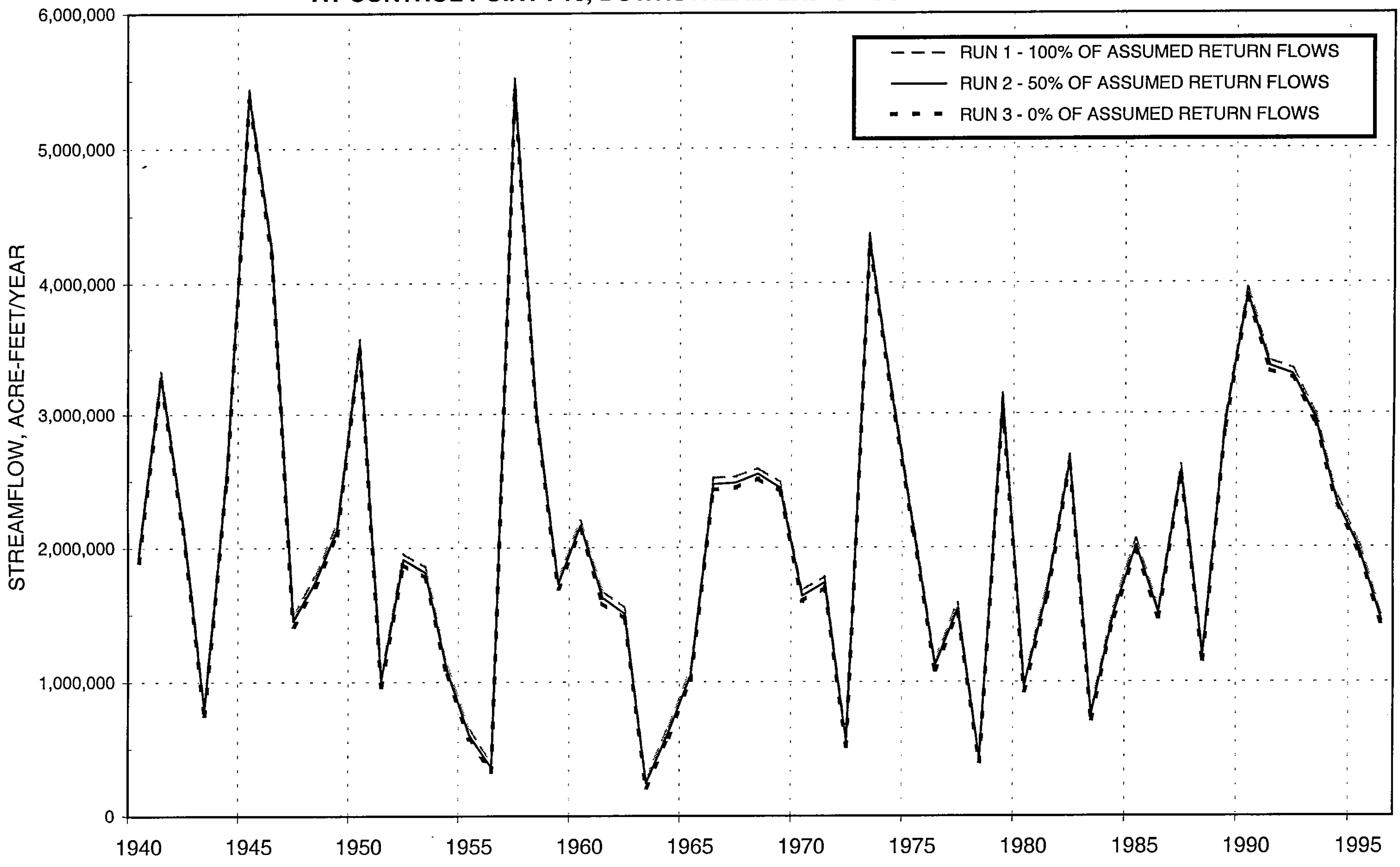


TABLE ES-3
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 1 - BASELINE					
			Maximum Authorized Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA .	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	8	1	88.3	89.5	1	1971
CITY OF NEW BOSTON	03 4832	1	325	116	53.7	64.3	103	1956
CITY OF NEW BOSTON	03 4831	1	31	0	100.0	100.0	31	all
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	378	54	87.1	85.7	184	1984
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	39	5	76.0	88.5	19	1988
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	4	1	79.2	74.2	1	1988
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	23	3	91.5	88.0	5	1971
WALTER W. LEE	03 4824	3	8	6	27.6	21.3	0	1955
JOHN E. & BERNICE BALDWIN	03 4822	3	100	0	100.0	100.0	100	all
BILLY J. MAXTON	03 4820	3	22	8	81.4	63.7	0	1977
ANNA PEARL LEWIS	03 4821	2	1	0	98.4	98.4	1	all
TEXAS UTILITIES MINING CO.	A 5562_1	2	9	3	64.2	64.1	1	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	28	61.8	64.6	6	1956
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	13	60.4	64.1	3	1956
ROBERT W. CAMPBELL, ET AL	03 4818	3	11	1	94.6	91.2	2	1956
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	333	88	91.5	73.5	0	1977
PAUL A. PIEFER, ET UX	A 5392	3	341	196	76.8	42.6	0	1956
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.0	95.3	43	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	15	92.5	93.2	30	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.9	96.1	19	1978
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.3	98.3	44	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	408	3	99.1	99.2	254	1956
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	200	4	98.3	97.8	133	1996
RED RIVER COUNTY WCID 1	03 4809	1	1,120	182	80.0	83.8	278	1978
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	2,500	348	93.6	86.1	926	1972
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	500	0	100.0	100.0	500	all
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	190	96.4	98.1	8,939	1978
HELMUT HERMANN, ET AL	03 4803_1	3	650	55	95.8	91.6	315	1972
HELMUT HERMANN, ET AL	03 4803_2	3	350	87	92.5	75.2	0	1956
HELMUT HERMANN, ET AL	03 4803_3	3	900	226	92.4	75.0	0	1956
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	272	1978
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,468	88.0	87.0	5,115	1956
SARA M. DUNHAM TRUST	A 4148	3	2,828	0	100.0	100.0	2,828	all
SARA M. DUNHAM TRUST	A 4148A	3	5,500	1,044	80.7	81.0	412	1956
CITY OF PECAN GAP	A 4205	1	102	2	97.4	97.9	57	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	9	95.0	96.6	96	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	44,820	81	99.6	99.8	40,229	1956
CITY OF IRVING	03 4799	2	9,180	41	99.6	99.6	6,866	1956
NORTH TEXAS MWD	03 4798	1	54,000	189	99.4	99.7	44,400	1956
SULPHUR RIVER MWD	03 4797A	1	26,960	153	99.4	99.4	20,509	1956
SULPHUR RIVER MWD	03 4797A	2	11,560	68	99.4	99.4	8,646	1956
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	31	55.9	61.5	0	1954
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					90.8			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when the fully authorized diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrence is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 2 - 50% REUSE					
			Maximum Authorized Diversion	Mean Shortage[1]	Reliability		Minimum Annual Diversion[4]	
					Month[2]	Volume[3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	8	1	88.3	89.5	1	1971
CITY OF NEW BOSTON	03 4832	1	325	116	53.7	64.3	103	1956
CITY OF NEW BOSTON	03 4831	1	31	0	100.0	100.0	31	all
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	378	72	81.3	81.0	130	1988
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	39	5	76.0	88.5	19	1988
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	4	1	79.2	74.2	1	1988
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	23	3	91.5	87.9	5	1971
WALTER W. LEE	03 4824	3	8	6	27.6	21.3	0	1956
JOHN E. & BERNICE BALDWIN	03 4822	3	100	0	100.0	100.0	100	all
BILLY J. MAXTON	03 4820	3	22	8	80.7	62.3	0	1956
ANNA PEARL LEWIS	03 4821	2	1	0	98.4	98.4	1	all
TEXAS UTILITIES MINING CO.	A 5562_1	2	9	3	63.7	63.8	2	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	28	61.1	64.5	20	1972
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	13	59.7	63.9	9	1956
ROBERT W. CAMPBELL, ET AL	03 4818	3	11	1	94.4	91.1	1	1956
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	333	96	90.8	71.1	0	1956
PAUL A. PIEFER, ET UX	A 5392	3	341	209	76.0	38.8	0	1955
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.0	95.3	43	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	15	92.5	93.1	31	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	18	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.3	98.4	44	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	408	3	99.1	99.2	273	1956
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	200	5	98.1	97.6	133	1996
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	254	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	2,500	358	92.8	85.7	1,023	1977
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	500	0	100.0	100.0	500	all
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	186	96.2	98.1	8,939	1978
HELMUT HERMANN, ET AL	03 4803_1	3	650	56	95.6	91.5	315	1972
HELMUT HERMANN, ET AL	03 4803_2	3	350	86	92.3	75.4	0	1956
HELMUT HERMANN, ET AL	03 4803_3	3	900	230	92.0	74.4	0	1956
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	272	1978
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,531	87.7	86.5	5,115	1956
SARA M. DUNHAM TRUST	A 4148	3	2,828	0	100.0	100.0	2,828	all
SARA M. DUNHAM TRUST	A 4148A	3	5,500	1,044	80.7	81.0	412	1956
CITY OF PECAN GAP	A 4205	1	102	2	96.8	97.7	54	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	10	94.6	96.3	96	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	44,820	102	99.6	99.8	39,019	1956
CITY OF IRVING	03 4799	2	9,180	41	99.6	99.6	6,866	1956
NORTH TEXAS MWD	03 4798	1	54,000	238	99.3	99.6	41,826	1956
SULPHUR RIVER MWD	03 4797A	1	26,960	194	99.3	99.3	18,204	1956
SULPHUR RIVER MWD	03 4797A	2	11,560	85	99.3	99.3	7,696	1956
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	32	55.0	60.0	0	1952
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					90.5			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when the fully authorized diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurreice is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER[5]	TYPE OF USE	RUN 3 - 100% REUSE					
			Maximum Authorized Diversion	Mean Shortage[1]	Reliability		Minimum Annual Diversion[4]	
					Month[2]	Volume[3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	8	1	88.3	89.5	1	1971
CITY OF NEW BOSTON	03 4832	1	325	116	53.7	64.3	103	1956
CITY OF NEW BOSTON	03 4831	1	31	0	100.0	100.0	31	all
WILLIAM E. JOHNSON JR.. ET AL	03 4830	3	378	98	79.5	74.1	69	1988
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	39	5	76.0	88.5	19	1988
WILLIAM E. JOHNSON JR.. ET AL	03 4829	3	4	1	79.2	74.2	1	1988
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1956
ARDELIA GAUNTT	03 4823	3	23	3	91.5	87.9	5	1971
WALTER W. LEE	03 4824	3	8	6	27.6	21.3	0	1955
JOHN E. & BERNICE BALDWIN	03 4822	3	100	0	100.0	100.0	100	all
BILLY J. MAXTON	03 4820	3	22	8	80.9	62.5	0	1956
ANNA PEARL LEWIS	03 4821	2	1	0	98.7	98.7	1	1978
TEXAS UTILITIES MINING CO.	A 5562_1	2	9	3	64.2	64.2	2	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	28	61.3	65.2	22	1978
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	13	59.9	64.5	9	1978
ROBERT W. CAMPBELL, ET AL	03 4818	3	11	1	94.4	91.1	1	1956
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	333	102	89.9	69.3	0	1956
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	188	9	93.9	95.0	29	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	15	92.5	93.0	20	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	18	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.0	98.1	36	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	408	4	98.5	99.0	212	1956
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	200	5	98.1	97.6	133	1996
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	258	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	2,500	407	92.5	83.7	996	1978
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	500	0	100.0	100.0	500	all
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	196	96.4	98.0	8,520	1956
HELMUT HERMANN, ET AL	03 4803_1	3	650	55	95.6	91.6	315	1972
HELMUT HERMANN, ET AL	03 4803_2	3	350	83	92.7	76.3	0	1956
HELMUT HERMANN, ET AL	03 4803_3	3	900	234	91.8	74.0	0	1956
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	263	1956
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,574	87.3	86.1	4,842	1996
SARA M. DUNHAM TRUST	A 4148	3	2,828	0	100.0	100.0	2,828	all
SARA M. DUNHAM TRUST	A 4148A	3	5,500	1,044	80.7	81.0	412	1956
CITY OF PECAN GAP	A 4205	1	102	3	96.8	97.5	49	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	11	94.3	96.0	85	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	44,820	108	99.6	99.8	38,667	1956
CITY OF IRVING	03 4799	2	9,180	46	99.4	99.5	6,537	1956
NORTH TEXAS MWD	03 4798	1	54,000	303	99.3	99.4	38,293	1956
SULPHUR RIVER MWD	03 4797A	1	26,960	194	99.3	99.3	18,204	1956
SULPHUR RIVER MWD	03 4797A	2	11,560	85	99.3	99.3	7,696	1956
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	33	54.4	59.2	0	1952
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					90.7			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when the fully authorized diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrerce is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 4 - CANCELLATION					
			Simulated Diversion	Mean Shortage[1]	Reliability		Minimum Annual Diversion[4]	
					Month[2]	Volume[3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	0	0	n/a	n/a	n/a	n/a
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	0	0	n/a	n/a	n/a	n/a
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	79	27	61.6	65.4	17	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	37	13	60.2	64.8	7	1956
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	341	183	76.8	46.2	0	1955
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.2	95.3	43	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	14	92.5	93.3	30	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	30	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.3	98.3	44	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	254	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	186	96.5	98.1	9,055	1978
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	272	1978
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,425	88.6	87.4	5,115	1956
SARA M. DUNHAM TRUST	A 4148	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148A	3	5,500	926	80.3	83.2	1,099	1956
CITY OF PECAN GAP	A 4205	1	102	2	97.2	98.0	58	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	9	95.0	96.6	96	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	11	82.3	86.4	0	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					93.0			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.6		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrerce is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 5 - 10 YEAR MAX					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	93,165	0	100.0	100.0	93,165	all
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	40	0	100.0	100.0	40	all
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	1	0	100.0	100.0	1	all
CITY OF MOUNT VERNON	03 4816_2	1	0	0	n/a	n/a	n/a	n/a
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	5	0	100.0	100.0	5	all
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	27	0	100.0	100.0	27	all
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	4,809	0	100.0	100.0	4,809	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	0	0	n/a	n/a	n/a	n/a
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	396	0	100.0	100.0	396	all
MARY MARGARET VAUGHAN	03 4807	3	0	0	n/a	n/a	n/a	n/a
MARY MARGARET VAUGHAN	03 4806	3	4	0	100.0	100.0	4	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	103	0	100.0	100.0	103	all
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	320	6	97.8	98.1	275	1978
SARA M. DUNHAM TRUST	A 4148B	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148	3	2,744	0	100.0	100.0	2,744	all
SARA M. DUNHAM TRUST	A 4148A	3	2,744	56	97.7	98.0	1,120	1956
CITY OF PECAN GAP	A 4205	1	34	0	100.0	100.0	34	all
DELTA COUNTRY CLUB INC.	03 4801	3	0	0	n/a	n/a	n/a	n/a
CITY OF COOPER	03 4800	1	462	59	81.6	87.2	98	1956
CITY OF COOPER	A 4395	1	462	0	100.0	100.0	462	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	244	0	99.9	100.0	239	1957
CITY OF WOLFE CITY	03 4795_2	1	0	0	n/a	n/a	n/a	n/a
WEBB HILL COUNTRY CLUB	03 4796_1	3	22	0	98.5	98.9	12	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					98.6			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						99.9		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurreice is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 6 - CANCELLATION, 100% REUSE					
			Simulated Diversion	Mean Shortage [1]	Reliability Month [2]	Reliability Volume [3]	Minimum Annual Diversion [4]	
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	0	0	n/a	n/a	n/a	n/a
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	0	0	n/a	n/a	n/a	n/a
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	26	62.6	67.2	22	1978
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	12	61.0	66.4	9	1940
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.0	95.1	29	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	14	92.5	93.3	20	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	18	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.0	98.1	36	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	258	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	196	96.4	98.0	8,520	1976
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	263	1956
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,450	88.3	87.2	4,867	1996
SARA M. DUNHAM TRUST	A 4148	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148A	3	5,500	926	80.3	83.2	1,099	1956
CITY OF PECAN GAP	A 4205	1	102	2	97.2	97.9	54	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	10	94.6	96.3	85	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	11	82.0	86.0	0	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					93.6			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurreıce is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 7 - 10 YEAR MAX, 100% REUSE					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	93,165	0	100.0	100.0	93,165	all
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	40	0	100.0	100.0	40	all
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	1	0	100.0	100.0	1	all
CITY OF MOUNT VERNON	03 4816_2	1	0	0	n/a	n/a	n/a	n/a
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	5	0	100.0	100.0	5	all
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	27	0	100.0	100.0	27	all
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	4,809	0	100.0	100.0	4,809	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	0	0	n/a	n/a	n/a	n/a
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	396	0	100.0	100.0	396	all
MARY MARGARET VAUGHAN	03 4807	3	0	0	n/a	n/a	n/a	n/a
MARY MARGARET VAUGHAN	03 4806	3	4	0	100.0	100.0	4	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	103	0	100.0	100.0	103	all
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	320	6	97.8	98.1	275	1978
SARA M. DUNHAM TRUST	A 4148B	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148	3	2,744	0	100.0	100.0	2,744	all
SARA M. DUNHAM TRUST	A 4148A	3	2,744	55	97.8	98.0	1,162	1956
CITY OF PECAN GAP	A 4205	1	34	0	100.0	100.0	34	all
DELTA COUNTRY CLUB INC.	03 4801	3	0	0	n/a	n/a	n/a	n/a
CITY OF COOPER	03 4800	1	462	60	81.6	87.1	98	1956
CITY OF COOPER	A 4395	1	462	0	100.0	100.0	462	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	244	0	99.9	100.0	239	1957
CITY OF WOLFE CITY	03 4795_2	1	0	0	n/a	n/a	n/a	n/a
WEBB HILL COUNTRY CLUB	03 4796_1	3	22	0	98.5	98.9	12	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					98.6			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						99.9		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrerce is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 8 - CURRENT CONDITIONS					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	93,165	0	100.0	100.0	93,165	all
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	20	0	100.0	100.0	20	all
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	40	0	100.0	100.0	40	all
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	1	0	100.0	100.0	1	all
CITY OF MOUNT VERNON	03 4816_2	1	0	0	n/a	n/a	n/a	n/a
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	5	0	100.0	100.0	5	all
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	27	0	100.0	100.0	27	all
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	4,809	0	100.0	100.0	4,809	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	0	0	n/a	n/a	n/a	n/a
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	396	0	100.0	100.0	396	all
MARY MARGARET VAUGHAN	03 4807	3	0	0	n/a	n/a	n/a	n/a
MARY MARGARET VAUGHAN	03 4806	3	4	0	100.0	100.0	4	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	103	0	100.0	100.0	103	all
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	320	5	98.1	98.4	275	1978
SARA M. DUNHAM TRUST	A 4148B	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148	3	2,744	0	100.0	100.0	2,744	all
SARA M. DUNHAM TRUST	A 4148A	3	2,744	41	98.8	98.5	1,800	1957
CITY OF PECAN GAP	A 4205	1	34	0	100.0	100.0	34	all
DELTA COUNTRY CLUB INC.	03 4801	3	0	0	n/a	n/a	n/a	n/a
CITY OF COOPER	03 4800	1	462	59	81.4	87.2	180	1956
CITY OF COOPER	A 4395	1	462	0	100.0	100.0	462	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	244	0	99.9	100.0	239	1957
CITY OF WOLFE CITY	03 4795_2	1	0	0	n/a	n/a	n/a	n/a
WEBB HILL COUNTRY CLUB	03 4796_1	3	22	0	98.8	99.4	18	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					98.7			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						99.9		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurreıce is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

Supplemental Information Regarding Water Right Identification Numbers

WATER RIGHT PERMITTEE	WATER RIGHT NO.	TYPE OF USE	REASON FOR MULTIPLE ENTRY OF WATER RIGHT ID NUMBERS
CITY OF TEXARKANA	03 4836	1	Priority date = March 5, 1951
CITY OF TEXARKANA	03 4836	1	Priority date = February 17, 1957
CITY OF TEXARKANA	03 4836	1	Priority date = September 9, 1967
CITY OF TEXARKANA	03 4836	2	Priority date = February 17, 1957
CITY OF TEXARKANA	03 4836	2	Priority date = September 19, 1967
TEXAS UTILITIES MINING CO. / TU SVCS	03 5562_1	2	Multiple diversion points
TEXAS UTILITIES MINING CO. / TU SVCS	03 5562_2	2	Multiple diversion points
TEXAS UTILITIES MINING CO. / TU SVCS	03 5562_3	2	Multiple diversion points
CITY OF MOUNT VERNON	03 4816_1	1	Priority date = March 1, 1976
CITY OF MOUNT VERNON	03 4816_2	1	Priority date = November 22, 1982
CITY OF SULPHUR SPRINGS	03 4812_1	1	Priority date = February 1, 1975 (Storage Only)
CITY OF SULPHUR SPRINGS	03 4812_2	1	Priority date = February 12, 1985 (Diversion Only)
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	Priority date = July 24, 1951
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	Priority date = November 25, 1968
E. P. LAND & CATTLE CO., INC.	03 4805_1	3	Storage Only
E. P. LAND & CATTLE CO., INC.	03 4805_2	3	Storage Only
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	Multiple diversion points
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	Multiple diversion points
HELMUT HERMANN, ET AL	03 4803_1	3	Multiple diversion points, priority date = June 19,1978
HELMUT HERMANN, ET AL	03 4803_2	3	Multiple diversion points, priority date = June 19,1978
HELMUT HERMANN, ET AL	03 4803_3	3	Priority date = November 15, 1982
CITY OF WOLFE CITY	03 4795_1	1	Priority date = December 31, 1925
CITY OF WOLFE CITY	03 4795_2	1	Priority date = August 12, 1957
WEBB HILL COUNTRY CLUB	03 4796_1	3	Priority date = March 11, 1968
WEBB HILL COUNTRY CLUB	03 4796_2	3	Priority date = April 18, 1983, additional impoundment

Comparison of the various numbers presented in Table ES-3 for the different runs indicates that the effects of different levels of reuse, water rights cancellations, and varying reservoir area-capacity relationships do not appreciably influence the ability of the existing water rights (those not subject to cancellation) to obtain their authorized diversion amounts. This is not surprising, considering the abundant supply of surface water in the Sulphur River Basin relative to the total amount of existing authorized diversions. The mean annual naturalized flow at the downstream end of the basin at the state line is on the order 2.5 million acre-feet. The total of the authorized diversions for the basin is less than 400,000 acre-feet.

At the bottom of Table ES-3 for each of the eight different runs, basin-wide reliability values also are presented. These include the average percentage value for all water rights reflecting the percent of the total months analyzed for which the full authorized diversion for each water right was satisfied and the percentage of the total authorized diversions for all water rights that was actually diverted over the entire 1940-1996 analysis period. As indicated, on the average, the simulation results show that the water rights in the basin are able to divert their entire authorized amounts about 85 to 90 percent of the time, depending on which run is considered. With regard to total diversion volume, on the order of 98 to 99 percent of the total authorized diversion amount for the entire Sulphur River Basin can be diverted over the entire 1940-1996 analysis period.

The reliability results summarized in Table ES-3 do identify several problems with regard to water availability for some individual water rights. In particular, the very low reliabilities indicated for diversions by Water Right 03-4832 (City of New Boston), Water Right 03-4824 (Walter W. Lee), and Water Right 03-5392 (Paul A. Piefer, et ux), suggest that the small drainage areas, small storage volumes, and/or lack of storage limit the water available at these locations.

Flow-duration curves have been computed for Control Points C10, which is below the confluence of the North and South Sulphur Rivers, and F10, which is the Sulphur River outlet at the Texas-Arkansas state line. These are presented in Figures ES-6 and ES-7, respectively. Curves are shown for naturalized flows and for regulated flows as simulated with the WRAP model for Run 1 (fully authorized diversions with full return flows), Run 3 (fully authorized diversions with no return flows, i.e. 100% reuse), and Run 8 (maximum use for the last 10 years and existing return flows, i.e. current conditions). Comparison of these curves can be used to assess the cumulative impact of appropriations on regulated streamflows. As can be seen from the curves, Run 3 results in the greatest reduction in streamflows from the naturalized conditions. This is to be expected because fully authorized diversions are modeled and return flows are eliminated.

FIGURE ES-6
ANNUAL FLOW-DURATION CURVES AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

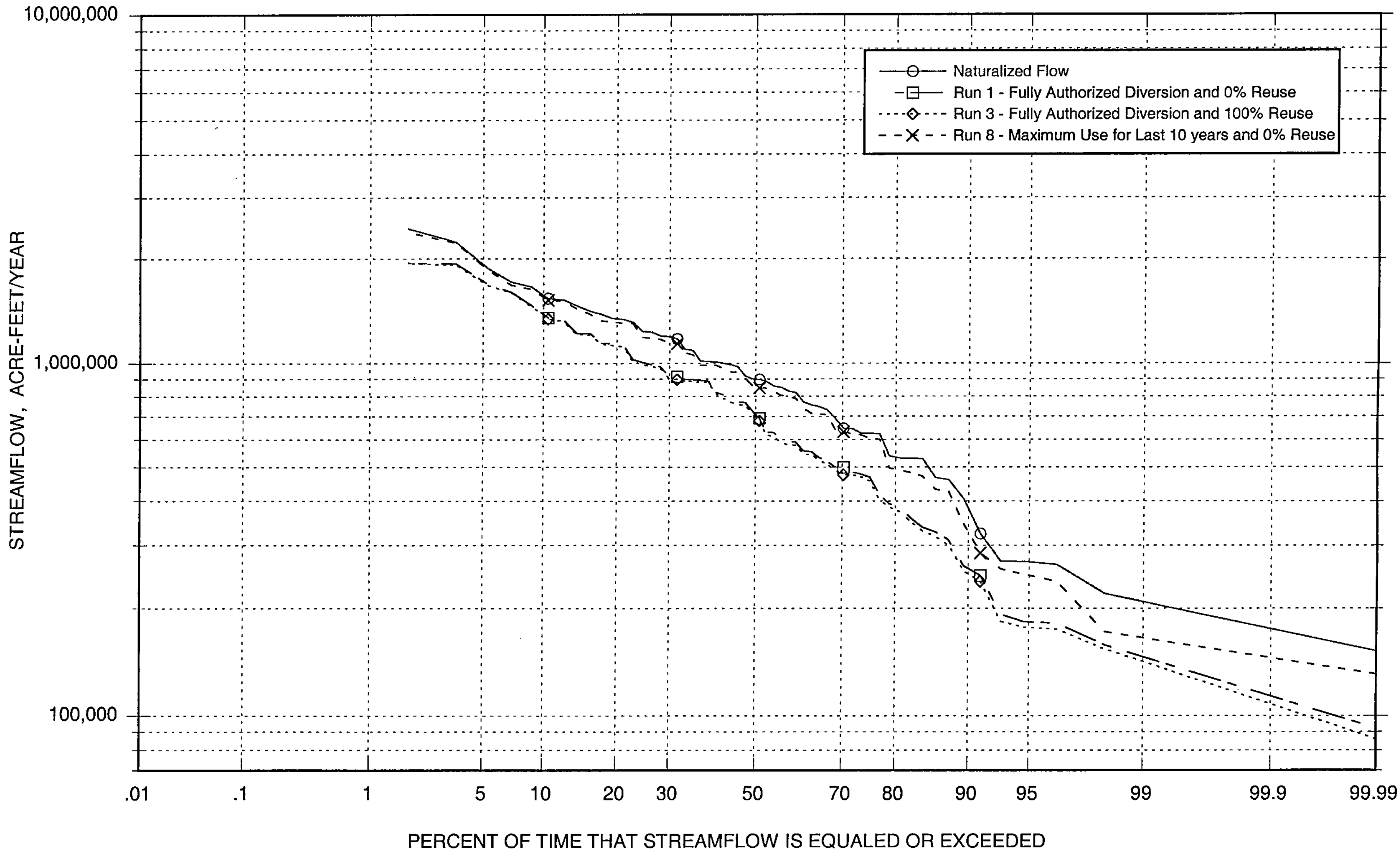
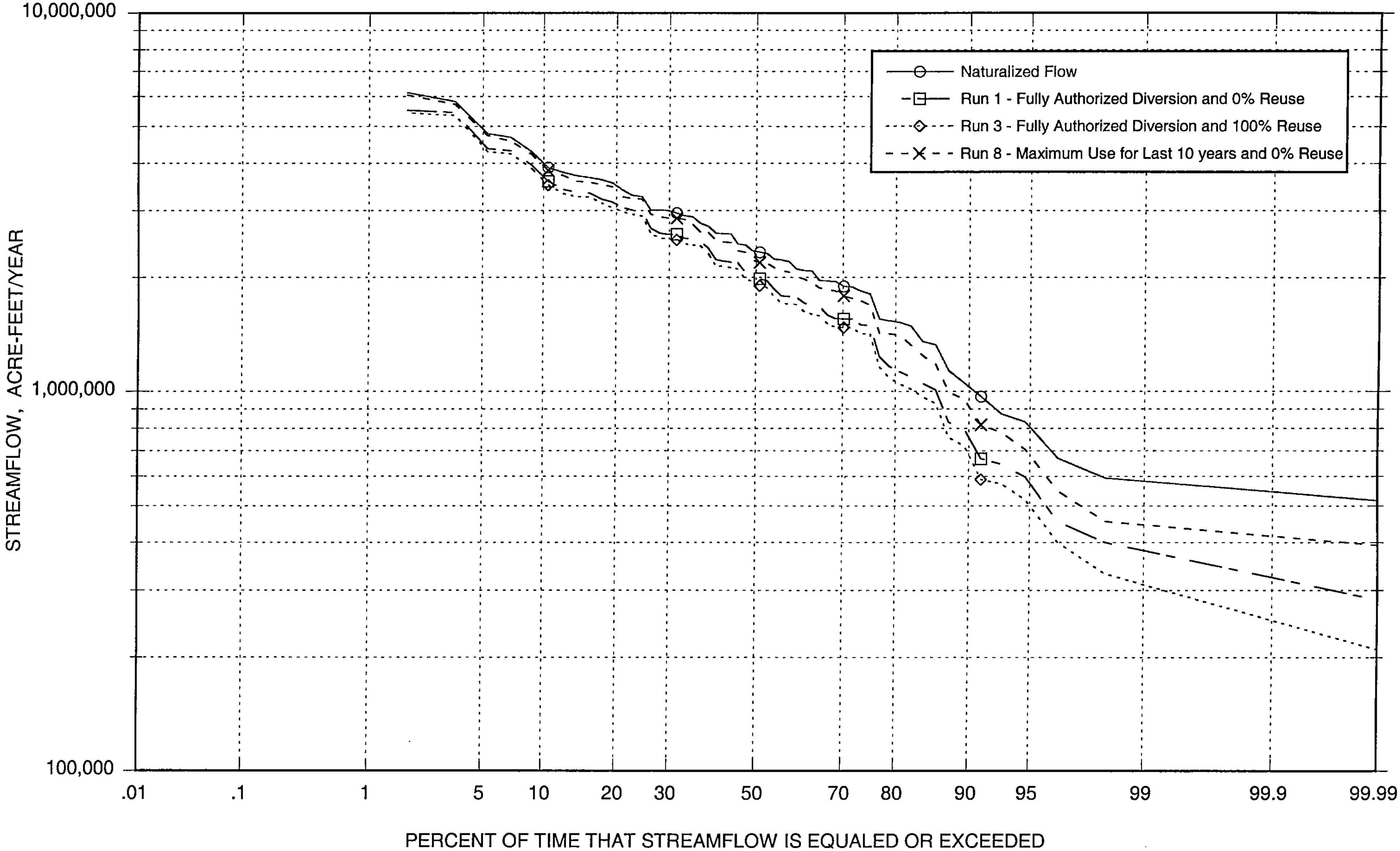


FIGURE ES-7
ANNUAL FLOW-DURATION CURVES AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F



FACTORS AFFECTING WATER AVAILABILITY AND MODELING RESULTS

The single issue of most concern with regard to the water availability analyses performed for the Sulphur River Basin and the results from the WRAP model relates to the accuracy of the naturalized streamflows that have been used in the calculations. The problems associated with estimating historical streamflows for the lower reaches of the basin for the period 1961 through 1996 are documented in the final report. The primary reason for these uncertainties is that the inflows to Wright Patman Lake were deduced through water balance analyses, rather than derived directly from actual streamflow measurements. Because of these uncertainties, the resulting naturalized streamflows as used in the water availability analyses may not truly represent actual streamflow conditions. However, at this time, it appears that there are neither more reliable data nor any other better means available for developing the required naturalized streamflows.

Another factor that may have influenced the water availability and modeling results relates to the possibility that the drainage areas and SCS curve numbers assigned to individual control points for modeling purposes may not accurately reflect actual watershed conditions, particularly for the smaller water rights on small tributaries. The accuracy of the drainage areas derived using GIS procedures is limited by the resolution of the available digital elevation data. For the Sulphur River Basin, the only digital elevation data that have been available to date are based on 90-meter-square cells. Consequently, some of the resulting GIS-based drainage areas that have been used for distributing the naturalized streamflows from gaged to ungaged locations may have caused the available streamflows for some water rights to be underestimated. Apparently, more refined digital elevation data (30-meter-square cells) will be forthcoming from the U. S. Geological Survey in 1999, and these data should provide for a better definition of drainage areas in the WRAP model.

Also, the procedures that have been used in the WRAP model for describing off-channel reservoirs with stream diversions for make-up water and with separate reservoir diversions for associated uses (such as irrigation) may not effectively represent actual operations in all cases. It is possible that the procedures used may not allow the maximum use of available water by these water rights. The model fills such reservoirs beginning in January of each year and keeps the reservoirs full until the annual limit of streamflow depletions is reached. This keeps the reservoir full for as long as possible and may tend to increase evaporation losses. Actual practice could be somewhat different. This primarily affects the reported reliability of the water right since that is calculated based on diversions out of the off-channel reservoir, rather than diversions out of the stream and into the off-channel reservoir. However, actual diversions out of the stream are still maximized in accordance with the water right's priority.

Water rights with multiple diversion points generally have been represented in the model either by using the most downstream diversion point for all diversions or by grouping some of the diversions at a single point and assigning a portion of the annual authorized diversion amount for a given water right to this group of diversions. The allocation of different fractions of the annual authorized diversion amount to individual diversion points can only be estimated considering such factors as drainage area size and historical water use patterns. Because of these uncertainties, there may be some unnecessary limitations on water availability as simulated with the WRAP model for those water rights with multiple diversion points.

One last point to note relates to the manner in which the WRAP model, through its strict application of the prior appropriation doctrine, handles the authorized monthly-varying conservation storage specifications for Wright Patman Lake that are contained in its Certificate of Adjudication. Basically, the existing water right for Wright Patman Lake authorizes different amounts of conservation storage depending on the month of the year. The schedule of authorized maximum conservation storage amounts for Wright Patman Lake are listed in the following table.

MAXIMUM MONTHLY CONSERVATION STORAGE CAPACITY
FOR WRIGHT PATMAN LAKE

MONTH	AUTHORIZED STORAGE CAPACITY acre-feet	MONTH	AUTHORIZED STORAGE CAPACITY acre-feet
January	265,300	July	380,800
February	265,300	August	355,700
March	265,300	September	324,900
April	325,300	October	302,000
May	385,800	November	282,600
June	386,900	December	273,600

A potential problem exists when the authorized conservation storage capacity for Wright Patman Lake increases from one month to the next, such that a sudden demand for water occurs in order to fill the newly created conservation storage. For example, between March and April and between April and May, the conservation storage capacity of the reservoir increases instantaneously by 60,000 acre-feet. In a perfect world under strict interpretation of the prior appropriation doctrine, Wright Patman Lake would be entitled to the additional 60,000 acre-feet of water required to fill its conservation pool in each of these months before any upstream junior water rights could store or divert the water, and this is exactly how the WRAP model simulates the Wright Patman Lake water right. The effects of these sudden demands for stored water in Wright Patman Lake are apparent in the simulated operations of Jim Chapman Lake, which is junior to Wright Patman Lake and located upstream on the South Sulphur River. During periods of low streamflow, inflows to Jim Chapman Lake are passed in order to satisfy the senior downstream demand for stored water in Wright Patman Lake. The effect of passing of these inflows is to cause additional shortages in the demands for water from Jim Chapman Lake (as authorized by water rights held by North Texas Municipal Water District, City of Irving, and Sulphur River Municipal Water District) to be shorted during 1956 and 1957, i. e., the critical drought period for the reservoir. The occurrence of these shortages is evident in the annual diversion plot presented in Figure ES-3. This situation probably is somewhat artificial and not likely to happen under current reservoir operating procedures and water rights administration policies. Nonetheless, it is reflected in the results from the WRAP model. The TNRCC staff has confirmed that the prior appropriation doctrine, for purposes of the Senate Bill 1 water availability analyses, requires that all conservation storage capacity in reservoirs with senior water rights must first be completely filled before any upstream junior water rights can store or divert water. This situation may warrant further clarification and interpretation from TNRCC in order to provide more realistic projections of water availability.

SUMMARY AND CONCLUSIONS

The revised Texas A&M WRAP model, now known as WRAP-SIM, has been applied to the Sulphur River Basin in Texas to determine water availability. All 54 water rights in the basin have been modeled for a 57-year period of naturalized streamflows under eight different scenarios (referred to as "Runs"). The runs consist of three basic sets of conditions: (1) fully authorized diversion amounts and varied return flow amounts (Reuse Runs), (2) varied diversion amounts and varied return flow assumptions (Cancellation Runs), and (3) approximate current diversion and return flow conditions with year-2000 area-capacity relationships for reservoirs (Current Conditions Run). Special conditions reflecting environmental flow requirements have been included in all model runs where applicable. Only four water rights in the basin have permitted special conditions associated with environmental flow needs.

The primary conclusions from this water availability investigation and modeling effort for the Sulphur River Basin are as follows:

1) The Sulphur River Basin is a prolific water resource. It is in one of the highest rainfall and lowest evaporation areas of the state. There are approximately 400,000 acre-feet per year of authorized (State-permitted) diversions in the basin,

yet naturalized flows at the Texas-Arkansas state line have averaged approximately 2.5 million acre-feet per year during the period 1940 through 1996. During the driest years of record (1963 and 1956), the flows still have been in the range of 500,000 to 600,000 acre-feet.

2) Based on simulated results from the WRAP water availability model of the basin assuming fully authorized diversions by all water rights, the major diverters rarely, if ever, experience shortages. The one exception is at Jim Chapman Lake where shortages are indicated in 1956 and 1957.

3) Comparison of the WRAP results from the different runs indicates that the effects of varying levels of reuse, water rights cancellations, and reservoir sedimentation conditions (area-capacity relationships) do not appreciably influence the ability of the existing water rights (those not subject to cancellation) to obtain their authorized diversion amounts. Similarly, there is little impact on the storage conditions for the major reservoirs in the basin, with the exception of Jim Chapman Lake, where the diversion rights were simulated as cancelled for the cancellation and current conditions runs, resulting in significantly increased storage.

4) Based on the simulation results from the WRAP model for all of the different runs, the average percentage of time that the water rights in the basin are able to divert their entire authorized amounts varies between about 85 and 90 percent, depending on which run is considered. With regard to the total diversion volume for all water rights, on the order of 98 to 99 percent of the total authorized diversion amount for the entire Sulphur River Basin can be diverted over the entire 1940-1996 analysis period.

5) Selected water rights exhibit very low reliabilities in obtaining their authorized diversion amounts. This is likely attributable to small drainage areas and the lack of sufficient storage.

6) Representation of off-channel reservoirs in the WRAP model generally results in small shortages for water rights where there is no difference between the amount of water that can be diverted into the off-channel reservoir and the amount that can be consumed for the stated use. This is because the model limits the annual amount of water that can be placed into storage for such a reservoir. This results

in the amount available to be diverted out of the reservoir for consumption being reduced by evaporative losses.

7) Simulated results from the WRAP model indicate that there is a significant quantity of unappropriated water in the basin. The impacts on unappropriated water of the effects of varying levels of reuse, water rights cancellations, and reservoir sedimentation conditions (area-capacity relationships) as analyzed with the various runs are indicated to be relatively small. The greatest impact occurs for the current conditions run and those cancellation runs where the 10-year maximum use has been specified, since the actual historical diversions during the last ten years were substantially less than the fully appropriated diversion amounts. Future appropriations are subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code.

8) The single issue of most concern with regard to the water availability analyses performed for the Sulphur River Basin and the results from the WRAP model relates to the accuracy of the naturalized streamflows that have been used in the calculations. In particular, there is uncertainty in the estimation of historical streamflows for the lower reaches of the basin for the period 1961 through 1996 because of the absence of gaged flows into or below Wright Patman Lake. However, at this time there are neither more reliable data nor any other better means available for developing the required naturalized streamflows.

1.0 INTRODUCTION

1.1 BASIN DESCRIPTION

The Sulphur River Basin lies within 11 counties (Bowie, Cass, Delta, Fannin, Franklin, Hopkins, Hunt, Lamar, Morris, Red River, and Titus) in northeast Texas and drains an area of approximately 3,600 square miles within Texas. From the state line, the Sulphur River flows into Arkansas and eventually joins with the Red River, a tributary of the Mississippi River. Figure 1-1 presents a general map of the Sulphur River Basin and shows its location in northeast Texas.

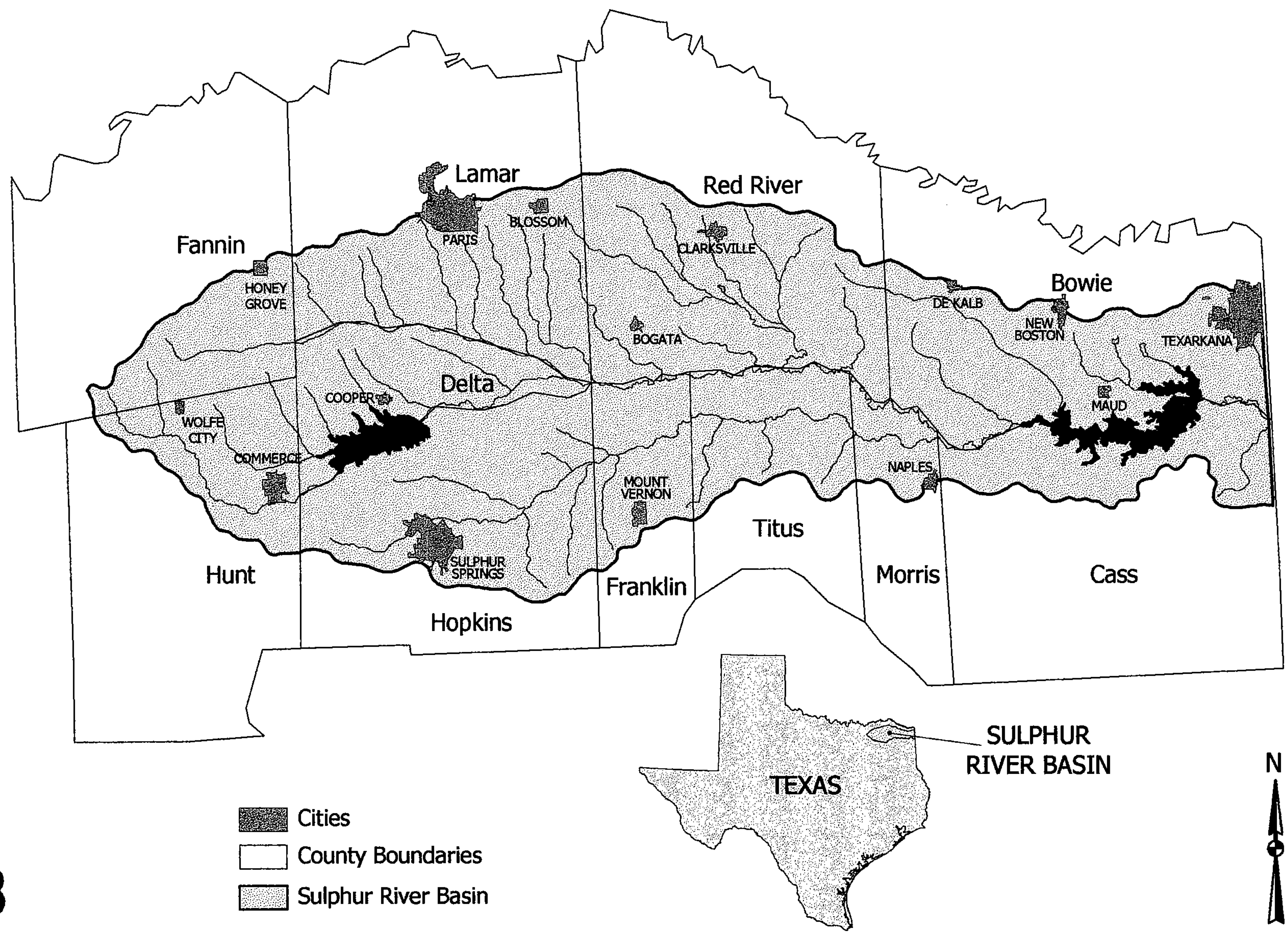
The South and North Sulphur Rivers originate in southern Fannin County and flow eastward 50 to 60 miles to their confluence on the boundary of eastern Delta and Lamar Counties. In the late 1920's, the U. S. Army Corps of Engineers initiated extensive channelization of these streams, particularly the North Sulphur River, for flood control purposes, and the confluence of the rectified channels was moved some distance west of where the natural confluence existed. This confluence forms the Sulphur River, which flows eastward an additional 75 miles to the Texas-Arkansas state line. White Oak Creek is the largest tributary of the Sulphur River, and it drains about 500 square miles in the southern part of the basin, including the city of Sulphur Springs. Ground elevations in the basin range from about 700 feet above sea level at the headwaters down to about 190 feet at the state line.

The climate of the basin is classified as humid subtropical. Rainfall is high, and average annual precipitation ranges from approximately 40 inches in the western portion of the basin to approximately 47 inches at the state line. The mean annual gross lake evaporation rate within the basin is approximately 50 inches, nearly the lowest in the state. The low evaporation rates are the result of the low wind speeds and high average relative humidity that characterize the region.

The Sulphur River Basin is largely rural in nature and lies in the Coastal Plain geographic province. Overall relief is low. The western part of the basin lies in the Blackland Prairie belt and generally is comprised of open rolling prairies with small tracts of woodlands. Pasture and cropland are the predominant land uses. The eastern part of the basin lies in the Forested Coastal Plain and is typically forested, with a smaller amount of cropland and pasture. Since the 1940's, land use has changed from primarily cropland (mostly cotton) to a predominance of pastureland.

The total population of the basin increased from about 154,000 in 1980 to around 162,000 in 1990. By 2050, the basin population is projected to increase to 196,000 (TWDB, 1997). The largest

FIGURE 1-1
SULPHUR RIVER BASIN LOCATION MAP



cities are Texarkana (32,000[1] – Texas side), Sulphur Springs (14,000), Commerce (7,000), and New Boston (5,000). The city of Paris (25,000) lies on the divide between the Sulphur and Red River Basins. Water for Paris is supplied from the Red River Basin.

The Sulphur River Basin is a prolific water resource, primarily because of the high annual rainfall. Average runoff is estimated to range from about 14 inches per year (750 acre-feet per square mile) in the eastern portion of the basin to about 10 inches per year (550 acre-feet per square mile) at the headwaters. Surface water resources supply more than 91 percent of the water used for all purposes in the basin, with groundwater supplying the remainder.

Wright Patman Lake (formerly Lake Texarkana), covering approximately 20,000 acres and located on the Sulphur River about seven miles upstream of the state line, and Jim Chapman Lake (formerly Cooper Lake), covering about 19,000 acres and located on the South Sulphur River near the city of Cooper, are the two largest reservoirs within the basin. These reservoirs are owned and operated by the U. S. Army Corps of Engineers, and they provide water supply, flood control, and recreational benefits. Several other minor impoundments exist on tributaries, the most significant of which is Lake Sulphur Springs (sometimes referred to as White Oak Reservoir). This reservoir covers approximately 1,600 acres on White Oak Creek in Hopkins County and is owned by the Sulphur Springs Water District. Wright Patman and Jim Chapman Lakes and Lake Sulphur Springs are permitted by the State to supply approximately 336,000 acre-feet of water per year. Wright Patman Lake, which was constructed in the mid-1950's, is the water supply source for the city of Texarkana and for a number of smaller cities in Bowie County, as well as major industries in the region. Jim Chapman Lake, which began impoundment in 1991, provides supplemental water supplies for its water rights owners, i. e., the City of Irving, the North Texas Municipal Water District, and the Sulphur River Municipal Water District, and by contract to the Upper Trinity Regional Water District. Lake Sulphur Springs supplies municipal water primarily to the City of Sulphur Springs.

There are 29 impoundments in the Sulphur River Basin with a normal storage capacity greater than 200 acre-feet. The total storage capacity of these impoundments is about 750,000 acre-feet; however, Lakes Wright Patman, Jim Chapman, and Sulphur Springs comprise approximately 95 percent of this total capacity. The permitted authorized diversions from these impoundments total about 376,000 acre-feet per year. Approximately 49 percent of the total authorized diversion volume is for municipal supply purposes, and about 44 percent is for industrial usage. The remainder is for irrigation and other (fish and wildlife) purposes.

[1] 1990 population based on U. S. Census Bureau data (Texas State Library, 1998).

1.2 STUDY OBJECTIVES

Pursuant to Senate Bill 1 passed by the 75th Texas Legislature, the Texas Natural Resource Conservation Commission (TNRCC) must develop or acquire new reservoir/river basin simulation models in order to determine available water in accordance with the Texas Water Code. Under Contract No. 9880059300 with TNRCC, R. J. Brandes Company (RJBCO) of Austin, Texas has performed these water availability analyses for the Sulphur River Basin. Specifically, naturalized streamflows have been developed for the Sulphur River Basin, and the Texas A&M Water Rights Analysis Package (WRAP) (Wurbs, 1996, 1998, 1999) has been applied to model and determine available water in the basin in accordance with the requirements of Senate Bill 1.

The water availability analyses being undertaken by the TNRCC pursuant to the requirements of Senate Bill 1 are intended to provide useful information that will assist existing water rights holders, prospective water rights applicants, regional water supply planning entities, and state water and environmental regulatory agencies in determining the quantities of water that are likely to be available for use throughout a river basin under varying climatic and hydrologic conditions. This process necessarily includes consideration and application of the Prior Appropriation Doctrine as it dictates the priorities (based on permit application dates) by which limited water supplies must be allocated among existing water rights within a basin during low-flow or drought periods when authorized water demands may exceed available water supplies.

As stated in Senate Bill 1, the following information is to be developed by the TNRCC through water availability analyses for each of the river basins in the state, excluding the Rio Grande[2]:

1. For all holders of existing permits, certified filings, and certificates of adjudication, the projected amount of water that would be available during a drought of record and when flows are at 75 percent of normal and at 50 percent of normal.

2. For each regional water planning group created under Section 16.053 as amended by Senate Bill 1, the projected amount of water that would be available if cancellation procedures were instigated under Subchapter E, Chapter 11 of the Texas Water Code.

3. In coordination with the Texas Parks and Wildlife Department, the potential impact of reusing municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries.

[2] Water rights in the Middle and Lower Rio Grande Basins in Texas are not subject to the prior appropriation doctrine, but rather are founded on and regulated in accordance with the decision of the Thirteenth Court of Civil Appeals in "State of Texas, et al. vs. Hidalgo County Water Control and Improvement District No. 18, et al.", 1969; and therefore, the Rio Grande Basin has been excluded from the Senate Bill 1 water availability analyses. However, there are other efforts underway involving water availability modeling above and below Fort Quitman.

1.3 STUDY APPROACH

The TNRCC, working with the Texas Water Development Board (TWDB) and the Texas Parks and Wildlife Department (TPWD) and with assistance from outside consultants, has developed specific procedures and criteria for undertaking the water availability analyses pursuant to the requirements of Senate Bill 1, with consideration of the Prior Appropriation Doctrine, the Texas Water Code, and the water management and regulatory policies of the TNRCC. The basic procedure applied in analyzing water availability in any particular river basin involves simulating on a monthly basis the ability of individual water rights to satisfy their authorized diversions or storage quantities in accordance with the Prior Appropriation Doctrine under hydrologic conditions characterized by historical, but naturalized streamflows. By taking into consideration a wide range of naturally occurring streamflow conditions, the results from these analyses provide a meaningful indication of the extent to which water will be available for specific water rights in the foreseeable future.

For performing the actual water availability calculations, the TNRCC has adopted the Texas A&M WRAP model (Wurbs, 1996). The simulation routine in this model balances available water in terms of streamflows at specified control points against specified demands that reflect the authorized diversions and storage amounts of existing water rights. The WRAP model incorporates the Prior Appropriation Doctrine and has been applied to a number of Texas river basins to simulate water availability for a wide variety of different types of water rights. To better address the specific requirements of the water availability analyses as required by Senate Bill 1, the TNRCC has engaged the author of the WRAP model from Texas A&M to make a number of useful modifications (Wurbs, 1998, 1999). The resulting model has been called WRAP-SIM, but is referred to as WRAP in this document. The version of WRAP used for this water availability analysis is known as the February 1999 version (Wurbs, 1999). This version of WRAP was the best available at the time of modeling for the Sulphur River Basin.

Naturalized streamflows must be used in the water availability analyses so that the diversion and storage amounts for individual water rights can be satisfied at any prescribed levels without double accounting for their effects in the baseline (historical) streamflows. Naturalized streamflows represent historical streamflow conditions, including typical wet, dry, and normal flow periods, without the influence of man's historical activities as they relate to water rights and water use. In essence, naturalized streamflows exclude the effects of historical diversions, return flows, and reservoir storage and evaporation.

The process of determining water availability for existing and future water rights in the Sulphur River Basin has encompassed several sequential steps, with the output from one task providing the input to subsequent tasks. The initial effort involved the compilation and organization of all available data describing and pertaining to existing water rights, historical gaged streamflows, historical reservoir operations, historical surface water diversions, historical return flows, and historical rainfall and reservoir evaporation. In addition, information contained in previous water resources studies and in the files and records of such agencies as the TNRCC, TWDB, U. S. Geological Survey, U. S. Department of Agriculture Natural Resources Conservation Service, and the U. S. Army Corps of Engineers also has been compiled, reviewed and examined.

Development of the naturalized streamflow data base for the basin probably has been the most import activity in the overall process. This has involved adjusting historical streamflows at gage locations for the effects of historical diversions, return flows, and reservoir storage and evaporation, and developing continuous naturalized streamflow records for the desired analysis period. For the Sulphur River Basin, this analysis period extends from 1940 through 1996. The WRAP model has been used to perform the actual analyses of water availability by simulating monthly streamflows throughout the basin for the 1940-1996 hydrologic period in response to specified diversions, reservoir storage, and special conditions for each water right. The principal results from these simulations are the monthly quantities of water that would be available for diversion and/or storage by the individual water rights over the 1940-1996 hydrologic period, with all senior water rights fully honored to the extent that water is available. These quantities, in essence, provide a measure of water availability for each water right, taking into consideration actual hydrologic conditions as they have occurred over the last 50 years or so and the higher priorities of other water rights. By examining these results for drought-of-record and 50-percent and 75-percent of normal streamflow conditions as they have occurred during the 1940-1996 hydrologic period and under varied assumptions regarding water rights cancellations and reuse of municipal and industrial effluent, the specific information required by Senate Bill 1 has been developed.

The water availability results presented in this report represent only a partial summary of the complete sets of output generated with the WRAP model for the Sulphur River Basin. Information regarding available water for diversion and storage by some of the larger and typical water rights is presented, along with summaries of projected unappropriated water at selected locations within the basin. Complete water availability summaries for all existing water rights in the Sulphur River Basin under various drought conditions and assumptions regarding cancellation and reuse are available from the TNRCC.

2.0 EXISTING WATER AVAILABILITY INFORMATION

2.1 WATER RIGHTS

The locations and general types of existing water rights in the Sulphur River Basin are identified on the map in Figure 2-1. The total amount of authorized diversions for these water rights is approximately 380,000 acre-feet per year. As indicated in Table 2-1, approximately 49 percent of the total authorized diversion volume is for municipal supplies and about 44 percent is for industrial purposes. The remainder is for irrigation and other (fish and wildlife) uses. All water rights issued by the TNRCC through August 7, 1998 have been included in the Sulphur River Basin water availability model.

TABLE 2-1 SULPHUR RIVER BASIN DIVERSION RIGHTS BY USE CATEGORY

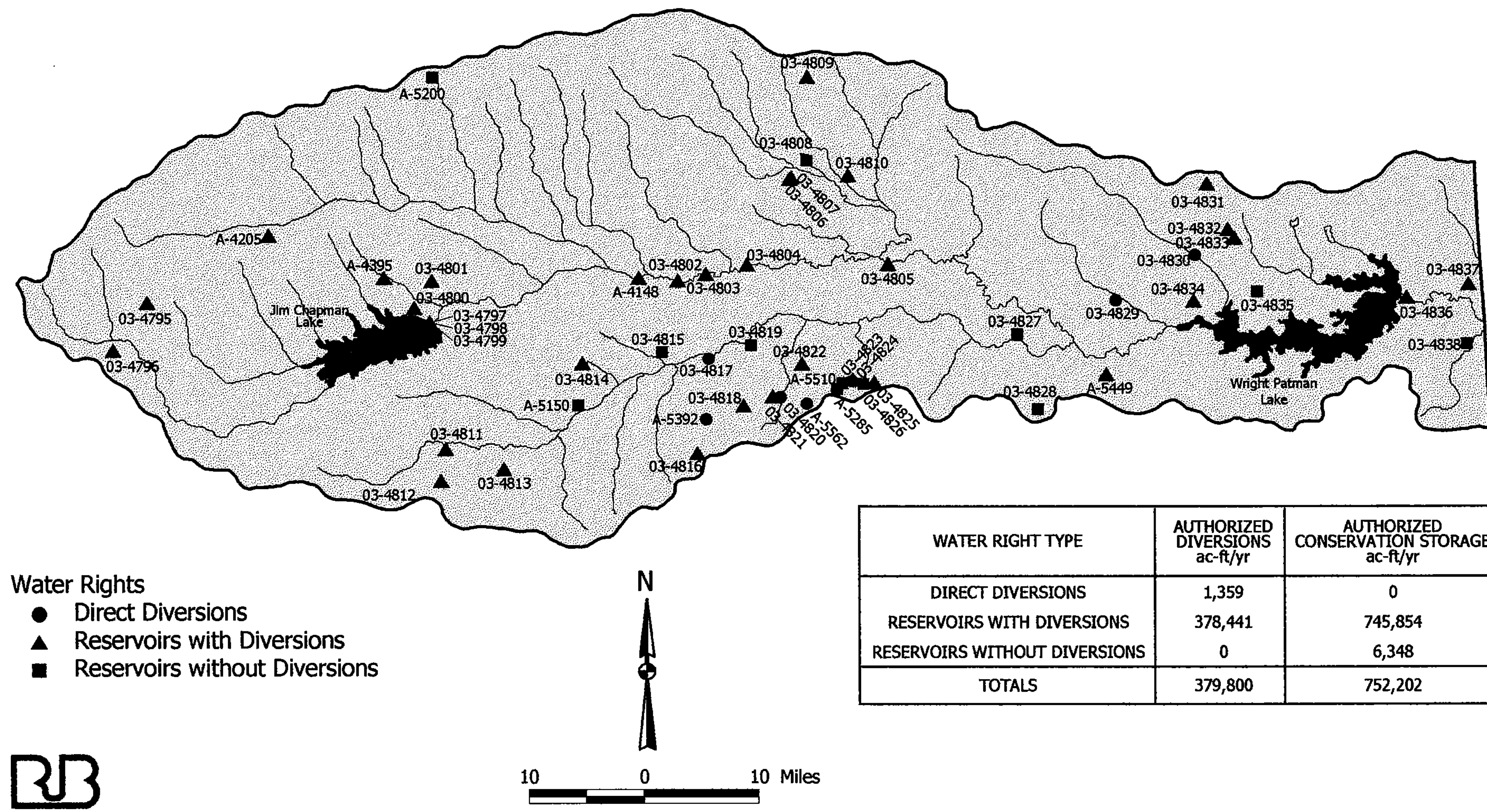
USE CATEGORY	NUMBER OF RIGHTS	AUTHORIZED DIVERSION acre-feet/year
Municipal	15*	185,057
Industrial	9*	165,875
Irrigation	23	26,635
Mining	0	0
Recreation	9	0
Other	1	863
TOTAL	- -	378,430

* Note: Three water rights include both municipal and industrial uses.

There are 54 identifiable existing water rights located within the Sulphur River Basin. These are listed in Table 2-2 in river order beginning at the downstream end of the basin, and they include all existing certificates of adjudication and permits that authorize the diversion and/or storage of surface water throughout the basin. Information in the table for each water right includes the water right number[1], the name of the permittee, the county and stream where the water right is located, the type of authorized use (municipal, industrial, irrigation, etc.), the amount of authorized annual diversion and/or storage capacity, and the oldest priority date associated with each water right in accordance with the Prior Appropriation Doctrine. Amendments to individual water rights are indicated by sequential alphabetic characters, with the letter "A" representing the first

[1] Water right numbers preceded by "03" refer to Certificates of Adjudication; those preceded by the letter "A" refer to permits issued by the TNRCC since the adjudication process.

FIGURE 2-1
EXISTING WATER RIGHTS IN THE SULPHUR RIVER BASIN BY TYPE



WATER RIGHT TYPE	AUTHORIZED DIVERSIONS ac-ft/yr	AUTHORIZED CONSERVATION STORAGE ac-ft/yr
DIRECT DIVERSIONS	1,359	0
RESERVOIRS WITH DIVERSIONS	378,441	745,854
RESERVOIRS WITHOUT DIVERSIONS	0	6,348
TOTALS	379,800	752,202

RJB

TABLE 2-2

EXISTING WATER RIGHTS IN THE SULPHUR RIVER BASIN (8/7/98)

Water Right Identification No.[1]	Amend-ments	WRAP Control Point No.	County	Permittee's Name	Stream	Type of Use[2]	Diversion Amount Ac-Ft/Yr	Irrigation Acreage Acres	Reservoir Capacity Ac-Ft	Oldest Priority Date	Facility
03- 004838		F40	Cass	INTERNATIONAL PAPER CO.	GRASSY CRK	7			52	17-Nov-75	SUPERVISOR'S CLUB RESERVOIR
03- 004837		F50	Bowie	LEON S KENNEDY JR	CRUTCHERS CRK	3	80	157	550	30-Jun-62	KENNEDY LAKE
03- 004836		F60	Bowie	CITY OF TEXARKANA	SULPHUR RIVER	1	45,000		386,900	5-Mar-51	WRIGHT PATMAN LAKE
03- 004836		F60	Bowie	CITY OF TEXARKANA	SULPHUR RIVER	2	135,000			17-Feb-57	WRIGHT PATMAN LAKE
03- 004835		F70	Bowie	JERRY D PRATHER ET UX	UNNAMED TRIB MOSS CRK	7			78	31-Dec-48	
03- 004833		F80, F81	Bowie	H C PRANGE JR	UNNAMED TRIB RICE CRK	2	8		14	31-Jan-56	
03- 004832	A	F90	Bowie	CITY OF NEW BOSTON	HOLLY BR	1	325		8	29-Aug-44	
03- 004831	A	F100	Bowie	CITY OF NEW BOSTON	UNNAMED TRIB RICE CRK	1	31		259	30-Jun-14	
03- 004830		F110	Bowie	WILLIAM E JOHNSON JR ET AL	UNNAMED TRIB	3	378	501		30-Apr-40	
03- 004834		F120	Bowie	WILLIAM E JOHNSON JR ET AL	BROOKS CRK	3	39	66	15	30-Apr-40	
03- 004829		F140	Bowie	WILLIAM E JOHNSON JR ET AL	EDS CRK	3	4	16		30-Apr-40	
A- 005449		F150	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8	863		504	18-Feb-93	ON-CHAN RESERVOIR
A- 005449		F151	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8			436	18-Feb-93	OFF-CHAN RES - CELL #1
A- 005449		F151	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8			195	18-Feb-93	OFF-CHAN RES - CELL #2
A- 005449		F151	Cass	TEXAS PARKS & WILDLIFE DEPT	TOYAH CRK	8			232	18-Feb-93	OFF-CHAN RES - CELL #3
03- 004828		E30	Morris	GLASS CLUB LAKE INC	UNNAMED TRIB VILLAGE CRK	7			500	29-Jan-73	
03- 004827		E40, E50	Morris	BROVENTURE COMPANY INC	MURPHY BR	7			1,455	18-Oct-74	
03- 004825		E60	Titus	ROBERT CROOKS ET AL	E PINEY CRK	3	20	7	30	31-Dec-63	
03- 004826		E70	Titus	ELLIS-KELLY LAKE CLUB	E PINEY CRK	7			151	8-Jan-73	
03- 004823		E80	Titus	ARDELIA GAUNTT	UNNAMED TRIB PINEY CRK	3	22	16	24	1-Jun-65	
03- 004824		E90	Titus	WALTER W LEE	UNNAMED TRIB PINEY CRK	3	7	4		1-Jun-65	
A- 005285		E110	Titus	TEXAS UTIL MINING CO/TU SVCS	UNNAMED TRIB PINEY CRK	2			190	20-Feb-90	MONTICELLO B-2 MINING AREA
A- 005510		E100	Titus	TEXAS UTIL MINING CO/TU SVCS	UNNAMED TRIB	4			172	3-Jan-95	MONTICELLO B-2 MINE, POND L-1
03- 004822		E120	Titus	JOHN E & BERNICE BALDWIN	UNNAMED TRIB MCCULLOUGH CRK	3	100	58	196	31-Jul-67	
03- 004821		E130	Titus	ANNA PEARL LEWIS	UNNAMED TRIB RIPLEY CRK	2	1		1	31-Dec-53	
03- 004820		E160	Titus	BILLY J MAXTON	RIPLEY CRK	3	22	22		31-Dec-64	
A- 005562		E140, E150, E170	Titus	TEXAS UTILITIES MINING CO	UNNAMED TRIBS RIPLEY/DORSEY CRKS	2	125			19-Nov-96	MONTICELLO-WINFIELD N. LIGNITE MINE
03- 004819		D20	Franklin	DDC PROPERTIES LTD	LICK CRK	7			2,360	18-Mar-74	LAKE ROMAL
03- 004818		D30	Franklin	ROBERT W CAMPBELL ET AL	UNNAMED TRIB CAMPBELL CRK	3	11	21	24	31-Dec-64	
03- 004817		D40	Franklin	HANS WEISS ET UX	BEAR PEN CRK	3	333	200		30-Jun-64	
A- 005392		D50	Franklin	PAUL A PIEFER ET UX	TOWN BR	3	341	207		6-Dec-91	
03- 004816		D60	Franklin	CITY OF MOUNT VERNON	DENTON CRK	1	400		434	1-Mar-76	
03- 004815		D70	Franklin	CHARLES HELM & LEWIS HELM	UNNAMED TRIB MITCHELL CRK	7			760	28-Mar-76	
03- 004814		D80	Hopkins	JERRY N JORDAN TRUSTEE ET AL	UNNAMED TRIB WOLFPEN CRK	3	30	12	26	16-Jul-59	
A- 005150		D90	Hopkins	LARRY MILES ET AL	UNNAMED TRIB	1			269	28-Jul-87	
03- 004813		D100	Hopkins	SULPHUR SPGS COUNTRY CLUB	UNNAMED TRIB ROCK CRK	3	113	75	127	15-Dec-75	
03- 004812		D110	Hopkins	CITY OF SULPHUR SPRINGS	UNNAMED TRIB WHITE OAK CRK	1	408		408	1-Dec-75	LAKE COLEMAN

TABLE 2-2, CONT'D

EXISTING WATER RIGHTS IN THE SULPHUR RIVER BASIN (8/7/98)

Water Right Identification No.[1]	Amend-ments	WRAP Control Point No.	County	Permittee's Name	Stream	Type of Use[2]	Diversion Amount Ac-Ft/Yr	Irrigation Acreage Acres	Reservoir Capacity Ac-Ft	Oldest Priority Date	Facility
03- 004811		D120	Hopkins	SULPHUR SPRINGS WATER DIST	WHITE OAK CRK	1	9,800		17,838	24-Jul-51	LAKE SULPHUR SPRINGS
03- 004810		E190	Red River	PERRY R BASS INC	SAND BR	3	200	106	200	4-Apr-60	MAGIC VALLEY LAKE
03- 004809		E200	Red River	RED RIVER COUNTY WCID 1	LANGFORD CRK	1	1,120		1,225	20-Jan-64	LANGFORD CR LAKE
03- 004809		E200	Red River	RED RIVER COUNTY WCID 1	LANGFORD CRK	2	1			20-Jan-64	
03- 004808		E210	Red River	RED RIVER COUNTRY CLUB	PICKETT CRK	7			670	6-Jan-75	SOUTH LAKE
03- 004806		E230	Red River	MARY MARGARET VAUGHAN	BARNARD DRAW	3	8	8	75	22-Sep-69	
03- 004807		E220	Red River	MARY MARGARET VAUGHAN	BARNARD DRAW	3	22	22		22-Sep-69	
03- 004805		E240, E250, E260, E270	Titus	E P LAND & CATTLE CO INC	UNNAMED TRIB SULPHUR RIVER	3	3,700	1,500	2,063	5-Jan-81	
03- 004804		C20, C21	Red River	TEXAS UTILITIES ELECTRIC CO	SULPHUR RIVER	2	10,000		7,100	5-Mar-52	RIVERCREST STEAM ELEC. STA.
03- 004803		C30, C40	Franklin	HELMUT HERMANN ET AL	UNNAMED TRIB SULPHUR RIVER	3	1,900	750	328	19-Jun-78	TERRY LAKE
03- 004802		C50	Red River	ALEXANDER FRICK ET AL	UNNAMED TRIB SULPHUR RIVER	3	278	94	300	31-Dec-55	
A- 004148		C70, C71	Delta	SARA M DUNHAM TRUST	OLD CHANNEL S SULPHUR RIVER	3	3,500	1,924	3,875	14-Sep-81	
A- 004148	A	C80, C81	Delta	SARA M DUNHAM TRUST	OLD CHANNEL S SULPHUR RIVER	3	5,500	3,162	3,623	7-Nov-84	
A- 004148	B	C60, C61	Delta	SARA M DUNHAM TRUST	SULPHUR R & S SULPHUR RIVER	3	11,312	13,511	2,925	11-Apr-97	
A- 005200		C100	Lamar	GORDON COUNTRY CLUB	COTTONWOOD BR	7			394	1-Nov-88	
A- 004205		B20	Fannin	CITY OF PECAN GAP	UNNAMED TRIB SULPHUR RIVER	1	102		152	26-Apr-82	
03- 004801		C110	Delta	DELTA COUNTRY CLUB INC	UNNAMED TRIB BRUSHY CRK	3	5	1	34	2-Jul-79	
03- 004800		A20	Delta	CITY OF COOPER	CEDAR CRK	1	273		164	3-Jan-77	
A- 004395		A30	Delta	CITY OF COOPER	BIG CRK	1	1,518		4,890	6-Sep-83	
03- 004799		A40	Delta	CITY OF IRVING	S SULPHUR RIVER	1	44,820		114,265	19-Nov-65	JIM CHAPMAN LAKE
03- 004799		A40	Delta	CITY OF IRVING	S SULPHUR RIVER	2	9,180			19-Nov-65	JIM CHAPMAN LAKE
03- 004798		A40	Delta	NORTH TEXAS MWD	S SULPHUR RIVER	1	54,000		114,265	19-Nov-65	JIM CHAPMAN LAKE
03- 004797	B	A40	Delta	SULPHUR RIVER M W D	S SULPHUR RIVER	1	26,960		81,470	19-Nov-65	JIM CHAPMAN LAKE
03- 004797	B	A40	Delta	SULPHUR RIVER M W D	S SULPHUR RIVER	2	11,560			19-Nov-65	JIM CHAPMAN LAKE
03- 004797	A	A40	Delta	CITY OF COMMERCE	S SULPHUR RIVER	1				19-Nov-65	JIM CHAPMAN LAKE
03- 004797	A	A40	Delta	CITY OF COMMERCE	S SULPHUR RIVER	2				19-Nov-65	JIM CHAPMAN LAKE
03- 004795		A70	Hunt	CITY OF WOLFE CITY	E FRK TURKEY CRK	1	300		855	31-Dec-25	
03- 004796		A80	Hunt	WEBB HILL COUNTRY CLUB	UNNAMED TRIB S SULPHUR RIVER	3	80	80	60	11-Mar-68	

[1] Water Right Identification No.: 03 = Certificate of Adjudication in Basin 03 (Sulphur Basin)
A = Application Number associated with Water Right Permit

[2] Type of use:
1 = Municipal
2 = Industrial
3 = Irrigation
7 = Recreation
8 = Other

amendment. All of these water rights have been accounted for and represented with regard to their individual features in the WRAP model of the Sulphur River Basin.

2.2 HISTORICAL WATER USE

The Texas Water Development Board (TWDB) has summarized historical water use and made future water use projections for the Sulphur River Basin. Total water used within the basin increased by over 50 percent from 1980 to 1990. This significant increase was attributable to a large increase in manufacturing water use during this decade. Water used for manufacturing purposes now accounts for about 70 percent of all water used within the basin. Currently, surface-water resources supply over 90 percent of the water used for all purposes in the basin, with groundwater supplying the balance.

A summary of historical water use and future demand projections from the TWDB is presented in Table 2-3. Water exported from the Sulphur River Basin to other basins is not included in these totals. However, water imported from other basins and used in the Sulphur River Basin is included.

TABLE 2-3 SULPHUR RIVER BASIN HISTORICAL WATER USE AND DEMAND PROJECTIONS
(acre-feet/year)

USE CATEGORY	1980	1990	2000 (projected)	2050 (projected)
Municipal	28,063	25,770	29,286	28,621
Manufacturing	45,120	88,281	87,627	93,844
Steam Electric	1,947	1,494	1,500	5,000
Mining	1,328	1,155	1,725	1,202
Irrigation	1,775	2,066	2,044	1,933
Livestock	6,459	9,540	9,934	9,934
TOTAL	84,692	128,306	132,116	140,534

Source: TWDB, 1997

2.3 HISTORICAL RETURN FLOWS

Historically, water has been discharged into the surface-water system of the Sulphur River Basin as return flows from municipal and industrial wastewater treatment plants, mine dewatering operations, and other miscellaneous sources. Both the TNRCC and the TWDB maintain historical records of many of these return flows as reported by individual dischargers. Based on these data, the locations and average amounts of return flows discharged into the basin have been determined, and these data have been used in the water availability analyses for the Sulphur River Basin.

The locations of known currently existing return flows within the Sulphur River Basin are identified on the map in Figure 2-2. On the map, these return flows are identified by name, which usually refers to the specific city or industry discharging the return flows via a wastewater treatment plant, and by category, which relates to whether a given return flow source is from surface-water diversions associated with an existing water right. Those return flows not associated with an existing water right (surface-water diversions) originate either from groundwater or from surface water that has been purchased from a water right holder within the basin or imported into the basin from an adjacent basin. The vast majority of return flows discharged into the basin are predominantly associated with existing water rights. The specific quantities of return flows for individual dischargers as specified in the WRAP model for purposes of the water availability analyses of the Sulphur River Basin are presented in Section 4.0.

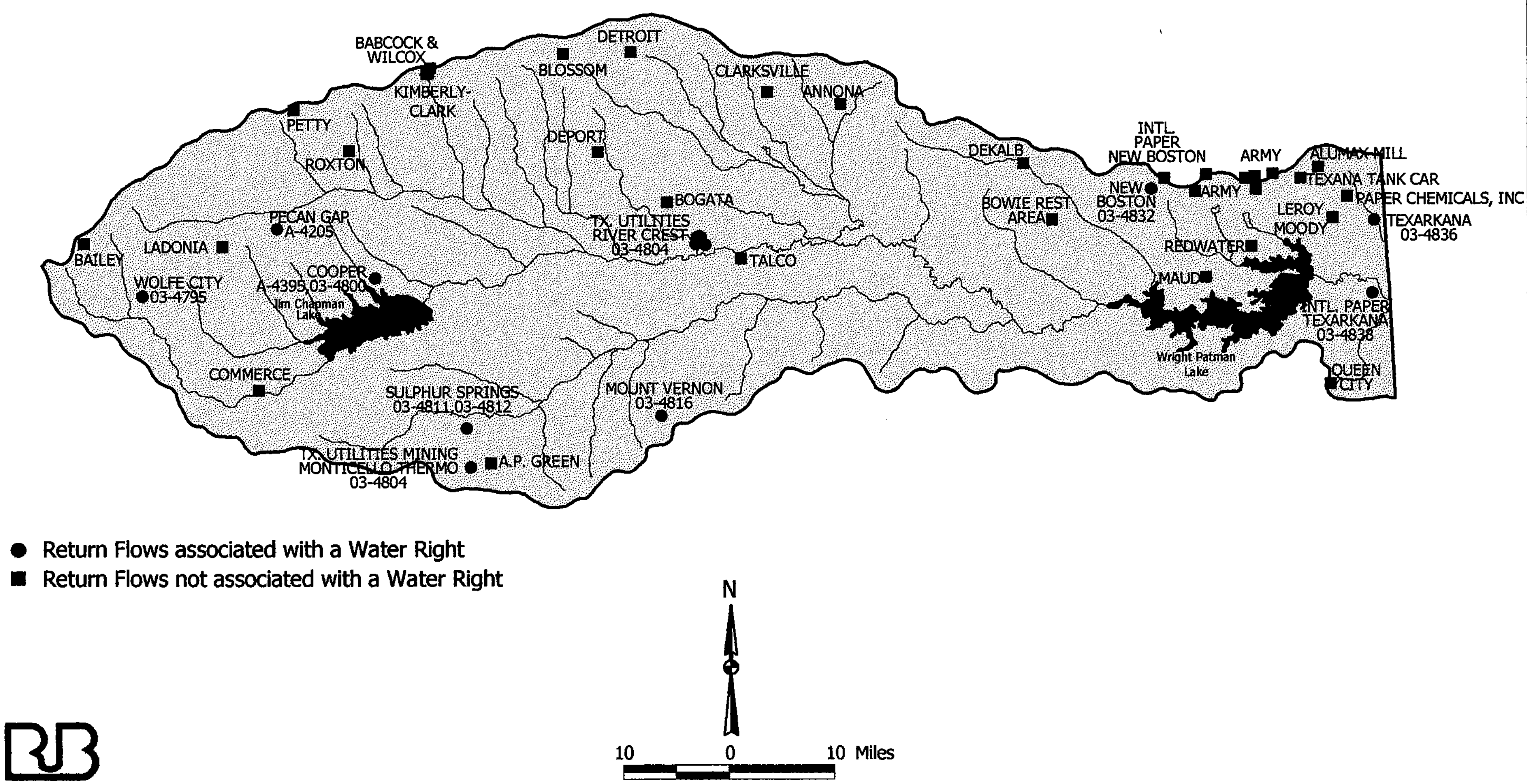
2.4 PREVIOUS WATER AVAILABILITY AND PLANNING STUDIES

No formal comprehensive studies of water availability with respect to existing basin-wide water rights have been previously conducted for the Sulphur River Basin by either regional or state agencies. Furthermore, the water availability modeling that was previously conducted by the predecessor agencies of the TNRCC for selected basins in Texas during the 1970's and 1980's also did not include the Sulphur River Basin (TNRCC, 1998). The U. S. Bureau of Reclamation, however, did conduct studies of water availability throughout Texas for the U. S. Study Commission-Texas in the early 1960's. The Sulphur River Basin was included in this federally sponsored investigation (USBR, 1960).

In the late 1960's and early 1970's, the TWDB conducted hydrologic data refinement studies for several basins in Texas, including the Sulphur River Basin (TWDB, 1971). While this study did not address water availability directly, it did result in the development of naturalized streamflows for several of the streamflow gages in the basin for the period 1925 through 1968.

The most recent water planning studies of the basin have been conducted by the TWDB as part of preparing the statewide water plan titled "Water For Texas" (TWDB, 1997). In this effort, the TWDB evaluated existing surface and ground water supplies, examined historical water use and projected future water demands by various use categories, quantified potential future water needs both within and outside the basin, and identified prospective surface-water development projects,

FIGURE 2-2
EXISTING RETURN FLOWS IN THE SULPHUR RIVER BASIN



including major reservoirs, that could be implemented to satisfy future water demands. On the Sulphur River just upstream of the White Oak Creek confluence, the TWDB 1997 plan includes Marvin Nichols I Reservoir, with a maximum conservation storage capacity of 1,369,717 acre-feet and an annual supply of 560,151 acre-feet, as a recommended project. George Parkhouse II Reservoir, with a maximum conservation storage capacity of 243,617 acre-feet and an annual supply of 134,232 acre-feet, also is a recommended project located on the North Sulphur River. Both of these projects are proposed as supplemental water supplies to meet local needs and the projected water demands in the Dallas-Fort Worth metroplex area.

In addition to the planning studies conducted by the TWDB, various local water authorities also have performed studies to evaluate potential water supply projects in the Sulphur River Basin. These have included earlier studies of now existing Wright Patman Lake on the Sulphur River and Jim Chapman Lake on the South Sulphur River, as well as, Lake Sulphur Springs and other smaller projects. The U. S. Army Corps of Engineers performed several of these studies. Parkhouse and Nichols Reservoirs also have been investigated by various water supply entities in the Dallas-Fort Worth area.

2.5 SIGNIFICANT CONSIDERATIONS AFFECTING WATER AVAILABILITY

The overall process of determining water availability for existing water rights and potential future water resource development projects in an entire river basin such as the Sulphur requires substantial data and information. Descriptions of historical streamflows, evaporation and precipitation, reservoir storage and releases, diversions, return flows, watershed changes affecting runoff, water facility operations, and hydrologic system physiography are needed. In some cases, monthly variations of these quantities over the last 50 to 60 years are required in order to effectively establish representative naturalized hydrologic conditions for different parts of the basin. Complete records for these quantities seldom, or never, exist, and it is inevitable that some parameters have to be estimated and certain simplifying assumptions have to be made.

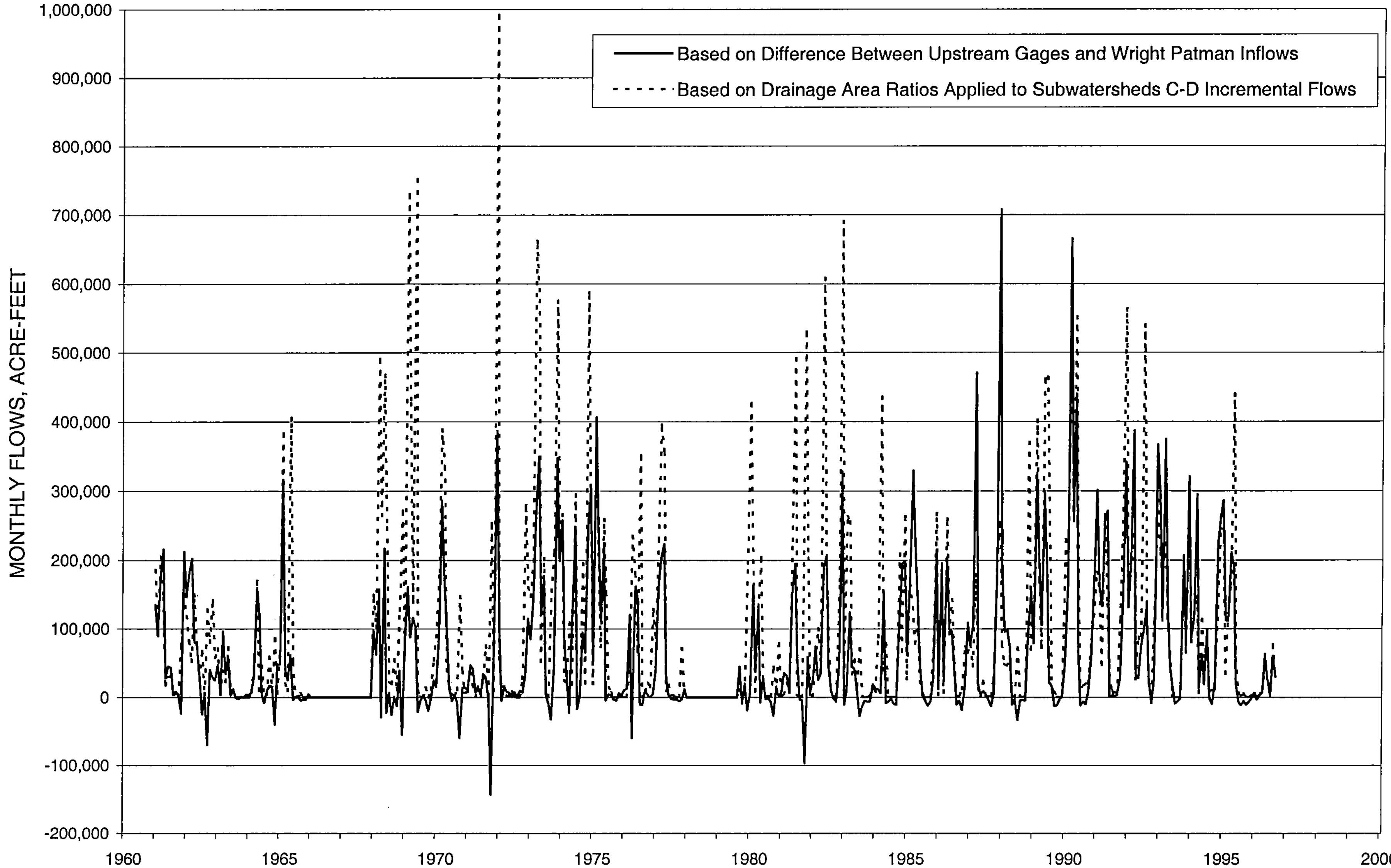
Certainly, this is the case for the Sulphur River Basin, and the accuracy of estimated parameters and the reasonableness of assumptions used in the water availability analyses directly affect the end results. Probably, the single issue of most concern with regard to the water availability analyses performed for the Sulphur River Basin relates to the accuracy of the naturalized streamflows that have been used in the calculations. Although, for the upper and middle reaches of the basin, actual historical streamflow measurements have been used for establishing monthly naturalized streamflows for most of the 1940 through 1996 analysis period, corresponding gaged streamflow data for the lower portion of the basin generally have not been available. In this lower reach, estimates of total historical streamflows have been made for the period 1961 through 1996 based on the calculated inflows to Wright Patman Lake as deduced through water balance analyses involving historical monthly changes in reservoir storage, net evaporation losses, water supply diversions, return flows, and downstream releases. The accuracy of the resulting calculated streamflow values is directly dependent, of course, on the accuracy of the input data used in the analyses. It is common knowledge that there often are inherent uncertainties in such parameters as reservoir storage determined from stage-area-capacity relationships, evaporation from a reservoir surface when estimated from pan evaporation measurements, total rainfall on a reservoir based on limited gage locations in the vicinity of the reservoir, diversions derived from pump operation records, and reservoir releases based on gate discharge ratings. Furthermore, it is practically impossible to estimate water losses from an existing reservoir due to seepage, infiltration, and depression storage without considerable hydrogeologic data and supporting hydrologic and topographic information. In this study, contacts have been made with personnel from the U. S. Army Corps of Engineers in the Fort Worth District Office and in the Field Office at Wright Patman Lake to discuss the possibility of significant unidentified water losses from the reservoir that may not have been properly accounted for in the inflow calculation process. Other than gate leakage, which potentially could have been as much as 50 cubic feet per second during some low release periods, the Corps noted no major sources of unaccounted for water losses from the reservoir.

The true extent to which the calculated historical inflows to Wright Patman Lake represent actual streamflows in the lower portion of the Sulphur River Basin is not fully known. Comparisons of the naturalized versions of these calculated reservoir inflows with corresponding monthly values of the naturalized streamflows at upstream gages, after adjustment for travel time, indicate the occurrence of periodic zero or negative incremental monthly inflows from the intervening watershed, i. e., the upstream gaged streamflows equal or exceed the corresponding downstream calculated reservoir inflows. Zero incremental inflows from the intervening watershed certainly could be possible as runoff may have occurred above the upstream gages in response to rainfall in certain months when no rainfall occurred below the gages; hence, there would have been no runoff from the intervening watershed and the reservoir inflows would have been equal to the upstream gaged streamflows. Negative incremental inflows from the intervening watershed, however, suggest either the occurrence of significant channel losses along the reach of the river through the intervening watershed or possible inaccuracies in either the upstream gaged streamflows or the downstream calculated reservoir inflows. As described later in this report in Section 3.1.3, the potential for significant channel losses along the lower reach of the Sulphur River is not supported by existing geologic and subsurface conditions in this area. Therefore, it may be most likely that the negative incremental inflows from the intervening watershed are the result of inaccuracies in either the upstream gaged streamflows or the downstream calculated reservoir inflows.

While there are several possible approaches for adjusting the naturalized streamflows used in the water availability analyses to account for the negative incremental inflows from the intervening watershed above Wright Patman Lake, the most appropriate means to use remains somewhat uncertain. The negative incremental inflow monthly values simply could be set to zero, recognizing that theoretically they should not occur in any significant magnitudes and are likely the result of errors in either the gaged streamflows or the calculated reservoir inflows. This is probably conservative from the standpoint of water availability in that there probably was, at least, some inflow, not zero, from the intervening watershed during those months when the negative values are indicated; hence, setting the negative incremental inflows to zero probably understates the available water supply. Another possibility would be to replace the negative incremental monthly inflow values with corresponding streamflows from the upstream gages, after adjustment for drainage area size. While this approach generally would always provide some inflow from the intervening watershed, it is based on the assumption that whatever occurs during any given month with respect to rainfall and runoff within the watershed above the upstream gages also occurs in exactly the same manner within the intervening watershed downstream between the gages and Wright Patman Lake. This assumption, of course, is known to not always hold true. A third approach would be to abandon the calculated reservoir inflows for Wright Patman Lake altogether and, instead, use the streamflows from the upstream gages, after adjustment for drainage area size, as the sole basis for estimating inflows from the intervening watershed above Wright Patman Lake. Again, this approach is somewhat flawed because it assumes uniform historical rainfall and runoff conditions across the entire region above Wright Patman Lake.

A comparison of the monthly naturalized incremental inflows from the watershed between Wright Patman Lake and the upstream gages for the period 1961 through 1996, exclusive of portions of 1966, 1967, 1978 and 1979, is presented in Figure 2-3. This comparison was derived by: (1) subtracting the naturalized streamflows at the upstream gages from the naturalized calculated reservoir inflows to Wright Patman Lake; and (2) adjusting based on drainage area size (drainage area ratio) the naturalized streamflows at the upstream gages to represent the incremental watershed between Wright Patman Lake and the upstream gages. The negative incremental inflows resulting from application of the first method using the calculated reservoir inflows to Wright Patman Lake are readily apparent on the graph. As indicated, these conditions typically occur during periods of relatively low flow as denoted by both of the curves. What is most peculiar is the significant difference between the high inflow values as derived with the two methods. Those based on simply adjusting the upstream gaged streamflows for drainage area size (Method 2) are significantly higher than those derived from the calculated inflows to Wright Patman Lake. One possible reason for these streamflow variations could be differences in land use conditions. The intervening watershed between Wright Patman Lake and the upstream gages is much more forested than the upstream watershed above the gages, which largely is composed of

FIGURE 2-3
COMPARISON OF INCREMENTAL NATURALIZED FLOWS FOR SUBWATERSHED E AND SUBWATERSHED F ABOVE WRIGHT PATMAN LAKE



cropland and pasture. Runoff from forested areas typically is less than that from cropland and pasture; hence, the trend for less runoff from the intervening watershed and corresponding lower streamflows would appear to be reasonable.

Considering that the calculated reservoir inflows to Wright Patman Lake should provide a better representation of actual hydrologic conditions for the intervening watershed between the reservoir and the upstream gages, as opposed to the drainage-area adjusted streamflows derived from the upstream gaged streamflows, it has been decided for purposes of the water availability analyses to use the naturalized streamflows based on the calculated reservoir inflows. In deriving these naturalized streamflows, the negative incremental inflows from the intervening watershed between Wright Patman Lake and the upstream gages have been set equal to zero. As noted previously, this is probably conservative with regard to water availability since it is likely that, at least, some runoff actually occurred from the intervening watershed during some of the months characterized by negative incremental inflows.

2.6 RED RIVER COMPACT

Under the terms of the Red River Compact, the State of Texas is entitled to the "free and unrestricted use" of all water in the Sulphur River Basin above Wright Patman Lake. However, flows from the Texas portion of the Sulphur River Basin below Wright Patman Lake are subject to certain restrictions in the Red River Compact that guarantee minimum flows to the State of Louisiana. The Compact provides that when the flow at a stream gage on the Red River at the Arkansas-Louisiana state line falls below 3,000 cfs, certain flows originating in the Red River Basin portions of Texas, Oklahoma and Arkansas, including the Sulphur River Basin below Wright Patman Lake, must be delivered downstream to Louisiana. Only two existing water rights in the Texas portion of the Sulphur River Basin are downstream of Wright Patman Lake (Water Right Numbers 03-004838 and 03-004837). They have a total authorized diversion of 80 acre-feet per year. Considering this relatively small amount of annual diversion and the fact that deliveries of flows to Louisiana from this portion of the Sulphur River Basin have never been required under the Compact, the terms of the Compact have not been considered in the water availability model.

3.0 HYDROLOGIC DATA REFINEMENT

3.1 NATURAL STREAMFLOWS AT GAGED LOCATIONS

3.1.1 Streamflow Naturalization Methodology

Knowing the amount and distribution of naturalized streamflows throughout the Sulphur River Basin is fundamental to the analysis of water availability for existing water rights as required by Senate Bill 1 and to the determination of unappropriated water when considering water availability for new water rights. By definition, naturalized streamflows represent historical streamflow conditions, including typical wet, dry and normal flow periods, without the influence of man's activities as they relate to water rights and water use. For example, the construction and operation of reservoirs, the diversion of surface waters, and the discharge of return flows are all activities related to water rights and water use that have had an impact on historical streamflows. In the determination of naturalized streamflows, the historical effects of these types of activities on streamflows must be removed from those portions of the historical streamflow records when such activities actually occurred. The resulting historical trace of naturalized streamflows then represents streamflow conditions uninfluenced by man's water rights or water use activities such that these streamflows can be used for water availability analyses.

When performing water availability analyses, the potential effects of all existing water rights within a basin, i. e., diversions and reservoir storage, must be considered and accounted for in accordance with their individual water rights priorities. Similarly, the effects of any anticipated return flows also must be factored into the analyses. In essence, for purposes of the water availability analyses, the historical record of naturalized streamflows is readjusted to reflect the anticipated future effects of man's water rights and water use activities, taking into account the potential effects of these activities over the entire period of record of naturalized streamflows. By design, this period should be long enough to encompass a broad range of historical hydrologic conditions so that the availability of water for specific water rights and uses can be meaningfully evaluated. Typically, this would encompass on the order of 50 years of monthly streamflow data, and it would include the drought of record. For many parts of Texas, including streams in the Sulphur River Basin, the drought of record corresponds to the severe drought that occurred during the early to mid 1950's. The analysis period used in this study extends from 1940 through 1996.

The determination of naturalized streamflows for the Sulphur River Basin has involved making adjustments to historical streamflows as measured at gages or as determined from reservoir operations data in order to remove those historical influences of man related to water rights or water use. As described above, this has included adjustments for historical surface-water diversions by water rights holders; historical return flows from municipal and industrial wastewater treatment plants or other discharge operations; and historical reservoir streamflow depletions due to storage and net evaporation losses. Consideration also has been given to evaluating the potential effects of historical watershed changes involving agricultural practices or land use that may have gradually influenced runoff patterns and historical streamflows over the years and that may continue to affect streamflows in the future. In this study, the effects of these types of influences have not been found to be significant and, therefore, adjustments for these effects have not been incorporated into the final naturalized streamflow values.

In accordance with the above discussion, the general equation that has been used for calculating monthly naturalized streamflows at selected locations where historical streamflow data are available within the Sulphur River Basin is as follows:

NATURALIZED STREAMFLOW	=	HISTORICAL STREAMFLOW
	+	DIVERSIONS
	-	RETURN FLOWS
	+	RESERVOIR DEPLETIONS

The procedures and data used in quantifying and making these adjustments and the resulting naturalized streamflows are described in detail in a companion report (Brandes, 1998). Some of the more important aspects of the streamflow naturalization process also are described and presented in this section.

3.1.2 Streamflow Data Sources

Because historical measured or deduced streamflow data normally provide the basis for the streamflow naturalization process, the locations where naturalized streamflows are determined are coincident with the locations on watercourses where such historical data are available. These locations, of course, typically are where U. S. Geological Survey (USGS) streamflow gaging stations are, or have been, in operation. However, they also can be at other locations where historical streamflows can be calculated or deduced, such as at reservoirs, based on other related historical data.

For developing the naturalized streamflows for the Sulphur River Basin, historical streamflow data have been used from both actual streamflow gaging records and deduced reservoir inflows. The

USGS streamflow gages in the Sulphur River Basin for which historical streamflow data are available are listed in Table 3-1, along with their respective periods of record and drainage areas. All of these gages are shown on the map of the basin in Figure 3-1. The gaging stations that have provided historical streamflow records that actually have been used in the streamflow naturalization process are noted in the table. Also indicated are those gaging stations that define the downstream end of the individual subwatersheds that have been used in developing the naturalized streamflows.

In addition to the streamflow gage records, historical inflows to existing reservoirs in the Sulphur River Basin also have been used in the streamflow naturalization process. These include deduced or calculated monthly inflows for Jim Chapman Lake (formerly Cooper Lake) for the period October 1991, through December 1996, and for Wright Patman Lake (formerly Lake Texarkana) for the period January 1961 through December 1996, exclusive of 1966, 1967, 1978, and 1979. Although Wright Patman Lake was completed and actually began impounding water in July 1953, records of historical releases from the reservoir are available only since January 1961; hence, the historical inflows to the reservoir could only be calculated beginning in January 1961. Both Jim Chapman Lake and Wright Patman Lake are owned and operated by the U. S. Army Corps of Engineers (Corps), and much of the data used for these inflow calculations has been obtained from the Corps' District Office in Fort Worth.

The deduced monthly inflows to both Jim Chapman Lake and Wright Patman Lake have been determined based on monthly water balance calculations. This involved examination of the historical monthly changes in the amount of water stored in the reservoirs, adjusted for corresponding evaporation losses from the reservoirs' surface, direct rainfall on the reservoirs, and diversions and releases of stored water from the reservoirs, including any uncontrolled spills of floodwater. The basic equation used for determining the historical monthly reservoir inflows is stated below. In essence, it says that the monthly inflow to a reservoir is equal to the change in the storage of the reservoir from the beginning to the end of the month, plus any water lost from the reservoir due to evaporation, minus any water contributed to the reservoir due to rainfall on its surface, plus any water diverted or released from the reservoir.

$$QI_i = (ST_i - ST_{i-1}) + (EV_i * AR_i) - (PE_i * AR_i) + DV_i + RL_i$$

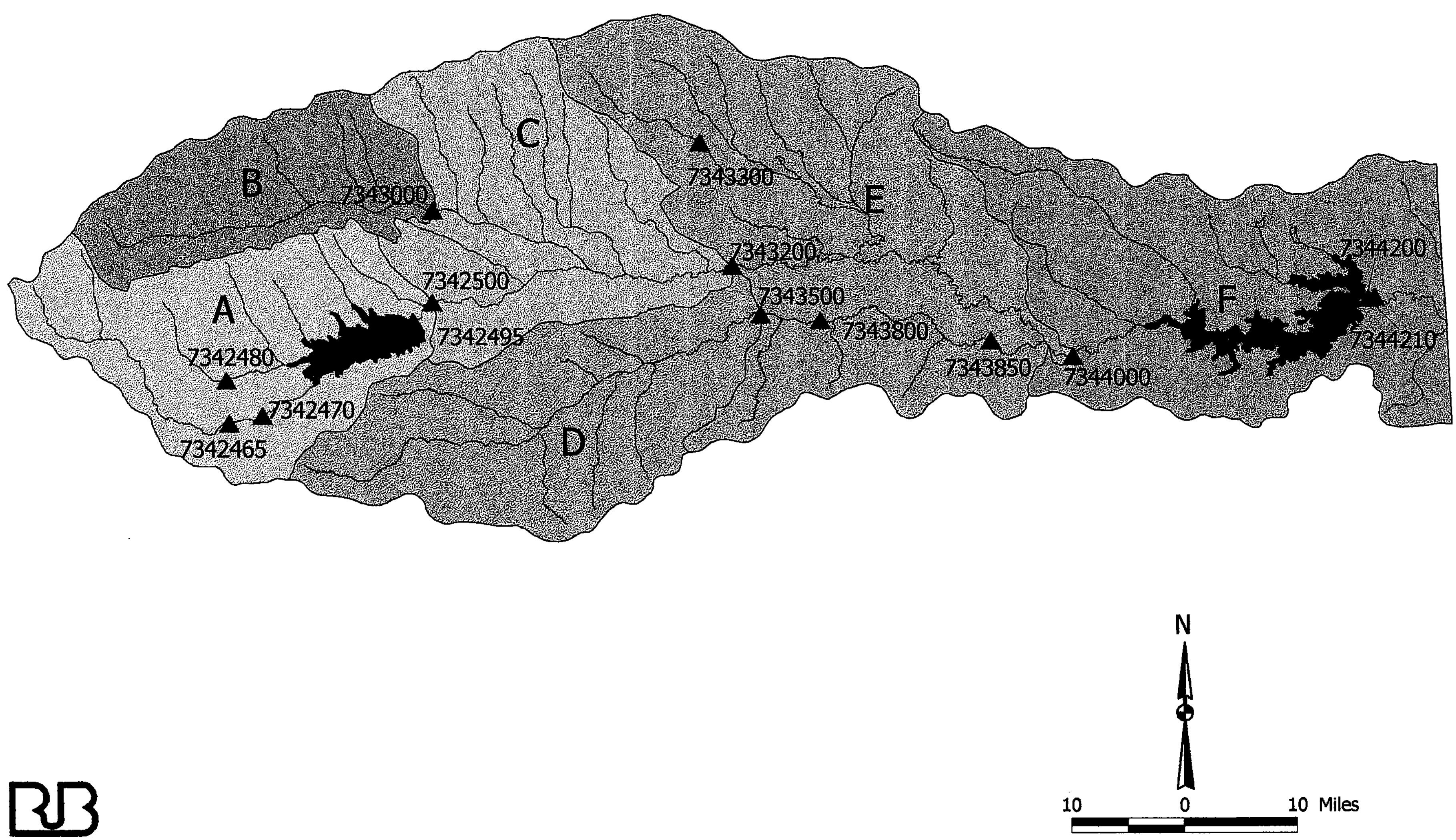
where:
QI_i = Historical inflow to the reservoir during Month i
ST_i = Storage in reservoir at end of Month i
ST_{i-1} = Storage in reservoir at end of Month i-1
EV_i = Gross reservoir evaporation rate during Month i
AR_i = Average surface area of reservoir during Month i

TABLE 3-1
STREAMFLOW GAGES IN THE SULPHUR RIVER BASIN

U.S.G.S. STATION NO.	STATION NAME	DRAINAGE AREA Sq. Miles	AVAILABLE PERIOD OF RECORD		MONTHS OF RECORD	SUB-WATERSHED TERMINUS
			BEGINNING DATE	ENDING DATE		
7342465	SOUTH SULPHUR AT COMMERCE	150	October-91	September-97	72	- -
7342470	SOUTH SULPHUR NEAR COMMERCE	189	October-87	September-97	**	- -
7342480	MIDDLE SULPHUR AT COMMERCE	44.1	October-91	September-97	72	- -
7342495	COOPER LAKE NEAR COOPER *	479	October-91	September-97	72	- -
7342500	SOUTH SULPHUR RIVER NEAR COOPER *	527	June-42	September-97	664	A
7343000	NORTH SULPHUR NEAR COOPER *	276	October-49	September-97	576	B
7343200	SULPHUR RIVER NEAR TALCO *	1,365	October-56	September-96	480	C
7343300	CUTHAND CREEK NEAR BOGATA	69	October-63	September-74	132	- -
7343500	WHITE OAK CREEK NEAR TALCO *	494	December-49	September-97	574	D
7343800	WHITE OAK CREEK BELOW TALCO *	579	October-37	November-49	145	- -
7343850	WHITE OAK CREEK NEAR OMAHA	772	February-65	September-97	**	- -
7344000	SULPHUR RIVER NEAR DARDEN *	2,774	October-23	December-56	399	E
7344200	WRIGHT PATMAN LAKE NEAR TEXARKANA *	3,443	July-53	September-97	531	- -
7344210	SULPHUR RIVER NEAR TEXARKANA	3,433	January-83	September-97	**	- -

* Used in streamflow naturalization process.
** Water Quality Stations with only limited streamflow data.

FIGURE 3-1
U.S. GEOLOGICAL SURVEY STREAMFLOW AND WATER QUALITY GAGE LOCATIONS
IN THE SULPHUR RIVER BASIN



PE_i = Effective rainfall on reservoir during Month i
DV_i = Total diversions from reservoir during Month i
RL_i = Total releases from reservoir during Month i

It should be noted that effective rainfall in the above equation, PE, is defined as that portion of the total rainfall on a given area that does not run off as stormwater, and it represents that portion of the total rainfall that generally is lost either to surface depression storage, evapotranspiration, or infiltration into the subsurface. In the reservoir inflow water balance calculations for any given month, only the effective rainfall is accounted for in the analyses so that the resulting inflow value will include the quantity of runoff that would have occurred from the reservoir area had the reservoir not been in place during the rainfall period. This procedure is necessary in order for the resulting calculated reservoir inflows to accurately represent the total runoff, or streamflow, at the location of the impounding structure or dam. This is the streamflow quantity normally required for and used in water availability analyses.

3.1.3 Delivery Factors and Channel Loss Rates

In order to develop monthly naturalized streamflows for the entire period 1940 through 1996, which is the analysis period adopted for purposes of the water availability analyses of the Sulphur River Basin, the gage-based naturalized streamflows from one gage or location sometimes have been used to estimate the naturalized streamflows at another gage or location. This is sometimes referred to "filling in" missing data records.

For this purpose, one of the methods that has been used in this study has involved the development and application of correlation equations. Separate correlation equations for each month of the year relating the monthly naturalized streamflow at one location to the monthly naturalized streamflow or streamflows at other locations have been derived through regression analyses of corresponding monthly streamflow values for common periods when records for both the dependent and independent sets of variables (naturalized streamflows) have been available. The correlation equations then have been used to estimate or fill in the missing monthly naturalized streamflows for those periods when historical records for a particular gage are not available. The various correlation equations developed and used in this study are summarized in Table 3-2. The particular streamflow locations representing the dependent and independent variables in these equations are indicated in the table, along with the common periods of record used to derive the different equations.

The drainage area ratio method also has been used to estimate or fill in missing naturalized streamflow values. With this method, the unknown naturalized streamflow at one location has

TABLE 3-2
SUMMARY OF MONTHLY STREAMFLOW CORRELATION EQUATIONS AND DRAINAGE AREA RATIOS USED IN THE STREAMFLOW NATURALIZATION PROCESS

STREAMFLOW DEPENDENT VARIABLE	STREAMFLOW INDEPENDENT VARIABLE	PERIOD OF DATA OVERLAP	MONTH	SLOPE OF REGRESSION EQUATION	R^2 COEFFICIENT
SUBWATERSHED A NATURALIZED FLOWS	SUBWATERSHED D NATURALIZED FLOWS	6/42 - 12/96	JAN	0.73465	0.73
			FEB	0.79814	0.80
			MAR	0.79043	0.82
			APR	0.81459	0.79
			MAY	0.75233	0.47
			JUN	0.81347	0.49
			JUL	0.68063	0.67
			AUG	0.78845	0.85
			SEP	0.81955	0.81
			OCT	0.74122	0.65
			NOV	0.77186	0.58
			DEC	0.73108	0.64
SUBWATERSHED B NATURALIZED FLOWS	SUBWATERSHED A NATURALIZED FLOWS	10/49 - 12/96	JAN	0.53091	0.60
			FEB	0.52314	0.75
			MAR	0.49841	0.79
			APR	0.60036	0.86
			MAY	0.54418	0.82
			JUN	0.58165	0.70
			JUL	0.46221	0.43
			AUG	0.39002	0.37
			SEP	0.47225	0.68
			OCT	0.70250	0.83
			NOV	0.47051	0.86
			DEC	0.47339	0.86

TABLE 3-2, CONT'D
SUMMARY OF MONTHLY STREAMFLOW CORRELATION EQUATIONS AND DRAINAGE AREA RATIOS USED IN THE STREAMFLOW NATURALIZATION PROCESS

STREAMFLOW DEPENDENT VARIABLE	STREAMFLOW INDEPENDENT VARIABLE	PERIOD OF DATA OVERLAP	MONTH	SLOPE OF REGRESSION EQUATION	R^2 COEFFICIENT
SUBWATERSHED B NATURALIZED FLOWS	SUBWATERSHED D NATURALIZED FLOWS	10/49 - 12/96	JAN	0.26003	0.17
			FEB	0.42336	0.56
			MAR	0.41231	0.70
			APR	0.51971	0.76
			MAY	0.48291	0.40
			JUN	0.66460	0.45
			JUL	0.50653	0.51
			AUG	0.30998	0.44
			SEP	0.66693	0.48
			OCT	0.80158	0.48
			NOV	0.32671	0.48
			DEC	0.34158	0.65
SUBWATERSHED C NATURALIZED INCREMENTAL FLOWS	SUM OF NATURALIZED FLOWS FOR SUBWATERSHEDS A + B	10/56 - 12/96	JAN	1.8987	0.83
			FEB	1.8999	0.81
			MAR	1.9147	0.85
			APR	1.5979	0.87
			MAY	1.9982	0.94
			JUN	1.8675	0.89
			JUL	2.0480	0.87
			AUG	2.2203	0.91
			SEP	1.5841	0.93
			OCT	1.6706	0.93
			NOV	1.6142	0.81
			DEC	2.0277	0.88

TABLE 3-2, CONT'D
SUMMARY OF MONTHLY STREAMFLOW CORRELATION EQUATIONS AND DRAINAGE AREA RATIOS
USED IN THE STREAMFLOW NATURALIZATION PROCESS

STREAMFLOW DEPENDENT VARIABLE	STREAMFLOW INDEPENDENT VARIABLE	PERIOD OF DATA OVERLAP	MONTH	SLOPE OF REGRESSION EQUATION	R^2 COEFFICIENT
SUBWATERSHED C NATURALIZED INCREMENTAL FLOWS	SUBWATERSHED A NATURALIZED FLOWS	10/56 - 12/96	JAN	2.8256	0.81
			FEB	2.9471	0.85
			MAR	2.8562	0.81
			APR	2.5724	0.87
			MAY	3.0828	0.93
			JUN	2.8628	0.82
			JUL	2.9364	0.76
			AUG	3.0446	0.79
			SEP	2.4018	0.94
			OCT	2.8266	0.88
			NOV	2.3782	0.81
			DEC	3.0244	0.90
SUBWATERSHED C NATURALIZED INCREMENTAL FLOWS	SUBWATERSHED D NATURALIZED FLOWS	10/56 - 12/96	JAN	1.5362	0.42
			FEB	2.5738	0.76
			MAR	2.3959	0.77
			APR	2.3238	0.81
			MAY	3.0277	0.61
			JUN	3.3407	0.71
			JUL	1.3351	0.55
			AUG	1.2496	0.62
			SEP	3.9081	0.68
			OCT	3.5647	0.68
			NOV	2.1535	0.75
			DEC	2.3563	0.86

TABLE 3-2, CONT'D

SUMMARY OF MONTHLY STREAMFLOW CORRELATION EQUATIONS AND DRAINAGE AREA RATIOS USED IN THE STREAMFLOW NATURALIZATION PROCESS

STREAMFLOW DEPENDENT VARIABLE	STREAMFLOW INDEPENDENT VARIABLE	ANALYSIS PERIOD	DRAINAGE AREA RATIO
GAGE 7343500 WHITE OAK CREEK HISTORICAL STREAMFLOWS	GAGE 7343800 WHITE OAK CREEK HISTORICAL STREAMFLOWS	1/40 - 11/49	0.853
SUBWATERSHED E NATURALIZED INCREMENTAL FLOWS	SUM OF NATURALIZED FLOWS FOR SUBWATERSHED E AND SUBWATERSHED F ABOVE WRIGHT PATMAN	1/57 - 12/96	0.587
SUM OF NATURALIZED FLOWS FOR SUBWATERSHED E AND SUBWATERSHED F ABOVE WRIGHT PATMAN	SUM OF NATURALIZED FLOWS FOR SUBWATERSHED C AND SUBWATERSHED D	1/57 - 12/60 1/66 - 12/67 1/78 - 1/79	1.454
SUBWATERSHED F NATURALIZED INCREMENTAL FLOWS	SUM OF NATURALIZED FLOWS FOR SUBWATERSHED E AND SUBWATERSHED F ABOVE WRIGHT PATMAN	1/57 - 12/96	0.413

TABLE 3-2, CONT'D
SUMMARY OF MONTHLY STREAMFLOW CORRELATION EQUATIONS AND DRAINAGE AREA RATIOS
USED IN THE STREAMFLOW NATURALIZATION PROCESS

STREAMFLOW DEPENDENT VARIABLE	STREAMFLOW INDEPENDENT VARIABLE	ANALYSIS PERIOD	DRAINAGE AREA RATIO
SUBWATERSHED F ABOVE WRIGHT PATMAN NATURALIZED INCREMENTAL FLOWS	SUBWATERSHED E NATURALIZED INCREMENTAL FLOWS	1/40 - 12/56	0.703
SUBWATERSHED F NATURALIZED INCREMENTAL FLOWS	SUBWATERSHED F ABOVE WRIGHT PATMAN NATURALIZED INCREMENTAL FLOWS	1/40 - 12/96	1.135

been estimated by scaling a known value of naturalized streamflow at another location based on the ratio of their respective drainage areas. For this purpose, the drainage areas determined by the University of Texas Center for Research in Water Resources under contract to the TNRCC have been applied. These drainage areas represent computer-generated values based on a 90-meter-square digital elevation model of the Sulphur River Basin. The drainage area ratios used in the streamflow naturalization process also are listed in Table 3-2.

One other parameter that has been given consideration in this water availability study of the Sulphur River Basin is the channel loss rate for the different reaches of the overall stream system. As described below, the geologic and subsurface conditions within the basin and along the stream courses are not particularly conducive to channel losses, or even gains.

The Sulphur River flows over Upper Cretaceous and Lower Tertiary formations. From its headwaters over the Ozan Formation, the North Sulphur River flows eastward across the Wolfe City, Pecan Gap, Marlbrook Marl, and Navarro Group (undivided), all of which are Cretaceous Age. The Middle Sulphur River and South Sulphur River also originate over the Ozan Formation and flow over the same Cretaceous age formations, except that they cross the outcrop of the Neylandville Formation, which occurs between the Marlbrook Marl and Navarro Group. With the exception of the Wolfe City Formations, all these formations are predominantly clay and poorly transmissive to ground water. The Wolfe City is predominantly sand and silt, but is too thin to be of significance to the flow of the Sulphur River, either from stream losses or stream gains. The Wolfe City is known to yield only small quantities of ground water for domestic and live stock use. The Nacatoch Sand Formation of the Navarro Group cannot be separately distinguished in the Sulphur River Basin.

Below the juncture of the North Sulphur River and the South Sulphur River, the Sulphur River crosses the Midway Group, the basal unit of Tertiary age, before flowing onto the Wilcox Group (undivided) and entering Wright Patman Lake. Both of these geologic units comprise sand and mud with poorly transmissive mud predominating. Once on the Wilcox Group, swampy conditions predominate, suggesting hydraulic connection between surface and ground water, but insignificant exchange of flows. Locally, Recent alluvial deposits and terraces may provide some bank storage and delayed flow.

Based on this general review and analysis of the geologic and subsurface conditions of the Sulphur River, it has been determined that significant losses of streamflows due to seepage, infiltration and groundwater recharge are not likely. Hence, no channel loss rates have been developed or used in the water availability analyses.

3.1.4 Completion of Streamflow Records

The end result of the streamflow naturalization process for the Sulphur River Basin is a set of monthly naturalized streamflows at each of the following gage locations for the respective periods when gage records are available (through 1996).

Gage No. 7342500	South Sulphur River near Cooper
Gage No. 7343000	North Sulphur River near Cooper
Gage No. 7343200	Sulphur River near Talco
Gage No. 7343500	White Oak Creek near Talco
Gage No. 7344000	Sulphur River near Darden
Gage No. 7344200	Wright Patman Lake near Texarkana

These period-of-record monthly naturalized streamflows have been extended through the "filling in" process to provide complete 1940-1996 sets of monthly naturalized streamflows at the downstream end of each of the previously-defined subwatersheds in the Sulphur River Basin. These subwatershed naturalized streamflows then have been used as the fundamental inputs to the water availability analyses for the overall basin.

Outlined in the following sections are the specific procedures and steps that have been undertaken for naturalizing, combining and filling in the historical streamflows to arrive at the final 1940-1996 sets of monthly naturalized streamflows for the six subwatersheds.

<u>Subwatershed A - South Sulphur River</u>

1. Naturalize the monthly historical streamflows for Gage No. 7342500 for the period June 1942 - September 1991 prior to operation of Jim Chapman Lake.

2. Calculate the monthly historical inflows to Jim Chapman Lake based on available historical reservoir storage, evaporation, rainfall, and release data for the period October 1991 - December 1996.

3. Compute incremental monthly historical streamflows for the drainage area between Gage No. 7342500 and Jim Chapman Lake by subtracting the historical releases from Jim Chapman Lake from the historical streamflows at Gage No. 7342500 for the period October 1991 - December 1996.

4. Combine the incremental historical streamflows from Step 3 with the calculated historical inflows into Jim Chapman Lake from Step 2 to derive the estimated

streamflows at Gage No. 7342500 without Jim Chapman Lake in operation for the period October 1991 - December 1996.

5. Naturalize the computed monthly historical streamflows from Step 4 for Gage 7342500 for the period October 1991 - December 1996.

6. Combine the monthly naturalized streamflows from Step 1 for the period June 1942 - September 1991 with the monthly naturalized streamflows from Step 5 for the period October 1991 - December 1996 to provide a complete naturalized streamflow record for Subwatershed A for the period June 1942 - December 1996.

7. Develop monthly regression equations relating the monthly naturalized streamflows for Subwatershed A to the monthly naturalized streamflows for Subwatershed D for the period June 1942 - December 1996 (see Table 3-2).

8. Apply the monthly regression equations from Step 7 to estimate the monthly naturalized streamflows for Subwatershed A for the period January 1940 - May 1942.

9. Combine the monthly naturalized streamflows from Step 6 for the period June 1942 - December 1996 with the monthly naturalized streamflows from Step 8 for the period January 1940 - May 1942 to provide a complete naturalized streamflow record for Subwatershed A for the period January 1940 - December 1996.

Subwatershed B - North Sulphur River

1. Naturalize the monthly historical streamflows for Gage No. 7343000 for the period October 1949 - December 1996.

2. Develop monthly regression equations relating the monthly naturalized streamflows for Subwatershed B to the monthly naturalized streamflows for Subwatershed A for the period October 1949 - December 1996 (see Table 3-2).

3. Apply the monthly regression equations from Step 2 to estimate the monthly naturalized streamflows for Subwatershed B for the period June 1942 - September 1949.

4. Develop monthly regression equations relating the monthly naturalized streamflows for Subwatershed B to the monthly naturalized streamflows for Subwatershed D for the period October 1949 - December 1996 (see Table 3-2).

5. Apply the monthly regression equations from Step 4 to estimate the monthly naturalized streamflows for Subwatershed B for the period January 1940 - May 1942.

6. Combine the monthly naturalized streamflows from Step 1 with the monthly naturalized streamflows from Step 3 and the monthly naturalized streamflows from Step 5 to provide a complete naturalized streamflow record for Subwatershed B for the period January 1940 - December 1996.

Subwatershed C - Sulphur River

1. Subtract the monthly historical streamflows for Gage No. 7342500 (Subwatershed A) and Gage No. 7343000 (Subwatershed B) from the monthly historical streamflows for Gage No. 7343200 to obtain the monthly historical incremental streamflows for Subwatershed C for the period October 1956 - December 1996.

2. Naturalize the monthly historical incremental streamflows for Subwatershed C for the period October 1956 - December 1996.

3. Develop monthly regression equations relating the monthly naturalized incremental streamflows for Subwatershed C to the sum of the monthly naturalized streamflows for Subwatersheds A and B for the period October 1956 - December 1996 (see Table 3-2).

4. Apply the monthly regression equations from Step 3 to estimate the monthly naturalized incremental streamflows for Subwatershed C for the period October 1949 - September 1956.

5. Develop monthly regression equations relating the monthly naturalized incremental streamflows for Subwatershed C to the monthly naturalized streamflows for Subwatershed A for the period October 1956 - December 1996 (see Table 3-2).

6. Apply the monthly regression equations from Step 5 to estimate the monthly naturalized incremental streamflows for Subwatershed C for the period June 1942 - September 1949.

7. Develop monthly regression equations relating the monthly naturalized incremental streamflows for Subwatershed C to the monthly naturalized streamflows for Subwatershed D for the period October 1956 - December 1996 (see Table 3-2).

8. Apply the monthly regression equations from Step 7 to estimate the monthly naturalized incremental streamflows for Subwatershed C for the period January 1940 - April 1942.

9. Combine the monthly naturalized incremental streamflows from Step 2 for the period October 1956 - December 1996 with the monthly naturalized incremental streamflows from Step 4 for the period October 1949 - September 1956, from Step 6 for the period June 1942 - September 1949, and from Step 8 for the period

January 1940 - April 1942 to provide a complete monthly naturalized incremental streamflow record for Subwatershed C for the period January 1940 - December 1996.

10. Set any monthly naturalized incremental streamflows from Step 9 equal to zero.

11. Compute the total monthly naturalized streamflows at the downstream end of Subwatershed C (Gage 7343200) by combining the monthly incremental streamflows for Subwatershed C from Step 10 with the sum of the monthly naturalized streamflows for Subwatersheds A and B for the period January 1940 - December 1996.

Subwatershed D - Upper White Oak Creek

1. Adjust the monthly historical streamflows for Gage No. 7343800 (579 square miles) for the period January 1940 - November 1949 to represent the monthly historical streamflows at Gage No. 7343500 (Subwatershed D, 494 square miles) by applying the appropriate drainage area ratio (494/579 = 0.853).

2. Combine the computed monthly historical streamflows from Step 1 for the period January 1940 - November 1949 with the historical streamflows for Gage No. 7343500 for the period December 1949 - December 1996 to provide a complete monthly historical streamflow record at Gage No. 7343500 for the period January 1940 - December 1996.

3. Naturalize the monthly historical streamflows at Gage No. 7343500 to provide a complete naturalized streamflow record for Subwatershed D for the period January 1940 - December 1996.

Subwatershed E - Lower Sulphur River

1. Naturalize the total monthly historical streamflows for Gage No. 7344000 for the period January 1940 - December 1956 by adjusting for historical diversions, return flows and reservoir depletions in the entire upstream watershed, i. e., for Subwatersheds A, B, C, D and E.

2. Calculate the monthly incremental naturalized streamflows for Subwatershed E for the period January 1940 - December 1956 by subtracting the sum of the corresponding total monthly naturalized streamflows at the downstream ends of Subwatersheds C and D from the total monthly naturalized streamflows for Gage No. 7344000 in Step 1.

3. Adjust the monthly incremental naturalized streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake (1,565 square miles)

from Step 8 of the following section titled **Subwatershed F - Sulphur River at State Line** for the period January 1957 - December 1996 to represent only the incremental naturalized streamflows for Subwatershed E (919 square miles) by applying the appropriate drainage area ratio (919/1,565 = 0.587).

4. Combine the monthly incremental naturalized streamflows for Subwatershed E from Step 2 for the period January 1940 - December 1956 with the monthly incremental naturalized streamflows for Subwatershed E from Step 3 for the period January 1957 - December 1996 to provide a complete record of monthly incremental naturalized streamflows for Subwatershed E for the period January 1940 - December 1996.

5. Compute the total monthly naturalized streamflows at the downstream end of Subwatershed E (Gage 7344000) by combining the monthly incremental naturalized streamflows for Subwatershed E from Step 4 with the sum of the total monthly naturalized streamflows at the downstream ends of Subwatersheds C and D for the period January 1940 - December 1996.

Subwatershed F - Sulphur River at State Line

1. Calculate the monthly historical inflows to Wright Patman Lake based on available historical reservoir storage, evaporation, rainfall, diversion, and release data for the period October 1979 - December 1996.

2. Calculate the monthly historical inflows to Wright Patman Lake based on available historical reservoir storage, evaporation, rainfall, diversion, and release data for the period January 1961 - December 1977, exclusive of January 1966 - December 1967.

3. Combine the monthly historical inflows from Steps 1 and 2 to provide a complete record of the monthly historical inflows to Wright Patman Lake for the period January 1961 - December 1996, exclusive of January 1966 - December 1967 and January 1978 - September 1979.

4. Adjust the monthly historical streamflows at the downstream ends of Subwatershed C (Gage No. 7343200) and Subwatershed D (Gage No. 7343500) for travel time to Wright Patman Lake by shifting the flow for the last four days of each month at each gage to the following month for the period January 1961 - December 1996, exclusive of January 1966 - December 1967 and January 1978 - September 1979.

5. Compute the monthly incremental historical streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake (Gage No. 7344200) by subtracting the sum of the total monthly historical streamflows at the downstream ends of Subwatershed C (Gage No. 7343200) and Subwatershed D (Gage No.

7343500), each lagged in time by four days as in Step 4, from the monthly historical inflows to Wright Patman Lake from Step 3 for the period January 1961 - December 1996, exclusive of January 1966 - December 1967 and January 1978 - September 1979.

6. Naturalize the monthly incremental historical streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake (Gage No. 7344200) from Step 5 for the period January 1961 - December 1996, exclusive of January 1966 - December 1967 and January 1978 - September 1979, by adjusting for historical diversions, return flows and reservoir depletions in the incremental watershed, i. e., Subwatershed E and the portion of Subwatershed F above Wright Patman Lake.

7. Adjust the monthly incremental naturalized streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake (Gage No. 7344200) from Step 6 for the period January 1961 - December 1996, exclusive of January 1966 - December 1967 and January 1978 - September 1979, to eliminate negative values (set equal to zero).

8. Estimate the monthly incremental naturalized streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake (1,565 square miles) for the periods 1957-1960, 1966-1967 and 1978-1979 by applying the appropriate drainage area ratio (1,565/1,076 = 1.454) to the sum of the monthly incremental naturalized streamflows for Subwatersheds C and D (1,076 square miles).

9. Combine the monthly incremental naturalized streamflows from Steps 7 and 8 to provide a complete record of the monthly incremental naturalized streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake for the period January 1957 - December 1996.

10. Adjust the monthly incremental naturalized streamflows for Subwatershed E plus the portion of Subwatershed F above Wright Patman Lake (1,565 square miles) for the period January 1957 - December 1996 from Step 9 to represent only the incremental naturalized streamflows for the portion of Subwatershed F above Wright Patman Lake (646 square miles) by applying the appropriate drainage area ratio (646/1,565 = 0.413).

11. Adjust the monthly incremental naturalized streamflows for Subwatershed E (919 square miles) for the period January 1940 - December 1956 to represent the corresponding monthly incremental naturalized streamflows for the portion of Subwatershed F above Wright Patman Lake (646 square miles) by applying the appropriate drainage area ratio (646/919= 0.703).

12. Combine the monthly incremental naturalized streamflows for Subwatershed F above Wright Patman Lake from Step 11 for the period January 1940 - December 1956 with the monthly incremental naturalized streamflows for Subwatershed F above Wright Patman Lake from Step 10 for the period January 1957 - December 1996 to provide a complete record of monthly incremental naturalized streamflows for Subwatershed F above Wright Patman Lake for the period January 1940 - December 1996.

13. Adjust the monthly incremental naturalized streamflows for Subwatershed F above Wright Patman Lake (646 square miles) for the period January 1940 - December 1996 from Step 12 to represent the corresponding monthly incremental naturalized streamflows for Subwatershed F at the state line (733 square miles) by applying the appropriate drainage area ratio (733/646= 1.135).

14. Compute the total monthly naturalized streamflows at the downstream end of Subwatershed F at the state line by combining the monthly incremental streamflows for Subwatershed F from Step 13 with the total monthly naturalized streamflows at the downstream end of Subwatershed E for the period January 1940 - December 1996.

Results from the applying the above procedures to the Sulphur River Basin include: (1) the monthly naturalized streamflows, or naturalized reservoir inflows, for the respective periods of record for each of the gages previously indicated in Table 3-1 as having been used in the streamflow naturalization process; and (2) the total monthly naturalized streamflows for the period 1940 through 1996 at the downstream end of each of the six subwatersheds as defined for the Sulphur River Basin in Figure 3-1.

The period-of-record monthly naturalized streamflows for each of the gages are tabulated and summarized in Appendix 1. The final total monthly naturalized streamflows for each of the six subwatersheds for the complete 1940-1996 period are listed in Tables 3-3 through 3-8. These are the values of naturalized streamflows that have been used in the water availability analyses for the Sulphur River Basin. To facilitate comparison of the naturalized streamflows among the different subwatersheds, the annual quantities of the final naturalized streamflows at the downstream ends of Subwatersheds A through F are plotted as bar charts in Figures 3-2 through 3-7, respectively.

3.1.5 Comparison with Other Naturalized Streamflows

The total annual naturalized streamflows developed in this study for the streamflow gages located at the downstream ends of Subwatersheds A, B, C, D and E are plotted and compared to the corresponding historical gaged streamflows in Figures A2-1 through A2-5, respectively, in

TABLE 3-3

TOTAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED A

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	170	2,809	2,376	44,621	26,170	22,500	14,608	276	586	47	31,054	57,673	202,889
1941	16,241	23,605	63,490	57,131	83,575	30,013	9,076	2,378	809	562	4,512	10,955	302,347
1942	1,797	5,127	16,651	194,648	31,741	39,004	2,150	2,957	10,748	430	8,166	27,396	340,816
1943	173	2,344	46,310	6,530	20,869	39,251	176	0	0	69	1,233	4,771	121,725
1944	12,478	38,458	55,915	14,052	118,503	17,096	1,122	3,245	569	0	5,374	38,479	305,289
1945	16,546	84,798	126,755	36,106	14,370	59,486	29,659	99	8,578	46,419	3,182	24	426,022
1946	36,394	79,591	31,619	24,006	110,323	41,046	490	14,243	233	183	124,377	27,658	490,163
1947	8,587	393	17,482	22,125	30,314	5,632	2	6,557	331	227	18,346	56,154	166,149
1948	39,349	35,760	41,720	17,233	70,981	3,010	3,911	52	0	19	0	2,150	214,184
1949	102,558	69,636	43,659	16,511	16,664	10,898	5,059	1,435	973	54,241	248	3,252	325,134
1950	58,877	160,465	7,533	7,942	91,105	19,303	8,967	1,400	77,697	134	5	23	433,452
1951	836	45,357	622	288	4,361	122,161	10,076	0	0	760	1,199	294	185,954
1952	3,933	1,869	5,124	105,706	33,714	5,941	0	0	0	0	15,544	22,328	194,158
1953	11,883	1,134	28,199	104,260	55,564	6	11,898	533	4	118	8,545	29,456	251,601
1954	43,353	6,665	110	12,005	44,063	3,899	0	0	0	50,745	12,087	552	173,479
1955	1,300	22,925	23,157	18,001	8,833	49	2,494	3,280	831	1,540	0	0	82,409
1956	0	21,622	10	390	23,789	1,449	0	0	0	0	2,504	2,030	51,794
1957	6,719	15,815	50,928	259,718	207,674	69,708	395	4,250	30,544	30,169	148,671	11,001	835,592
1958	34,431	828	54,281	94,839	141,913	29,493	15,985	61	3,267	565	831	715	377,208
1959	1,078	12,722	8,025	6,719	2,229	9,075	20,983	1,554	1,394	21,160	18,296	67,584	170,819
1960	49,620	16,475	10,809	2,218	15,937	22,873	11,680	1,621	7,917	20,083	749	112,806	272,787
1961	53,228	18,293	40,051	9,718	1,059	14,254	3,700	1,396	4,660	44	14,998	34,122	195,523
1962	13,584	10,461	5,625	25,701	7,260	35,874	19,976	3,392	68,832	10,042	41,060	4,734	246,540
1963	12,904	203	5,995	8,113	12,236	1,153	16,646	22	0	0	0	0	57,271
1964	0	73	9,383	23,028	18,012	24,323	0	0	22,279	420	35,912	1,188	134,618
1965	24,547	117,799	1,378	564	119,658	3,609	19	0	6,086	18	685	0	274,364
1966	700	27,548	860	201,997	97,921	44	481	2,365	6,490	1,851	52	664	340,974
1967	168	67	1,984	55,701	48,037	77,874	1,181	74	23,443	36,837	20,817	44,646	310,831
1968	35,017	16,451	102,163	54,819	81,486	40,900	27,268	4,255	21,152	2,921	25,796	40,088	452,317
1969	62,469	101,604	70,229	23,620	180,559	2,504	0	0	0	5,667	2,440	29,118	478,211
1970	10,306	58,973	87,912	60,530	6,263	3,499	0	0	8,986	45,313	4,414	1,575	287,769
1971	1,093	8,379	3,870	34	49	72	265	10,370	1,842	128,074	797	195,267	350,113
1972	4,923	673	5,743	222	737	795	0	0	165	13,982	39,393	17,385	84,017
1973	32,048	34,232	88,360	107,696	13,725	36,055	703	204	75,665	78,215	98,529	37,106	602,539
1974	76,516	3,928	9,252	86,054	14,499	112,847	51	502	74,074	9,477	143,372	67,950	598,522
1975	16,559	140,249	62,274	45,444	80,255	86,869	1,734	179	0	0	0	153	433,717
1976	0	37	5,642	57,365	36,275	13,523	39,511	425	4,432	23,764	3,532	50,562	235,069
1977	28,495	60,311	138,015	51,104	1,887	16,782	259	3,401	834	0	5,101	820	307,010
1978	4,889	36,391	33,799	2,166	5,120	7,137	0	0	0	0	3,468	2,656	95,627
1979	64,369	31,535	57,276	35,090	132,708	46,117	2,337	5,164	424	107	344	19,583	395,054
1980	33,966	21,742	202	8,968	27,617	907	0	0	4,775	5,904	134	20,794	125,009
1981	69	43	16,617	1,302	32,522	172,596	1,582	36	0	100,763	44,352	798	370,680
1982	1,170	14,460	8,590	10,264	233,227	42,359	7,447	316	489	0	12,756	64,899	395,976
1983	1,808	86,319	54,053	4,032	16,103	3,152	22,847	50	0	410	801	318	189,893
1984	306	20,183	99,899	14,479	6,075	222	0	0	0	38,437	13,929	77,745	271,275
1985	12,245	21,873	84,269	48,423	71,766	9,225	292	0	0	3,842	65,700	47,731	365,365
1986	91	46,789	265	51,412	17,802	53,970	4,917	0	3,947	6,971	60,878	19,174	266,216
1987	26,094	27,367	89,786	694	11,180	12,581	264	0	11,303	9,708	156,814	118,574	464,365
1988	25,673	21,868	17,582	23,318	6	96	39,096	0	2,248	5,124	43,235	15,735	193,980
1989	41,713	74,280	31,321	4,670	67,077	94,048	51,478	1,799	996	80	219	43	367,724
1990	12,074	65,099	136,238	86,334	138,642	35,281	0	1,483	509	3,114	15,317	15,374	509,467
1991	60,513	27,249	13,301	58,193	44,823	23,156	151	0	0	5,092	59,641	71,375	363,494
1992	48,139	44,369	93,531	9,752	121,797	81,762	63,140	19,666	1,530	2,876	2,384	50,324	539,271
1993	23,546	93,040	50,761	76,542	18,993	2,261	3,816	4,459	3,035	102,773	34,818	96,586	510,629
1994	17,035	34,798	46,030	13,463	85,353	5,339	56,214	5,782	7,504	22,300	88,360	62,333	444,510
1995	60,128	4,695	57,291	56,182	144,048	35,060	3,102	2,620	3,653	0	2,026	0	368,805
1996	4,213	2,208	3,915	6,898	2,263	6,019	5,777	5,958	2,472	12,609	152,089	22,097	226,518
MEAN	22,051	33,719	38,039	41,560	53,504	29,020	9,175	2,068	8,883	15,863	28,054	29,944	311,881

TABLE 3-4
TOTAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED B

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	60	1,490	1,239	28,468	16,798	18,382	10,871	109	477	50	14,593	26,946	119,484
1941	5,748	12,522	33,118	36,449	53,646	24,520	6,755	935	658	608	2,120	5,119	182,198
1942	636	2,720	8,686	124,186	20,374	25,922	994	1,153	5,076	302	3,842	12,969	206,860
1943	9	123	23,081	3,920	11,357	2,283	81	0	0	48	580	2,259	43,741
1944	662	2,012	27,869	8,436	64,487	994	518	1,265	269	0	2,528	18,216	127,257
1945	878	4,436	63,176	21,677	7,820	3,460	13,709	39	4,051	32,609	1,497	11	153,363
1946	1,932	4,164	15,759	14,412	60,036	2,387	226	5,555	110	129	58,520	13,093	176,324
1947	456	21	8,713	13,283	16,496	328	1	2,557	156	159	8,632	26,583	77,385
1948	2,089	1,871	20,794	10,346	38,626	175	1,807	20	0	13	0	1,018	76,760
1949	5,445	3,643	21,760	9,912	9,068	634	2,338	560	460	6,739	76	3,488	64,123
1950	72,069	82,363	1,435	2,619	64,671	3,827	20,153	2,207	34,158	340	98	160	284,100
1951	286	31,319	817	2,430	7,311	102,593	2,032	34	356	3,361	586	69	151,194
1952	243	239	9,280	71,228	11,863	3,631	29	0	0	0	10,309	4,275	111,096
1953	3,316	574	16,369	66,837	22,590	39	9,962	1,441	530	520	4,463	12,442	139,084
1954	18,866	9,951	270	7,668	52,375	4,174	0	0	8	34,664	3,144	549	131,669
1955	1,459	6,520	21,405	16,935	5,145	683	7,237	1,797	712	1,801	0	0	63,693
1956	321	39,137	621	2,610	16,059	459	0	0	0	22	2,160	371	61,762
1957	1,040	2,546	20,230	144,216	146,404	50,812	486	3,849	19,197	5,459	83,644	8,042	485,924
1958	20,638	1,511	34,182	56,571	70,015	33,534	2,020	75	442	51	321	338	219,698
1959	243	1,759	2,503	214	355	26,526	35,492	4,102	3,931	10,766	4,660	40,816	131,367
1960	26,650	14,622	13,925	2,211	7,197	17,755	5,787	5,547	11,184	23,873	615	89,140	218,506
1961	18,090	10,462	38,241	4,833	3,502	1,609	1,187	210	2,681	26	7,638	17,969	106,449
1962	13,991	5,843	10,018	13,277	2,786	33,493	2,964	259	29,531	14,642	48,799	2,362	177,966
1963	6,235	521	4,688	8,688	1,430	278	2,403	18	0	0	0	21	24,283
1964	5	164	10,721	19,803	14,327	15,807	21	18	18,658	90	18,773	1,922	100,307
1965	9,866	56,300	3,336	854	34,509	1,337	9	41	4,685	1	177	39	111,154
1966	81	7,267	534	179,508	22,736	539	65	4,998	4,619	1,568	71	715	222,701
1967	228	489	4,593	55,368	68,781	12,513	3,027	90	19,696	17,807	2,772	31,021	216,384
1968	17,160	12,968	75,180	37,380	54,417	50,906	23,680	2,092	29,684	6,207	19,714	23,694	353,080
1969	44,021	21,134	35,970	8,612	79,769	2,855	107	37	51	6,258	367	22,120	221,301
1970	3,031	58,994	53,845	41,585	5,149	453	27	34	11,748	25,298	8,205	2,674	211,045
1971	2,220	6,910	3,322	722	2,329	74	2,594	9,821	2,237	109,731	4,185	67,282	211,426
1972	3,467	992	1,073	181	157	324	58	337	45	17,079	18,056	6,126	47,896
1973	16,072	19,920	50,645	46,040	9,652	16,941	613	197	34,793	75,867	52,915	17,328	340,983
1974	19,929	2,725	1,502	16,677	10,490	49,617	116	385	23,597	30,581	47,746	15,553	218,917
1975	16,956	61,129	17,312	14,019	34,357	32,306	3,600	148	116	41	41	115	180,140
1976	57	52	2,972	10,854	7,142	30,458	53,606	689	807	8,258	954	8,722	124,571
1977	6,804	18,520	43,250	12,911	676	3,103	69	146	14	5	2,051	611	88,160
1978	1,763	11,120	8,219	1,430	3,837	6,845	22	16	0	1	14,926	14,410	62,589
1979	27,510	22,860	45,203	9,012	41,703	14,236	3,782	4,733	180	903	331	11,440	181,891
1980	4,860	8,350	703	1,272	7,472	77	20	7	18,592	2,762	271	12,301	56,685
1981	375	702	11,454	1,857	22,702	76,487	3,043	111	2,576	86,461	32,439	1,363	239,570
1982	7,505	15,475	7,445	10,727	151,320	25,653	8,501	1,722	325	568	6,724	19,455	255,421
1983	1,942	53,099	25,710	1,721	8,114	4,953	15,031	33	70	251	960	430	112,315
1984	669	32,433	33,455	9,298	24,379	157	7	0	2	10,755	10,483	36,909	158,546
1985	12,339	16,253	51,833	29,330	32,457	5,959	591	7	16	7,919	26,789	18,662	202,157
1986	661	20,859	1,756	27,597	18,597	22,411	7,854	0	3,577	7,182	50,567	15,623	176,683
1987	17,727	29,324	30,969	530	6,096	3,250	6,015	267	31,719	13,960	66,662	61,285	267,803
1988	15,675	13,069	18,758	11,310	380	31	3,336	18	970	2,540	9,670	8,399	84,156
1989	11,955	67,108	33,384	5,363	54,578	106,586	25,700	1,086	4,811	147	131	272	311,121
1990	31,386	48,025	61,570	39,107	85,708	14,229	740	642	424	10,259	9,125	11,015	312,230
1991	44,213	13,191	7,941	42,239	11,533	16,472	221	856	1,162	59,432	14,151	93,902	305,314
1992	37,900	15,738	46,218	2,984	36,979	55,051	13,631	3,444	332	129	2,184	29,146	243,735
1993	12,659	57,732	32,267	27,938	12,480	7,390	119	27	49	46,625	17,127	52,046	266,458
1994	1,869	16,081	43,560	13,900	62,380	13,134	30,668	3,578	661	5,631	61,802	26,599	279,864
1995	22,940	1,985	24,764	28,687	82,304	8,220	1,059	70	3,199	138	327	230	173,924
1996	1,873	238	983	908	2,609	5,767	3,054	7,874	1,352	12,082	68,322	12,495	117,558
MEAN	10,475	16,694	20,853	24,231	30,185	16,888	5,931	1,320	5,873	12,328	14,524	15,968	175,270

TABLE 3-5

TOTAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED C

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	355	7,276	7,201	127,291	105,319	92,402	28,655	438	2,792	225	86,640	185,882	644,475
1941	33,960	76,126	192,446	162,978	336,342	123,255	17,804	3,769	3,856	2,704	12,589	35,309	1,001,138
1942	3,758	16,535	50,471	555,278	127,740	111,661	6,313	4,700	16,225	1,215	12,077	70,959	976,932
1943	490	6,906	132,271	16,798	54,000	41,849	517	0	0	194	2,932	14,430	270,387
1944	35,258	113,334	159,704	36,148	365,321	48,941	3,293	4,510	1,366	0	12,780	116,375	897,031
1945	46,752	249,901	362,037	92,879	44,300	170,297	76,520	302	20,602	131,207	7,567	71	1,202,436
1946	102,834	234,556	90,310	61,753	340,104	117,507	1,438	20,553	559	518	295,793	83,650	1,349,573
1947	24,263	1,159	49,931	56,915	93,451	10,722	7	9,114	795	640	43,631	169,833	460,459
1948	111,184	105,383	119,161	44,331	218,820	8,618	11,483	157	0	53	0	6,503	625,694
1949	265,638	205,217	124,700	42,472	51,373	31,198	14,855	4,369	2,337	101,874	523	13,666	858,222
1950	248,627	461,349	17,171	16,876	311,272	43,196	29,120	8,009	177,190	793	166	372	1,314,140
1951	2,130	145,677	2,754	4,343	23,323	316,419	24,799	75	564	6,885	2,882	736	530,587
1952	7,929	4,003	27,580	282,722	91,072	17,875	59	0	0	0	41,731	53,943	526,914
1953	28,858	3,245	85,334	221,211	156,166	85	30,817	4,384	847	763	17,978	73,310	622,999
1954	118,136	31,569	728	31,436	192,703	15,076	0	0	12	121,199	24,586	2,232	537,677
1955	5,238	55,942	85,324	55,825	27,931	1,365	19,928	11,274	2,444	5,582	0	0	270,851
1956	610	115,436	1,208	4,793	79,625	3,564	0	0	0	38	11,068	3,358	219,699
1957	18,846	49,474	134,758	618,861	718,520	337,365	881	8,099	53,716	65,956	397,149	34,839	2,438,464
1958	110,564	3,280	134,832	188,099	481,569	72,322	49,885	1,144	16,981	2,470	23,732	3,519	1,088,397
1959	6,954	61,075	28,335	31,179	5,965	102,275	115,029	14,033	10,993	56,212	46,493	252,328	730,871
1960	156,262	44,003	39,102	4,429	34,771	61,651	71,554	14,398	77,211	99,586	9,440	402,485	1,014,892
1961	140,326	59,089	159,667	78,048	14,936	16,029	11,846	2,932	9,318	290	47,093	105,005	644,580
1962	73,350	41,238	26,898	102,450	35,474	81,464	61,016	4,233	160,049	67,139	152,822	23,526	829,659
1963	46,611	1,487	31,350	23,441	23,895	2,515	22,140	327	49	10	35	72	151,932
1964	9	1,430	39,138	113,015	32,340	58,520	97	204	50,363	6,686	98,283	5,843	405,929
1965	71,537	335,120	10,150	4,666	303,254	17,728	144	73	11,123	159	862	116	754,932
1966	1,777	84,960	2,151	482,210	380,362	1,237	574	7,363	16,691	26,520	123	3,752	1,007,720
1967	1,041	1,731	11,414	309,637	170,262	256,711	44,845	163	46,763	74,803	103,752	173,662	1,194,783
1968	115,978	68,878	384,839	238,174	333,500	234,811	59,153	18,756	78,083	15,735	123,474	206,665	1,878,045
1969	134,928	479,680	297,535	84,651	613,040	10,291	627	47	66	11,925	8,657	76,898	1,718,346
1970	50,069	194,484	299,145	211,305	29,764	8,680	338	34	23,211	135,781	30,102	7,147	990,059
1971	5,547	23,699	11,436	756	9,369	388	5,685	60,314	4,404	369,519	8,879	679,015	1,179,008
1972	19,321	4,834	11,119	944	1,919	2,210	472	337	211	31,566	173,691	77,045	323,668
1973	105,140	132,443	446,010	399,777	50,277	133,381	2,009	789	188,814	252,178	382,410	139,269	2,232,497
1974	173,824	12,380	11,225	110,831	30,237	287,383	273	887	175,361	40,058	405,784	170,465	1,418,708
1975	33,515	309,116	127,864	71,410	185,108	177,405	11,268	2,004	189	70	154	514	918,617
1976	233	154	18,106	145,974	101,906	75,788	236,454	1,113	8,316	41,645	11,653	129,131	770,471
1977	82,532	174,664	318,169	228,692	6,406	22,301	1,515	4,409	849	5	10,027	1,983	851,552
1978	12,845	63,801	104,176	7,190	17,069	13,982	22	16	1	1	28,667	17,067	264,838
1979	237,646	122,317	177,660	149,088	399,607	170,887	9,307	18,242	904	1,010	1,891	99,306	1,387,865
1980	124,741	104,377	2,149	49,883	114,861	7,313	35	7	23,367	32,444	1,112	69,578	529,867
1981	715	1,277	36,271	5,736	136,679	420,365	4,884	204	2,604	431,803	194,017	4,061	1,238,617
1982	8,674	59,051	66,877	51,967	757,998	189,841	34,803	7,846	1,613	1,881	110,772	367,912	1,659,236
1983	10,893	262,825	193,747	18,328	51,210	11,322	70,071	874	122	665	1,761	2,929	624,745
1984	2,405	87,504	351,929	37,679	82,214	1,041	352	612	248	106,337	45,368	185,320	901,009
1985	29,183	91,364	172,800	84,816	137,559	20,090	3,651	63	51	11,761	120,387	149,671	821,397
1986	1,314	118,585	4,531	150,167	60,375	130,015	45,355	1,111	8,820	21,523	145,596	59,243	746,635
1987	71,751	63,580	144,254	4,133	17,276	22,822	6,279	349	43,022	38,100	259,027	215,485	886,078
1988	64,403	44,431	48,797	56,222	1,196	127	47,479	291	3,218	7,664	154,748	38,085	466,660
1989	107,286	298,378	130,494	29,645	319,956	415,926	205,696	6,524	10,227	727	350	316	1,525,525
1990	173,922	178,326	340,673	229,517	398,593	81,843	1,644	2,659	11,547	23,255	44,072	53,722	1,539,773
1991	157,553	71,859	34,999	198,779	99,851	50,429	3,118	1,086	2,387	184,038	171,939	493,394	1,469,433
1992	126,502	129,580	187,101	17,919	201,629	163,255	222,593	61,428	17,042	6,268	40,314	167,802	1,341,435
1993	89,247	203,513	151,715	149,227	63,434	12,330	4,209	6,367	7,331	222,962	84,133	239,934	1,234,402
1994	50,573	87,869	132,271	32,525	204,146	37,656	116,265	16,042	18,215	40,288	188,714	175,265	1,099,831
1995	171,662	21,377	123,985	153,253	416,877	81,862	10,423	3,928	18,758	2,098	2,751	5,453	1,012,428
1996	10,396	3,555	10,802	14,439	32,664	30,761	13,628	42,387	24,414	51,128	383,905	73,693	691,770
MEAN	67,300	104,042	113,453	117,598	170,086	87,304	30,899	6,725	23,794	50,108	80,475	100,739	952,524

TABLE 3-6

TOTAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED D

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	231	3,520	3,006	54,777	34,785	27,659	21,463	351	714	63	40,232	78,887	265,688
1941	22,107	29,577	80,323	70,134	111,088	36,895	13,335	3,016	987	758	5,846	14,985	389,052
1942	2,446	6,424	21,066	238,952	42,191	24,109	2,092	2,170	3,234	412	2,309	26,347	371,752
1943	9,549	2,787	28,979	7,120	12,385	79,033	815	230	642	3,233	202	3,446	148,421
1944	11,932	25,255	81,118	17,940	156,204	21,949	587	373	2,588	443	6,780	30,347	355,517
1945	41,402	89,133	301,552	121,659	31,716	156,985	110,255	2,696	2,870	122,312	14,758	2,401	997,741
1946	157,064	228,289	67,430	35,123	261,382	139,772	1,921	3,725	4,727	1,191	146,535	78,681	1,125,841
1947	31,483	3,197	40,028	68,868	107,935	3,005	648	749	2,219	719	49,078	153,603	461,533
1948	39,303	80,348	86,938	15,937	188,117	2,220	2,765	1,324	736	1,033	1,749	1,386	421,855
1949	124,601	116,956	50,376	25,771	50,772	5,073	2,431	931	2,059	239,547	3,268	10,856	632,641
1950	71,521	199,535	39,885	9,048	114,206	10,819	11,658	9,216	63,356	698	379	458	530,780
1951	6,288	72,649	2,945	1,468	6,715	26,574	11,694	141	1,170	1,221	4,006	9,766	144,637
1952	26,689	10,025	14,717	167,631	38,891	2,912	3,693	136	74	71	28,025	64,147	357,012
1953	23,999	11,790	28,579	68,939	123,140	352	19,376	1,038	5,832	845	4,383	30,453	318,727
1954	63,471	31,678	2,476	4,542	49,437	651	105	64	57	32,564	18,511	2,035	205,591
1955	4,464	12,321	12,288	35,624	1,850	375	1,055	1,664	1,602	2,042	91	115	73,491
1956	221	29,289	755	260	18,452	95	0	0	0	0	14,810	76	63,958
1957	8,581	17,533	64,842	224,822	171,841	66,728	992	1,361	18,984	37,884	157,312	14,794	785,673
1958	70,703	2,554	51,713	159,289	165,207	40,376	39,911	1,906	13,391	1,777	10,061	3,941	560,830
1959	1,255	56,147	41,571	28,066	2,147	7,416	11,120	3,621	600	15,584	13,819	99,874	281,220
1960	81,947	22,621	24,336	1,691	2,327	7,023	7,617	751	7,783	15,225	6,933	134,985	313,239
1961	54,887	37,509	55,516	33,378	1,294	19,438	14,089	3,593	3,064	785	26,760	47,559	297,871
1962	33,192	29,098	23,507	36,784	26,203	5,586	6,854	1,324	23,682	10,969	31,609	22,389	251,198
1963	20,097	1,882	5,877	8,329	38,314	5,516	3,974	272	59	0	0	124	84,445
1964	82	3,500	9,359	43,181	5,978	12,557	0	2,359	30,123	1,937	13,741	1,172	123,991
1965	5,744	94,298	7,789	3,005	121,269	20,601	43	0	3,047	37	63	0	255,896
1966	4,923	42,043	3,073	216,605	164,758	903	2,728	5,046	10,169	16,808	385	3,641	471,082
1967	3,034	3,987	7,301	54,344	56,258	56,048	4,729	286	3,887	11,050	59,592	49,516	310,030
1968	35,752	28,265	119,782	30,143	114,193	22,043	7,117	700	9,662	310	6,489	38,393	412,849
1969	12,822	130,247	93,223	39,548	148,946	1,869	295	0	9,160	0	1,549	10,152	447,810
1970	21,814	45,795	101,615	113,470	8,779	5,483	3,617	1,565	4,754	33,110	7,975	1,389	349,365
1971	3,093	15,825	7,310	465	885	300	15,291	10,230	1,041	37,958	2,259	244,775	339,432
1972	27,785	7,353	6,085	1,231	859	4,378	385	0	263	17,575	70,390	53,225	189,529
1973	40,883	53,987	134,412	138,306	7,755	55,190	3,642	19	24,436	43,629	152,618	72,518	727,396
1974	100,805	10,397	11,584	64,897	7,178	71,477	578	1,290	52,865	13,627	177,515	74,813	587,024
1975	12,864	160,163	66,912	37,057	102,460	42,975	3,862	2,933	86	70	0	228	429,611
1976	88	440	19,877	79,027	60,853	12,468	90,647	239	2,606	4,022	2,536	15,858	288,663
1977	11,069	57,563	126,422	72,101	2,249	9,579	658	1,116	76	78	45,058	3,857	329,824
1978	14,195	25,406	45,991	3,247	3,051	1,036	19	0	8	0	1,008	865	94,826
1979	57,529	22,301	43,231	66,276	106,541	21,904	8,013	22,604	7,197	387	3,900	61,906	421,787
1980	198,424	47,514	4,610	45,769	56,694	7,602	1,372	1,587	863	5,830	2,403	16,138	388,805
1981	428	2,413	5,637	1,962	70,759	156,440	2,097	271	151	109,052	18,488	1,075	368,771
1982	1,172	6,086	16,179	4,062	32,250	15,744	39,424	444	0	49	21,898	177,191	314,499
1983	11,164	51,912	56,952	9,783	9,638	8,234	15,227	0	0	38	1,636	7,103	171,686
1984	3,786	23,443	71,634	12,221	1,170	87	27	0	0	82,735	23,041	105,210	323,354
1985	12,844	57,436	50,736	45,266	39,877	10,352	1,050	43	0	426	15,358	95,352	328,740
1986	1,624	79,086	2,042	102,025	37,177	41,879	2,397	0	361	281	14,997	18,934	300,803
1987	22,638	23,295	96,231	5,400	1,308	8,576	1,935	34	1,741	3,446	94,722	134,691	394,017
1988	27,809	22,963	18,180	17,529	307	0	42,854	680	0	1,755	144,971	32,409	309,456
1989	31,209	111,109	47,156	28,629	109,089	94,162	30,176	5,477	713	0	194	81	457,996
1990	23,176	49,352	214,001	90,054	194,035	76,937	7,916	10,514	2,254	3,931	36,680	51,071	759,921
1991	69,100	72,667	17,766	79,138	46,895	12,084	4,274	500	1,398	22,764	83,957	156,854	567,396
1992	52,576	59,736	115,862	14,123	20,893	30,358	230,767	56,215	1,329	391	44,079	111,168	737,497
1993	91,581	66,707	84,805	41,535	15,418	1,534	162	132	15	73,368	18,717	83,031	477,004
1994	27,008	48,782	57,674	4,295	28,098	15,008	41,116	2,598	443	3,664	43,316	86,551	358,553
1995	82,574	11,558	44,677	48,511	111,720	5,546	2,358	417	3,050	37	0	490	310,938
1996	1,647	170	631	2,799	4,754	2,271	1,094	27,657	3,453	5,721	158,709	66,515	275,421
MEAN	33,661	44,841	49,799	51,792	60,503	26,600	14,988	3,432	5,887	17,254	32,556	45,751	387,065

TABLE 3-7
TOTAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED E

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	587	10,796	10,344	283,838	257,674	263,120	236,363	1,002	3,824	401	184,327	442,653	1,694,927
1941	209,629	152,921	346,204	252,706	762,226	475,578	168,120	15,260	5,002	24,433	64,399	146,119	2,622,597
1942	23,231	60,435	161,417	982,319	464,440	196,525	9,217	6,870	20,428	1,628	19,878	97,306	2,043,694
1943	77,762	17,763	274,903	122,418	66,385	207,148	9,385	552	1,043	7,703	5,799	24,605	815,466
1944	78,730	181,351	539,212	166,376	754,692	214,439	3,880	4,883	19,861	443	50,482	208,421	2,222,770
1945	308,233	446,646	1,145,365	1,101,443	105,114	516,737	186,775	6,920	23,472	336,497	27,919	4,492	4,209,612
1946	388,947	715,800	157,957	207,166	720,582	455,059	7,920	24,278	5,285	2,122	744,285	268,777	3,698,177
1947	105,391	13,953	173,684	212,803	373,470	17,102	2,914	9,863	3,014	1,359	92,709	407,453	1,413,713
1948	256,993	301,539	352,138	73,741	579,206	25,322	14,509	3,913	736	1,086	1,749	7,889	1,618,822
1949	390,239	409,248	384,744	150,978	180,632	58,651	17,286	7,322	5,484	393,675	61,262	48,301	2,107,822
1950	470,029	1,009,121	146,900	25,923	659,361	76,619	40,778	54,479	481,900	13,153	2,031	1,438	2,981,734
1951	34,183	423,871	51,896	21,536	49,261	347,131	45,661	2,774	7,214	10,516	18,465	39,123	1,051,630
1952	124,955	53,228	97,308	809,706	221,429	63,663	9,250	2,267	74	71	69,756	246,029	1,697,734
1953	113,227	140,507	161,375	290,150	754,149	4,630	50,193	5,423	8,700	1,608	22,361	103,763	1,656,087
1954	244,752	124,516	14,135	60,000	472,719	31,975	356	64	69	153,763	43,097	10,954	1,156,401
1955	15,568	80,954	157,592	209,304	35,592	5,280	35,404	15,946	23,554	57,713	611	1,080	638,598
1956	1,708	277,984	7,734	5,053	124,495	4,888	1,693	1,005	784	826	25,877	3,435	455,481
1957	44,225	108,554	309,300	1,219,267	1,348,394	646,290	2,720	10,623	92,310	162,101	829,601	75,761	4,849,145
1958	289,051	8,820	270,316	514,772	1,018,176	155,121	151,112	5,538	53,146	7,347	61,670	12,932	2,548,002
1959	14,091	204,971	120,620	103,925	12,834	172,971	185,657	27,901	16,947	105,848	92,216	560,431	1,618,413
1960	376,519	96,969	96,495	7,565	49,024	92,628	131,872	21,966	141,272	175,327	29,192	824,038	2,042,866
1961	274,131	149,370	320,863	238,256	32,463	62,070	51,304	8,435	15,512	3,437	73,853	277,145	1,506,839
1962	192,589	178,544	169,104	187,087	107,175	105,698	67,870	8,290	183,731	101,555	201,640	60,375	1,563,658
1963	94,440	9,116	93,544	52,044	96,996	9,619	33,219	599	108	347	35	2,238	392,305
1964	2,133	9,043	66,767	250,090	109,277	73,163	97	8,179	90,193	17,639	112,024	35,624	774,229
1965	105,695	615,016	41,655	22,391	460,783	38,328	708	1,030	14,170	196	925	2,560	1,303,457
1966	11,755	205,740	8,494	969,825	907,648	3,470	5,655	16,719	40,313	77,415	837	12,530	2,260,402
1967	7,216	10,125	29,083	579,989	320,213	502,685	88,321	693	57,066	112,509	282,706	349,163	2,339,769
1968	209,639	133,930	597,302	268,316	575,013	256,854	70,304	19,456	88,304	16,045	152,863	245,058	2,633,084
1969	196,946	704,591	442,456	192,249	821,934	12,160	922	1,618	9,226	11,925	10,206	101,418	2,505,651
1970	80,715	294,449	568,945	422,112	97,403	22,201	3,955	3,414	27,965	168,890	46,181	16,953	1,753,184
1971	14,925	66,842	43,058	5,574	19,626	3,273	40,791	87,413	5,445	407,477	63,279	1,150,861	1,908,564
1972	107,718	12,187	25,494	6,842	6,538	6,793	5,049	939	5,901	53,316	262,169	197,786	690,734
1973	196,086	268,605	739,345	743,661	131,048	289,530	7,996	808	213,250	319,873	739,068	328,773	3,978,044
1974	426,123	70,973	38,811	175,728	109,309	503,931	851	2,825	283,823	92,079	731,632	423,632	2,859,716
1975	79,657	707,847	327,925	173,671	419,687	220,380	17,613	7,027	275	140	3,457	2,195	1,959,874
1976	6,194	8,116	108,650	225,001	256,847	173,783	327,101	1,352	17,089	47,477	14,246	147,924	1,333,779
1977	115,968	329,454	564,733	431,939	25,179	33,752	2,172	5,525	925	83	55,085	12,437	1,577,252
1978	44,454	124,821	242,536	16,279	29,653	15,903	57	16	16	1	39,311	18,670	531,718
1979	468,807	221,675	322,025	361,636	789,481	305,904	26,887	67,281	14,505	1,727	10,161	272,406	2,862,494
1980	326,307	248,852	28,352	175,230	171,554	31,997	1,407	1,594	24,230	38,274	12,382	86,610	1,146,788
1981	5,675	24,333	60,637	12,695	299,809	690,895	41,620	474	2,755	540,855	247,090	8,750	1,935,590
1982	24,755	108,570	98,031	75,642	901,756	326,975	100,733	14,399	1,613	1,930	158,500	737,588	2,550,494
1983	22,057	320,119	323,480	54,470	84,647	23,436	85,298	874	122	703	3,397	20,803	939,405
1984	13,708	117,637	427,059	140,104	83,383	1,128	379	612	248	259,106	183,225	407,298	1,633,887
1985	78,543	254,905	416,899	258,633	254,984	58,040	5,541	106	51	12,187	151,005	371,220	1,862,115
1986	9,680	309,418	24,567	372,120	155,829	228,703	70,565	1,111	9,181	21,804	169,284	141,878	1,514,140
1987	139,017	149,145	516,705	20,926	21,417	36,572	10,602	383	44,763	44,805	460,908	765,981	2,211,226
1988	197,665	123,401	125,534	116,920	1,504	127	90,333	971	3,218	9,419	360,813	161,432	1,191,335
1989	184,818	600,716	295,954	120,225	603,429	616,880	248,820	21,262	10,940	727	544	1,843	2,706,158
1990	226,993	323,723	945,772	470,013	850,831	200,276	9,560	13,173	13,800	32,820	116,790	206,757	3,410,507
1991	403,291	240,177	130,725	430,834	305,880	62,975	8,592	6,131	7,279	222,373	334,876	850,812	3,003,946
1992	256,142	305,637	530,134	50,805	238,844	236,991	511,310	194,393	33,440	6,660	99,839	494,099	2,958,295
1993	353,697	335,908	456,374	272,979	106,196	24,329	4,371	6,499	7,346	417,666	146,901	511,205	2,643,471
1994	128,047	203,195	363,012	44,436	269,649	63,778	215,609	18,640	18,657	55,389	363,099	416,725	2,160,237
1995	422,467	98,879	234,457	325,733	641,292	99,395	12,781	4,345	21,808	2,135	2,751	5,943	1,871,985
1996	13,184	3,725	13,060	21,174	74,315	48,372	16,818	105,255	45,417	79,264	802,926	228,841	1,452,351
MEAN	158,058	223,311	258,266	265,028	340,201	165,285	61,338	15,100	39,067	81,331	155,468	221,237	1,983,691

TABLE 3-8

TOTAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED F

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	587	10,796	10,454	365,387	351,884	377,755	385,603	1,172	4,079	491	230,366	585,194	2,323,767
1941	332,680	190,757	405,048	268,406	1,014,476	728,334	277,885	22,051	5,129	41,236	101,231	222,905	3,610,138
1942	36,875	90,466	233,438	1,133,037	700,433	245,209	9,869	6,870	21,204	1,628	24,279	97,306	2,600,613
1943	132,029	24,228	365,975	201,348	66,385	276,274	15,838	810	1,365	11,130	7,934	29,997	1,133,313
1944	104,004	215,615	778,315	256,354	941,530	329,466	3,880	4,883	32,608	443	75,260	257,860	3,000,219
1945	484,584	532,877	1,531,416	1,812,128	128,430	668,549	186,775	10,063	23,472	402,988	32,401	6,111	5,819,793
1946	492,355	918,495	158,131	295,542	816,015	613,542	11,574	24,278	5,285	2,453	986,246	354,073	4,677,990
1947	145,172	21,643	240,774	282,533	511,363	19,807	4,724	9,863	3,014	1,359	92,709	474,776	1,807,735
1948	342,337	394,337	469,161	84,537	717,247	36,929	14,719	5,862	736	1,086	1,749	7,889	2,076,588
1949	390,239	479,022	552,753	217,274	243,524	76,584	17,286	8,943	6,356	435,548	107,314	67,355	2,602,197
1950	590,129	1,288,167	218,893	25,923	846,775	94,732	40,778	84,331	675,299	22,499	3,222	1,926	3,892,675
1951	54,828	588,577	88,914	34,136	64,664	350,447	53,008	4,824	11,605	12,446	27,742	62,057	1,353,248
1952	197,342	84,638	141,389	1,097,659	294,721	98,020	13,655	3,974	74	71	69,756	348,547	2,349,847
1953	161,602	241,050	199,407	290,150	1,134,644	7,990	50,193	5,423	10,319	1,608	22,361	103,763	2,228,511
1954	295,351	173,612	22,895	79,249	657,485	44,994	556	64	69	153,763	43,097	16,313	1,487,448
1955	20,269	91,124	205,655	303,742	40,249	8,116	46,960	18,356	39,186	97,851	1,028	1,853	874,390
1956	2,412	384,766	12,358	5,053	145,664	5,872	3,050	1,810	1,412	1,457	25,877	3,435	593,164
1957	57,623	141,693	396,798	1,518,835	1,713,725	839,467	3,395	11,551	107,951	208,569	1,049,055	96,600	6,145,262
1958	375,020	11,202	337,132	648,278	1,314,406	188,958	200,019	7,522	71,310	9,820	83,906	17,297	3,264,870
1959	18,783	274,961	161,070	139,562	16,600	223,444	233,122	36,074	21,216	133,008	117,664	726,515	2,102,019
1960	486,836	121,171	122,861	8,717	58,536	111,734	173,907	27,403	186,160	223,595	39,416	1,052,606	2,612,943
1961	337,077	191,460	405,154	339,417	45,411	83,288	71,539	9,958	18,008	5,321	73,853	376,511	1,956,998
1962	261,221	264,851	263,779	225,254	143,464	120,572	67,870	10,470	183,731	120,256	215,365	71,908	1,948,742
1963	116,560	13,699	138,464	68,214	124,742	10,885	38,885	599	108	617	35	3,867	516,674
1964	3,761	12,323	81,339	324,981	165,874	74,827	97	12,659	97,936	24,830	112,024	58,442	969,092
1965	128,358	763,049	60,570	34,132	489,705	38,328	1,125	1,793	14,170	196	925	4,508	1,536,859
1966	15,787	268,540	11,103	1,185,985	1,196,803	4,531	7,533	20,157	51,042	104,603	1,099	16,627	2,883,810
1967	9,721	13,641	37,352	752,279	394,944	654,170	119,225	888	62,183	133,769	377,911	449,651	3,005,735
1968	255,827	163,271	671,226	268,316	676,565	256,854	73,521	19,456	88,749	16,045	171,129	245,058	2,906,018
1969	236,184	780,095	483,691	246,526	869,749	12,160	922	2,872	9,226	11,925	10,206	112,878	2,776,434
1970	87,759	337,656	703,090	499,749	144,351	28,613	3,955	4,863	27,965	168,890	52,645	23,665	2,083,201
1971	19,939	88,631	62,450	9,046	27,102	5,335	56,596	100,868	5,445	407,477	104,867	1,331,974	2,219,729
1972	156,062	12,187	32,107	10,565	9,538	6,956	8,393	1,420	10,230	56,647	276,595	251,637	832,338
1973	236,017	334,149	866,103	907,631	189,287	370,056	9,867	808	213,250	339,067	901,812	422,081	4,790,127
1974	546,955	109,414	51,574	175,728	166,651	619,641	851	3,342	328,168	122,703	849,943	565,888	3,540,858
1975	106,199	898,131	434,126	225,678	525,066	220,380	19,592	8,694	275	140	6,091	3,355	2,447,726
1976	10,879	14,115	165,014	225,001	331,891	241,999	327,101	1,352	22,008	48,921	14,292	150,265	1,552,837
1977	133,808	407,003	660,560	536,543	38,358	35,245	2,172	5,525	925	83	55,085	17,699	1,893,006
1978	58,344	153,226	316,210	20,939	37,257	16,609	69	16	22	1	46,996	19,259	668,949
1979	607,297	283,137	402,691	478,304	1,015,469	396,124	34,517	88,365	19,612	1,990	13,647	361,094	3,702,247
1980	328,814	326,188	45,575	238,701	171,554	45,621	1,407	1,594	24,230	38,274	19,453	87,324	1,328,734
1981	9,291	40,798	75,575	16,681	373,485	781,895	69,248	474	2,755	540,855	274,675	11,633	2,197,365
1982	36,646	143,213	109,976	91,286	990,696	423,796	121,875	19,272	1,613	1,930	179,102	891,116	3,010,520
1983	22,057	324,413	381,530	75,494	103,629	26,531	85,298	874	122	703	3,397	29,393	1,053,441
1984	19,704	122,972	429,847	212,050	83,383	1,128	379	612	248	314,965	274,804	500,433	1,960,526
1985	107,668	339,535	571,127	361,166	316,837	80,052	6,211	106	51	12,187	163,177	471,875	2,429,992
1986	15,057	398,549	38,919	467,775	202,310	274,015	88,761	1,111	9,181	21,804	176,216	192,687	1,886,384
1987	174,613	198,813	737,020	30,014	23,676	40,699	12,508	383	44,763	47,406	546,379	1,097,629	2,953,902
1988	281,775	168,072	172,238	151,353	1,504	127	90,333	971	3,218	9,419	409,542	233,965	1,522,516
1989	221,766	753,241	390,314	169,638	742,519	702,057	259,147	28,648	10,940	727	544	2,997	3,282,538
1990	250,838	400,329	1,257,714	590,005	1,056,775	233,373	9,560	13,173	13,800	37,314	145,534	288,083	4,296,498
1991	544,178	316,469	192,907	552,801	432,806	63,344	9,549	9,757	10,065	234,792	397,872	1,010,783	3,775,324
1992	317,609	398,416	711,327	65,771	251,862	271,589	557,531	255,610	45,458	6,660	112,159	665,688	3,659,679
1993	491,577	388,301	631,731	338,556	128,006	32,676	4,371	6,499	7,346	514,446	182,037	661,347	3,386,892
1994	168,299	256,271	501,050	50,511	299,484	72,643	262,052	18,640	18,657	64,512	467,640	540,281	2,720,040
1995	556,649	151,476	286,935	424,612	731,177	108,956	12,781	4,345	21,808	2,135	2,751	5,943	2,309,568
1996	14,095	3,725	14,358	24,314	103,743	60,606	18,491	133,341	59,416	97,142	1,010,552	299,535	1,839,318
MEAN	203,675	282,782	334,168	341,454	427,797	206,349	73,686	19,046	46,571	92,488	189,350	280,903	2,498,269

FIGURE 3-2
TOTAL ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED A

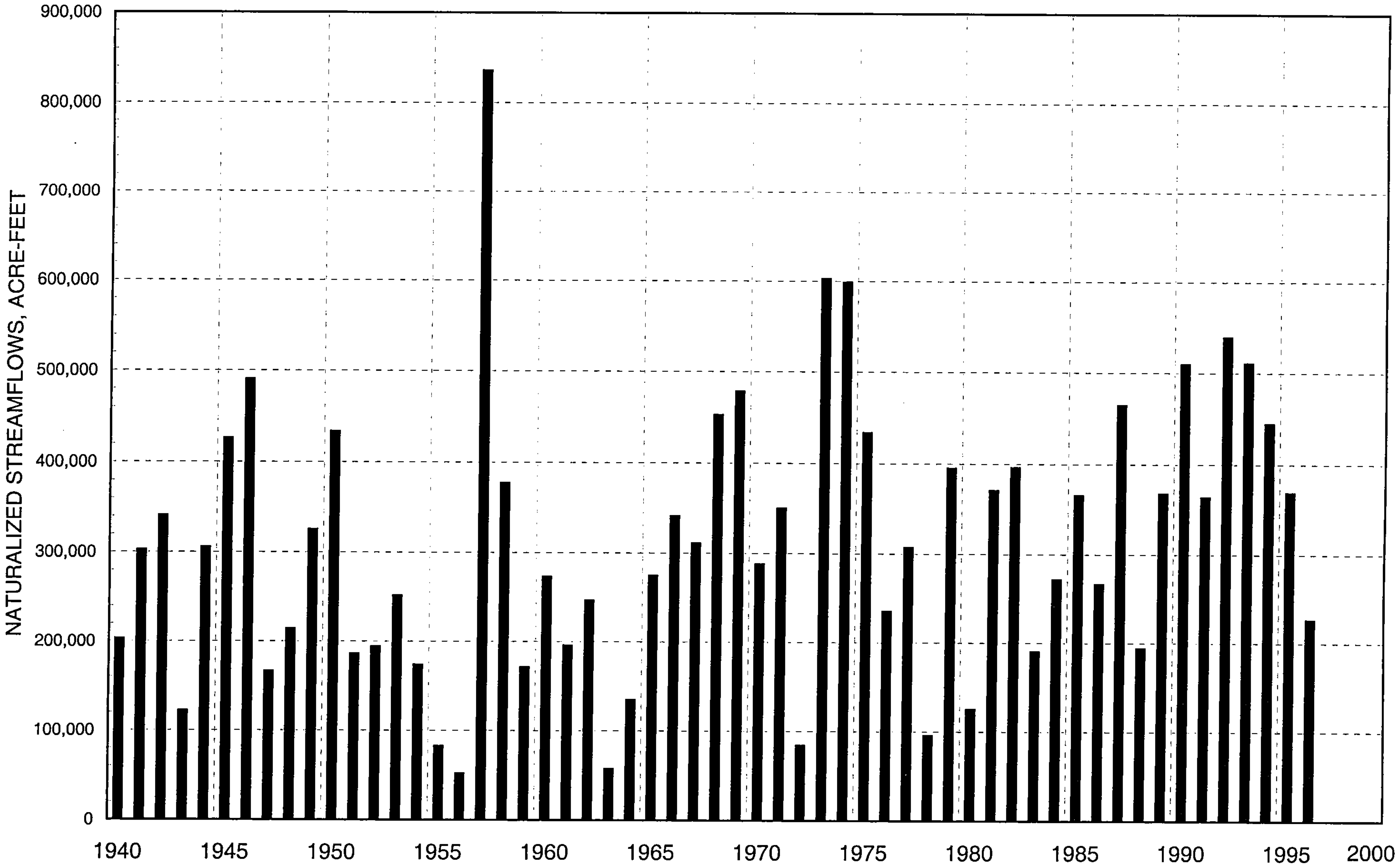


FIGURE 3-3
TOTAL ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED B

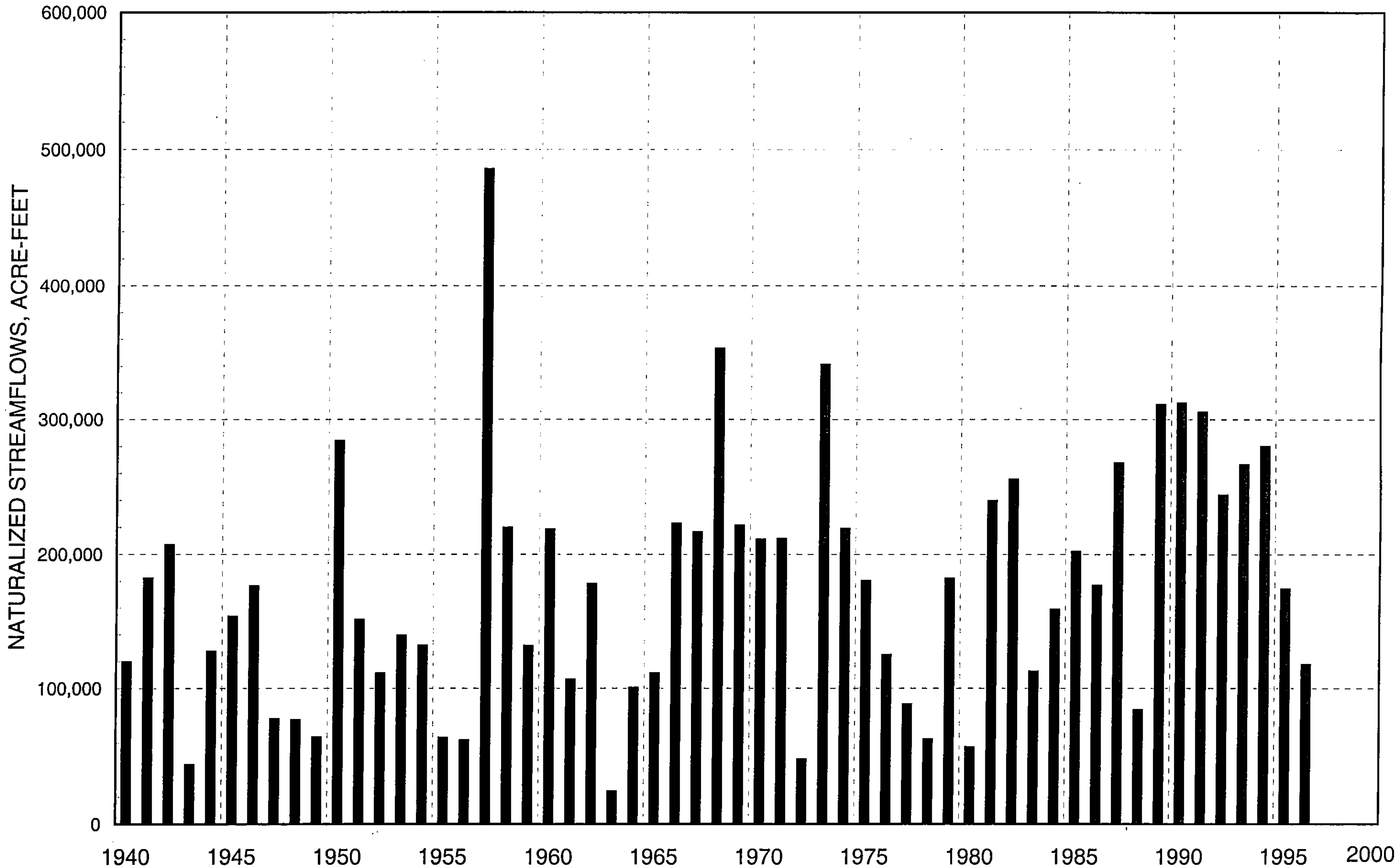


FIGURE 3-4
TOTAL ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED C

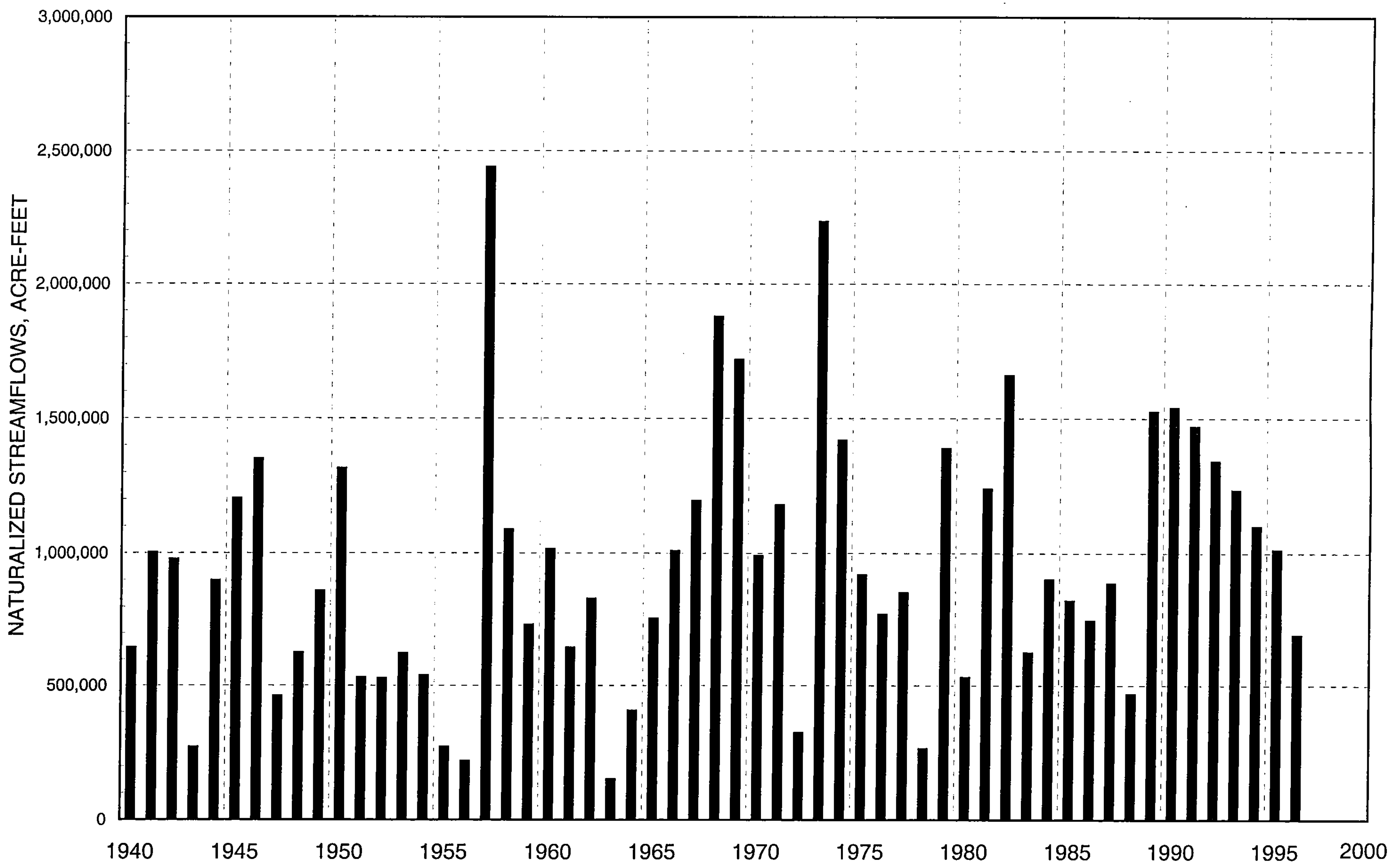


FIGURE 3-5
TOTAL ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED D

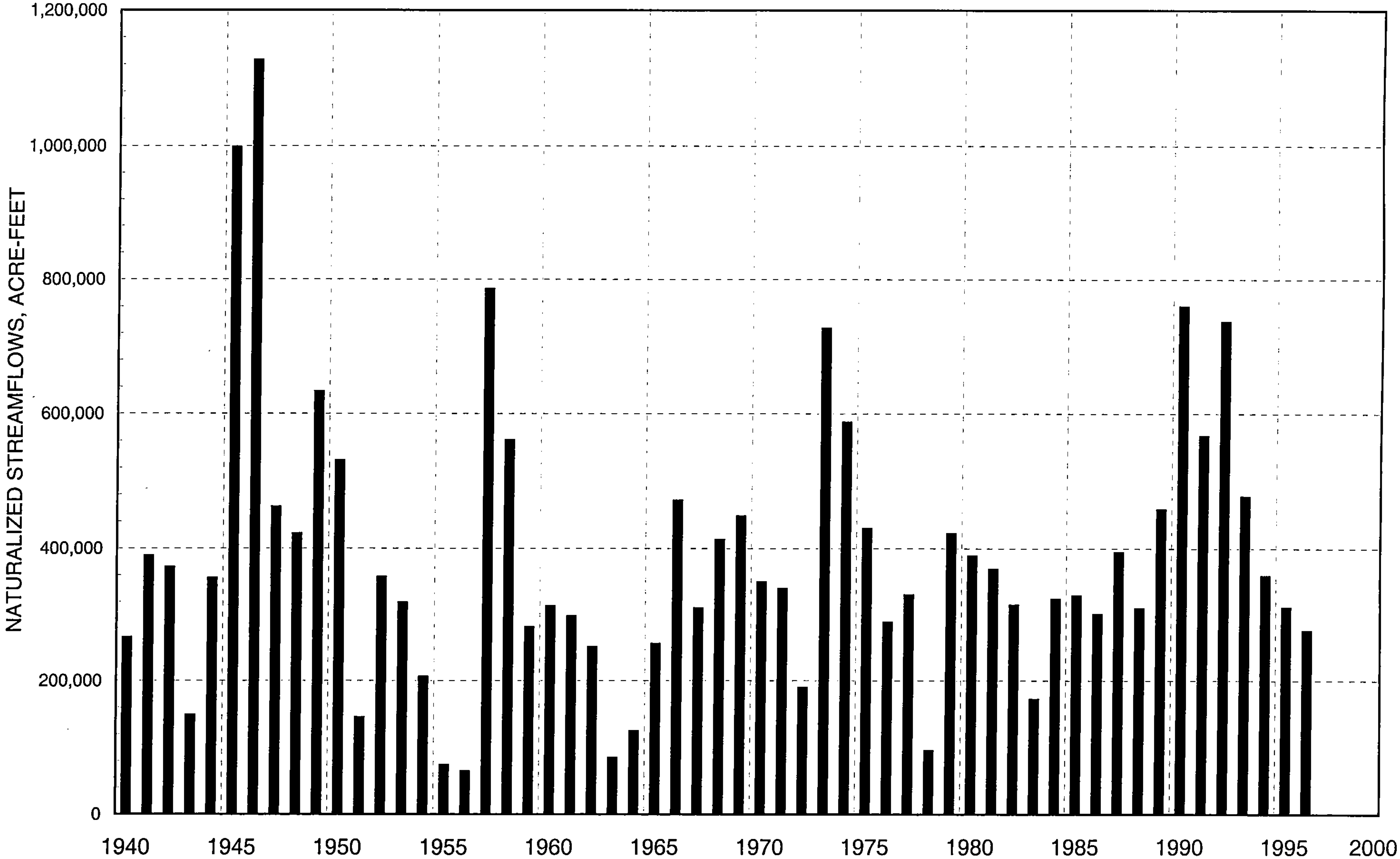


FIGURE 3-6
TOTAL ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED E

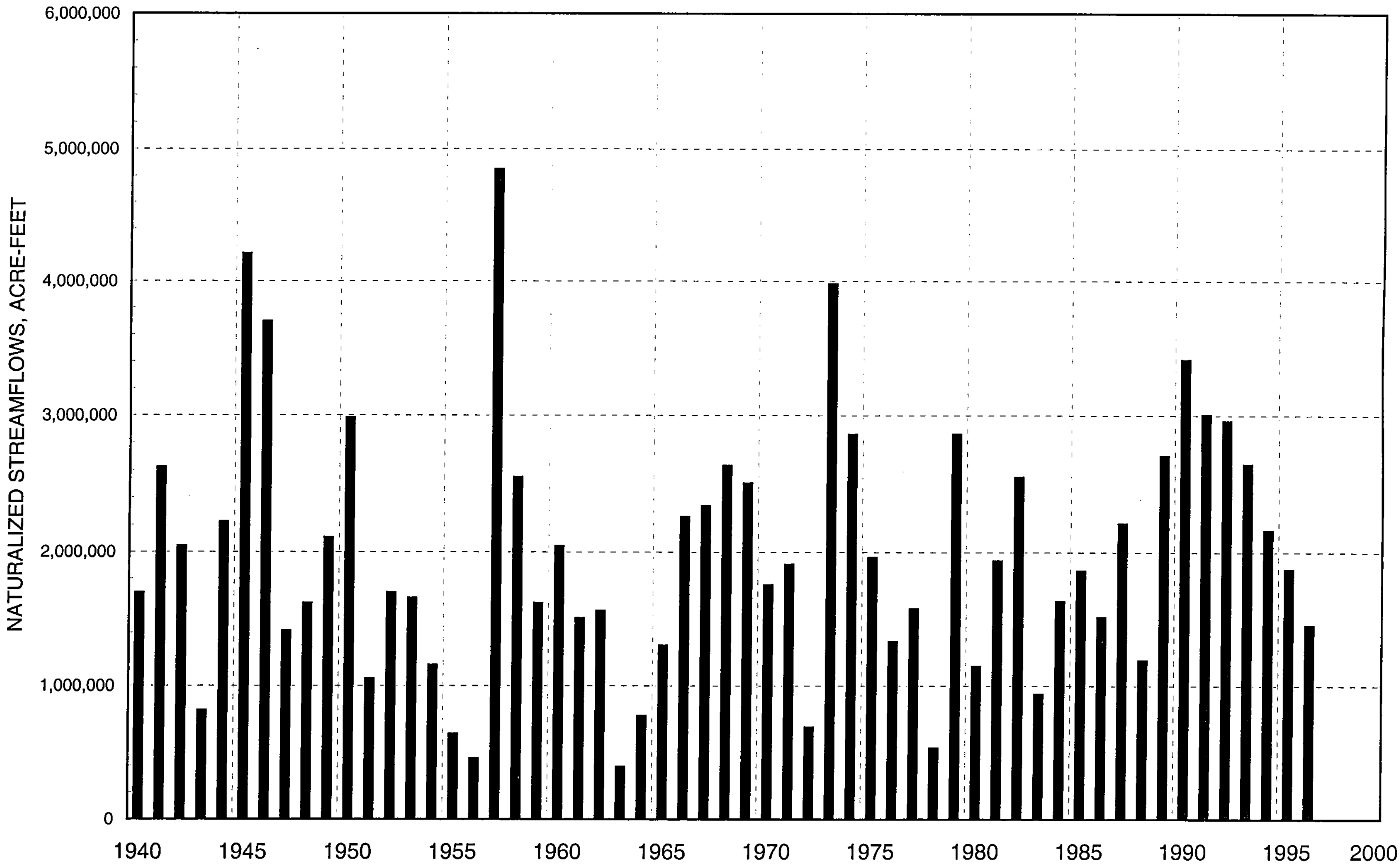
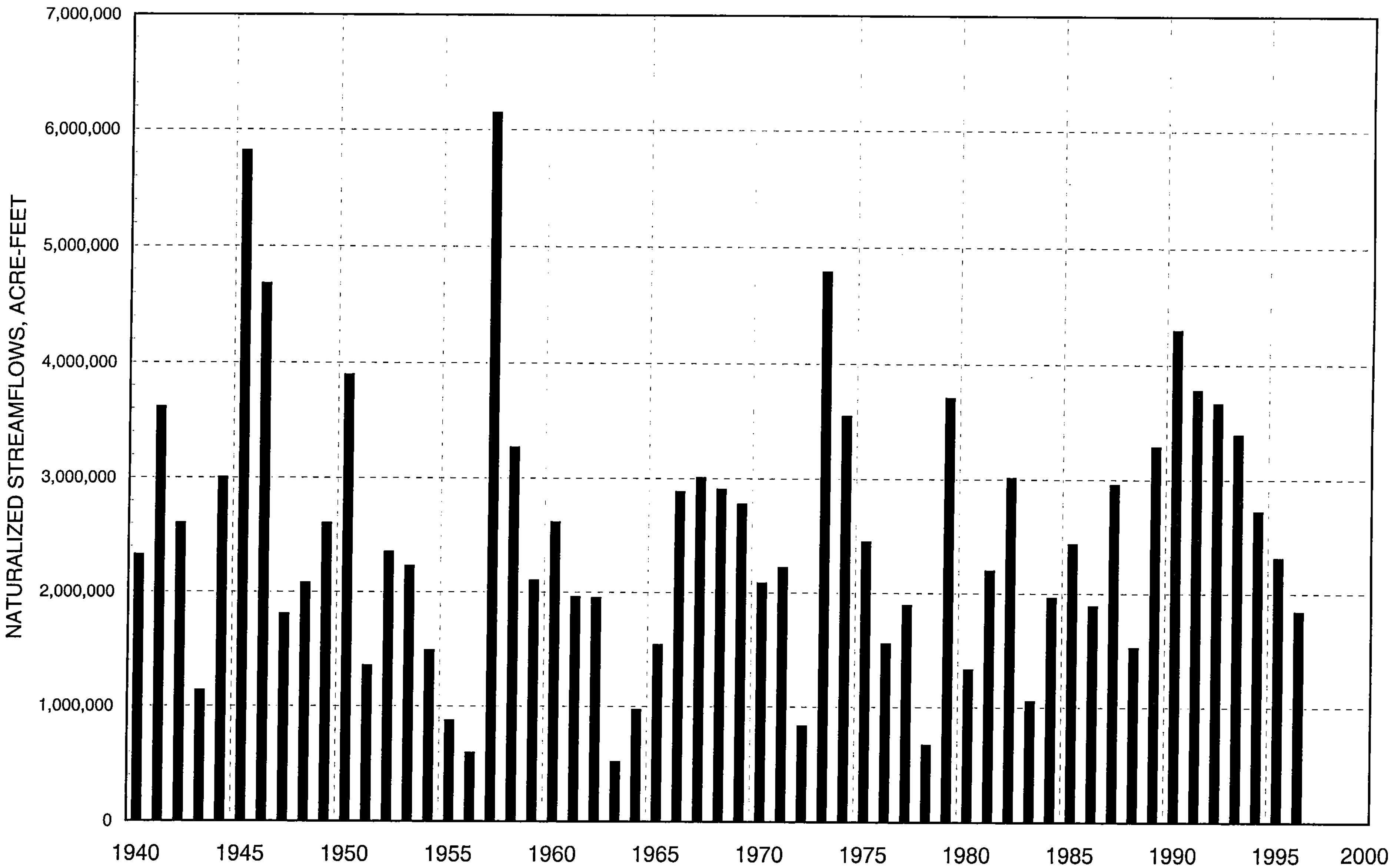


FIGURE 3-7
TOTAL ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM END OF SUBWATERSHED F



Appendix 2. Because of the relatively small adjustments made in the historical streamflows to account for historical diversions, return flows, and reservoir depletions (storage and evaporation losses), the naturalized streamflows are not significantly different from the historical streamflows. The only noticeable deviations are for Subwatersheds A and C. These differences between the two sets of streamflows are the result of Jim Chapman Lake, which began filling in late 1991 and, therefore, caused the historical streamflows measured at the USGS Gage No. 7342500 just downstream of the reservoir to be reduced.

As noted earlier, the TWDB (1971) conducted a Hydrologic Data Refinement Study (HDRS) of the Sulphur River Basin in the early 1970's and developed naturalized streamflows for gages located at the downstream ends of Subwatersheds A, B, C, D, and E. These earlier naturalized streamflows were determined for the period 1925 through 1968. Comparisons of the TWDB/HDRS annual naturalized streamflows with those developed in this present study are presented in Figures A2-6 through A2-10 in Appendix 2 for the gages located at the downstream ends of Subwatersheds A, B, C, D, and E, respectively.

While the corresponding values of these naturalized streamflows agree fairly well for most of the 1940-1968 common period, there are periods of several consecutive years for some of the gages when significant deviations occur. In every case, these differences between the two sets of naturalized streamflows correspond to periods when historical streamflow records are not available for some of the individual gages, and, consequently, records of monthly streamflows, either historical or naturalized, had to be generated and filled in order to provide the complete 1940-1968 set of monthly naturalized streamflows. It is likely that different techniques and procedures were used for data generation. In this present study, to the extent possible, correlations based on least square regressions have been developed relating the common records of monthly naturalized streamflows for a particular gage with missing historical data to those for another gage with historical data. These correlations (factors) then have been applied to estimate the missing naturalized streamflows. In some limited cases, drainage area ratios have been used to estimate the missing records.

The exact data generation and fill-in procedures used in the TWDB/HDRS investigation for the specific gages in the Sulphur River Basin are not known, but they very well could have been different from those used in this study. One primary reason for differences is that the locations of gages and, obviously, the periods of record for gages have changed. Much more data now are available for those gages that were in existence during the 1940-1968 period such that more meaningful relationships now can be developed relating the streamflows from one gage to those of another. Some of the older gages have been discontinued, while in some locations new gages have been established. Also, with the existence of Wright Patman Lake since the mid-1950's, there now is available a relatively long historical record of monthly reservoir inflows that provides a basis for generating missing streamflow records for gages in the lower and middle portions of the basin that previously was not available.

Given these overall differences in the available data bases for the TWDB/HDRS investigation and for this study, the variations between the two sets of naturalized streamflows as depicted on the plots in Figures A2-6 through A2-10 are not considered to be unreasonable. Both sets of naturalized streamflows incorporate values that have been generated and filled in for periods of missing historical streamflow data. The fact that more historical records have been available for this present study suggests that, overall, the naturalized streamflows derived in this study should provide a more accurate representation of the actual naturalized streamflows for the Sulphur River Basin.

3.1.6 Statistical Assessment of Trends in Streamflows

The monthly naturalized streamflows developed in this study at the downstream end of each of the six subwatersheds have been statistically analyzed, and monthly values of means, maximums, minimums, medians, and standard deviations have been determined. These values are summarized in Table 3-9. The percentage that each mean monthly flow value represents of its corresponding total annual flow also is indicated in the table.

The increasing trend in all of the streamflow values in the downstream direction is consistent with the normal streamflow variations in river basins. For example, the mean flow values for Subwatershed C are greater than the sum of the mean flow values for Subwatersheds A and B, both of which are located upstream of Subwatershed C and, therefore, contribute inflows to Subwatershed C. The difference in these mean flow values represents, of course, the incremental inflows from Subwatershed C. Similar trends are indicated for Subwatersheds C and D with respect to Subwatershed E and for Subwatershed E with respect to Subwatershed F. The magnitudes of the standard deviations of the different sets of streamflows relative to their respective mean flow values suggest that the monthly and annual streamflows can vary substantially from year to year.

The average monthly distributions of the streamflows among the different subwatersheds are generally similar. This is expected given the relatively small size of the Sulphur River Basin with respect to typical rainfall patterns and variations within the northeast Texas region.

TABLE 3-9
MONTHLY STREAMFLOW STATISTICS BY SUBWATERSHED
FOR ANALYSIS PERIOD 1940-1996

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
SUBWATERSHED A													
MEAN	22,051	33,719	38,039	41,560	53,504	29,020	9,175	2,068	8,883	15,863	28,054	29,944	311,881
MIN	0	37	10	34	6	6	0	0	0	0	0	0	51,794
MAX	102,558	160,465	138,015	259,718	233,227	172,596	63,140	19,666	77,697	128,074	156,814	195,267	835,592
MEDIAN	12,904	21,868	28,199	23,028	30,314	16,782	2,150	316	996	2,876	8,166	19,174	305,289
STD DEV	23,836	37,150	37,945	52,403	56,717	35,672	14,987	3,627	19,202	28,389	43,073	37,685	154,650
SUBWATERSHED B													
MEAN	10,475	16,694	20,853	24,231	30,185	16,888	5,931	1,320	5,873	12,328	14,524	15,968	175,270
MIN	5	21	270	181	157	31	0	0	0	0	0	0	24,283
MAX	72,069	82,363	75,180	179,508	151,320	106,586	53,606	9,821	34,793	109,731	83,644	93,902	485,924
MEDIAN	3,467	9,951	16,369	11,310	16,496	5,959	2,020	210	661	2,540	4,185	11,015	176,324
STD DEV	14,139	20,433	19,172	34,943	33,587	23,927	10,286	2,138	10,013	22,609	21,495	21,135	92,306
SUBWATERSHED C													
MEAN	67,300	104,042	113,453	117,598	170,086	87,304	30,899	6,725	23,794	50,108	80,475	100,739	952,524
MIN	9	154	728	756	1,196	85	0	0	0	0	0	0	151,932
MAX	265,638	479,680	446,010	618,861	757,998	420,365	236,454	61,428	188,814	431,803	405,784	679,015	2,438,464
MEDIAN	46,611	68,878	85,334	61,753	99,851	43,196	9,307	1,144	4,404	7,664	28,667	59,243	897,031
STD DEV	70,157	112,206	114,566	137,373	182,472	106,396	53,263	12,757	45,792	88,658	111,642	133,411	486,142
SUBWATERSHED D													
MEAN	33,661	44,841	49,799	51,792	60,503	26,600	14,988	3,432	5,887	17,254	32,556	45,751	387,065
MIN	82	170	631	260	307	0	0	0	0	0	0	0	63,958
MAX	198,424	228,289	301,552	238,952	261,382	156,985	230,767	56,215	63,356	239,547	177,515	244,775	1,125,841
MEDIAN	22,107	29,098	40,028	35,624	38,314	10,819	3,617	751	1,602	1,755	13,819	22,389	349,365
STD DEV	40,475	48,458	54,714	58,243	63,498	37,482	35,590	8,688	11,973	39,776	47,961	54,537	211,552
SUBWATERSHED E													
MEAN	158,058	223,311	258,266	265,028	340,201	165,285	61,338	15,100	39,067	81,331	155,468	221,237	1,983,691
MIN	587	3,725	7,734	5,053	1,504	127	57	16	16	1	35	1,080	392,305
MAX	470,029	1,009,121	1,145,365	1,219,267	1,348,394	690,895	511,310	194,393	481,900	540,855	829,601	1,150,861	4,849,145
MEDIAN	113,227	152,921	169,104	187,087	238,844	73,163	16,818	5,525	10,940	16,045	63,279	141,878	1,871,985
STD DEV	143,202	214,364	240,371	287,168	324,341	186,571	96,498	31,644	81,128	128,573	220,037	260,582	944,901
SUBWATERSHED F													
MEAN	203,675	282,782	334,168	341,454	427,797	206,349	73,686	19,046	46,571	92,488	189,350	280,903	2,498,269
MIN	587	3,725	10,454	5,053	1,504	127	69	16	22	1	35	1,853	516,674
MAX	607,297	1,288,167	1,531,416	1,812,128	1,713,725	839,467	557,531	255,610	675,299	540,855	1,049,055	1,331,974	6,145,262
MEDIAN	156,062	215,615	240,774	238,701	294,721	94,732	17,286	5,862	11,605	21,804	83,906	150,265	2,323,767
STD DEV	182,855	265,594	310,361	381,993	408,237	235,377	113,370	41,152	104,459	141,234	273,605	326,333	1,211,324

3.2 NATURAL STREAMFLOWS AT UNGAGED LOCATIONS

3.2.1 Distribution of Natural Flows

As described above, monthly naturalized streamflows for the period 1940 through 1996 have been derived from historical stream gage records for locations at the downstream ends of each of the subwatersheds that have been defined for the Sulphur River Basin, i. e. at gage locations and the state line. For the water availability analyses, the corresponding monthly naturalized streamflows are required at every location on streams within the basin where water availability calculations are to be performed. This includes the location of every water right, as well as other selected points such as stream confluences and the ends of TNRCC classified stream and lake segments. As described later in Section 4.2.1, all of the locations where the water availability calculations are to be performed are referred to as "control points". All of the control points used in the water availability analyses for the Sulphur River Basin are identified and described in Figure 4-1 and Table 4-1 in the next section.

For distributing the monthly naturalized streamflows from the primary locations at the downstream ends of the six subwatersheds (referred to as primary control points) to the locations of individual water rights and other selected points (referred to as secondary control points), procedures developed and investigated by Dr. Ralph Wurbs of Texas A&M and coded in program RECORDS (Wurbs, 1998) have been used. The specific method used for distributing the naturalized streamflows is referred to as the U. S. Natural Resources Conservation Service (NRCS) Curve Number (CN) method, and is it described in detail and documented in the RECORDS users manual (Wurbs, 1998). This method uses total drainage areas, curve numbers, and mean annual precipitation to distribute the flows from primary to secondary control points.

The basis for NRCS-CN streamflow distribution method dates back to the 1950's, and it is founded on rainfall-runoff relationships developed through extensive field testing conducted by the Soil Conservation Service (SCS, now known as the NRCS). From these studies, the SCS developed a range of watershed parameters, referred to as curve numbers, that could be used to describe the natural losses when computing total runoff volume for a given precipitation event, originally assumed to be one day in duration. The curve number watershed parameters are dimensionless and range from 0 to 100, where a curve number value of 100 represents a perfectly impervious watershed such that all precipitation occurs as runoff. A curve number value equal to zero would represent a watershed condition where all precipitation is lost to infiltration, evapotranspiration and/or surface depression storage such that there is no runoff. The NRCS has determined curve number values empirically, and they can be established for any watershed as a function of soil type, land use/cover condition, and antecedent moisture condition. For purposes of the NRCS-CN streamflow distribution method, as developed and applied for purposes of the water availability analyses, the curve number rainfall-runoff relationships have been extended to monthly conditions.

The following relationship between precipitation depth P, in inches, and runoff depth Q, in inches, is the fundamental curve number equation developed by the SCS, and this is the relationship that is incorporated into the NRCS-CN streamflow distribution procedure:

$$Q = (P - 0.2S)^2/(P + 0.8S) \quad \text{if } P \geq 0.2S$$

$$Q = 0 \quad \text{if } P < 0.2S$$

$$\text{where } S = (1000/CN) - 10$$

The NRCS-CN computational algorithm used by the RECORDS program converts the monthly streamflow in acre-feet at a primary control point (typically a gage location) to inches of runoff (Q_p) by dividing the streamflow by the contributing drainage area, and then computes the corresponding monthly precipitation (P_p) for the primary control point using the appropriate curve number for the watershed upstream of the primary control point and the above equations. The corresponding monthly precipitation for the secondary control point (P_s) to which streamflow is being distributed is estimated by multiplying P_p at the primary control point by the ratio of the long-term mean annual precipitation of the secondary control point subwatershed to that of the primary control point watershed. The streamflow at the secondary control point (Q_s) is then computed by solving the above equations using the computed precipitation at the secondary control point (P_s) and the specific curve number for the subwatershed above the secondary control point. The distributed Q_s values for all control points provide the fundamental inputs to the water availability calculations.

Drainage areas, mean annual precipitation, and SCS curve numbers for all of the primary and secondary control points used in the water availability analyses for the Sulphur River Basin have been determined by the University of Texas Center for Research in Water Resources (CRWR) using geographic information system (GIS) data bases and computerized procedures. The GIS has a physical resolution of 90 meters square, or 2 acres, which represents the size of the area with which each cell of digitized information is associated. Except for a few control points with exceptionally small drainage areas that were significantly affected by the physical resolution of the GIS data, the parameters derived by CRWR have been used directly in the RECORDS program. The parameters for the small drainage areas were determined separately. For control points representing off-channel reservoirs with no significant contributing drainage area, zero watershed inflows have been assumed, and the NRCS-CN distribution procedure has not been applied. However, direct rainfall on these impoundments has been accounted for in the analyses.

Table 3-10 summarizes the subwatershed data (drainage areas, curve numbers and mean annual precipitation) developed and provided by CRWR for all control points used in the water availability analyses. The types and associated water rights of the control points are indicated in the table. Again, the locations of these control points are identified on the map in Figure 4-1 in the next section.

3.2.2 Ungaged Freshwater Inflows to the Estuary

The Sulphur River Basin has no estuarine reach; therefore, there are no ungaged freshwater inflows to its estuary.

3.3 NET RESERVOIR EVAPORATION

3.3.1 Evaporation and Precipitation Data Sources

Historical monthly values of reservoir evaporation and corresponding precipitation have been used in the water availability analyses, and also the streamflow naturalization process, to describe the net evaporation losses from reservoirs throughout the Sulphur River Basin. For these purposes, data compiled primarily by the Texas Water Developed Board (TWDB, 1996) have been used.

The TWDB data base includes the average monthly historical gross reservoir evaporation and precipitation at the center of each one-degree latitude-longitude quadrangle for the entire state for the period 1953 through 1996. For the Sulphur River Basin, data for three quadrangles have been used, i. e., between Latitude 33° and 34° and Longitude 94° and 97°. The boundaries of these quadrangles superimposed on the Sulphur River Basin are shown on the map in Figure 3-8. For the period prior to 1953, historical monthly gross reservoir evaporation data for each of the three quadrangles from an older TWDB publication (TWDB, 1967) have been used, along with historical monthly precipitation records for individual National Weather Service rainfall gages in the Sulphur River Basin (Hydrosphere, 1998). These precipitation records have been analyzed to establish average values corresponding to the three quadrangles.

The complete sets of monthly gross reservoir evaporation values for each of the three quadrangles as used in the water availability analyses are listed in Tables 3-11 through 3-13 for the entire period 1940 through 1996. Corresponding sets of monthly precipitation values for the three quadrangles are listed in Tables 3-14 through 3-16.

TABLE 3-10
SUMMARY OF CONTROL POINT SUBWATERSHED DATA PROVIDED BY CRWR

CONTROL POINT NUMBER[1]	TYPE OF CONTROL POINT					WATER RIGHT IDENTIFICATION NUMBER[3]	NAME	STREAM	NEXT DOWNSTREAM CONTROL POINT	DOWNSTREAM PRIMARY CONTROL POINT USED FOR NATURALIZED FLOW	INCREMENTAL DRAINAGE AREA BELOW UPSTREAM CONTROL POINTS	TOTAL DRAINAGE AREA	MEAN CURVE NUMBER FOR TOTAL DRAINAGE AREA	MEAN ANNUAL PRECIPITATION FOR TOTAL DRAINAGE AREA
	NATURALIZED FLOW	CLASSIFIED SEGMENT	SPECIAL[2]	WATER RIGHT	OFF-CHANNEL RESERVOIR						Sq. Mi.	Sq. Mi.		In.
F10	X	X					TEXAS-ARKANSAS STATE LINE	Sulphur River	N/A	N/A	83.92	3579.67	69.4	45.0
F20		X					TEXAS-ARKANSAS STATE LINE	Days Creek	N/A	F10	66.22	66.22	82.9	47.0
F30			a				TEXAS-ARKANSAS STATE LINE	Cypress Creek	N/A	F10	48.93	49.28	62.6	46.9
F40				X		03- 4838	INTERNATIONAL PAPER COMPANY	Grassy Creek	F30	F10	0.35	0.35	58.6	47.0
F50				X		03- 4837	LEON S KENNEDY JR	Crutcher's Creek	F10	F10	2.50	2.50	76.1	47.0
F60		X		X		03- 4836	CITY OF TEXARKANA	Sulphur River, Wright Patman	F10	F10	371.62	3493.25	69.4	44.9
F70				X		03- 4835	JERRY D PRATHER ET UX	Unnamed trib. of Moss Creek	F60	F10	0.47	0.47	72.0	48.0
F80				X		03- 4833	H C PRANGE JR	Unnamed trib. of Rice Creek	F60	F10	0.05	0.05	62.1	48.0
F81					X	03- 4833	H C PRANGE JR		F80	F10	N/A	N/A	N/A	N/A
F90				X		03- 4832	CITY OF NEW BOSTON	Holly Branch	F60	F10	1.08	1.08	76.5	48.0
F100				X		03- 4831	CITY OF NEW BOSTON	Unnamed trib. of Rice Creek	F60	F10	1.26	1.26	82.1	48.0
F110			b	X		03- 4830	WILLIAM E JOHNSON JR ET AL	Unnamed trib. of Anderson Creek	F60	F10	104.56	104.56	78.7	48.2
F120				X		03- 4834	WILLIAM E JOHNSON JR ET AL	Brooks Creek	F60	F10	17.96	17.96	72.6	47.6
F130		X					HEADWATERS OF WRIGHT PATMAN LAKE	Sulphur River	F60	F10	127.67	2996.25	69.0	44.5
F140				X		03- 4829	WILLIAM E JOHNSON JR ET AL	Eds Creek	F130	F10	8.11	8.11	72.2	47.0
F150				X		A- 5449	TEXAS PARKS & WILDLIFE DEPT	Caney Creek	F130	F10	11.36	11.36	64.9	46.7
F151					X	A- 5449	TEXAS PARKS & WILDLIFE DEPT		F150	F10	N/A	N/A	N/A	N/A

TABLE 3-10, CONT'D
SUMMARY OF CONTROL POINT SUBWATERSHED DATA PROVIDED BY CRWR

CONTROL POINT NUMBER[1]	TYPE OF CONTROL POINT					WATER RIGHT IDENTIFICATION NUMBER[3]	NAME	STREAM	NEXT DOWNSTREAM CONTROL POINT	DOWNSTREAM PRIMARY CONTROL POINT USED FOR NATURALIZED FLOW	INCREMENTAL DRAINAGE AREA BELOW UPSTREAM CONTROL POINTS	TOTAL DRAINAGE AREA	MEAN CURVE NUMBER FOR TOTAL DRAINAGE AREA	MEAN ANNUAL PRECIPITATION FOR TOTAL DRAINAGE AREA
	NATURALIZED FLOW	CLASSIFIED SEGMENT	SPECIAL[2]	WATER RIGHT	OFF-CHANNEL RESERVOIR						Sq. Mi.	Sq. Mi.		In.
E10	X						SULPHUR RIVER NEAR DARDEN	Sulphur River	F130	N/A	175.63	2849.11	69.0	44.4
E20			a				WHITE OAK CREEK AT MOUTH	White Oak Creek	E10	E10	222.96	809.52	69.4	44.6
E30				X		03- 4828	GLASS CLUB LAKE INC	Unnamed trib. of Village Creek	E20	E10	3.50	3.50	78.1	46.0
E40				X		03- 4827	BROVENTURE COMPANY INC	Murphy Branch, Lake No. 1	E20	E10	1.49	2.76	72.2	47.0
E50				X		03- 4827	BROVENTURE COMPANY INC	Murphy Branch, Lake No. 2	E40	E10	1.27	1.27	73.1	47.0
E60				X		03- 4825	ROBERT CROOKS ET AL	East Piney Creek	E20	E10	0.30	0.30	63.9	46.0
E70				X		03- 4826	ELLIS-KELLY LAKE CLUB	East Piney Creek	E20	E10	0.97	0.97	45.6	46.0
E80				X		03- 4823	ARDELIA GAUNTT	Unnamed trib. of Piney Creek	E20	E10	0.11	0.13	58.5	46.0
E90				X		03- 4824	WALTER W LEE	Unnamed trib. of Piney Creek	E80	E10	0.02	0.02	61.0	46.0
E100				X		A- 5510	TEXAS UTIL MINING CO/TU SVCS	Unnamed trib. of Piney Creek	E20	E10	0.83	0.83	68.8	46.0
E110				X		A- 5285	TEXAS UTIL MINING CO/TU SVCS	Unnamed trib. of Piney Creek	E20	E10	0.20	0.20	69.0	46.0
E120				X		03- 4822	JOHN E & BERNICE BALDWIN	Unnamed trib. of McCullough Creek	E20	E10	4.93	4.93	69.3	45.3
E130				X		03- 4821	ANNA PEARL LEWIS	Unnamed trib. of Ripley Creek	E20	E10	5.63	5.63	68.5	45.0
E140				X		A- 5562	TEXAS UTILITIES MINING CO	Unnamed trib of Dorsey Creek (Pt 1)	E20	E10	0.13	0.13	70.3	46.0
E150			b	X		A- 5562	TEXAS UTILITIES MINING CO	Dorsey Creek (Pts 2 6)	E20	E10	0.98	0.98	72.7	46.0
E160				X		03- 4820	BILLY J MAXTON	Ripley Creek	E20	E10	19.52	20.24	71.8	44.1
E170			b	X		A- 5562	TEXAS UTILITIES MINING CO	Unnamed trib of Ripley Creek (Pts 7-9)	E160	E10	0.48	0.48	72.2	45.0

TABLE 3-10, CONT'D
SUMMARY OF CONTROL POINT SUBWATERSHED DATA PROVIDED BY CRWR

CONTROL POINT NUMBER[1]	TYPE OF CONTROL POINT: NATURALIZED FLOW	CLASSIFIED SEGMENT	SPECIAL[2]	WATER RIGHT	OFF-CHANNEL RESERVOIR	WATER RIGHT IDENTIFICATION NUMBER[3]	NAME	STREAM	NEXT DOWNSTREAM CONTROL POINT	DOWNSTREAM PRIMARY CONTROL POINT USED FOR NATURALIZED FLOW	INCREMENTAL DRAINAGE AREA BELOW UPSTREAM CONTROL POINTS Sq. Mi.	TOTAL DRAINAGE AREA Sq. Mi.	MEAN CURVE NUMBER FOR TOTAL DRAINAGE AREA	MEAN ANNUAL PRECIPITATION FOR TOTAL DRAINAGE AREA In.
D10	X						WHITE OAK CREEK NEAR TALCO, GAGE #7343500	White Oak Creek	E20	N/A	62.55	545.96	70.8	44.1
D20				X		03- 4819	DDC PROPERTIES LTD	Lick Creek	D10	D10	7.07	7.07	68.7	44.2
D30				X		03- 4818	ROBERT W CAMPBELL ET AL	Unnamed trib. of Campbell Creek	D10	D10	0.03	0.03	70.0	45.0
D40			b	X		03- 4817	HANS WEISS ET UX	Bear Pen (trib of White Oak) and White Oak Creeks	D10	D10	412.79	476.31	71.1	44.2
D50				X		A- 5392	PAUL A PIEFER ET UX	Town Branch	D40	D10	1.18	1.18	76.7	44.0
D60				X		03- 4816	CITY OF MOUNT VERNON	Denton Creek	D40	D10	0.04	0.04	70.0	44.0
D70				X		03- 4815	CHARLES HELM & LEWIS HELM	Unnamed trib. of Mitchell Creek	D40	D10	2.11	2.11	70.8	43.0
D80				X		03- 4814	JERRY N JORDAN TRUSTEE ET AL	Unnamed trib. of Wolfpen Creek	D40	D10	2.91	2.91	67.2	44.0
D90				X		A- 5150	LARRY MILES ET AL	Unnamed trib. of Cross Timber Creek	D40	D10	1.11	1.11	66.1	44.0
D100				X		03- 4813	SULPHUR SPRINGS COUNTRY CLUB	Unnamed trib. of Rock Creek	D40	D10	0.56	0.56	71.1	45.0
D110				X		03- 4812	CITY OF SULPHUR SPRINGS	Unnamed trib. White Oak Creek, L. Coleman	D40	D10	1.19	1.19	81.1	45.0
D120				X		03- 4811	SULPHUR SPRINGS WATER DIST	White Oak Creek, Lake Sulphur Springs	D40	D10	54.42	54.42	71.2	44.3
E180			a				CUTHAND CREEK AT MOUTH	Cuthand Creek	E10	E10	379.47	386.33	67.9	45.8
E190				X		03- 4810	PERRY R BASS INC	Sand Branch	E180	E10	1.28	1.28	69.4	46.0
E200				X		03- 4809	RED RIVER COUNTY WCID 1	Langford Creek	E180	E10	1.49	1.49	71.5	45.0
E210				X		03- 4808	RED RIVER COUNTRY CLUB	Pickett Creek	E180	E10	3.44	3.44	67.7	45.8
E220				X		03- 4807	MARY MARGARET VAUGHAN	Barnard Draw	E180	E10	0.03	0.64	64.4	45.0

TABLE 3-10, CONT'D

SUMMARY OF CONTROL POINT SUBWATERSHED DATA PROVIDED BY CRWR

CONTROL POINT NUMBER[1]	TYPE OF CONTROL POINT					WATER RIGHT IDENTIFICATION NUMBER[3]	NAME	STREAM	NEXT DOWNSTREAM CONTROL POINT	DOWNSTREAM PRIMARY CONTROL POINT USED FOR NATURALIZED FLOW	INCREMENTAL DRAINAGE AREA BELOW UPSTREAM CONTROL POINTS	TOTAL DRAINAGE AREA	MEAN CURVE NUMBER FOR TOTAL DRAINAGE AREA	MEAN ANNUAL PRECIPITATION FOR TOTAL DRAINAGE AREA
	NATURALIZED FLOW	CLASSIFIED SEGMENT	SPECIAL[2]	WATER RIGHT	OFF-CHANNEL RESERVOIR						Sq. Mi.	Sq. Mi.		In.
E230				X		03- 4806	MARY MARGARET VAUGHAN	Barnard Draw	E220	E10	0.62	0.62	64.7	45.0
E240			b	X		03- 4805	E P LAND & CATTLE CO INC	Unnamed tribs. of Sulphur Riv. (Res 5-7)	E10	E10	0.12	0.12	68.0	46.2
E250				X		03- 4805	E P LAND & CATTLE CO INC	Sulphur River	E10	E10	95.23	1477.53	69.2	43.5
E260				X		03- 4805	E P LAND & CATTLE CO INC	Unnamed trib. of Sulphur River (Res 4)	E250	E10	0.24	0.24	55.0	46.0
E270			b	X		03- 4805	E P LAND & CATTLE CO INC	Unnamed tribs. of Sulphur Riv. (Res 1-3)	E250	E10	0.48	0.48	58.6	45.9
C10	X						SULPHUR RIVER NEAR TALCO, GAGE #7343200	Sulphur River	E250	N/A	3.00	1381.88	69.5	43.4
C20				X		03- 4804	TEXAS UTILITIES ELECTRIC CO	Sulphur River	C10	C10	66.50	1378.88	69.5	43.4
C21					X	03- 4804	TEXAS UTILITIES ELECTRIC CO	Rivercrest Reservoir	C20	C10	N/A	N/A	N/A	N/A
C30				X		03- 4803	HELMUT HERMANN ET AL	Unnamed trib. of Sulphur River, Terry L.	C20	C10	3.54	3.54	67.8	43.0
C40				X		03- 4803	HELMUT HERMANN ET AL	Sulphur River	C20	C10	126.80	1308.84	69.5	43.4
C50				X		03- 4802	ALEXANDER FRICK ET AL	Unnamed trib. of Sulphur River	C40	C10	7.92	7.92	68.3	43.0
C60			b	X		A- 4148B	SARA M DUNHAM TRUST	Sulphur River and South Sulphur River	C40	C10	117.74	1174.12	69.6	43.2
C61					X	A- 4148B	SARA M DUNHAM TRUST		C60	C10	N/A	N/A	N/A	N/A
C70				X		A- 4148	SARA M DUNHAM TRUST	Old Channel South Sulphur River	C60	C10	22.85	35.45	67.5	43.9
C71				X	X	A- 4148	SARA M DUNHAM TRUST		C70	C10	N/A	N/A	N/A	N/A
C80				X		A- 4148A	SARA M DUNHAM TRUST	Old Channel South Sulphur River	C70	C10	12.60	12.60	65.5	44.0
C81						A- 4148A	SARA M DUNHAM TRUST		C80	C10	N/A	N/A	N/A	N/A
C90		X					NORTH SULPHUR RIVER AT MOUTH	North Sulphur River	C60	C10	166.13	479.46	70.1	43.7

TABLE 3-10, CONT'D
SUMMARY OF CONTROL POINT SUBWATERSHED DATA PROVIDED BY CRWR

CONTROL POINT NUMBER[1]	TYPE OF CONTROL POINT: NATURALIZED FLOW	CLASSIFIED SEGMENT	SPECIAL[2]	WATER RIGHT	OFF-CHANNEL RESERVOIR	WATER RIGHT IDENTIFICATION NUMBER[3]	NAME	STREAM	NEXT DOWNSTREAM CONTROL POINT	DOWNSTREAM PRIMARY CONTROL POINT USED FOR NATURALIZED FLOW	INCREMENTAL DRAINAGE AREA BELOW UPSTREAM CONTROL POINTS Sq. Mi.	TOTAL DRAINAGE AREA Sq. Mi.	MEAN CURVE NUMBER FOR TOTAL DRAINAGE AREA	MEAN ANNUAL PRECIPITATION FOR TOTAL DRAINAGE AREA In.
C100				X		A- 5200	GORDON COUNTRY CLUB	Cottonwood Branch	C90	C10	2.02	2.02	70.6	45.0
B10	X						NORTH SULPHUR RIVER NEAR COOPER, GAGE #7343000	North Sulphur River	C90	N/A	310.73	311.32	70.0	43.2
B20				X		A- 4205	CITY OF PECAN GAP	Unnamed trib. of North Sulphur River	B10	B10	0.42	0.42	72.3	43.0
B30			c				JACK KRECK	Unnamed trib. of Pickle Ck	B10	B10	0.18	0.18	73.5	43.0
C110				X		03- 4801	DELTA COUNTRY CLUB INC	Unnamed trib. of Brushy Creek	C60	C10	0.46	0.46	71.9	43.0
A10	X						SOUTH SULPHUR RIVER NEAR COOPER, GAGE #7342500	South Sulphur River	C60	N/A	23.94	541.01	69.4	42.7
A20				X		03- 4800	CITY OF COOPER	Cedar Creek, City Lake	A10	A10	0.04	0.04	75.5	44.0
A30				X		A- 4395	CITY OF COOPER	Big Creek, Big Creek Lake	A10	A10	12.44	12.44	69.9	43.0
A40		X		X		03- 4799 03- 4798 03- 4797	CITY OF IRVING NORTH TEXAS MWD SULPHUR RIVER MWD	South Sulphur River, Jim Chapman Lake	A10	A10	174.90	504.58	69.4	42.6
A50		X	d				MIDDLE SULPHUR RIVER BELOW BARNETT CREEK	Middle Sulphur River	A40	A10	106.34	106.34	69.9	42.4
A60		X	d				HEADWATERS OF JIM CHAPMAN LAKE	South Sulphur River	A40	A10	222.32	223.33	69.6	42.2
A70			b	X		03- 4795	CITY OF WOLFE CITY	East Fork of Turkey Ck and Turkey Creek	A60	A10	0.74	0.74	72.8	42.0
A80				X		03- 4796	WEBB HILL COUNTRY CLUB	Unnamed trib. of South Sulphur River	A60	A10	0.28	0.28	70.0	42.0

[1] Control points listed in river order beginning at downstream end of basin.

[2] Special Control Points:
- a = mouth of major tributary
- b = functional control point representing multiple impoundments/diversion points
- c = impoundment greater than 200 ac-ft with no associated water right
- d = major tributary to Jim Chapman Lake

[3] Water Right ID Number:
- 03 = Certificate of Adjudication in Basin 03 (Sulphur River Basin)
- A = Application Number associated with Water Right Permit

FIGURE 3-8
TEXAS WATER DEVELOPMENT BOARD RESERVOIR EVAPORATION QUADRANGLES FOR THE SULPHUR RIVER BASIN

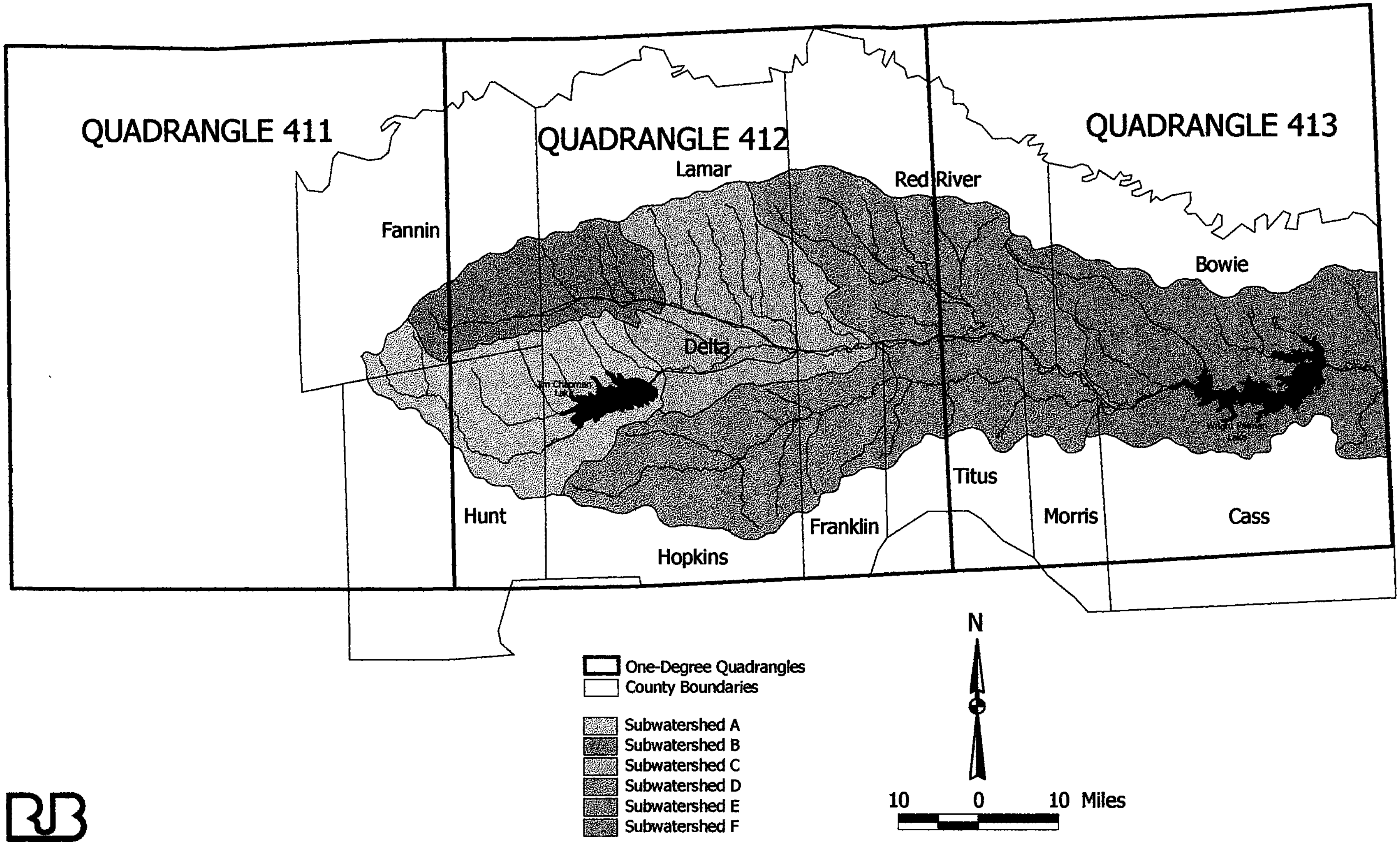


TABLE 3-11
GROSS RESERVOIR EVAPORATION FOR TWDB QUADRANGLE 411
(Inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	1.60	2.20	4.80	4.80	5.70	6.20	8.00	8.90	8.20	6.10	3.40	2.10	62.00
1941	2.10	2.10	2.80	2.90	4.80	5.60	7.90	7.50	6.80	4.40	3.00	2.10	52.00
1942	2.10	2.60	4.20	3.70	5.00	6.20	8.30	7.30	6.00	4.50	4.10	2.00	56.00
1943	2.30	3.20	3.40	4.70	4.50	6.80	9.00	10.70	6.70	5.30	3.50	1.90	62.00
1944	1.60	2.00	2.90	4.80	4.40	7.70	8.40	10.10	6.80	5.30	3.40	2.60	60.00
1945	2.00	2.10	2.90	3.40	5.90	6.50	6.20	7.90	7.80	4.20	3.80	2.30	55.00
1946	1.90	3.00	3.40	4.40	4.30	6.10	9.20	9.30	5.00	5.00	2.80	2.60	57.00
1947	2.20	2.70	3.10	3.50	4.80	6.80	9.00	10.10	8.80	5.80	3.30	1.90	62.00
1948	1.70	1.50	3.20	6.50	6.00	8.10	8.10	8.30	7.60	5.60	4.40	3.00	64.00
1949	1.90	1.90	2.80	3.70	4.90	7.20	8.50	7.40	5.70	4.10	4.00	1.90	54.00
1950	2.00	3.30	4.30	4.90	5.80	7.00	5.70	7.20	4.60	5.90	4.70	2.60	58.00
1951	3.10	2.20	4.10	5.30	5.30	6.70	8.50	10.30	7.30	6.40	2.90	2.90	65.00
1952	2.70	2.80	4.00	4.10	7.40	9.40	9.40	10.50	6.80	6.50	4.50	1.90	70.00
1953	2.40	2.30	3.80	4.90	6.20	10.60	8.30	8.10	7.70	4.90	2.70	3.10	65.00
1954	1.23	4.22	4.94	5.55	4.06	6.96	9.25	10.61	7.37	4.25	2.99	2.36	63.33
1955	1.74	1.84	4.02	4.47	5.18	6.97	8.09	7.28	6.47	6.00	4.32	2.47	59.67
1956	2.08	2.20	4.85	5.78	6.13	8.44	9.43	11.14	8.82	5.43	3.36	2.19	62.89
1957	1.85	1.79	2.73	2.78	3.20	6.03	8.17	7.21	5.42	3.63	1.76	2.08	43.31
1958	1.40	1.56	2.37	3.49	4.18	6.56	8.50	6.81	4.54	3.57	3.17	1.35	42.88
1959	1.31	2.06	4.78	4.66	4.97	5.64	5.84	6.56	5.63	4.25	2.14	2.18	49.83
1960	1.42	1.93	2.86	4.33	5.13	6.79	6.50	6.26	5.10	3.48	2.60	1.49	50.83
1961	1.34	1.79	3.92	4.92	4.72	6.09	6.27	6.50	5.57	3.96	2.47	1.81	47.89
1962	1.61	2.61	3.72	4.00	6.09	5.03	6.30	6.91	4.67	4.17	2.31	1.69	50.39
1963	1.62	2.02	5.03	4.84	4.82	6.69	6.69	7.69	5.39	5.99	3.47	1.90	56.74
1964	1.91	2.14	3.92	4.61	4.75	6.81	9.36	7.83	4.17	4.45	2.55	2.23	54.20
1965	2.14	1.74	2.96	5.38	4.20	5.58	8.18	7.89	6.87	4.14	2.46	1.91	51.92
1966	1.48	1.48	4.70	4.47	4.32	5.81	7.55	5.78	4.18	4.55	3.55	1.88	49.29
1967	2.78	3.03	5.65	3.87	4.80	6.46	6.51	7.74	3.72	5.25	2.54	2.07	53.56
1968	1.11	1.80	3.45	4.12	4.10	5.70	6.21	7.16	4.98	4.36	3.08	2.70	48.39
1969	2.02	2.18	3.18	4.28	3.92	7.22	8.16	6.48	5.17	4.26	2.99	2.26	54.48
1970	0.92	2.64	2.76	3.90	4.95	5.46	7.50	7.31	4.92	3.49	3.41	2.47	51.83
1971	2.23	2.67	5.16	5.79	5.15	7.55	8.15	5.19	5.40	3.71	3.24	2.05	53.91
1972	1.72	2.80	4.35	5.48	5.19	7.13	8.45	5.80	5.53	4.60	2.36	1.60	54.30
1973	1.25	1.90	4.23	3.48	5.14	5.23	6.49	7.02	4.41	3.49	3.01	2.29	46.78
1974	1.53	3.65	4.56	5.84	5.61	6.73	8.17	6.19	3.22	3.89	2.75	1.51	49.19
1975	2.23	2.03	3.16	4.54	3.72	6.12	6.53	6.58	5.00	5.08	3.96	1.96	48.26
1976	3.17	3.83	3.68	4.15	3.98	5.68	6.12	6.73	5.39	3.75	2.40	2.87	51.57
1977	1.43	2.80	4.67	4.98	5.15	7.09	8.58	6.42	6.03	4.74	3.27	3.46	57.08
1978	1.40	1.42	3.35	5.30	5.02	7.05	9.60	7.83	5.52	4.71	2.54	2.54	56.62
1979	2.29	1.43	3.69	4.01	4.98	6.80	6.83	6.52	5.43	5.83	3.18	2.61	49.79
1980	2.16	2.77	4.05	5.10	4.74	8.25	10.47	9.92	7.43	5.21	2.82	2.43	60.48
1981	2.06	2.00	3.97	4.83	4.37	6.17	7.77	7.08	5.54	3.97	3.12	2.81	57.47
1982	2.40	1.92	3.44	3.99	3.97	5.23	6.79	7.35	5.81	4.27	2.81	1.73	47.85
1983	1.95	1.71	3.46	4.13	4.33	5.27	7.10	6.69	6.29	4.42	3.35	1.71	50.90
1984	1.59	3.02	3.51	4.90	5.36	6.62	7.57	7.55	6.85	3.71	3.33	2.10	57.76
1985	1.50	1.25	3.62	4.67	4.86	6.82	7.32	8.48	6.72	3.82	2.75	1.61	51.72
1986	2.81	2.45	4.81	4.02	3.94	5.76	8.92	7.53	5.11	3.09	1.87	1.32	54.10
1987	2.35	2.25	2.94	5.37	4.19	5.86	6.83	7.98	4.95	4.64	3.03	1.21	47.51
1988	2.14	2.32	3.50	5.10	5.79	7.42	7.19	7.77	5.05	4.41	3.60	1.85	49.01
1989	2.24	2.36	3.82	5.23	5.07	5.13	5.66	6.20	5.12	5.60	3.62	2.68	49.84
1990	2.95	2.46	2.97	3.61	4.36	7.06	7.67	6.67	5.23	4.21	3.27	1.61	46.68
1991	1.94	2.34	4.36	3.88	4.59	6.36	8.08	6.55	4.82	5.43	3.17	4.81	59.87
1992	2.37	2.26	4.06	4.15	3.90	5.24	6.99	5.62	4.72	4.89	2.80	3.19	53.20
1993	1.68	1.89	3.23	4.33	4.45	5.76	10.39	8.91	6.62	4.80	2.76	3.34	64.35
1994	2.25	1.72	3.66	4.37	3.99	6.44	7.57	7.33	5.51	4.48	2.92	2.86	57.55
1995	1.94	2.45	2.50	4.07	3.91	5.62	6.57	6.92	4.72	5.52	3.60	2.47	55.89
1996	2.77	5.29	4.06	5.42	5.94	6.34	7.11	4.81	3.89	5.27	3.62	2.61	55.81

Source: Texas Water Development Board

TABLE 3-12
GROSS RESERVOIR EVAPORATION FOR TWDB QUADRANGLE 412
(Inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	1.60	2.10	3.50	4.10	4.70	5.30	6.40	7.30	6.10	4.90	3.10	2.90	52.00
1941	2.00	2.20	2.90	3.30	4.20	4.80	6.20	6.40	5.60	4.10	2.90	2.40	47.00
1942	2.40	2.30	3.40	3.30	4.40	5.50	6.60	6.70	5.50	4.50	3.50	1.90	50.00
1943	2.20	3.20	3.10	4.40	5.00	6.00	7.10	8.30	6.00	4.50	3.20	2.00	55.00
1944	1.80	2.40	2.80	4.20	3.70	6.00	6.90	7.30	5.70	5.00	3.00	2.20	51.00
1945	1.90	2.40	2.50	3.20	4.90	5.30	5.30	5.90	6.90	4.60	3.60	2.50	49.00
1946	1.80	2.80	3.40	3.70	4.70	5.10	6.60	7.20	5.00	4.50	3.80	2.40	51.00
1947	1.60	2.80	3.10	2.90	4.20	5.70	7.30	7.50	6.50	5.20	3.70	2.50	53.00
1948	1.30	1.10	2.80	4.90	4.60	6.30	7.80	8.60	7.20	5.10	3.70	2.60	56.00
1949	1.50	1.60	2.60	3.00	4.60	5.30	6.60	6.50	6.80	3.70	3.50	2.30	48.00
1950	1.60	2.00	3.50	3.20	4.20	5.20	5.80	6.50	4.30	4.20	3.90	2.60	47.00
1951	2.40	1.60	3.50	4.00	4.80	5.20	6.90	8.70	3.70	4.60	3.10	2.50	51.00
1952	2.40	3.10	2.90	3.40	4.50	5.30	6.80	9.70	8.50	7.10	3.80	2.50	60.00
1953	2.40	2.30	3.20	3.50	4.10	7.50	5.20	6.70	6.00	5.70	3.30	3.10	53.00
1954	1.27	4.21	4.82	5.06	4.19	7.66	9.21	10.00	7.25	4.26	3.03	2.36	63.33
1955	1.70	1.99	4.20	5.13	5.31	6.85	8.30	7.22	6.22	5.90	4.37	2.47	59.67
1956	2.05	2.33	4.40	5.08	5.65	7.35	8.64	9.79	7.45	4.88	3.08	2.19	62.89
1957	1.81	1.69	2.62	2.66	3.56	5.52	7.29	6.57	4.49	3.29	1.73	2.08	43.31
1958	1.46	1.83	2.43	3.39	3.85	5.94	6.58	5.85	4.25	3.14	2.81	1.35	42.88
1959	1.11	1.96	5.01	4.69	4.67	5.64	5.89	6.44	5.66	4.06	2.50	2.18	49.83
1960	1.33	2.19	2.96	5.25	5.73	7.06	7.24	6.09	5.00	3.77	2.72	1.49	50.83
1961	1.46	1.76	3.86	5.09	5.25	4.11	5.99	6.19	5.99	4.09	2.28	1.81	47.89
1962	1.45	2.66	3.43	3.96	6.00	5.63	6.98	7.36	4.57	4.29	2.37	1.69	50.39
1963	1.61	2.38	4.68	4.52	4.86	6.34	7.18	7.65	5.82	6.06	3.75	1.90	56.74
1964	2.23	2.41	3.74	4.28	4.85	6.61	8.60	6.96	5.01	4.31	2.98	2.23	54.20
1965	2.12	2.15	2.86	5.08	4.06	5.61	7.95	7.67	6.00	4.08	2.42	1.91	51.92
1966	1.47	1.53	4.09	4.46	4.25	6.74	7.44	5.80	3.96	4.19	3.47	1.88	49.29
1967	2.29	2.46	4.86	3.85	4.66	6.93	6.37	8.06	4.10	5.14	2.76	2.07	53.56
1968	1.27	2.08	3.17	4.07	4.18	5.18	6.37	7.15	5.02	4.34	2.87	2.70	48.39
1969	2.33	2.16	3.17	4.36	4.15	7.00	8.67	7.43	5.48	4.71	2.77	2.26	54.48
1970	1.26	2.37	2.94	4.16	5.09	5.94	7.03	8.11	5.55	3.80	3.13	2.47	51.83
1971	2.11	2.75	4.77	5.65	5.04	7.42	7.31	4.96	5.09	3.56	3.19	2.05	53.91
1972	1.75	2.74	4.40	5.59	5.46	6.47	7.38	7.17	5.62	3.79	2.33	1.60	54.30
1973	1.27	2.02	3.66	3.13	5.25	5.05	6.48	7.07	4.26	3.34	2.97	2.29	46.78
1974	1.02	2.94	4.19	5.41	5.15	6.31	7.72	5.80	3.13	3.67	2.34	1.51	49.19
1975	1.66	2.48	3.46	4.11	3.98	5.37	6.42	6.33	4.68	4.75	3.07	1.96	48.26
1976	3.19	3.56	3.96	4.47	4.31	5.46	6.14	7.27	4.61	3.40	2.33	2.87	51.57
1977	1.45	2.92	4.79	4.80	5.03	7.02	7.64	6.68	5.64	4.70	2.96	3.46	57.08
1978	1.40	1.47	3.55	4.87	4.92	6.84	9.14	7.97	5.23	5.62	3.07	2.54	56.62
1979	2.29	1.47	3.83	4.23	4.43	5.93	6.06	5.90	5.48	4.69	2.86	2.61	49.79
1980	2.11	2.77	4.03	5.22	4.69	6.42	9.34	8.73	7.20	4.42	3.12	2.43	60.48
1981	2.81	2.98	4.46	4.85	5.10	6.25	6.97	7.12	5.92	4.91	3.29	2.81	57.47
1982	2.10	1.71	3.72	4.28	4.36	5.98	6.34	6.21	5.78	3.34	2.29	1.73	47.85
1983	1.45	1.99	4.06	4.06	4.70	5.87	6.70	6.10	6.27	4.20	3.81	1.71	50.90
1984	1.21	3.73	4.20	4.92	5.43	6.87	6.32	6.96	6.47	4.72	4.83	2.10	57.76
1985	1.50	1.25	3.11	3.90	4.72	6.24	7.39	7.63	6.71	4.28	3.37	1.61	51.72
1986	2.22	3.16	4.62	4.31	5.19	5.55	7.08	8.32	7.78	2.73	1.81	1.32	54.10
1987	1.73	2.72	3.01	5.14	4.30	4.97	6.21	7.15	4.48	4.47	2.12	1.21	47.51
1988	1.85	2.09	2.99	4.51	5.48	7.29	6.22	6.05	4.92	3.43	2.33	1.85	49.01
1989	1.75	2.00	3.51	4.54	4.22	4.77	5.40	6.07	5.28	4.58	3.56	2.68	49.84
1990	2.33	2.68	2.88	3.96	4.06	5.83	5.74	6.13	4.57	3.45	2.79	1.61	46.68
1991	2.16	2.52	4.10	3.68	4.66	7.64	7.91	6.85	5.80	5.69	4.05	4.81	59.87
1992	3.47	2.75	4.03	4.41	4.32	4.75	6.93	5.66	5.05	4.97	3.66	3.19	53.20
1993	3.92	3.37	3.45	4.67	4.44	5.70	10.34	8.69	6.48	6.83	3.15	3.34	64.35
1994	3.16	2.65	3.74	3.85	4.19	6.57	7.84	6.90	6.84	5.03	3.91	2.86	57.55
1995	3.84	2.72	4.69	4.35	4.79	5.85	6.43	7.16	4.86	5.11	3.61	2.47	55.89
1996	2.29	5.17	4.68	5.35	5.35	6.18	4.85	5.62	4.23	4.75	4.72	2.61	55.81

Source: Texas Water Development Board

TABLE 3-13
GROSS RESERVOIR EVAPORATION FOR TWDB QUADRANGLE 413
(Inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	1.50	1.90	3.20	3.70	4.30	4.80	5.70	6.60	5.40	4.50	2.80	2.60	47.00
1941	1.90	2.00	2.70	3.10	3.90	4.50	5.80	6.00	5.20	3.90	2.70	2.30	44.00
1942	2.20	2.00	3.00	2.90	3.80	4.80	5.80	5.90	4.80	4.00	3.10	1.70	44.00
1943	2.00	2.90	2.70	4.00	4.50	5.30	6.30	7.40	5.20	4.00	2.90	1.80	49.00
1944	1.60	2.00	2.50	3.70	3.20	5.30	6.10	6.50	5.10	4.40	2.70	1.90	45.00
1945	1.80	2.10	2.30	2.90	4.50	4.80	4.90	5.50	6.40	4.20	3.30	2.30	45.00
1946	1.60	2.30	3.00	3.30	4.20	4.50	5.90	6.20	4.50	4.00	3.30	2.20	45.00
1947	1.40	2.30	2.70	2.50	3.70	4.90	6.30	6.50	5.80	4.50	3.20	2.20	46.00
1948	1.20	1.00	2.40	4.30	3.90	5.50	6.90	7.60	6.30	4.40	3.20	2.30	49.00
1949	1.30	1.40	2.30	2.60	4.00	4.60	5.80	5.70	5.90	3.30	3.10	2.00	42.00
1950	1.30	1.70	3.00	2.80	3.60	4.40	4.90	5.50	3.70	3.50	3.40	2.20	40.00
1951	2.20	1.50	3.20	3.60	4.30	4.70	6.30	7.80	3.30	4.00	2.80	2.30	46.00
1952	2.00	2.60	2.50	2.90	3.80	4.50	5.80	8.30	7.20	6.00	3.30	2.10	51.00
1953	2.10	2.00	2.80	3.00	3.50	6.50	4.60	5.80	5.20	5.00	2.80	2.70	46.00
1954	1.27	2.53	3.07	3.79	3.06	6.26	7.14	9.00	6.06	4.00	2.25	1.45	49.88
1955	1.14	1.99	3.99	4.16	5.24	4.58	5.86	5.04	4.37	3.24	3.87	2.22	45.69
1956	2.05	2.32	2.47	3.15	3.90	4.82	5.25	5.86	3.99	3.04	1.97	1.20	40.00
1957	1.51	1.12	2.03	2.12	3.33	3.74	4.13	4.46	3.29	2.32	1.49	1.53	31.08
1958	1.11	1.62	1.81	2.45	2.46	3.86	4.06	3.45	2.78	1.98	1.78	1.04	28.41
1959	1.07	1.29	3.73	3.52	4.18	5.04	5.20	5.68	4.75	3.75	2.36	2.23	42.82
1960	1.14	1.93	3.11	5.15	5.30	6.20	6.80	5.77	4.40	3.27	2.34	1.36	46.77
1961	1.49	1.60	3.35	4.72	5.21	3.68	5.15	5.13	5.03	2.66	1.83	1.93	41.78
1962	1.57	2.56	2.92	3.97	5.37	5.85	6.63	6.93	4.45	3.49	2.16	1.79	47.67
1963	1.40	2.39	4.26	3.53	4.33	5.92	5.26	6.05	4.66	5.08	3.01	1.67	47.55
1964	1.89	2.28	3.36	4.00	4.46	5.70	6.14	5.84	4.80	3.87	2.44	1.63	46.41
1965	2.02	2.02	2.81	4.72	4.00	5.08	7.14	6.43	4.97	3.74	2.18	1.76	46.86
1966	1.47	1.93	3.93	4.45	4.19	6.69	6.45	5.32	3.80	3.64	2.66	1.43	45.97
1967	2.06	2.23	4.25	3.59	4.27	4.94	5.49	6.55	3.96	4.41	2.43	2.11	46.29
1968	1.12	2.02	2.78	3.92	4.09	4.96	5.52	5.80	4.58	3.64	2.40	2.47	43.29
1969	1.96	2.27	3.02	4.07	4.11	5.89	7.45	7.41	4.96	4.39	2.14	1.92	49.60
1970	1.67	2.31	2.93	3.62	4.89	5.45	5.84	6.98	5.06	3.53	2.59	2.35	47.22
1971	2.16	2.77	4.02	4.66	4.70	6.92	5.85	4.63	4.77	3.50	2.70	2.37	49.05
1972	1.78	2.70	4.02	4.56	5.12	5.64	6.53	6.77	4.97	3.31	2.08	1.64	49.13
1973	1.35	2.08	3.87	2.93	5.20	4.89	6.32	6.56	4.02	3.20	2.85	2.06	45.32
1974	1.01	2.50	3.96	4.98	4.84	5.02	6.14	5.53	3.07	3.49	2.10	1.25	43.90
1975	1.62	1.73	3.02	3.70	3.92	5.32	6.25	5.87	4.37	4.05	2.70	1.57	44.10
1976	2.49	2.74	2.80	3.73	3.85	5.26	5.65	6.34	3.92	2.74	1.88	1.58	42.98
1977	1.46	2.67	3.83	4.59	5.23	6.13	6.92	5.89	4.67	4.05	2.40	2.31	50.14
1978	1.46	1.47	3.02	4.63	5.24	6.80	8.72	7.79	4.68	4.69	2.07	2.17	52.74
1979	1.86	1.43	3.15	3.66	4.00	5.51	6.28	5.43	4.79	4.48	2.54	2.38	45.52
1980	1.68	2.69	3.64	4.59	4.08	6.08	9.04	7.97	6.04	4.11	3.48	2.52	55.94
1981	2.29	1.84	3.46	4.47	3.88	5.09	6.10	5.66	4.91	2.94	1.96	2.68	45.28
1982	2.10	0.99	2.78	3.07	3.59	4.83	5.25	6.25	4.39	3.05	2.05	1.82	40.18
1983	1.03	2.04	2.80	3.43	4.01	4.59	5.35	5.77	5.12	3.46	2.18	1.75	41.53
1984	1.21	1.89	2.74	4.05	4.79	5.84	5.63	4.84	4.77	2.45	2.00	1.50	41.71
1985	1.50	1.25	2.82	4.01	4.19	5.42	5.75	6.57	5.05	3.05	2.03	1.61	43.24
1986	2.77	1.82	3.97	3.82	3.97	4.67	7.22	6.27	3.98	2.76	1.53	1.44	44.22
1987	1.72	1.65	3.39	4.57	4.22	4.92	5.21	6.39	4.69	4.05	1.87	1.03	43.72
1988	1.85	1.87	3.40	4.13	5.28	6.22	6.25	5.56	4.98	3.25	2.43	1.36	46.57
1989	1.52	1.99	2.98	4.32	3.76	4.37	4.92	5.16	4.40	3.62	2.80	2.64	43.33
1990	1.92	2.46	2.64	3.78	3.64	5.69	5.47	6.01	4.46	3.04	2.21	1.61	43.30
1991	0.84	1.69	3.11	2.63	3.78	4.50	6.05	5.00	4.28	3.52	1.98	1.68	39.07
1992	1.55	2.04	2.58	3.26	3.57	4.22	4.79	4.44	3.51	2.72	2.04	1.56	36.25
1993	1.86	1.48	2.29	2.92	3.12	5.00	6.83	5.70	5.35	3.16	2.04	1.77	41.53
1994	1.52	1.62	2.65	3.27	3.37	4.88	5.18	5.26	5.08	3.11	2.20	1.56	39.68
1995	2.19	1.72	2.44	2.77	3.03	4.09	5.20	5.61	3.77	3.38	2.40	2.55	39.14
1996	2.27	2.51	3.26	4.38	4.05	4.42	4.86	4.14	2.87	3.10	4.11	2.62	42.60

Source: Texas Water Development Board

TABLE 3-14
AVERAGE MONTHLY PRECIPITATION FOR TWDB QUADRANGLE 411
(Inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	0.85	3.53	1.95	7.49	5.79	3.68	4.24	1.46	0.63	1.64	7.26	5.99	44.49
1941	0.87	3.27	2.74	6.70	4.29	8.56	4.22	3.05	0.86	6.16	1.42	3.13	45.25
1942	1.38	1.09	1.81	12.92	4.40	5.59	0.08	3.17	4.20	3.72	2.46	3.01	43.80
1943	0.27	1.02	5.40	1.62	5.95	5.25	0.48	0.00	2.28	2.22	0.78	3.47	28.70
1944	2.93	6.66	2.55	3.20	9.05	4.12	2.46	3.74	1.50	1.52	3.86	4.61	46.18
1945	1.84	7.62	10.59	2.50	3.03	7.27	5.31	1.85	4.94	3.55	1.61	0.91	50.99
1946	3.43	4.89	4.03	4.52	11.89	3.07	0.85	5.04	2.60	1.46	13.42	3.20	58.38
1947	1.73	0.48	2.75	4.08	3.58	4.12	0.55	5.56	2.45	2.55	3.52	5.75	37.10
1948	2.52	4.17	2.77	2.68	8.95	2.85	3.92	1.02	0.08	2.63	0.79	2.22	34.60
1949	8.75	5.04	3.23	3.45	4.44	4.90	4.32	3.43	3.15	7.44	0.61	3.72	52.46
1950	5.10	3.93	1.12	3.24	8.06	3.19	8.37	6.39	3.94	0.47	0.31	0.16	44.26
1951	2.02	4.06	0.89	2.41	3.45	9.06	2.39	0.93	3.21	3.80	1.95	0.79	34.96
1952	1.02	2.01	3.59	7.26	4.62	0.46	2.10	0.80	0.94	0.14	6.28	3.21	32.44
1953	0.88	1.64	4.15	6.53	3.84	0.65	4.19	2.14	2.43	3.85	3.47	2.00	35.77
1954	3.33	0.98	0.84	4.46	6.48	3.02	0.51	2.37	2.88	7.06	1.01	2.57	35.51
1955	1.70	2.70	3.21	3.79	5.40	2.38	2.77	1.99	4.36	1.37	0.29	0.72	30.70
1956	1.67	4.55	0.71	2.80	3.47	1.34	0.85	0.77	0.14	2.36	3.37	2.45	24.47
1957	2.26	2.58	4.79	12.36	12.30	3.30	1.28	1.16	6.31	3.03	8.67	2.07	60.11
1958	3.19	1.01	4.73	6.18	5.80	3.71	3.22	1.86	3.74	1.35	2.61	1.13	38.53
1959	0.64	1.72	2.32	2.33	2.88	6.10	6.52	2.33	2.28	7.30	1.63	4.15	40.20
1960	2.94	2.65	1.96	2.27	3.28	3.21	4.96	3.58	3.75	2.90	1.09	6.43	39.03
1961	1.80	2.95	4.58	0.81	4.01	4.93	3.47	1.24	4.58	2.61	4.33	2.84	38.15
1962	1.96	1.92	2.95	4.33	1.68	8.64	3.75	2.27	9.27	3.44	3.80	1.08	45.08
1963	0.44	0.38	2.22	4.35	3.96	1.33	3.36	0.62	0.71	0.08	1.63	1.82	20.90
1964	1.70	1.84	5.33	4.65	5.33	3.29	0.64	4.91	10.36	0.87	5.78	1.35	46.06
1965	2.34	4.49	1.25	1.84	7.41	3.66	1.20	1.89	6.58	1.36	2.37	1.27	35.66
1966	1.80	3.08	1.46	11.86	2.32	2.32	2.42	5.52	3.36	1.09	0.90	2.01	38.15
1967	0.38	1.26	2.77	6.98	8.32	2.17	2.94	1.06	7.25	3.79	1.22	2.96	41.10
1968	3.90	1.62	6.64	4.38	6.57	5.20	4.02	1.64	6.78	2.13	4.12	2.29	49.27
1969	3.30	3.35	4.39	3.29	8.93	3.41	0.33	1.99	3.24	5.32	0.82	4.51	42.89
1970	0.76	5.79	3.48	5.49	3.75	2.08	0.91	2.41	8.72	3.13	0.93	1.22	38.68
1971	1.04	1.94	0.91	2.33	4.23	1.10	3.47	4.44	4.10	7.00	2.13	8.33	41.01
1972	0.86	0.51	1.30	3.87	2.55	1.80	1.76	2.31	4.20	7.84	4.23	1.29	32.53
1973	2.90	2.86	4.95	6.21	4.32	6.58	4.29	1.18	10.21	6.32	3.17	1.74	54.72
1974	1.67	1.43	1.46	4.99	3.04	5.56	1.37	5.61	7.38	6.59	4.03	2.42	45.55
1975	2.53	3.51	3.54	2.50	6.32	5.20	2.86	2.26	1.99	0.35	2.54	1.82	35.41
1976	0.41	1.14	3.46	5.57	6.05	3.77	4.69	1.93	3.02	4.48	0.75	1.92	37.20
1977	3.02	2.56	7.48	4.03	2.10	3.02	1.35	4.38	2.51	0.70	1.94	0.94	34.02
1978	2.21	3.39	3.15	2.03	5.34	2.42	0.91	2.15	1.85	0.23	6.43	1.52	31.64
1979	3.72	3.28	5.99	2.96	7.81	1.86	3.36	3.65	1.94	2.90	0.89	2.79	41.15
1980	2.15	1.65	1.88	2.04	4.20	2.05	0.42	0.23	8.98	3.62	1.78	1.96	30.93
1981	0.77	1.51	3.92	2.99	7.01	6.18	2.53	1.73	2.77	15.70	4.65	0.28	50.04
1982	3.65	2.39	1.66	2.91	16.29	6.76	2.98	2.37	1.01	2.33	5.80	5.36	53.51
1983	1.40	3.68	3.49	1.43	6.17	4.68	2.76	1.95	0.99	4.23	3.60	2.10	36.49
1984	1.32	3.22	4.93	2.13	4.29	2.71	1.36	2.09	1.88	8.84	3.67	5.25	41.69
1985	1.83	2.84	4.92	5.94	4.67	4.06	2.53	0.54	2.93	6.60	4.56	1.29	42.72
1986	0.14	3.71	1.66	6.45	6.34	6.97	1.03	2.27	4.78	3.69	4.85	2.26	44.14
1987	2.40	4.68	2.76	0.50	8.23	4.85	2.41	1.60	4.93	2.26	6.08	5.55	46.27
1988	1.17	1.76	3.12	2.38	1.20	3.34	3.80	1.49	5.63	2.83	3.56	3.12	33.40
1989	3.74	5.43	5.07	1.04	8.93	10.49	5.54	1.52	4.06	1.90	0.68	0.55	48.94
1990	5.57	5.16	7.63	8.55	9.13	2.62	2.95	2.07	2.75	3.05	4.22	3.17	56.86
1991	3.49	1.92	2.00	5.41	5.12	5.80	2.46	3.22	3.64	9.63	2.57	8.94	54.20
1992	3.06	2.60	3.17	2.29	5.81	7.24	5.06	1.45	4.75	1.21	3.51	4.37	44.52
1993	1.83	5.48	3.43	4.38	4.43	4.11	0.04	1.84	4.87	7.80	2.23	3.76	44.21
1994	1.46	2.19	2.25	3.87	6.65	2.35	9.04	3.69	3.67	8.27	7.63	2.73	53.82
1995	1.94	2.45	6.10	5.38	9.51	3.03	2.74	1.11	5.13	0.87	0.98	2.77	42.03
1996	1.96	0.43	2.86	2.93	1.56	2.86	4.25	6.95	4.04	3.87	9.94	3.31	44.95

Source: Texas Water Development Board, 1940-1949 data represents the average rainfall of Bonham, Greenville, and Wolfe City

TABLE 3-15
AVERAGE MONTHLY PRECIPITATION FOR TWDB QUADRANGLE 412
(Inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	1.32	2.68	1.82	7.88	7.84	5.44	5.13	2.62	1.10	3.20	8.28	5.88	53.18
1941	1.38	3.61	3.22	7.97	3.10	8.81	5.41	2.55	1.58	6.71	1.70	3.49	49.51
1942	1.27	1.05	2.85	12.41	4.09	4.88	0.25	3.72	4.25	2.79	2.65	4.53	44.73
1943	0.37	1.24	4.84	3.09	4.94	4.67	0.96	0.42	2.54	2.61	1.85	3.45	30.97
1944	2.78	6.26	4.92	3.82	9.53	2.11	1.98	5.26	1.54	1.15	6.37	5.72	51.43
1945	1.96	8.16	11.87	2.54	2.79	7.37	5.18	2.81	6.46	5.26	1.60	0.95	56.93
1946	5.06	5.23	4.45	4.57	11.49	1.83	1.39	4.84	2.42	1.62	12.09	3.65	58.62
1947	1.70	0.78	4.18	6.41	3.96	2.59	0.82	3.76	3.04	3.13	4.28	6.23	40.87
1948	2.75	3.27	3.34	2.53	8.67	2.12	2.59	1.31	0.53	3.27	1.83	2.50	34.71
1949	10.05	4.62	3.58	5.17	2.17	3.94	3.77	2.41	3.12	7.64	0.53	3.33	50.33
1950	5.96	6.54	2.87	4.41	7.35	4.00	6.55	4.35	6.75	1.48	0.61	0.22	51.09
1951	3.35	4.81	2.50	2.40	2.87	6.93	4.10	1.18	6.19	2.59	2.33	2.41	41.66
1952	2.35	3.73	3.82	8.97	5.51	0.84	4.56	1.79	0.83	0.13	7.16	5.72	45.41
1953	2.59	3.01	4.80	8.02	8.65	1.68	8.05	4.08	2.00	1.79	4.33	5.90	54.90
1954	4.51	1.74	1.23	3.42	7.76	1.70	1.39	1.06	3.33	8.80	1.81	2.58	39.33
1955	2.24	3.32	2.90	5.14	5.09	1.55	4.40	6.08	3.28	1.71	1.16	0.98	37.85
1956	2.06	5.75	1.25	2.49	3.23	2.76	1.00	1.66	0.16	1.74	5.54	1.65	29.29
1957	3.21	2.51	6.02	11.99	11.53	5.85	1.18	2.57	7.70	4.57	8.56	2.74	68.43
1958	3.38	1.18	4.90	7.73	4.98	5.82	4.92	3.63	5.43	1.52	3.81	1.69	48.99
1959	0.71	3.59	2.65	2.89	3.28	6.51	7.44	3.13	2.31	5.64	1.83	5.70	45.68
1960	4.04	2.96	2.04	2.36	3.65	5.33	4.50	4.20	5.43	3.99	1.35	7.19	47.04
1961	2.09	3.35	5.35	1.83	3.85	5.25	4.57	2.56	4.28	1.69	5.63	4.30	44.75
1962	3.84	2.59	3.18	4.10	1.91	7.43	3.23	2.28	6.99	5.80	3.89	1.38	46.62
1963	1.74	0.72	2.73	4.08	3.16	2.66	6.14	0.93	0.93	0.51	2.54	2.05	28.19
1964	1.86	2.86	5.26	6.08	3.87	2.63	1.45	5.28	7.13	1.43	4.29	1.41	43.55
1965	2.83	6.50	2.37	1.70	7.66	2.65	1.54	1.63	5.60	1.16	2.18	1.83	37.65
1966	3.40	5.30	0.86	13.22	4.79	1.29	3.46	6.56	4.00	2.45	0.80	3.08	49.21
1967	0.96	1.63	2.62	7.03	9.09	1.92	4.37	2.55	5.67	6.04	1.46	4.34	47.68
1968	3.91	2.15	6.20	4.90	6.52	6.25	3.94	1.99	6.56	2.08	5.12	4.14	53.76
1969	4.18	4.46	5.84	3.71	9.32	2.15	1.57	0.79	2.86	5.15	1.22	4.89	46.14
1970	1.05	5.63	4.73	5.71	1.89	2.55	0.87	2.76	6.17	6.10	1.96	1.79	41.21
1971	1.07	2.98	1.17	1.92	3.59	0.96	6.29	3.57	3.14	8.37	2.03	12.77	47.86
1972	1.84	0.68	1.62	2.37	2.41	3.54	1.92	1.68	5.10	8.09	4.93	2.43	36.61
1973	3.18	2.96	7.75	7.52	3.56	6.45	2.44	1.68	9.82	7.47	4.99	3.65	61.47
1974	3.91	1.03	1.49	5.50	3.28	6.78	1.52	5.39	9.69	5.43	6.92	3.22	54.16
1975	2.11	4.64	4.56	2.89	6.87	6.33	2.42	1.85	1.08	0.23	2.05	2.29	37.32
1976	0.60	1.45	5.68	5.83	5.45	4.44	7.12	1.42	4.86	5.01	1.07	2.94	45.87
1977	3.33	3.44	7.21	5.03	1.88	3.96	2.03	3.86	1.95	1.10	4.96	1.43	40.18
1978	2.86	3.22	3.80	1.82	4.22	2.24	1.42	1.16	1.01	0.37	8.36	4.08	34.56
1979	4.19	3.69	5.69	3.40	8.79	3.27	4.79	3.80	3.80	3.59	1.98	4.56	51.55
1980	4.15	1.93	2.08	3.85	5.18	3.84	0.76	0.40	8.20	2.86	2.15	2.39	37.79
1981	0.92	1.72	3.15	2.25	8.63	7.58	2.79	1.64	1.59	12.28	2.67	0.39	45.61
1982	2.72	2.76	2.13	2.99	11.27	6.82	3.13	2.82	0.87	3.06	6.75	7.35	52.67
1983	0.67	4.27	4.56	1.26	5.91	4.30	2.64	1.79	1.41	3.11	3.34	3.17	36.43
1984	1.74	4.36	5.98	2.35	5.63	1.73	2.49	1.82	3.73	10.36	3.80	5.24	49.23
1985	1.78	3.63	6.09	5.21	5.63	3.03	2.99	0.40	2.82	6.15	6.36	3.35	47.44
1986	0.13	4.82	1.67	6.78	5.32	5.97	2.13	1.98	4.55	4.22	6.12	2.63	46.32
1987	2.54	4.36	4.06	0.61	5.15	5.32	2.92	1.33	5.30	3.97	8.11	7.17	50.84
1988	1.35	2.60	4.33	2.61	0.68	1.48	5.55	2.80	2.26	4.64	6.98	2.82	38.10
1989	3.29	5.06	4.47	1.47	9.75	7.96	6.81	2.06	2.90	1.71	0.58	0.81	46.87
1990	6.68	4.78	9.32	5.83	10.80	2.68	3.86	1.85	4.54	4.18	5.27	3.78	63.57
1991	3.95	3.61	2.20	7.59	5.62	3.90	3.72	3.19	3.08	9.64	4.15	8.03	58.68
1992	3.50	3.26	4.83	2.66	5.02	8.15	8.63	1.08	4.52	1.20	5.33	5.74	53.92
1993	3.65	4.74	4.20	5.23	3.59	2.32	0.11	2.11	3.44	11.39	3.67	4.59	49.04
1994	2.78	2.89	3.31	4.12	6.33	2.41	7.79	2.57	2.56	5.75	5.99	4.35	50.85
1995	3.84	2.72	3.58	5.27	8.84	2.87	2.41	1.12	5.05	0.85	1.12	2.70	40.37
1996	1.89	0.56	3.02	2.95	3.27	4.79	6.67	5.84	4.34	3.90	9.93	3.77	50.93

Source: Texas Water Development Board; 1940-1949 data represents the average rainfall of Paris, Honey Grove, Sulphur Springs, Clarksville, Deport and Cooper

TABLE 3-16
AVERAGE MONTHLY PRECIPITATION FOR TWDB QUADRANGLE 413
(Inches)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	1.08	2.98	3.33	7.34	4.58	4.39	6.29	3.84	1.25	2.57	6.94	4.52	49.08
1941	1.39	3.11	5.14	5.65	3.85	8.64	3.65	3.63	2.49	3.67	3.44	4.78	49.40
1942	1.72	1.19	3.34	8.71	4.39	3.99	0.24	7.80	2.89	2.44	1.01	5.23	42.93
1943	1.26	1.50	3.37	1.50	7.62	2.60	1.97	1.78	2.55	3.71	0.12	4.00	31.97
1944	4.17	6.39	4.87	6.30	9.62	1.44	1.96	7.45	0.83	0.20	8.52	7.96	59.69
1945	2.33	7.25	16.92	4.19	5.28	8.77	3.22	3.21	1.67	4.37	2.57	1.87	61.62
1946	7.07	4.47	4.01	5.64	13.27	2.61	2.39	4.29	1.00	1.09	12.26	1.98	60.06
1947	2.60	1.04	4.83	4.32	3.52	2.91	0.41	3.97	5.84	2.36	8.27	6.33	46.39
1948	4.41	4.42	4.36	3.72	11.53	1.28	3.12	1.92	1.46	3.11	3.80	1.92	45.05
1949	9.18	3.14	4.21	3.90	1.18	4.80	5.46	2.28	1.85	13.20	0.35	3.31	52.85
1950	6.34	7.29	3.37	3.69	10.62	2.08	6.39	2.83	10.03	1.56	0.80	0.20	55.19
1951	4.58	5.07	1.55	4.50	2.32	7.06	4.11	1.40	6.35	3.00	3.35	2.43	45.73
1952	3.23	2.87	4.40	8.54	4.88	0.68	2.23	2.35	0.39	0.32	9.16	5.41	44.45
1953	3.94	1.85	4.47	7.26	8.60	0.57	5.95	1.70	1.75	1.58	3.02	4.42	45.10
1954	4.76	1.55	0.93	4.20	9.11	0.96	1.59	0.59	1.63	9.12	1.90	3.43	39.76
1955	1.92	3.37	4.42	4.89	4.75	1.11	3.59	4.78	4.51	3.42	1.00	1.52	39.27
1956	2.30	6.46	1.87	2.98	3.01	3.10	1.53	1.64	0.49	1.79	3.42	1.16	29.75
1957	4.27	3.95	6.46	12.80	7.67	5.82	2.16	1.93	5.63	6.35	9.01	3.11	69.14
1958	3.92	1.17	4.84	11.23	5.21	5.62	4.74	5.82	4.80	2.49	4.80	0.69	55.33
1959	1.01	4.78	3.53	4.09	4.28	5.06	6.29	2.20	2.78	3.96	2.55	6.62	47.16
1960	5.17	3.56	2.35	1.66	3.72	5.45	3.41	3.80	5.28	3.02	1.91	8.26	47.60
1961	1.86	3.75	7.52	2.25	3.55	5.61	6.17	2.54	3.84	2.69	5.45	5.99	51.20
1962	4.93	5.09	3.55	3.88	1.53	6.20	2.23	1.79	6.21	7.46	3.89	1.33	48.08
1963	1.54	0.75	4.58	4.83	2.26	3.09	4.83	1.92	0.78	0.43	3.40	2.73	31.14
1964	1.04	2.95	4.51	8.02	2.61	1.66	1.48	5.88	7.54	0.37	3.66	2.09	41.82
1965	3.68	7.58	3.14	1.70	6.73	3.17	2.37	1.85	4.39	0.70	1.32	1.64	38.26
1966	3.38	3.99	0.87	14.44	4.04	0.55	3.78	6.55	3.50	3.22	1.90	5.01	51.23
1967	1.16	2.03	2.15	7.24	9.66	3.06	3.06	1.85	3.87	3.79	1.78	6.67	46.31
1968	4.68	1.70	6.02	5.07	11.66	7.02	2.80	2.06	6.75	2.96	5.79	4.10	60.61
1969	4.49	5.16	5.52	3.34	6.27	1.84	1.59	1.01	2.27	4.49	3.24	6.09	45.30
1970	1.19	5.30	5.50	6.28	2.90	3.15	1.91	5.61	2.01	5.47	2.36	2.31	44.00
1971	1.41	3.75	2.23	2.33	3.67	0.89	8.96	3.31	1.50	2.84	3.33	8.77	42.99
1972	3.57	0.78	1.87	1.49	2.38	3.11	3.71	1.74	4.97	6.37	5.99	4.45	40.43
1973	3.85	3.26	9.58	9.59	2.81	7.67	4.06	2.00	7.92	8.48	7.53	4.26	71.00
1974	5.88	1.56	1.51	5.15	4.26	8.85	2.24	5.77	10.52	3.92	9.17	4.05	62.86
1975	1.80	6.48	5.46	3.70	8.52	4.54	3.28	2.39	1.44	0.92	3.05	2.87	44.45
1976	2.02	2.65	7.16	3.14	6.28	6.41	3.38	0.98	5.26	4.10	1.44	3.55	46.37
1977	3.24	4.32	7.30	4.41	1.61	3.28	2.85	2.75	3.06	0.93	5.67	1.89	41.32
1978	4.47	2.31	3.84	2.12	3.89	1.84	2.00	1.84	1.85	1.17	9.60	4.10	39.02
1979	5.35	4.19	6.49	6.41	6.47	3.79	8.67	3.91	5.46	3.99	2.72	3.94	61.39
1980	4.92	2.43	3.28	5.20	4.88	3.84	1.32	0.63	7.19	3.31	3.59	1.99	42.57
1981	0.87	2.76	3.12	1.50	10.29	7.45	5.53	3.18	1.66	9.70	1.59	0.54	48.18
1982	3.91	2.73	1.61	3.81	7.00	8.10	2.35	2.86	0.70	4.10	8.28	10.60	56.06
1983	0.82	4.34	3.76	2.22	4.96	4.80	3.81	1.65	1.05	2.06	3.81	4.69	37.98
1984	1.72	4.51	5.51	2.45	5.70	1.54	4.87	2.85	4.81	12.46	4.43	4.03	54.88
1985	2.27	4.68	5.37	5.46	4.93	4.03	2.86	0.45	2.76	5.49	6.56	4.77	49.62
1986	0.34	4.05	2.14	7.84	5.06	6.36	2.53	1.31	6.10	3.89	6.41	4.20	50.25
1987	2.36	6.03	5.33	0.44	3.05	3.40	3.44	1.25	3.31	4.36	10.08	11.48	54.51
1988	1.77	3.11	4.74	2.49	0.70	1.14	5.29	4.58	1.81	4.50	10.29	4.08	44.50
1989	3.27	6.80	6.79	3.12	10.29	8.14	6.22	3.88	1.56	1.70	0.69	1.39	53.85
1990	7.57	4.38	11.16	5.64	9.56	3.32	3.88	1.39	4.08	6.59	5.28	6.15	69.00
1991	5.24	4.60	2.51	10.24	6.37	1.99	3.62	3.80	3.91	7.55	5.46	5.99	61.29
1992	3.41	4.21	5.58	2.95	3.21	8.65	8.00	0.71	6.97	1.40	6.13	7.06	58.28
1993	5.24	4.19	4.81	4.74	4.18	3.10	0.20	3.13	3.67	12.08	4.21	5.73	55.29
1994	3.97	3.68	4.60	2.09	6.78	3.28	6.94	1.74	0.82	8.09	6.61	6.29	54.90
1995	2.19	1.72	2.47	6.51	6.04	2.14	2.13	1.13	3.88	1.10	1.67	3.25	34.23
1996	1.91	0.80	2.71	3.31	4.05	6.38	7.15	5.46	4.49	4.38	8.80	3.88	53.31

Source: Texas Water Development Board; 1940-1949 data represents the average rainfall of Mt. Pleasant, Naples, DeKalb and Boxelder

3.3.2 Procedures for Estimation of Net Evaporation

In the water availability analyses for the Sulphur River Basin, the water losses due to net evaporation from the reservoirs located throughout the basin have been accounted for through application of the WRAP model. For this purpose, the net evaporation data that have been input to the model have been calculated as the difference between gross reservoir evaporation and precipitation, with positive values representing conditions when evaporation exceeds precipitation.

The use of net evaporation defined in this manner has been necessary in order to use a new option in the WRAP model that adjusts for the portion of the natural runoff from each reservoir area (surface footprint) that is inherently included in the naturalized streamflows specified in the WRAP model as inflows to each reservoir. Since the naturalized streamflows as derived in this study include, as part of the inflows to each reservoir, the fraction of the precipitation that actually occurred as natural runoff from the reservoir area (surface footprint), it is not proper to fully account for all of the precipitation falling on the reservoir surface in the water availability simulation process. Otherwise, a portion of the inflows to each reservoir would be double-accounted for.

The new option in the WRAP model automatically adjusts the net evaporation at each reservoir site to account for natural runoff from the reservoir area (surface footprint). This adjustment is made by converting the inflow to a reservoir each month from a volume expressed in acre-feet to a corresponding depth expressed in feet or inches by dividing the total inflow volume by the "effective" drainage area of the watershed above the reservoir. This depth of runoff then is added to the net evaporation value for the reservoir, which, in effect, reduces the rainfall portion of the net evaporation value by an amount equal to the runoff from the reservoir area. The resulting "adjusted net evaporation" value is the quantity used in the simulation of reservoir evaporation losses in the WRAP model.

The "effective" drainage area of the watershed above a reservoir used in calculating the monthly runoff depth is calculated based on differences between the characteristics of the total watershed above the reservoir and the local watershed in the immediate vicinity of the reservoir. Since total runoff depth at a point reflects the characteristics of the total watershed (precipitation, land use, soil type, etc.), the runoff depth that would be generated by rainfall over the reservoir area (surface footprint) may be a different value. This of course would affect the calculation of adjusted net evaporation from the reservoir. Therefore, for the purposes of calculating adjusted net evaporation, the total drainage areas above each control point have been adjusted for differences in precipitation and runoff-generating potential (represented by the NRCS Curve Number) between the total watershed and the local watershed using the following equation:

$$D.A._{effective} = D.A._{total} * (P_{incremental}/P_{total}) * (CN_{incremental}/CN_{total})$$

where:

$D.A._{effective}$ = effective drainage area used in adjusted net evaporation calculations
$D.A._{total}$ = actual total drainage area above reservoir (control point)
$P_{incremental}$, $CN_{incremental}$ = mean annual precipitation, or Curve Number, of incremental drainage area between reservoir control point and the next upstream control points
P_{total}, CN_{total} = mean annual precipitation, or Curve Number, of total drainage area above reservoir

This procedure is roughly analogous to the process used in distributing gaged flows to ungaged locations as described in Section 3.2.1.

For specifying the monthly net evaporation values as input to the WRAP model for the entire 1940 through 1996 analysis period for each reservoir site, the net evaporation rates for each of the three quadrangles have been combined and averaged as necessary to provide more site-specific data at the individual reservoir locations. In this regard, four sets of net evaporation values have been derived and used as input to the WRAP model, with one of these four sets of net evaporation values assigned to each of the reservoirs included in the model. These data sets include the monthly net evaporation values for Quadrangles 412 and 413 as identified on the map in Figure 3-8 and the average of the net evaporation values for Quadrangles 411 and 412 and for Quadrangles 412 and 413. These average net evaporation values theoretically are applicable at the boundaries of their respective quadrangles; however, in establishing the net evaporation data for each of the reservoirs included in the model, the data set located closest to each reservoir site has been used.

3.3.3 Comparison of Net Evaporation Data Sets

The annual values from the four sets of net evaporation data used as input to the WRAP model are plotted on the graph in Figure 3-9 for the entire 1940 through 1996 analysis period. As expected, the general trend exhibited by these sets of data is for the net evaporation to increase in the westerly direction across the Sulphur River Basin. Hence, the net evaporation for Quadrangle 411 near the headwaters of the basin is greater that the net evaporation for Quadrangle 413 near the state line.

FIGURE 3-9
COMPARISON OF ANNUAL NET RESERVOIR EVAPORATION RATES
FOR SULPHUR RIVER BASIN

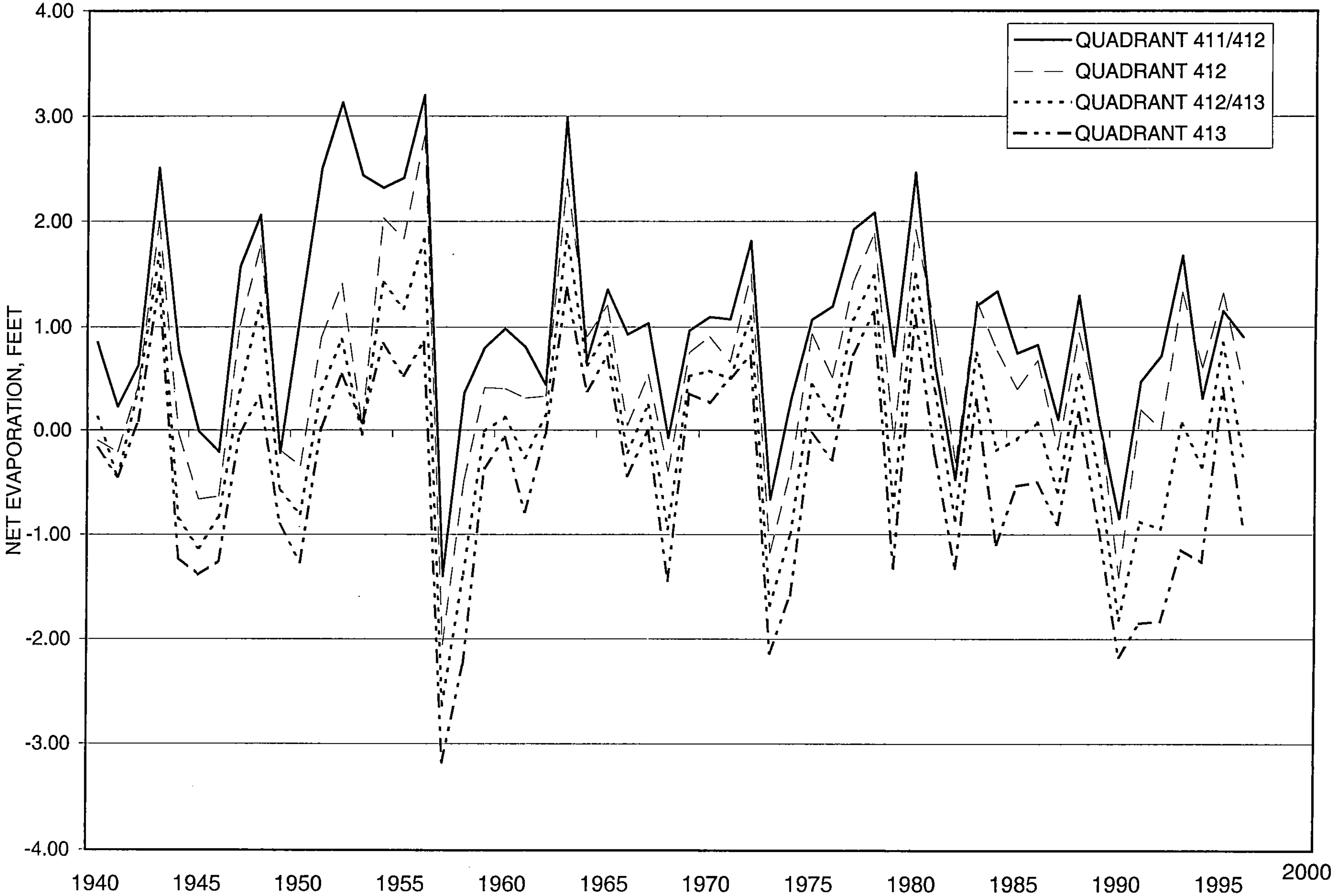
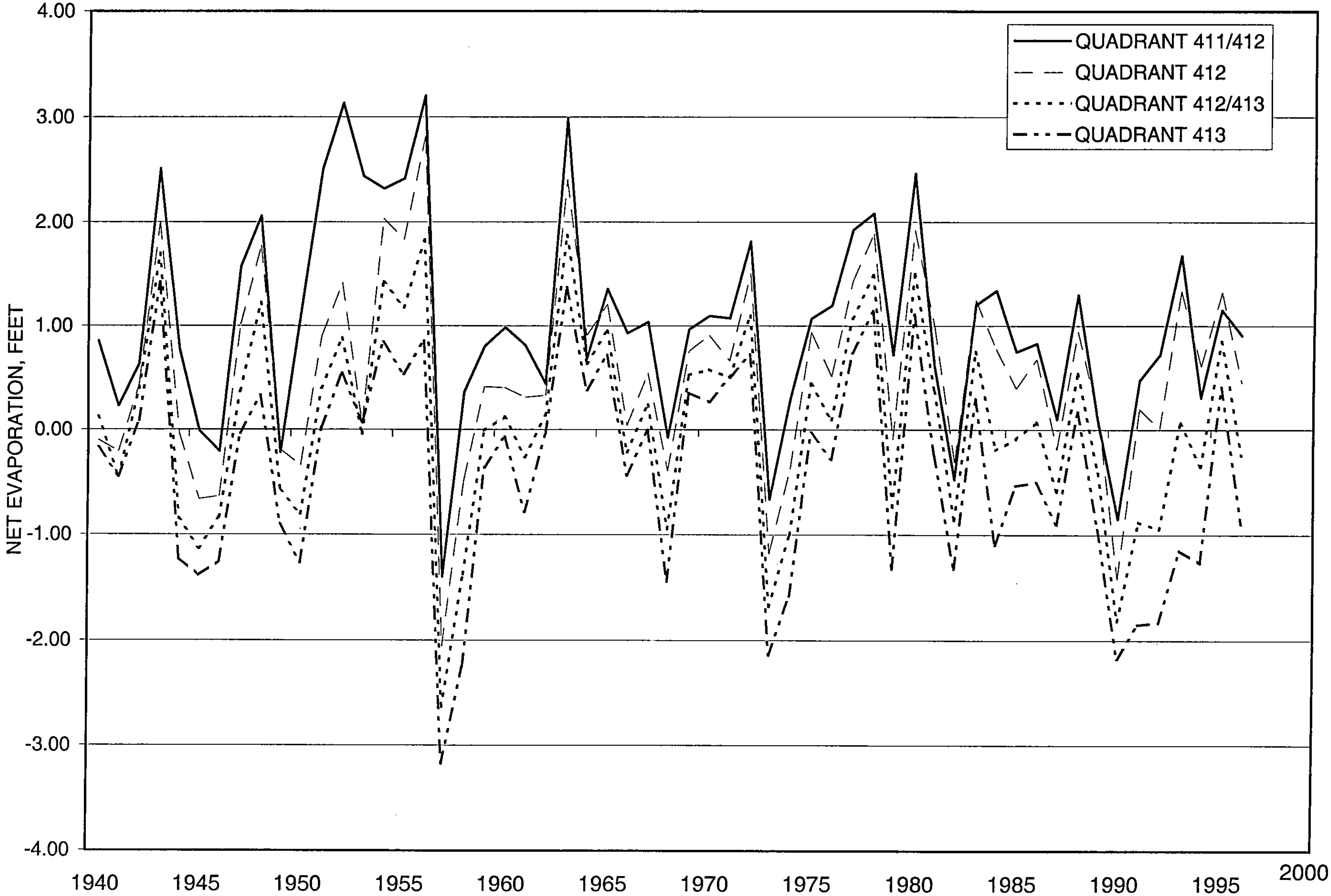


FIGURE 3-9
COMPARISON OF ANNUAL NET RESERVOIR EVAPORATION RATES
FOR SULPHUR RIVER BASIN



3.4 RESERVOIR ELEVATION-AREA-CAPACITY RELATIONSHIPS

The elevation-area-capacity relationship (also referred to as area-capacity curve) for a reservoir is generally developed during the reservoir design phase. This relationship is based on the topographic characteristics of the land to be inundated by the reservoir. During the life of the reservoir, sediment deposition within the reservoir typically alters that relationship and reduces the capacity of the reservoir. Sediment deposition is distributed in various zones of a reservoir at differing rates, dependent on the shape of the reservoir and other factors.

As requested by TNRCC, two different elevation-area-capacity relationships have been considered for the reservoirs in the Sulphur River Basin for purposes of the water availability analyses. One is referred to as the "authorized" area-capacity relationship, and it corresponds to the original area-capacity curve that was adopted at the time each impoundment was permitted. The other area-capacity relationship corresponds to reservoir sedimentation conditions for the year 2000, and it is to be used for large reservoirs, defined as those with authorized conservation storage capacity greater than 5,000 acre-feet. The year-2000 area-capacity relationships for off-channel reservoirs with no watershed inflows have not been considered in the water availability analyses since sedimentation effects on such reservoirs would be relatively insignificant.

Area-capacity curves have been specified assuming that stored water would be available down to the bottom of the channel, ignoring dead storage. It is presumed that during an extreme drought a means would be devised to gain access to all stored water.

3.4.1 Large Reservoirs

Year-2000 area-capacity curves have been developed for all on-channel reservoirs with a capacity greater than 5,000 acre-feet: Wright Patman Lake, Jim Chapman Lake, and Lake Sulphur Springs. A year-2000 area-capacity curve also has been developed for the City of Cooper's Big Creek Lake, since its conservation storage capacity (4,890 acre-feet) is marginally less than 5,000 acre-feet. No other impoundments in the Sulphur River Basin have authorized storage capacities that are close to 5,000 acre-feet.

The general methodology used for developing the required area-capacity relationship for each of the large reservoirs has involved the following steps:

1) Obtain the authorized and any more recent area-capacity curves.
2) Estimate annual sediment delivery to the impoundments.
3) Distribute the sediment throughout the impoundment using the SEDDIS2 program.

4) Prepare the year 2000 curve using the SEDDIS2 output.

The authorized area-capacity curves have been obtained from the Fort Worth District Office of the U. S. Army Corps of Engineers for Wright Patman Lake and Jim Chapman Lake, and from the design curves prepared by Hayter Engineering for Lake Sulphur Springs and Big Creek Lake. More recent data for Wright Patman Lake were also obtained from the volumetric survey of the reservoir that was performed by the Texas Water Development Board in January 1997 (TWDB, 1997).

Estimates of historical sediment delivery to the different reservoirs have been obtained from several sources. For Wright Patman Lake, the Corps of Engineers "Definite Project Report, Texarkana Dam and Reservoir" (1952) provides an estimate of 0.4 acre-feet of sediment delivered per square mile of drainage area per year, or approximately 1,360 acre-feet of sediment delivered per year. Comparison of the authorized area-capacity curve with the area-capacity curve from the 1997 TWDB survey indicates that the actual sediment delivery rate might be slightly higher. However, since the construction of Jim Chapman Lake upstream in 1991, it is expected that sediment delivery also may have been reduced slightly. Because of these offsetting factors, the original sediment delivery estimate from the Corps has been used and added to the 1997 survey data for the three years between 1997 and 2000. The differences between 1997 and 2000 data are small. The two sets of area-capacity curves used for Wright Patman Lake are plotted on the graph in Figure 3-10. As indicated, above about Elevation 215 feet mean sea level (MSL), the year-2000 storage capacity of the reservoir is about 35,000 acre-feet less than the original storage condition. Construction of Wright Patman Lake was completed in the mid 1950's.

For Jim Chapman Lake, the Corps of Engineers "Cooper Reservoir and Channels, Hydrology and Hydraulic Analysis, Design Memorandum No. 1" presents an estimated sediment delivery rate of 1.17 acre-feet per square mile per year, including channel erosion from the upstream rectified channel. This results in 560 acre-feet of sediment per year, which is the value used for adjusting the original area-capacity curve to the year-2000 condition. The two sets of area-capacity curves used for Jim Chapman Lake are plotted on the graph in Figure 3-11. As expected, since the impoundment of water in this reservoir only began in 1991, the two sets of curves are very similar.

For Lake Sulphur Springs, Report 268 from the Texas Department of Water Resources (TDWR) titled "Erosion and Sedimentation by Water in Texas" (1982) provides an estimated sediment delivery rate of 0.23 acre-feet per square mile per year for the White Oak Creek watershed. Since Lake Sulphur Springs has a smaller drainage area than the area used in the TDWR report, a higher yield per square mile would be expected. Also, recent data from the Corps of Engineers on other reservoirs in the Blackland Prairies (where Sulphur Springs is located) indicate that previous

FIGURE 3-10
WRIGHT PATMAN LAKE AREA-CAPACITY CURVES
FOR AUTHORIZED AND YEAR-2000 SEDIMENT CONDITIONS

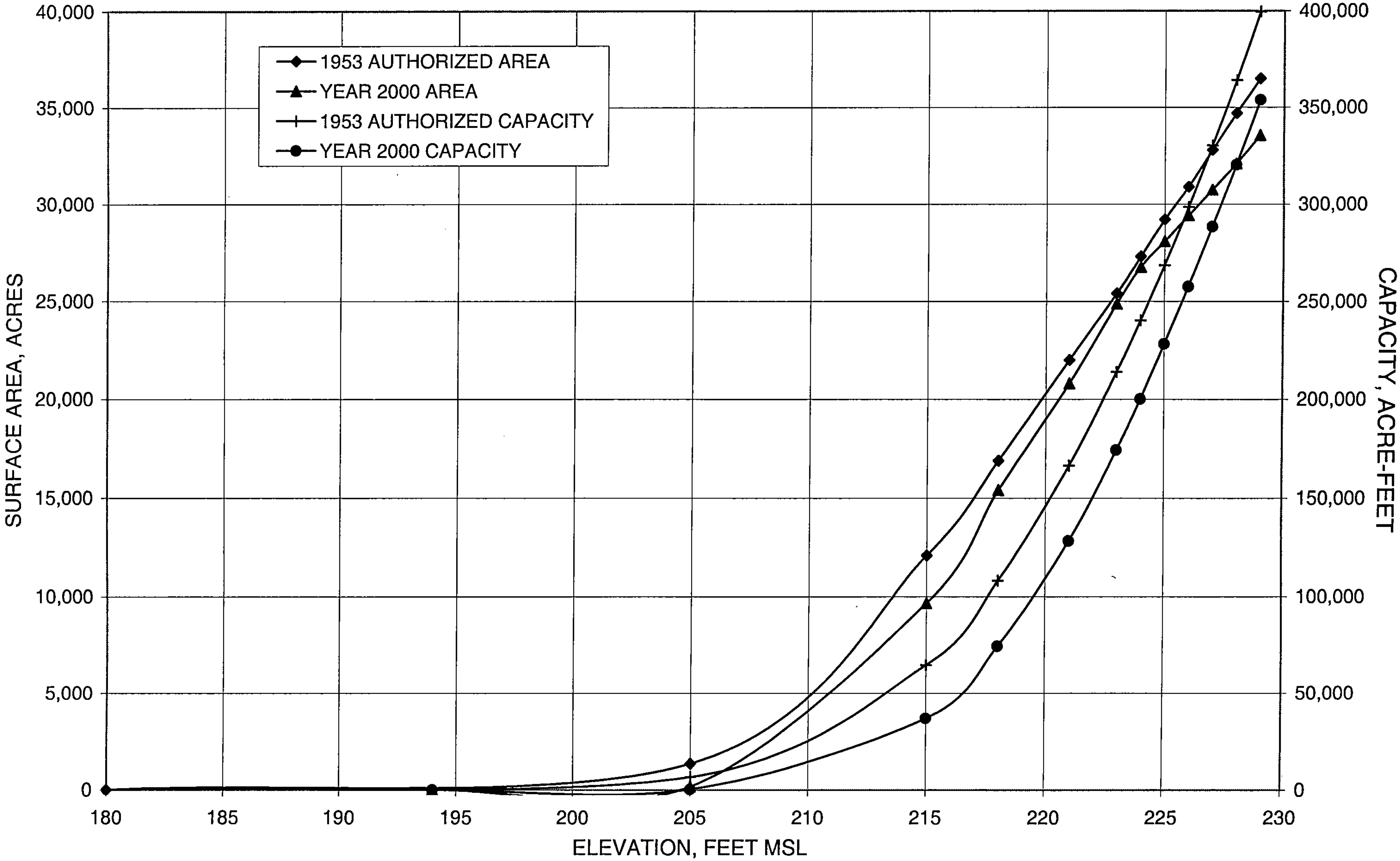
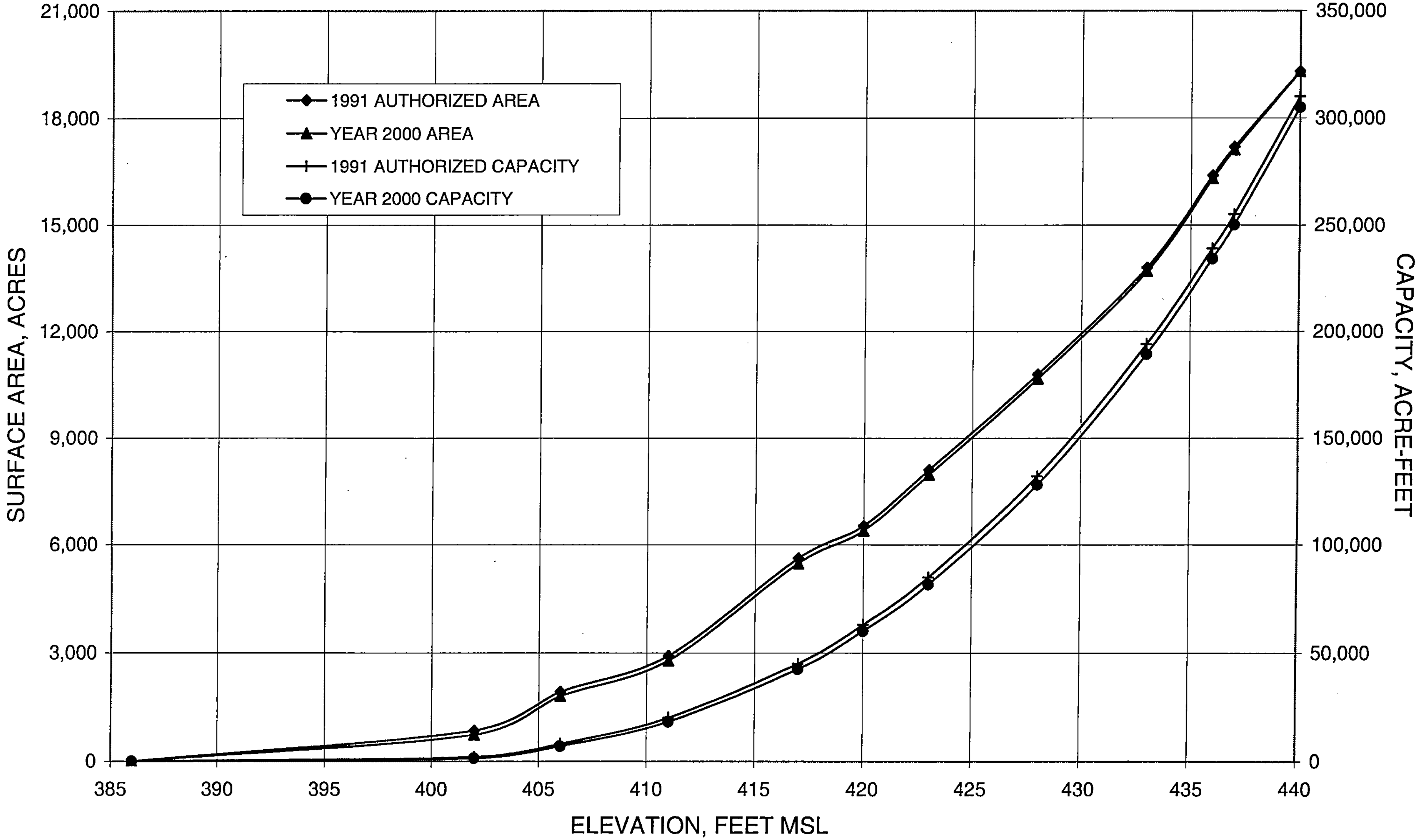


FIGURE 3-11
JIM CHAPMAN LAKE ELEVATION-AREA-CAPACITY CURVES
FOR AUTHORIZED AND YEAR-2000 SEDIMENT CONDITIONS



estimates may be low. Therefore, a value of 0.3 acre-feet per square mile per year, or 16 acre-feet per year, has been used to construct the year-2000 area-capacity curve. Figure 3-12 presents a graph of the two sets of area-capacity curves for Lake Sulphur Springs. As shown, the effects of sedimentation in the reservoir since it was completed in 1973 are not significant.

Big Creek Lake is located close to Jim Chapman Lake. Since it has a much smaller drainage area, a considerably higher sediment yield per square mile would be expected. However, there is no channel rectification above Big Creek, so channel erosion would be expected to be much less. Because of these offsetting factors, the same sediment delivery value used for Jim Chapman Lake (1.17 acre-feet per square mile per year) has been used for Big Creek Lake. This results in a total sediment delivery of 14 acre-feet per year. The two sets of area-capacity curves for Big Creek Lake are plotted on the graph in Figure 3-13.

For all four of the large reservoirs discussed above, the computed sediment loadings have been distributed within the reservoirs using a special computer program called SEDDIS2. This program distributes sediment throughout the elevations of a reservoir between the bottom of the original streambed at the dam and the maximum normal water surface. Computations are based on the U. S. Bureau of Reclamation's Empirical Area-Reduction Method (Borland and Miller, 1958). Distribution of the sediment is based primarily on the reservoir type: 1) lake, 2) flood plain-foothill, 3) hill, or 4) gorge. The program determines the type based on the original elevation-area-capacity data. Based on the program results, Wright Patman Lake is classified as Type 1, Jim Chapman Lake and Lake Sulphur Springs are Type 2, and Big Creek Lake is in the third category.

Distribution of the sediment in the reservoirs generally has been limited to the area below the elevation of the top of the conservation pool. For Wright Patman Lake, an elevation of 229 feet MSL has been selected, which corresponds approximately to the maximum permitted seasonal elevation (228.6 feet MSL) under the City of Texarkana's water right. The originally-authorized conservation pool elevation is at elevation 220 feet MSL; however, since Wright Patman Lake is a flood control reservoir, it frequently has been operated with water stored in the flood pool. Furthermore, since the construction of Jim Chapman Lake upstream, which reduced expected flood flows into Wright Patman, Wright Patman Lake has been operated with a conservation storage rule curve that allows the normal level of the reservoir to be maintained in the original flood pool with specified seasonal variations.

The City of Texarkana only has a right to use water in Wright Patman Lake down to elevation 220. However, under the City's contract, it can develop a contingency plan with the Corps of Engineers to use water from lower elevations if needed. It is assumed that under a severe drought

FIGURE 3-12
LAKE SULPHUR SPRINGS AREA-CAPACITY CURVES
FOR AUTHORIZED AND YEAR-2000 SEDIMENT CONDITIONS

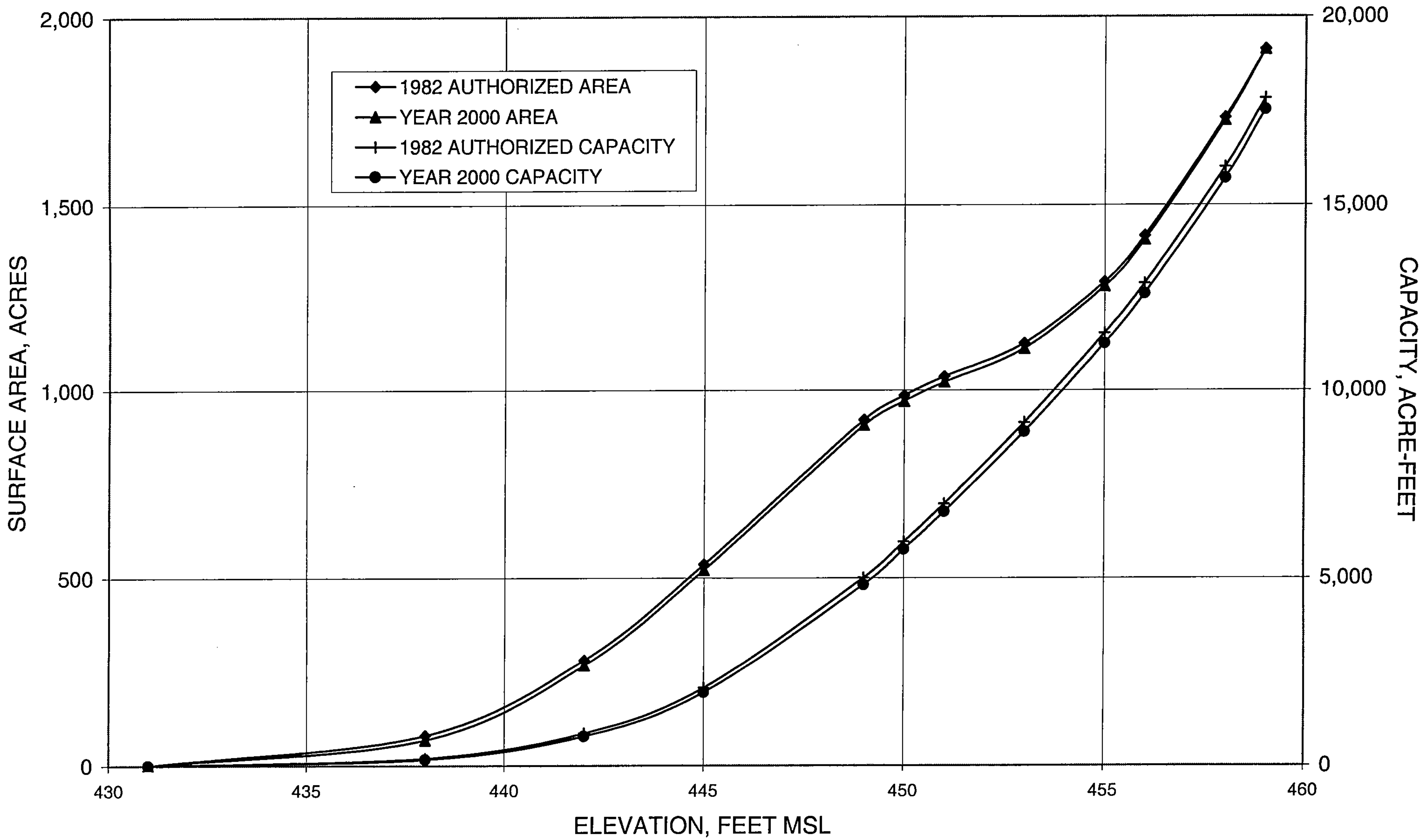
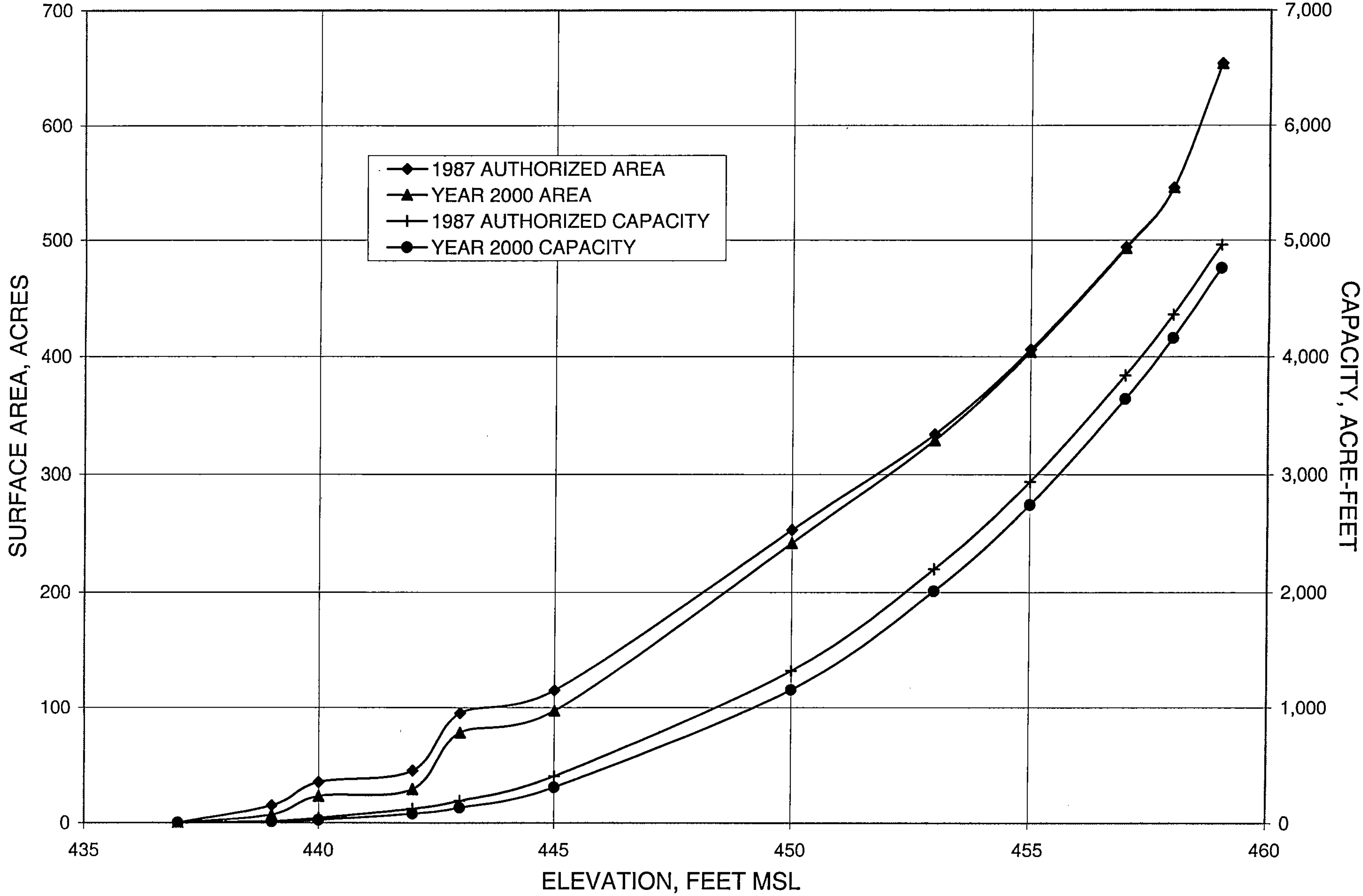


FIGURE 3-13
BIG CREEK LAKE AREA-CAPACITY CURVES
FOR AUTHORIZED AND YEAR-2000 SEDIMENT CONDITIONS



such a plan would be developed. Consequently, all water in the reservoir has been assumed to be available for diversion.

3.4.2 Small Reservoirs

As noted above, a single elevation-area-capacity relationship has been used in the water availability analyses for the small reservoirs with less than 5,000 acre-feet of storage capacity (excluding Big Creek Lake as discussed above) and the off-channel reservoirs. The elevation-area-capacity relationships as originally permitted for these reservoirs have been used. All permitted impoundments have been included in the WRAP model regardless of size, and all unpermitted impoundments greater than 200 acre-feet also have been modeled. The only such unpermitted impoundment in the Sulphur River Basin is Jack Kreck Dam (295 acre-feet, Control Point B30).

Area-capacity curves for these reservoirs have been developed using several methods. The NRCS (formerly SCS) was involved in the design and construction of some of these impoundments, and elevation-area-capacity curves for these impoundments were obtained from the NRCS office in Temple, Texas or from available SCS reports. The TNRCC Dam Safety files also have been examined for all impoundments, and in most cases, specified maximum reservoir capacities, and occasionally, maximum reservoir surface areas or area-capacity curves, have been obtained. For other impoundments, they have been located on U. S. Geological Survey 7.5-minute topographic maps, and the delineated water surface areas have been measured using planimetry. For selected off-channel reservoirs, engineering sketches that typically indicated maximum reservoir surface areas and capacities have been obtained from TNRCC files or the original engineering design firm.

For those impoundments where only the maximum storage capacity could be obtained, standardized area-capacity curves have been generated using an equation of the form:

$$\text{Area} = a(\text{Capacity})^{b} + c$$

where:
$a = 0.8136$
$b = 0.7505$
$c = 0$
$r^2 = 0.955$

To obtain the coefficients a, b, and c, regression analyses of available area-capacity data for existing small reservoirs have been performed. Available area-capacity curves for seven small reservoirs in the Sulphur River Basin were plotted (Deport Creek, Langford Creek, Wolfe City 2, Romal, Coleman, Gordon Country Club, and Cross Timbers), and power function regression analyses were performed to obtain the best-fit equation. This best-fit equation resulted in the above coefficients. The plot is presented as Figure 3-14.

For those impoundments where both the maximum storage capacity and maximum surface area could be obtained, representative area-capacity curves have been generated using an equation of the form:

$$\%\ \text{Total Capacity} = a(\%\ \text{Total Area})^2 + b(\%\ \text{Total Area}) + c$$

where:
$a = 0.5417$
$b = 0.4819$
$c = -0.011$
$r^2 = 0.998$

To obtain the coefficients a, b, and c for the above equation, regression analyses of available area-capacity data for three existing small reservoirs (Wolfe City 2, Deport Creek, and Langford Creek) have been performed considering percent total volume versus percent total area. Polynomial function regression analyses were performed to obtain the best fit through the points and to derive the above coefficients. The plot is presented as Figure 3-15. The use of this equation assures that the maximum surface area and maximum storage capacity for a particular reservoir will occur at the same elevation.

For the off-channel impoundments where no area-capacity curves were available, a synthetic area-capacity curve has been developed based on engineering judgement and familiarity with these types of reservoirs. The adopted area-capacity curve represents a typical off-channel impoundment that is contained by a relatively steep-sided levee and has a relatively flat bottom. In the absence of any more descriptive information, the surface area of these impoundments has been estimated based on the permitted storage capacity and an assumed maximum water depth.

3.5 AQUIFER RECHARGE

Aquifer recharge with respect to water availability is not an important consideration in the Sulphur River Basin and, therefore, it has not been accounted for in the water availability analyses.

3.5.1 Historical Recharge

Not applicable.

FIGURE 3-14
GENERALIZED AREA-CAPACITY RELATIONSHIP BASED ON VOLUME

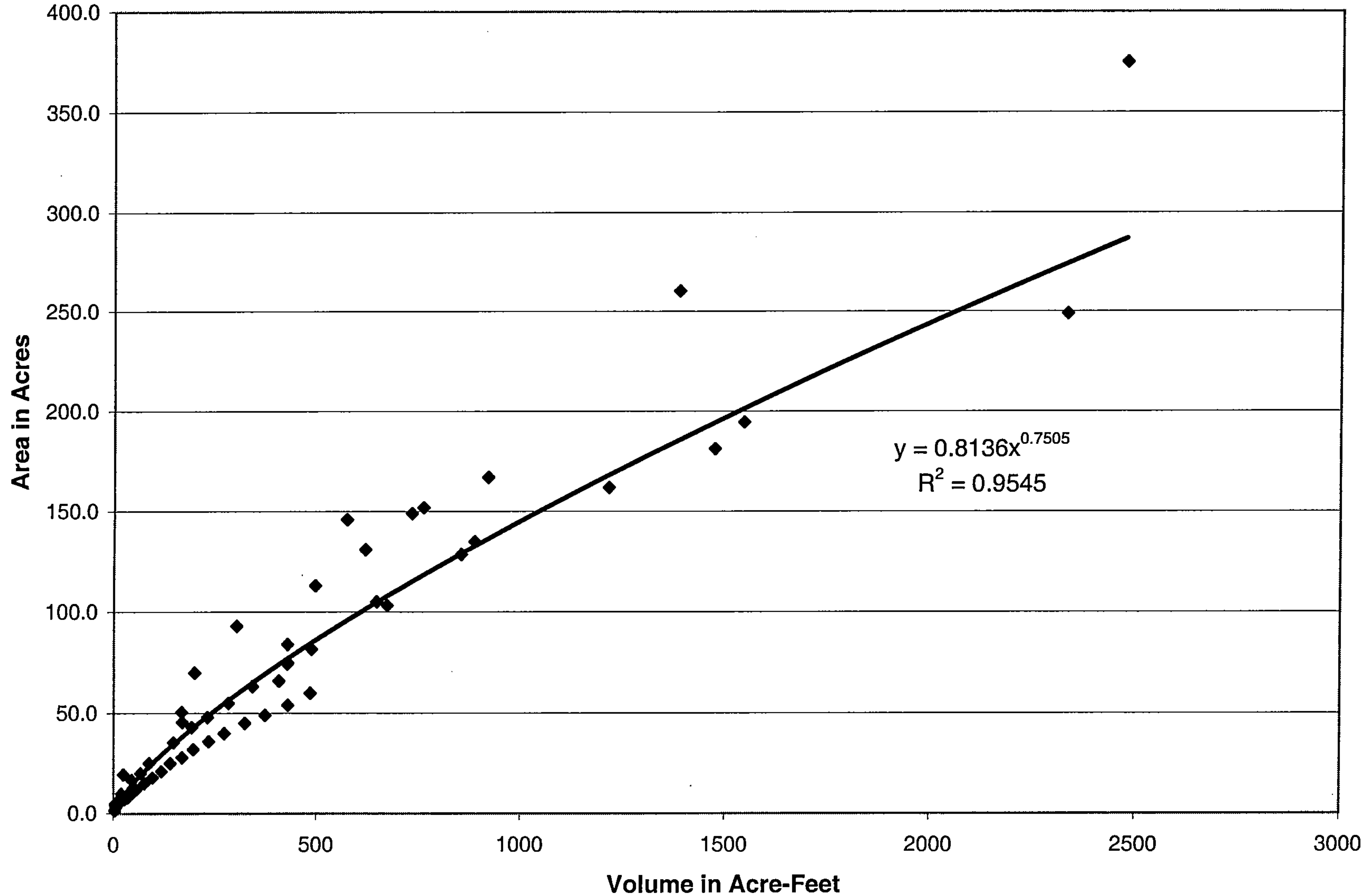
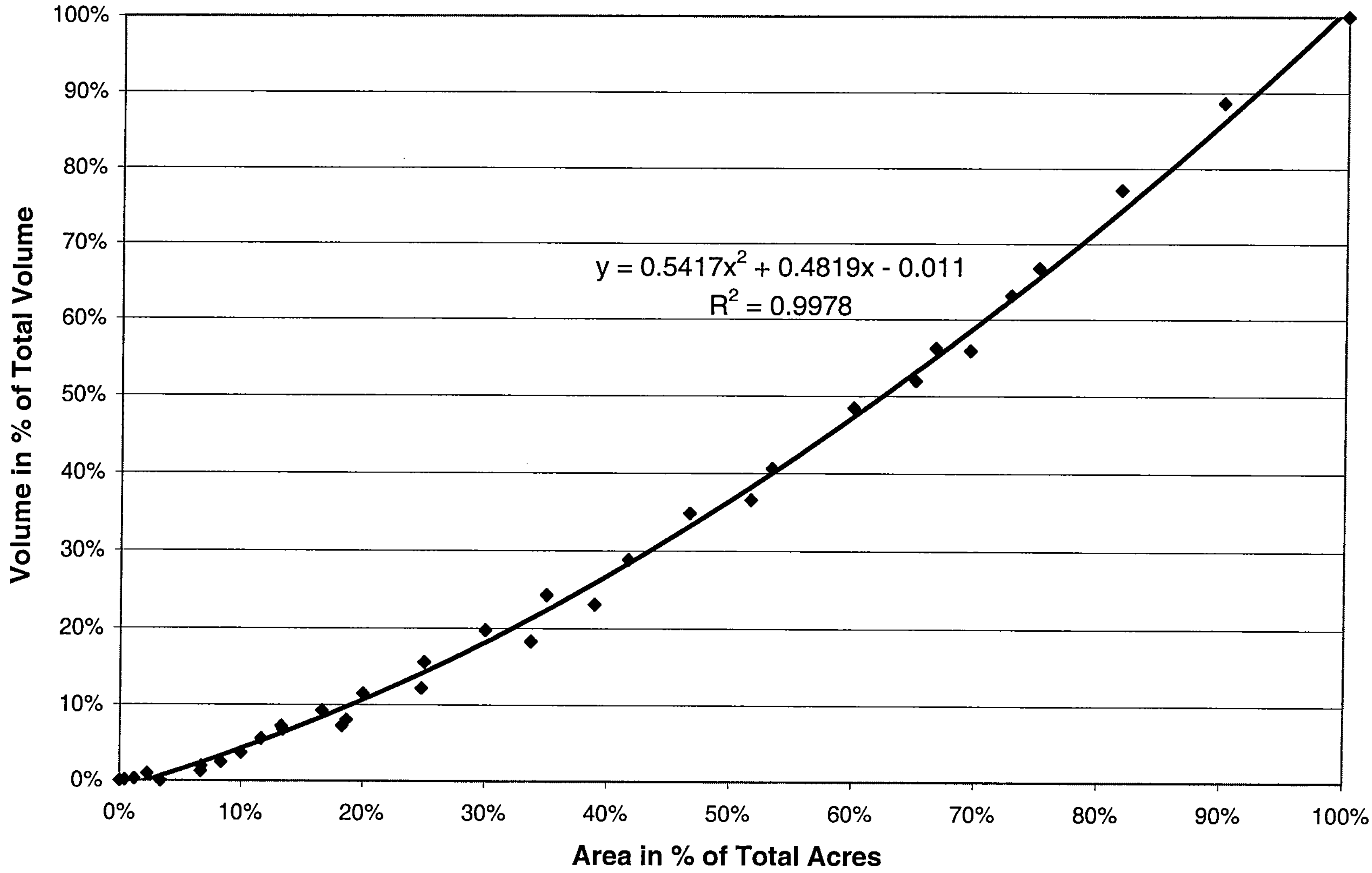


FIGURE 3-15
GENERALIZED AREA-CAPACITY RELATIONSHIP
AS PERCENT OF TOTAL AREA AND VOLUME



3.5.2 Enhanced Recharge

Not applicable.

4.0 WATER AVAILABILITY MODEL OF THE SULPHUR RIVER BASIN

4.1 DESCRIPTION OF *WRAP* MODEL

4.1.1 Base *WRAP* Model

The basic WRAP model is described in the report titled "Water Rights Analysis Package (WRAP), Model Description and Users Manual", as published in October 1996, by the Texas Water Resources Institute at Texas A&M. Dr. Ralph Wurbs of Texas A&M is the primary author of the WRAP model. The WRAP program is coded in FORTRAN and is operational in DOS or Windows operating systems on personal computers. The WRAP model is in the public domain and is available upon request from Texas Water Resources Institute at Texas A&M. The TNRCC is responsible for distributing versions of the WRAP model, including data files, as developed in this study for the Sulphur River Basin.

The WRAP model simulates the allocation of prescribed amounts of water within a river basin to individual water rights, i. e., diversions and storage, subject to the Prior Appropriation Doctrine as it is applied for water rights administration in Texas. WRAP utilizes a network of control points with interconnected links to describe flow paths and the locations of inflows, diversions, reservoirs, and return flows. Simulations are performed sequentially in time using time series. Typically, monthly values are specified for inflows, reservoir net evaporation rates, and water demands subject to prescribed water rights conditions and reservoir system operating rules.

Results from the WRAP model include monthly time series data for: diversions, storage amounts, and shortages for each water right; naturalized flow, regulated flow, and remaining unappropriated water at each control point; reservoir contents and evaporation; and summary tables by control point, water right, water right group, reservoir, and the entire river basin, including summary tables of reliability for each water right. These results are displayed and stored in tabular form. This is contrasted with the TNRCC's former water availability models, which could output the following: baseflow (BA), naturalized baseflow; diversions (DI), simulated diversions from a stream (S) or a reservoir (R) for water rights; unappropriated water (EX), the total runoff (naturalized storm runoff plus baseflow) remaining after simulated upstream diversions have been taken out and after simulated priority release for downstream rights included in the model have been taken out; outflow (OU), the total runoff remaining after the simulated upstream diversions and the simulated diversions for a subwatershed have been taken out, but before the simulated priority releases for downstream rights have been taken out; priority releases (PR), simulated releases of inflow to satisfy downstream senior water rights (Updated Trinity Model runs only); reservoir contents (RC), the simulated contents of any reservoir; reservoir evaporation (RE), simulated evaporation from any reservoir; storm runoff (SR), naturalized storm runoff; total runoff (TR), storm runoff plus baseflow, which is also known as naturalized flow; and total inflow (TI), the cumulative sum from the basin of the total runoff remaining after simulated upstream diversions have been taken out, but before simulated diversions for the subwatershed have been taken out and before priority releases for simulated downstream water rights have been taken out.

The WRAP model has previously been applied to simulate simplified water rights systems in several basins in Texas, including the Brazos, San Jacinto, and Lavaca Basins. Because of the model's general capabilities for describing hydrologic and water resource system features in Texas and its inclusion of the Prior Appropriation Doctrine, the TNRCC adopted the WRAP model as the basic water rights simulation tool for performing the water availability analyses required by Senate Bill 1.

While the basic WRAP model in its original form does provide the fundamental framework for structuring water availability models of Texas river basins, there are a number of additional routines that have been recently incorporated into the WRAP program that have enhanced its capabilities for performing the required water availability analyses. These program modifications have been made for the most part by Dr. Wurbs under contract to the TNRCC. The revised model has been called WRAP-SIM, but is referred to as WRAP in this document. The version of WRAP used for this water availability analysis is known as the February 1999 version (Wurbs, 1999). This version of WRAP was the best available at the time of Sulphur River Basin water availability modeling. A general listing of the additional simulation capabilities and data handling features incorporated into the WRAP model as used in this study is presented below:

1. Routine to transfer or distribute naturalized streamflows from gage locations, or other points where they are known, to ungaged locations or other points where they are not known, i. e., from gages to water rights, based on watershed hydrologic parameters.

2. Calculations to determine regulated streamflows, which are the simulated streamflows that actually would occur at a given location within a river basin, including quantities dedicated to downstream senior water rights, after adjustments for upstream diversions, upstream reservoir evaporation and storage, upstream return flows, and any upstream imports of water.

3. Procedures to allow the specification of minimum instream flow requirements by month at any point in a river basin such that a designated water right can not divert and/or store water when the minimum instream flow requirements are not satisfied.

4. Routines to incorporate the effects of channel losses due to seepage, evapotranspiration, and diversions not reflected in water rights into the streamflow calculations and other system operation simulations between specified control points.

5. Procedures to allow return flow factors to be specified by type of water use rather than for each individual water right and to be varied over the 12 months of the year.

6. Routine to add specified monthly gains (return flows) to or subtract specified monthly losses from the naturalized streamflows at any control point.

7. Option to adjust net reservoir evaporation, defined as gross reservoir evaporation minus precipitation, to account for the portion of the naturalized streamflow that represents runoff from the land area now covered by a reservoir.

8. Procedures to specify monthly varying limits on the conservation storage capacity of a reservoir for describing seasonal rule curve reservoir operations.

9. Restructuring of the naturalized streamflow and evaporation input data to make data entry more efficient.

10. Revision of the water rights input routine to increase the length of the water rights identifier (14 characters) and to expand the system for grouping water rights for organizing simulation results.

11. Procedure to limit the annual amount of water placed into storage in a reservoir to effectively describe off-channel reservoirs with authorized diversions for makeup water from adjacent streams.

12. Procedure to allow reservoir storage to be refilled from streamflow depletions at multiple control points.

4.1.2 Basin-Specific *WRAP* Model

No basin-specific modifications have been made to the WRAP model as part of this water availability modeling study of the Sulphur River Basin.

4.2 DEVELOPMENT OF *WRAP* WATER RIGHTS INPUT FILE

4.2.1 Control Points

Control points used with the WRAP model provide a mechanism to describe the locational configuration of a river basin. Control points are specified in the input data to indicate the location of streamflow information, reservoirs, water rights diversions, return flows, imports, and other system features. The computations performed by the WRAP model are based on knowing which of the other control points are located downstream of each control point. Essentially any configuration of stream tributaries, reservoirs, and within-basin or interbasin conveyance facilities can be modeled. Each water right can be assigned a separate control point, or alternatively, water rights can be aggregated such that the water rights assigned to a given control point include all water rights located between that control point and the next adjacent control point. Multiple water rights at the same control point all have access, in priority order, to the streamflow available at the control point.

Naturalized streamflows are provided as input for all control points, and the model computes unappropriated and regulated streamflows and other quantities for each control point. The WRAP model limits water available to a water right at a control point to the lesser of naturalized flows at the control point or unappropriated flows at downstream control points.

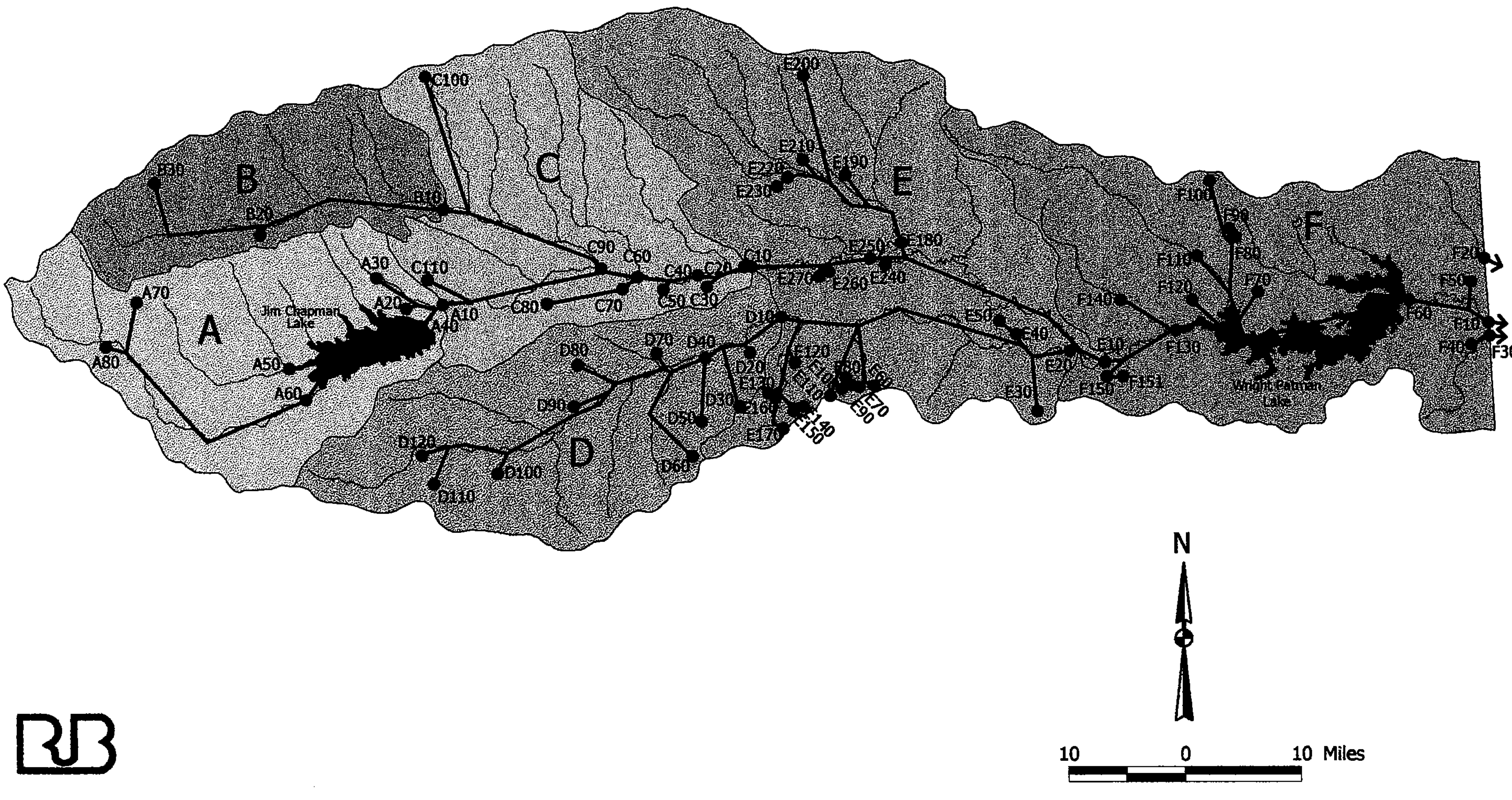
For the WRAP model of the Sulphur River Basin, control points have been assigned at the location of all existing water rights. In some cases, multiple water rights have been specified at a single control point, such as the water rights for North Texas Municipal Water District, the City of Irving, and the Sulphur River Municipal Water District at Jim Chapman Lake. Additional control points have been assigned at the downstream ends of each of the six subwatersheds where the known naturalized streamflows are specified in the model, at the end points of classified stream and lake segments defined by the TNRCC, at the confluence of certain streams, and at other special locations. Return flows have been added to the next control point downstream of the discharge. The locations of all of the control points specified in the WRAP model of the Sulphur River Basin together with their connecting links are shown on the map in Figure 4-1. A map showing the drainage areas (subwatersheds) for each control point as delineated by CRWR (see Section 3.2.1) is presented in Figure 4-2. A listing of the control points indicating the TNRCC number and name of their associated water right(s), if any, and the type of use, priority date, authorized diversion amount, authorized reservoir storage capacity, monthly demand distribution record, return flow record, and return flow control point for the associated water rights is presented in Table 4-1. In all, there are 77 control points that have been defined for structuring the WRAP model of the Sulphur River Basin.

4.2.2 Monthly Demand Distribution Factors

In the WRAP model, the monthly variations of individual water demands associated with water rights are described by specifying the annual diversion amount in acre-feet for each water right

FIGURE 4-1

CONTROL POINTS AND LINKS USED IN THE SULPHUR RIVER BASIN WRAP MODEL




F100
F90
F80
F70
F60
F10
F30
F40
A50

TABLE 4-1
WRAP MODEL INPUT SUMMARY BY CONTROL POINT

CONTROL POINT NUMBER[1]	WATER RIGHT IDENTIFICATION NUMBER[2]	NAME	TYPE OF USE[3]	PRIORITY DATE	AUTHORIZED DIVERSION AMOUNT Ac-Ft/Yr	AUTHORIZED STORAGE AMOUNT Ac-Ft	MONTHLY DEMAND FACTOR RECORD (Table 4-2)	RETURN FLOW RECORDS ENTERING AT CONTROL POINT (Tables 4-6 through 4-9)
F10		TEXAS-ARKANSAS STATE LINE						23, 36
F20		TEXAS-ARKANSAS STATE LINE						12, 34, 35
F30		TEXAS-ARKANSAS STATE LINE						
F40	03- 4838	INTERNATIONAL PAPER COMPANY	7	27715		52	CONST	
F50	03- 4837	LEON S KENNEDY JR	3	22827	80	550	IRRIGN	
F60	03- 4836	CITY OF TEXARKANA	1	18692	14,572	386,900	4836M	11, 27, 31, 32, 33, 37
"	03- 4836	CITY OF TEXARKANA	1	20868	10,428		4836M	
"	03- 4836	CITY OF TEXARKANA	1	24734	20,000		4836M	
"	03- 4836	CITY OF TEXARKANA	2	20868	35,000		4836I	
"	03- 4836	CITY OF TEXARKANA	2	24734	100,000		4836I	
F70	03- 4835	JERRY D PRATHER ET UX	7	17898		78	CONST	
F80	03- 4833	H C PRANGE JR	2	20485	8	14	CONST	
F90	03- 4832	CITY OF NEW BOSTON	1	16313	325	8	4832	
F100	03- 4831	CITY OF NEW BOSTON	1	5295	31	259	4831	
F110	03- 4830	WILLIAM E JOHNSON JR ET AL	3	14731	378		IRRIGN	30
F120	03- 4834	WILLIAM E JOHNSON JR ET AL	3	14731	39	15	IRRIGN	
F121	03- 4834	WILLIAM E JOHNSON JR ET AL						
F130		HEADWATERS OF WRIGHT PATMAN LAKE						28
F140	03- 4829	WILLIAM E JOHNSON JR ET AL	3	14731	4		IRRIGN	
F150	A- 5449	TEXAS PARKS & WILDLIFE DEPT	8	34018	863	504	CONST	
F151	A- 5449	(Off-Channel Reservoir)	8	34019		863	CONST	
E10		SULPHUR RIVER NEAR DARDEN, GAGE #7344000						10, 19, 21, 29
E20		WHITE OAK CREEK AT MOUTH						
E30	03- 4828	GLASS CLUB LAKE INC	7	26693		500	CONST	
E40	03- 4827	BROVENTURE COMPANY INC (Lake 1)	7	27320		796	CONST	
E50	03- 4827	BROVENTURE COMPANY INC (Lake 2)	7	27320		659	CONST	
E60	03- 4825	ROBERT CROOKS ET AL	3	23376	20	30	4825	
E70	03- 4826	ELLIS-KELLY LAKE CLUB	7	26672		151	CONST	
E80	03- 4823	ARDELIA GAUNTT	3	23894	23	24	4822	
E90	03- 4824	WALTER W LEE	3	23894	8		IRRIGN	
E100	A- 5510	TEXAS UTIL MINING CO/ TU SERVICES	2	34702		172	CONST	
E110	A- 5285	TEXAS UTIL MINING CO/ TU SERVICES	2	32924		125	CONST	
E120	03- 4822	JOHN E & BERNICE BALDWIN	3	24684	100	196	4822	
E130	03- 4821	ANNA PEARL LEWIS	2	19724	1	1	CONST	
E140	A- 5562	TEXAS UTILITIES MINING CO	2	35388	9		CONST	
E150	A- 5562	TEXAS UTILITIES MINING CO	2	35388	79		CONST	
E160	03- 4820	BILLY J MAXTON	3	23742	22		4820	
E170	A- 5562	TEXAS UTILITIES MINING CO	2	35388	37		CONST	

TABLE 4-1, CONT'D
WRAP MODEL INPUT SUMMARY BY CONTROL POINT

CONTROL POINT NUMBER[1]	WATER RIGHT IDENTIFICATION NUMBER[2]	NAME	TYPE OF USE[3]	PRIORITY DATE	AUTHORIZED DIVERSION AMOUNT Ac-Ft/Yr	AUTHORIZED STORAGE AMOUNT Ac-Ft	MONTHLY DEMAND FACTOR RECORD (Table 4-2)	RETURN FLOW RECORDS ENTERING AT CONTROL POINT (Tables 4-6 through 4-9)
D10		WHITE OAK CREEK NEAR TALCO, GAGE #7343500						
D20	03- 4819	DDC PROPERTIES LTD	7	3/18/74		2,360	CONST	
D30	03- 4818	ROBERT W CAMPBELL ET AL	3	12/31/64	11	24	4810	
D40	03- 4817	HANS WEISS ET UX	3	6/30/64	333		4817	7, 8, 26
D50	A- 5392	PAUL A PIEFER ET UX	3	12/6/91	341		4817	9
D60	03- 4816	CITY OF MOUNT VERNON	1	3/1/76	188	434	4811	
"	03- 4816	CITY OF MOUNT VERNON	1	11/22/82	212		4811	
D70	03- 4815	CHARLES HELM & LEWIS HELM	7	3/28/76		760	CONST	
D80	03- 4814	JERRY N JORDAN TRUSTEE ET AL	3	7/16/59	30	26	IRRIGN	
D90	A- 5150	LARRY MILES ET AL	1	7/28/87		269	IRRIGN	
D100	03- 4813	SULPHUR SPRINGS COUNTRY CLUB	3	12/15/75	113	127	4813	
D110	03- 4812	CITY OF SULPHUR SPRINGS	1	12/1/75		408	4811	
"	03- 4812	CITY OF SULPHUR SPRINGS	1	2/12/85	408		4811	
D120	03- 4811	SULPHUR SPRINGS WATER DISTRICT	1	7/24/51	2,000	2,100	4811	
"	03- 4811	SULPHUR SPRINGS WATER DISTRICT	1	11/25/68	7,800	11,900	4811	
"	03- 4811	SULPHUR SPRINGS WATER DISTRICT	1	11/30/70		2,260	4811	
"	03- 4811	SULPHUR SPRINGS WATER DISTRICT	1	9/26/83		1,578	4811	
E180		MOUTH OF CUTHAND CREEK						
E190	03- 4810	PERRY R BASS INC	3	4/4/60	200	200	4810	
E200	03- 4809	RED RIVER COUNTY WCID 1	1	1/20/64	1,120	1,225	4800	
"	03- 4809	RED RIVER COUNTY WCID 1	2	1/20/64	1		CONST	
E210	03- 4808	RED RIVER COUNTRY CLUB	7	1/6/75		670	CONST	
E220	03- 4807	MARY MARGARET VAUGHAN	3	9/22/69	22	75	IRRIGN	
E230	03- 4806	MARY MARGARET VAUGHAN	3	9/22/69	8		IRRIGN	
E240	03- 4805	E P LAND & CATTLE CO INC	3	1/5/81	200	186	4817	
E250	03- 4805	E P LAND & CATTLE CO INC	3	1/5/81	3,200		4817	20, 22
E260	03- 4805	E P LAND & CATTLE CO INC	3	1/5/81	2,500	1,307	4817	
E270	03- 4805	E P LAND & CATTLE CO INC	3	1/5/81	300	570	4817	
C10		SULPHUR RIVER NEAR TALCO, GAGE #7343200						
C20	03- 4804	TEXAS UTILITIES ELECTRIC CO	2	3/5/52	10,000	7,100	POWER	18
C30	03- 4803	HELMUT HERMANN ET AL	3	6/19/78	650	328	4803	
C40	03- 4803	HELMUT HERMANN ET AL	3	6/19/78	350		4803	
"	03- 4803	HELMUT HERMANN ET AL	3	11/15/82	900		4803	
C50	03- 4802	ALEXANDER FRICK ET AL	3	12/31/55	278	300	4802	
C60	A- 4148B	SARA M DUNHAM TRUST	3	4/11/97	11,312	2,925	4148	

TABLE 4-1, CONT'D
WRAP MODEL INPUT SUMMARY BY CONTROL POINT

CONTROL POINT NUMBER[1]	WATER RIGHT IDENTIFICATION NUMBER[2]	NAME	TYPE OF USE[3]	PRIORITY DATE	AUTHORIZED DIVERSION AMOUNT Ac-Ft/Yr	AUTHORIZED STORAGE AMOUNT Ac-Ft	MONTHLY DEMAND FACTOR RECORD (Table 4-2)	RETURN FLOW RECORDS ENTERING AT CONTROL POINT (Tables 4-6 through 4-9)
C70	A- 4148	SARA M DUNHAM TRUST	3	9/14/81	2,828	3,875	4148	
C80	A- 4148A	SARA M DUNHAM TRUST	3	11/7/84	5,500	3,623	4148	
C90		MOUTH OF NORTH SULPHUR RIVER						24, 25
C100	A- 5200	GORDON COUNTRY CLUB	7	11/1/88		394	CONST	
B10		NORTH SULPHUR RIVER NEAR COOPER, GAGE #7343000						16, 17
B20	A- 4205	CITY OF PECAN GAP	1	4/26/82	102	152	4205	
B30	N.A.	JACK KRECK (no water right)		none		295	CONST	
C110	03- 4801	DELTA COUNTRY CLUB INC	3	7/2/79	5	34	4796	
A10		SOUTH SULPHUR RIVER NEAR COOPER, GAGE #7342500						1
A20	03- 4800	CITY OF COOPER	1	1/3/77	273	164	4800	
A30	A- 4395	CITY OF COOPER	1	9/6/83	1,518	4,890	4800	
A40	03- 4799	CITY OF IRVING	1	11/19/65	44,820	114,265	4799M	3, 4, 5, 6
"	03- 4799	CITY OF IRVING	2	11/19/65	9,180		CONST	
"	03- 4798	NORTH TEXAS MWD	1	11/19/65	54,000	114,265	4798	
"	03- 4797	SULPHUR RIVER MWD	1	11/19/65	26,960	81,470	4797M	
"	03- 4797	SULPHUR RIVER MWD	2	11/19/65	11,560		CONST	
A50		MIDDLE SULPHUR RIVER BELOW BARNETT CREEK						15
A60		HEADWATERS OF JIM CHAPMAN/COOPER LAKE						2, 13, 14
A70	03- 4795	CITY OF WOLFE CITY	1	12/31/25	69	425	4795	
"	03- 4795	CITY OF WOLFE CITY	1	8/12/57	232	430	4795	
A80	03- 4796	WEBB HILL COUNTRY CLUB	3	3/11/68	80	39	4796	
"	03- 4796	WEBB HILL COUNTRY CLUB	3	4/18/83		21		

[1] Control points listed in river order beginning at downstream end of basin.

[2] Water Right Identification Number: 03 = Certificate of Adjudication in Basin 03 (Sulphur River Basin)
A = Application Number associated with Water Right Permit

[3] Type of use:
1= Municipal
2= Industrial
3 = Irrigation
7 = Recreation
8 = Other

and a set of 12 monthly demand distribution factors. The monthly demand distribution factors are multiplied times the annual diversion amount for a given water right to determine its diversion amounts for the different months of the year.

To establish appropriate demand distribution factors for each of the water rights, historical monthly water use data as reported by the water rights holders to the TNRCC and the TWDB have been compiled and analyzed. These are the same data that have been used in the streamflow naturalization process. For each water right with an authorized diversion, the average monthly water use has been determined based on the most recent five years of available data. The fractions of the total annual water use represented by the average monthly water use values have been determined and then assigned as the monthly demand distribution factors for each of the water rights. Those water rights with multiple use authorizations have been assigned more than one set of monthly demand distribution factors to properly describe their different use patterns.

The demand distribution factors that have been determined for each of the different types of water rights diversions for which adequate data have been available are summarized in Table 4-2. The water rights are organized in the table according to type of use, and for each type of use, the combined average monthly demand distribution factors are indicated. These combined average monthly values have been used for describing the demand patterns for some water rights with limited or no historical water use data. In other cases, the demand distribution factors for one of the water rights listed in Table 4-2 have been used for other similar water rights. These are indicated in the table.

4.2.3 Water Rights

The locations and general characteristics of the existing water rights in the Sulphur River Basin have been previously identified and described in Section 2.1. The map of the basin presented in Figure 2-1 shows the locations of the water rights. Their authorized diversion amounts and storage capacities and their oldest priority dates are listed in Table 2-2. The water right numbers of the water rights listed in Table 2-2 are indexed to the control points used to structure the WRAP model of the Sulphur River Basin in Table 4-1, and vice versa. Specific features of the water rights that have required special attention in developing the WRAP input data are discussed in the following sections.

TABLE 4-2

WATER RIGHTS MONTHLY DEMAND DISTRIBUTION FACTORS FOR SULPHUR RIVER BASIN

Demand Distrib. ID	Water Rights Permittee	Water Rights Identification Number	Maximum Authorized Diversion Ac-Ft/Yr	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
INDUSTRIAL WATER USE															
4804	TEXAS UTILITIES ELECTRIC CO.	03 4804	10,000	0.0335	0.0303	0.0303	0.1164	0.1100	0.0510	0.1244	0.2249	0.2073	0.0191	0.0159	0.0367
EVAP	H. C. PRANGE JR.	03 4833	8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0900	0.1900	0.2700	0.0900	0.0000	0.0000	0.0000
4836I	CITY OF TEXARKANA	03 4836	135,000	0.0797	0.0772	0.0876	0.0813	0.0827	0.0872	0.0851	0.0888	0.0831	0.0869	0.0822	0.0781
INDUST	Average Industrial Demand Distribution			0.0377	0.0358	0.0393	0.0659	0.0643	0.0761	0.1332	0.1946	0.1268	0.0353	0.0327	0.0383
IRRIGATION WATER USE															
4796	WEBB HILL COUNTRY CLUB	03 4796	80	0.0435	0.0435	0.0435	0.0696	0.1304	0.1391	0.1391	0.1652	0.0783	0.0609	0.0435	0.0435
4802	ALEXANDER FRICK, ET AL	03 4802	278	0.0000	0.0000	0.0000	0.0000	0.0000	0.2778	0.3056	0.3056	0.1111	0.0000	0.0000	0.0000
4803	HELMUT HERMANN, ET AL	03 4803	1,900	0.0000	0.0000	0.1200	0.3600	0.3600	0.1600	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4148	SARA M. DUNHAM TRUST	03 4148B	11,312	0.1240	0.2200	0.0750	0.0440	0.0310	0.0390	0.0390	0.0360	0.0030	0.0450	0.2210	0.1230
4813	SULPHUR SPRINGS COUNTRY CLUB	03 4813	113	0.0415	0.0543	0.0415	0.0447	0.0447	0.1278	0.1565	0.2045	0.1438	0.0639	0.0383	0.0383
4817	HANS WEISS, ET UX (Thrasher Land & Cattle)	03 4817	333	0.0000	0.0000	0.0000	0.0000	0.2051	0.2115	0.3782	0.2051	0.0000	0.0000	0.0000	0.0000
4810	ROBERT W. CAMPBELL, ET AL	03 4818	11	0.0000	0.0000	0.0000	0.0000	0.1964	0.1994	0.2508	0.2085	0.1450	0.0000	0.0000	0.0000
4806	MARY MARGARET VAUGHAN	03 4806	8	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.1600	0.8398	0.0000	0.0000	0.0000	0.0000
4810	PERRY R. BASS INC.	03 4810	200	0.0000	0.0000	0.0000	0.0000	0.1964	0.1994	0.2508	0.2085	0.1450	0.0000	0.0000	0.0000
4820	BILLY J. MAXTON	03 4820	22	0.0000	0.0000	0.0000	0.0000	0.1694	0.2581	0.1613	0.1694	0.0000	0.1210	0.1210	0.0000
4822	JOHN E. & BERNICE BALDWIN	03 4822	100	0.0000	0.0000	0.0000	0.0000	0.0000	0.2561	0.2683	0.3659	0.1098	0.0000	0.0000	0.0000
4825	ROBERT CROOKS, ET AL	03 4825	20	0.0000	0.0000	0.0000	0.2381	0.2381	0.2381	0.2857	0.0000	0.0000	0.0000	0.0000	0.0000
IRRIGN	Average Irrigation Demand Distribution			0.0150	0.0227	0.0200	0.0719	0.1291	0.1665	0.1773	0.2433	0.0738	0.0276	0.0382	0.0146
CONST	Constant Demand Distribution			0.0849	0.0767	0.0849	0.0822	0.0849	0.0822	0.0849	0.0849	0.0822	0.0849	0.0822	0.0849
MUNICIPAL WATER USE															
4799M	CITY OF IRVING	03 4799	44,820	0.0651	0.0607	0.0648	0.0697	0.0802	0.0951	0.1161	0.1176	0.1034	0.0905	0.0715	0.0653
4798	NORTH TEXAS MWD	03 4798	54,000	0.0728	0.0653	0.0590	0.0857	0.0689	0.0876	0.1232	0.1467	0.1131	0.0867	0.0518	0.0393
4797M	SULPHUR RIVER MWD	03 4797	26,960	0.0848	0.0804	0.0836	0.0758	0.0762	0.0834	0.0960	0.0950	0.0855	0.0883	0.0780	0.0730
4795	CITY OF WOLFE CITY	03 4795	300	0.0989	0.0627	0.0966	0.0696	0.0963	0.0786	0.1081	0.0892	0.0806	0.0783	0.0685	0.0725
4800	CITY OF COOPER	03 4800	273	0.0785	0.0700	0.0747	0.0738	0.0830	0.0815	0.1036	0.1042	0.0914	0.0838	0.0755	0.0800
4205	CITY OF PECAN GAP	03 4205	102	0.0832	0.0749	0.0835	0.0796	0.0833	0.0832	0.0895	0.0844	0.0858	0.0844	0.0813	0.0866
4811	CITY OF SULPHUR SPRINGS WATER DISTRICT	03 4811	9,800	0.0756	0.0732	0.0785	0.0731	0.0791	0.0861	0.1009	0.0989	0.0908	0.0872	0.0768	0.0798
4816	CITY OF MOUNT VERNON	03 4816	400	0.1997	0.1877	0.1621	0.0188	0.0017	0.0017	0.0256	0.0290	0.0051	0.0802	0.1433	0.1451
4831	CITY OF NEW BOSTON	03 4831	31	0.0795	0.0730	0.0792	0.0779	0.0801	0.0866	0.0965	0.0954	0.0862	0.0848	0.0808	0.0799
4832	CITY OF NEW BOSTON	03 4832	325	0.0795	0.0730	0.0792	0.0779	0.0801	0.0866	0.0965	0.0954	0.0862	0.0848	0.0808	0.0799
4836M	CITY OF TEXARKANA	03 4836	45,000	0.0801	0.0729	0.0771	0.0777	0.0849	0.0849	0.0942	0.0996	0.0898	0.0825	0.0747	0.0816
MUNICP	Average Municipal Demand Distribution			0.0907	0.0813	0.0853	0.0709	0.0740	0.0778	0.0955	0.0959	0.0834	0.0847	0.0803	0.0803

4.2.3.1 Priority Dates

Most water rights in the Sulphur River Basin have a single priority date for either or both diversions and reservoir storage. Representation of these water rights in the WRAP model is relatively straightforward.

Other water rights have multiple dates establishing their time priorities for diverting and/or impounding water. This occurs for a variety of reasons, including amendments to the original permit increasing the diversion amount, changing the type of use, increasing the storage capacity of a reservoir, or adding additional reservoirs. Each priority date for use and/or impoundment of water, with its associated authorized amount, has been accounted for separately in the WRAP water availability model. The WRAP program accommodates these types of water rights with multiple priority dates; however, the routine for allocating evaporation losses to individual water rights with multiple priority dates in reservoirs may not be consistent with any special agreements that may exist among the different water rights. Specific information regarding the water rights with multiple priority dates is presented in Table 4-3.

4.2.3.2 Treatment of Annual Diversions

The WRAP model accounts for the maximum annual diversion amount associated with each water right and each priority date. In the model, this amount of diversion cannot be exceeded in any given year. Specification of these quantities in the WRAP data file is a straightforward operation, and the model is fully capable of appropriately limiting annual diversions in the simulation process.

For purposes of the water availability analyses for the Sulphur River Basin, two different sets of annual diversion data have been developed as required by the different simulation conditions specified by the TNRCC. One set corresponds to the condition of fully authorized water rights diversions, and these amounts are those previously listed in Table 2-2 for each water right and in Table 4-1 for each control point. Table 4-4, which follows, also lists these authorized diversion amounts. The other set of annual diversions is based on the actual maximum use condition for existing water rights during the last ten years. These values have been determined from the historical water use records of the TNRCC and the TWDB, and they are listed in Table 4-4 for each water right by type of use.

To address the issue of water rights cancellation and its potential impact on water availability, the TNRCC has requested that the WRAP model be operated under the fully authorized water rights diversions, but with zero diversion amounts (simulated as cancelled) specified for those water

TABLE 4-3
WATER RIGHTS WITH MULTIPLE PRIORITY DATES

WATER RIGHT IDENTIFICATION NUMBER	NAME	STREAM	TYPE OF USE	DIVERSION AMOUNT Ac-Ft/Yr	RESERVOIR CAPACITY Ac-Ft	PRIORITY DATES - DIVERSIONS	PRIORITY DATES - IMPOUNDMENT
03-4836	CITY OF TEXARKANA	Sulphur River, Wright Patman Lake	1,2	180,000	386,900	3/5/51: first 14,572 municipal 2/17/57: next 10,428 municipal and first 35,000 industrial 9/19/67: remaining 20,000 municipal and 100,000 industrial 5/18/81: priority for transbasin diversions (11,000 municipal, 9,500 industrial)	Monthly schedule for maximum impoundment volumes
03-4825	ROBERT CROOKS ET AL	East Piney Creek	3	20	30	12/31/63: 20 ac-ft irrigation 12/31/65: 0.04 ac-ft industrial	12/31/63
A-5392	PAUL A PIEFER ET UX	Town Branch	3	341			
03-4816	CITY OF MOUNT VERNON	Denton Creek	1	400	434	3/1/76: first 188 ac-ft 11/22/82: remaining 212 ac-ft	3/1/76
03-4812	CITY OF SULPHUR SPRINGS	Unnamed trib. of White Oak Creek	1	408	408	2/12/85	12/1/75
03-4811	SULPHUR SPRINGS WATER DISTRICT	White Oak Creek, Lake Sulphur Springs	1	9,800	17,838	7/24/51: first 2,000 ac-ft 11/25/68: remaining 7,800 ac-ft	7/24/51: first 2,100 ac-ft 11/25/68: next 11,900 ac-ft 11/30/70: next 2,260 ac-ft 9/26/83: remaining 1,578 ac-ft
03-4803	HELMUT HERMANN ET AL	Unnamed trib. of Sulphur River and Sulphur River	3	1,900	328	6/19/78: first 1,000 a-f 11/15/82: remaining 900 ac-ft	6/19/78
A-4148B	SARA M DUNHAM TRUST	Sulphur River	3	11,312 (19,640 tot)	2,925 (10,423 tot)	11/7/97	11/7/97
A-4148	SARA M DUNHAM TRUST	Old Channel South Sulphur River	3	2,828 (19,640 tot)	3,849 (10,423 tot)	9/14/81	9/14/81
A-4148	SARA M DUNHAM TRUST	Old Channel South Sulphur River	3	2,828 (19,640 tot)	26 (10,423 tot)	9/14/81	9/14/81
A-4148A	SARA M DUNHAM TRUST	Old Channel South Sulphur River	3	5,500 (19,640 tot)	3,623 (10,423 tot)	11/7/84	11/7/84
03-4795	CITY OF WOLFE CITY	East Fork of Turkey Creek and Turkey Creek	1	300	855	12/31/25: first 68.5 ac-ft 8/12/57: remaining 231.5 ac-ft	12/31/25: first 425 a-f 8/12/57: remaining 430 a-f
03-4796	WEBB HILL COUNTRY CLUB	Unnamed trib. of South Sulphur River	3	80	60	3/11/68	3/11/68: first 39 ac-ft 4/18/83: remaining 21 ac-ft

Type of use: 1 = Municipal, 2 = Industrial, 3 = Irrigation

TABLE 4-4
ANNUAL DIVERSIONS BY WATER RIGHT AND USE TYPE
AS SPECIFIED IN THE WRAP MODEL

WATER RIGHT IDENTIFICATION NO.	CONTROL POINT NO.	WATER USE TYPE	AUTHORIZED ANNUAL DIVERSION Ac-Ft/Yr	TEN-YEAR MAXIMUM ANNUAL DIVERSION Ac-Ft/Yr	SIMULATED AS CANCELLED
03 4796	A80	3	80	22	No
03 4795	A70	1	69	244	No
03 4795	A70	1	232	0	No
03 4799	A40	1	44,820	0	Yes
03 4799	A40	2	9,180	0	Yes
03 4798	A40	1	54,000	0	Yes
03 4797	A40	1	26,960	0	Yes
03 4797	A40	2	11,560	0	Yes
A 4395	A30	1	1,518	462	No
03 4800	A20	1	273	462	No
03 4801	C110	3	5	0	Yes
A 4205	B20	1	102	34	No
A 4148A	C80	3	5,500	2,744	No
A 4148	C70	3	2,828	2,744	No
A 4148B	C60	3	11,312	0	No
03 4802	C50	3	278	320	No
03 4803	C40	3	748	0	Yes
03 4803	C40	3	900	0	Yes
03 4803	C30	3	252	0	Yes
03 4804	C20	2	10,000	103	No
03 4805	E270	3	200	0	Yes
03 4805	E260	3	2,700	0	Yes
03 4805	E240	3	100	0	Yes
03 4806	E230	3	8	4	No
03 4807	E220	3	22	0	Yes
03 4809	E200	1	1,120	396	No
03 4809	E200	2	1	1	No
03 4810	E190	3	200	0	Yes
03 4811	D120	1	2,000	4,809	No
03 4811	D120	1	7,800	0	No
03 4812	D110	1	408	0	Yes
03 4813	D100	3	113	27	No
03 4814	D80	3	30	5	No
03 4816	D60	1	188	1	No
03 4816	D60	1	212	0	No
A 5392	D50	3	341	0	No
03 4817	D40	3	333	0	Yes
03 4818	D30	3	11	0	Yes
A 5562	E170	2	37	0	No
03 4820	E160	3	22	0	Yes
A 5562	E150	2	79	0	No
A 5562	E140	2	9	0	No

TABLE 4-4, CONT'D
ANNUAL DIVERSIONS BY WATER RIGHT AND USE TYPE
AS SPECIFIED IN THE WRAP MODEL

WATER RIGHT IDENTIFICATION NO.	CONTROL POINT NO.	WATER USE TYPE	AUTHORIZED ANNUAL DIVERSION Ac-Ft/Yr	TEN-YEAR MAXIMUM ANNUAL DIVERSION Ac-Ft/Yr	SIMULATED AS CANCELLED
03 4821	E130	2	1	0	Yes
03 4822	E120	3	100	40	No
03 4824	E90	3	8	0	Yes
03 4823	E80	3	23	0	Yes
03 4825	E60	3	20	0	Yes
A 5449	F150	8	863	0	No
03 4829	F140	3	4	0	Yes
03 4834	F120	3	39	0	Yes
03 4830	F110	3	378	0	Yes
03 4831	F100	1	31	0	Yes
03 4832	F90	1	325	0	Yes
03 4833	F80	2	8	0	Yes
03 4836	F60	1	14,572	93,165 *	No
03 4836	F60	1	10,428	0	Yes
03 4836	F60	1	20,000	0	Yes
03 4836	F60	2	35,000	0	Yes
03 4836	F60	2	100,000	0	Yes
03 4837	F50	3	80	0	Yes

* Represents water for all of the Wright Patman Lake diversions.

rights that have reported zero use during the last ten years. An exception is water rights with priority dates less than 10 years old, which were not simulated as cancelled regardless of reported usage. The water rights subject to simulated cancellation are indicated in Table 4-4.

4.2.3.3 Treatment of Reservoir Storage

Generally, the maximum conservation storage for each reservoir has been specified in the WRAP model of the Sulphur River Basin in accordance with the maximum authorized storage amounts listed in Table 2-1 for each water right and in Table 4-1 for each control point. The exceptions are those water rights with multiple priority dates for different storage amounts as listed in Table 4-3, and Wright Patman Lake, which is authorized to vary its maximum conservation storage capacity monthly in accordance with prescribed quantities in the City of Texarkana's permit.

As noted above, the multiple priority dates for reservoir storage have been accounted for in the WRAP model. When simulating storage in a particular reservoir with multiple priority dates for specific storage amounts, the WRAP model uses the priority dates and the authorized storage amounts to determine when and how much water can be stored in the reservoir as water is available from upstream inflows. Each water right's storage is filled in order of priority to the extent inflows are available. In effect, storage for the most senior water right is at the bottom of the reservoir, while the storage for the most junior water right is at the top of the reservoir. Once water is stored in the reservoir under any one of its multiple priority dates, the WRAP model performs no further accounting of the water within the reservoir with respect to the different priority dates. Depletions of reservoir storage with multiple priority dates due to diversions and evaporation are made in order of priority, with the most senior water right's demand being satisfied first. The quantity of stored water available for a given water right (and given priority date) is essentially all of the water contained in the reservoir, unless a dead pool is specified for the given water right that restricts its lower level of available storage. Since all of the water rights in each of the reservoirs in the Sulphur River Basin with multiple storage priority dates are owned by the same entity, all dead pools have been specified as zero, and the entire contents of the reservoirs have been made available to all of the water rights for satisfying their demands.

The monthly maximum conservation storage limits that have been specified in the WRAP model for Wright Patman Lake are listed below in Table 4-5. As indicated, the maximum storage capacity of the reservoir is maintained constant at its lowest level during the period January through March, and then it is allowed to increase to its highest level in June. After June, water is deliberately evacuated from the reservoir through releases downstream according to the specified maximum storage capacities for each month until January, when the cycle begins again. This seasonal operating rule allows excess flows in the river to be stored in the reservoir during the spring and early summer months, and then to be subsequently used during the late summer and early fall months. This procedure increases the available yield from the impoundment.

TABLE 4-5 MAXIMUM MONTHLY CONSERVATION STORAGE CAPACITY FOR WRIGHT PATMAN LAKE

MONTH	AUTHORIZED STORAGE CAPACITY acre-feet	MONTH	AUTHORIZED STORAGE CAPACITY acre-feet
January	265,300	July	380,800
February	265,300	August	355,700
March	265,300	September	324,900
April	325,300	October	302,000
May	385,800	November	282,600
June	386,900	December	273,600

It is noteworthy that no instream flow limitation has been imposed on Wright Patman Lake for minimum releases. Although in practice the Corps of Engineers typically has a minimum release dependent on storage, there is no water right or permit condition that requires such a release. Consequently, it has not been included in the model.

4.2.3.4 Return Flows

In the WRAP model for the Sulphur River Basin, return flows associated with water rights diversions have been specified either as constant monthly amounts or as prescribed fractions of the diversion amounts. As directed by TNRCC, all return flows associated with municipal water rights have been set equal to constant monthly values for each model run. This provides for continuous and constant return flows throughout an entire simulation period, even if the source of the return flows, i. e., the associated water rights diversions, becomes curtailed by senior water rights. The underlying assumption is that municipal water use will be continuous, even during drought periods when municipal water rights diversions may be significantly reduced because of limited streamflows or available reservoir storage. The specification of the constant monthly return flows in the WRAP data file is accomplished with the CI (Constant Inflow) record.

The constant inflow method also has been used to describe the return flows from municipal and industrial water users that obtain their water supplies from water rights holders within the Sulphur River Basin. This group includes primarily those entities that rely upon and purchase water from the City of Texarkana through its water rights in Wright Patman Lake. Analyses of these return flows have been made to assure that they are not also included in the return flows for the in-basin water rights holders. Constant inflows also have been used to account for return flows from municipal and industrial water users within the basin that do not have their own water rights, but, instead, rely on groundwater and/or out-of-basin import of water for their water supplies. These return flows would not necessarily be reduced or curtailed when the available supplies for in-basin water rights holders become limited during drought periods.

Historical return flow data from the TNRCC and the TWDB for all of the entities that have discharged water into the Sulphur River Basin have been compiled and analyzed. Based on the last five years of available records (generally 1992-1996), average monthly return flow quantities have been established, and corresponding monthly return flow factors have been determined where possible. These return flow factors have been used to calculate the monthly return flow amounts for each of the water rights holders with diversions, i. e., the monthly return flow factors have been multiplied times the fully authorized annual diversion amounts. For those return flow dischargers without water rights, the five-year average values have been used directly for all simulations (with appropriate adjustments for the 50-percent and 100-percent reuse runs and the current conditions/10-year maximum diversion runs) to specify return flows on the CI records in the WRAP data file. Population projections from the Texas Water Plan (TWDB, 1997) were examined for the cities with return flows but without water rights. These projections indicate little population change through 2050. Therefore, the assumption of constant return flows for these cities based on the average of the last five years is reasonable.

For purposes of the water availability analyses for the Sulphur River Basin, five different sets of return flow data have been developed as required by the different simulation conditions specified by the TNRCC. These are listed below:

Return Flow Data Set 1	Return flows corresponding to fully authorized diversions with no reuse (Run 1, Section 5.1)
Return Flow Data Set 2	Return flows corresponding to fully authorized diversions with 50-percent reuse (Run 2, Section 5.1)
Return Flow Data Set 3	Return flows corresponding to fully-authorized diversions with 100-percent reuse, which means zero return flows (Run 3 and also Runs 6 and 7, Section 5.1)
Return Flow Data Set 4	Return flows corresponding to fully-authorized diversions with no reuse, except for water rights with no reported use

	during the last ten years, which are assumed to be cancelled and, therefore, have zero return flows (Run 4, Section 5.1)
Return Flow Data Set 5	Return flows corresponding to maximum reported water rights diversions during the last 10 years with no reuse (Runs 5 and 8, Section 5.1)

The monthly return flow values that have been developed for each discharge for the all of the sets of data listed above, excluding Data Set 3 because all return flows for this case are set equal to zero, are presented in Tables 4-6 through 4-9, i. e., for Data Sets 1, 2, 4, and 5, respectively.

It should be noted that the return flows from a portion of one industrial water right diversion included in the WRAP model (Water Right 03-4836, Control Point F60, City of Texarkana industrial diversion) are described in the model by applying monthly return flow factors times the annual diversion amount. This approach, rather than the constant inflow method, was used because this is an industrial diversion that possibly would be subject to being reduced or curtailed during the occurrence of drought conditions. The monthly return flow factors that have been developed for this water right and that are specified in the WRAP model input file for January through December are as follows: 0.05, 0.05, 0.05, 0.05, 0.04, 0.03, 0.03, 0.04, 0.03, 0.04, 0.04, and 0.05. These return flows are discharge in the next timestep (month) in the model so that the flows are available to downstream senior water rights.

4.2.3.5 Multiple Diversion Locations

There are eight significant water rights in the Sulphur River Basin with multiple diversion or impoundment points. Multiple diversion points, in this context, include only those water rights with diversion points on different streams or different locations on the same stream where drainage areas, and thus streamflows, are significantly different. This excludes water rights with multiple diversion points on the same reservoir, or water rights with multiple diversion points on a short reach of a stream. Multiple impoundment points include only those water rights that are permitted to impound runoff in more than one reservoir. This excludes off-channel reservoirs that are only permitted to store diversions. Information describing these water rights is presented in Table 4-10. For modeling purposes, "functional" control points that do not necessarily represent the exact location of the water right were created to handle these water rights. The specific procedures used in representing these water rights in the WRAP model are described below:

1. Water Right 03-4830 (William E. Johnson, et al) – The most downstream of the five authorized diversion points has been specified in the WRAP model as the sole diversion point for all five of the diversion points (Control Point F110).

TABLE 4-6

MONTHLY RETURN FLOW DATA SET NO. 1 USED IN WRAP MODEL FOR RUN 1

Return Flow Record	Control Point No.	Discharger Name	Water Rights Identification No.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				MONTHLY RETURN FLOWS IN ACRE-FEET											
MUNICIPAL WITH WATER RIGHTS															
1	A10	SULPHUR RIVER MWD	03 4797	836.0	803.0	728.0	601.0	597.0	491.0	552.0	456.0	501.0	706.0	805.0	695.0
2	A60	CITY OF WOLFE CITY	03 4795	20.8	12.9	22.2	9.8	16.9	10.8	11.2	6.3	7.7	9.1	9.4	12.8
3	A40	CITY OF COOPER	A 4395	94.2	84.9	79.1	71.1	79.1	58.3	72.5	60.9	65.2	81.5	94.8	92.5
4	A40	CITY OF COOPER	03 4800	16.9	15.3	14.2	12.8	14.2	10.5	13.0	10.9	11.7	14.7	17.1	16.6
5	A40	CITY OF COOPER (sum)		111.1	100.2	93.4	83.9	93.3	68.8	85.5	71.8	76.9	96.1	111.9	109.1
6	A40	CITY OF PECAN GAP	A 4205	11.4	9.3	11.3	10.7	11.2	9.4	8.6	8.2	8.1	10.1	9.4	12.2
7	D40	SULPHUR SPRINGS WATER DISTRICT	03 4811	678.8	604.4	674.4	617.2	630.3	581.7	572.3	566.6	552.5	580.1	597.4	667.3
8	D40	CITY OF SULPHUR SPRINGS	03 4812	24.5	20.6	23.6	19.4	20.8	19.5	18.2	17.5	17.8	18.2	20.2	20.6
9	D50	MOUNT VERNON	03 4816	29.4	22.3	28.1	24.5	23.5	20.6	22.2	21.3	17.8	20.3	23.0	26.7
10	E10	RED RIVER COUNTY WCID 1	03 4809	255.8	173.8	213.9	157.1	179.6	113.3	138.8	127.6	114.3	100.9	169.7	217.4
11	F60	CITY OF NEW BOSTON	03 4832	9.5	8.3	9.2	7.7	7.9	7.1	5.9	5.9	6.1	6.6	8.0	8.1
12	F20	CITY OF TEXARKANA	03 4836	6,357.2	6,070.3	6,118.7	5,013.4	4,806.5	3,712.6	3,512.8	4,341.6	3,761.6	4,112.2	5,212.4	6,245.1
MUNICIPAL WITHOUT WATER RIGHTS															
13	A60	BAILEY TOWN OF	-	1.3	0.9	1.2	1.2	1.2	2.3	0.5	0.7	0.8	1.0	1.2	1.4
14	A60	CITY OF COMMERCE	-	142.4	128.3	142.7	126.5	133.8	117.7	117.6	118.7	126.7	121.4	132.4	131.3
15	A50	CITY OF LADONIA	-	22.6	18.2	18.2	21.0	20.9	17.0	17.1	23.4	18.9	21.1	21.9	19.5
16	B10	PETTY WS&SW	-	0.5	0.4	0.6	0.3	0.7	0.4	0.2	0.2	0.1	0.4	0.3	0.6
17	B10	CITY OF ROXTON	-	5.0	3.4	4.0	3.4	4.0	2.5	2.3	1.9	2.6	2.7	3.8	4.5
18	C20	CITY OF DEPORT	-	10.0	5.2	6.8	5.7	5.5	6.5	5.9	3.4	4.8	5.1	7.7	9.4
19	E10	CITY OF BLOSSOM	-	5.1	4.4	6.0	6.0	6.0	4.0	10.5	6.5	11.6	6.6	5.3	5.6
20	E250	CITY OF BOGATA	-	24.1	19.9	24.7	22.2	22.2	17.0	19.9	16.7	16.0	15.5	18.8	21.7
21	E10	CITY OF DETROIT	-	9.7	6.8	7.7	6.5	7.2	5.2	5.6	4.9	5.4	5.0	7.3	8.4
22	E250	CITY OF TALCO	-	3.4	1.7	2.2	2.2	3.0	2.0	2.2	1.9	1.7	1.7	2.1	3.0
23	F10	LEROY'S MOBILE HOME	-	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
INDUSTRIAL WITHOUT WATER RIGHTS															
24	C90	BABCOCK&WILCOX - PARIS PLANT	-	29.2	28.2	38.5	31.4	36.2	28.8	25.8	17.6	20.6	35.4	32.7	32.5
25	C90	KIMBERLY CLARK - PARIS PLANT	-	34.5	31.2	61.3	104.4	108.6	21.4	42.4	54.1	143.1	78.0	18.8	46.5
26	D40	A P GREEN INDUSTRIES INC	-	0.4	0.4	0.6	0.5	0.6	0.6	0.8	0.8	0.7	0.6	0.4	0.3
27	F60	LONE STAR AMMUNITION	-	1.5	1.9	1.7	1.7	1.7	2.0	1.5	2.1	1.9	2.1	1.6	1.6
28	F130	BOWIE COUNTY REST AREA	-	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1
PURCHASES FROM TEXARKANA: MUNICIPAL															
29	E10	CITY OF ANNONA	-	2.1	1.7	1.1	2.2	1.2	0.7	1.1	1.1	0.9	0.7	2.3	0.9
30	F110	CITY OF DEKALB - SOUTH PLANT	-	42.3	30.9	27.9	27.1	21.1	16.5	19.4	30.8	16.6	18.2	28.2	31.8
31	F60	NEW BOSTON	-	134.4	94.3	103.0	88.9	72.9	57.2	54.5	69.7	64.9	77.2	101.3	118.4
32	F60	CITY OF MAUD	-	8.4	8.0	8.6	7.8	6.2	5.1	6.1	5.1	5.4	6.0	6.3	6.2
33	F60	CITY OF REDWATER	-	10.5	10.1	10.8	9.8	7.8	6.5	7.7	6.5	6.7	7.5	8.0	7.8
PURCHASES FROM TEXARKANA: INDUSTRIAL															
34	F20	ALUMAX MILL	-	13.7	12.2	14.0	35.9	13.1	13.3	14.6	66.0	16.6	16.4	13.5	14.7
35	F20	PAPER CHEMICALS, INC.	-	7.5	6.5	7.3	6.7	7.4	6.9	6.9	7.1	6.8	7.0	6.9	7.1
36	F10	INTERNATIONAL PAPER - TEXARKANA MIL	-	1,942.1	4,437.5	3,916.7	1,323.4	1,165.3	6,558.9	3,909.7	4,548.7	0.0	4,710.0	3,727.4	3,507.9
37	F60	INTERNATIONAL PAPER - SAWMILL	-	9.4	7.2	10.9	9.1	8.9	12.8	1.5	10.3	0.1	17.0	7.2	4.9

TABLE 4-7

MONTHLY RETURN FLOW DATA SET NO. 2 USED IN WRAP MODEL FOR RUN 2

Return Flow Record	Control Point No.	Discharger Name	Water Rights Identification No.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				MONTHLY RETURN FLOWS IN ACRE-FEET											
MUNICIPAL WITH WATER RIGHTS															
1	A10	SULPHUR RIVER MWD	03 4797	418.0	401.5	364.0	300.5	298.5	245.5	276.0	228.0	250.5	353.0	402.5	347.5
2	A60	CITY OF WOLFE CITY	03 4795	10.4	6.4	11.1	4.9	8.5	5.4	5.6	3.2	3.9	4.6	4.7	6.4
3	A40	CITY OF COOPER	A 4395	47.1	42.5	39.6	35.5	39.5	29.2	36.2	30.4	32.6	40.7	47.4	46.2
4	A40	CITY OF COOPER	03 4800	8.5	7.6	7.1	6.4	7.1	5.2	6.5	5.5	5.9	7.3	8.5	8.3
5	A40	CITY OF COOPER (sum)		55.6	50.1	46.7	41.9	46.7	34.4	42.8	35.9	38.4	48.1	55.9	54.6
6	A40	CITY OF PECAN GAP	A 4205	5.7	4.7	5.7	5.3	5.6	4.7	4.3	4.1	4.1	5.1	4.7	6.1
7	D40	SULPHUR SPRINGS WATER DISTRICT	03 4811	339.4	302.2	337.2	308.6	315.2	290.8	286.1	283.3	276.3	290.1	298.7	333.7
8	D40	CITY OF SULPHUR SPRINGS	03 4812	12.3	10.3	11.8	9.7	10.4	9.7	9.1	8.7	8.9	9.1	10.1	10.3
9	D50	MOUNT VERNON (sum of both plants)	03 4816	14.7	11.2	14.0	12.3	11.7	10.3	11.1	10.7	8.9	10.1	11.5	13.3
10	E10	RED RIVER COUNTY WCID 1	03 4809	127.9	86.9	106.9	78.5	89.8	56.6	69.4	63.8	57.1	50.4	84.9	108.7
11	F60	CITY OF NEW BOSTON	03 4832	4.8	4.2	4.6	3.9	4.0	3.6	3.0	3.0	3.1	3.3	4.0	4.1
12	F20	CITY OF TEXARKANA	03 4836	3,178.6	3,035.1	3,059.3	2,506.7	2,403.2	1,856.3	1,756.4	2,170.8	1,880.8	2,056.1	2,606.2	3,122.6
MUNICIPAL WITHOUT WATER RIGHTS															
13	A60	BAILEY TOWN OF	-	0.6	0.5	0.6	0.6	0.6	1.2	0.3	0.4	0.4	0.5	0.6	0.7
14	A60	CITY OF COMMERCE	-	71.2	64.1	71.4	63.3	66.9	58.8	58.8	59.4	63.3	60.7	66.2	65.6
15	A50	CITY OF LADONIA	-	11.3	9.1	9.1	10.5	10.4	8.5	8.5	11.7	9.5	10.5	11.0	9.8
16	B10	PETTY WS&SW	-	0.2	0.2	0.3	0.1	0.4	0.2	0.1	0.1	0.1	0.2	0.2	0.3
17	B10	CITY OF ROXTON	-	2.5	1.7	2.0	1.7	2.0	1.3	1.2	0.9	1.3	1.4	1.9	2.2
18	C20	CITY OF DEPORT	-	5.0	2.6	3.4	2.9	2.8	3.2	2.9	1.7	2.4	2.6	3.9	4.7
19	E10	CITY OF BLOSSOM	-	2.6	2.2	3.0	3.0	3.0	2.0	5.2	3.3	5.8	3.3	2.6	2.8
20	E250	CITY OF BOGATA	-	12.1	9.9	12.3	11.1	11.1	8.5	10.0	8.4	8.0	7.8	9.4	10.9
21	E10	CITY OF DETROIT	-	4.8	3.4	3.8	3.2	3.6	2.6	2.8	2.4	2.7	2.5	3.6	4.2
22	E250	CITY OF TALCO	-	1.7	0.8	1.1	1.1	1.5	1.0	1.1	1.0	0.8	0.8	1.0	1.5
23	F10	LEROY'S MOBILE HOME	-	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
INDUSTRIAL WITHOUT WATER RIGHTS															
24	C90	BABCOCK&WILCOX - PARIS PLANT	-	14.6	14.1	19.2	15.7	18.1	14.4	12.9	8.8	10.3	17.7	16.3	16.2
25	C90	KIMBERLY CLARK - PARIS PLANT	-	17.2	15.6	30.7	52.2	54.3	10.7	21.2	27.1	71.5	39.0	9.4	23.3
26	D40	A P GREEN INDUSTRIES INC	-	0.2	0.2	0.3	0.2	0.3	0.3	0.4	0.4	0.3	0.3	0.2	0.2
27	F60	LONE STAR AMMUNITION	-	0.8	0.9	0.8	0.9	0.9	1.0	0.8	1.1	1.0	1.0	0.8	0.8
28	F130	BOWIE COUNTY REST AREA	-	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
PURCHASES FROM TEXARKANA: MUNICIPAL															
29	E10	CITY OF ANNONA	-	1.0	0.8	0.6	1.1	0.6	0.3	0.6	0.6	0.5	0.4	1.2	0.5
30	F110	CITY OF DEKALB - SOUTH PLANT	-	21.2	15.5	14.0	13.5	10.6	8.2	9.7	15.4	8.3	9.1	14.1	15.9
31	F60	NEW BOSTON	-	67.2	47.1	51.5	44.4	36.4	28.6	27.2	34.8	32.5	38.6	50.6	59.2
32	F60	CITY OF MAUD	-	4.2	4.0	4.3	3.9	3.1	2.6	3.1	2.6	2.7	3.0	3.2	3.1
33	F60	CITY OF REDWATER	-	5.3	5.1	5.4	4.9	3.9	3.2	3.9	3.2	3.4	3.7	4.0	3.9
PURCHASES FROM TEXARKANA: INDUSTRIAL															
34	F20	ALUMAX MILL	-	6.8	6.1	7.0	17.9	6.5	6.7	7.3	33.0	8.3	8.2	6.8	7.3
35	F20	PAPER CHEMICALS, INC.	-	3.7	3.2	3.6	3.4	3.7	3.4	3.5	3.5	3.4	3.5	3.4	3.5
36	F10	INTERNATIONAL PAPER - TEXARKANA MILL	-	971.1	2,218.8	1,958.4	661.7	582.7	3,279.5	1,954.9	2,274.4	0.0	2,355.0	1,863.7	1,754.0
37	F60	INTERNATIONAL PAPER - SAWMILL	-	4.7	3.6	5.4	4.5	4.5	6.4	0.7	5.1	0.1	8.5	3.6	2.5

TABLE 4-8

MONTHLY RETURN FLOW DATA SET NO. 4 USED IN WRAP MODEL FOR RUN 4

Return Flow Record	Control Point No.	Discharger Name	Water Rights Identification No.	MONTHLY RETURN FLOWS IN ACRE-FEET Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MUNICIPAL WITH WATER RIGHTS															
1	A10	SULPHUR RIVER MWD	03 4797	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	A60	CITY OF WOLFE CITY	03 4795	20.8	12.9	22.2	9.8	16.9	10.8	11.2	6.3	7.7	9.1	9.4	12.8
3	A40	CITY OF COOPER	A 4395	94.2	84.9	79.1	71.1	79.1	58.3	72.5	60.9	65.2	81.5	94.8	92.5
4	A40	CITY OF COOPER	03 4800	16.9	15.3	14.2	12.8	14.2	10.5	13.0	10.9	11.7	14.7	17.1	16.6
5	A40	CITY OF COOPER (sum)		111.1	100.2	93.4	83.9	93.3	68.8	85.5	71.8	76.9	96.1	111.9	109.1
6	A40	CITY OF PECAN GAP	A 4205	11.4	9.3	11.3	10.7	11.2	9.4	8.6	8.2	8.1	10.1	9.4	12.2
7	D40	SULPHUR SPRINGS WATER DISTRICT	03 4811	678.8	604.4	674.4	617.2	630.3	581.7	572.3	566.6	552.5	580.1	597.4	667.3
8	D40	CITY OF SULPHUR SPRINGS	03 4812	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	D50	MOUNT VERNON (sum of both plants)	03 4816	29.4	22.3	28.1	24.5	23.5	20.6	22.2	21.3	17.8	20.3	23.0	26.7
10	E10	RED RIVER COUNTY WCID 1	03 4809	255.8	173.8	213.9	157.1	179.6	113.3	138.8	127.6	114.3	100.9	169.7	217.4
11	F60	CITY OF NEW BOSTON	03 4832	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	F20	CITY OF TEXARKANA	03 4836	6,357.2	6,070.3	6,118.7	5,013.4	4,806.5	3,712.6	3,512.8	4,341.6	3,761.6	4,112.2	5,212.4	6,245.1
MUNICIPAL WITHOUT WATER RIGHTS															
13	A60	BAILEY TOWN OF	-	1.3	0.9	1.2	1.2	1.2	2.3	0.5	0.7	0.8	1.0	1.2	1.4
14	A60	CITY OF COMMERCE	-	142.4	128.3	142.7	126.5	133.8	117.7	117.6	118.7	126.7	121.4	132.4	131.3
15	A50	CITY OF LADONIA	-	22.6	18.2	18.2	21.0	20.9	17.0	17.1	23.4	18.9	21.1	21.9	19.5
16	B10	PETTY WS&SW	-	0.5	0.4	0.6	0.3	0.7	0.4	0.2	0.2	0.1	0.4	0.3	0.6
17	B10	CITY OF ROXTON	-	5.0	3.4	4.0	3.4	4.0	2.5	2.3	1.9	2.6	2.7	3.8	4.5
18	C20	CITY OF DEPORT	-	10.0	5.2	6.8	5.7	5.5	6.5	5.9	3.4	4.8	5.1	7.7	9.4
19	E10	CITY OF BLOSSOM	-	5.1	4.4	6.0	6.0	6.0	4.0	10.5	6.5	11.6	6.6	5.3	5.6
20	E250	CITY OF BOGATA	-	24.1	19.9	24.7	22.2	22.2	17.0	19.9	16.7	16.0	15.5	18.8	21.7
21	E10	CITY OF DETROIT	-	9.7	6.8	7.7	6.5	7.2	5.2	5.6	4.9	5.4	5.0	7.3	8.4
22	E250	CITY OF TALCO	-	3.4	1.7	2.2	2.2	3.0	2.0	2.2	1.9	1.7	1.7	2.1	3.0
23	F10	LEROY'S MOBILE HOME	-	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
INDUSTRIAL WITHOUT WATER RIGHTS															
24	C90	BABCOCK&WILCOX - PARIS PLANT	-	29.2	28.2	38.5	31.4	36.2	28.8	25.8	17.6	20.6	35.4	32.7	32.5
25	C90	KIMBERLY CLARK - PARIS PLANT	-	34.5	31.2	61.3	104.4	108.6	21.4	42.4	54.1	143.1	78.0	18.8	46.5
26	D40	A P GREEN INDUSTRIES INC	-	0.4	0.4	0.6	0.5	0.6	0.6	0.8	0.8	0.7	0.6	0.4	0.3
27	F60	LONE STAR AMMUNITION	-	1.5	1.9	1.7	1.7	1.7	2.0	1.5	2.1	1.9	2.1	1.6	1.6
28	F130	BOWIE COUNTY REST AREA	-	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1
PURCHASES FROM TEXARKANA: MUNICIPAL															
29	E10	CITY OF ANNONA	-	2.1	1.7	1.1	2.2	1.2	0.7	1.1	1.1	0.9	0.7	2.3	0.9
30	F110	CITY OF DEKALB - SOUTH PLANT	-	42.3	30.9	27.9	27.1	21.1	16.5	19.4	30.8	16.6	18.2	28.2	31.8
31	F60	NEW BOSTON	-	134.4	94.3	103.0	88.9	72.9	57.2	54.5	69.7	64.9	77.2	101.3	118.4
32	F60	CITY OF MAUD	-	8.4	8.0	8.6	7.8	6.2	5.1	6.1	5.1	5.4	6.0	6.3	6.2
33	F60	CITY OF REDWATER	-	10.5	10.1	10.8	9.8	7.8	6.5	7.7	6.5	6.7	7.5	8.0	7.8
PURCHASES FROM TEXARKANA: INDUSTRIAL															
34	F20	ALUMAX MILL	-	13.7	12.2	14.0	35.9	13.1	13.3	14.6	66.0	16.6	16.4	13.5	14.7
35	F20	PAPER CHEMICALS, INC.	-	7.5	6.5	7.3	6.7	7.4	6.9	6.9	7.1	6.8	7.0	6.9	7.1
36	F10	INTERNATIONAL PAPER - TEXARKANA MILL	-	1,942.1	4,437.5	3,916.7	1,323.4	1,165.3	6,558.9	3,909.7	4,548.7	0.0	4,710.0	3,727.4	3,507.9
37	F60	INTERNATIONAL PAPER - SAWMILL	-	9.4	7.2	10.9	9.1	8.9	12.8	1.5	10.3	0.1	17.0	7.2	4.9

TABLE 4-9

MONTHLY RETURN FLOW DATA SET NO. 5 USED IN WRAP MODEL FOR RUNS 5 AND 8

Return Flow Record	Control Point No.	Discharger Name	Water Rights Identification Number	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
MUNICIPAL WITH WATER RIGHTS															
1	A10	SULPHUR RIVER MWD	03 4797	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	A60	CITY OF WOLFE CITY	03 4795	16.9	10.5	18.0	8.0	13.8	8.8	9.1	5.1	6.3	7.4	7.6	10.4
3	A40	CITY OF COOPER	A 4395	28.7	25.8	24.1	21.6	24.1	17.7	22.1	18.5	19.8	24.8	28.9	28.1
4	A40	CITY OF COOPER	03 4800	28.7	25.8	24.1	21.6	24.1	17.7	22.1	18.5	19.8	24.8	28.9	28.1
5	A40	CITY OF COOPER (sum)		57.3	51.7	48.2	43.3	48.1	35.5	44.1	37.1	39.7	49.6	57.7	56.3
6	A40	CITY OF PECAN GAP	A 4205	3.7	3.1	3.7	3.5	3.7	3.1	2.8	2.7	2.7	3.3	3.1	4.0
7	D40	SULPHUR SPRINGS WATER DISTRICT	03 4811	333.1	296.6	331.0	302.9	309.3	285.5	280.8	278.0	271.2	284.7	293.2	327.5
8	D40	CITY OF SULPHUR SPRINGS	03 4812	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	D50	MOUNT VERNON (sum of both plants)	03 4816	29.4	22.3	28.1	24.5	23.5	20.6	22.2	21.3	17.8	20.3	23.0	26.7
10	E10	RED RIVER COUNTY WCID 1	03 4809	90.4	61.4	75.6	55.5	63.4	40.0	49.0	45.1	40.4	35.6	59.9	76.8
11	F60	CITY OF NEW BOSTON	03 4832	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	F20	CITY OF TEXARKANA	03 4836	17,888.7	17,081.3	17,217.5	14,107.3	13,525.1	10,447.1	9,884.7	12,217.1	10,584.8	11,571.5	14,667.2	17,573.4
MUNICIPAL WITHOUT WATER RIGHTS															
13	A60	BAILEY TOWN OF	-	1.3	0.9	1.2	1.2	1.2	2.3	0.5	0.7	0.8	1.0	1.2	1.4
14	A60	CITY OF COMMERCE	-	142.4	128.3	142.7	126.5	133.8	117.7	117.6	118.7	126.7	121.4	132.4	131.3
15	A50	CITY OF LADONIA	-	22.6	18.2	18.2	21.0	20.9	17.0	17.1	23.4	18.9	21.1	21.9	19.5
16	B10	PETTY WS&SW	-	0.5	0.4	0.6	0.3	0.7	0.4	0.2	0.2	0.1	0.4	0.3	0.6
17	B10	CITY OF ROXTON	-	5.0	3.4	4.0	3.4	4.0	2.5	2.3	1.9	2.6	2.7	3.8	4.5
18	C20	CITY OF DEPORT	-	10.0	5.2	6.8	5.7	5.5	6.5	5.9	3.4	4.8	5.1	7.7	9.4
19	E10	CITY OF BLOSSOM	-	5.1	4.4	6.0	6.0	6.0	4.0	10.5	6.5	11.6	6.6	5.3	5.6
20	E250	CITY OF BOGATA	-	24.1	19.9	24.7	22.2	22.2	17.0	19.9	16.7	16.0	15.5	18.8	21.7
21	E10	CITY OF DETROIT	-	9.7	6.8	7.7	6.5	7.2	5.2	5.6	4.9	5.4	5.0	7.3	8.4
22	E250	CITY OF TALCO	-	3.4	1.7	2.2	2.2	3.0	2.0	2.2	1.9	1.7	1.7	2.1	3.0
23	F10	LEROY'S MOBILE HOME	-	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
INDUSTRIAL WITHOUT WATER RIGHTS															
24	C90	BABCOCK&WILCOX - PARIS PLANT	-	29.2	28.2	38.5	31.4	36.2	28.8	25.8	17.6	20.6	35.4	32.7	32.5
25	C90	KIMBERLY CLARK - PARIS PLANT	-	34.5	31.2	61.3	104.4	108.6	21.4	42.4	54.1	143.1	78.0	18.8	46.5
26	D40	A P GREEN INDUSTRIES INC	-	0.4	0.4	0.6	0.5	0.6	0.6	0.8	0.8	0.7	0.6	0.4	0.3
27	F60	LONE STAR AMMUNITION	-	1.5	1.9	1.7	1.7	1.7	2.0	1.5	2.1	1.9	2.1	1.6	1.6
28	F130	BOWIE COUNTY REST AREA	-	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1
PURCHASES FROM TEXARKANA: MUNICIPAL															
29	E10	CITY OF ANNONA	-	2.1	1.7	1.1	2.2	1.2	0.7	1.1	1.1	0.9	0.7	2.3	0.9
30	F110	CITY OF DEKALB - SOUTH PLANT	-	42.3	30.9	27.9	27.1	21.1	16.5	19.4	30.8	16.6	18.2	28.2	31.8
31	F60	NEW BOSTON	-	134.4	94.3	103.0	88.9	72.9	57.2	54.5	69.7	64.9	77.2	101.3	118.4
32	F60	CITY OF MAUD	-	8.4	8.0	8.6	7.8	6.2	5.1	6.1	5.1	5.4	6.0	6.3	6.2
33	F60	CITY OF REDWATER	-	10.5	10.1	10.8	9.8	7.8	6.5	7.7	6.5	6.7	7.5	8.0	7.8
PURCHASES FROM TEXARKANA: INDUSTRIAL															
34	F20	ALUMAX MILL	-	13.7	12.2	14.0	35.9	13.1	13.3	14.6	66.0	16.6	16.4	13.5	14.7
35	F20	PAPER CHEMICALS, INC.	-	7.5	6.5	7.3	6.7	7.4	6.9	6.9	7.1	6.8	7.0	6.9	7.1
36	F10	INTERNATIONAL PAPER - TEXARKANA MILL	-	1,942.1	4,437.5	3,916.7	1,323.4	1,165.3	6,558.9	3,909.7	4,548.7	0.0	4,710.0	3,727.4	3,507.9
37	F60	INTERNATIONAL PAPER - SAWMILL	-	9.4	7.2	10.9	9.1	8.9	12.8	1.5	10.3	0.1	17.0	7.2	4.9

MONTHLY RETURN FLOWS IN ACRE-FEET

TABLE 4-10

SIGNIFICANT WATER RIGHTS WITH MULTIPLE DIVERSION/IMPOUNDMENT POINTS

WATER RIGHT IDENTIFICATION NUMBER	NAME	STREAM	TYPE OF USE	DIVERSION AMOUNT Ac-Ft/Yr	TOTAL RESERVOIR CAPACITY Ac-Ft	NUMBER OF DIVERSION POINTS	NUMBER OF IMPOUND-MENTS
03-4830	WILLIAM E JOHNSON JR ET AL	Unnamed trib. of Anderson Creek and Anderson Creek	3	378		5	0
03-4827	BROVENTURE COMPANY INC	Murphy Branch	7		1,455	0	2
A-5562	TEXAS UTILITIES MINING CO	Ripley Ck and Dorsey Ck and various unnamed tribs. of these creeks	2	125		9	0
03-4817	HANS WEISS ET UX	Bear Pen (trib. of White Oak) and White Oak Creeks	3	333		3	0
03-4805	E P LAND & CATTLE CO INC	Unnamed tribs. of Sulphur River	3	3,000	2,063	10	7
03-4803	HELMUT HERMANN ET AL	Unnamed trib. of Sulphur River	3	1,900	328	2	1
A-4148A,B	SARA M DUNHAM TRUST	Old Channel South Sulphur River, South Sulphur River, and Sulphur River	3	19,640	10,423	4	4
03-4795	CITY OF WOLFE CITY	East Fork of Turkey Creek and Turkey Creek	1	300	855	3	2

Type of use: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation

2. Water Right 03-4827 (Broventure Company, Inc.) – Each of the two impoundments has been modeled separately (Control Points E40 and E50).

3. Water Right A-5562 (Texas Utilities Mining Company) – The nine authorized diversion points have been grouped and modeled as three control points based on proximity of drainage areas as follows: Diversion Point 1 = Control Point E140; downstream of Diversion Points 2 through 6 = Control Point E150; and downstream of Diversion Points 7 through 9 = Control Point E170. The drainage areas at Control Points E150 and E170 were set equal to the sum of the drainage areas above their respective Diversion Points for purposes of computing naturalized flows.

4. Water Right 03-4817 (Hans Weiss, et ux) – The most downstream of the three authorized diversion points has been specified as the sole diversion point for all three of the diversion points (Control Point D40).

5. Water Right 03-4805 (EP Land and Cattle Co., Inc.) – The ten authorized diversion points and seven impoundments have been grouped and modeled as four control points based on proximity of drainage areas as follows: Reservoirs 1 through 3 = Control Point E270, Reservoir 4 = Control Point E260, Reservoirs 5 through 7 = Control Point E240, Diversion Points on the Rectified Channel and Old Channel Sulphur River = Control Point E250. The drainage areas at Control Points E270 and E240 were set equal to the sum of the drainage areas above their respective diversion/impoundment points for purposes of computing naturalized flows. Control Point E250 has been specified at the downstream-most diversion point on the Sulphur River. The authorized diversion from the impoundments has been set up as a system operation to allow releases from multiple reservoirs.

6. Water Right 03-4803 (Helmut Hermann, et al) – The diversion point on the Sulphur River and the diversion/impoundment point on Terry Lake have been modeled separately (Control Points C40 and C30).

7. Water Right A-4148, (Sara M. Dunham Trust) – The authorized diversion point and two impoundments have been modeled using one control point (C70) as an off-channel reservoir as described in Section 4.3.3.

8. Water Right A-4148A, (Sara M. Dunham Trust) – The authorized diversion point and impoundment have been modeled using one control point (C80) as an off-channel reservoir as described in Section 4.3.3.

9. Water Right A-4148B, (Sara M. Dunham Trust) – A point on the Sulphur River at the downstream end of the reach where diversions are authorized has been specified as the sole diversion point (Control Point C60) with an off-channel reservoir as described in Section 4.3.3.

10. Water Right 03-4795, (City of Wolfe City) – The two impoundments are hydraulically connected by a channel and function as a single impoundment. The three authorized diversion points on the impoundments and channel have been specified as a single control point on the channel. The sum of the drainage areas of the two impoundments has been used for purposes of computing naturalized flows.

4.2.3.6 Water Rights Requiring Special Consideration

A number of water rights have special conditions that affect water availability. These conditions relate to various items including amount and/or location of water storage, transbasin diversions, diversion limitations based on minimum instream flow requirements, and different diversion amounts for direct irrigation versus off-channel storage. Information regarding the special conditions included in these water rights is presented in Table 4-11. The specific procedures and assumptions used in handling these special conditions in the modeling are described below:

1. Water Right 03-4836 (City of Texarkana) – As a subset of the authorized municipal and industrial uses, the City is authorized to make transbasin diversions to the Cypress Creek and Red River basins. The priority dates established for the municipal and industrial uses account for 100% of the authorized diversions. However, a conflicting priority date is specified for the transbasin diversions, even though they are a part of the authorized uses for which the priority dates are already established. The priority dates for the authorized uses have been used in the modeling, and the conflicting dates for the transbasin diversions have been ignored. However, since it is anticipated that transbasin diversions would be made, the return flows associated with the amount of authorized transbasin diversions have been set to zero in the modeling.

2. Water Right A-5392 (Paul A. Piefer, et ux) – This permit is based on re-use of the City of Mount Vernon's upstream wastewater effluent discharge. It is also specified as a term permit that may be renewed if an extension is applied for. This is somewhat of a hybrid permit, unlike a true term permit that has a firm expiration date. It is likely that the permit will be renewed indefinitely as long as Mount Vernon continues to discharge. Therefore, this permit has been treated the same as all other water rights in the various model runs, with the exception of the runs where return flows were eliminated. For those runs, this permit was cancelled, since the Mount Vernon return flow also was eliminated.

3. Water Right 03-4805 (EP Land and Cattle Co., Inc.) – Diversions from the Sulphur River are permitted only when instream flows are greater than or equal to

TABLE 4-11

WATER RIGHTS WITH SPECIAL CONDITIONS

WATER RIGHT IDENTIFICATION NUMBER	NAME	STREAM	TYPE OF USE	DIVERSION AMOUNT Ac-Ft/Yr	RESERVOIR CAPACITY Ac-Ft	REMARKS	SPECIAL CONDITIONS
03-4836	CITY OF TEXARKANA	Sulphur River	1,2	180,000	386,900	Wright Patman Reservoir	- Maximum allowable elevation of lake varies by month. - 20,500 ac-ft transbasin diversions to Red and Cypress Basins.
A-5392	PAUL A PIEFER ET UX	Town Branch	3	341			- Term permit, expires 2002, re-use of Mt. Vernon effluent.
03-4805	E P LAND & CATTLE CO INC	Unnamed tribs. of Sulphur River	3	3,000	2,063	7 reservoirs	- Divert from rectified channel Sulphur River when flow in Old Channel Sulphur River $\geq$10cfs. - Can divert 3200 ac-ft from rectified channel to fields or into off-channel reservoirs, plus 500 ac-ft from reservoirs, but total diversions to fields cannot exceed 3000 ac-ft.
03-4803	HELMUT HERMANN ET AL	Unnamed trib. of Sulphur River	3	1,900	328	Terry Lake	- Divert up to 1648 ac-ft from Sulphur River to fields or into off-channel reservoir, but only when flow @Talco$\geq$20cfs. Balance of diversions from reservoir.
A-4148 A-4148A	SARA M DUNHAM TRUST	Old Channel South Sulphur River	3	8,328	7,498	1 reservoir on Old Channel South Sulphur River; 2 off-channel reservoirs	- Divert from Old Channel South Sulphur River when flow @Talco$\geq$20cfs. - Can divert from Old Channel South Sulphur River to fields or into off-channel reservoirs. - Divert into off-channel reservoirs Oct 15 - Jun 15. - Total diversions to fields from on-channel res and off-channel res #1 cannot exceed 2828 ac-ft. Can divert 600 ac-ft from inflows to off-channel res #1, plus up to 2828 ac-ft from on-channel res to fields or 3500 ac-ft into off-channel res #1. - Can divert 5500 ac-ft from Old Channel South Sulphur River to fields or into off-channel res #2.
A-4148B	SARA M DUNHAM TRUST	South Sulphur River and Sulphur River	3	11,312	2,925	Off-channel reservoir	- Divert from South Sulphur or Sulphur River when flow @ Talco$\geq$163 cfs Nov-Jun and $\geq$20 cfs Jul-Oct.
03-4799	CITY OF IRVING	South Sulphur River	1,2	54,000	114,265	Part of Jim Chapman Lake; 310,000 ac-ft total capacity	- Transbasin diversion to Trinity Basin.
03-4798	NORTH TEXAS MWD	South Sulphur River	1	54,000	114,265	Part of Jim Chapman Lake	- Transbasin diversion to Trinity Basin.
03-4797	SULPHUR RIVER MWD	South Sulphur River	1,2	38,520	81,470	Part of Jim Chapman Lake	- 19,320 ac-ft transbasin diversion to Trinity Basin.
N/A	JIM CHAPMAN LAKE	South Sulphur River	N/A	N/A	310,000	Department of Army 404 permit	- 5 CFS minimum release required at all times.

Type of use: 1= Municipal, 2 = Industrial, 3 = Irrigation

10 cfs. This condition has been imposed as a limitation in the model. A total of 3,200 acre-feet is permitted to be diverted from the Sulphur River into Reservoir No. 4, plus 500 acre-feet is permitted to be diverted from the inflows of all seven reservoirs combined, but a maximum of only 3,000 acre-feet may be consumed for irrigation purposes. Therefore, 500 acre-feet has been diverted for irrigation from all reservoirs except Reservoir No. 4 as a system operation, a diversion of up to 3,200 acre-feet has been specified from the Sulphur River into Reservoir No. 4, and the remaining 2,500 acre-feet has been diverted for irrigation from Reservoir No. 4.

4. Water Right 03-4803 (Helmut Hermann, et al) – Diversions from the Sulphur River are permitted only when instream flows are greater than or equal to 20 cfs. This condition has been imposed as a limitation in the model.

5. Water Rights A-4148 and A-4148A, (Sara M. Dunham Trust) – Diversions from the Old Channel South Sulphur River are permitted only when instream flows in the Sulphur River are greater than or equal to 20 cfs. Diversions into the off-channel reservoirs are only permitted during the period October 15 through June 15. These conditions have been imposed as limitations in the model. Diversions out of the off-channel reservoirs were given a distribution based on historical usage for this water right. In addition, under Water Right A-4148, a total of 3,500 acre-feet is permitted to be diverted from the Old Channel South Sulphur River into the 3,849 acre-foot off-channel reservoir, but a maximum of only 2,828 acre-feet may be consumed for irrigation purposes. This condition has been modeled using an off-channel reservoir as described in Section 4.3.3.

6. Water Right A-4148B, (Sara M. Dunham Trust) – Diversions from the South Sulphur River and Sulphur River are permitted only when instream flows in the Sulphur River are greater than or equal to 163 cfs during the period November through June and 20 cfs during the period July through October. These conditions have been imposed as limitations in the model.

7. Water Rights 03-4799, 4798, and 4797 (City of Irving, North Texas Municipal Water District, and Sulphur River Texas Municipal Water District) – Part or all of these water rights authorize transbasin diversions to the Trinity River Basin. These transbasin diversions have been assigned return flow factors of zero in the modeling.

8. The Department of the Army (Section 404) permit for Jim Chapman Lake requires a minimum release of 5 cfs at all times. The condition has been imposed as an instream flow limitation in the model immediately downstream of Jim Chapman Lake.

4.2.4 Data for Basin-Specific Features Added to *WRAP* Model

No basin-specific modifications have been made to the WRAP model as part of this water availability modeling study of the Sulphur River Basin; consequently, no special data are required for basin-specific features.

4.3 SIGNIFICANT ASSUMPTIONS AFFECTING WATER AVAILABILITY MODELING

4.3.1 Reuse

For the analyses of water availability for the Sulphur River Basin, existing reuse projects, to the extent such projects have been in operation for the past five years, have been included in the WRAP simulations. It has been assumed that the effects of these projects are embedded in the historical return flow data that have been compiled from TNRCC and TWDB records; hence, it also has been assumed that the effects of these projects are accounted for in the five-year average return flow values that have been used in the water availability analyses.

The only modifications that have been made to the current values of return flows to reflect different levels of reuse have been those required by the TNRCC for the specific purpose of evaluating different reuse effects on water availability, i. e., Runs 2, 3, 6, and 7 as described in Section 5.1.

4.3.2 Return Flows/Constant Inflows

As noted above in Section 4.2.3.4, for purposes of the water availability analyses, it has been assumed that return flows associated with municipal water rights would not be reduced or curtailed during drought periods, even if the source of the return flows, i. e., the associated water rights diversions, should become limited by senior water rights. The underlying assumption is that municipal water use will be continuous, even during drought periods when municipal water rights diversions may be significantly reduced because of limited streamflows or available reservoir storage.

This same assumption also has been made with regard to the return flows from municipal and industrial water users that obtain their water supplies from water rights holders within the Sulphur River Basin. This group includes primarily those entities that rely upon and purchase water from the City of Texarkana through its water rights in Wright Patman Lake. Return flows from municipal and industrial water users within the basin that do not have their own water rights, but instead rely on groundwater and/or out-of-basin import of water for their water supplies, also have been assumed to be continuous throughout dry periods. These return flows would not necessarily be reduced or curtailed when the available supplies for in-basin water rights holders become limited during drought periods.

4.3.3 Off-Channel Reservoirs

Off-channel reservoirs are permitted to store diversions from a stream, but typically do not have any drainage area of their own and are not permitted to store runoff. They differ from impoundments on tributaries, which can impound runoff and also may be permitted to store diversions from the main stream. Off-channel reservoirs are typically authorized in water rights with a diversion from an adjacent stream into the reservoir for make-up water and a separate diversion from the reservoir, or directly from the stream, for a specified use, usually irrigation. These reservoirs pose special problems with regard to their proper description in the WRAP model. In some cases, the authorized amount of the stream diversion into the off-channel reservoir is greater than the authorized diversion for the specified use to allow for evaporation from the reservoir. However, often the authorized amount of the stream diversion into the off-channel reservoir is the same as the authorized diversion from the reservoir for the specified use. In this situation, the amount of water available for diversion from the off-channel reservoir for the specified use usually is limited to less than its authorized amount because of the evaporation losses from the off-channel reservoir.

The version of WRAP used in this analysis includes a procedure that applies to most off-channel reservoirs. This procedure limits the total cumulative amount of streamflow that may be taken each year to meet the sum of consumptive diversions plus the water stored to refill reservoir storage at a specified control point. For the applicable water rights in the Sulphur River Basin, this annual limit has been set equal to the authorized diversions into off-channel reservoirs as specified in the water rights. WRAP also includes a monthly limit, which in the model input has been set equal to the maximum allowable diversion rate of the water right. This limits the rate at which an off-channel reservoir can be filled by streamflow diversions in a manner that is consistent with the terms of the water right.

Water for consumptive use has been diverted from the control points containing the off-channel reservoirs in the model. The diversion amounts have been set to the authorized consumptive diversions specified in the applicable water rights. In some cases, to allow for evaporation this amount is less than the annual storage limit described above. But in other cases, the water right does not specify a separate amount. In the latter cases, the amount of water available for diversion from the off-channel reservoir will typically be less than the authorized amount because of evaporative losses from the reservoir, and the water right will show a shortage for the year equal to the evaporative losses. Furthermore, in a typical year in which evaporation exceeds precipitation, the reservoir will be dry by the end of the year because there is no inflow to replace the water lost through evaporation.

Although the model may show a shortage for a water right with an off-channel reservoir, the actual water right holder would not likely perceive this as a shortage. The water right holder's diversions are those diversions pumped out of the stream and into the off-channel reservoir. Because of the WRAP model's method of replenishing storage in this type of reservoir, the model considers the diversions to be those that are pumped out of the off-channel reservoir for consumptive use.

The water rights in the Sulphur River Basin with off-channel reservoirs are listed in Table 4-12. A brief discussion of how each of these water rights has been described and simulated in the WRAP model is presented below:

1. Water Right 03-4833 (H. C. Prange, Jr.) – This is an industrial permit with a 7.9 acre-foot/year diversion and one small on-channel and 19 small off-channel reservoirs (total capacity 13.8 acre-feet) that are used for minnow production. All reservoirs have been combined into one off-channel reservoir with an annual storage limit equal to the authorized diversion amount. Diversions of the same amount are made at a constant rate from the reservoir.

2. Water Right 03-4834 (William E. Johnson Jr., et al) – This is an irrigation permit with a 39 acre-foot/year diversion and a relatively small (15 acre-foot) off-channel reservoir. Diversions can be made either to the reservoir or directly to the fields for irrigation. The reservoir has been modeled with an annual storage limit equal to the authorized diversion amount. Diversions of the same amount are made from the reservoir with a typical irrigation distribution.

3. Water Right A-5449 (Texas Parks and Wildlife Department) – This permit has a sizeable (504 acre-foot) on-channel reservoir and three off-channel shallow wetland cells for waterfowl habitat. It is assumed that the primary consumptive use of water is evaporation and that no significant diversions are made out of the off-channel reservoirs. Therefore, two separate control points have been established: one for the on-channel reservoir and one for the wetland cells combined into an off-channel reservoir. A system operation procedure has been set up to allow the off-channel reservoir to be filled by releases from the on-channel reservoir to replenish water lost through evaporation. It is not possible in WRAP to limit those releases in accordance with the diversion amount specified in the permit, but a review of the simulation output indicates that the evaporative

TABLE 4-12
WATER RIGHTS WITH OFF-CHANNEL RESERVOIRS

WATER RIGHT IDENTIFICATION NUMBER	NAME	STREAM	TYPE OF USE	DIVERSION AMOUNT Ac-Ft/Yr	OFF-CHANNEL RESERVOIR CAPACITY Ac-Ft	NUMBER OF IMPOUND-MENTS	IMPOUNDMENT INFORMATION
03-4833	H C PRANGE JR	Unnamed trib. of Rice Creek	2	7.9	12.8 (13.8 total)	20	1 reservoir on unnamed trib. of Rice Ck. (1 ac-ft); 19 off-channel reservoirs totalling 12.8 ac-ft
03-4834	WILLIAM E JOHNSON JR ET AL	Brooks Creek	3	39	15	1	Off-channel reservoir: 15 ac-ft
A-5449	TEXAS PARKS & WILDLIFE DEPT	Caney Creek	8	863	863 (1,367 total)	4	1 reservoir on Caney Ck. (504 ac-ft); 3 off-channel wetland cells (436 ac-ft, 195 ac-ft, 232 ac-ft: total area=381 ac)
03-4804	TEXAS UTILITIES ELECTRIC CO	Sulphur River	2	10,000	7,100	1	Rivercrest off-channel reservoir near Sulphur River: 7,100 ac-ft
A-4148B	SARA M DUNHAM TRUST	Sulphur River	3	11,312 (19,640 total)	2,925 (10,423 total)	1 (4 total)	Off-channel reservoir near South Sulphur River: 2,925 ac-ft
A-4148	SARA M DUNHAM TRUST	Old Channel South Sulphur River	3	2,828 (19,640 total)	3,849 (10,423 total)	1 (4 total)	1 reservoir on Old Channel South Sulphur River (26 ac-ft); off-channel reservoir: 3,849 ac-ft
A-4148A	SARA M DUNHAM TRUST	Old Channel South Sulphur River	3	5,500 (19,640 total)	3,623 (10,423 total)	1 (4 total)	Off-channel reservoir: 3,623 ac-ft

Type of use: 2 = Industrial, 3= Irrigation, 8 = Other losses, and hence the releases from the on-channel reservoir, never exceed the permit amount.

4. Water Right 03-4804 (Texas Utilities Electric Company) – This is the Rivercrest Steam Electric Station which has a 10,000 acre-foot diversion water right and a 7,100 acre-foot off-channel reservoir which is currently used as a cooling pond. Current use is considerably less than the authorized diversion. However, under future conditions, TU would likely have a second generating unit with diversions from the reservoir to a forced evaporation cooling tower. Therefore, this water right has been modeled using an off-channel reservoir with an annual storage limit equal to the authorized diversion amount. Diversions of the same amount are made from the reservoir with a distribution typical of power generation needs (peaks in the winter and summer).

5. Water Right A-4148 (Sara M. Dunham Trust) – This is an irrigation water right with a 3,849 acre-foot off-channel reservoir and a small (26 acre-foot) on-channel reservoir. As described in Section 4.2.3.6, a total of 3,500 acre-feet is permitted to be diverted from the Old Channel South Sulphur River into the 3,849 acre-foot off-channel reservoir from October 15 through June 15, but a maximum of only 2,828 acre-feet may be removed for irrigation purposes. This has been modeled with both reservoirs combined into one off-channel reservoir with an annual storage limit of 3,500 acre-feet to be stored during the permitted time period and with irrigation diversions from the reservoir at the authorized annual amount (2,828 acre-feet) with a distribution based on historical usage for this water right. The simulated total consumptive use from the off-channel reservoir (diversions plus evaporation) during the peak year was approximately 3,500 acre feet, in accordance with the permit. Finally, the permit allows the diversion of 600 acre-feet per year of the inflows from the drainage area of the off-channel reservoir. TNRCC has indicated that typically off-channel reservoirs do not impound runoff from state watercourses, and any inflows would be considered diffused surface runoff, which is not subject to state permitting. Consequently, this provision has not been included in the model.

6. Water Rights A-4148A and A-4148B, (Sara M. Dunham Trust) – These amendments authorize additional diversions and off-channel reservoirs subject to various special conditions as discussed in Section 4.2.3.6. The diversion amounts into the off-channel reservoirs are the same as the consumptive amount for irrigation purposes. They have been modeled as described above for water right 03-4834. Irrigation diversions from the reservoirs have been modeled with a distribution based on historical usage for these water rights.

4.3.4 Term Permits

Only one term permit exists within the Sulphur River Basin (Water Right A-5392, Paul A. Piefer, et ux). As discussed in Section 4.2.3.6, this is a hybrid permit that is dependent upon the return flows from the City of Mount Vernon, and it is subject to cancellation if the discharge of these return flows should ever cease. For all of the simulations made for purposes of the water availability analyses, except Runs 3, 6, and 7 (see Section 5.1), this term permit has been assumed to be active.

5.0 WATER AVAILABILITY IN THE SULPHUR RIVER BASIN

5.1 DESCRIPTIONS OF SCENARIOS MODELED

The TNRCC has defined eight specific scenarios that have been evaluated with respect to water availability in the Sulphur River Basin. These various scenarios, referred to as "Runs", are described in the following sections. The output from these runs is intended to address directly the requirements for water availability information specified in of Senate Bill 1 as described in Section 1.2 of this report. Basically, the eight different runs are characterized by different combinations of input conditions for: (1) the diversion amounts specified for water rights; (2) the area-capacity relationships specified for reservoirs; (3) the quantities specified for return flows corresponding to assumed levels of reuse; and (4) diversions and/or storage associated with term water rights permits. The various combinations of these parameters for each of the eight runs are indicated in the matrix in Table 5-1.

It should be noted that the simulated water availability results from the WRAP model for each of these runs are described and summarized only in general terms in this report. Results for specific water rights and specific locations are presented as examples to demonstrate the general condition of the Sulphur River Basin with regard to overall water availability and to illustrate the types of water rights output that has been generated with the WRAP model. More detailed results from the WRAP water availability analyses for individual water rights, including plots of water availability and reliability, are available from the TNRCC.

5.1.1 Reuse Runs

Three different simulations of water availability with the WRAP model have been made to address the effects of different levels of reuse of return flows. The first of these, Run 1, is considered the baseline simulation for water availability in the Sulphur River Basin for comparative purposes for simulations pursuant to Senate Bill 1. It includes fully authorized diversions by all water rights, authorized area-capacity relationships for all reservoirs as they were originally permitted, no term water right permits, and current levels of return flows, i. e., no reuse beyond what is reflected in historical return flows as reported for the last five years. The results from Run 1 provide the standard against which the results from all other runs have been compared.

Runs 2 and 3 incorporate exactly the same input conditions as Run 1, except that Run 2 assumes that 50 percent of the current return flows are reused and Run 3 assumes that all of the current return flows are reused (zero return flow condition). Hence, in general, the results from Run 1

TABLE 5-1
SPECIFICATIONS FOR WRAP INPUT PARAMETERS FOR DIFFERENT MODEL RUNS

PARAMETERS VARIED BY WRAP-SIM RUN	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8
AUTHORIZED DIVERSION AMOUNTS	X	X	X					
AUTHORIZED DIVERSION AMOUNTS WITH CANCELLATION				X		X		
MAXIMUM 10-YEAR DIVERSION AMOUNTS					X		X	X
AUTHORIZED RESERVOIR AREA-CAPACITY RELATIONSHIPS	X	X	X	X	X	X	X	
YEAR-2000 RESERVOIR AREA-CAPACITY RELATIONSHIPS								X
ASSUMED RETURN FLOWS WITH NO REUSE	X			X	X			X
ASSUMED RETURN FLOWS WITH 50% REUSE		X						
ASSUMED RETURN FLOWS WITH 100% REUSE (NO RETURN FLOWS)			X			X	X	
WITHOUT TERM WATER RIGHTS	X	X	X	X	X	X	X	
WITH TERM WATER RIGHTS								X

should reflect more water available than those from either Run 2 or Run 3, and the results from Run 2 should reflect more water available than those from Run 3. The different amounts of return flows that have been incorporated into the Run 1 and Run 2 simulations previously have been summarized in Tables 4-6 and 4-7. For Run 3, all return flow amounts have been set equal to zero.

5.1.2 Cancellation Runs

Various simulations have been made with the WRAP model to provide information regarding the potential water availability impacts of canceling water rights pursuant to the provisions of Subchapter E, Chapter 11 of the Texas Water Code. Under this section of the Water Code, the TNRCC has the authority to cancel a permit, certified filing or certificate of adjudication if the water authorized to be appropriated is not beneficially used during the last ten years. Hence, as described previously, those water rights in the Sulphur River Basin that have not been used in the last ten years according to TNRCC and TWDB records have been identified and assumed to be cancelled for purposes of these analyses. The water rights with no reported usage in the last ten years are identified in Table 4-4.

It should be noted that under the TNRCC-specified criteria for identifying water rights that should be cancelled for purposes of these analyses, the diversion rights for Jim Chapman Lake (Water Rights 4797, 4798 and 4799) have been cancelled due to non-use during the last ten years, but the reservoir storage has been left in place in the WRAP model since the reservoir has been constructed and does indeed exist. The only reason that water has not been diverted from this reservoir during the last ten years is because there has not been an immediate need and the pumping and transmission facilities have not been in place. Caution should be used in interpreting the results of model Runs 4, 5, and 6 (Cancellation Runs). Just because these runs show what appears to be additional water, that does not mean that TNRCC could, or would, actually cancel water rights that were simulated in these runs as cancelled.

Four different runs have been made for purposes of investigating water rights cancellation. For current reuse conditions, two runs have been made. One, Run 4, incorporates fully authorized diversions in the WRAP model, except for those water rights subject to cancellation (diversions for these have been set equal to zero). The return flow amounts used in this run are those listed in Table 4-8. The other, Run 5, has all diversions set equal to the maximum annual use reported during the last ten years, which, by definition, also includes zero diversions for those water rights subject to cancellation. The return flow amounts used in this run are those listed in Table 4-9. Runs 6 and 7 correspond to Runs 4 and 5 directly, except that 100-percent reuse of all return flows is assumed (zero return flow amounts). For all four of these runs, the authorized area-capacity relationships for all reservoirs have been used, and all term water rights permits have been excluded.

5.1.3 Current Conditions Runs

The final simulation that has been made with the WRAP model for purposes of evaluating water availability in the Sulphur River Basin corresponds to current conditions. This means that the annual diversion amounts for all water rights have been set equal to the maximum annual use reported during the last ten years, the area-capacity relationships for all reservoirs have been assumed to correspond to year-2000 sedimentation conditions, all return flows have been based on current conditions without any additional reuse, and all term water rights permits have been fully accounted for. The return flow amounts used in this run are those listed in Table 4-9. The year-2000 area-capacity curves for the four largest reservoirs (Wright Patman Lake, Jim Chapman Lake, Lake Sulphur Springs, and the City of Cooper's Big Creek Lake) as shown on the graphs in Figures 3-10 through 3-13 have been used for this run.

5.2 RESULTS FROM WATER AVAILABILITY MODEL RUNS

The simulated results from the WRAP model for the various input conditions corresponding to the eight runs provide an indication of water availability for each water right in the Sulphur River Basin. All of these simulations have encompassed actual monthly hydrologic conditions for the 1940 through 1996 period. The basic results from the different runs with regard to water availability consist of monthly values of simulated diversions and simulated end-of-month reservoir storage for each of the water rights in the basin. Also of importance are the simulated quantities of monthly unappropriated streamflows and monthly regulated streamflows at various locations throughout the Sulphur River Basin. The unappropriated streamflows, of course, provide an indication of the water available for future water resource development projects, while the regulated streamflows reflect the actual levels of flow that can be expected in the streams under the various scenarios of diversions, reservoir storage, return flows, and term permits.

To illustrate the variations in water availability among large and different types of water rights in the Sulphur River Basin for the different simulation runs, several individual water rights have been selected for graphically displaying the model results. For describing the simulated quantities of unappropriated water and regulated flows corresponding to the different runs, model results have been plotted for locations at the downstream end of each of the subwatersheds defined in this study and at the mouth of selected major tributaries.

A summary of the results from the eight runs with regard to the amount and reliability of simulated diversions is presented in Table 5-2. This table lists the water rights with authorized diversions in the Sulphur River Basin, and indicates their respective water right numbers and types of use, i. e., municipal, industrial, irrigation, or other. For each of the eight runs, the authorized annual diversion amount for each water right and type of use is listed, along with the simulated mean annual shortage amount, the percent of the total months analyzed (57 years x 12 = 684 months) for which the authorized diversion was satisfied, and the percent of the total authorized diversion amount over the entire 1940-1996 analysis period that was actually diverted. Although these results do not provide a complete picture of when and how much water is available for each water right, the two percentage quantities in the table do provide an indication of the reliability with which water can be diverted. At 100 percent, the fully authorized annual diversion of a particular water right is satisfied in every month. A zero value means water is never available.

Comparison of the various numbers presented in Table 5-2 for the different runs indicates that the effects of different levels of reuse, water rights cancellations, and varying reservoir area-capacity relationships do not appreciably influence the ability of the existing water rights (those not subject to cancellation) to obtain their authorized diversion amounts. This is not surprising, considering the abundant supply of surface water in the Sulphur River Basin relative to the total amount of existing authorized diversions. As illustrated by the naturalized streamflow statistics in Table 3-9, the mean annual flow at the downstream end of the basin at the state line is on the order 2.5 million acre-feet. The total of the authorized diversions for the basin, as shown in Table 2-1, is less than 400,000 acre-feet.

The reliability results summarized in Table 5-2 do identify several problems with regard to water availability for some individual water rights. In particular, the very low reliabilities indicated for diversions by Water Right 03-4832 (City of New Boston), Water Right 03-4824 (Walter W. Lee), and Water Right 03-5392 (Paul A. Piefer, et ux), suggest that the small drainage areas, small storage volumes, and/or lack of storage limit the water available at these locations.

5.2.1 Reuse Runs

5.2.1.1 Specific Large Water Rights

Bar charts showing the annual diversions simulated with the WRAP model for the period 1940 through 1996 for selected water rights in the Sulphur River Basin are presented in Figures A3-1 through A3-8 in Appendix 3 for each of the three reuse scenarios, i. e., Runs 1, 2, and 3. On each graph, three bars are plotted for each year of the analysis period indicating the simulated annual

TABLE 5-2
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 1 - BASELINE					
			Maximum Authorized Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	8	1	88.3	89.5	1	1971
CITY OF NEW BOSTON	03 4832	1	325	116	53.7	64.3	103	1956
CITY OF NEW BOSTON	03 4831	1	31	0	100.0	100.0	31	all
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	378	54	87.1	85.7	184	1984
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	39	5	76.0	88.5	19	1988
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	4	1	79.2	74.2	1	1988
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	23	3	91.5	88.0	5	1971
WALTER W. LEE	03 4824	3	8	6	27.6	21.3	0	1955
JOHN E. & BERNICE BALDWIN	03 4822	3	100	0	100.0	100.0	100	all
BILLY J. MAXTON	03 4820	3	22	8	81.4	63.7	0	1977
ANNA PEARL LEWIS	03 4821	2	1	0	98.4	98.4	1	all
TEXAS UTILITIES MINING CO.	A 5562_1	2	9	3	64.2	64.1	1	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	28	61.8	64.6	6	1956
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	13	60.4	64.1	3	1956
ROBERT W. CAMPBELL, ET AL	03 4818	3	11	1	94.6	91.2	2	1956
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	333	88	91.5	73.5	0	1977
PAUL A. PIEFER, ET UX	A 5392	3	341	196	76.8	42.6	0	1956
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.0	95.3	43	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	15	92.5	93.2	30	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.9	96.1	19	1978
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.3	98.3	44	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	408	3	99.1	99.2	254	1956
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	200	4	98.3	97.8	133	1996
RED RIVER COUNTY WCID 1	03 4809	1	1,120	182	80.0	83.8	278	1978
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	2,500	348	93.6	86.1	926	1972
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	500	0	100.0	100.0	500	all
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	190	96.4	98.1	8,939	1978
HELMUT HERMANN, ET AL	03 4803_1	3	650	55	95.8	91.6	315	1972
HELMUT HERMANN, ET AL	03 4803_2	3	350	87	92.5	75.2	0	1956
HELMUT HERMANN, ET AL	03 4803_3	3	900	226	92.4	75.0	0	1956
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	272	1978
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,468	88.0	87.0	5,115	1956
SARA M. DUNHAM TRUST	A 4148	3	2,828	0	100.0	100.0	2,828	all
SARA M. DUNHAM TRUST	A 4148A	3	5,500	1,044	80.7	81.0	412	1956
CITY OF PECAN GAP	A 4205	1	102	2	97.4	97.9	57	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	9	95.0	96.6	96	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	44,820	81	99.6	99.8	40,229	1956
CITY OF IRVING	03 4799	2	9,180	41	99.6	99.6	6,866	1956
NORTH TEXAS MWD	03 4798	1	54,000	189	99.4	99.7	44,400	1956
SULPHUR RIVER MWD	03 4797A	1	26,960	153	99.4	99.4	20,509	1956
SULPHUR RIVER MWD	03 4797A	2	11,560	68	99.4	99.4	8,646	1956
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	31	55.9	61.5	0	1954
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					90.8			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when the fully authorized diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrence is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 2 - 50% REUSE					
			Maximum Authorized Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	8	1	88.3	89.5	1	1971
CITY OF NEW BOSTON	03 4832	1	325	116	53.7	64.3	103	1956
CITY OF NEW BOSTON	03 4831	1	31	0	100.0	100.0	31	all
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	378	72	81.3	81.0	130	1988
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	39	5	76.0	88.5	19	1988
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	4	1	79.2	74.2	1	1988
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	23	3	91.5	87.9	5	1971
WALTER W. LEE	03 4824	3	8	6	27.6	21.3	0	1956
JOHN E. & BERNICE BALDWIN	03 4822	3	100	0	100.0	100.0	100	all
BILLY J. MAXTON	03 4820	3	22	8	80.7	62.3	0	1956
ANNA PEARL LEWIS	03 4821	2	1	0	98.4	98.4	1	all
TEXAS UTILITIES MINING CO.	A 5562_1	2	9	3	63.7	63.8	2	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	28	61.1	64.5	20	1972
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	13	59.7	63.9	9	1956
ROBERT W. CAMPBELL, ET AL	03 4818	3	11	1	94.4	91.1	1	1956
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	333	96	90.8	71.1	0	1956
PAUL A. PIEFER, ET UX	A 5392	3	341	209	76.0	38.8	0	1955
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.0	95.3	43	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	15	92.5	93.1	31	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	18	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.3	98.4	44	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	408	3	99.1	99.2	273	1956
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	200	5	98.1	97.6	133	1996
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	254	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	2,500	358	92.8	85.7	1,023	1977
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	500	0	100.0	100.0	500	all
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	186	96.2	98.1	8,939	1978
HELMUT HERMANN, ET AL	03 4803_1	3	650	56	95.6	91.5	315	1972
HELMUT HERMANN, ET AL	03 4803_2	3	350	86	92.3	75.4	0	1956
HELMUT HERMANN, ET AL	03 4803_3	3	900	230	92.0	74.4	0	1956
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	272	1978
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,531	87.7	86.5	5,115	1956
SARA M. DUNHAM TRUST	A 4148	3	2,828	0	100.0	100.0	2,828	all
SARA M. DUNHAM TRUST	A 4148A	3	5,500	1,044	80.7	81.0	412	1956
CITY OF PECAN GAP	A 4205	1	102	2	96.8	97.7	54	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	10	94.6	96.3	96	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	44,820	102	99.6	99.8	39,019	1956
CITY OF IRVING	03 4799	2	9,180	41	99.6	99.6	6,866	1956
NORTH TEXAS MWD	03 4798	1	54,000	238	99.3	99.6	41,826	1956
SULPHUR RIVER MWD	03 4797A	1	26,960	194	99.3	99.3	18,204	1956
SULPHUR RIVER MWD	03 4797A	2	11,560	85	99.3	99.3	7,696	1956
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	32	55.0	60.0	0	1952
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					90.5			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when the fully authorized diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurreice is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 3 - 100% REUSE					
			Maximum Authorized Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	8	1	88.3	89.5	1	1971
CITY OF NEW BOSTON	03 4832	1	325	116	53.7	64.3	103	1956
CITY OF NEW BOSTON	03 4831	1	31	0	100.0	100.0	31	all
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	378	98	79.5	74.1	69	1988
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	39	5	76.0	88.5	19	1988
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	4	1	79.2	74.2	1	1988
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1956
ARDELIA GAUNTT	03 4823	3	23	3	91.5	87.9	5	1971
WALTER W. LEE	03 4824	3	8	6	27.6	21.3	0	1955
JOHN E. & BERNICE BALDWIN	03 4822	3	100	0	100.0	100.0	100	all
BILLY J. MAXTON	03 4820	3	22	8	80.9	62.5	0	1956
ANNA PEARL LEWIS	03 4821	2	1	0	98.7	98.7	1	1978
TEXAS UTILITIES MINING CO.	A 5562_1	2	9	3	64.2	64.2	2	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	28	61.3	65.2	22	1978
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	13	59.9	64.5	9	1978
ROBERT W. CAMPBELL, ET AL	03 4818	3	11	1	94.4	91.1	1	1956
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	333	102	89.9	69.3	0	1956
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	188	9	93.9	95.0	29	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	15	92.5	93.0	20	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	18	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.0	98.1	36	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	408	4	98.5	99.0	212	1956
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	200	5	98.1	97.6	133	1996
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	258	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	2,500	407	92.5	83.7	996	1978
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	500	0	100.0	100.0	500	all
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	196	96.4	98.0	8,520	1956
HELMUT HERMANN, ET AL	03 4803_1	3	650	55	95.6	91.6	315	1972
HELMUT HERMANN, ET AL	03 4803_2	3	350	83	92.7	76.3	0	1956
HELMUT HERMANN, ET AL	03 4803_3	3	900	234	91.8	74.0	0	1956
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	263	1956
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,574	87.3	86.1	4,842	1996
SARA M. DUNHAM TRUST	A 4148	3	2,828	0	100.0	100.0	2,828	all
SARA M. DUNHAM TRUST	A 4148A	3	5,500	1,044	80.7	81.0	412	1956
CITY OF PECAN GAP	A 4205	1	102	3	96.8	97.5	49	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	11	94.3	96.0	85	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	44,820	108	99.6	99.8	38,667	1956
CITY OF IRVING	03 4799	2	9,180	46	99.4	99.5	6,537	1956
NORTH TEXAS MWD	03 4798	1	54,000	303	99.3	99.4	38,293	1956
SULPHUR RIVER MWD	03 4797A	1	26,960	194	99.3	99.3	18,204	1956
SULPHUR RIVER MWD	03 4797A	2	11,560	85	99.3	99.3	7,696	1956
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	33	54.4	59.2	0	1952
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					90.7			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when the fully authorized diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrence is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 4 - CANCELLATION					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	0	0	n/a	n/a	n/a	n/a
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	0	0	n/a	n/a	n/a	n/a
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	79	27	61.6	65.4	17	1956
TEXAS UTILITIES MINING CO.	A 5562_2	2	37	13	60.2	64.8	7	1956
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	341	183	76.8	46.2	0	1955
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.2	95.3	43	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	14	92.5	93.3	30	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	30	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.3	98.3	44	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	254	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	186	96.5	98.1	9,055	1978
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	272	1978
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,425	88.6	87.4	5,115	1956
SARA M. DUNHAM TRUST	A 4148	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148A	3	5,500	926	80.3	83.2	1,099	1956
CITY OF PECAN GAP	A 4205	1	102	2	97.2	98.0	58	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	9	95.0	96.6	96	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	11	82.3	86.4	0	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					93.0			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.6		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrence is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 5 - 10 YEAR MAX					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	93,165	0	100.0	100.0	93,165	all
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	40	0	100.0	100.0	40	all
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	1	0	100.0	100.0	1	all
CITY OF MOUNT VERNON	03 4816_2	1	0	0	n/a	n/a	n/a	n/a
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	5	0	100.0	100.0	5	all
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	27	0	100.0	100.0	27	all
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	4,809	0	100.0	100.0	4,809	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	0	0	n/a	n/a	n/a	n/a
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	396	0	100.0	100.0	396	all
MARY MARGARET VAUGHAN	03 4807	3	0	0	n/a	n/a	n/a	n/a
MARY MARGARET VAUGHAN	03 4806	3	4	0	100.0	100.0	4	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	103	0	100.0	100.0	103	all
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	320	6	97.8	98.1	275	1978
SARA M. DUNHAM TRUST	A 4148B	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148	3	2,744	0	100.0	100.0	2,744	all
SARA M. DUNHAM TRUST	A 4148A	3	2,744	56	97.7	98.0	1,120	1956
CITY OF PECAN GAP	A 4205	1	34	0	100.0	100.0	34	all
DELTA COUNTRY CLUB INC.	03 4801	3	0	0	n/a	n/a	n/a	n/a
CITY OF COOPER	03 4800	1	462	59	81.6	87.2	98	1956
CITY OF COOPER	A 4395	1	462	0	100.0	100.0	462	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	244	0	99.9	100.0	239	1957
CITY OF WOLFE CITY	03 4795_2	1	0	0	n/a	n/a	n/a	n/a
WEBB HILL COUNTRY CLUB	03 4796_1	3	22	0	98.5	98.9	12	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					98.6			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						99.9		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when then the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrence is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 6 - CANCELLATION, 100% REUSE					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	80	0	100.0	100.0	80	all
CITY OF TEXARKANA	03 4836	1	14,572	0	100.0	100.0	14,572	all
CITY OF TEXARKANA	03 4836	1	10,428	0	100.0	100.0	10,428	all
CITY OF TEXARKANA	03 4836	1	20,000	0	100.0	100.0	20,000	all
CITY OF TEXARKANA	03 4836	2	35,000	0	100.0	100.0	35,000	all
CITY OF TEXARKANA	03 4836	2	100,000	0	100.0	100.0	100,000	all
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	0	0	n/a	n/a	n/a	n/a
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	0	0	n/a	n/a	n/a	n/a
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	79	26	62.6	67.2	22	1978
TEXAS UTILITIES MINING CO.	A 5562_3	2	37	12	61.0	66.4	9	1940
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	188	9	94.0	95.1	29	1956
CITY OF MOUNT VERNON	03 4816_2	1	212	14	92.5	93.3	20	1956
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	30	1	95.8	95.7	18	1956
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	113	2	98.0	98.1	36	1956
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	2,000	0	100.0	100.0	2,000	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	7,800	0	100.0	100.0	7,800	all
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	1,120	183	80.0	83.7	258	1956
MARY MARGARET VAUGHAN	03 4807	3	22	0	100.0	100.0	22	all
MARY MARGARET VAUGHAN	03 4806	3	8	0	100.0	100.0	8	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	10,000	196	96.4	98.0	8,520	1976
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	278	0	99.6	99.9	263	1956
SARA M. DUNHAM TRUST	A 4148B	3	11,312	1,450	88.3	87.2	4,867	1996
SARA M. DUNHAM TRUST	A 4148	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148A	3	5,500	926	80.3	83.2	1,099	1956
CITY OF PECAN GAP	A 4205	1	102	2	97.2	97.9	54	1956
DELTA COUNTRY CLUB INC.	03 4801	3	5	0	100.0	100.0	5	all
CITY OF COOPER	03 4800	1	273	10	94.6	96.3	85	1956
CITY OF COOPER	A 4395	1	1,518	0	100.0	100.0	1,518	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	69	0	99.6	99.6	52	1956
CITY OF WOLFE CITY	03 4795_2	1	232	2	99.0	99.2	138	1956
WEBB HILL COUNTRY CLUB	03 4796_1	3	80	11	82.0	86.0	0	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					93.6			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						98.7		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurreice is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 7 - 10 YEAR MAX, 100% REUSE					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	93,165	0	100.0	100.0	93,165	all
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	20	0	99.7	99.5	14	1996
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	40	0	100.0	100.0	40	all
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	1	0	100.0	100.0	1	all
CITY OF MOUNT VERNON	03 4816_2	1	0	0	n/a	n/a	n/a	n/a
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	5	0	100.0	100.0	5	all
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	27	0	100.0	100.0	27	all
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	4,809	0	100.0	100.0	4,809	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	0	0	n/a	n/a	n/a	n/a
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	396	0	100.0	100.0	396	all
MARY MARGARET VAUGHAN	03 4807	3	0	0	n/a	n/a	n/a	n/a
MARY MARGARET VAUGHAN	03 4806	3	4	0	100.0	100.0	4	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	103	0	100.0	100.0	103	all
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	320	6	97.8	98.1	275	1978
SARA M. DUNHAM TRUST	A 4148B	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148	3	2,744	0	100.0	100.0	2,744	all
SARA M. DUNHAM TRUST	A 4148A	3	2,744	55	97.8	98.0	1,162	1956
CITY OF PECAN GAP	A 4205	1	34	0	100.0	100.0	34	all
DELTA COUNTRY CLUB INC.	03 4801	3	0	0	n/a	n/a	n/a	n/a
CITY OF COOPER	03 4800	1	462	60	81.6	87.1	98	1956
CITY OF COOPER	A 4395	1	462	0	100.0	100.0	462	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	244	0	99.9	100.0	239	1957
CITY OF WOLFE CITY	03 4795_2	1	0	0	n/a	n/a	n/a	n/a
WEBB HILL COUNTRY CLUB	03 4796_1	3	22	0	98.5	98.9	12	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED					98.6	99.9		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when then the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrece is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE 5-2, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

WATER RIGHT PERMITTEE	WATER RIGHT IDENTIFICATION NUMBER [5]	TYPE OF USE	RUN 8 - CURRENT CONDITIONS					
			Simulated Diversion	Mean Shortage [1]	Reliability		Minimum Annual Diversion [4]	
					Month [2]	Volume [3]		
			Ac-Ft/Yr	Ac-Ft/Yr	Percent	Percent	Ac-Ft/Yr	Year
LEON S. KENNEDY JR.	03 4837	3	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	93,165	0	100.0	100.0	93,165	all
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	1	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
CITY OF TEXARKANA	03 4836	2	0	0	n/a	n/a	n/a	n/a
H. C. PRANGE JR.	03 4833	2	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4832	1	0	0	n/a	n/a	n/a	n/a
CITY OF NEW BOSTON	03 4831	1	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4830	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4834	3	0	0	n/a	n/a	n/a	n/a
WILLIAM E. JOHNSON JR., ET AL	03 4829	3	0	0	n/a	n/a	n/a	n/a
ROBERT CROOKS, ET AL	03 4825	3	20	0	100.0	100.0	20	all
ARDELIA GAUNTT	03 4823	3	0	0	n/a	n/a	n/a	n/a
WALTER W. LEE	03 4824	3	0	0	n/a	n/a	n/a	n/a
JOHN E. & BERNICE BALDWIN	03 4822	3	40	0	100.0	100.0	40	all
BILLY J. MAXTON	03 4820	3	0	0	n/a	n/a	n/a	n/a
ANNA PEARL LEWIS	03 4821	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_1	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_2	2	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES MINING CO.	A 5562_3	2	0	0	n/a	n/a	n/a	n/a
ROBERT W. CAMPBELL, ET AL	03 4818	3	0	0	n/a	n/a	n/a	n/a
H. WEISS, ET UX (Thrasher L & C)	03 4817	3	0	0	n/a	n/a	n/a	n/a
PAUL A. PIEFER, ET UX	A 5392	3	0	0	n/a	n/a	n/a	n/a
CITY OF MOUNT VERNON	03 4816_1	1	1	0	100.0	100.0	1	all
CITY OF MOUNT VERNON	03 4816_2	1	0	0	n/a	n/a	n/a	n/a
JERRY N. JORDAN TRUSTEE, ET AL	03 4814	3	5	0	100.0	100.0	5	all
SULPHUR SPRINGS COUNTRY CLUB	03 4813	3	27	0	100.0	100.0	27	all
CITY OF SULPHUR SPRINGS	03 4812_2	1	0	0	n/a	n/a	n/a	n/a
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	4,809	0	100.0	100.0	4,809	all
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	0	0	n/a	n/a	n/a	n/a
PERRY R. BASS INC.	03 4810	3	0	0	n/a	n/a	n/a	n/a
RED RIVER COUNTY WCID 1	03 4809	1	396	0	100.0	100.0	396	all
MARY MARGARET VAUGHAN	03 4807	3	0	0	n/a	n/a	n/a	n/a
MARY MARGARET VAUGHAN	03 4806	3	4	0	100.0	100.0	4	all
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	0	0	n/a	n/a	n/a	n/a
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	0	0	n/a	n/a	n/a	n/a
TEXAS UTILITIES ELECTRIC CO.	03 4804	2	103	0	100.0	100.0	103	all
HELMUT HERMANN, ET AL	03 4803_1	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_2	3	0	0	n/a	n/a	n/a	n/a
HELMUT HERMANN, ET AL	03 4803_3	3	0	0	n/a	n/a	n/a	n/a
ALEXANDER FRICK, ET AL	03 4802	3	320	5	98.1	98.4	275	1978
SARA M. DUNHAM TRUST	A 4148B	3	0	0	n/a	n/a	n/a	n/a
SARA M. DUNHAM TRUST	A 4148	3	2,744	0	100.0	100.0	2,744	all
SARA M. DUNHAM TRUST	A 4148A	3	2,744	41	98.8	98.5	1,800	1957
CITY OF PECAN GAP	A 4205	1	34	0	100.0	100.0	34	all
DELTA COUNTRY CLUB INC.	03 4801	3	0	0	n/a	n/a	n/a	n/a
CITY OF COOPER	03 4800	1	462	59	81.4	87.2	180	1956
CITY OF COOPER	A 4395	1	462	0	100.0	100.0	462	all
CITY OF IRVING	03 4799	1	0	0	n/a	n/a	n/a	n/a
CITY OF IRVING	03 4799	2	0	0	n/a	n/a	n/a	n/a
NORTH TEXAS MWD	03 4798	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	1	0	0	n/a	n/a	n/a	n/a
SULPHUR RIVER MWD	03 4797A	2	0	0	n/a	n/a	n/a	n/a
CITY OF WOLFE CITY	03 4795_1	1	244	0	99.9	100.0	239	1957
CITY OF WOLFE CITY	03 4795_2	1	0	0	n/a	n/a	n/a	n/a
WEBB HILL COUNTRY CLUB	03 4796_1	3	22	0	98.8	99.4	18	1956
AVERAGE DIVERSION RELIABILITY BASED ON MONTHS SATISFIED					98.7			
TOTAL BASIN DIVERSION RELIABILITY BASED ON VOLUME SATISFIED						99.9		

1 - Mean Shortage represents the average of all annual shortage amounts for an individual water right as simulated for the 1940-1996 analysis period.
2 - Reliability/Months is the percent of the total number of months simulated (684) when thhen the simulated diversion amount of a particular water right could be satisfied.
3 - Reliability/Volume is the percent of the total volume of authorized diversion amount that could be satisfied over the entire 1940-1996 analysis period.
4 - When Minimum Annual Diversion is zero for multiple years, the first year of occurrerce is listed.
5 - Supplemental descriptive information regarding Water Right Identification Numbers is provided on the last page of this table.
TYPE OF USE: 1 = Municipal, 2 = Industrial, 3 = Irrigation, 7 = Recreation, 8 = Other

TABLE ES-3, CONT'D.
SUMMARY OF RELIABILITY OF WATER AVAILABILITY FOR DIVERSIONS

Supplemental Information Regarding Water Right Identification Numbers

WATER RIGHT PERMITTEE	WATER RIGHT NO.	TYPE OF USE	REASON FOR MULTIPLE ENTRY OF WATER RIGHT ID NUMBERS
CITY OF TEXARKANA	03 4836	1	Priority date = March 5, 1951
CITY OF TEXARKANA	03 4836	1	Priority date = February 17, 1957
CITY OF TEXARKANA	03 4836	1	Priority date = September 9, 1967
CITY OF TEXARKANA	03 4836	2	Priority date = February 17, 1957
CITY OF TEXARKANA	03 4836	2	Priority date = September 19, 1967
TEXAS UTILITIES MINING CO. / TU SVCS	03 5562_1	2	Multiple diversion points
TEXAS UTILITIES MINING CO. / TU SVCS	03 5562_2	2	Multiple diversion points
TEXAS UTILITIES MINING CO. / TU SVCS	03 5562_3	2	Multiple diversion points
CITY OF MOUNT VERNON	03 4816_1	1	Priority date = March 1, 1976
CITY OF MOUNT VERNON	03 4816_2	1	Priority date = November 22, 1982
CITY OF SULPHUR SPRINGS	03 4812_1	1	Priority date = February 1, 1975 (Storage Only)
CITY OF SULPHUR SPRINGS	03 4812_2	1	Priority date = February 12, 1985 (Diversion Only)
SULPHUR SPRINGS WATER DISTRICT	03 4811_1	1	Priority date = July 24, 1951
SULPHUR SPRINGS WATER DISTRICT	03 4811_2	1	Priority date = November 25, 1968
E. P. LAND & CATTLE CO., INC.	03 4805_1	3	Storage Only
E. P. LAND & CATTLE CO., INC.	03 4805_2	3	Storage Only
E. P. LAND & CATTLE CO., INC.	03 4805_3	3	Multiple diversion points
E. P. LAND & CATTLE CO., INC.	03 4805_4	3	Multiple diversion points
HELMUT HERMANN, ET AL	03 4803_1	3	Multiple diversion points, priority date = June 19,1978
HELMUT HERMANN, ET AL	03 4803_2	3	Multiple diversion points, priority date = June 19,1978
HELMUT HERMANN, ET AL	03 4803_3	3	Priority date = November 15, 1982
CITY OF WOLFE CITY	03 4795_1	1	Priority date = December 31, 1925
CITY OF WOLFE CITY	03 4795_2	1	Priority date = August 12, 1957
WEBB HILL COUNTRY CLUB	03 4796_1	3	Priority date = March 11, 1968
WEBB HILL COUNTRY CLUB	03 4796_2	3	Priority date = April 18, 1983, additional impoundment

diversion amounts from the three runs. This allows a direct comparison of the diversion results for the three levels of reuse considered in the analyses.

The simulated total annual diversions from Wright Patman Lake are shown on the graph in Figure A3-1. As indicated, no shortages in these diversions have been simulated for any of the reuse cases. Similar results are illustrated for Lake Sulphur Springs in Figure A3-3, the City of Cooper's Big Creek Lake in Figure A3-4, and Texas Utilities River Crest Plant in Figure A3-6. For Jim Chapman Lake on the South Sulphur River, Figure A3-2 indicates diversion shortages during the critical drought years of 1956 and 1957. In all other years, the fully authorized annual diversion amount for this reservoir is satisfied for all three reuse conditions. In 1956 when the diversion shortages occur for Jim Chapman Lake, the effect of increased reuse and the corresponding decreases in return flows is apparent with respect to the simulated total annual diversion amounts for the three different runs.

The simulated annual diversions for a small irrigation water user (William E. Johnson) without the benefit of reservoir storage are plotted on the graph in Figure A3-5. As expected, these direct diversions vary considerably in response to available streamflows. Again, the effect of increased reuse decreases the available water supply for this diverter, i. e., from Run 1 to Run 3. Similar results (highly variable simulated annual diversion amounts) also are illustrated for another irrigation water user (Hans Weiss) in Figure A3-7. This water right exhibits less sensitivity to the different levels of reuse, probability due to less availability of return flows from upstream.

The simulated annual diversions plotted in Figure A3-8 are for an irrigation water right with an off-channel reservoir (Sarah M. Dunham Trust, Water Right No. 4148B). This particular water right is authorized to divert up to 11,312 acre-feet of water per year from either the old channel or the rectified channel of the Sulphur River either to fill the off-channel reservoir (maximum storage capacity equals 2,925 acre-feet) or to irrigate agricultural fields (maximum authorized use equals 11,312 acre-feet/year). The simulated diversions for this water right that are plotted in Figure A3-8 represent the annual quantities of water diverted from the off-channel reservoir or from the streams at their confluence for irrigation. It does not include water depleted from streamflow and placed into storage in the off-channel reservoir. Although major shortages reflect years with deficient available streamflow, several minor shortages are attributable to evaporation losses in the off-channel reservoir or changes in reservoir storage between the beginning and end of the year, even though the entire authorized amount has been depleted from streamflow and placed into storage.

In several instances, simulated diversions available to a water right during selected years are greater for Run 3 (no return flows) than for Run 1 (full return flows). In other words, Run 1 experiences more shortages than Run 3. This is the opposite of what would be expected. This occurs only with those water rights with off-channel reservoirs and is attributable to a combination of the manner in which off-channel reservoirs are modeled and the occurrence of certain streamflow conditions. An example of this occurs with the Texas Utilities water right in 1965 as shown on Figure A3-6.

As described in Section 4.3.3, off-channel reservoirs are modeled in WRAP similar to other reservoirs in that available streamflow is depleted and placed into storage each month. However, with an off-channel reservoir, there is an annual limit on the amount of water that can be depleted for consumptive use and/or placed into storage, as specified in the permit. Once that limit has been reached, no additional streamflow can be depleted and/or placed into storage until January of the following year. In a dry year, the reservoir may be empty at the end of the year. If dry conditions continue into January of the following year or beyond, there may be insufficient streamflow to meet the consumptive demand (the water right experiences a shortage) and the reservoir remains unfilled during those months. Under Run 3, the absence of return flows would exacerbate this situation. Consequently, under Run 3 the annual limit on streamflow depletions for storage would not be reached until later in the year. Under Run 1, the presence of return flows would have resulted in fewer shortages for the water right, and the annual limit on streamflow depletions for storage would be reached earlier in the year. Since the storage limit is reached earlier under Run 1 as compared to Run 3, more of the water in storage is consumed or evaporated by the end of the year, resulting in less water in storage at the end of the year under Run 1. This sets the stage for the following year, where there is less storage available at the beginning of the year under Run 1 than Run 3. Consequently, if there are again dry conditions early in the year, Run 1 could experience more shortages than Run 3 because of the lack of water in storage.

The effects on reservoir storage of the varying levels of reuse specified in the WRAP model for Runs 1, 2, and 3 are illustrated in Figures A3-9 through A3-13 in Appendix 3. On these graphs, the simulated end-of-month storage is plotted for the entire 1940-1996 analysis period for Wright Patman Lake (Figure A3-9), Jim Chapman Lake (A3-10), Lake Sulphur Springs (Figure A3-11), the City of Cooper's Big Creek Lake (Figure A3-12), and the Sarah M. Dunham Trust off-channel reservoir authorized under Water Right 03-4148B (Figure A3-13). As illustrated, very little difference is evident in the reservoir storage conditions for the three reuse levels.

Among the four larger on-stream reservoirs, the simulated storage plots indicate that only Jim Chapman Lake appears to go dry during the 1940-1996 analysis period with its maximum annual diversion in the model set equal to its authorized annual diversion amount, i. e., 146,520 acre-feet. This is consistent with the diversion plot for this reservoir as discussed above (Figure A3-2) which shows shortages for Jim Chapman Lake during 1956 and 1957. The simulated storage in Lake

Sulphur Springs (Figure A3-11) also approaches zero during these critical drought years, indicating that the authorized annual diversion amount for this reservoir is approximately equal to its firm annual yield value.
One point worthy of note is that the critical drought for Wright Patman Lake appears to occur in the late 1970s, as opposed to the mid-1950s for the other large reservoirs. The minimum simulated storage level in this reservoir occurs in 1978. The differences in the occurrence of the critical droughts for the various reservoirs in the basin could be used to maximize the overall yield of the reservoirs through system operations.

The simulated monthly variations in the storage of the Sarah M. Dunham Trust off-channel reservoir that are illustrated by the graph in Figure A3-13 occur because of the significant magnitude of the associated authorized diversion amount (11,312 acre-feet/year) for this water right relative to the maximum authorized storage capacity of the reservoir (2,925 acre-feet). With this level of demand, the contents of the reservoir vary considerably and are totally depleted in many years.

5.2.1.2 Unappropriated Flows at Selected Locations

Annual quantities of the simulated unappropriated streamflows for the analysis period 1940-1996 for each of the three reuse conditions specified in Runs 1, 2, and 3 are plotted in Figures A3-14 through A3-19 at locations corresponding to the downstream end of each of the six subwatersheds of the Sulphur River Basin as defined in this study. The plots are presented from downstream to upstream in reverse alphabetical order; hence, Figure A3-14 shows the total amount of unappropriated water flowing across the state line in the Sulphur River at the downstream end of Subwatershed F. The effects of the different levels of return flows associated with the three reuse conditions are apparent, although these effects do not appear to be significant. Table 5-3 presents the annual unappropriated flows for Run 1 (permitted conditions with existing return flows) and Run 3 (permitted conditions with no return flows, i.e. 100% reuse) at the downstream end of each subwatershed.

Additional plots of the simulated amounts of unappropriated water for the different reuse conditions are presented in Figure A3-20 at the mouth of White Oak Creek, Figure A3-21 at the mouth of Cuthand Creek, and Figure A3-22 near the mouth of the North Sulphur River. As illustrated, none of these plots of unappropriated water illustrate any significant effects of the reduced return flows from the Run 1 to the Run 3 conditions.

TABLE 5-3
UNAPPROPRIATED FLOW AT SUBWATERSHED OUTLETS
(ACRE-FEET)

RUN 1

YEAR	SUBWATERHED					
	A	B	C	D	E	F
1940	44,771	115,950	400,189	257,592	1,480,656	1,980,335
1941	214,268	179,053	805,762	393,664	2,453,413	3,330,197
1942	155,153	195,622	693,911	370,156	1,824,139	2,222,804
1943	4,066	23,283	72,854	134,103	609,765	830,825
1944	62,766	122,445	546,032	347,474	1,937,978	2,590,339
1945	240,829	151,538	922,884	992,631	3,914,859	5,436,042
1946	309,362	173,677	1,057,451	1,119,233	3,453,798	4,305,802
1947	32,399	73,986	234,757	453,303	1,212,438	1,498,178
1948	105,298	63,267	413,063	403,006	1,395,723	1,786,435
1949	86,135	59,492	507,936	621,168	1,771,197	2,181,819
1950	265,743	277,603	1,057,257	523,665	2,752,503	3,574,505
1951	52,373	139,100	299,609	135,480	751,757	1,051,709
1952	18,315	106,357	263,025	342,894	1,460,581	1,958,198
1953	71,077	126,159	337,222	306,361	1,340,893	1,860,833
1954	14,394	117,570	280,058	196,622	873,419	1,126,586
1955	9,212	47,285	102,023	70,169	465,983	645,313
1956	2,174	39,059	73,078	38,041	253,203	399,467
1957	372,445	480,017	1,861,013	765,957	4,322,955	5,515,428
1958	292,073	217,769	907,489	560,092	2,427,076	3,049,817
1959	20,610	130,518	481,175	277,432	1,347,321	1,775,256
1960	23,086	190,494	624,318	300,059	1,651,655	2,204,731
1961	75,213	101,226	416,358	296,544	1,297,799	1,677,058
1962	39,369	177,733	492,714	252,090	1,194,949	1,551,959
1963	4,177	12,200	27,462	45,045	179,492	282,152
1964	14,326	89,287	198,093	114,865	542,155	666,437
1965	24,463	103,909	422,265	238,372	873,037	1,091,506
1966	163,615	215,433	763,548	452,657	2,019,700	2,521,803
1967	40,410	210,637	838,549	297,135	2,002,763	2,530,442
1968	295,331	352,872	1,567,460	414,939	2,334,242	2,592,910
1969	383,693	211,531	1,516,286	439,357	2,289,564	2,487,305
1970	91,484	207,590	691,456	332,050	1,446,886	1,683,786
1971	110,560	181,530	814,643	307,966	1,489,272	1,782,401
1972	4,707	24,137	164,988	141,999	447,653	596,742
1973	336,071	339,844	1,852,480	723,554	3,637,601	4,365,802
1974	428,987	209,656	1,150,125	582,425	2,541,310	3,216,202
1975	354,461	166,388	745,753	432,361	1,796,679	2,190,682
1976	21,015	119,613	468,930	282,403	968,965	1,164,042
1977	176,137	81,357	640,808	302,426	1,359,467	1,589,775
1978	5,701	18,359	67,999	82,156	318,399	454,219
1979	62,058	180,560	948,508	410,486	2,482,719	3,155,571
1980	14,534	39,350	304,477	387,319	873,332	1,009,189
1981	69,656	224,938	858,785	358,569	1,510,180	1,712,676
1982	239,225	243,769	1,369,530	315,753	2,292,952	2,690,830
1983	101,223	97,921	428,029	158,302	676,142	797,887
1984	24,234	137,347	498,913	313,290	1,236,816	1,558,132
1985	174,117	183,292	516,532	325,482	1,606,150	2,060,573
1986	104,710	174,039	490,715	303,116	1,266,315	1,555,717
1987	254,768	219,733	532,010	367,173	1,848,167	2,614,023
1988	47,072	76,787	220,906	260,254	905,264	1,235,297
1989	221,417	310,359	1,289,066	463,868	2,500,815	2,975,928
1990	335,562	310,648	1,251,237	739,672	3,180,264	3,960,199
1991	147,020	303,581	1,133,729	562,205	2,719,654	3,402,084
1992	364,830	240,563	1,022,906	720,987	2,628,964	3,339,077
1993	302,057	258,970	909,339	472,757	2,308,724	3,008,882
1994	253,945	265,765	785,475	352,843	1,818,749	2,380,057
1995	277,356	170,952	815,856	314,319	1,727,650	2,023,232
1996	18,057	104,973	366,685	250,331	1,063,761	1,493,541
MEAN	139,967	164,861	675,855	375,863	1,703,296	2,153,382

RUN 3

YEAR	SUBWATERSHED					
	A	B	C	D	E	F
1940	38,440	115,868	390,248	246,723	1,450,816	1,900,549
1941	208,019	178,490	798,234	378,563	2,427,008	3,254,780
1942	148,024	194,737	685,229	354,327	1,795,375	2,143,572
1943	3,203	23,032	71,880	123,084	591,535	757,487
1944	49,070	122,415	531,641	335,788	1,907,303	2,503,158
1945	231,990	151,504	912,328	977,216	3,886,072	5,357,870
1946	299,179	170,177	1,044,103	1,102,859	3,424,092	4,227,041
1947	27,374	73,561	226,749	438,632	1,187,456	1,419,798
1948	100,066	63,248	407,390	391,788	1,377,362	1,712,885
1949	75,786	57,071	496,564	606,214	1,741,051	2,098,804
1950	257,791	277,144	1,048,415	511,221	2,726,944	3,497,492
1951	48,328	138,261	286,155	124,059	723,689	968,952
1952	13,647	104,353	254,865	332,670	1,436,680	1,879,291
1953	59,099	119,732	320,478	288,571	1,309,123	1,778,576
1954	11,215	116,659	275,739	185,520	849,204	1,048,230
1955	5,545	46,125	96,551	60,897	449,723	572,002
1956	1,501	39,055	72,312	25,978	240,732	331,158
1957	364,294	479,978	1,851,461	752,580	4,297,753	5,429,088
1958	285,398	217,658	899,261	546,240	2,401,551	2,973,280
1959	14,006	130,483	473,583	263,555	1,319,764	1,696,139
1960	18,490	190,002	619,148	288,607	1,632,212	2,134,310
1961	54,105	101,010	394,609	280,477	1,255,793	1,585,234
1962	26,707	176,844	476,980	236,524	1,162,592	1,468,509
1963	2,470	11,429	24,794	36,163	166,535	209,331
1964	9,720	87,826	189,340	103,862	516,918	587,349
1965	19,435	101,796	416,153	225,124	849,674	1,014,620
1966	149,635	215,403	747,027	442,409	1,988,559	2,430,839
1967	29,969	210,608	825,359	283,302	1,972,590	2,446,613
1968	286,219	352,827	1,553,001	399,811	2,305,792	2,516,317
1969	379,713	211,503	1,511,653	429,969	2,269,637	2,416,346
1970	79,175	207,557	677,989	319,656	1,416,788	1,599,940
1971	100,950	176,746	800,570	296,185	1,461,818	1,701,221
1972	3,718	24,128	163,843	137,905	420,407	519,668
1973	324,482	339,800	1,839,800	710,680	3,609,821	4,284,656
1974	421,186	208,704	1,139,849	567,843	2,516,537	3,137,861
1975	350,040	165,397	740,714	418,375	1,771,255	2,116,203
1976	16,383	119,588	461,586	268,999	944,339	1,085,372
1977	167,854	81,339	633,242	279,077	1,326,279	1,508,658
1978	4,420	18,449	67,376	77,990	313,626	400,134
1979	51,486	180,106	936,381	395,404	2,452,018	3,051,257
1980	9,578	36,930	294,518	373,910	848,070	930,736
1981	57,607	222,617	844,101	345,372	1,477,067	1,627,793
1982	230,171	240,889	1,357,879	300,705	2,264,612	2,611,523
1983	94,722	93,730	417,348	140,595	648,861	718,516
1984	19,643	134,898	491,144	302,698	1,218,218	1,478,673
1985	161,966	181,659	503,539	313,765	1,579,583	1,977,612
1986	95,808	173,930	480,692	288,843	1,238,775	1,476,586
1987	247,260	205,768	509,872	356,235	1,818,287	2,536,404
1988	43,079	76,760	214,218	249,689	885,291	1,160,513
1989	212,477	310,322	1,279,147	450,022	2,473,816	2,899,637
1990	326,751	310,607	1,240,434	724,068	3,151,537	3,878,838
1991	135,983	300,830	1,119,456	548,199	2,690,461	3,320,953
1992	357,933	240,522	1,010,934	707,252	2,602,522	3,264,104
1993	292,712	258,573	894,552	459,833	2,280,094	2,931,623
1994	245,482	265,720	775,913	339,066	1,790,489	2,303,600
1995	271,728	170,519	809,361	301,418	1,704,365	1,947,679
1996	12,993	101,907	353,815	241,560	1,039,167	1,417,067
MEAN	132,527	163,628	665,956	362,949	1,677,327	2,074,499

5.2.1.3 Regulated Flows at Selected Locations

Annual quantities of the simulated regulated streamflows for the analysis period 1940-1996 for each of the three reuse conditions specified in Runs 1, 2, and 3 are plotted in Figures A3-23 through A3-31 for the same locations used for presenting the unappropriated streamflows. The effects of the different levels of return flows associated with the three reuse conditions on the regulated streamflows are essentially the same as those indicated for the unappropriated flows.

5.2.2 Cancellation Runs

5.2.2.1 Specific Large Water Rights

Bar charts showing the annual diversions simulated with the WRAP model for the period 1940 through 1996 for selected water rights in the Sulphur River Basin are presented in Figures A4-1 through A4-16 in Appendix 4 for each of the four cancellation scenarios, i. e., Runs 4, 5, 6, and 7. For purposes of comparison, the corresponding annual diversion amounts simulated for the baseline water availability condition (Run 1) also are plotted on the graphs. For each of the water rights considered, two bar graphs are presented: one showing the simulated diversions from Runs 4 and 5 with 100-percent of the assumed current return flows (no reuse) along with the Run 1 baseline simulated diversions, and the other showing simulated diversions from Runs 6 and 7 with zero return flows (full reuse) along with the Run 1 baseline simulated diversions.

Figures A4-1 and A4-2 present the simulated diversion results for Wright Patman Lake. As shown, the effects of canceling upstream water rights does not increase the available water from this reservoir since it already can fully satisfy its authorized diversion amount under the baseline case with fully-authorized water rights in effect. The 10-year maximum use simulation, of course, reflects the actual diversions from the reservoir during the last ten years. Results similar to these also are illustrated for other large reservoirs, i. e., Lake Sulphur Springs in Figures A4-5 and A4-6, the City of Cooper's Big Creek Lake in Figures A4-7 and A4-8, and the Texas Utilities River Crest Plant in Figures A4-11 and A4-12.

Results for Jim Chapman Lake are presented in Figures A4-3 and A4-4. As described in Section 5.1.2, the diversions from this reservoir for purposes of the cancellation runs have been assumed to be cancelled because of non-use during the last ten years. Hence, no diversions are indicated in the plots for Runs 4 and 6. Of course, these diversions also are zero for Runs 5 and 7 since there have been no diversions under these water rights during the last ten years. Similar situations exist for the small irrigation diverters as shown by the graphs in Figures A4-9 and A4-10 for Water

Right 4830 (William E. Johnson) and Figures A4-13 and A4-14 for Water Right 4817 (Hans Weiss).

The simulated annual diversions plotted in Figures A4-15 and A4-16 are for the Sarah M. Dunham Trust irrigation water right with an off-channel reservoir (Water Right No. 4148B). This particular water right has a priority date of April 11, 1997; consequently, even though no water use has been reported during the last ten years, this water right has not been cancelled for purposes of these analyses (see Section 4.2.3.2). Hence, simulated diversions for the cancellation Runs 4 and 6 are shown on the bar charts, but zero diversions are shown for the maximum ten-year use Runs 5 and 7. In only a few isolated years (1963, 1971, 1972), the effects of other water rights cancellations results in a significant increase in available diversions for this particular water right.

The plots in Figures A4-17 through A4-26 illustrate the effects of water rights cancellation on storage in the large reservoirs. Again, these plots present simulated monthly storage variations for selected reservoirs over the period 1940 through 1996 for the baseline water availability case (Run 1) and the different cancellation conditions (Runs 4, 5, 6, and 7). In general, the major deviations in the simulated reservoir storage levels from the baseline case (Run 1) result from the maximum 10-year use simulations (Runs 5 and 7). The diversion amounts specified in the model for these simulations are considerably less than the fully authorized diversions; consequently, more water generally is stored in the reservoirs.

The effects of canceling the water rights diversions for Jim Chapman Lake are apparent on the plots shown in Figures A4-19 and A4-20. Without the diversions, there is considerably more water stored in the impoundment throughout the duration of the analysis period.

5.2.2.2 Unappropriated Flows at Selected Locations

Annual quantities of the simulated unappropriated streamflows for the analysis period 1940-1996 for each of the four cancellation scenarios, i. e., Runs 4, 5, 6, and 7, are plotted in Figures A4-27 through A4-44. The Run 1 baseline unappropriated streamflows also are shown on these plots. As expected, the general trend illustrated by these plots is that there is slightly more unappropriated water available throughout the basin with cancellation in effect, and there is even more water available for the 10-year maximum use case since the actual historical diversions have been substantially less than the fully-appropriated diversion amounts.

5.2.2.3 Regulated Flows at Selected Locations

Annual quantities of the simulated regulated streamflows for the analysis period 1940-1996 for the baseline case (Run 1), the two cancellation conditions (Runs 4 and 6), and the two 10-year maximum use scenarios are plotted in Figures A4-45 through A4-62 for the same locations used for presenting the unappropriated streamflows. The effects of the different cancellation and maximum water use scenarios on the regulated streamflows are essentially the same as those indicated for the unappropriated flows. The regulated streamflows, of course, are somewhat greater than the unappropriated flows because they do not reflect all of the streamflow depletions associated with all water rights.

5.2.3 Current Conditions Runs

5.2.3.1 Specific Large Water Rights

Bar charts showing the annual diversions simulated with the WRAP model for the period 1940 through 1996 for selected water rights in the Sulphur River Basin are presented in Figures A5-1 through A5-8 in Appendix 5 for the current conditions scenario (Run 8), and for the baseline water availability condition (Run 1). The current conditions run includes the year-2000 area-capacity relationships for all of the major reservoirs. Both runs account for current return flows, but adjusted to reflect either fully authorized diversions (Run 1) or the 10-year maximum use diversions (Run 8).

Figure A5-1 presents the simulated diversion results for Wright Patman Lake. The lower storage levels corresponding to the 10-year maximum use simulation (Run 8), of course, reflect the actual diversions from the reservoir during the last ten years, which are considerably less than the fully-authorized diversions used for Run 1. Results similar to these also are illustrated for other large reservoirs, i. e., Lake Sulphur Springs in Figure A5-3, the City of Cooper's Big Creek Lake in Figure A5-4, and the Texas Utilities River Crest Plant in Figure A5-6.

Results for Jim Chapman Lake are presented in Figure A5-2. As described previously in Section 5.1.2, the diversions from this reservoir are zero for the current conditions Run 8 since there have been no diversions under the Jim Chapman Lake water rights during the last ten years. Similar situations exist for the small irrigation diverters as shown by the graphs in Figure A5-5 for Water Right 4830 (William E. Johnson) and Figure A5-7 for Water Right 4817 (Hans Weiss).

The simulated annual diversions plotted in Figure A5-8 are for the Sarah M. Dunham Trust irrigation water right with an off-channel reservoir (Water Right No. 4148B). Again, since this particular water right has a priority date of April 11, 1997, no water use has been reported during the last ten years; consequently, zero diversions have been specified in the model for Run 8 and are shown for the maximum ten-year use case on the plot.

The differences in the area-capacity curves corresponding to the authorized storage conditions and year-2000 storage conditions are reflected on the reservoir storage plots in Figures A5-9 through A5-13. These plots present simulated monthly storage variations for selected reservoirs over the period 1940 through 1996 for the baseline water availability case (Run 1) and the current conditions case (Run 8). One obvious difference between these two sets of results relates to the maximum available storage capacities that have been used for each of the reservoirs for the two conditions. Because of sedimentation, the year-2000 maximum reservoir storage capacities generally are somewhat less than the authorized storage amounts. In general, the major deviations in the Run 8 simulated reservoir storage levels from the baseline case (Run 1) occur because the diversion amounts specified in the model for these current conditions simulations are considerably less than the fully-authorized diversions; consequently, more water is stored in the reservoirs.

5.2.3.2 Unappropriated Flows at Selected Locations

Under current conditions, almost all water rights are not using their fully authorized amounts. Therefore, although there are currently unused flows, all of this water is technically not "unappropriated", since some of it is subject to lawful claim by existing water rights holders. However, although all of the flows may not be available on a perpetual basis, they could possibly be available on a temporary basis. Annual quantities of the simulated unappropriated streamflows for the analysis period 1940-1996 for the baseline (Run 1) and the current conditions (Run 8) scenarios are plotted in Figures A5-14 through A5-22. As expected, the general trend illustrated by these plots is that there is slightly more water available throughout the basin under current conditions. This occurs primarily because the actual 10-year maximum use diversions are substantially less than the fully appropriated diversion amounts.

5.2.3.3 Regulated Flows at Selected Locations

Annual quantities of the simulated regulated streamflows for the analysis period 1940-1996 for the baseline case (Run 1) and the current conditions scenario (Run 8) are plotted in Figures A5-23 through A5-31 for the same locations used for presenting the unappropriated streamflows. The differences between the two sets of simulated regulated streamflows are similar to those indicated for the unappropriated flows, and again, these deviations are the result primarily of the lower diversions associated with the 10-year maximum water use condition. The regulated streamflows, of course, are somewhat greater than the unappropriated flows because they do not reflect all of the streamflow depletions associated with all water rights.

5.2.4 Flow-Duration Curves

When a time series of hydrologic events, in this case annual streamflows at a location, are arranged in order of their magnitude, the percent of time that each annual streamflow value is equaled or exceeded can be computed. A plot of the annual streamflows versus the corresponding percentages of time is known as a flow-duration curve. Flow-duration curves have been computed for Control Points C10, which is below the confluence of the North and South Sulphur Rivers, and F10, which is the Sulphur River outlet at the Texas-Arkansas state line. These are presented in Figures 5-1 and 5-2, respectively. Curves are shown for naturalized flows and for regulated flows as simulated with the WRAP model for Run 1 (fully authorized diversions with full return flows), Run 3 (fully authorized diversions with no return flows, i.e. 100% reuse), and Run 8 (maximum use for the last 10 years and existing return flows, i.e. current conditions).

Comparison of these curves can be used to assess the cumulative impact of appropriations on regulated streamflows. As can be seen from the curves, Run 3 results in the greatest reduction in streamflows from the naturalized conditions. This is to be expected because fully authorized diversions are modeled and return flows are eliminated.

5.3 COMPARISON TO EXISTING RIVER BASIN MODEL

No other river basin or water rights model for the Sulphur River Basin is known to exist within the public domain. Consequently, no comparisons can be made using the results generated with the WRAP model.

5.4 FACTORS AFFECTING WATER AVAILABILITY AND MODELING RESULTS

As described in Section 2.5, the single issue of most concern with regard to the water availability analyses performed for the Sulphur River Basin and the results from the WRAP model relates to the accuracy of the naturalized streamflows that have been used in the calculations. The problems associated with estimating historical streamflows for the lower reaches of the basin for the period 1961 through 1996 based on the calculated inflows to Wright Patman Lake as deduced through water balance analyses, rather than using actual streamflow measurements, have been documented. Because of these data uncertainties, the resulting naturalized streamflows used in the water availability analyses may not truly represent actual streamflow conditions. However, at this

FIGURE 5-1
ANNUAL FLOW-DURATION CURVES AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

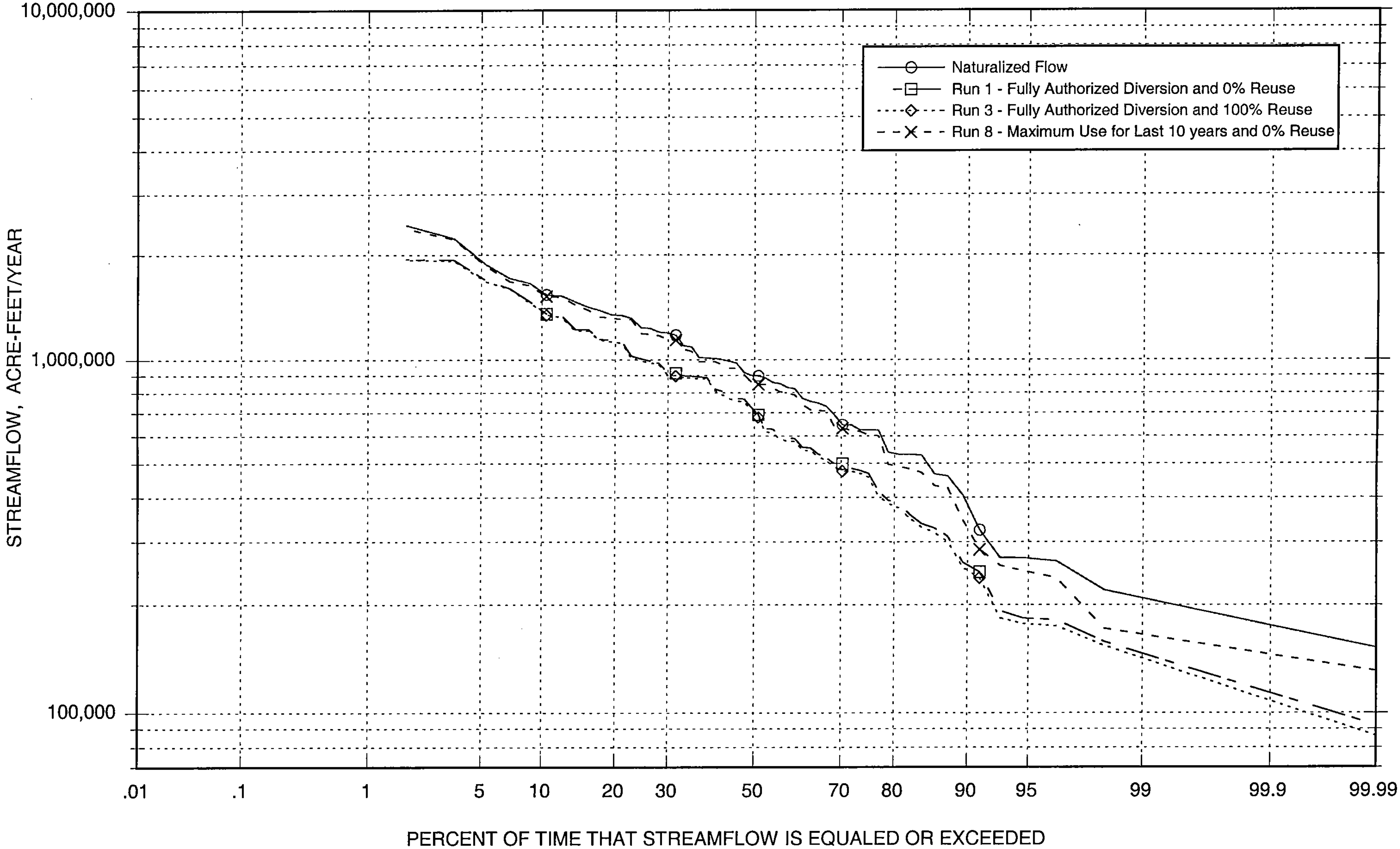
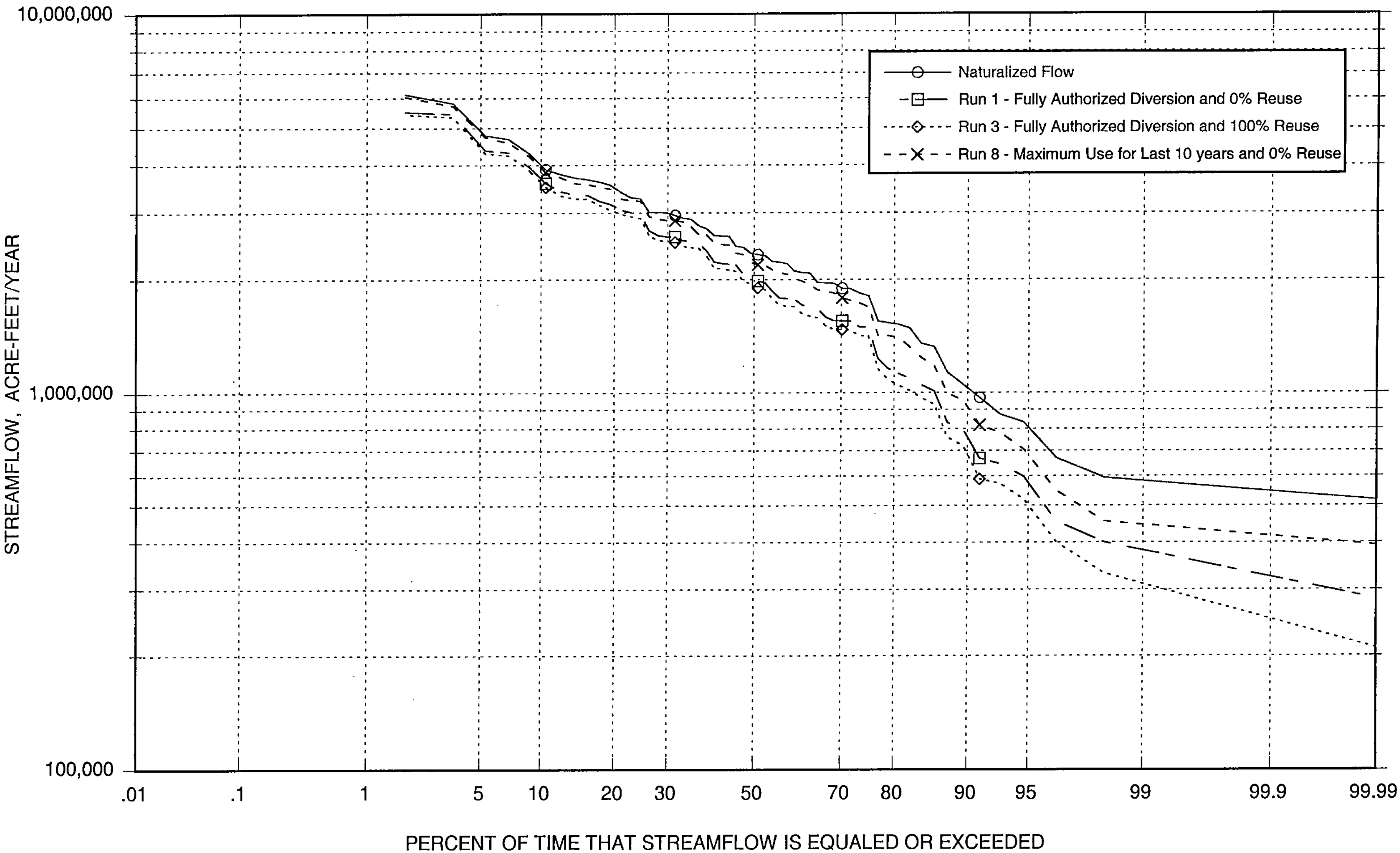


FIGURE 5-2
ANNUAL FLOW-DURATION CURVES AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F



time, it appears that there are no better means available for developing the naturalized streamflows required for input to the model.

Another factor that may have influenced the water availability and modeling results relates to the possibility that the drainage areas and SCS curve numbers assigned to individual control points for modeling purposes may not accurately reflect actual watershed conditions for the smaller water rights on small tributaries. The accuracy of the drainage areas derived using GIS procedures appears to be limited by resolution of the available digital elevation data such that some of the drainage areas that have been used for distributing the naturalized streamflows from gaged to ungaged locations may be causing the available streamflows for some water rights to be underestimated. For the Sulphur River Basin, the only digital elevation data that have been available to date are based on 90-meter-square cells. Consequently, some of the resulting GIS-based drainage areas that have been used for distributing the naturalized streamflows from gaged to ungaged locations may have caused the available streamflows for some water rights to be underestimated. Apparently, more refined digital elevation data (30-meter-square cells) will be forthcoming from the U. S. Geological Survey in 1999, and these data should provide for a better definition of drainage areas in the WRAP model. For several suspect locations, the drainage areas have been delineated on USGS 7.5-minute quadrangles, and the areas have been determined by planimetry. With regard to the SCS curve numbers assigned to the watersheds of individual control points in the model, there appear to be significant differences between the curve number values for some small, proximate watersheds. These differences can result in significantly different flows as derived with the model using the NRCS-CN distribution method (see Section 3.2).

Also, the procedures that have been used in the WRAP model for describing off-channel reservoirs with stream diversions for make-up water and with separate reservoir diversions for associated uses (such as irrigation) do not effectively represent actual operations in all cases. It is possible that the procedures used may not allow the maximum use of available water by these water rights. The model fills such reservoirs beginning in January of each year and keeps the reservoirs full until the annual limit of streamflow depletions is reached. This keeps the reservoir full for as long as possible and may tend to increase evaporation losses. Actual practice could be somewhat different. This primarily affects the reported reliability of the water right since that is calculated based on diversions out of the off-channel reservoir, rather than diversions out of the stream and into the off-channel reservoir. However, actual diversions out of the stream are still maximized in accordance with the water right's priority.

Water rights with multiple diversion points generally have been represented in the model either by using the most downstream diversion point for all diversions or by grouping some of the diversions at a single point and assigning a portion of the annual authorized diversion amount for a given water right to this group of diversions. The allocation of different fractions of the annual authorized diversion amount to individual diversion points can only be estimated considering such factors as drainage area size and historical water use patterns. Because of these uncertainties, there may be some unnecessary limitations on water availability as simulated with the WRAP model for those water rights with multiple diversion points.

One last point to note relates to the manner in which the WRAP model, through its strict application of the prior appropriation doctrine, handles the authorized monthly-varying conservation storage specifications for Wright Patman Lake that are contained in its Certificate of Adjudication. Basically, the existing water right for Wright Patman Lake authorizes different amounts of conservation storage depending on the month of the year. The schedule of authorized maximum conservation storage amounts for Wright Patman Lake previously have been listed in Table 4-5. A potential problem exists when the authorized conservation storage capacity for Wright Patman Lake increases from one month to the next, such that a sudden demand for water occurs in order to fill the newly created conservation storage. For example, between March and April and between April and May, the conservation storage capacity of the reservoir increases instantaneously by 60,000 acre-feet. In a perfect world under strict interpretation of the prior appropriation doctrine, Wright Patman Lake would be entitled to the additional 60,000 acre-feet of water required to fill its conservation pool in each of these months before any upstream junior water rights could store or divert the water, and this is exactly how the WRAP model simulates the Wright Patman Lake water right. The effects of these sudden demands for stored water in Wright Patman Lake are apparent in the simulated operations of Jim Chapman Lake, which is junior to Wright Patman Lake and located upstream on the South Sulphur River. During periods of low streamflow, inflows to Jim Chapman Lake are passed in order to satisfy the senior downstream demand for stored water in Wright Patman Lake. The effect of passing of these inflows is to cause additional shortages in the demands for water from Jim Chapman Lake (as authorized by water rights held by North Texas Municipal Water District, City of Irving, and Sulphur River Municipal Water District) to be shorted during 1956 and 1957, i. e., the critical drought period for the reservoir. The occurrence of these shortages is evident in the annual diversion plot presented in Figure ES-3. This situation probably is somewhat artificial and not likely to happen under current reservoir operating procedures and water rights administration policies. Nonetheless, it is reflected in the results from the WRAP model. The TNRCC staff has confirmed that the prior appropriation doctrine, for purposes of the Senate Bill 1 water availability analyses, requires that all conservation storage capacity in reservoirs with senior water rights must first be completely filled before any upstream junior water rights can store or divert water. This situation may warrant further clarification and interpretation from TNRCC in order to provide more realistic projections of water availability.

6.0 SUMMARY AND CONCLUSIONS

The revised Texas A&M WRAP model, now known as WRAP-SIM, has been applied to the Sulphur River Basin in Texas to determine water availability. All 54 water rights in the basin have been modeled for a 57-year period of naturalized streamflows under eight different scenarios (referred to as "Runs"). The runs consist of three basic sets of conditions: (1) fully authorized diversion amounts and varied return flow amounts (Reuse Runs), (2) varied diversion amounts and varied return flow assumptions (Cancellation Runs), and (3) approximate current diversion and return flow conditions with year-2000 area-capacity relationships for reservoirs (Current Conditions Run). Special conditions reflecting environmental flow requirements have been included in all model runs where applicable. Only four water rights in the basin have permitted special conditions associated with environmental flow needs.

The primary conclusions from this water availability investigation and modeling effort for the Sulphur River Basin are as follows:

1) The Sulphur River Basin is a prolific water resource. It is in one of the highest rainfall and lowest evaporation areas of the state. There are approximately 400,000 acre-feet per year of authorized (State-permitted) diversions in the basin, yet naturalized flows at the Texas-Arkansas state line have averaged approximately 2.5 million acre-feet per year during the period 1940 through 1996. During the driest years of record (1963 and 1956), the flows still have been in the range of 500,000 to 600,000 acre-feet.

2) Based on simulated results from the WRAP water availability model of the basin assuming fully authorized diversions by all water rights, the major diverters rarely, if ever, experience shortages. The one exception is at Jim Chapman Lake where shortages are indicated in 1956 and 1957.

3) Comparison of the WRAP results from the different runs indicates that the effects of varying levels of reuse, water rights cancellations, and reservoir sedimentation conditions (area-capacity relationships) do not appreciably influence the ability of the existing water rights (those not subject to cancellation) to obtain their authorized diversion amounts. Similarly, there is little impact on the storage conditions for the major reservoirs in the basin, with the exception of Jim Chapman Lake, where the diversion rights were simulated as cancelled for the

cancellation and current conditions runs, resulting in significantly increased storage.

4) Based on the simulation results from the WRAP model for all of the different runs, the average percentage of time that the water rights in the basin are able to divert their entire authorized amounts varies between about 85 and 90 percent, depending on which run is considered. With regard to the total diversion volume for all water rights, on the order of 98 to 99 percent of the total authorized diversion amount for the entire Sulphur River Basin can be diverted over the entire 1940-1996 analysis period.

5) Selected water rights exhibit very low reliabilities in obtaining their authorized diversion amounts. This is likely attributable to small drainage areas and the lack of sufficient storage.

6) Representation of off-channel reservoirs in the WRAP model generally results in small shortages for water rights where there is no difference between the amount of water that can be diverted into the off-channel reservoir and the amount that can be consumed for the stated use. This is because the model limits the annual amount of water that can be placed into storage for such a reservoir. This results in the amount available to be diverted out of the reservoir for consumption being reduced by evaporative losses.

7) Simulated results from the WRAP model indicate that there is a significant quantity of unappropriated water in the basin. The impacts on unappropriated water of the effects of varying levels of reuse, water rights cancellations, and reservoir sedimentation conditions (area-capacity relationships) as analyzed with the various runs are indicated to be relatively small. The greatest impact occurs for the current conditions run and those cancellation runs where the 10-year maximum use has been specified, since the actual historical diversions during the last ten years were substantially less than the fully appropriated diversion amounts. Future appropriations are subject to environmental flow restrictions pursuant to Chapter 11 of the Texas Water Code.

8) The single issue of most concern with regard to the water availability analyses performed for the Sulphur River Basin and the results from the WRAP model relates to the accuracy of the naturalized streamflows that have been used in the calculations. In particular, there is uncertainty in the estimation of historical

streamflows for the lower reaches of the basin for the period 1961 through 1996 because of the absence of gaged flows into or below Wright Patman Lake. However, at this time there are neither more reliable data nor any other better means available for developing the required naturalized streamflows.

7.0 REFERENCES

1) Allgeier, Martin & Associates of Texas, 1966, "Preliminary Engineering Report on Water Supply Requirements for the City of Cooper, Texas".

2) Black and Veatch, 1988, "Cooper Reservoir Water Supply Study".

3) Borland and Miller, 1958, "Distribution of Sediment in Large Reservoirs", J. Hydraulics Division ASCE.

4) Camp Dresser & McKee, Inc., 1979, "Sulphur River Basin, Broseco Dam No. 1 : Morris County, Texas, Inventory Number TX 4007: Phase 1 Inspection Report, National Dam Safety Program".

5) Camp Dresser & McKee, Inc., 1979, "Sulphur River Basin, Broseco Dam No. 2 : Morris County, Texas, Inventory Number TX 4006: Phase 1 Inspection Report, National Dam Safety Program".

6) City of Sulphur Springs, 1988, "Cooper Reservoir Water Supply Study".

7) Forrest and Cotton, Inc., 1966, "Report on Water Resource Investigation, Sulphur River Basin and Red River and Tributaries in Texas Below Denison Dam".

8) Fowler & Grafe, Inc., 1968, "Preliminary Engineering Report : White Oak Bayou Dam and Reservoir, City of Sulphur Springs, Hopkins County, Texas".

9) Freese Nichols & Endress, 1962, "Report on Additional Water Supply for the Cities of Texarkana, Texas and Arkansas from Texarkana Reservoir".

10) Hydrosphere Data Products, Inc., 1998, "Hydrodata for Windows".

11) R. J. Brandes Company, 1998, "Naturalized Streamflows for Water Availability Analyses of the Sulphur River Basin", prepared for Texas Natural Resource Conservation Commission.

12) Texas Department of Water Resources, 1978 rev. 1981, "Plan Summary Report for the Sulphur River Basin Water Quality Management Plan".

13) Texas Department of Water Resources, 1978, "Sulphur River Basin, Lake Coleman Dam: Hopkins County, Texas, Inventory Number TX 00661 : Phase 1 Inspection Report, National Dam Safety Program".

14) Texas Department of Water Resources, 1982, "Erosion and Sedimentation by Water in Texas", Report 268.

15) Texas Natural Resource Conservation Commission, 1996, "The State of Texas Water Quality Inventory".

16) Texas Natural Resource Conservation Commission, October 13, 1997, "Evaluation of Naturalized Streamflow Methodologies", Technical Paper No.1 – Water Availability Modeling Project.

17) Texas Natural Resource Conservation Commission, December 10, 1998, "Evaluation of Existing Water Availability Models", Revised Technical Paper No. 2 – Water Availability Modeling Project.

18) Texas Natural Resource Conservation Commission, July 3, 1998, "Digital Elevation Modeling for the WAM and other TNRCC OWRM Projects", Technical Paper No.3 – Water Availability Modeling Project.

19) Texas Natural Resource Conservation Commission, June 12, 1998, Regulatory and Compliance System, Wastewater Permit Monthly Effluent Report.

20) Texas Natural Resource Conservation Commission, August 7, 1998, Water Rights Masterfile.

21) Texas Natural Resource Conservation Commission, August 1998 – February 1999, Minutes of Basin Modeling – Technical Coordination Meetings #1 – #7.

22) Texas Natural Resource Conservation Commission, 1998, "Methodology for Establishing Surface Water Quality Priorities for Texas River Basins".

23) Texas Natural Resource Conservation Commission Memo, "Policy Guidance for the Water Availability Model Project", July 31, 1998.

24) Texas Natural Resource Conservation Commission WAM Internal Decisionmaking Team Meeting 1 Summary, October 19, 1998.

25) Texas Natural Resource Conservation Commission Workgroup of Water Use Interests, January 22, 1999, "Resolved Technical Issues".

26) Texas State Library, July 9, 1998, Texas City Population Estimates, 1990-96, http://www.tsl.state.tx.us/lobby/ref/popcity2.htm.

27) Texas Water Commission, 1983, "Preliminary Determination of all Claims of Water Rights in the Sulphur River Basin".

28) Texas Water Development Board, 1966, "A Summary of the Preliminary Plan for Proposed Water Resources Development in the Sulphur River Basin".

29) Texas Water Development Board, 1967, "Monthly Reservoir Evaporation Rates for Texas 1940 through 1965", Report 64.

30) Texas Water Development Board, 1967, "Water Requirements in Texas and Proposed Projects in Lower Red River Basin, Sulphur River Basin, and Cypress Creek".

31) Texas Water Development Board, 1971, "Hydrologic Data Refinement, Sulphur River Basin".

32) Texas Water Development Board, 1974, "Report 126, Engineering Data on Dams and Reservoirs in Texas".

33) Texas Water Development Board, 1996, Unpublished record regarding development of revised evaporation data for Texas.

34) Texas Water Development Board, 1997, "Volumetric Survey of Wright Patman Lake".

35) Texas Water Development Board, 1997, "Water for Texas" (Texas Water Plan).

36) U. S. Army Corps of Engineers, 1952, "Definite Project Report, Texarkana Dam and Reservoir".

37) U. S. Army Corps of Engineers, 1969, "Flood Plain Information, White Oak Creek, Rock Creek, and Town Branch, Sulphur Springs, Texas".

38) U. S. Army Corps of Engineers, New Orleans District, 1967, "Cooper Reservoir and Channels, General Design Memorandum No. 2-B, Revised Cooper Dam and Reservoir".

39) U. S. Army Corps of Engineers, New Orleans District, 1973, "Water Storage and Conveyance Systems, Sulphur River and Cypress Creek Basins, Texas. Texas Water Plan Study".

40) U. S. Army Corps of Engineers, undated, "Cooper Reservoir and Channels, Hydrology and Hydraulic Analysis, Design Memorandum No. 1"

41) U. S. Army Corps of Engineers, Waterways Experimental Station, 1980, "Spillway for Cooper Dam, Sulphur River, Texas".

42) U. S. Environmental Protection Agency, 1977, "Report on Wright Patman (Texarkana) Reservoir, Bowie and Cass Counties, Texas".

43) U. S. Geological Survey, 1998 and previous years, "Water Resources Data, Texas, Water Year [various]".

44) U. S. Public Health Service, 1963, "Water Resources Study, Cooper Reservoir, South Sulphur River, Texas".

45) U. S. Study Commission-Texas, 1960, "Effect on Surface Runoff of Land Treatment, Ponds and Minor Reservoirs, and Floodwater Retarding Structures".

46) Various authors, 1968-1970, Comprehensive Water and Sewer Plans for: Delta, Fannin, Hopkins, and Hunt Counties.

47) Wurbs, Ralph A. and D. Dunn, 1996, "Water Rights Analysis Package (WRAP) Model Description and Users Manual", Texas Water Resources Institute, Texas A&M University.

48) Wurbs, Ralph A., September 30, 1998, "Draft Users Manual for Program Records", Texas Water Resources Institute, Texas A&M University.

49) Wurbs, Ralph A., February 1999, "Documentation of New Features in the February 1999 Version of the Water Rights Analysis Package (WRAP)", Texas Water Resources Institute, Texas A&M University.

APPENDIX 1

PERIOD-OF-RECORD MONTHLY NATURALIZED STREAMFLOWS AT GAGE LOCATIONS

APPENDIX 1 PERIOD OF RECORD NATURALIZED STREAMFLOWS (ACRE-FEET)
USGS GAGE NO. 734500 - SOUTH SULPHUR RIVER NEAR COOPER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	-	-	-	-	-	-	-	-	-	-	-	-	-
1941	-	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	39,004	2,150	2,957	10,748	430	8,166	27,396	90,851
1943	173	2,344	46,310	6,530	20,869	39,251	176	0	0	69	1,233	4,771	121,725
1944	12,478	38,458	55,915	14,052	118,503	17,096	1,122	3,245	569	0	5,374	38,479	305,289
1945	16,546	84,798	126,755	36,106	14,370	59,486	29,659	99	8,578	46,419	3,182	24	426,022
1946	36,394	79,591	31,619	24,006	110,323	41,046	490	14,243	233	183	124,377	27,658	490,163
1947	8,587	393	17,482	22,125	30,314	5,632	2	6,557	331	227	18,346	56,154	166,149
1948	39,349	35,760	41,720	17,233	70,981	3,010	3,911	52	0	19	0	2,150	214,184
1949	102,558	69,636	43,659	16,511	16,664	10,898	5,059	1,435	973	54,241	248	3,252	325,134
1950	58,877	160,465	7,533	7,942	91,105	19,303	8,967	1,400	77,697	134	5	23	433,452
1951	836	45,357	622	288	4,361	122,161	10,076	0	0	760	1,199	294	185,954
1952	3,933	1,869	5,124	105,706	33,714	5,941	0	0	0	0	15,544	22,328	194,158
1953	11,883	1,134	28,199	104,260	55,564	6	11,898	533	4	118	8,545	29,456	251,601
1954	43,353	6,665	110	12,005	44,063	3,899	0	0	0	50,745	12,087	552	173,479
1955	1,300	22,925	23,157	18,001	8,833	49	2,494	3,280	831	1,540	0	0	82,409
1956	0	21,622	10	390	23,789	1,449	0	0	0	0	2,504	2,030	51,794
1957	6,719	15,815	50,928	259,718	207,674	69,708	395	4,250	30,544	30,169	148,671	11,001	835,592
1958	34,431	828	54,281	94,839	141,913	29,493	15,985	61	3,267	565	831	715	377,208
1959	1,078	12,722	8,025	6,719	2,229	9,075	20,983	1,554	1,394	21,160	18,296	67,584	170,819
1960	49,620	16,475	10,809	2,218	15,937	22,873	11,680	1,621	7,917	20,083	749	112,806	272,787
1961	53,228	18,293	40,051	9,718	1,059	14,254	3,700	1,396	4,660	44	14,998	34,122	195,523
1962	13,584	10,461	5,625	25,701	7,260	35,874	19,976	3,392	68,832	10,042	41,060	4,734	246,540
1963	12,904	203	5,995	8,113	12,236	1,153	16,646	22	0	0	0	0	57,271
1964	0	73	9,383	23,028	18,012	24,323	0	0	22,279	420	35,912	1,188	134,618
1965	24,547	117,799	1,378	564	119,658	3,609	19	0	6,086	18	685	0	274,364
1966	700	27,548	860	201,997	97,921	44	481	2,365	6,490	1,851	52	664	340,974
1967	168	67	1,984	55,701	48,037	77,874	1,181	74	23,443	36,837	20,817	44,646	310,831
1968	35,017	16,451	102,163	54,819	81,486	40,900	27,268	4,255	21,152	2,921	25,796	40,088	452,317
1969	62,469	101,604	70,229	23,620	180,559	2,504	0	0	0	5,667	2,440	29,118	478,211
1970	10,306	58,973	87,912	60,530	6,263	3,499	0	0	8,986	45,313	4,414	1,575	287,769
1971	1,093	8,379	3,870	34	49	72	265	10,370	1,842	128,074	797	195,267	350,113
1972	4,923	673	5,743	222	737	795	0	0	165	13,982	39,393	17,385	84,017
1973	32,048	34,232	88,360	107,696	13,725	36,055	703	204	75,665	78,215	98,529	37,106	602,539
1974	76,516	3,928	9,252	86,054	14,499	112,847	51	502	74,074	9,477	143,372	67,950	598,522
1975	16,559	140,249	62,274	45,444	80,255	86,869	1,734	179	0	0	0	153	433,717
1976	0	37	5,642	57,365	36,275	13,523	39,511	425	4,432	23,764	3,532	50,562	235,069
1977	28,495	60,311	138,015	51,104	1,887	16,782	259	3,401	834	0	5,101	820	307,010
1978	4,889	36,391	33,799	2,166	5,120	7,137	0	0	0	0	3,468	2,656	95,627
1979	64,369	31,535	57,276	35,090	132,708	46,117	2,337	5,164	424	107	344	19,583	395,054
1980	33,966	21,742	202	8,968	27,617	907	0	0	4,775	5,904	134	20,794	125,009
1981	69	43	16,617	1,302	32,522	172,596	1,582	36	0	100,763	44,352	798	370,680
1982	1,170	14,460	8,590	10,264	233,227	42,359	7,447	316	489	0	12,756	64,899	395,976
1983	1,808	86,319	54,053	4,032	16,103	3,152	22,847	50	0	410	801	318	189,893
1984	306	20,183	99,899	14,479	6,075	222	0	0	0	38,437	13,929	77,745	271,275
1985	12,245	21,873	84,269	48,423	71,766	9,225	292	0	0	3,842	65,700	47,731	365,365
1986	91	46,789	265	51,412	17,802	53,970	4,917	0	3,947	6,971	60,878	19,174	266,216
1987	26,094	27,367	89,786	694	11,180	12,581	264	0	11,303	9,708	156,814	118,574	464,365
1988	25,673	21,868	17,582	23,318	6	96	39,096	0	2,248	5,124	43,235	15,735	193,980
1989	41,713	74,280	31,321	4,670	67,077	94,048	51,478	1,799	996	80	219	43	367,724
1990	12,074	65,099	136,238	86,334	138,642	35,281	0	1,483	509	3,114	15,317	15,374	509,467
1991	60,513	27,249	13,301	58,193	44,823	23,156	151	0	0	5,092	59,641	71,375	363,494
1992	48,139	44,369	93,531	9,752	121,797	81,762	63,140	19,666	1,530	2,876	2,384	50,324	539,271
1993	23,546	93,040	50,761	76,542	18,993	2,261	3,816	4,459	3,035	102,773	34,818	96,586	510,629
1994	17,035	34,798	46,030	13,463	85,353	5,339	56,214	5,782	7,504	22,300	88,360	62,333	444,510
1995	60,128	4,695	57,291	56,182	144,048	35,060	3,102	2,620	3,653	0	2,026	0	368,805
1996	4,213	2,208	3,915	6,898	2,263	6,019	5,777	5,958	2,472	12,609	152,089	22,097	226,518
MEAN	22,939	35,008	38,624	38,380	53,856	29,121	9,078	2,095	9,180	16,429	28,428	29,785	309,492

APPENDIX 1 PERIOD OF RECORD NATURALIZED STREAMFLOWS (ACRE-FEET)
USGS GAGE NO. 7343000 - NORTH SULPHUR RIVER NEAR COOPER

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	-	-	-	-	-	-	-	-	-	-	-	-	-
1941	-	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	-	-	-	-	-	-
1943	-	-	-	-	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	6,739	76	3,488	10,303
1950	72,069	82,363	1,435	2,619	64,671	3,827	20,153	2,207	34,158	340	98	160	284,100
1951	286	31,319	817	2,430	7,311	102,593	2,032	34	356	3,361	586	69	151,194
1952	243	239	9,280	71,228	11,863	3,631	29	0	0	0	10,309	4,275	111,096
1953	3,316	574	16,369	66,837	22,590	39	9,962	1,441	530	520	4,463	12,442	139,084
1954	18,866	9,951	270	7,668	52,375	4,174	0	0	8	34,664	3,144	549	131,669
1955	1,459	6,520	21,405	16,935	5,145	683	7,237	1,797	712	1,801	0	0	63,693
1956	321	39,137	621	2,610	16,059	459	0	0	0	22	2,160	371	61,762
1957	1,040	2,546	20,230	144,216	146,404	50,812	486	3,849	19,197	5,459	83,644	8,042	485,924
1958	20,638	1,511	34,182	56,571	70,015	33,534	2,020	75	442	51	321	338	219,698
1959	243	1,759	2,503	214	355	26,526	35,492	4,102	3,931	10,766	4,660	40,816	131,367
1960	26,650	14,622	13,925	2,211	7,197	17,755	5,787	5,547	11,184	23,873	615	89,140	218,506
1961	18,090	10,462	38,241	4,833	3,502	1,609	1,187	210	2,681	26	7,638	17,969	106,449
1962	13,991	5,843	10,018	13,277	2,786	33,493	2,964	259	29,531	14,642	48,799	2,362	177,966
1963	6,235	521	4,688	8,688	1,430	278	2,403	18	0	0	0	21	24,283
1964	5	164	10,721	19,803	14,327	15,807	21	18	18,658	90	18,773	1,922	100,307
1965	9,866	56,300	3,336	854	34,509	1,337	9	41	4,685	1	177	39	111,154
1966	81	7,267	534	179,508	22,736	539	65	4,998	4,619	1,568	71	715	222,701
1967	228	489	4,593	55,368	68,781	12,513	3,027	90	19,696	17,807	2,772	31,021	216,384
1968	17,160	12,968	75,180	37,380	54,417	50,906	23,680	2,092	29,684	6,207	19,714	23,694	353,080
1969	44,021	21,134	35,970	8,612	79,769	2,855	107	37	51	6,258	367	22,120	221,301
1970	3,031	58,994	53,845	41,585	5,149	453	27	34	11,748	25,298	8,205	2,674	211,045
1971	2,220	6,910	3,322	722	2,329	74	2,594	9,821	2,237	109,731	4,185	67,282	211,426
1972	3,467	992	1,073	181	157	324	58	337	45	17,079	18,056	6,126	47,896
1973	16,072	19,920	50,645	46,040	9,652	16,941	613	197	34,793	75,867	52,915	17,328	340,983
1974	19,929	2,725	1,502	16,677	10,490	49,617	116	385	23,597	30,581	47,746	15,553	218,917
1975	16,956	61,129	17,312	14,019	34,357	32,306	3,600	148	116	41	41	115	180,140
1976	57	52	2,972	10,854	7,142	30,458	53,606	689	807	8,258	954	8,722	124,571
1977	6,804	18,520	43,250	12,911	676	3,103	69	146	14	5	2,051	611	88,160
1978	1,763	11,120	8,219	1,430	3,837	6,845	22	16	0	1	14,926	14,410	62,589
1979	27,510	22,860	45,203	9,012	41,703	14,236	3,782	4,733	180	903	331	11,440	181,891
1980	4,860	8,350	703	1,272	7,472	77	20	7	18,592	2,762	271	12,301	56,685
1981	375	702	11,454	1,857	22,702	76,487	3,043	111	2,576	86,461	32,439	1,363	239,570
1982	7,505	15,475	7,445	10,727	151,320	25,653	8,501	1,722	325	568	6,724	19,455	255,421
1983	1,942	53,099	25,710	1,721	8,114	4,953	15,031	33	70	251	960	430	112,315
1984	669	32,433	33,455	9,298	24,379	157	7	0	2	10,755	10,483	36,909	158,546
1985	12,339	16,253	51,833	29,330	32,457	5,959	591	7	16	7,919	26,789	18,662	202,157
1986	661	20,859	1,756	27,597	18,597	22,411	7,854	0	3,577	7,182	50,567	15,623	176,683
1987	17,727	29,324	30,969	530	6,096	3,250	6,015	267	31,719	13,960	66,662	61,285	267,803
1988	15,675	13,069	18,758	11,310	380	31	3,336	18	970	2,540	9,670	8,399	84,156
1989	11,955	67,108	33,384	5,363	54,578	106,586	25,700	1,086	4,811	147	131	272	311,121
1990	31,386	48,025	61,570	39,107	85,708	14,229	740	642	424	10,259	9,125	11,015	312,230
1991	44,213	13,191	7,941	42,239	11,533	16,472	221	856	1,162	59,432	14,151	93,902	305,314
1992	37,900	15,738	46,218	2,984	36,979	55,051	13,631	3,444	332	129	2,184	29,146	243,735
1993	12,659	57,732	32,267	27,938	12,480	7,390	119	27	49	46,625	17,127	52,046	266,458
1994	1,869	16,081	43,560	13,900	62,380	13,134	30,668	3,578	661	5,631	61,802	26,599	279,864
1995	22,940	1,985	24,764	28,687	82,304	8,220	1,059	70	3,199	138	327	230	173,924
1996	1,873	238	983	908	2,609	5,767	3,054	7,874	1,352	12,082	68,322	12,495	117,558
MEAN	12,323	19,544	20,520	23,618	30,252	18,799	6,399	1,342	6,883	13,933	15,324	16,749	182,775

APPENDIX 1 - PERIOD OF RECORD NATURALIZED STREAMFLOWS (ACRE-FEET)
USGS GAGE NO. 7343200 - SULPHUR RIVER NEAR TALCO

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	-	-	-	-	-	-	-	-	-	-	-	-	-
1941	-	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	-	-	-	-	-	-
1943	-	-	-	-	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	11,068	3,358	14,426
1957	18,846	49,474	134,758	618,861	718,520	337,365	881	8,099	53,716	65,956	397,149	34,839	2,438,464
1958	110,564	3,280	134,832	188,099	481,569	72,322	49,885	1,144	16,981	2,470	23,732	3,519	1,088,397
1959	6,954	61,075	28,335	31,179	5,965	102,275	115,029	14,033	10,993	56,212	46,493	252,328	730,871
1960	156,262	44,003	39,102	4,429	34,771	61,651	71,554	14,398	77,211	99,586	9,440	402,485	1,014,892
1961	140,326	59,089	159,667	78,048	14,936	16,029	11,846	2,932	9,318	290	47,093	105,005	644,580
1962	73,350	41,238	26,898	102,450	35,474	81,464	61,016	4,233	160,049	67,139	152,822	23,526	829,659
1963	46,611	1,487	31,350	23,441	23,895	2,515	22,140	327	49	10	35	72	151,932
1964	9	1,430	39,138	113,015	32,340	58,520	97	204	50,363	6,686	98,283	5,843	405,929
1965	71,537	335,120	10,150	4,666	303,254	17,728	144	73	11,123	159	862	116	754,932
1966	1,777	84,960	2,151	482,210	380,362	1,237	574	7,363	16,691	26,520	123	3,752	1,007,720
1967	1,041	1,731	11,414	309,637	170,262	256,711	44,845	163	46,763	74,803	103,752	173,662	1,194,783
1968	115,978	68,878	384,839	238,174	333,500	234,811	59,153	18,756	78,083	15,735	123,474	206,665	1,878,045
1969	134,928	479,680	297,535	84,651	613,040	10,291	627	47	66	11,925	8,657	76,898	1,718,346
1970	50,069	194,484	299,145	211,305	29,764	8,680	338	34	23,211	135,781	30,102	7,147	990,059
1971	5,547	23,699	11,436	756	9,369	388	5,685	60,314	4,404	369,519	8,879	679,015	1,179,008
1972	19,321	4,834	11,119	944	1,919	2,210	472	337	211	31,566	173,691	77,045	323,668
1973	105,140	132,443	446,010	399,777	50,277	133,381	2,009	789	188,814	252,178	382,410	139,269	2,232,497
1974	173,824	12,380	11,225	110,831	30,237	287,383	273	887	175,361	40,058	405,784	170,465	1,418,708
1975	33,515	309,116	127,864	71,410	185,108	177,405	11,268	2,004	189	70	154	514	918,617
1976	233	154	18,106	145,974	101,906	75,788	236,454	1,113	8,316	41,645	11,653	129,131	770,471
1977	82,532	174,664	318,169	228,692	6,406	22,301	1,515	4,409	849	5	10,027	1,983	851,552
1978	12,845	63,801	104,176	7,190	17,069	13,982	22	16	1	1	28,667	17,067	264,838
1979	237,646	122,317	177,660	149,088	399,607	170,887	9,307	18,242	904	1,010	1,891	99,306	1,387,865
1980	124,741	104,377	2,149	49,883	114,861	7,313	35	7	23,367	32,444	1,112	69,578	529,867
1981	715	1,277	36,271	5,736	136,679	420,365	4,884	204	2,604	431,803	194,017	4,061	1,238,617
1982	8,674	59,051	66,877	51,967	757,998	189,841	34,803	7,846	1,613	1,881	110,772	367,912	1,659,236
1983	10,893	262,825	193,747	18,328	51,210	11,322	70,071	874	122	665	1,761	2,929	624,745
1984	2,405	87,504	351,929	37,679	82,214	1,041	352	612	248	106,337	45,368	185,320	901,009
1985	29,183	91,364	172,800	84,816	137,559	20,090	3,651	63	51	11,761	120,387	149,671	821,397
1986	1,314	118,585	4,531	150,167	60,375	130,015	45,355	1,111	8,820	21,523	145,596	59,243	746,635
1987	71,751	63,580	144,254	4,133	17,276	22,822	6,279	349	43,022	38,100	259,027	215,485	886,078
1988	64,403	44,431	48,797	56,222	1,196	127	47,479	291	3,218	7,664	154,748	38,085	466,660
1989	107,286	298,378	130,494	29,645	319,956	415,926	205,696	6,524	10,227	727	350	316	1,525,525
1990	173,922	178,326	340,673	229,517	398,593	81,843	1,644	2,659	11,547	23,255	44,072	53,722	1,539,773
1991	157,553	71,859	34,999	198,779	99,851	50,429	3,118	1,086	2,387	184,038	171,939	493,394	1,469,433
1992	126,502	129,580	187,101	17,919	201,629	163,255	222,593	61,428	17,042	6,268	40,314	167,802	1,341,435
1993	89,247	203,513	151,715	149,227	63,434	12,330	4,209	6,367	7,331	222,962	84,133	239,934	1,234,402
1994	50,573	87,869	132,271	32,525	204,146	37,656	116,265	16,042	18,215	40,288	188,714	175,265	1,099,831
1995	171,662	21,377	123,985	153,253	416,877	81,862	10,423	3,928	18,758	2,098	2,751	5,453	1,012,428
1996	10,396	3,555	10,802	14,439	32,664	30,761	13,628	42,387	24,414	-	-	-	183,045
MEAN	70,002	102,420	123,962	122,227	176,902	95,558	37,390	7,792	28,166	62,337	91,033	121,030	1,011,960

APPENDIX 1 PERIOD OF RECORD NATURALIZED STREAMFLOWS (ACRE-FEET)
USGS GAGES NO. 7343800 & 7343500 - WHITE OAK CREEK BELOW AND NEAR TALCO

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	231	3,520	3,006	54,777	34,785	27,659	21,463	351	714	63	40,232	78,887	265,688
1941	22,107	29,577	80,323	70,134	111,088	36,895	13,335	3,016	987	758	5,846	14,985	389,052
1942	2,446	6,424	21,066	238,952	42,191	24,109	2,092	2,170	3,234	412	2,309	26,347	371,752
1943	9,549	2,787	28,979	7,120	12,385	79,033	815	230	642	3,233	202	3,446	148,421
1944	11,932	25,255	81,118	17,940	156,204	21,949	587	373	2,588	443	6,780	30,347	355,517
1945	41,402	89,133	301,552	121,659	31,716	156,985	110,255	2,696	2,870	122,312	14,758	2,401	997,741
1946	157,064	228,289	67,430	35,123	261,382	139,772	1,921	3,725	4,727	1,191	146,535	78,681	1,125,841
1947	31,483	3,197	40,028	68,868	107,935	3,005	648	749	2,219	719	49,078	153,603	461,533
1948	39,303	80,348	86,938	15,937	188,117	2,220	2,765	1,324	736	1,033	1,749	1,386	421,855
1949	124,601	116,956	50,376	25,771	50,772	5,073	2,431	931	2,059	239,547	3,268	10,856	632,641
1950	71,521	199,535	39,885	9,048	114,206	10,819	11,658	9,216	63,356	698	379	458	530,780
1951	6,288	72,649	2,945	1,468	6,715	26,574	11,694	141	1,170	1,221	4,006	9,766	144,637
1952	26,689	10,025	14,717	167,631	38,891	2,912	3,693	136	74	71	28,025	64,147	357,012
1953	23,999	11,790	28,579	68,939	123,140	352	19,376	1,038	5,832	845	4,383	30,453	318,727
1954	63,471	31,678	2,476	4,542	49,437	651	105	64	57	32,564	18,511	2,035	205,591
1955	4,464	12,321	12,288	35,624	1,850	375	1,055	1,664	1,602	2,042	91	115	73,491
1956	221	29,289	755	260	18,452	95	0	0	0	0	14,810	76	63,958
1957	8,581	17,533	64,842	224,822	171,841	66,728	992	1,361	18,984	37,884	157,312	14,794	785,673
1958	70,703	2,554	51,713	159,289	165,207	40,376	39,911	1,906	13,391	1,777	10,061	3,941	560,830
1959	1,255	56,147	41,571	28,066	2,147	7,416	11,120	3,621	600	15,584	13,819	99,874	281,220
1960	81,947	22,621	24,336	1,691	2,327	7,023	7,617	751	7,783	15,225	6,933	134,985	313,239
1961	54,887	37,509	55,516	33,378	1,294	19,438	14,089	3,593	3,064	785	26,760	47,559	297,871
1962	33,192	29,098	23,507	36,784	26,203	5,586	6,854	1,324	23,682	10,969	31,609	22,389	251,198
1963	20,097	1,882	5,877	8,329	38,314	5,516	3,974	272	59	0	0	124	84,445
1964	82	3,500	9,359	43,181	5,978	12,557	0	2,359	30,123	1,937	13,741	1,172	123,991
1965	5,744	94,298	7,789	3,005	121,269	20,601	43	0	3,047	37	63	0	255,896
1966	4,923	42,043	3,073	216,605	164,758	903	2,728	5,046	10,169	16,808	385	3,641	471,082
1967	3,034	3,987	7,301	54,344	56,258	56,048	4,729	286	3,887	11,050	59,592	49,516	310,030
1968	35,752	28,265	119,782	30,143	114,193	22,043	7,117	700	9,662	310	6,489	38,393	412,849
1969	12,822	130,247	93,223	39,548	148,946	1,869	295	0	9,160	0	1,549	10,152	447,810
1970	21,814	45,795	101,615	113,470	8,779	5,483	3,617	1,565	4,754	33,110	7,975	1,389	349,365
1971	3,093	15,825	7,310	465	885	300	15,291	10,230	1,041	37,958	2,259	244,775	339,432
1972	27,785	7,353	6,085	1,231	859	4,378	385	0	263	17,575	70,390	53,225	189,529
1973	40,883	53,987	134,412	138,306	7,755	55,190	3,642	19	24,436	43,629	152,618	72,518	727,396
1974	100,805	10,397	11,584	64,897	7,178	71,477	578	1,290	52,865	13,627	177,515	74,813	587,024
1975	12,864	160,163	66,912	37,057	102,460	42,975	3,862	2,933	86	70	0	228	429,611
1976	88	440	19,877	79,027	60,853	12,468	90,647	239	2,606	4,022	2,536	15,858	288,663
1977	11,069	57,563	126,422	72,101	2,249	9,579	658	1,116	76	78	45,058	3,857	329,824
1978	14,195	25,406	45,991	3,247	3,051	1,036	19	0	8	0	1,008	865	94,826
1979	57,529	22,301	43,231	66,276	106,541	21,904	8,013	22,604	7,197	387	3,900	61,906	421,787
1980	198,424	47,514	4,610	45,769	56,694	7,602	1,372	1,587	863	5,830	2,403	16,138	388,805
1981	428	2,413	5,637	1,962	70,759	156,440	2,097	271	151	109,052	18,488	1,075	368,771
1982	1,172	6,086	16,179	4,062	32,250	15,744	39,424	444	0	49	21,898	177,191	314,499
1983	11,164	51,912	56,952	9,783	9,638	8,234	15,227	0	0	38	1,636	7,103	171,686
1984	3,786	23,443	71,634	12,221	1,170	87	27	0	0	82,735	23,041	105,210	323,354
1985	12,844	57,436	50,736	45,266	39,877	10,352	1,050	43	0	426	15,358	95,352	328,740
1986	1,624	79,086	2,042	102,025	37,177	41,879	2,397	0	361	281	14,997	18,934	300,803
1987	22,638	23,295	96,231	5,400	1,308	8,576	1,935	34	1,741	3,446	94,722	134,691	394,017
1988	27,809	22,963	18,180	17,529	307	0	42,854	680	0	1,755	144,971	32,409	309,456
1989	31,209	111,109	47,156	28,629	109,089	94,162	30,176	5,477	713	0	194	81	457,996
1990	23,176	49,352	214,001	90,054	194,035	76,937	7,916	10,514	2,254	3,931	36,680	51,071	759,921
1991	69,100	72,667	17,766	79,138	46,895	12,084	4,274	500	1,398	22,764	83,957	156,854	567,396
1992	52,576	59,736	115,862	14,123	20,893	30,358	230,767	56,215	1,329	391	44,079	111,168	737,497
1993	91,581	66,707	84,805	41,535	15,418	1,534	162	132	15	73,368	18,717	83,031	477,004
1994	27,008	48,782	57,674	4,295	28,098	15,008	41,116	2,598	443	3,664	43,316	86,551	358,553
1995	82,574	11,558	44,677	48,511	111,720	5,546	2,358	417	3,050	37	0	490	310,938
1996	1,647	170	631	2,799	4,754	2,271	1,094	27,657	3,453	5,721	158,709	66,515	275,421
MEAN	33,661	44,841	49,799	51,792	60,503	26,600	14,988	3,432	5,887	17,254	32,556	45,751	387,065

APPENDIX 1 - PERIOD OF RECORD NATURALIZED STREAMFLOWS (ACRE-FEET)
USGS GAGE NO. 7344000 - SULPHUR RIVER NEAR DARDEN

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	587	10,796	10,344	283,838	257,674	263,120	236,363	1,002	3,824	401	184,327	442,653	1,694,927
1941	209,629	152,921	346,204	252,706	762,226	475,578	168,120	15,260	5,002	24,433	64,399	146,119	2,622,597
1942	23,231	60,435	161,417	982,319	464,440	196,525	9,217	6,870	20,428	1,628	19,878	97,306	2,043,694
1943	77,762	17,763	274,903	122,418	66,385	207,148	9,385	552	1,043	7,703	5,799	24,605	815,466
1944	78,730	181,351	539,212	166,376	754,692	214,439	3,880	4,883	19,861	443	50,482	208,421	2,222,770
1945	308,233	446,646	1,145,365	1,101,443	105,114	516,737	186,775	6,920	23,472	336,497	27,919	4,492	4,209,612
1946	388,947	715,800	157,957	207,166	720,582	455,059	7,920	24,278	5,285	2,122	744,285	268,777	3,698,177
1947	105,391	13,953	173,684	212,803	373,470	17,102	2,914	9,863	3,014	1,359	92,709	407,453	1,413,713
1948	256,993	301,539	352,138	73,741	579,206	25,322	14,509	3,913	736	1,086	1,749	7,889	1,618,822
1949	390,239	409,248	384,744	150,978	180,632	58,651	17,286	7,322	5,484	393,675	61,262	48,301	2,107,822
1950	470,029	1,009,121	146,900	25,923	659,361	76,619	40,778	54,479	481,900	13,153	2,031	1,438	2,981,734
1951	34,183	423,871	51,896	21,536	49,261	347,131	45,661	2,774	7,214	10,516	18,465	39,123	1,051,630
1952	124,955	53,228	97,308	809,706	221,429	63,663	9,250	2,267	74	71	69,756	246,029	1,697,734
1953	113,227	140,507	161,375	290,150	754,149	4,630	50,193	5,423	8,700	1,608	22,361	103,763	1,656,087
1954	244,752	124,516	14,135	60,000	472,719	31,975	356	64	69	153,763	43,097	10,954	1,156,401
1955	15,568	80,954	157,592	209,304	35,592	5,280	35,404	15,946	23,554	57,713	611	1,080	638,598
1956	1,708	277,984	7,734	5,053	124,495	4,888	1,693	1,005	784	826	25,877	3,435	455,481
1957	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	-	-	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-	-	-	-	-	-	-
1961	-	-	-	-	-	-	-	-	-	-	-	-	-
1962	-	-	-	-	-	-	-	-	-	-	-	-	-
1963	-	-	-	-	-	-	-	-	-	-	-	-	-
1964	-	-	-	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-
1976	-	-	-	-	-	-	-	-	-	-	-	-	-
1977	-	-	-	-	-	-	-	-	-	-	-	-	-
1978	-	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	-	-	-	-	-
1980	-	-	-	-	-	-	-	-	-	-	-	-	-
1981	-	-	-	-	-	-	-	-	-	-	-	-	-
1982	-	-	-	-	-	-	-	-	-	-	-	-	-
1983	-	-	-	-	-	-	-	-	-	-	-	-	-
1984	-	-	-	-	-	-	-	-	-	-	-	-	-
1985	-	-	-	-	-	-	-	-	-	-	-	-	-
1986	-	-	-	-	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-	-	-	-	-
1989	-	-	-	-	-	-	-	-	-	-	-	-	-
1990	-	-	-	-	-	-	-	-	-	-	-	-	-
1991	-	-	-	-	-	-	-	-	-	-	-	-	-
1992	-	-	-	-	-	-	-	-	-	-	-	-	-
1993	-	-	-	-	-	-	-	-	-	-	-	-	-
1994	-	-	-	-	-	-	-	-	-	-	-	-	-
1995	-	-	-	-	-	-	-	-	-	-	-	-	-
1996	-	-	-	-	-	-	-	-	-	-	-	-	-
MEAN	167,304	260,037	246,053	292,674	387,143	174,345	49,394	9,578	35,909	59,235	84,412	121,285	1,887,369

APPENDIX 1 PERIOD OF RECORD NATURALIZED STREAMFLOWS (ACRE-FEET)
USGS GAGE NO. 7344200 - WRIGHT-PATMAN INFLOWS

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
1940	-	-	-	-	-	-	-	-	-	-	-	-	-
1941	-	-	-	-	-	-	-	-	-	-	-	-	-
1942	-	-	-	-	-	-	-	-	-	-	-	-	-
1943	-	-	-	-	-	-	-	-	-	-	-	-	-
1944	-	-	-	-	-	-	-	-	-	-	-	-	-
1945	-	-	-	-	-	-	-	-	-	-	-	-	-
1946	-	-	-	-	-	-	-	-	-	-	-	-	-
1947	-	-	-	-	-	-	-	-	-	-	-	-	-
1948	-	-	-	-	-	-	-	-	-	-	-	-	-
1949	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	-	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	-	-	-	-	-	-	-	-	-	-	-
1953	-	-	-	-	-	-	-	-	-	-	-	-	-
1954	-	-	-	-	-	-	-	-	-	-	-	-	-
1955	-	-	-	-	-	-	-	-	-	-	-	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	-	-
1957	-	-	-	-	-	-	-	-	-	-	-	-	-
1958	-	-	-	-	-	-	-	-	-	-	-	-	-
1959	-	-	-	-	-	-	-	-	-	-	-	-	-
1960	-	-	-	-	-	-	-	-	-	-	-	-	-
1961	337,077	191,460	405,154	339,417	45,411	83,288	71,539	9,958	18,008	5,321	73,853	376,511	1,956,998
1962	261,221	264,851	263,779	225,254	143,464	120,572	67,870	10,470	183,731	120,256	215,365	71,908	1,948,742
1963	116,560	13,699	138,464	68,214	124,742	10,885	38,885	599	108	617	35	3,867	516,674
1964	3,761	12,323	81,339	324,981	165,874	74,827	97	12,659	97,936	24,830	112,024	58,442	969,092
1965	128,358	763,049	60,570	34,132	489,705	38,328	1,125	1,793	14,170	196	925	4,508	1,536,859
1966	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	255,827	163,271	671,226	268,316	676,565	256,854	73,521	19,456	88,749	16,045	171,129	245,058	2,906,018
1969	236,184	780,095	483,691	246,526	869,749	12,160	922	2,872	9,226	11,925	10,206	112,878	2,776,434
1970	87,759	337,656	703,090	499,749	144,351	28,613	3,955	4,863	27,965	168,890	52,645	23,665	2,083,201
1971	19,939	88,631	62,450	9,046	27,102	5,335	56,596	100,868	5,445	407,477	104,867	1,331,974	2,219,729
1972	156,062	12,187	32,107	10,565	9,538	6,956	8,393	1,420	10,230	56,647	276,595	251,637	832,338
1973	236,017	334,149	866,103	907,631	189,287	370,056	9,867	808	213,250	339,067	901,812	422,081	4,790,127
1974	546,955	109,414	51,574	175,728	166,651	619,641	851	3,342	328,168	122,703	849,943	565,888	3,540,858
1975	106,199	898,131	434,126	225,678	525,066	220,380	19,592	8,694	275	140	6,091	3,355	2,447,726
1976	10,879	14,115	165,014	225,001	331,891	241,999	327,101	1,352	22,008	48,921	14,292	150,265	1,552,837
1977	133,808	407,003	660,560	536,543	38,358	35,245	2,172	5,525	925	83	55,085	17,699	1,893,006
1978	-	-	-	-	-	-	-	-	-	-	-	-	-
1979	-	-	-	-	-	-	-	-	19,612	1,990	13,647	361,094	396,343
1980	328,814	326,188	45,575	238,701	171,554	45,621	1,407	1,594	24,230	38,274	19,453	87,324	1,328,734
1981	9,291	40,798	75,575	16,681	373,485	781,895	69,248	474	2,755	540,855	274,675	11,633	2,197,365
1982	36,646	143,213	109,976	91,286	990,696	423,796	121,875	19,272	1,613	1,930	179,102	891,116	3,010,520
1983	22,057	324,413	381,530	75,494	103,629	26,531	85,298	874	122	703	3,397	29,393	1,053,441
1984	19,704	122,972	429,847	212,050	83,383	1,128	379	612	248	314,965	274,804	500,433	1,960,526
1985	107,668	339,535	571,127	361,166	316,837	80,052	6,211	106	51	12,187	163,177	471,875	2,429,992
1986	15,057	398,549	38,919	467,775	202,310	274,015	88,761	1,111	9,181	21,804	176,216	192,687	1,886,384
1987	174,613	198,813	737,020	30,014	23,676	40,699	12,508	383	44,763	47,406	546,379	1,097,629	2,953,902
1988	281,775	168,072	172,238	151,353	1,504	127	90,333	971	3,218	9,419	409,542	233,965	1,522,516
1989	221,766	753,241	390,314	169,638	742,519	702,057	259,147	28,648	10,940	727	544	2,997	3,282,538
1990	250,838	400,329	1,257,714	590,005	1,056,775	233,373	9,560	13,173	13,800	37,314	145,534	288,083	4,296,498
1991	544,178	316,469	192,907	552,801	432,806	63,344	9,549	9,757	10,065	234,792	397,872	1,010,783	3,775,324
1992	317,609	398,416	711,327	65,771	251,862	271,589	557,531	255,610	45,458	6,660	112,159	665,688	3,659,679
1993	491,577	388,301	631,731	338,556	128,006	32,676	4,371	6,499	7,346	514,446	182,037	661,347	3,386,892
1994	168,299	256,271	501,050	50,511	299,484	72,643	262,052	18,640	18,657	64,512	467,640	540,281	2,720,040
1995	556,649	151,476	286,935	424,612	731,177	108,956	12,781	4,345	21,808	2,135	2,751	5,943	2,309,568
1996	14,095	3,725	14,358	24,314	103,743	60,606	18,491	133,341	59,416	97,142	1,010,552	299,535	1,839,318
MEAN	193,664	70,892	127,523	176,847	189,271	207,264	202,091	187,233	170,264	157,821	152,708	158,012	170,994

APPENDIX 2

COMPARISON OF ANNUAL NATURALIZED STREAMFLOWS AT THE DOWNSTREAM ENDS OF SUBWATERSHEDS A, B, C, D, AND E WITH HISTORICAL GAGED AND TWDB/HDRS STREAMFLOWS

FIGURE A2-1
COMPARISON OF NATURALIZED AND HISTORICAL STREAMFLOWS
FOR USGS GAGE 07342500 - SUBWATERSHED A

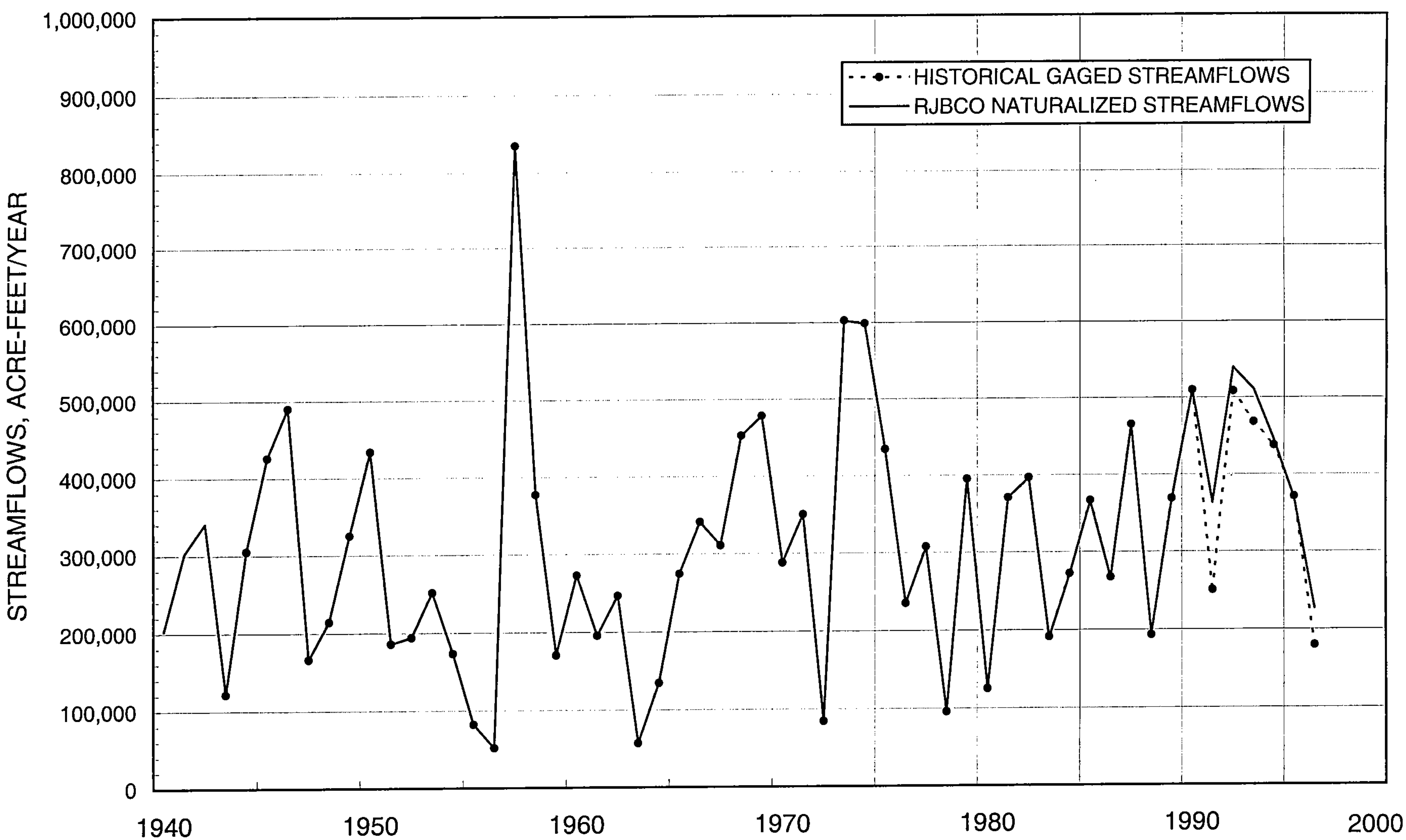


FIGURE A2-2
COMPARISON OF NATURALIZED AND HISTORICAL STREAMFLOWS
FOR USGS GAGE 07343000 - SUBWATERSHED B

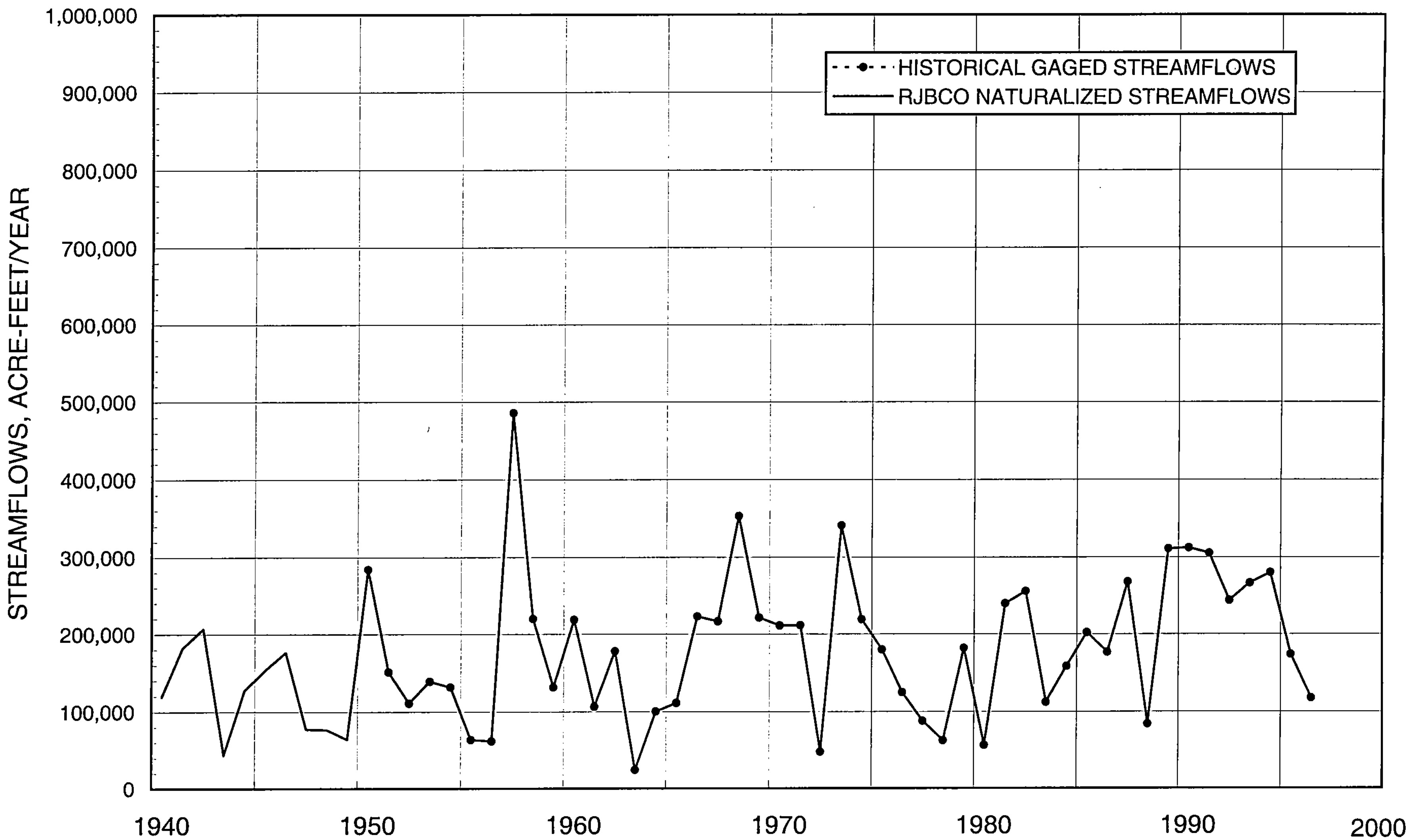


FIGURE A2-3
COMPARISON OF NATURALIZED AND HISTORICAL STREAMFLOWS
FOR USGS GAGE 07343200 - SUBWATERSHED C

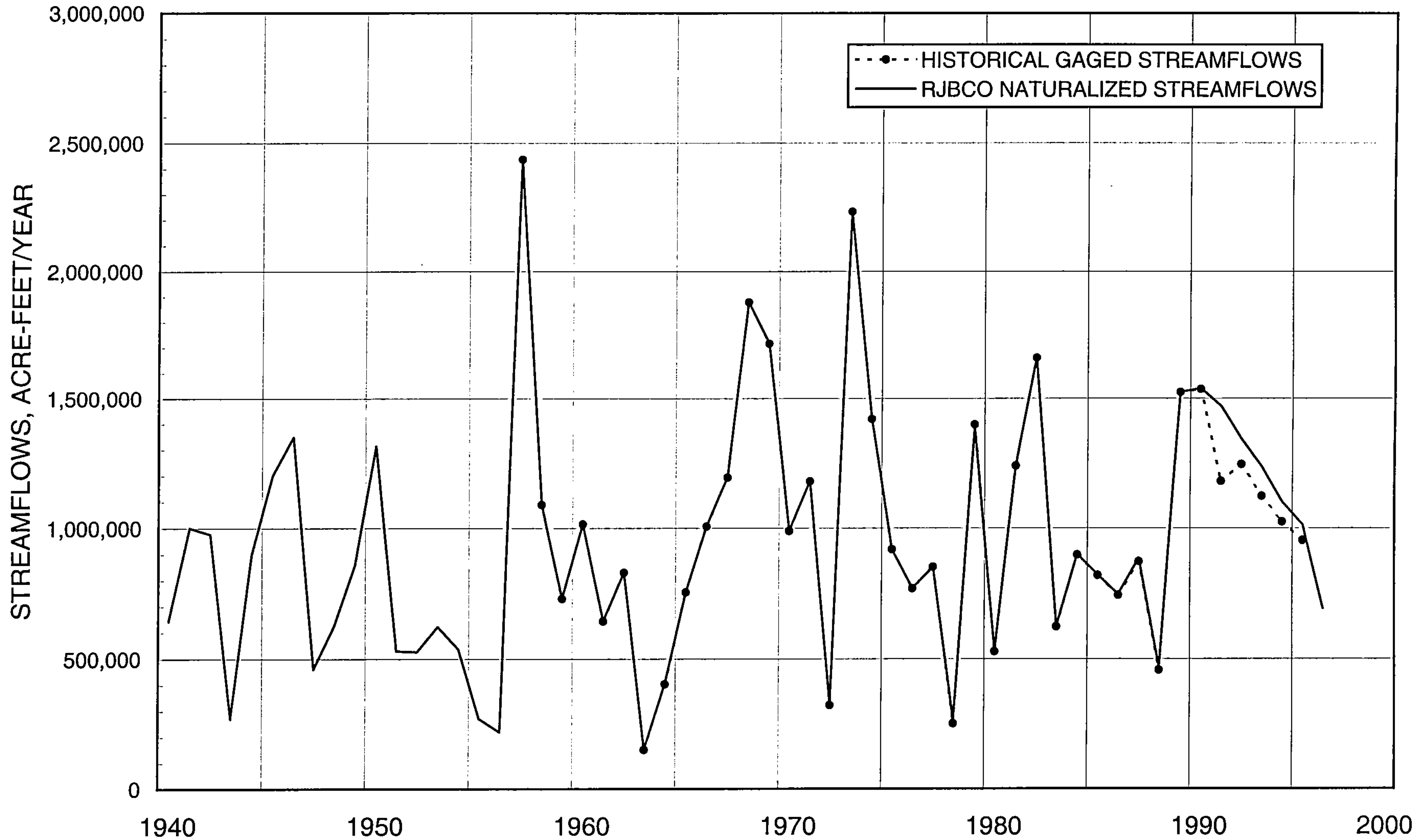


FIGURE A2-4
COMPARISON OF NATURALIZED AND HISTORICAL STREAMFLOWS
FOR USGS GAGE 07343500 - SUBWATERSHED D

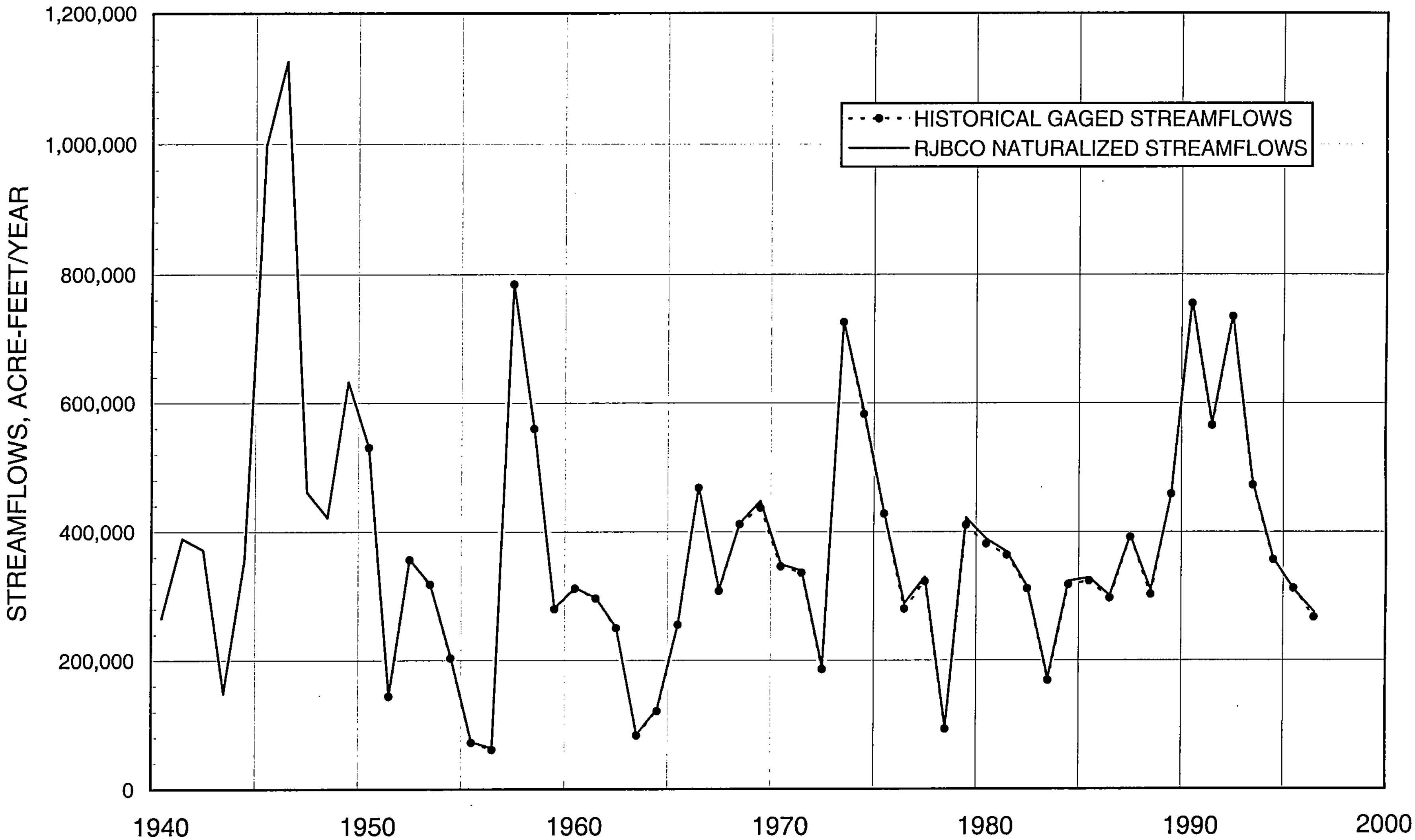


FIGURE A2-5
COMPARISON OF NATURALIZED AND HISTORICAL STREAMFLOWS
FOR USGS GAGE 07344000 - SUBWATERSHED E

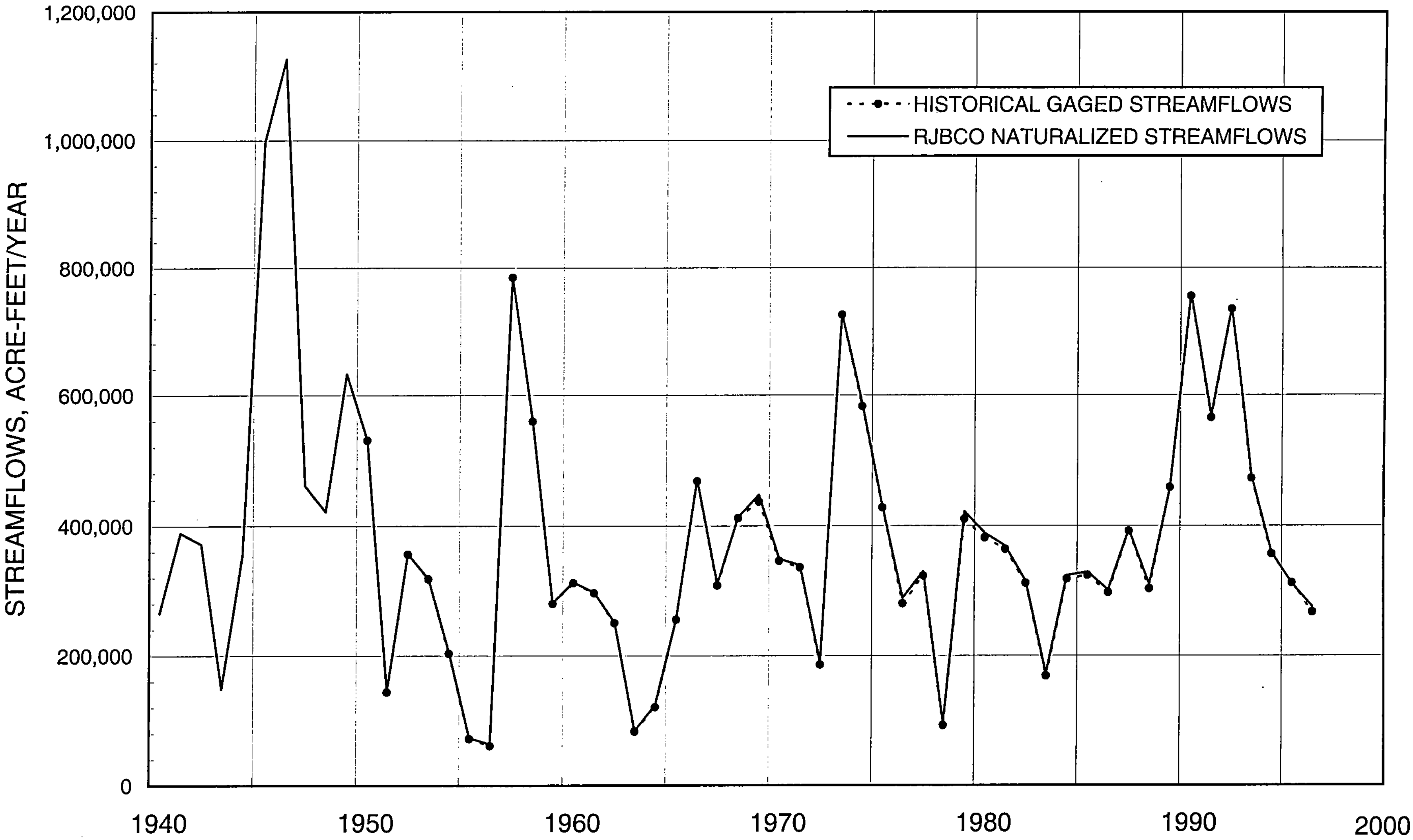


FIGURE A2-6
COMPARISON OF RJBCO AND TWDB/HDRS NATURALIZED STREAMFLOWS
FOR USGS GAGE 07342500 - SUBWATERSHED A

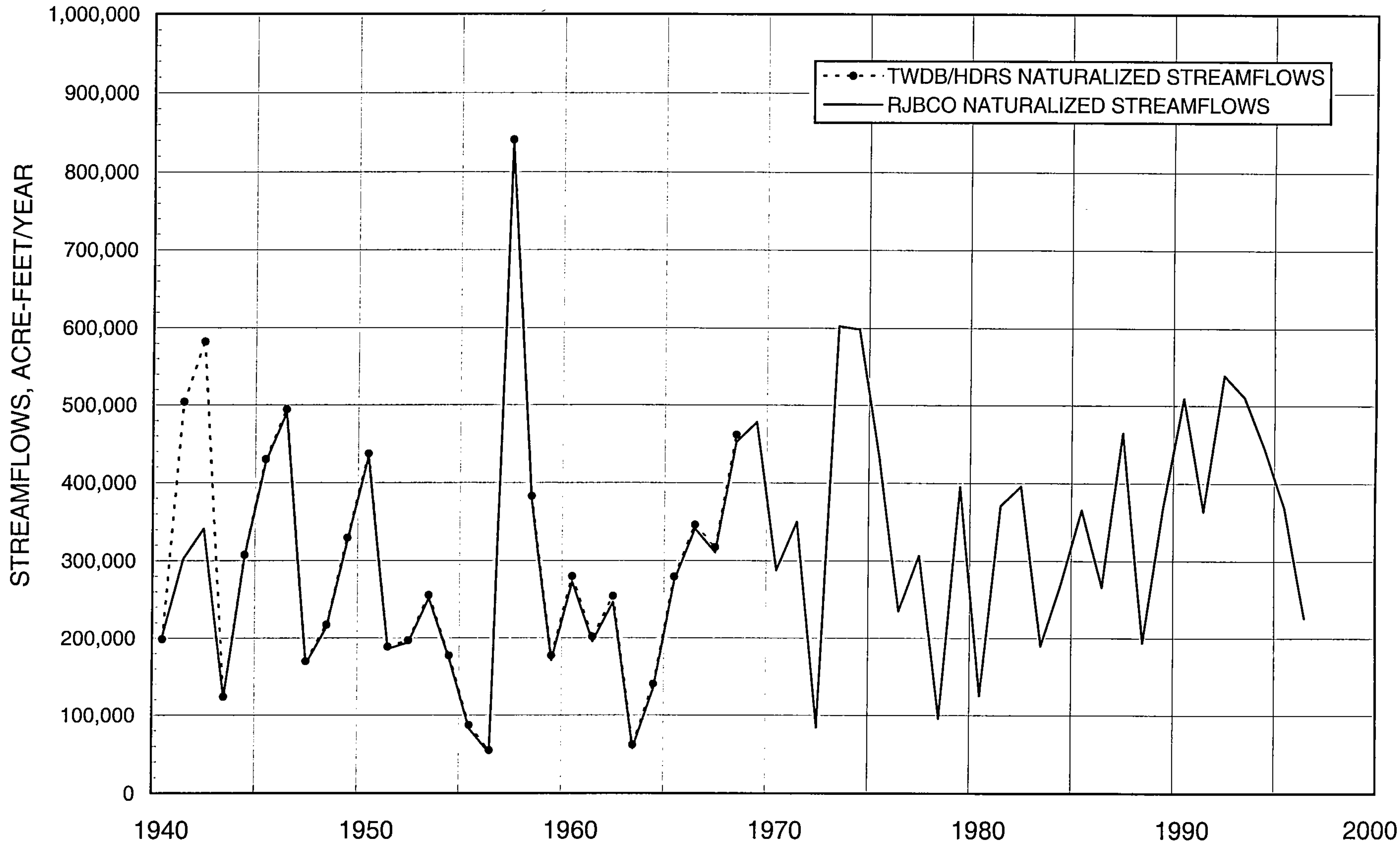


FIGURE A2-7
COMPARISON OF RJBCO AND TWDB/HDRS NATURALIZED STREAMFLOWS
FOR USGS GAGE 07343000 - SUBWATERSHED B

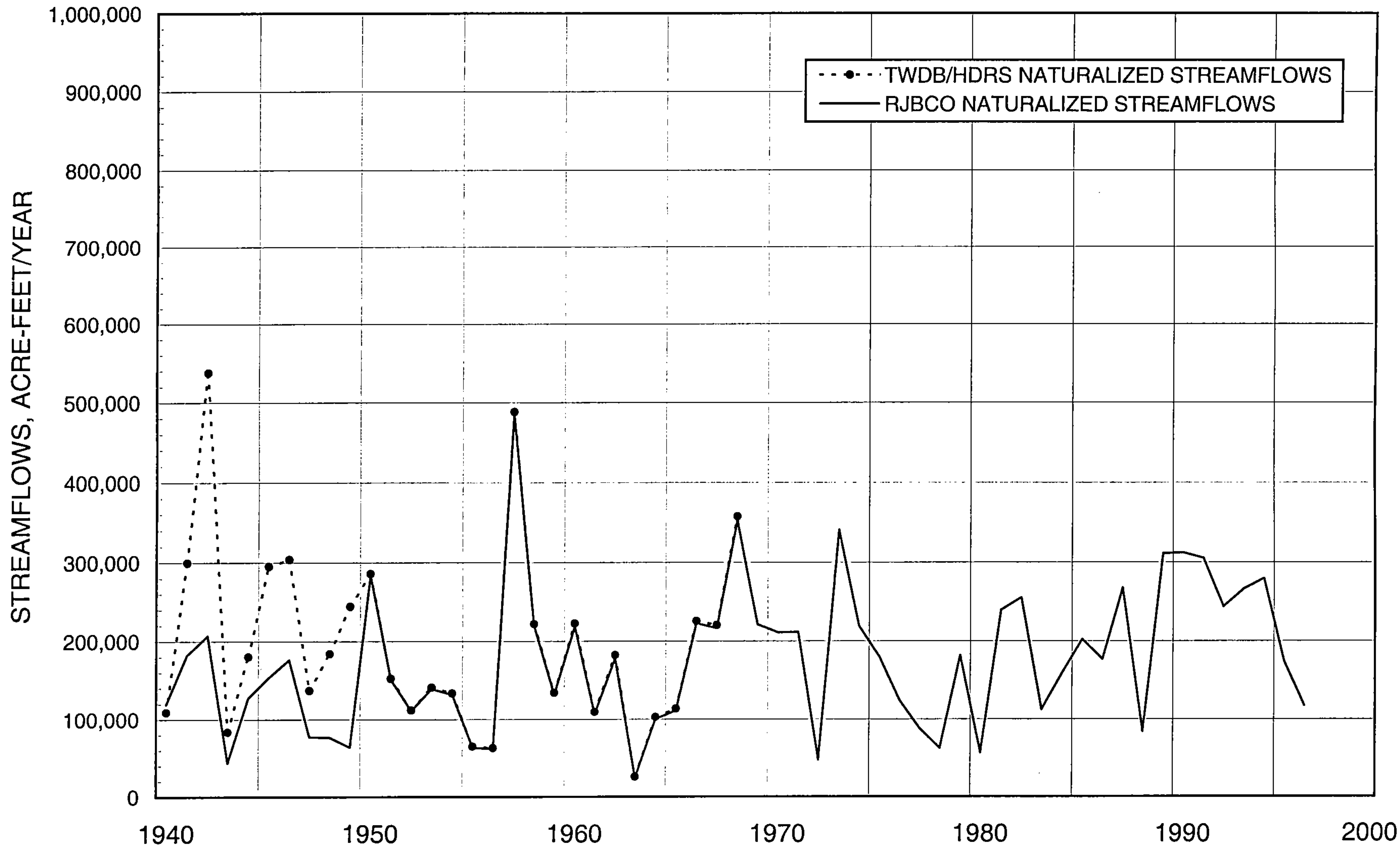


FIGURE A2-8
COMPARISON OF RJBCO AND TWDB/HDRS NATURALIZED STREAMFLOWS FOR USGS GAGE 07343200 - SUBWATERSHED C

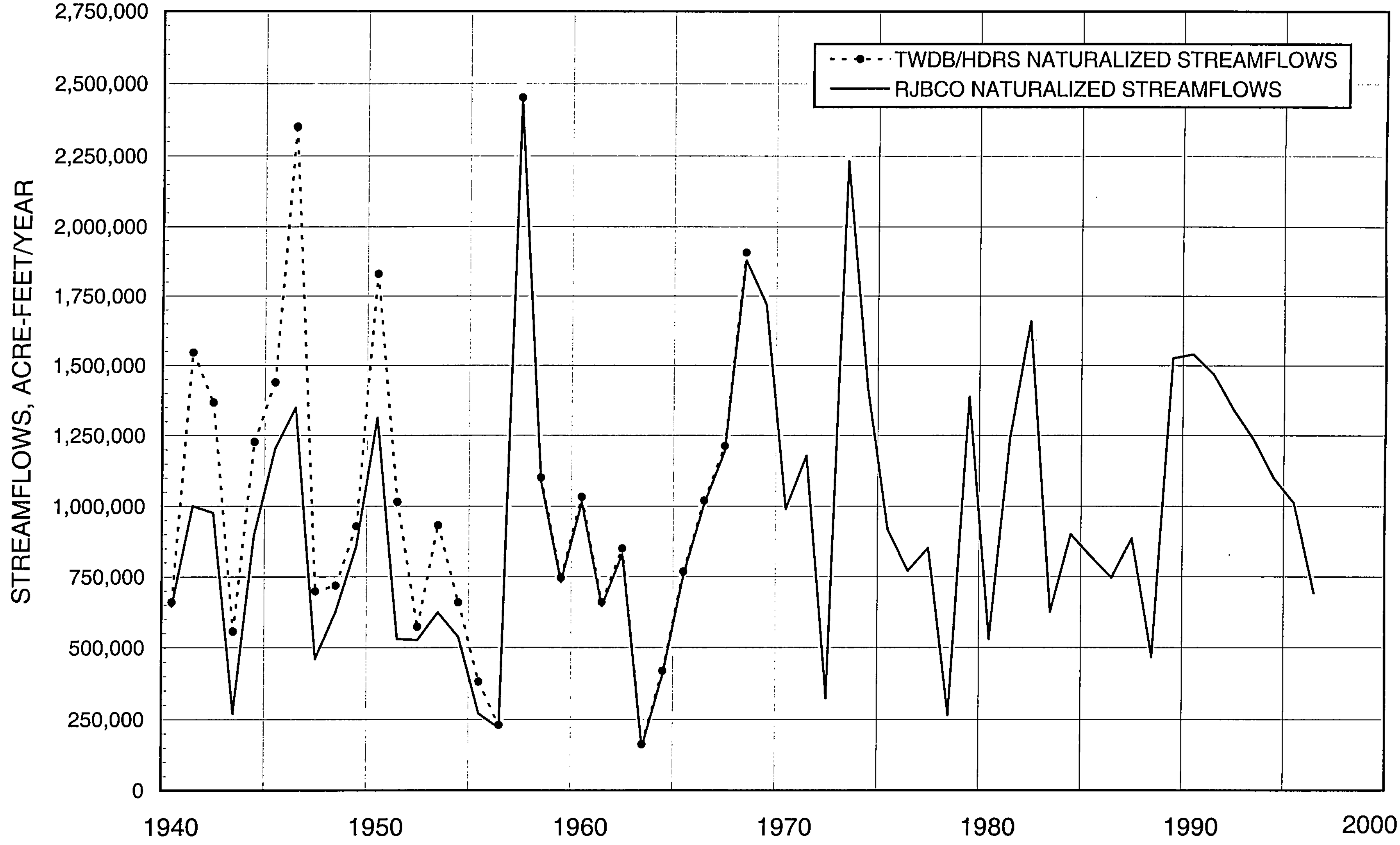


FIGURE A2-9
COMPARISON OF RJBCO AND TWDB/HDRS NATURALIZED STREAMFLOWS
FOR USGS GAGE 07343500 - SUBWATERSHED D

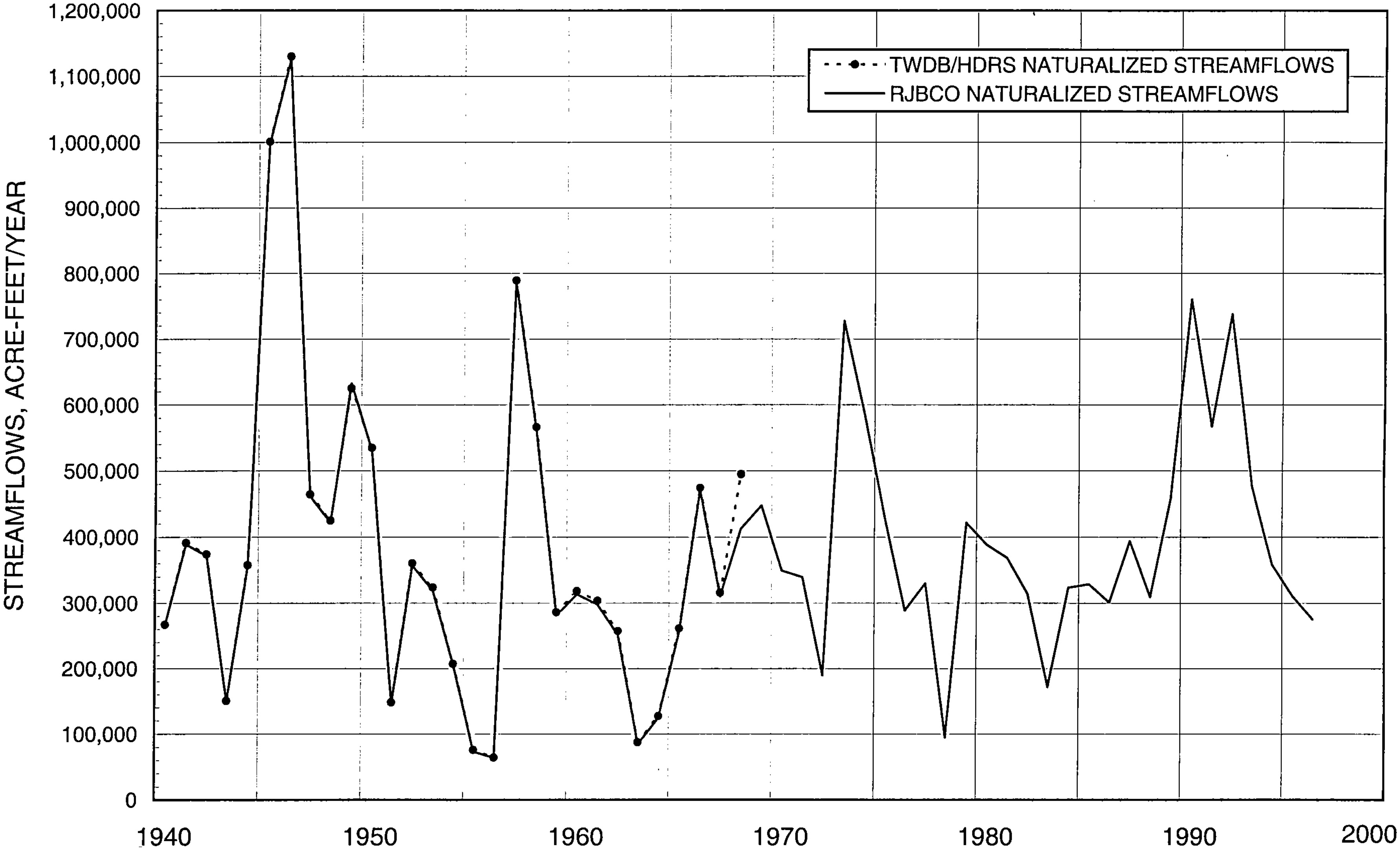
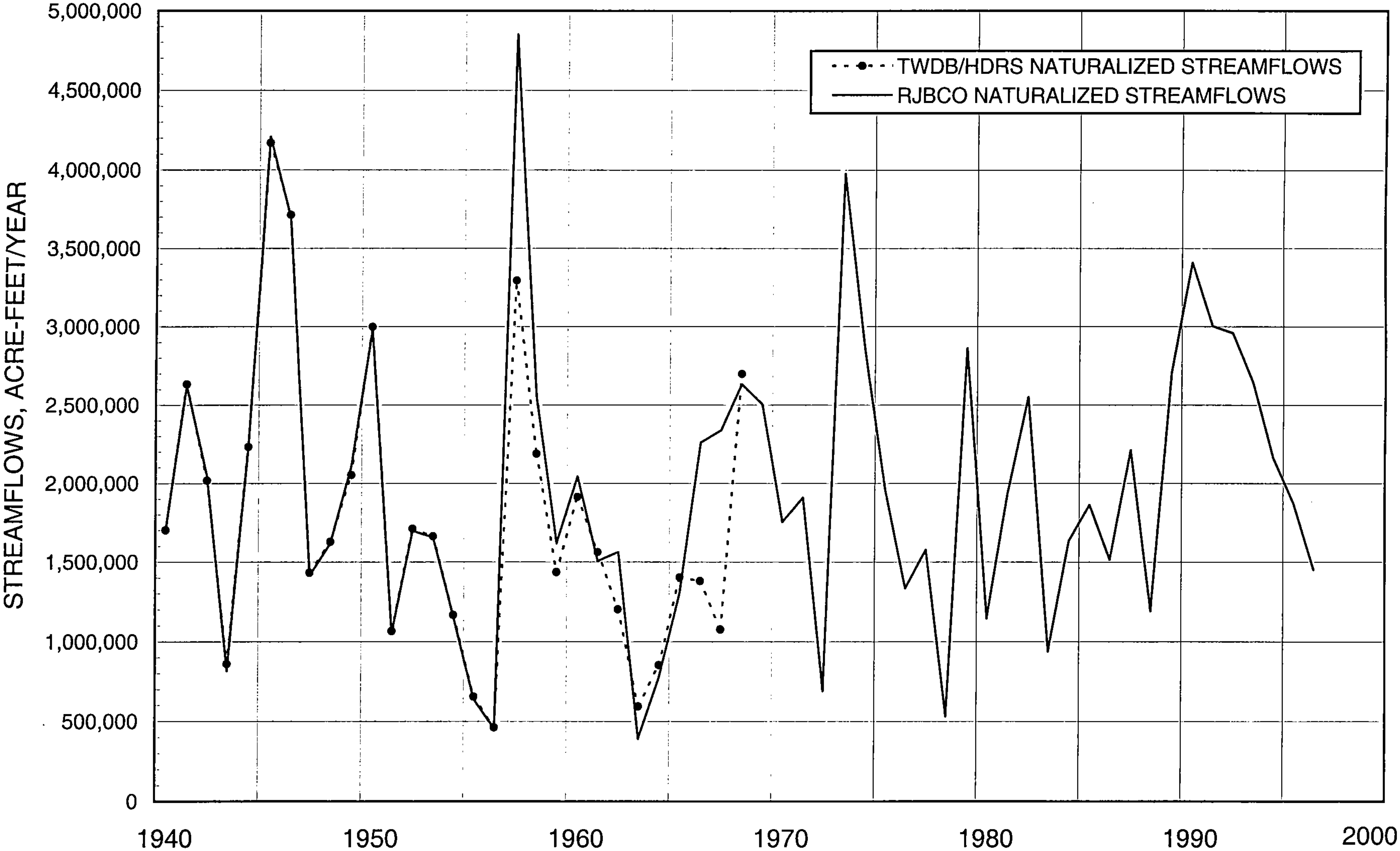


FIGURE A2-10
COMPARISON OF RJBCO AND TWDB/HDRS NATURALIZED STREAMFLOWS FOR USGS GAGE 07344000 - SUBWATERSHED E



APPENDIX 3

SELECTED WRAP RESULTS FROM REUSE ANALYSES
RUNS 1, 2, AND 3

Diversions:	Figures A3-1 through A3-8
Reservoir Storage:	Figures A3-9 through A3-13
Unappropriated Flows:	Figures A3-14 through A3-22
Regulated Flows:	Figures A3-23 through A3-31

FIGURE A3-1
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHT 4836, WRIGHT PATMAN LAKE (CONTROL POINT F60)

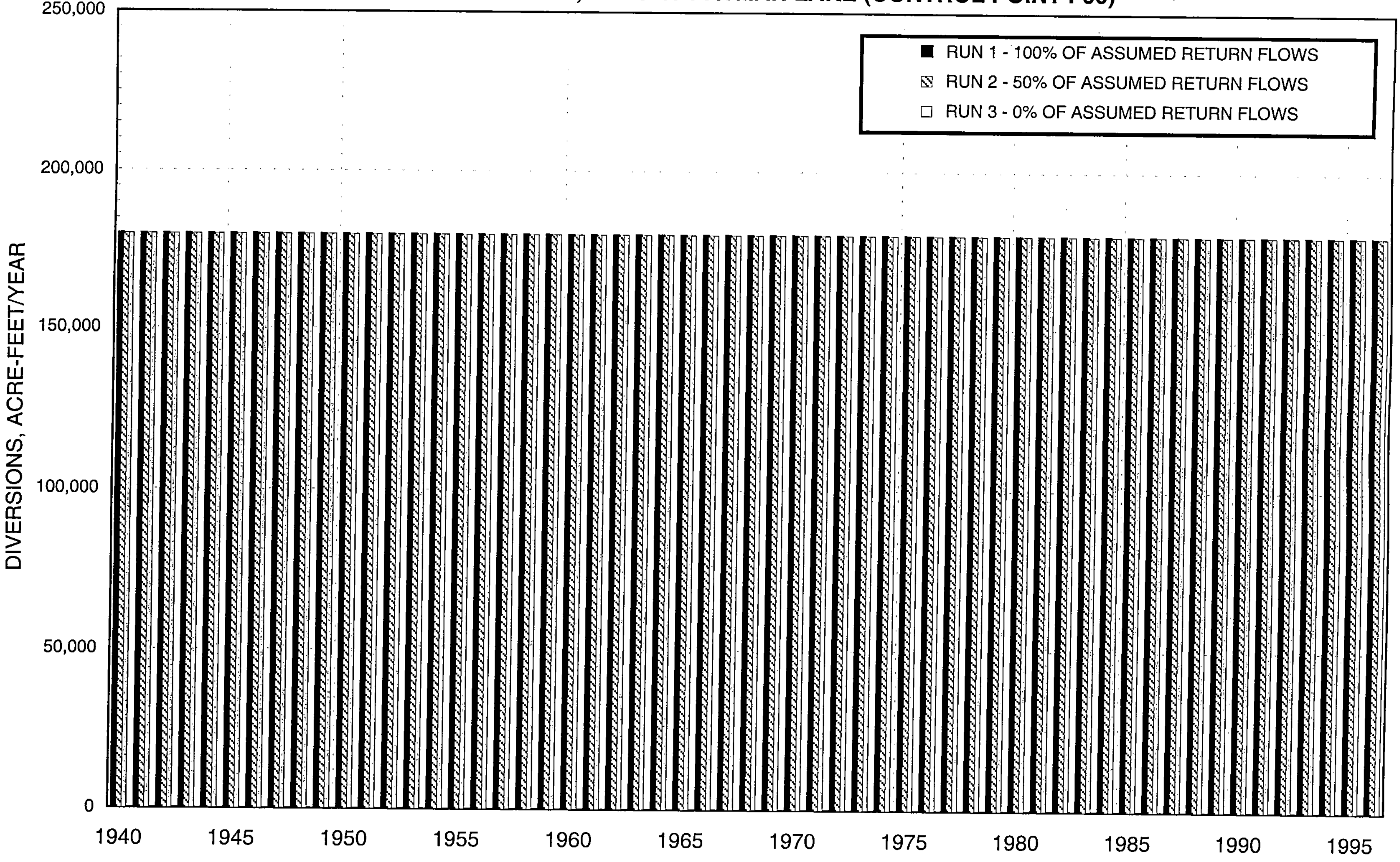


FIGURE A3-2
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

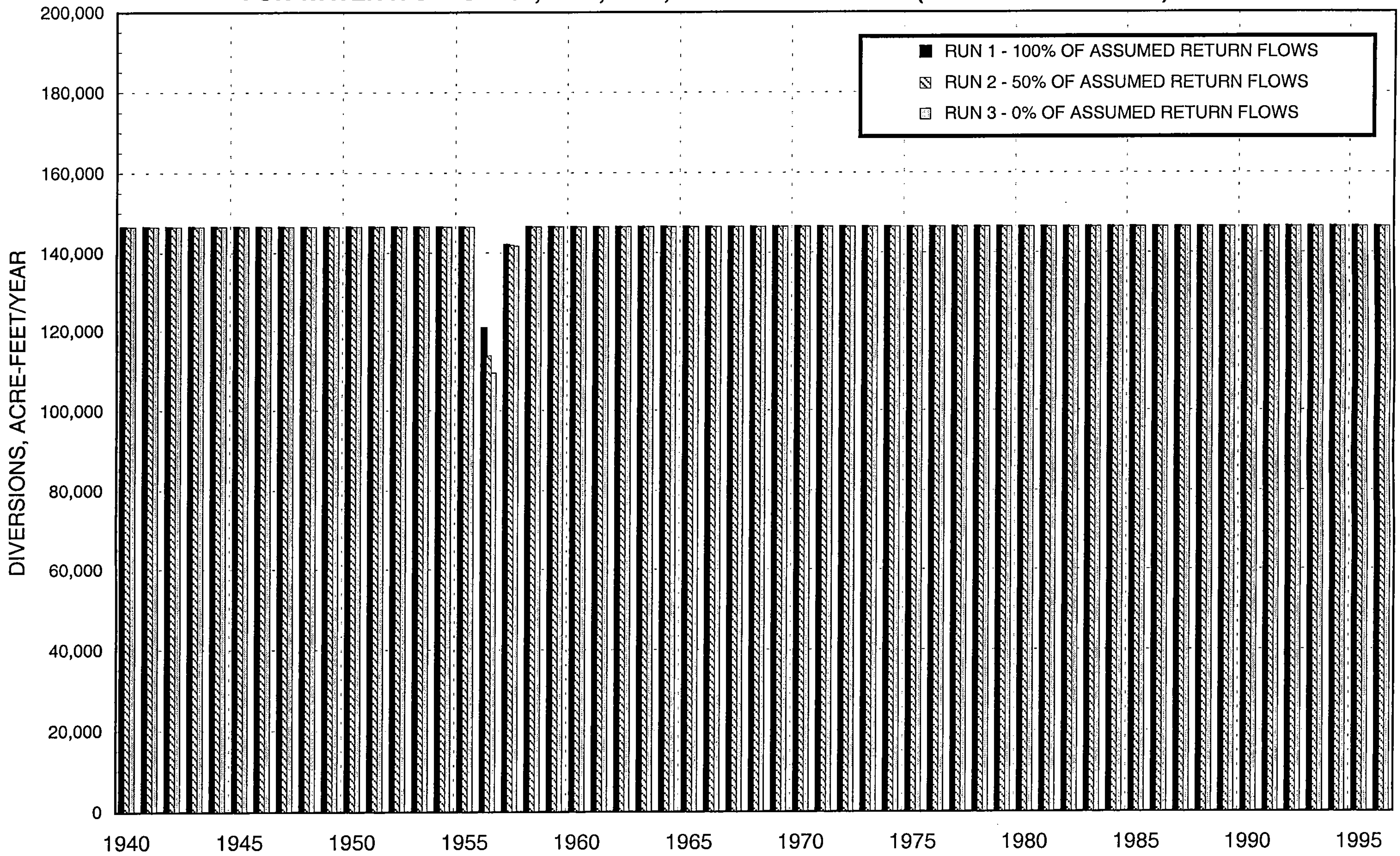


FIGURE A3-3
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

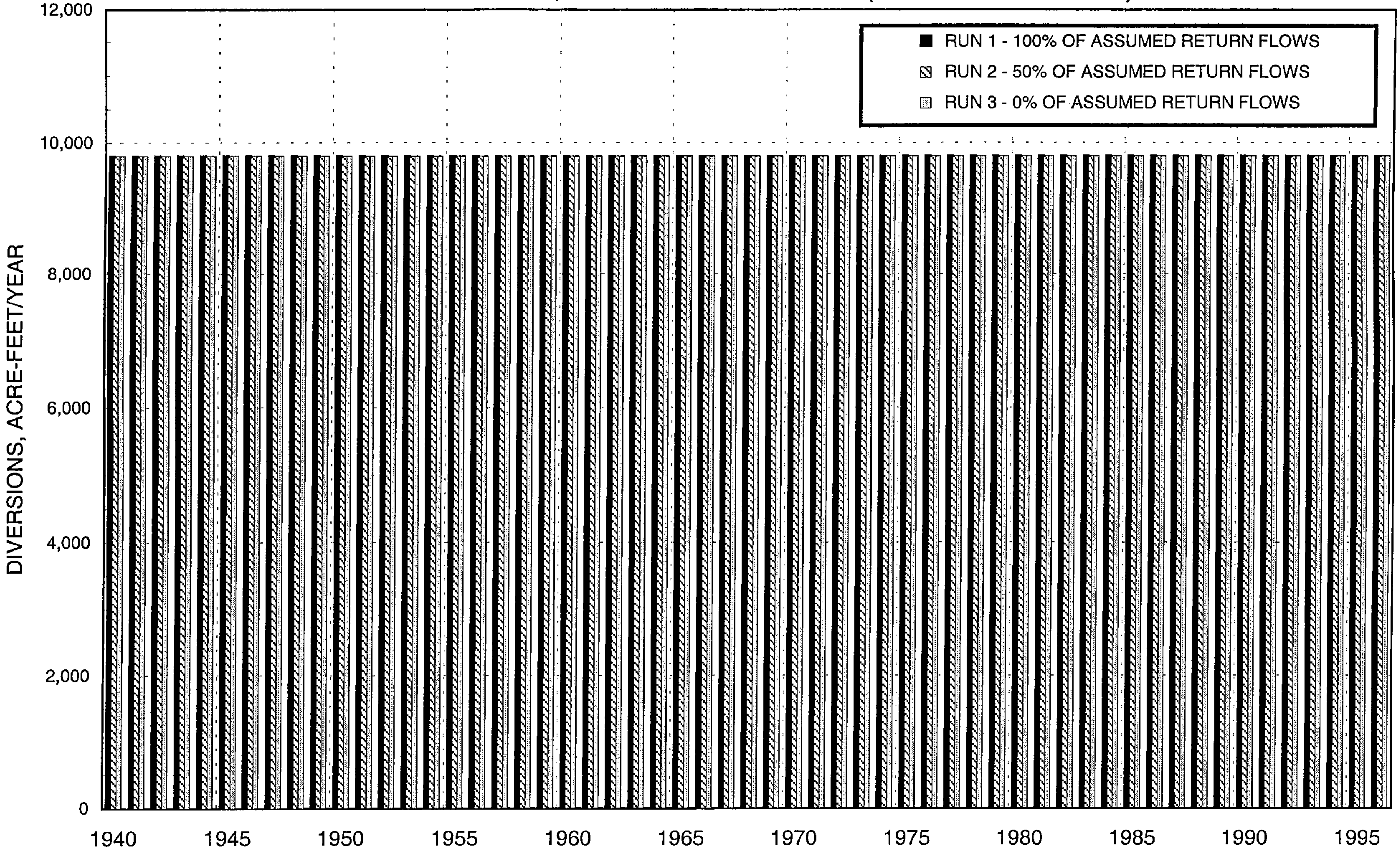


FIGURE A3-4
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

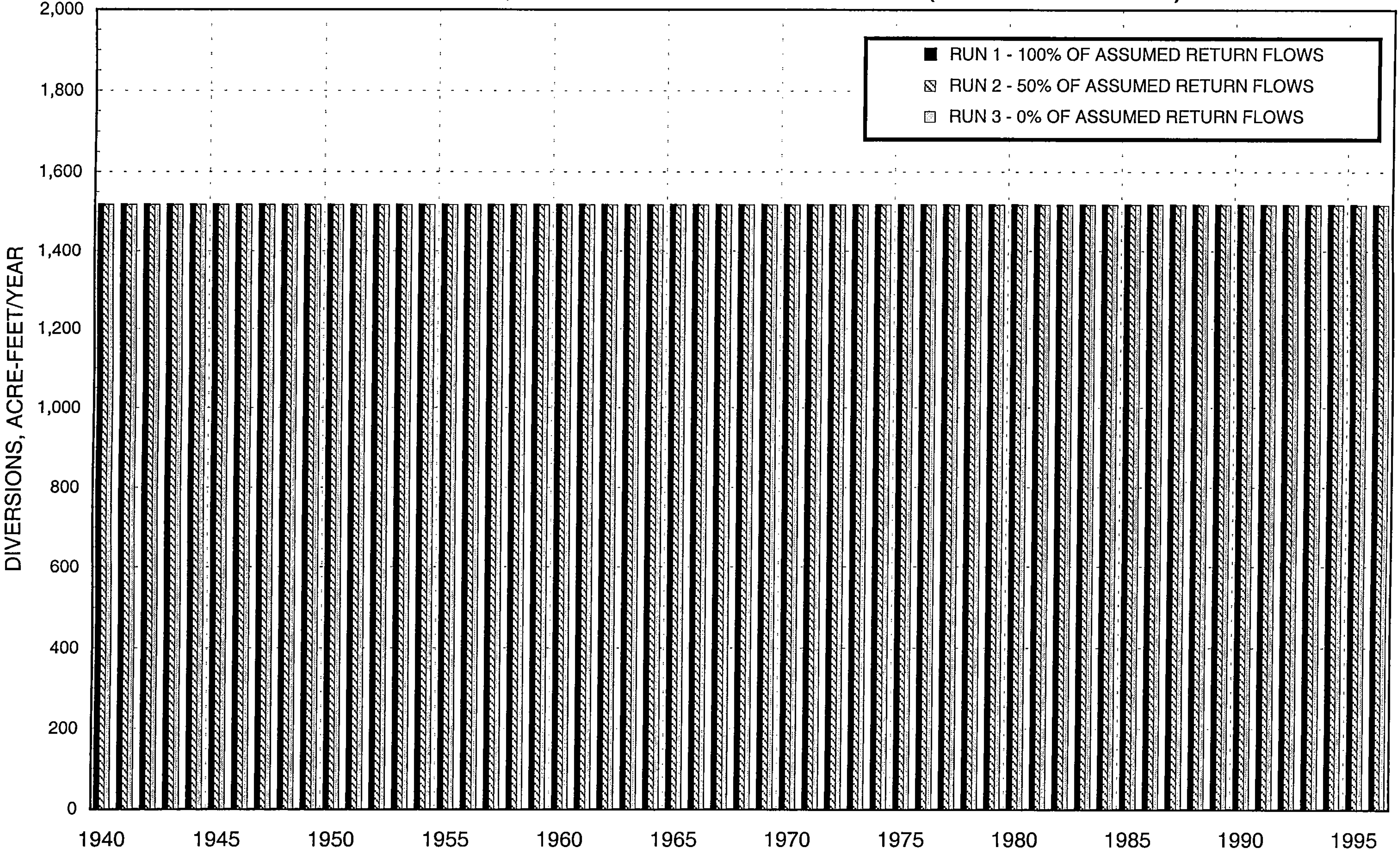


FIGURE A3-5
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHT 4830, WILLIAM E. JOHNSON, JR., ET AL (CONTROL POINT F110)

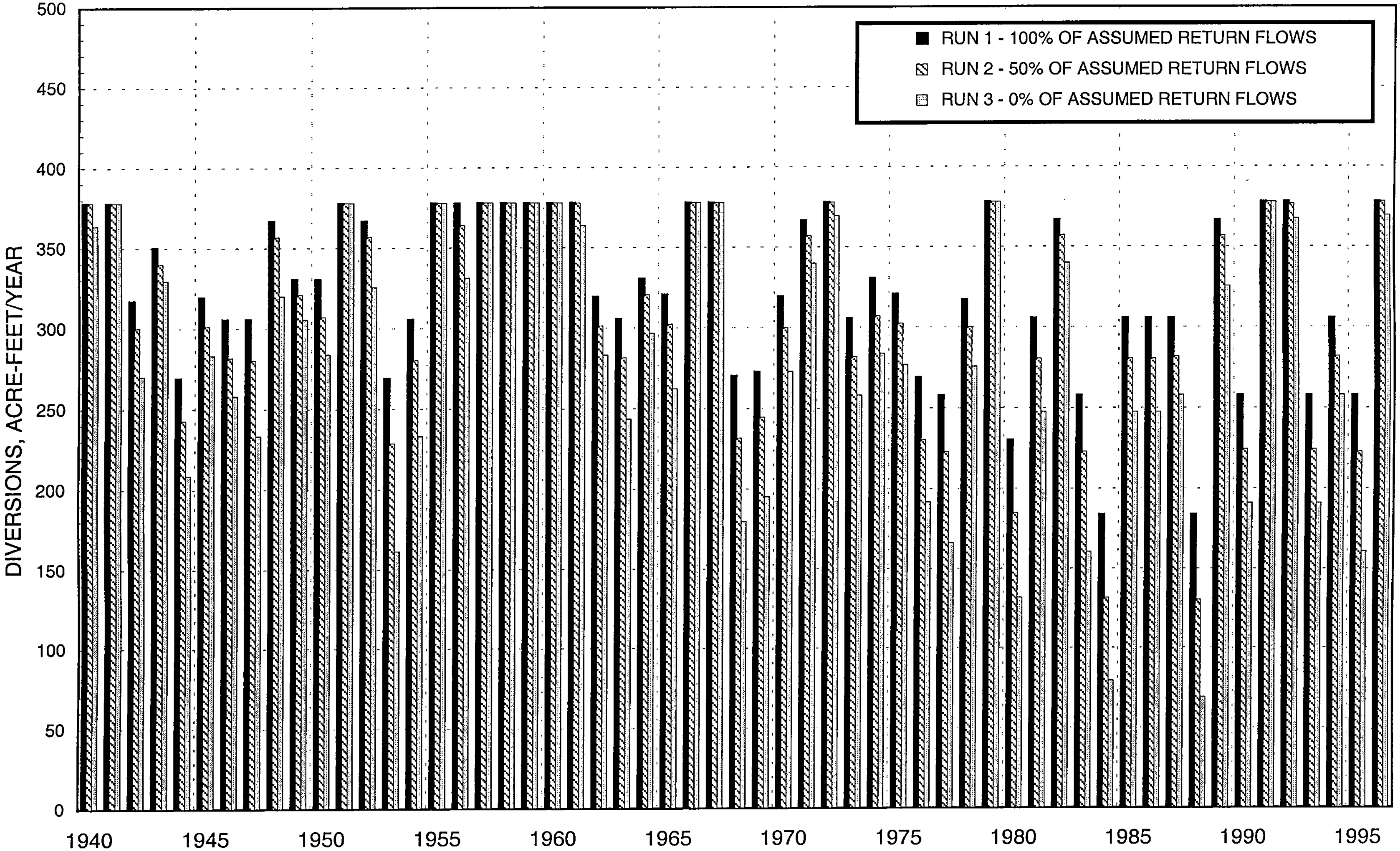


FIGURE A3-6
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHT 4804, TEXAS UTILITIES ELECTRIC RIVER CREST PLANT (CONTROL POINT C20)

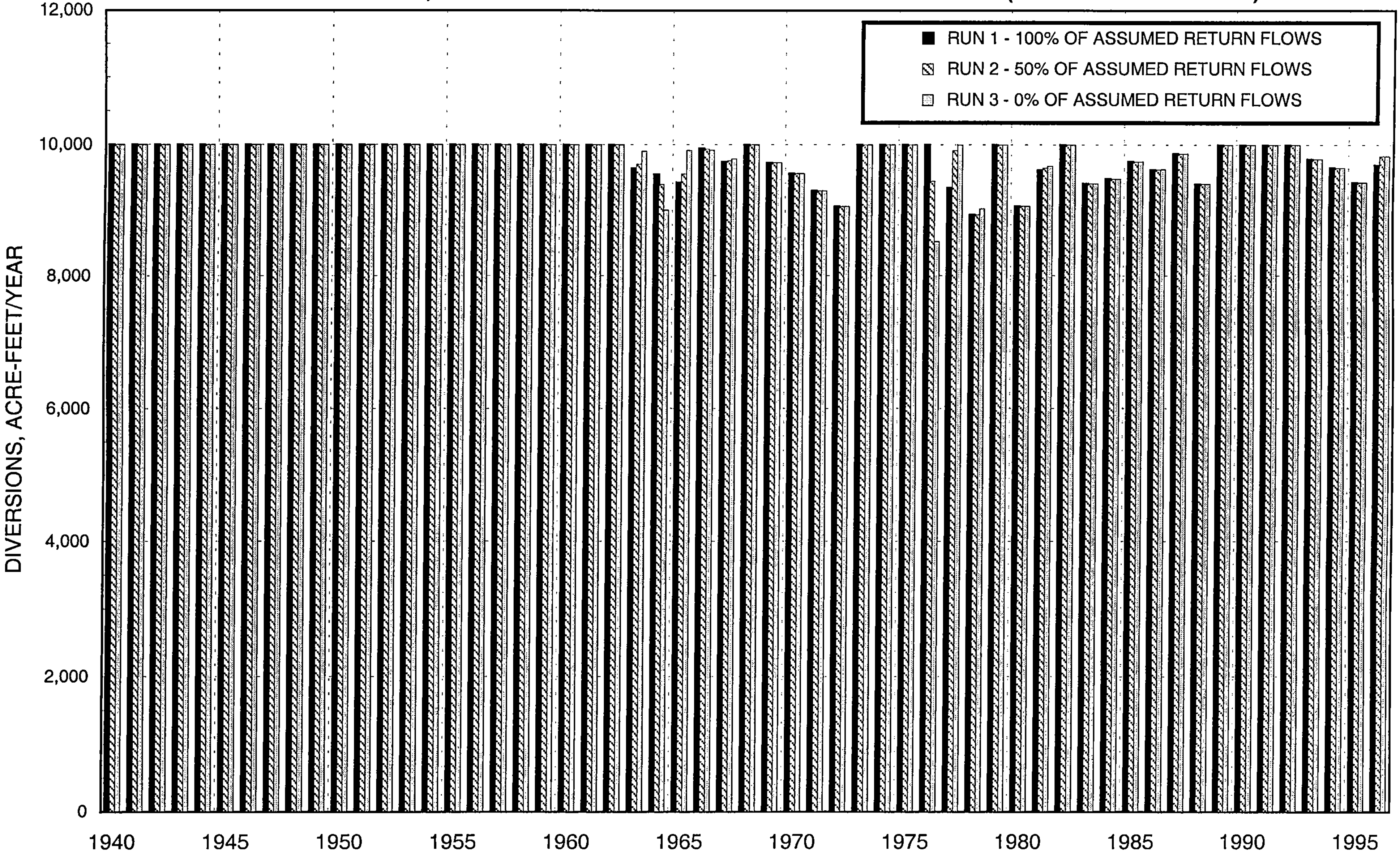


FIGURE A3-7
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHT 4817, HANS WEISS (CONTROL POINT D40)

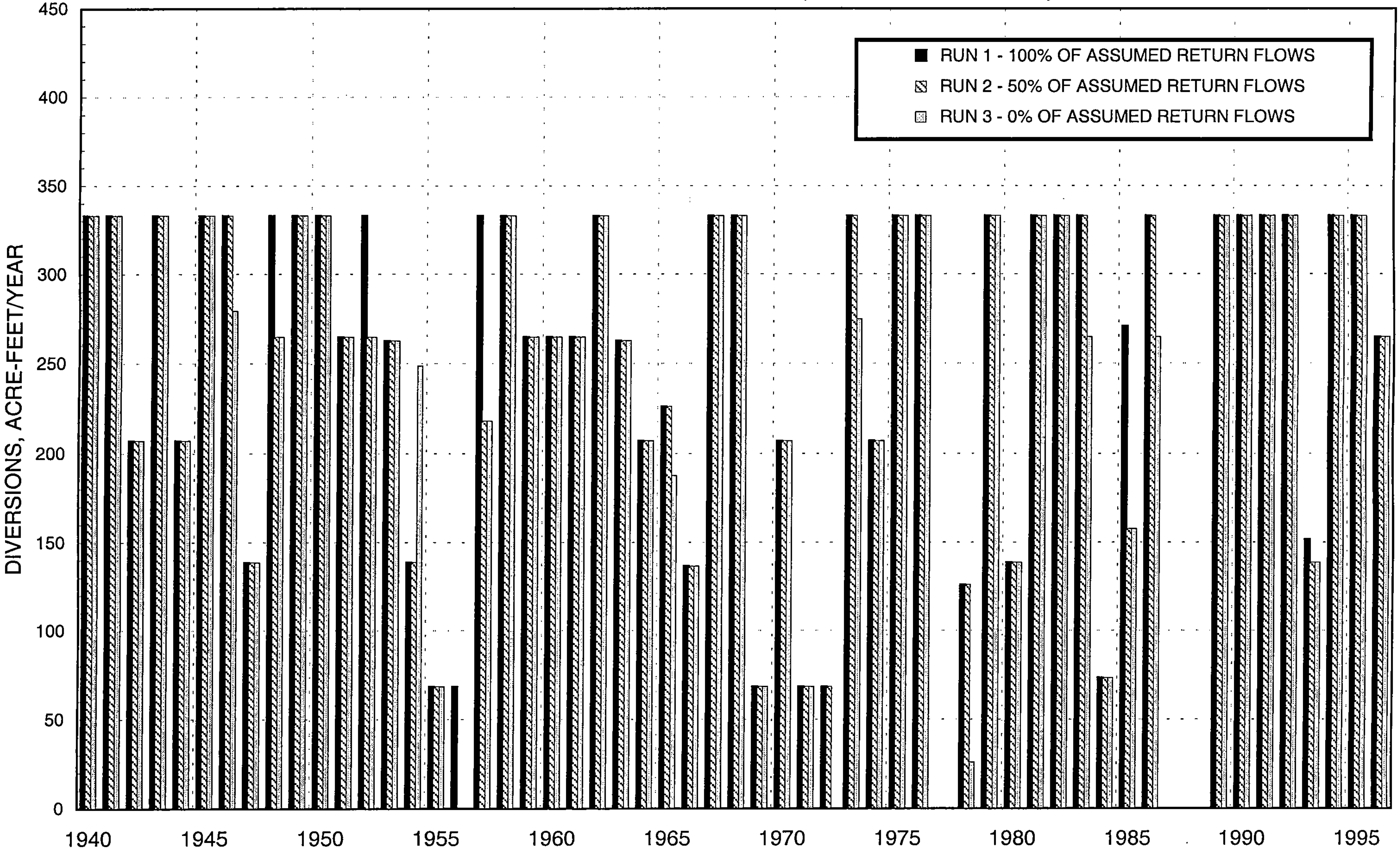


FIGURE A3-8
ANNUAL DIVERSIONS AVAILABLE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHT 4148B, SARA M. DUNHAM TRUST RIVER DIVERSIONS (CONTROL POINT C60)

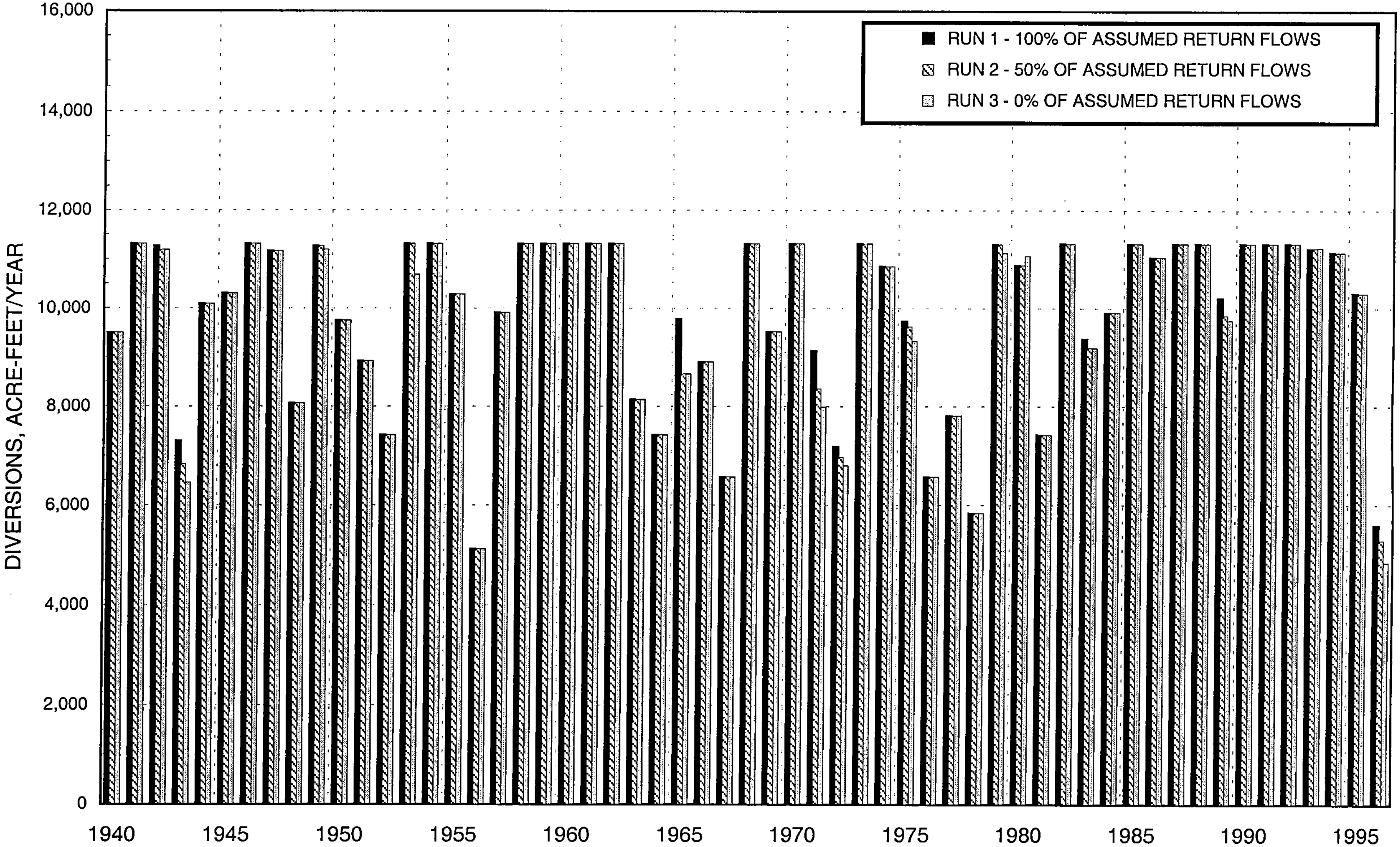


FIGURE A3-9
MONTHLY RESERVOIR STORAGE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHT 4830, WRIGHT PATMAN LAKE (CONTROL POINT F60)

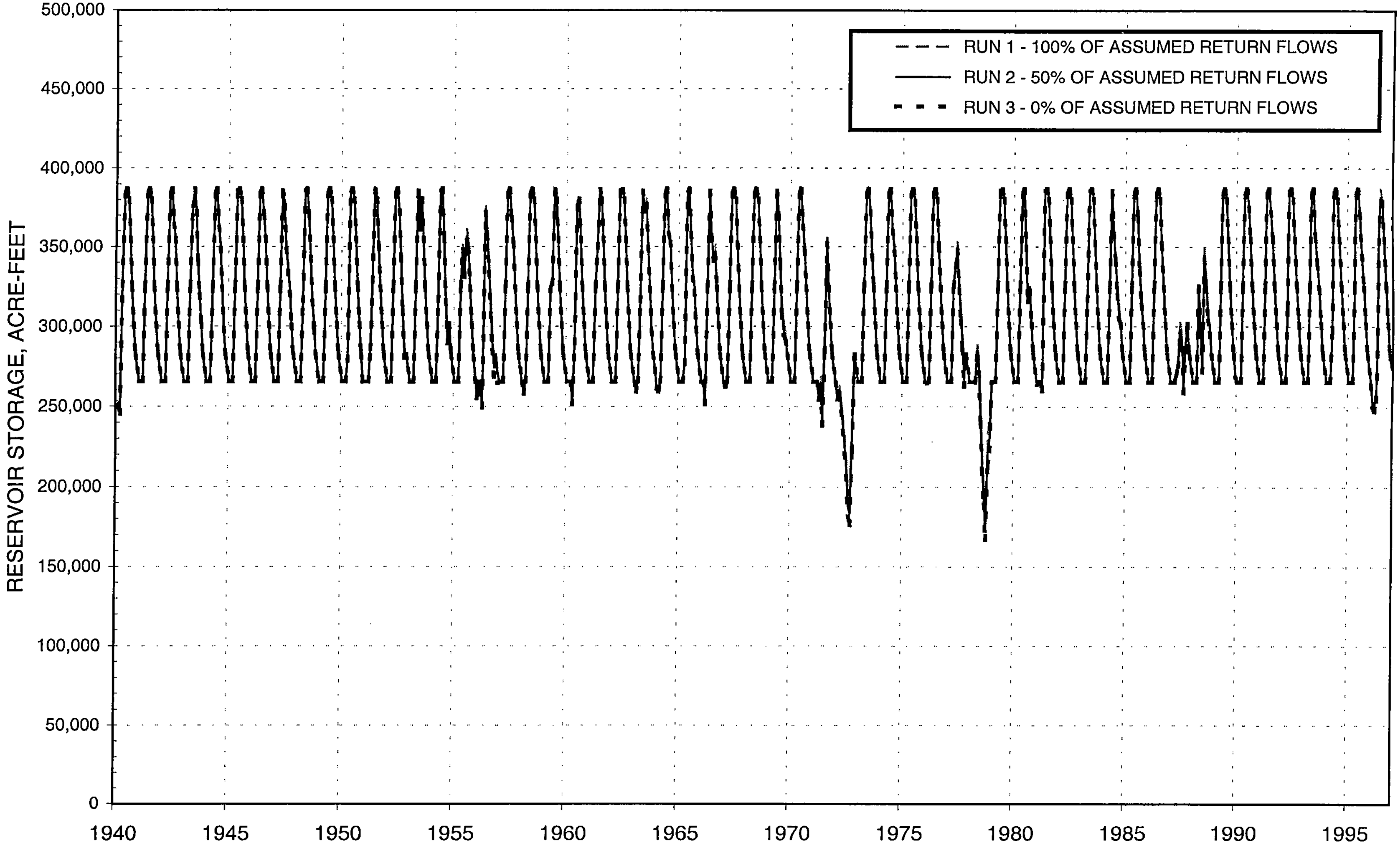


FIGURE A3-10
MONTHLY RESERVOIR STORAGE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

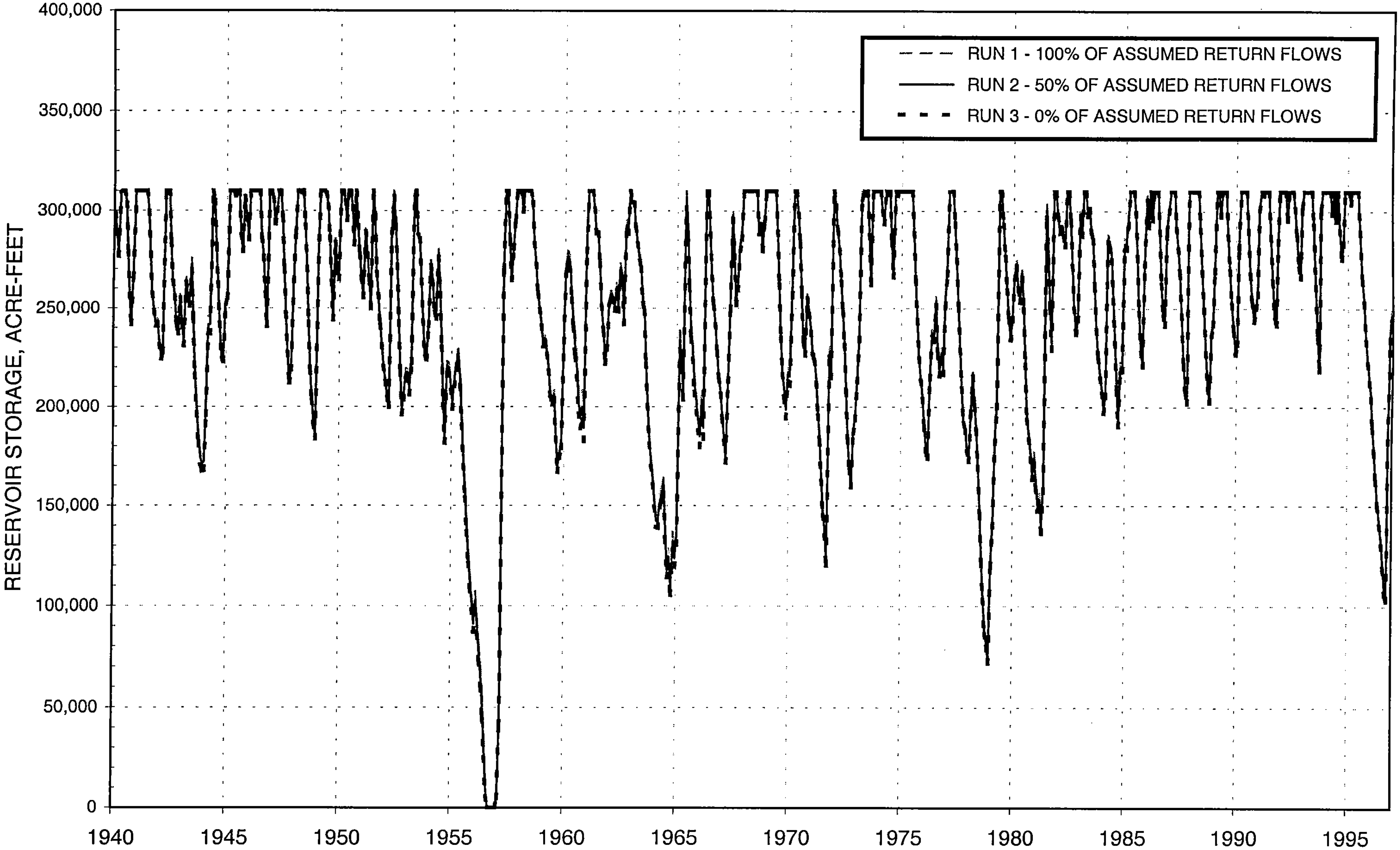


FIGURE A3-11
MONTHLY RESERVOIR STORAGE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

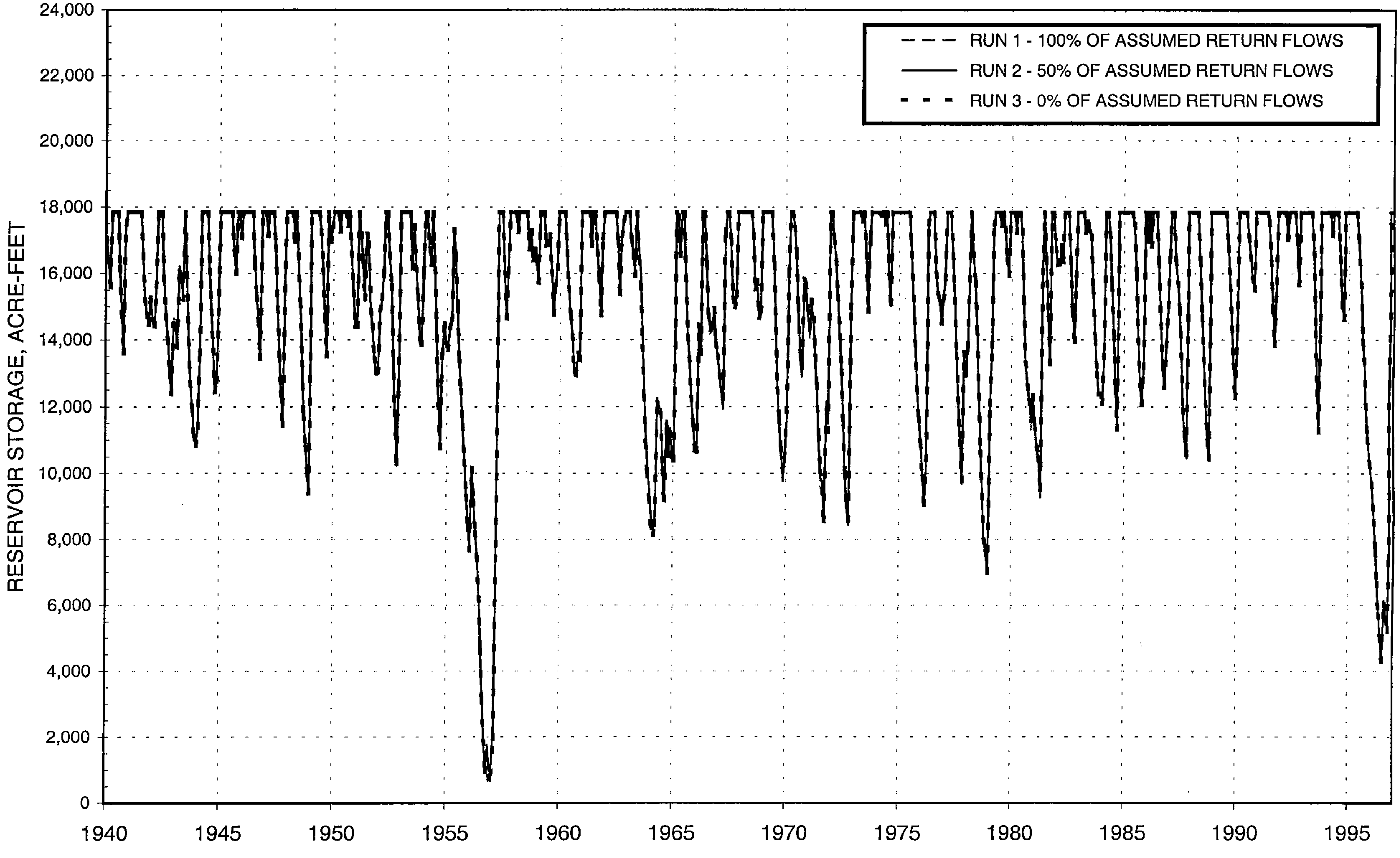


FIGURE A3-12
MONTHLY RESERVOIR STORAGE UNDER VARYING LEVELS OF RETURN FLOWS
FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

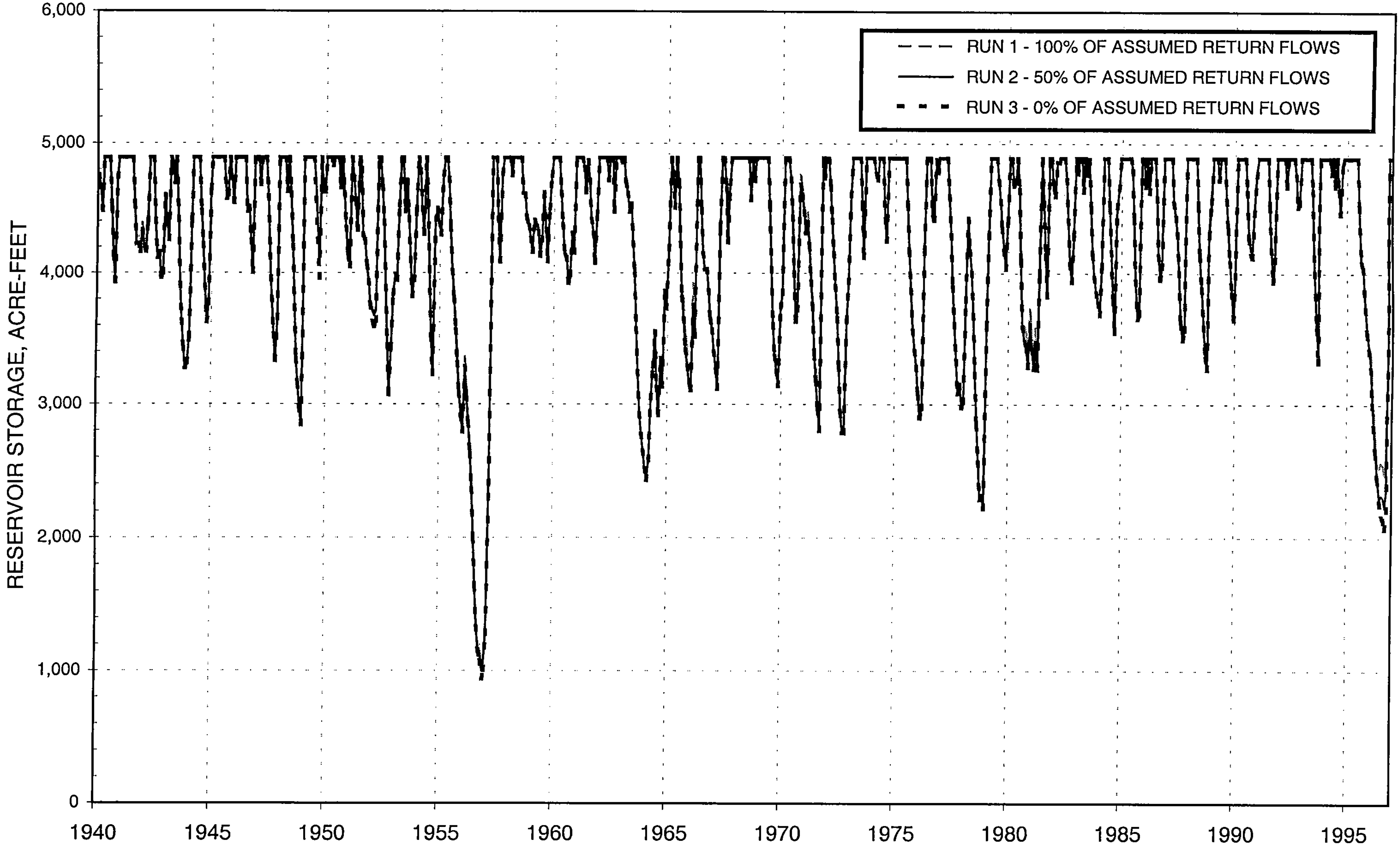


FIGURE A3-13
MONTHLY RESERVOIR STORAGE UNDER VARYING LEVELS OF RETURN FLOWS FOR WATER RIGHT 4148B, SARAH M. DUNHAM TRUST (CONTROL POINT C60)

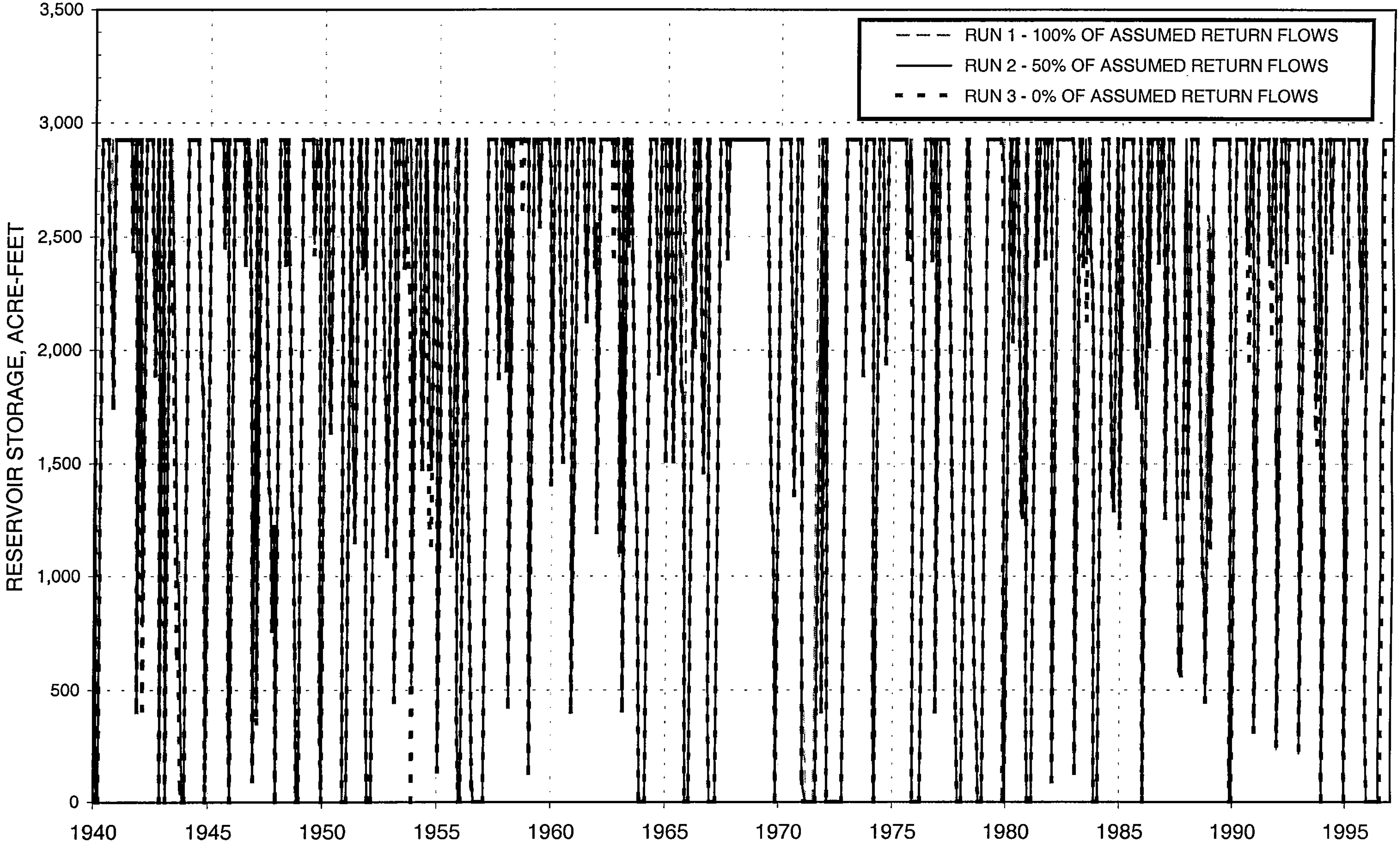


FIGURE A3-14

ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

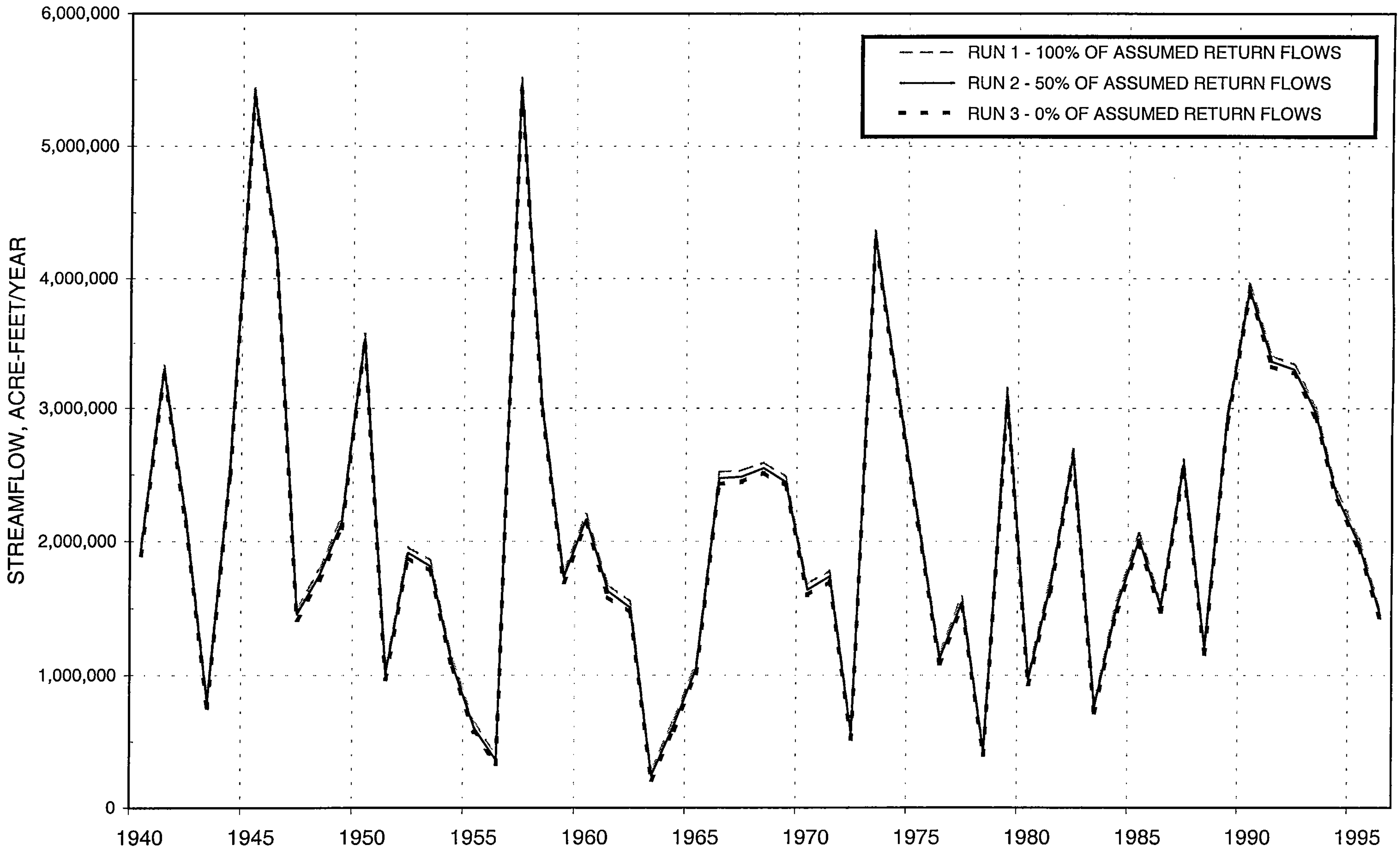


FIGURE A3-15
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

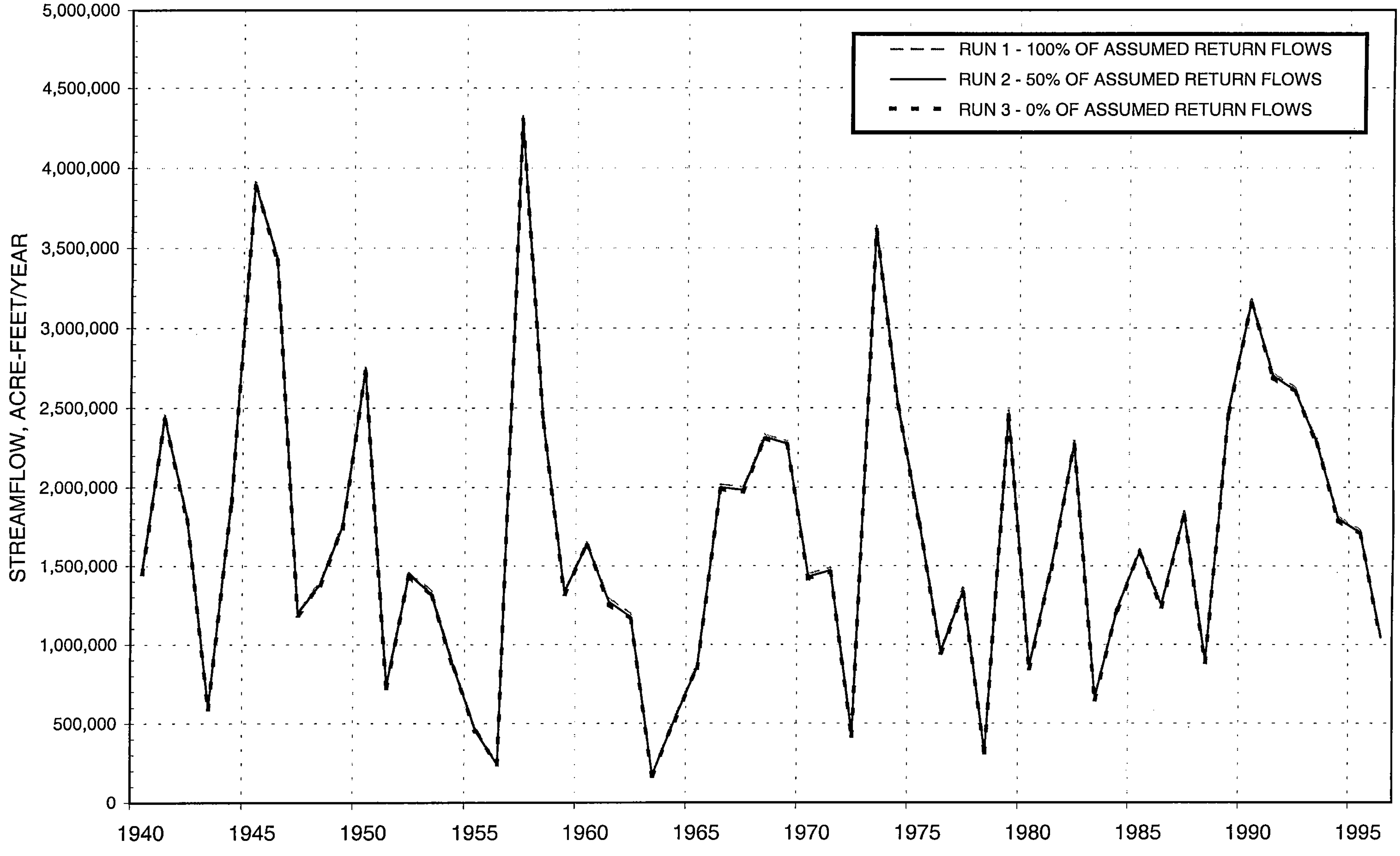


FIGURE A3-16
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS
AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

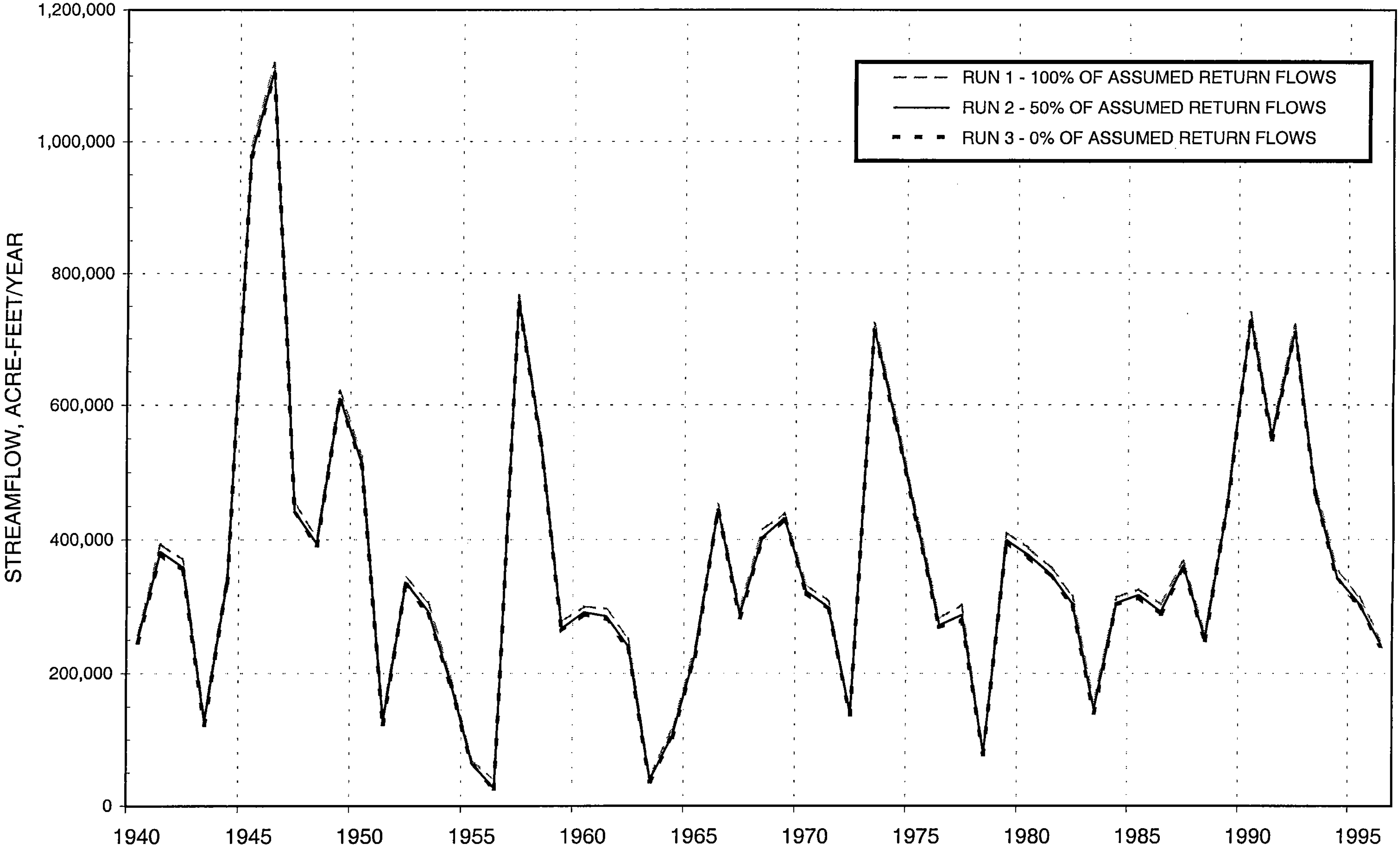


FIGURE A3-17
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

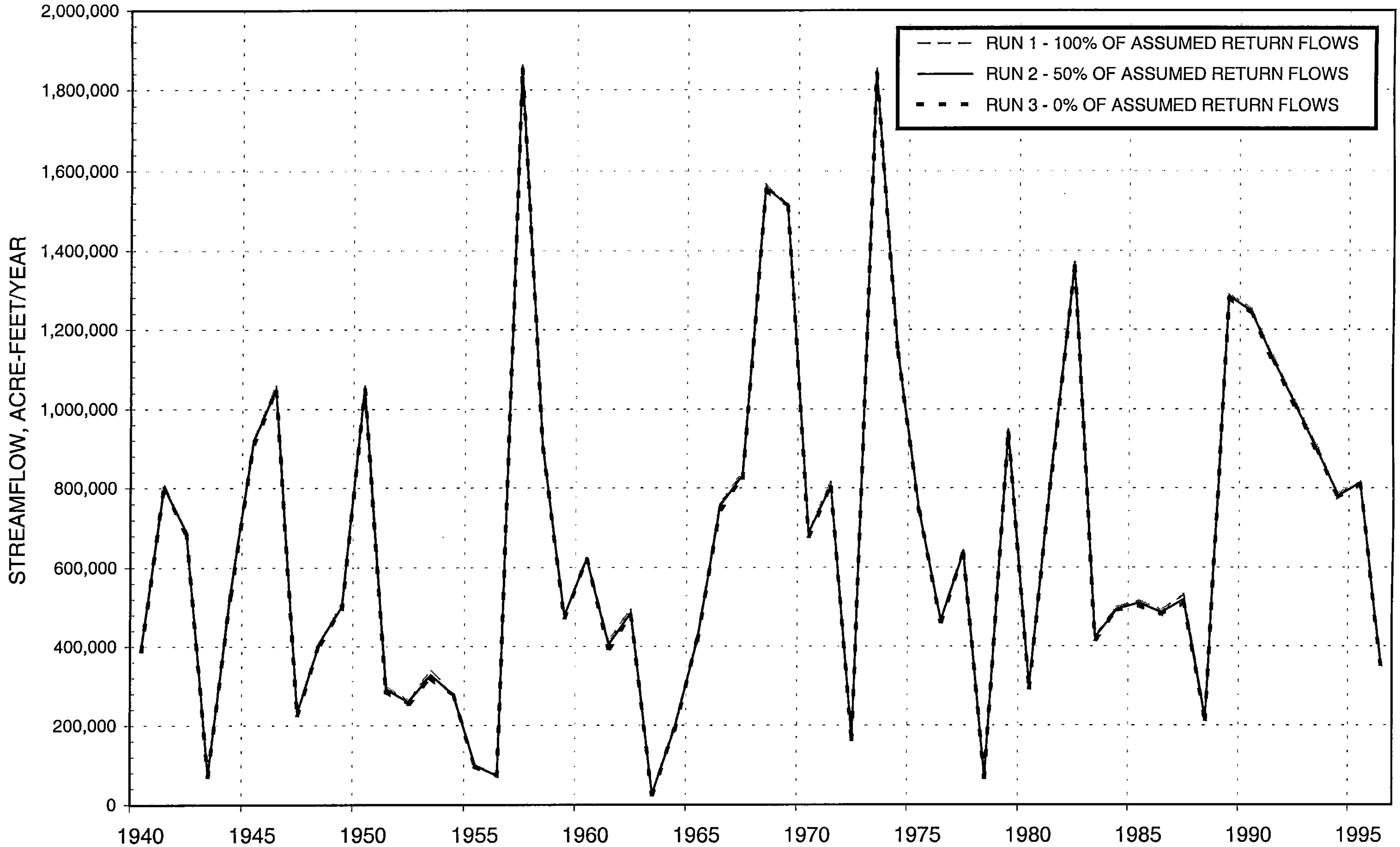


FIGURE A3-18
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS
AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

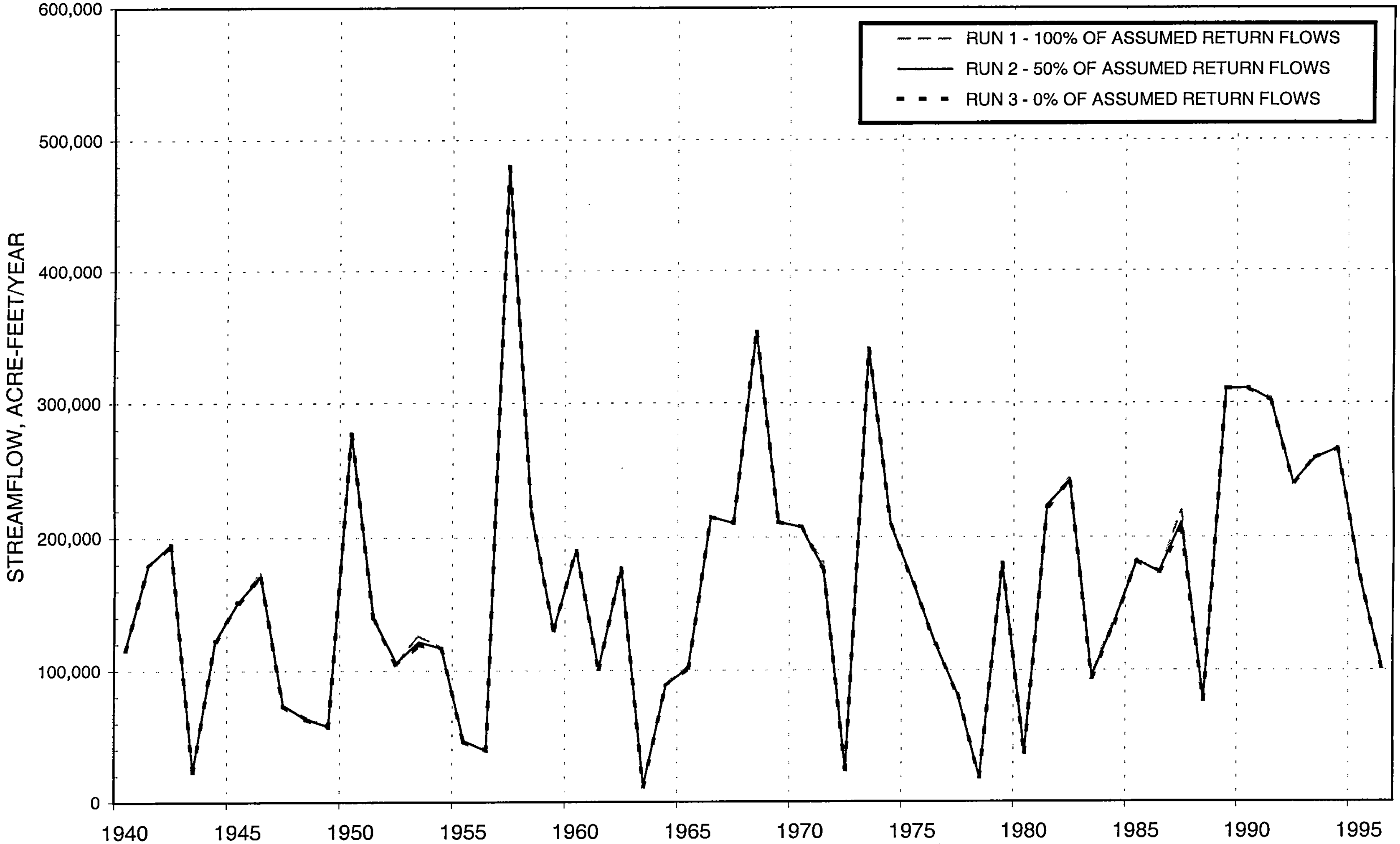


FIGURE A3-19
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

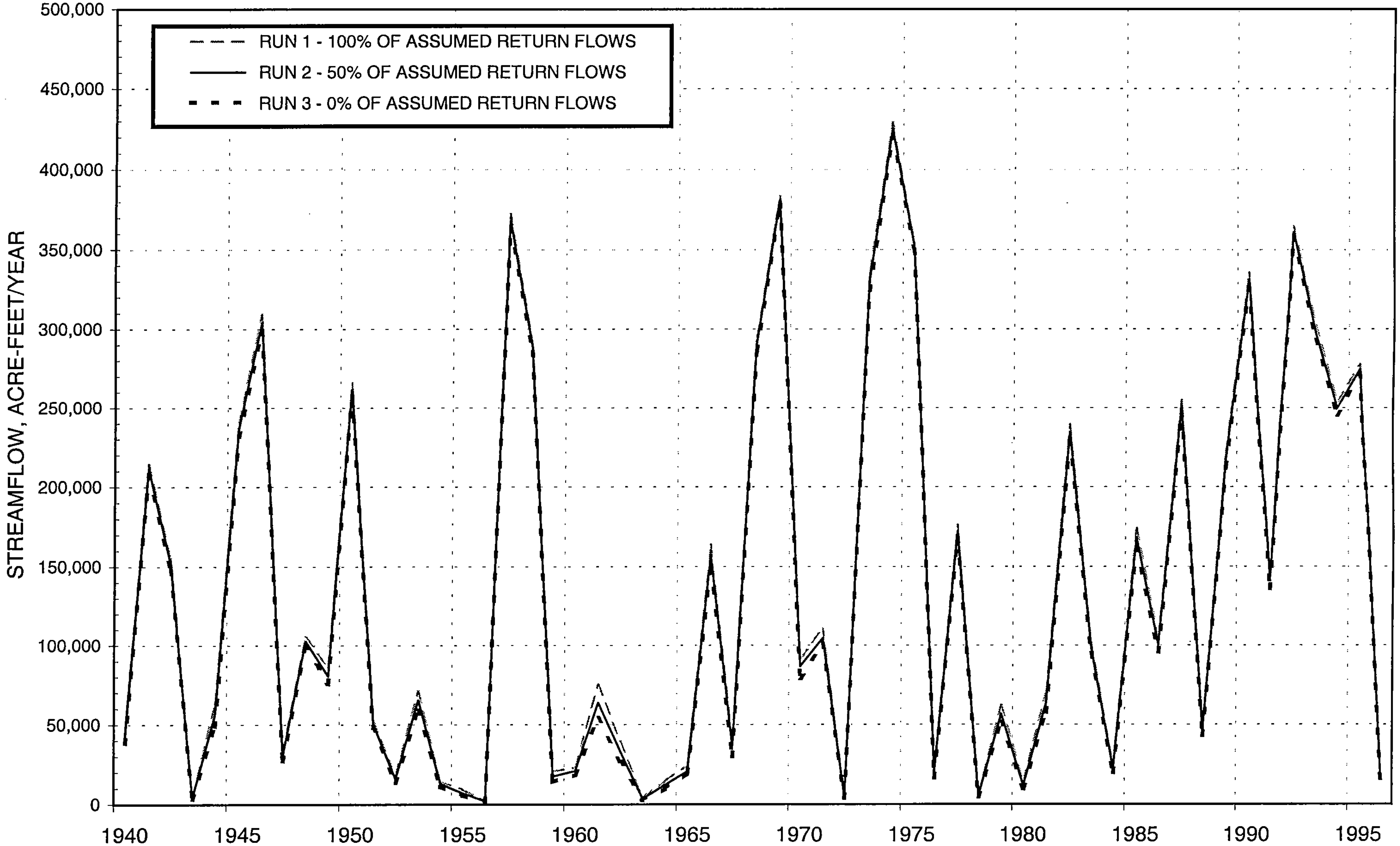


FIGURE A3-20
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

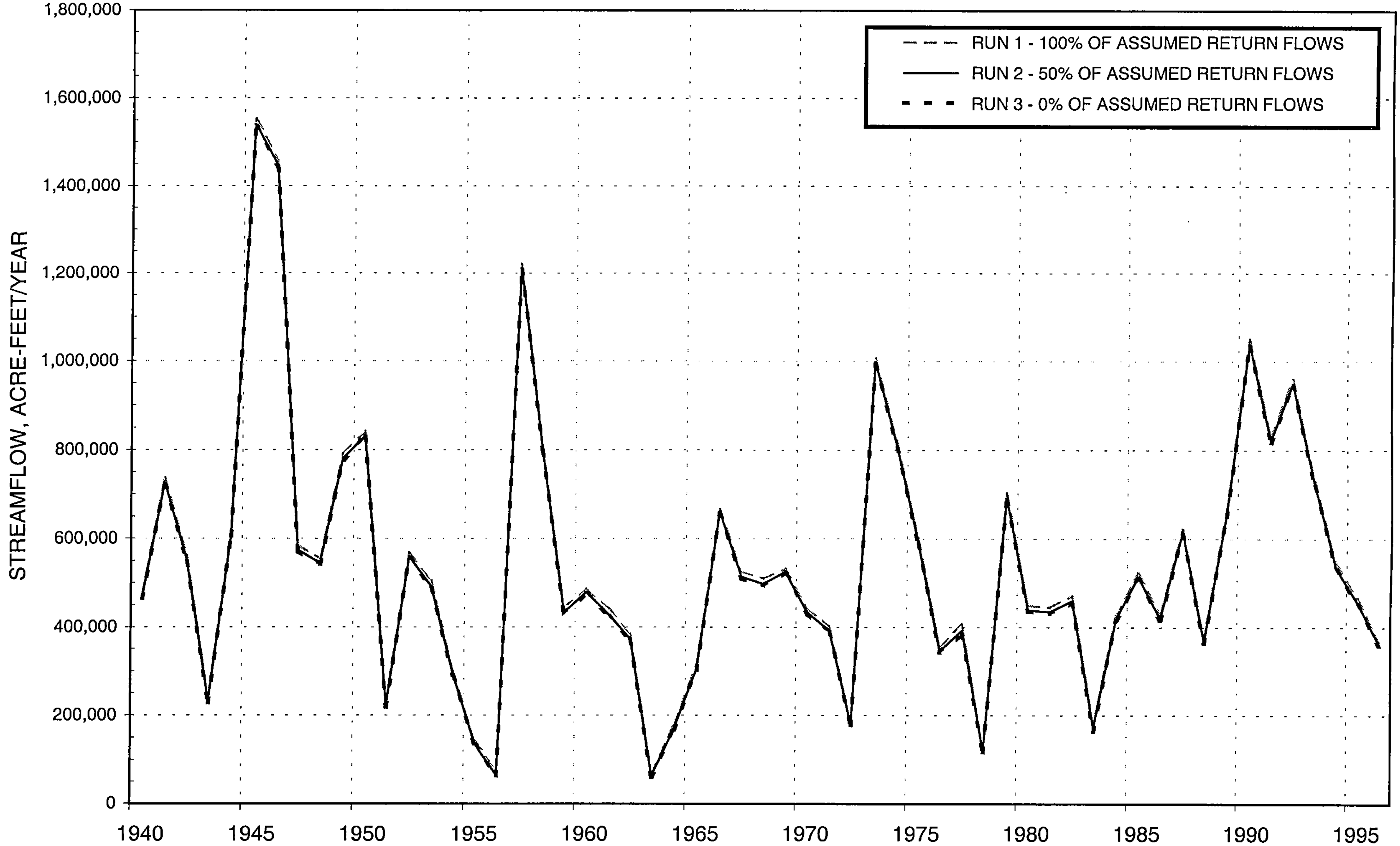


FIGURE A3-21
ANNUAL UNAPPROPRIATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

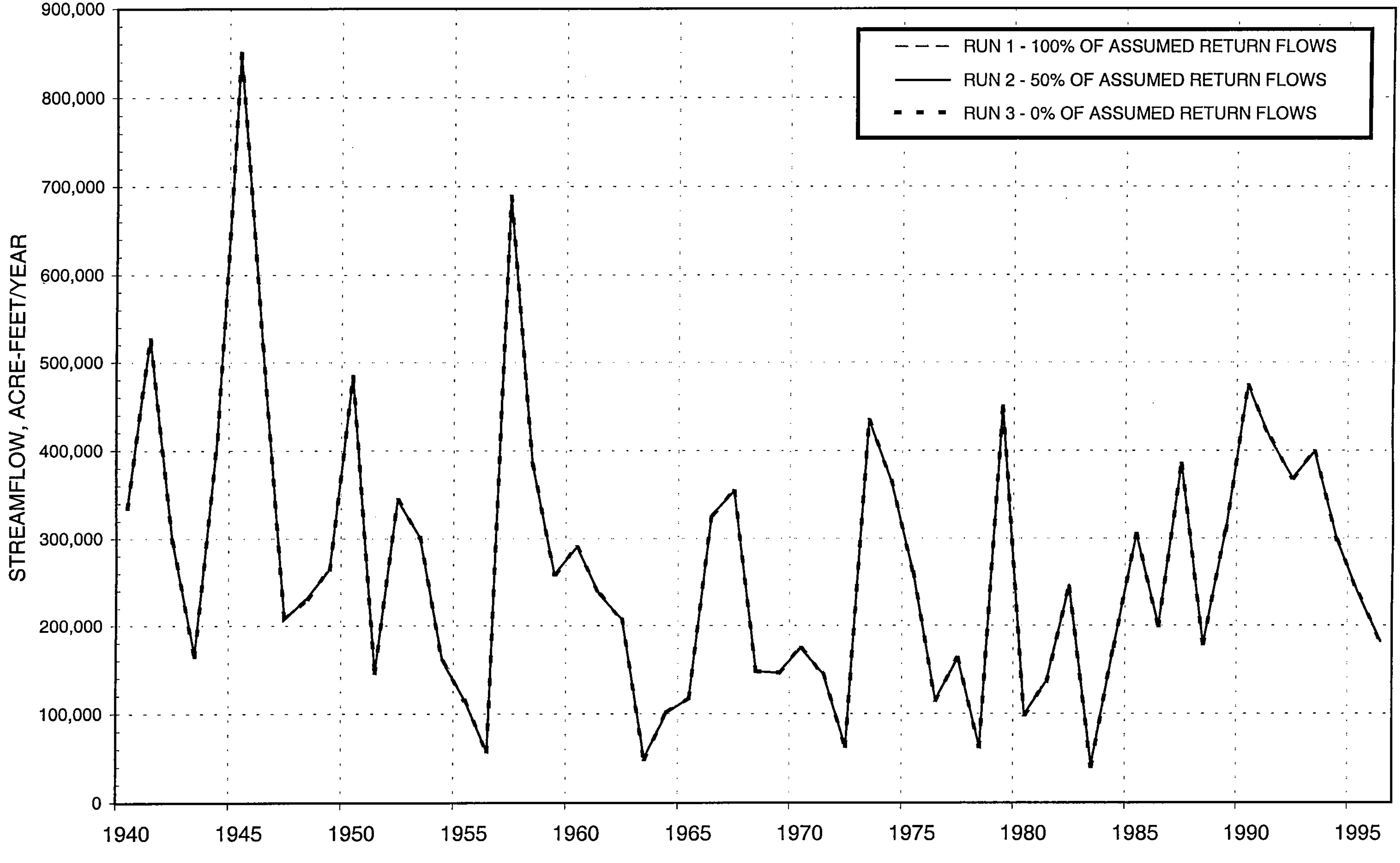


FIGURE A3-23
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

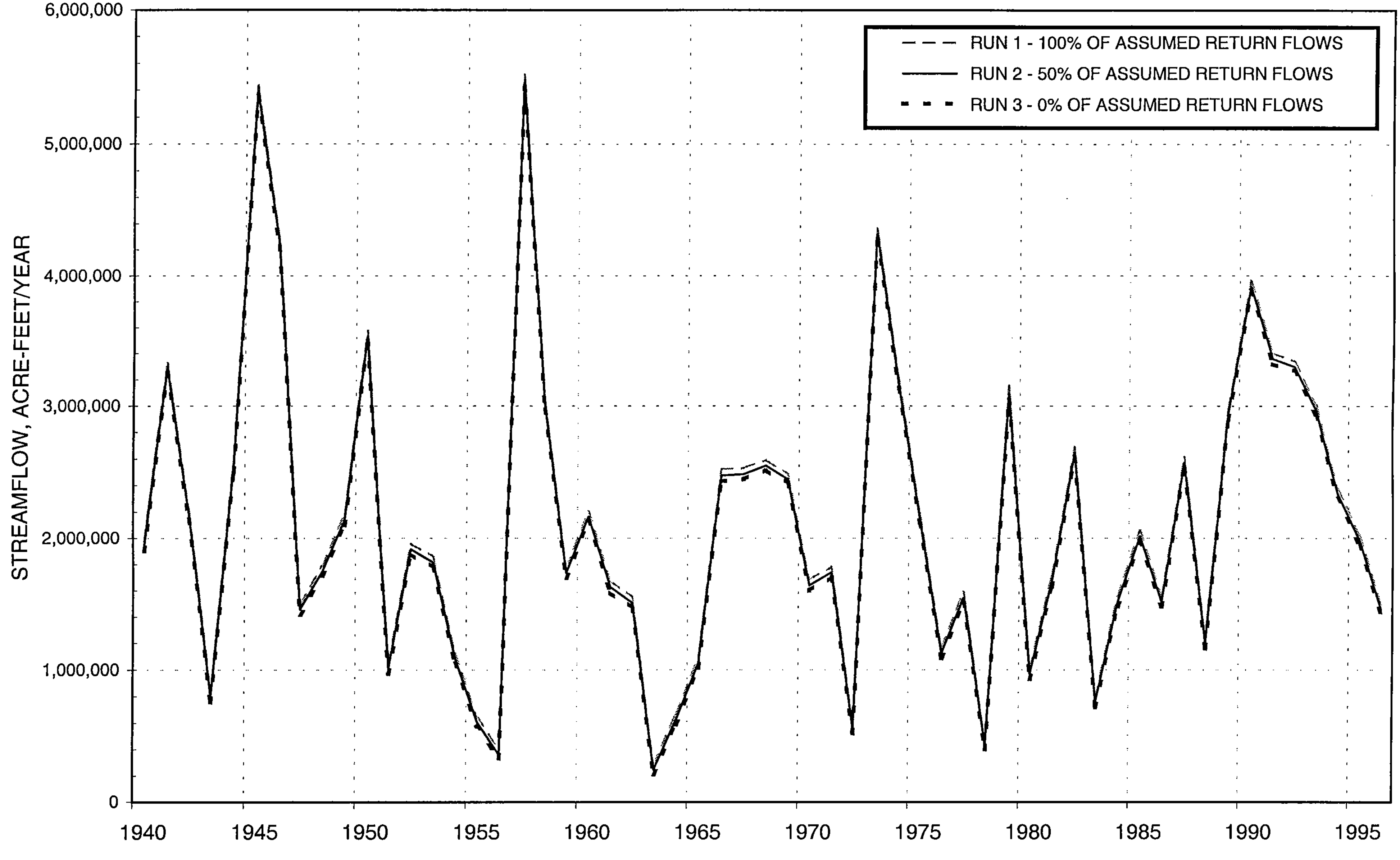


FIGURE A3-24
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

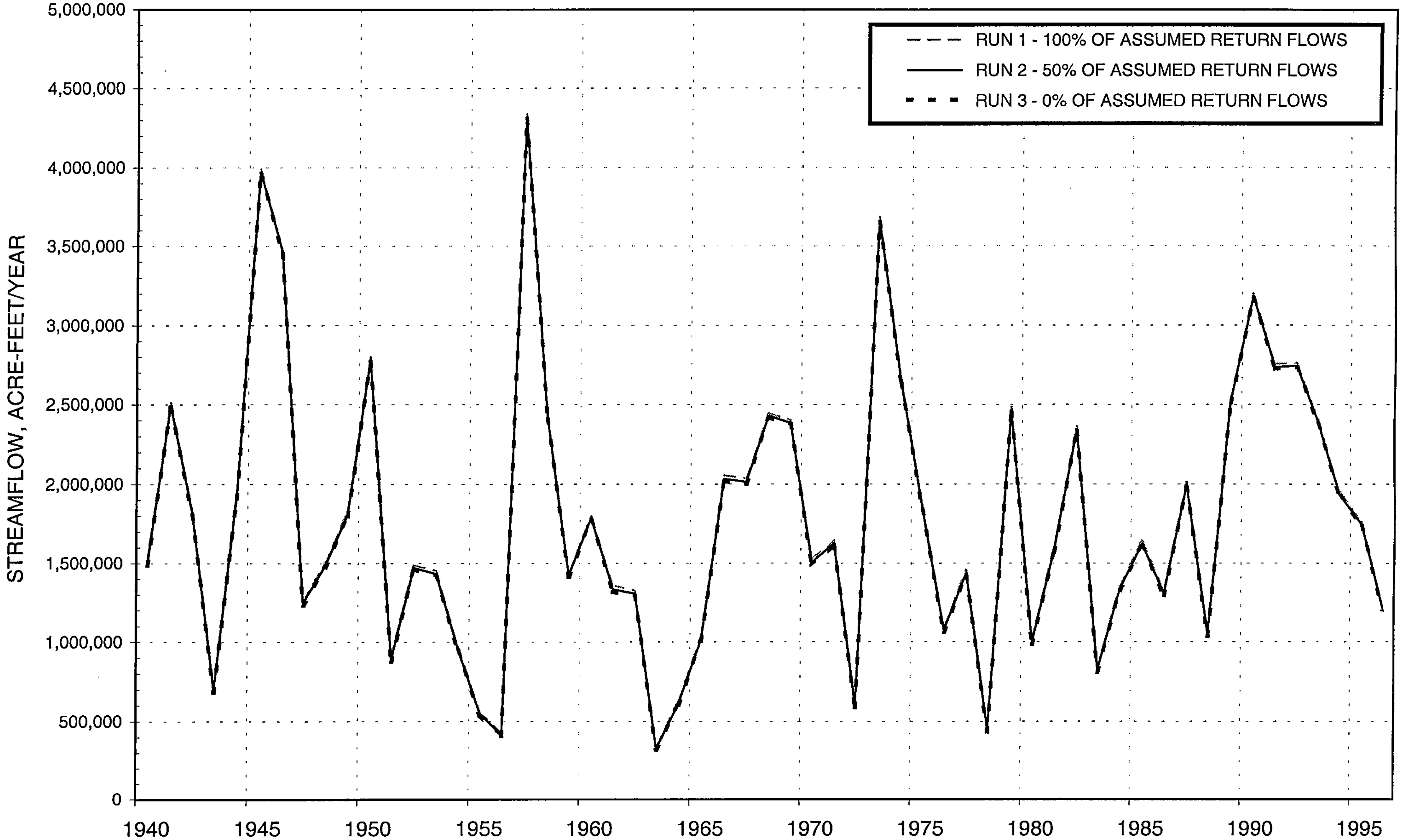


FIGURE A3-25
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS
AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

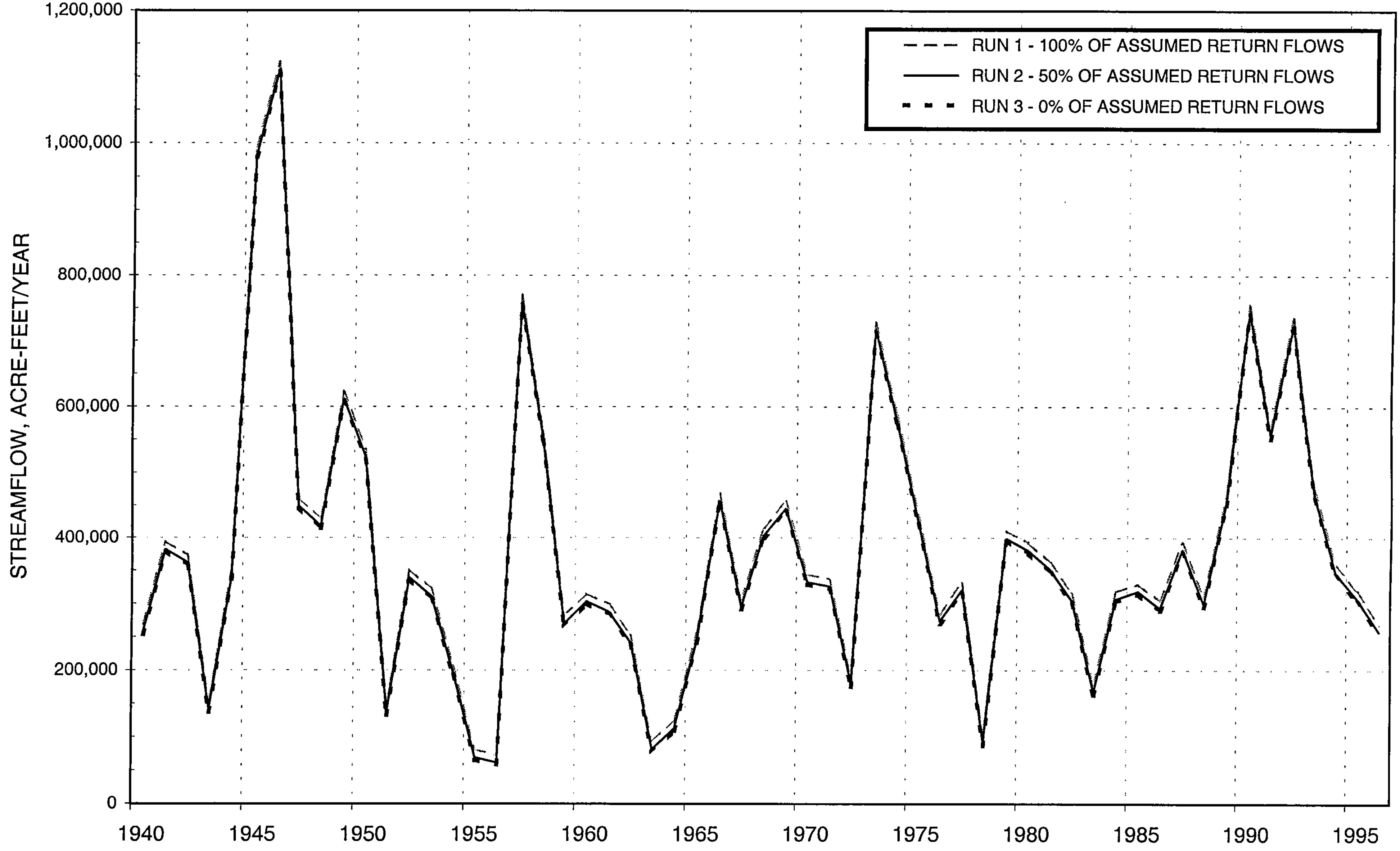


FIGURE A3-26
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS
AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

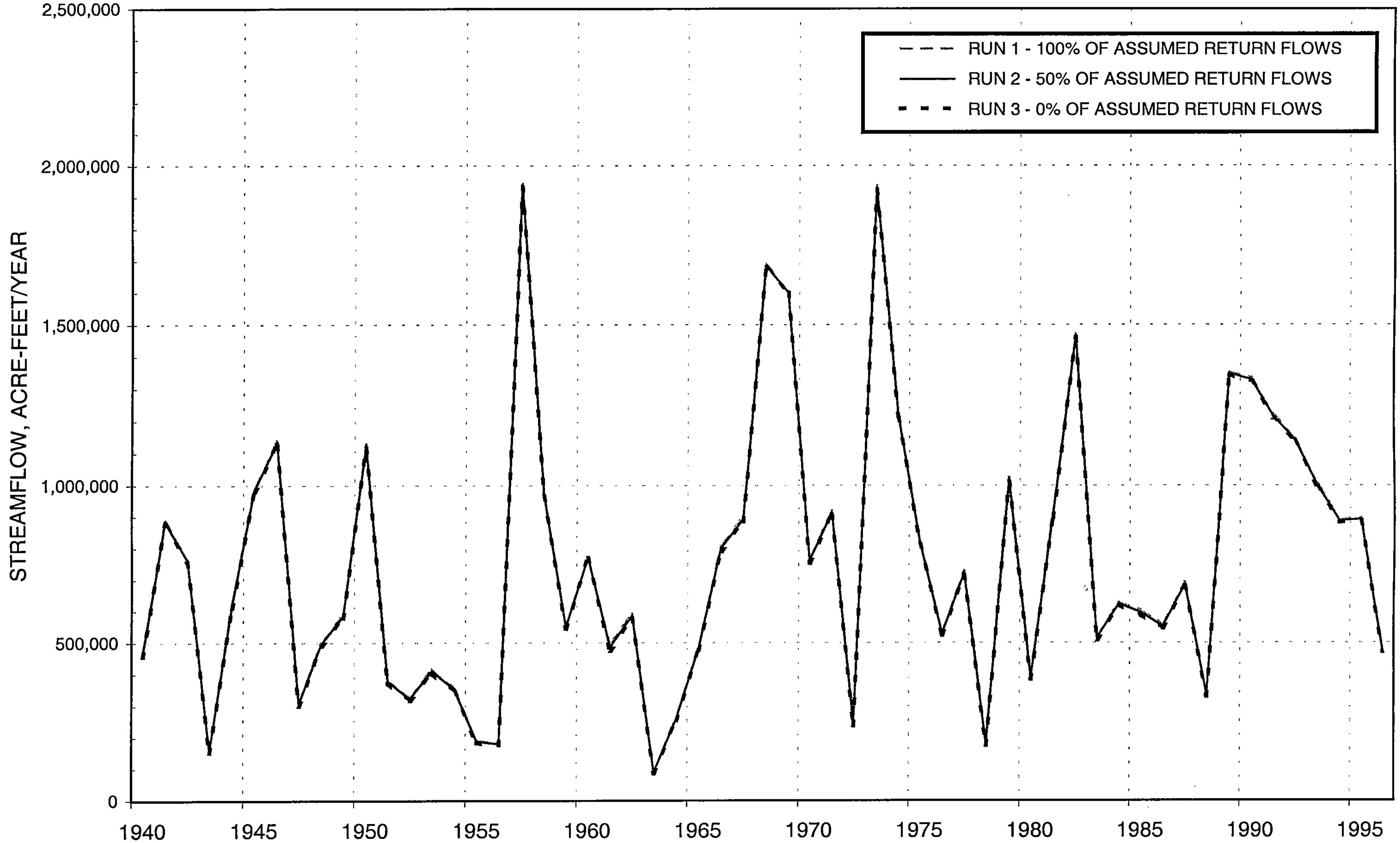


FIGURE A3-27
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

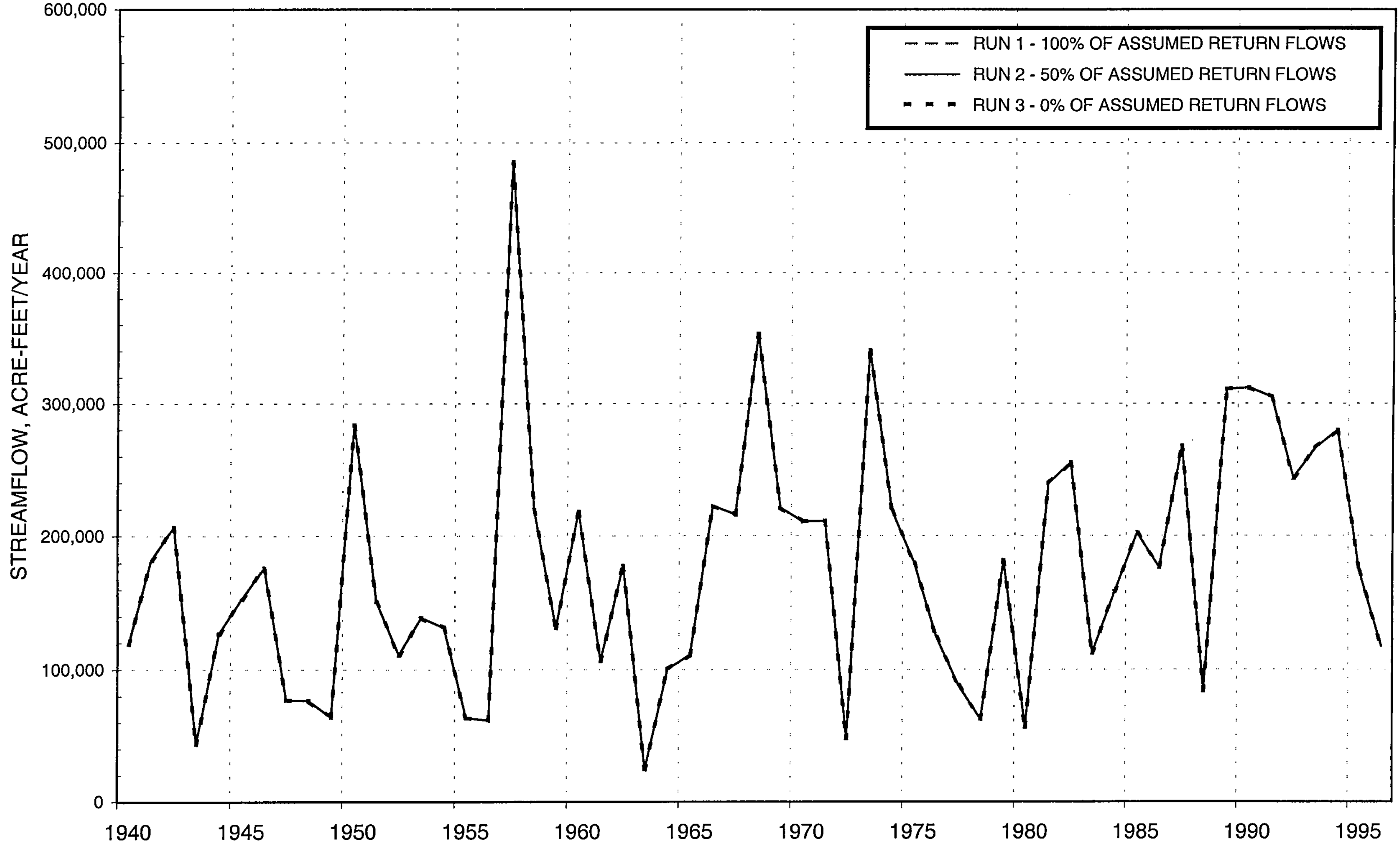


FIGURE A3-28
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

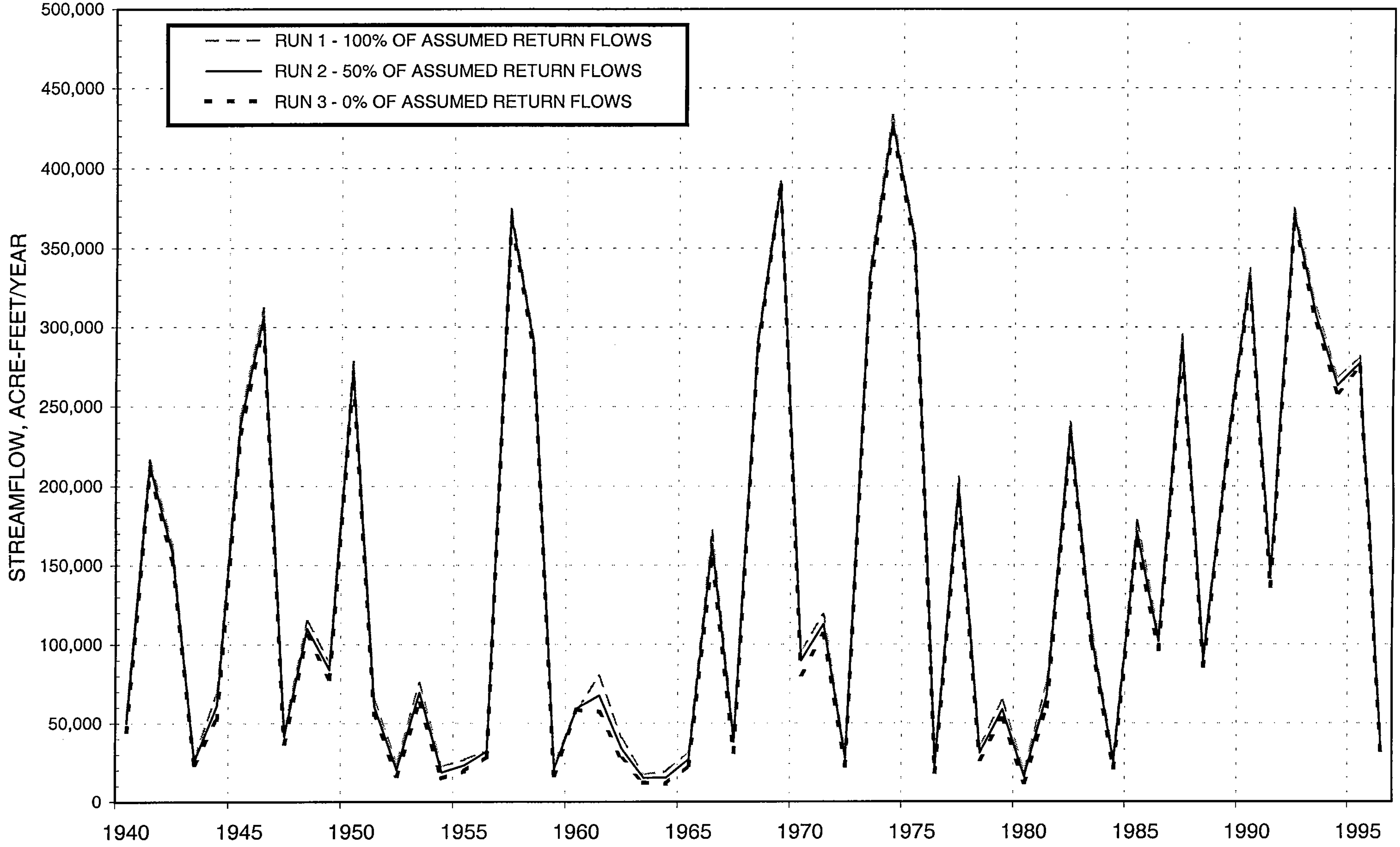


FIGURE A3-29
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

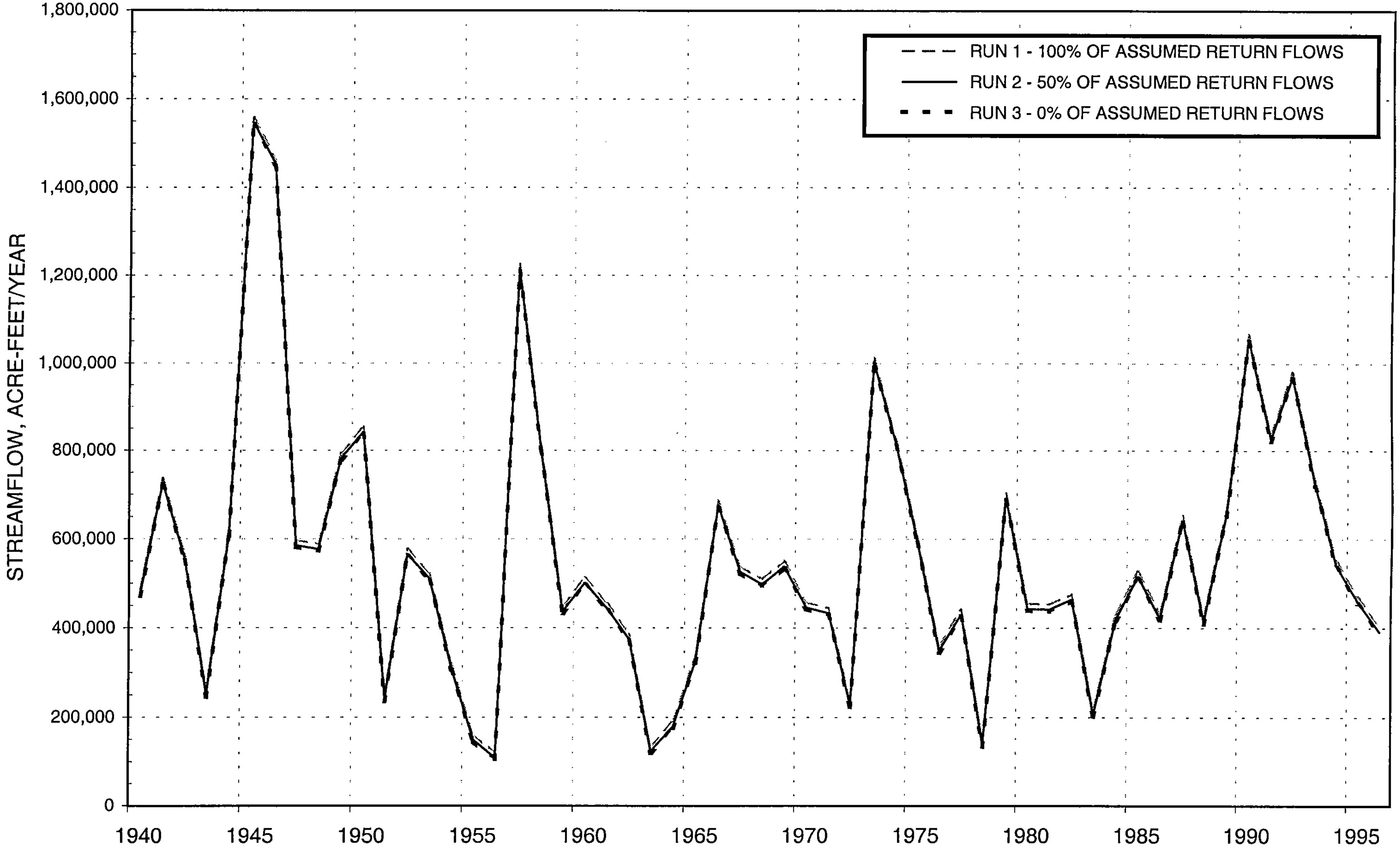


FIGURE A3-30
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS
AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

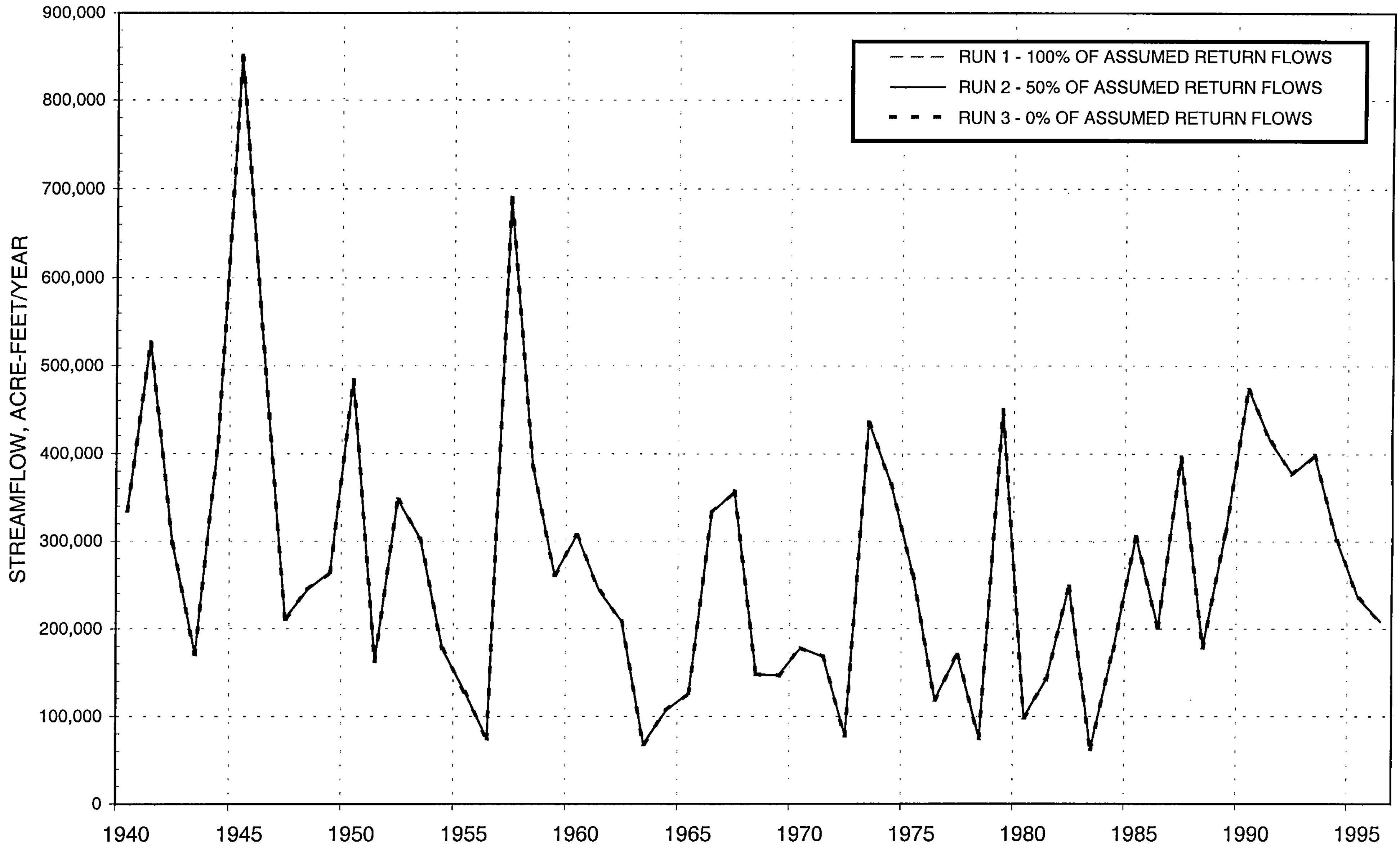
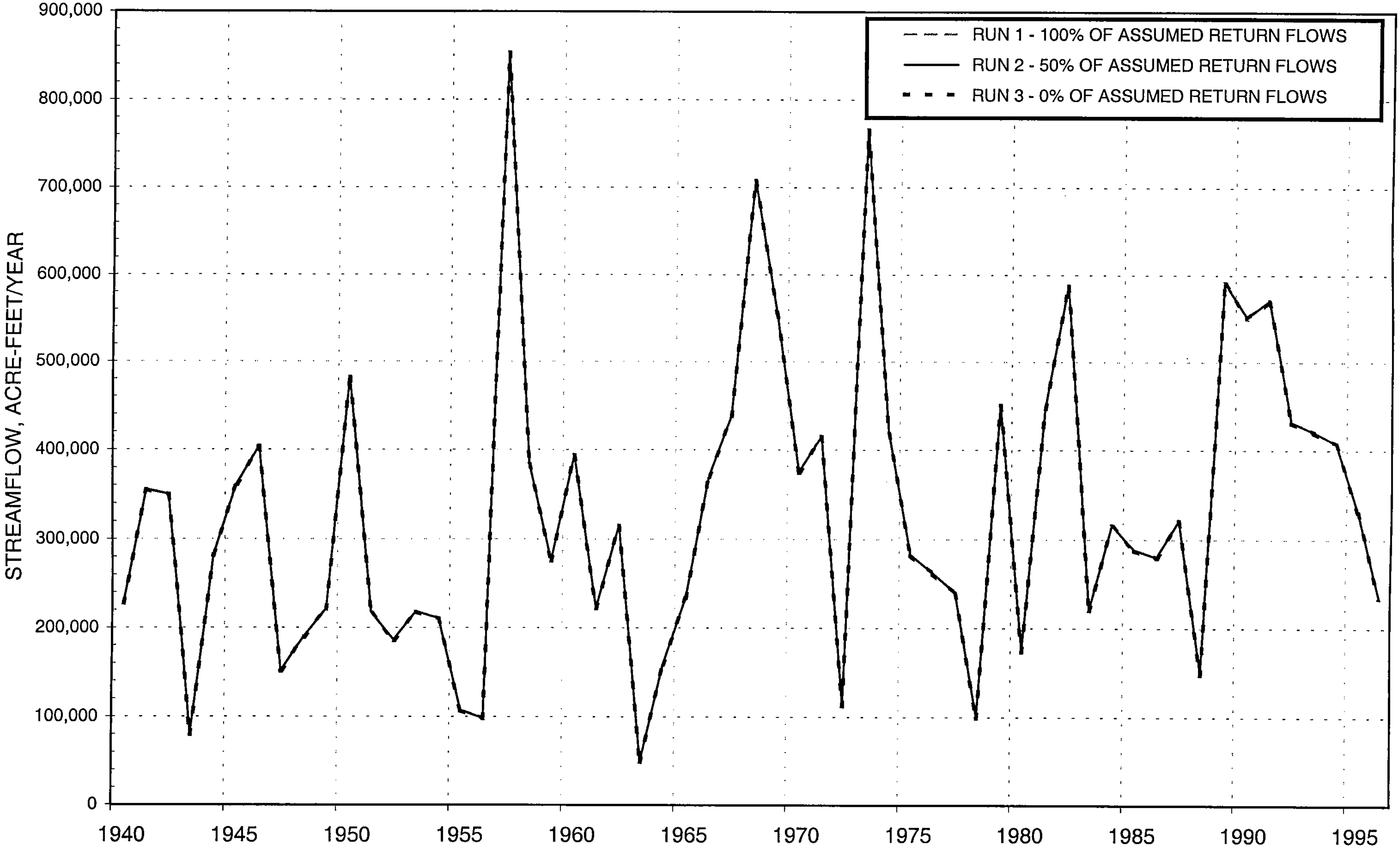


FIGURE A3-31
ANNUAL REGULATED FLOWS UNDER VARYING LEVELS OF RETURN FLOWS AT CONTROL POINT C90, NORTH SULPHUR RIVER



APPENDIX 4

SELECTED WRAP RESULTS FROM CANCELLATION ANALYSES RUNS 1, 4, 5, 6, AND 7

Diversions:	Figures A4-1 through A4-16
Reservoir Storage:	Figures A4-17 through A4-26
Unappropriated Flows:	Figures A4-27 through A4-44
Regulated Flows:	Figures A4-45 through A4-62

FIGURE A4-1

ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4836, WRIGHT PATMAN LAKE (CONTROL POINT F60)

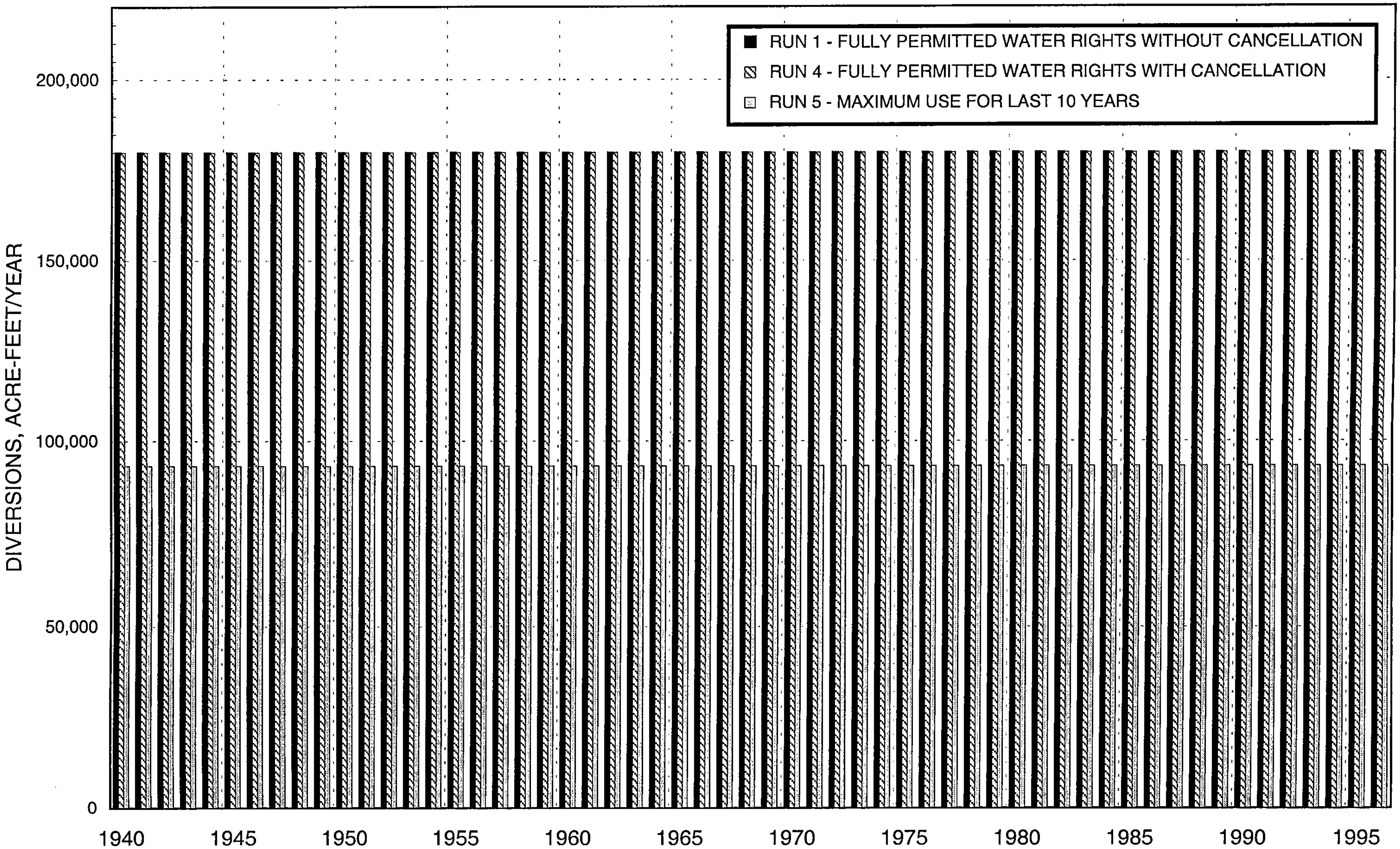


FIGURE A4-2
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4836, WRIGHT PATMAN LAKE (CONTROL POINT F60)

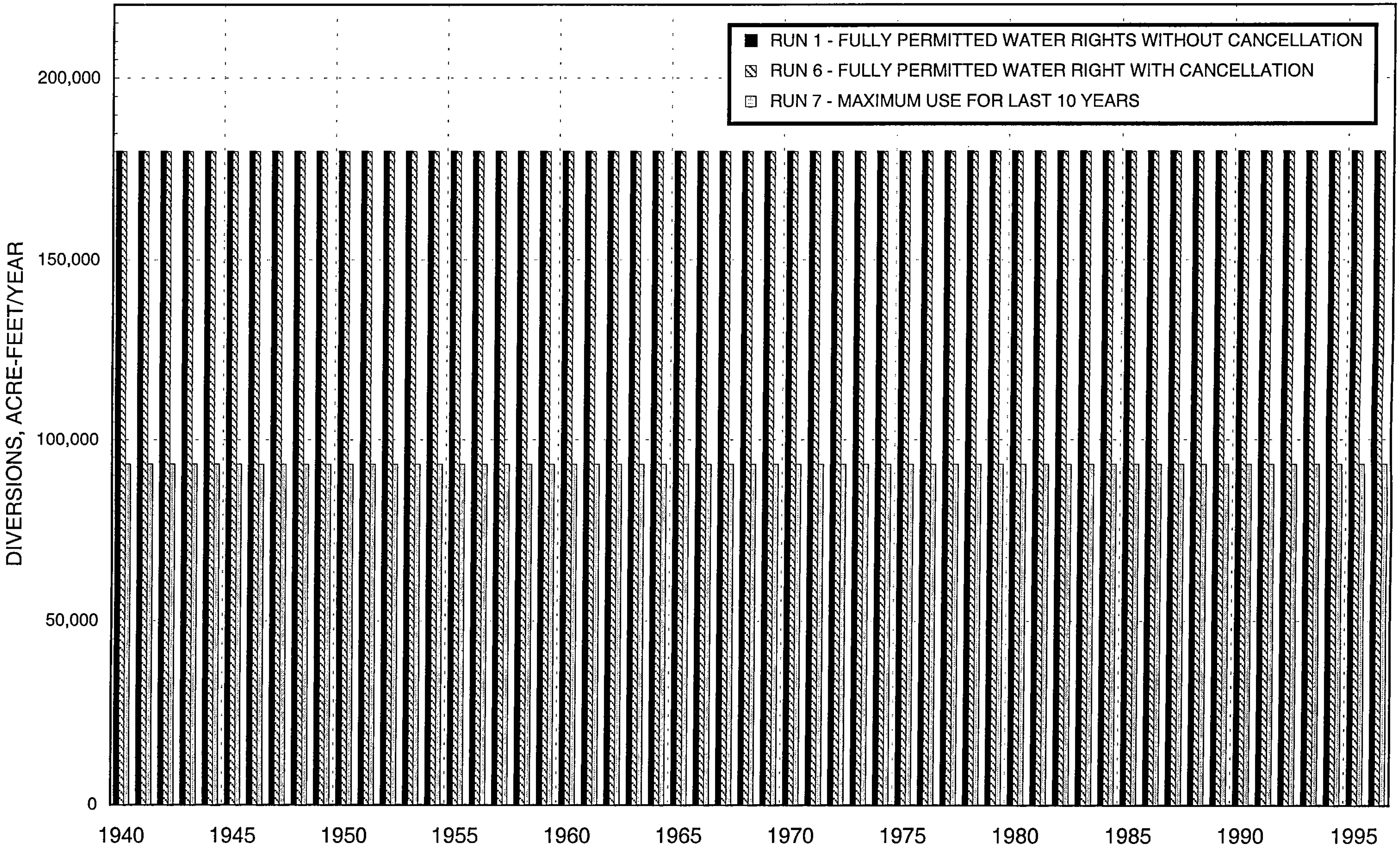


FIGURE A4-3
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

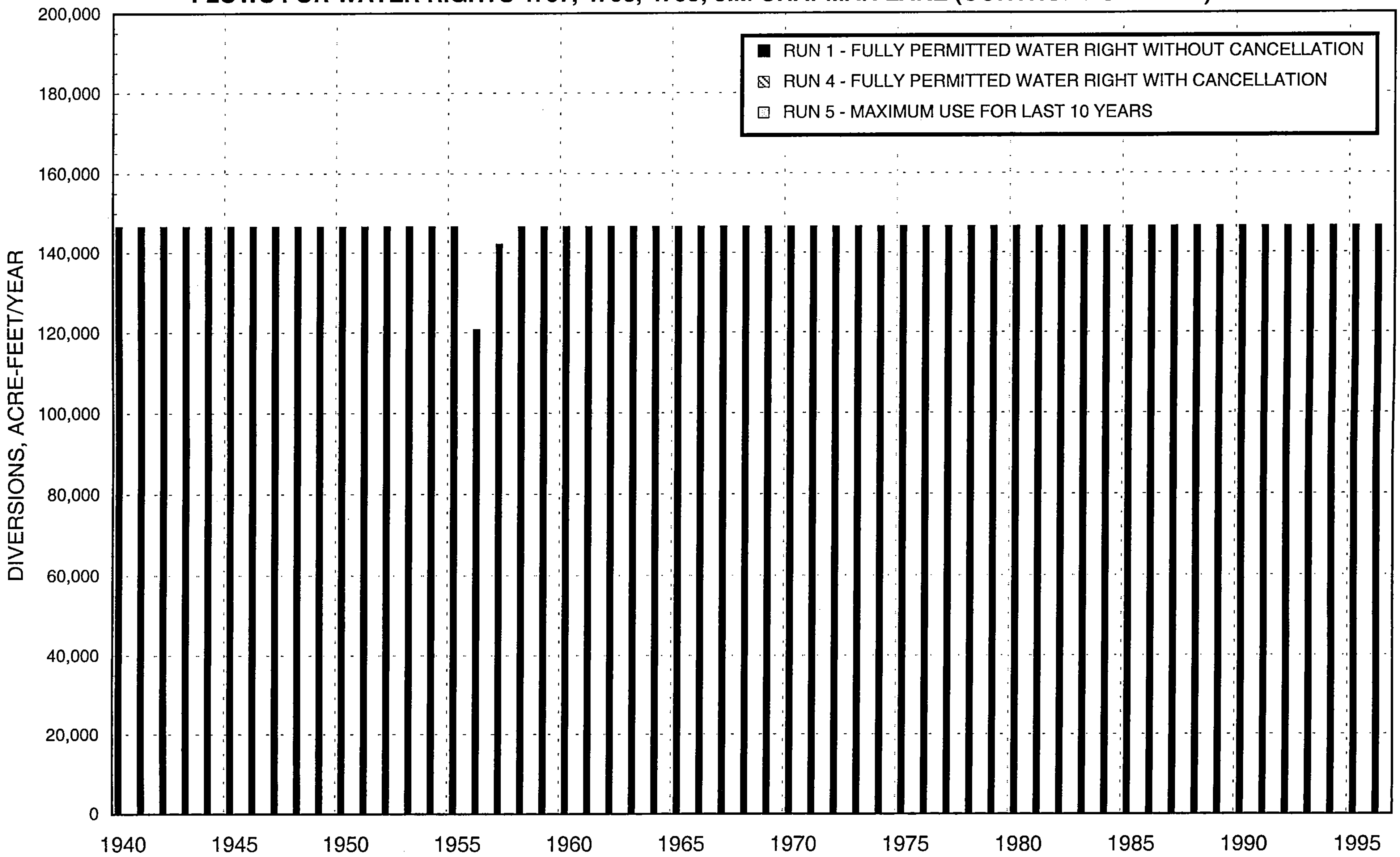


FIGURE A4-4
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

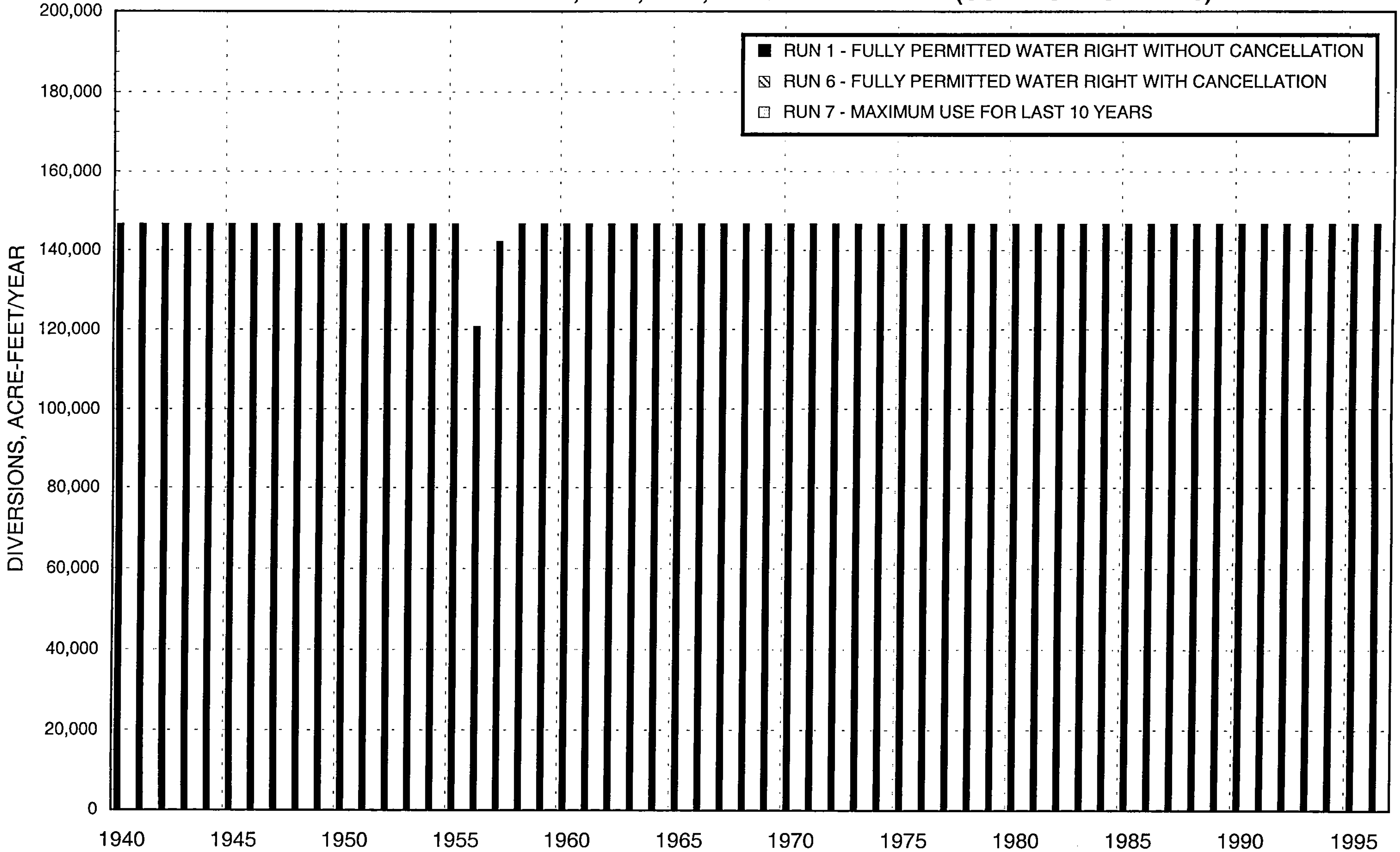


FIGURE A4-5
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

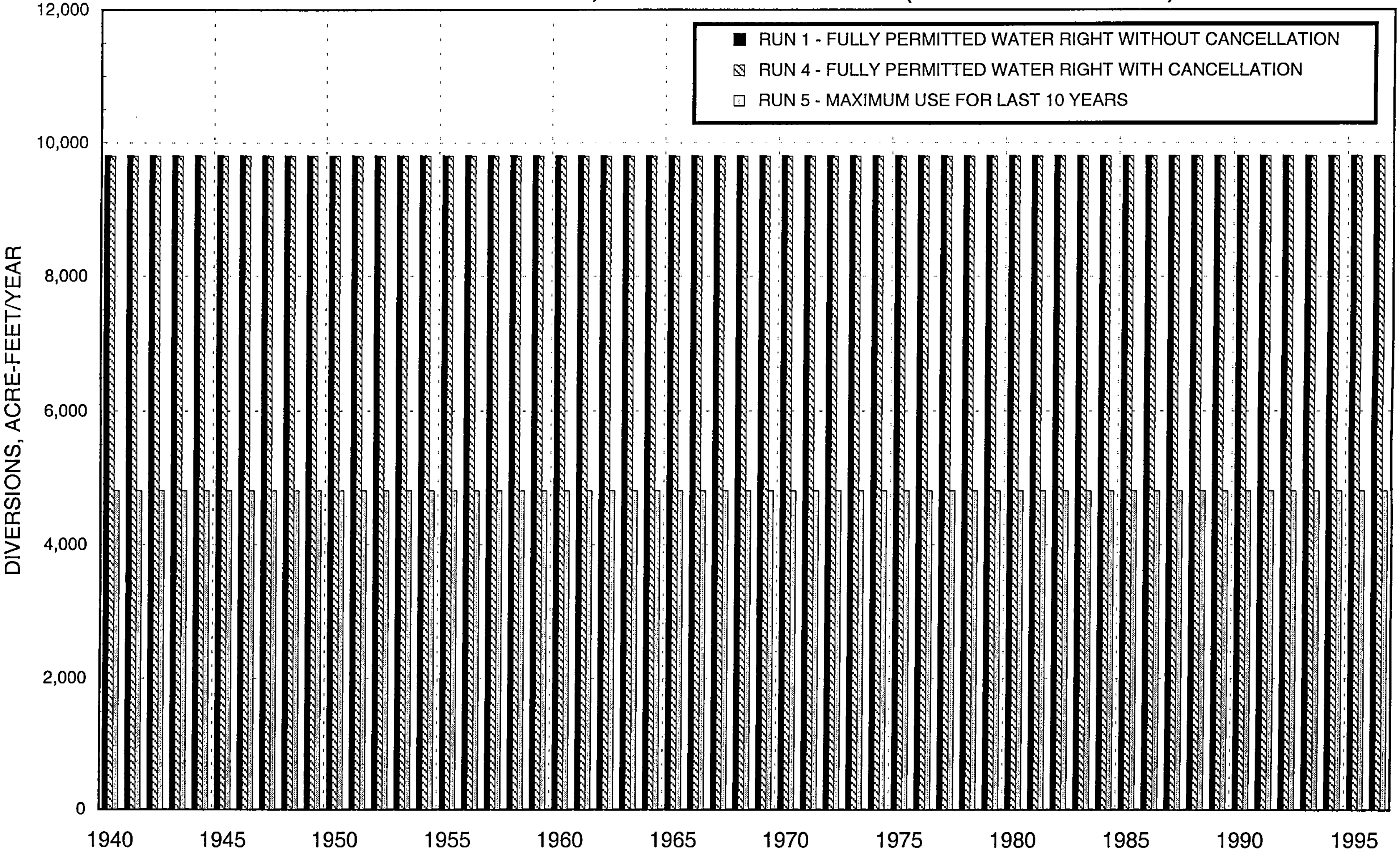


FIGURE A4-6
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

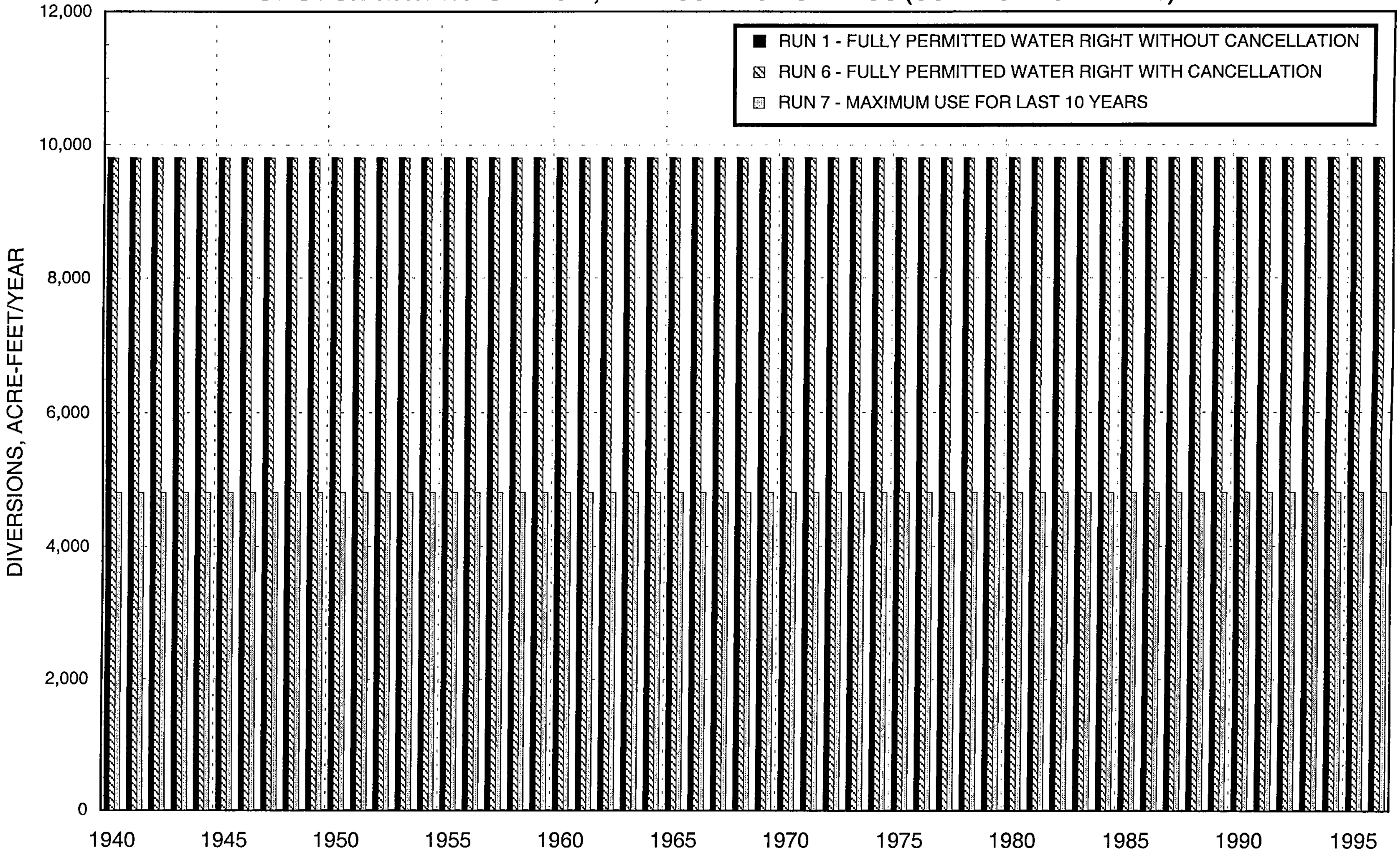


FIGURE A4-7
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

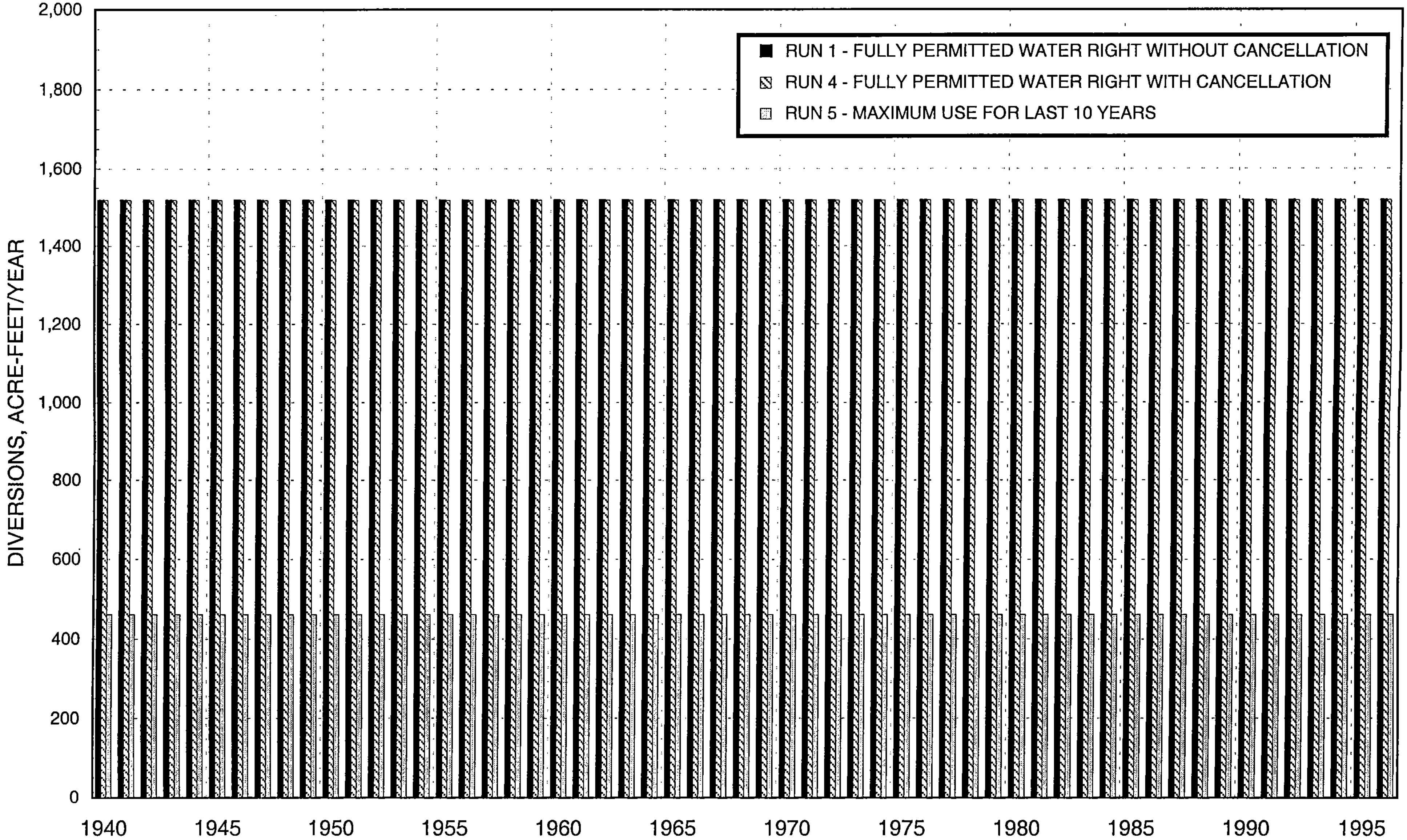


FIGURE A4-8
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

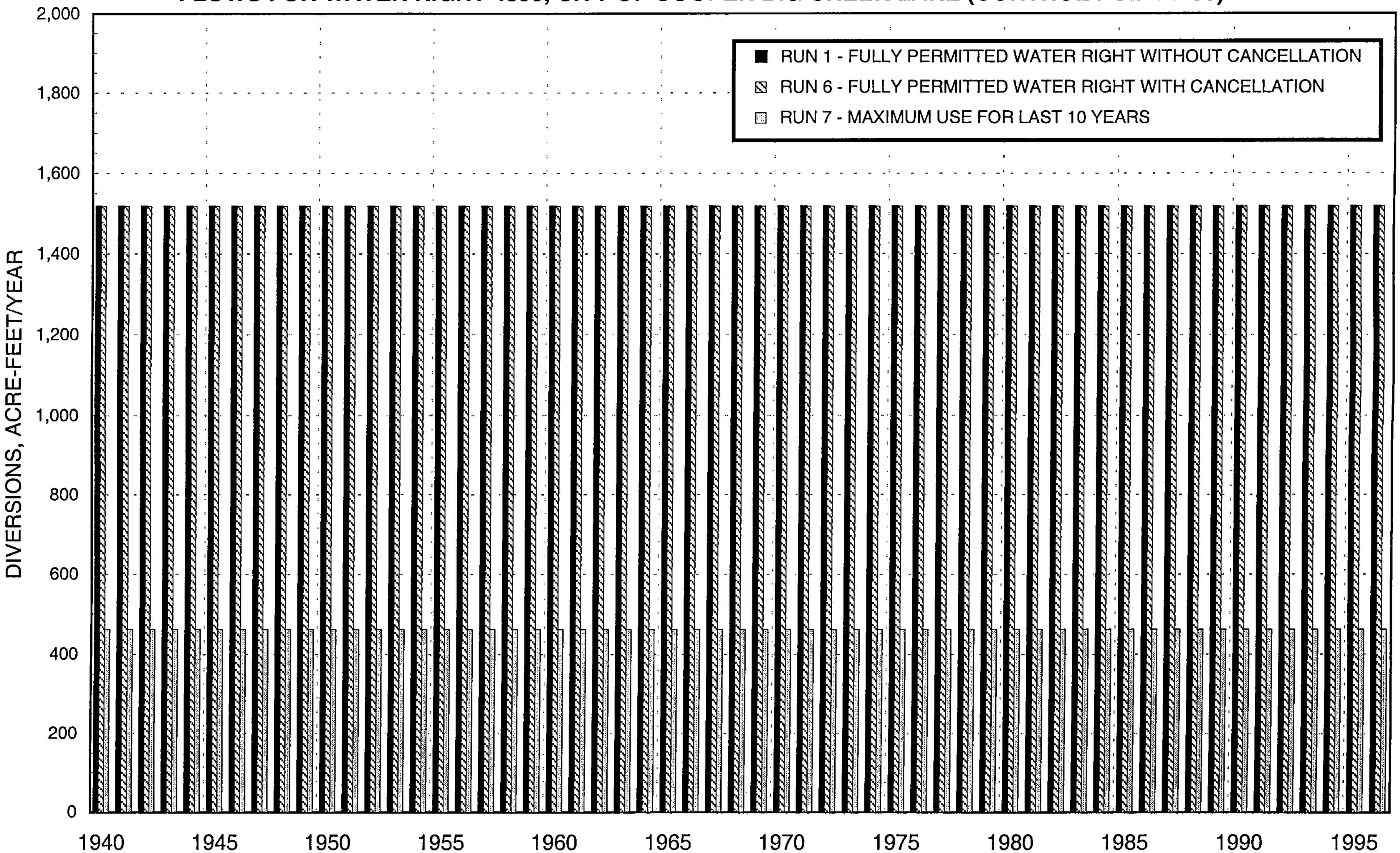


FIGURE A4-9
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4830, WILLIAM E. JOHNSON, JR., ET AL (CONTROL POINT F110)

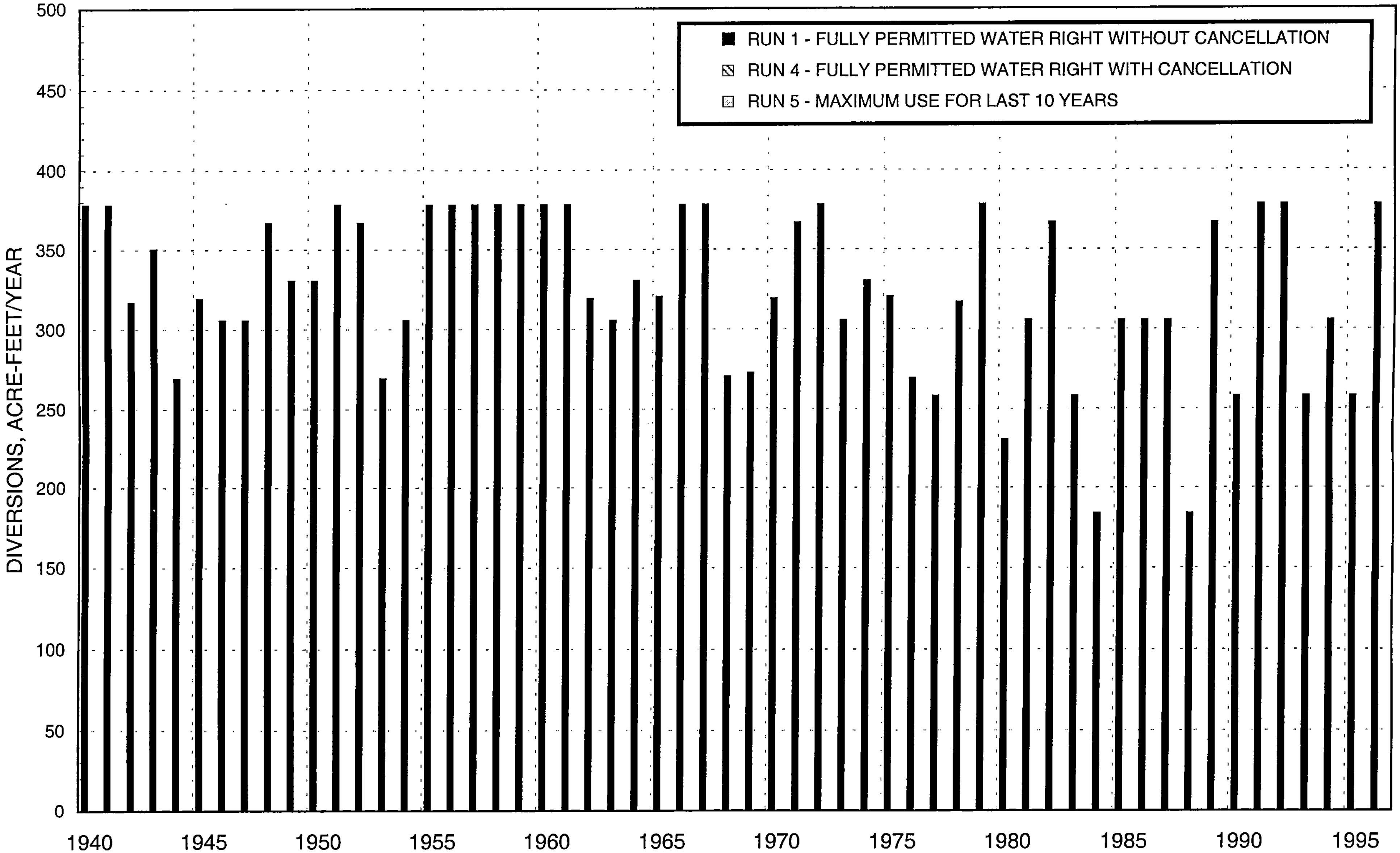


FIGURE A4-10
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4830, WILLIAM E. JOHNSON, JR., ET AL (CONTROL POINT F110)

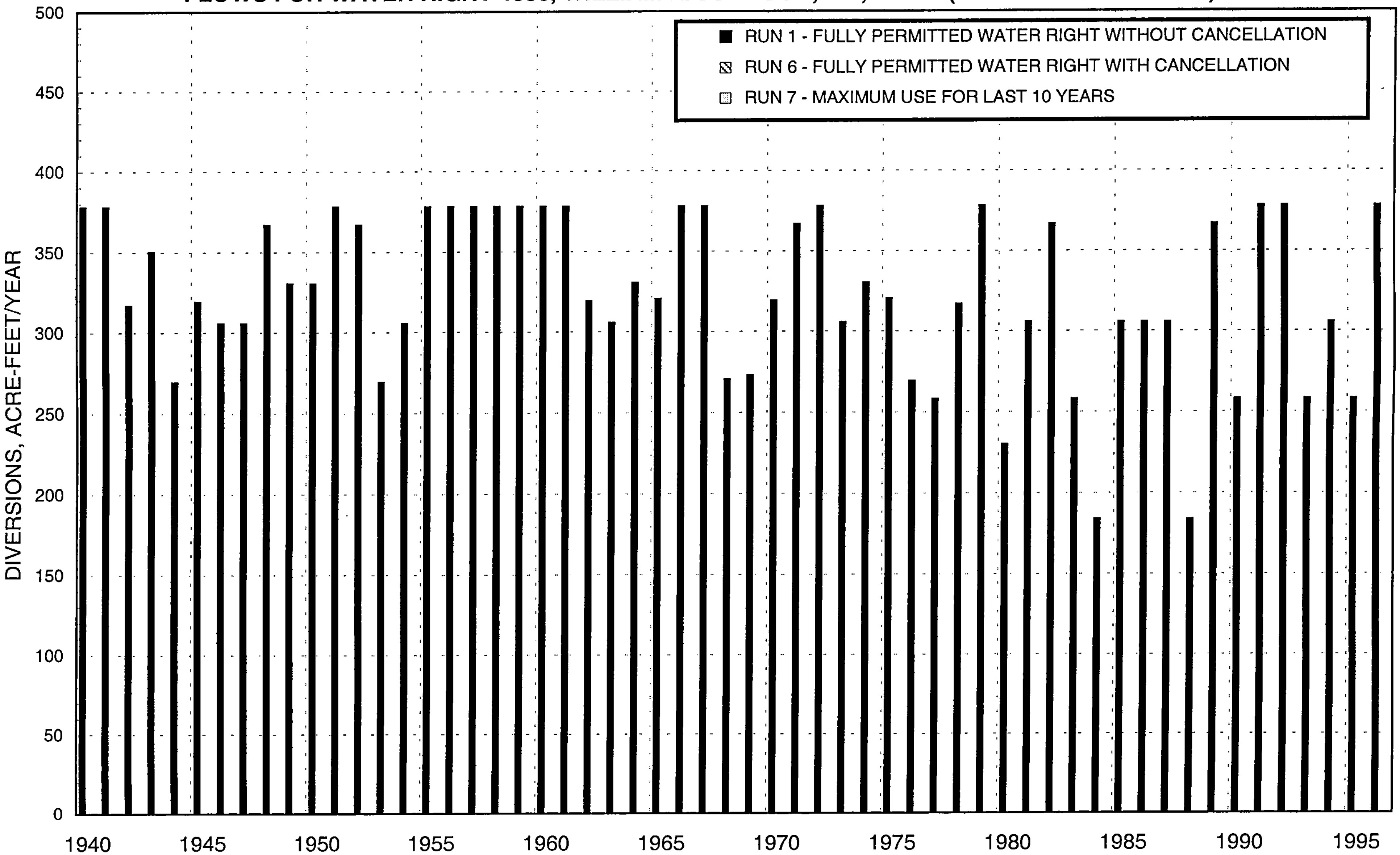


FIGURE A4-11
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4804, TEXAS UTILITIES ELECTRIC RIVER CREST PLANT (CONTROL POINT C20)

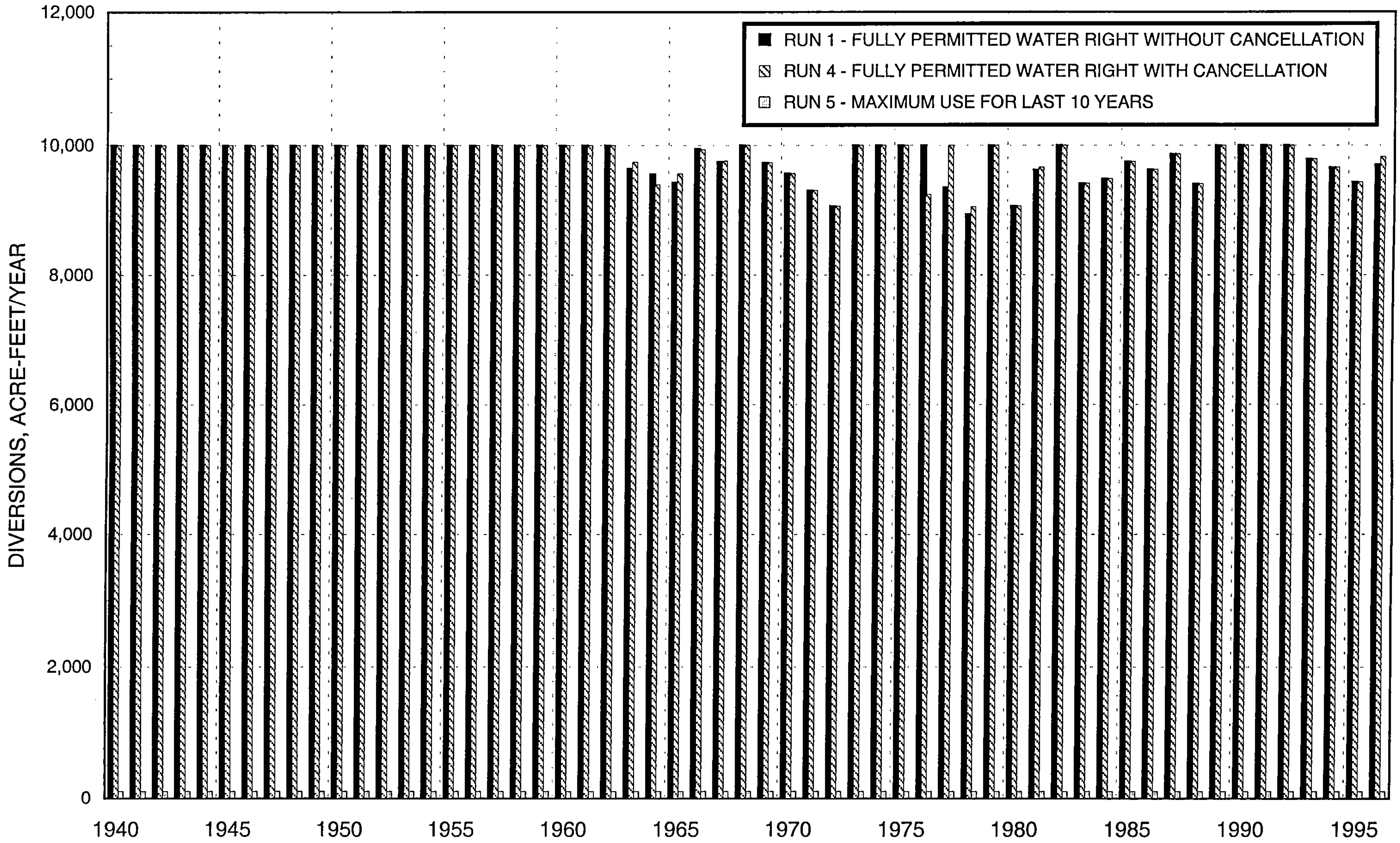


FIGURE A4-12
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4804, TEXAS UTILITIES ELECTRIC RIVER CREST PLANT (CONTROL POINT C20)

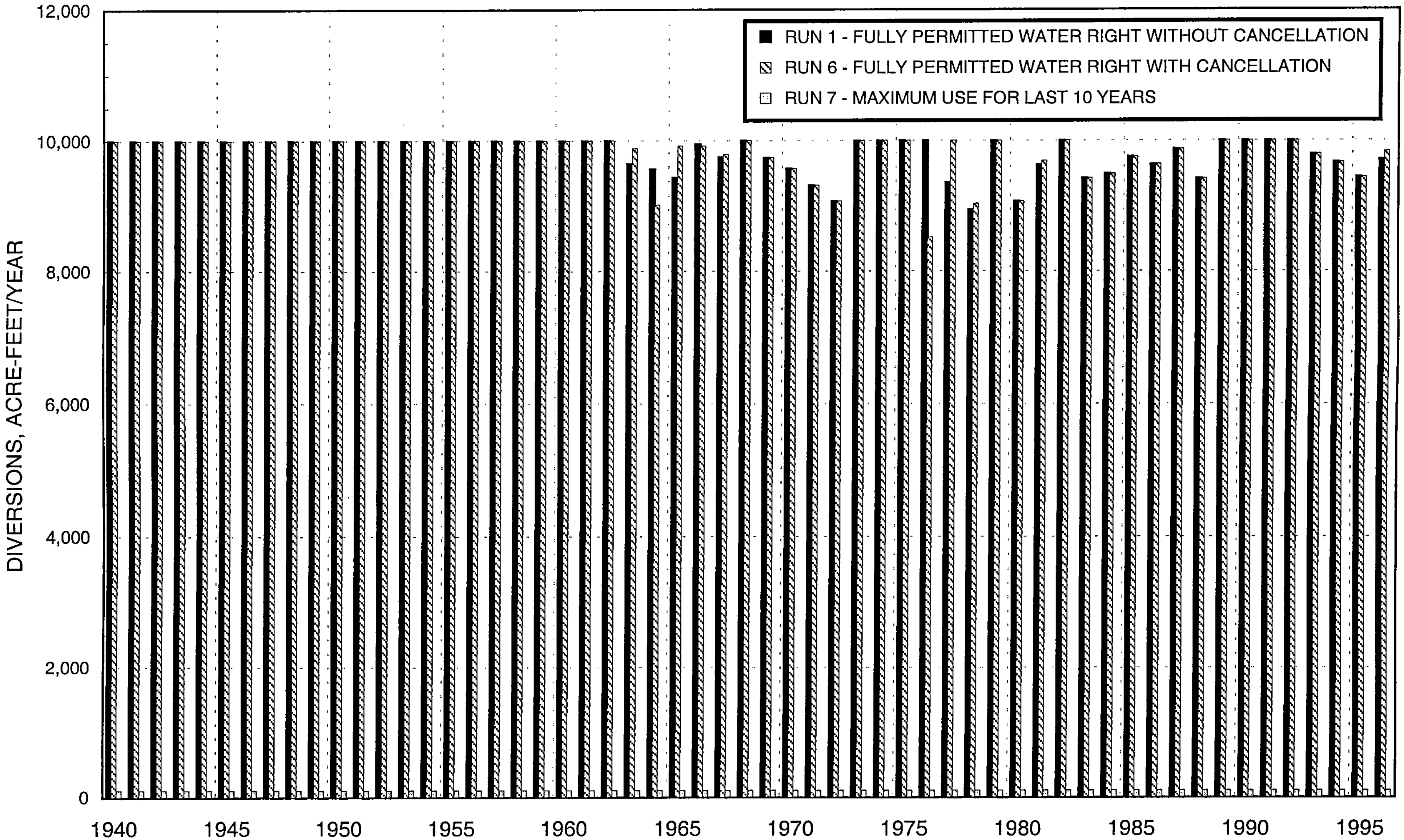


FIGURE A4-13
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4817, HANS WEISS (CONTROL POINT D40)

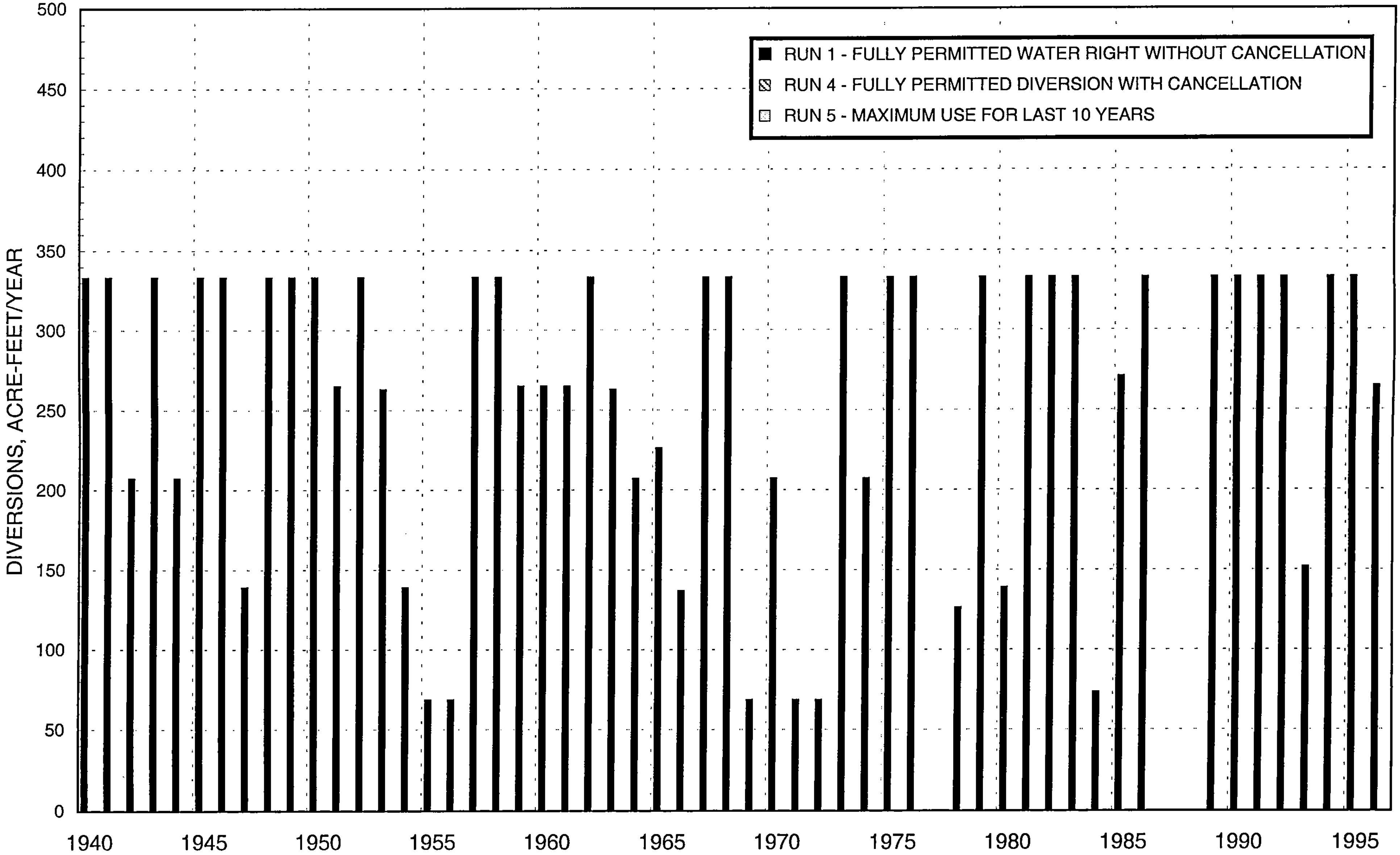


FIGURE A4-14
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4817, HANS WEISS (CONTROL POINT D40)

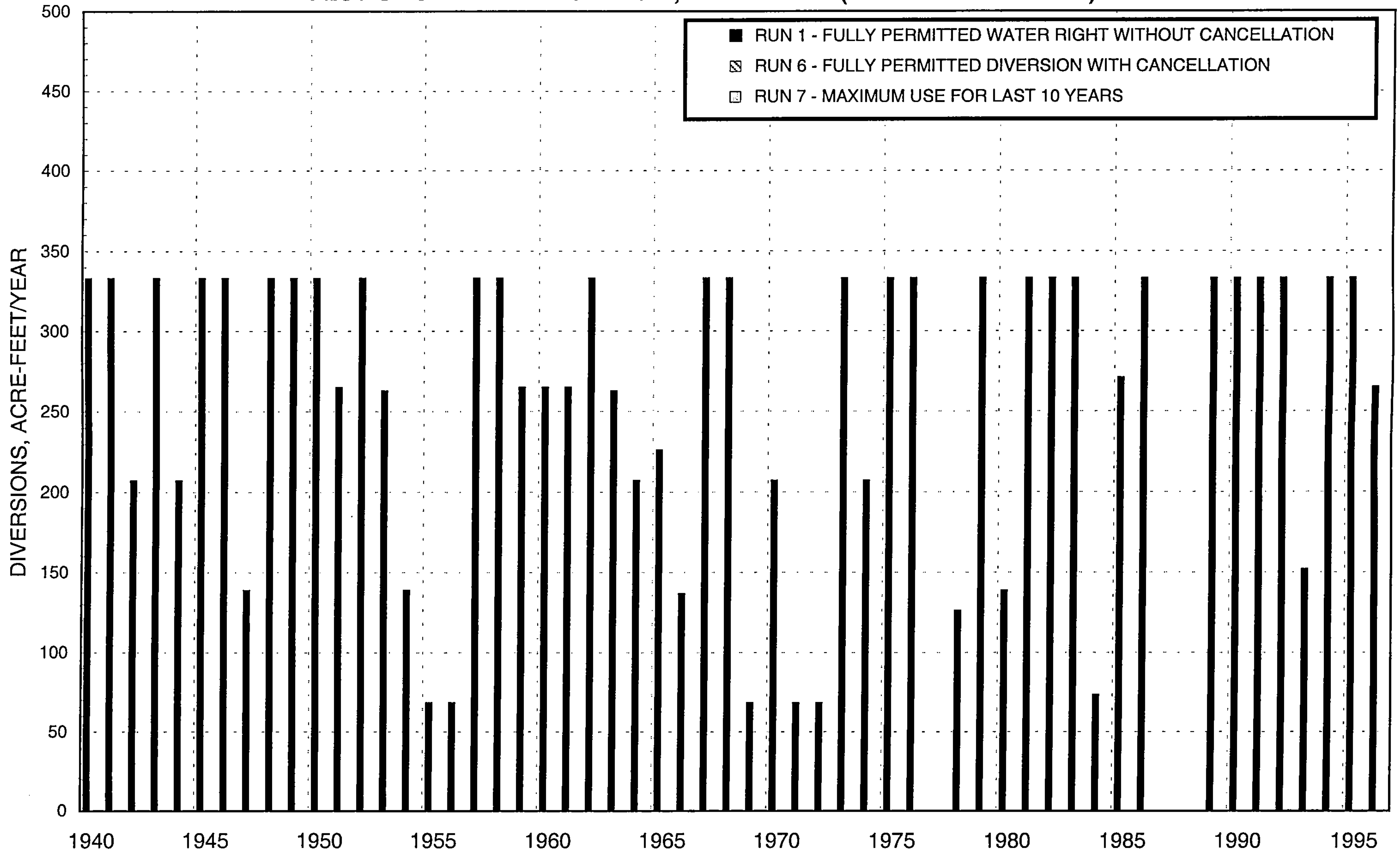


FIGURE A4-15
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4148B, SARA M. DUNHAM TRUST RESERVOIR DIVERSIONS (CONTROL POINT C60)

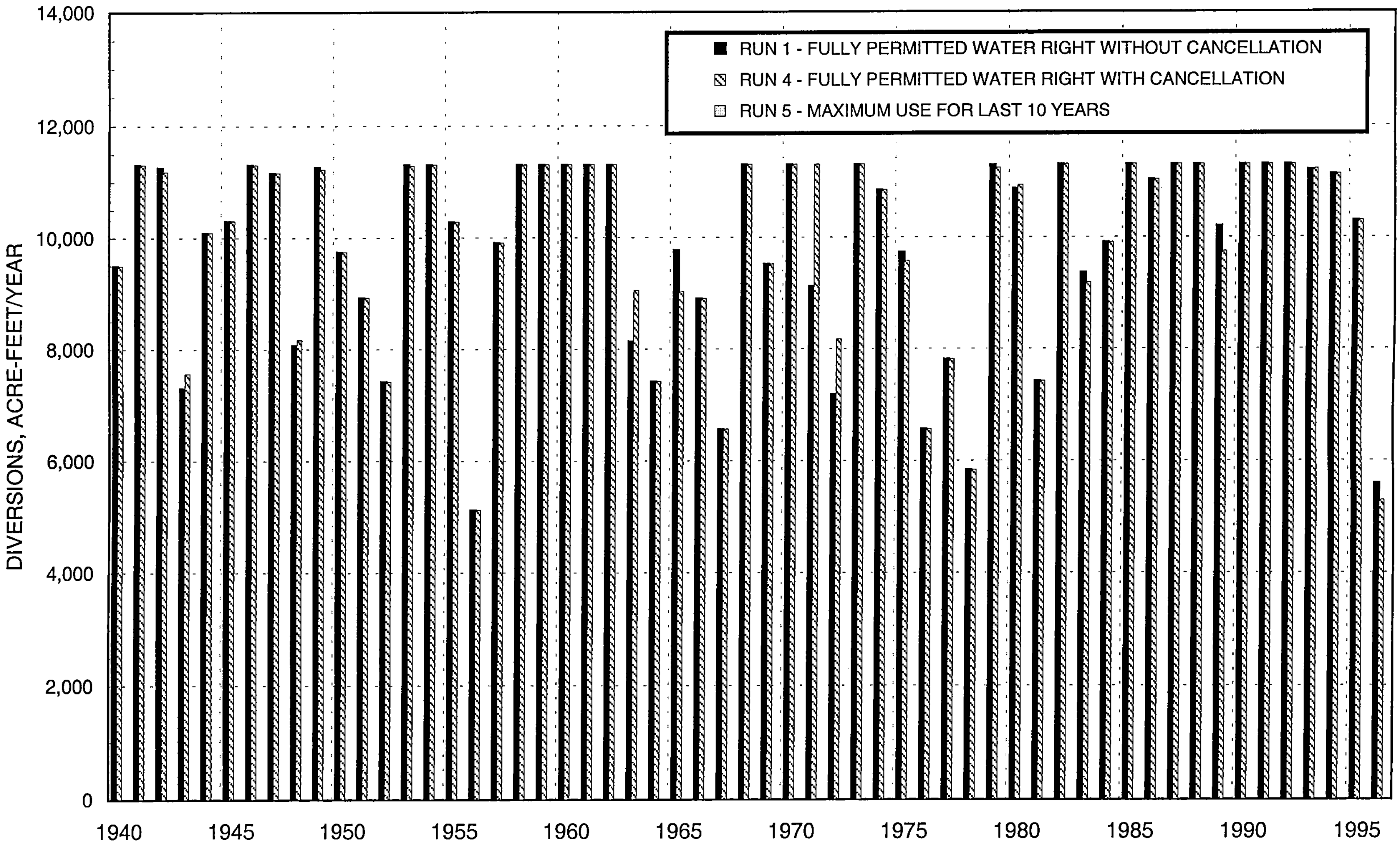


FIGURE A4-16
ANNUAL DIVERSIONS AVAILABLE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4148B, SARA M. DUNHAM TRUST RESERVOIR DIVERSIONS (CONTROL POINT C60)

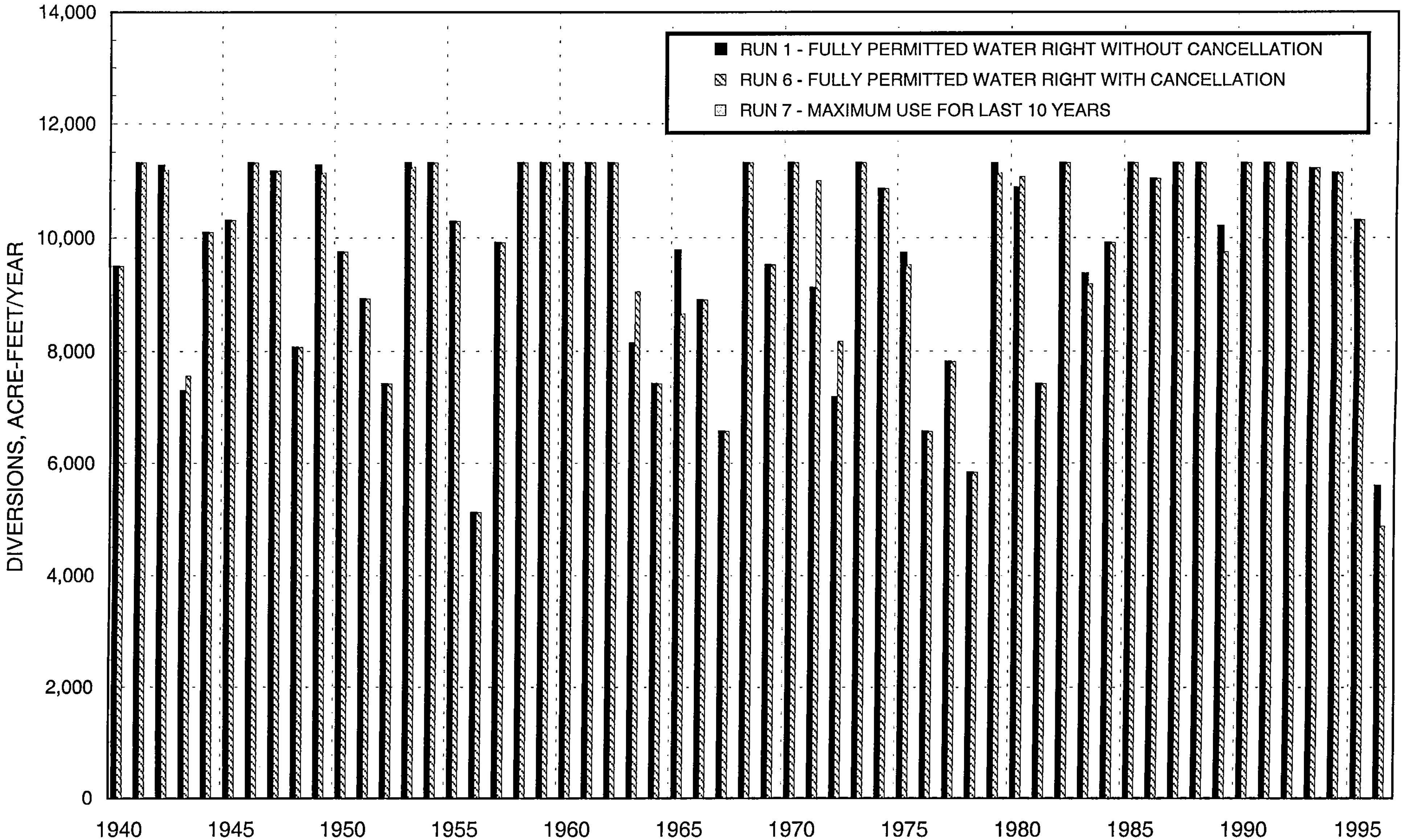


FIGURE A4-17
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4830, WRIGHT PATMAN LAKE (CONTROL POINT F60)

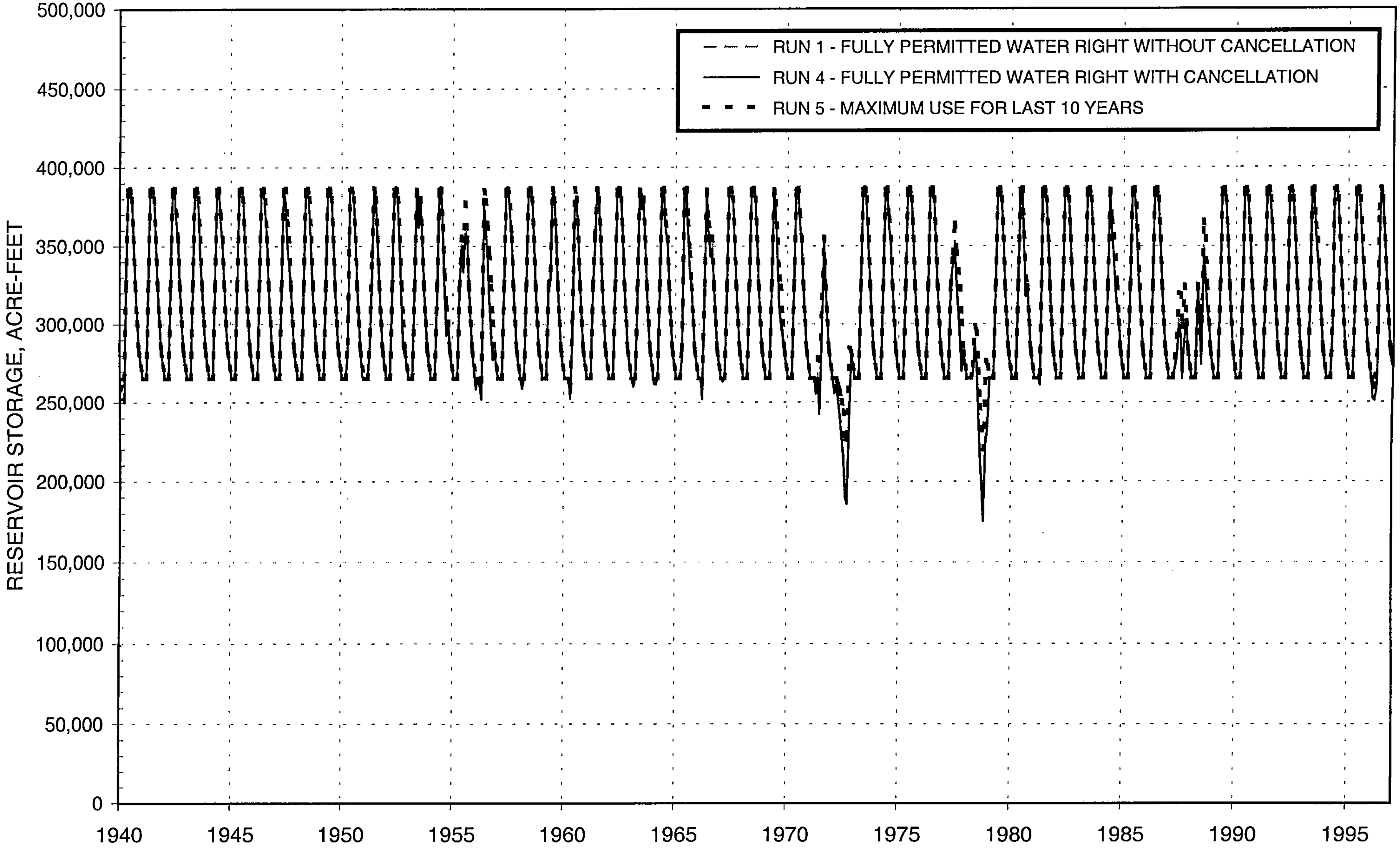


FIGURE A4-18
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4830, WRIGHT PATMAN LAKE (CONTROL POINT F60)

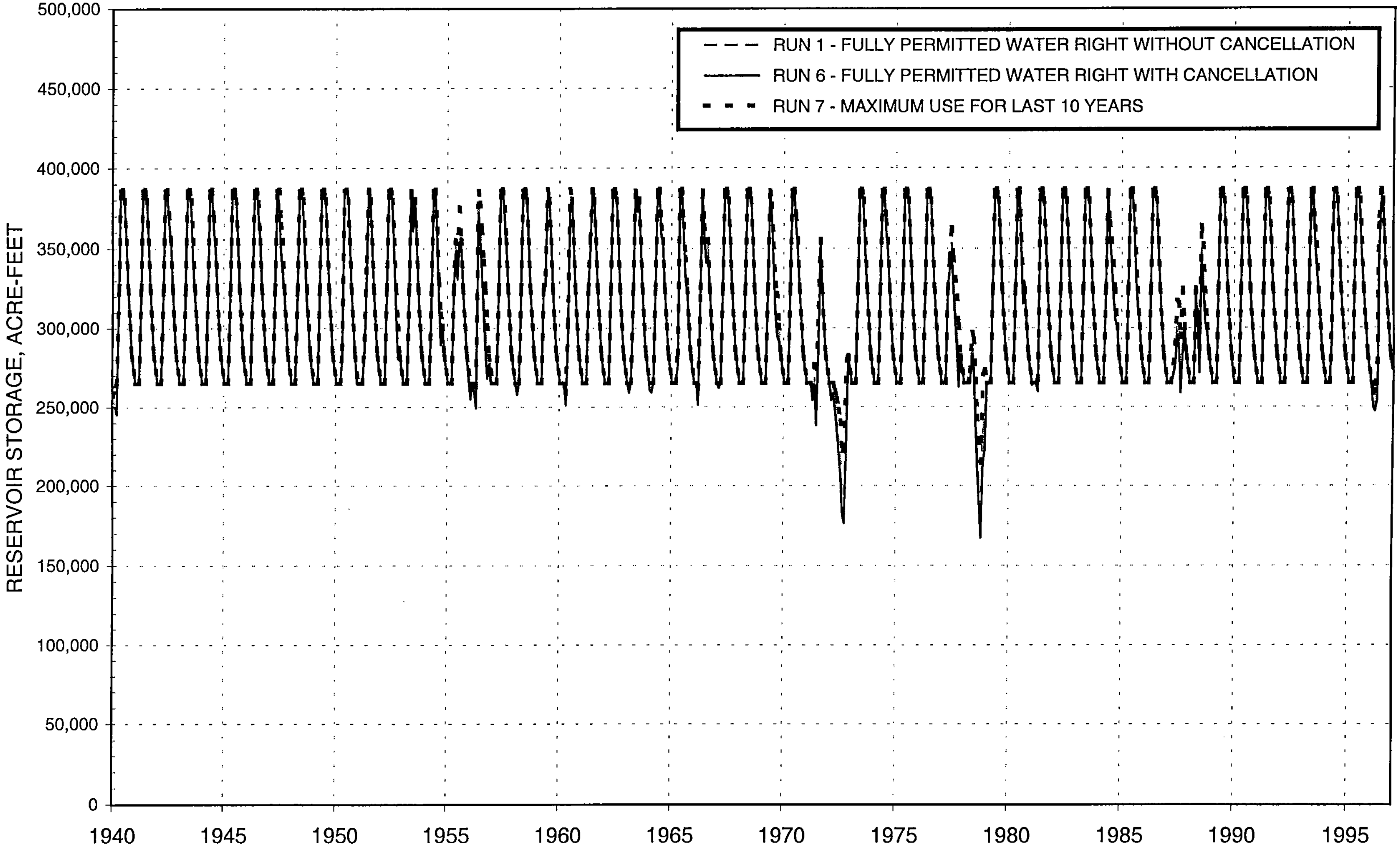


FIGURE A4-19
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

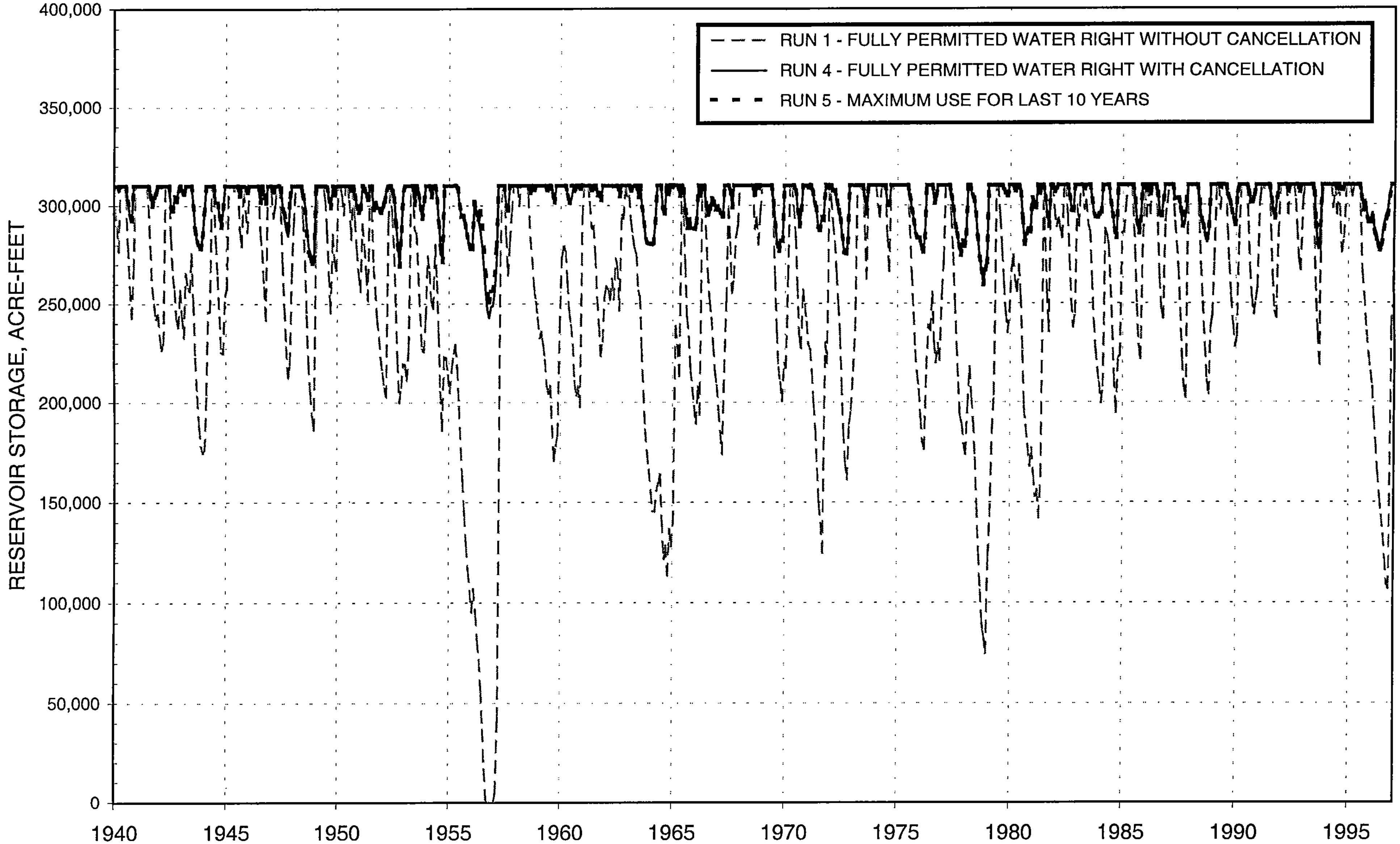


FIGURE A4-20
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

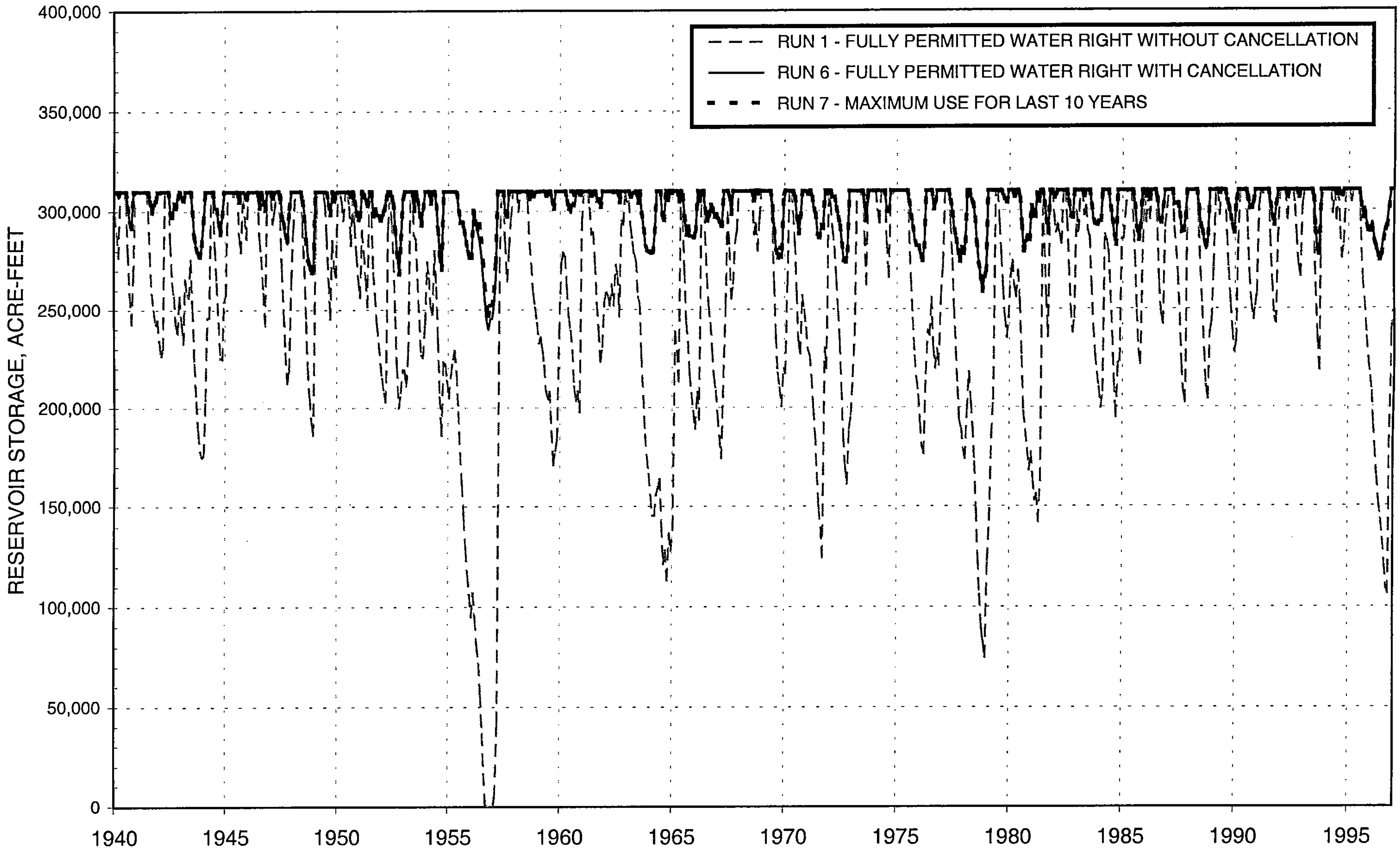


FIGURE A4-21
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

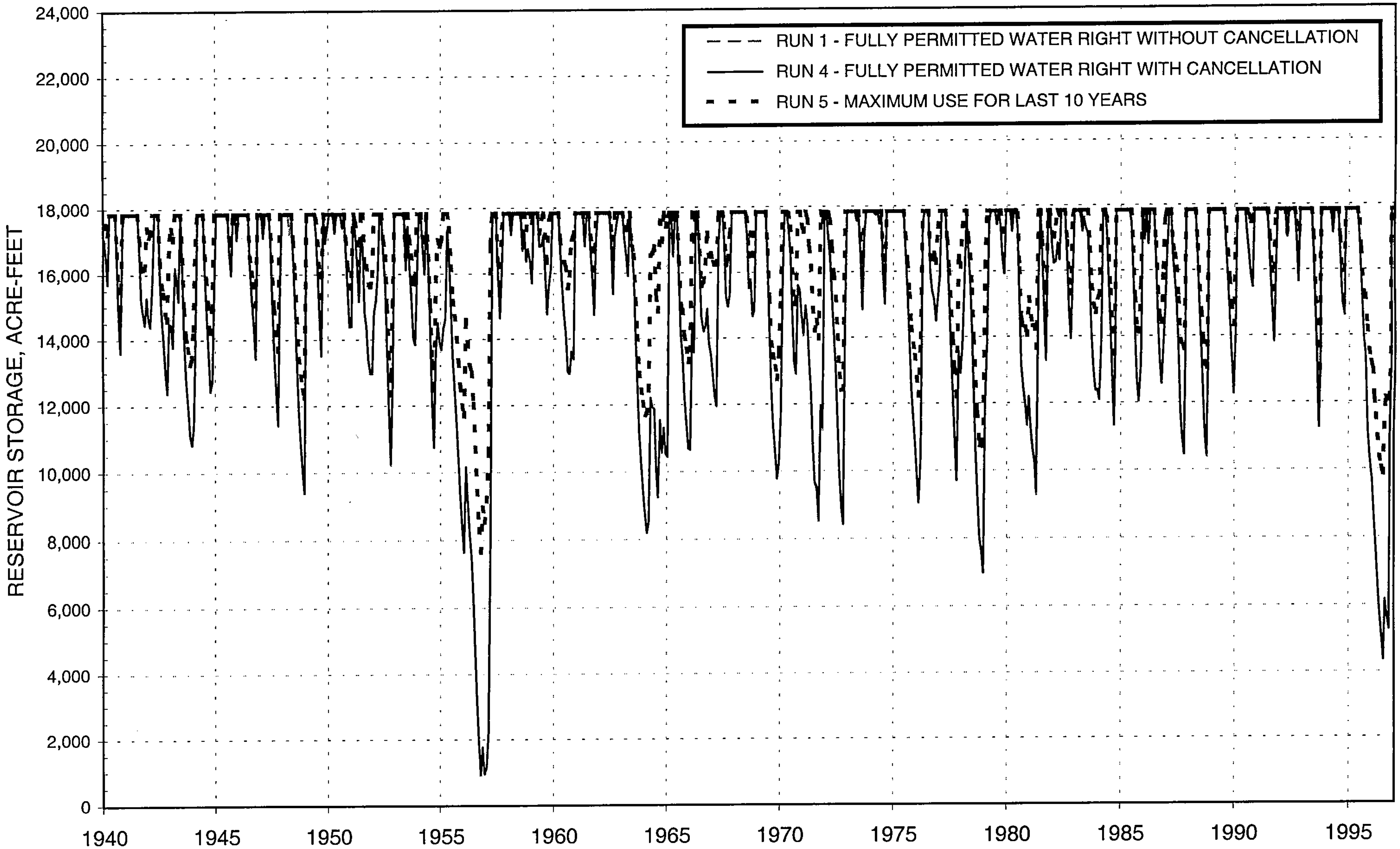


FIGURE A4-22

MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

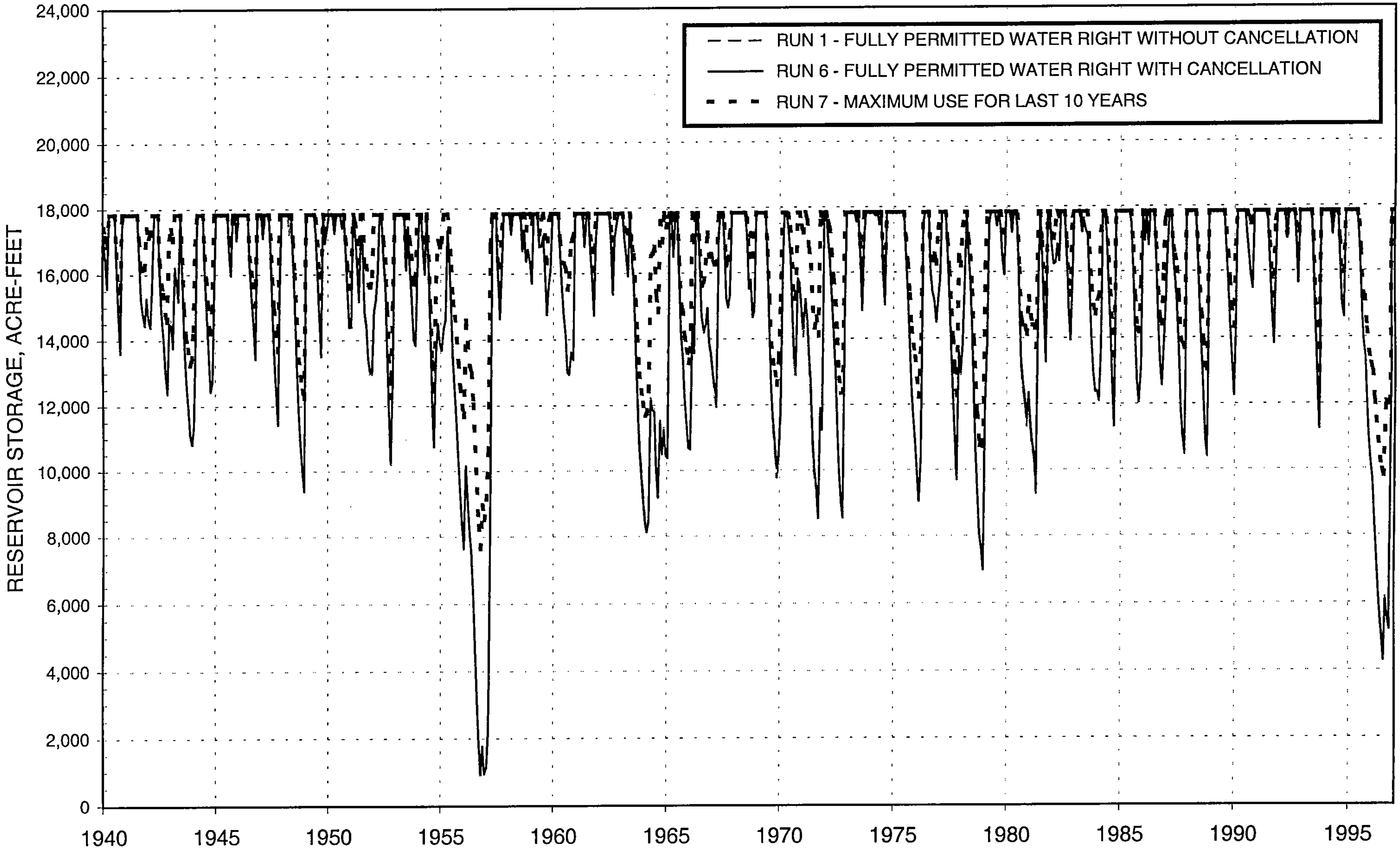


FIGURE A4-23
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

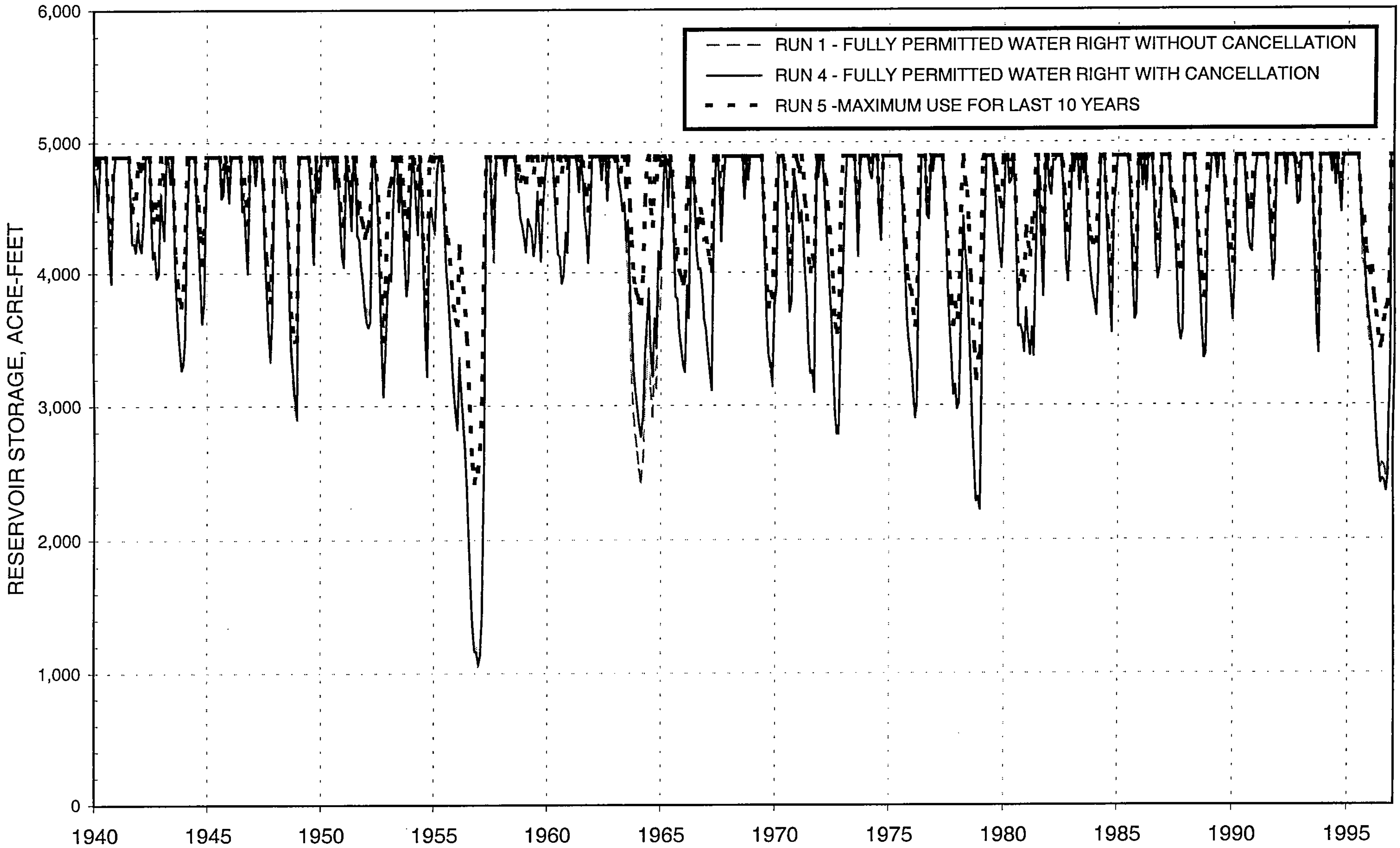


FIGURE A4-24
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

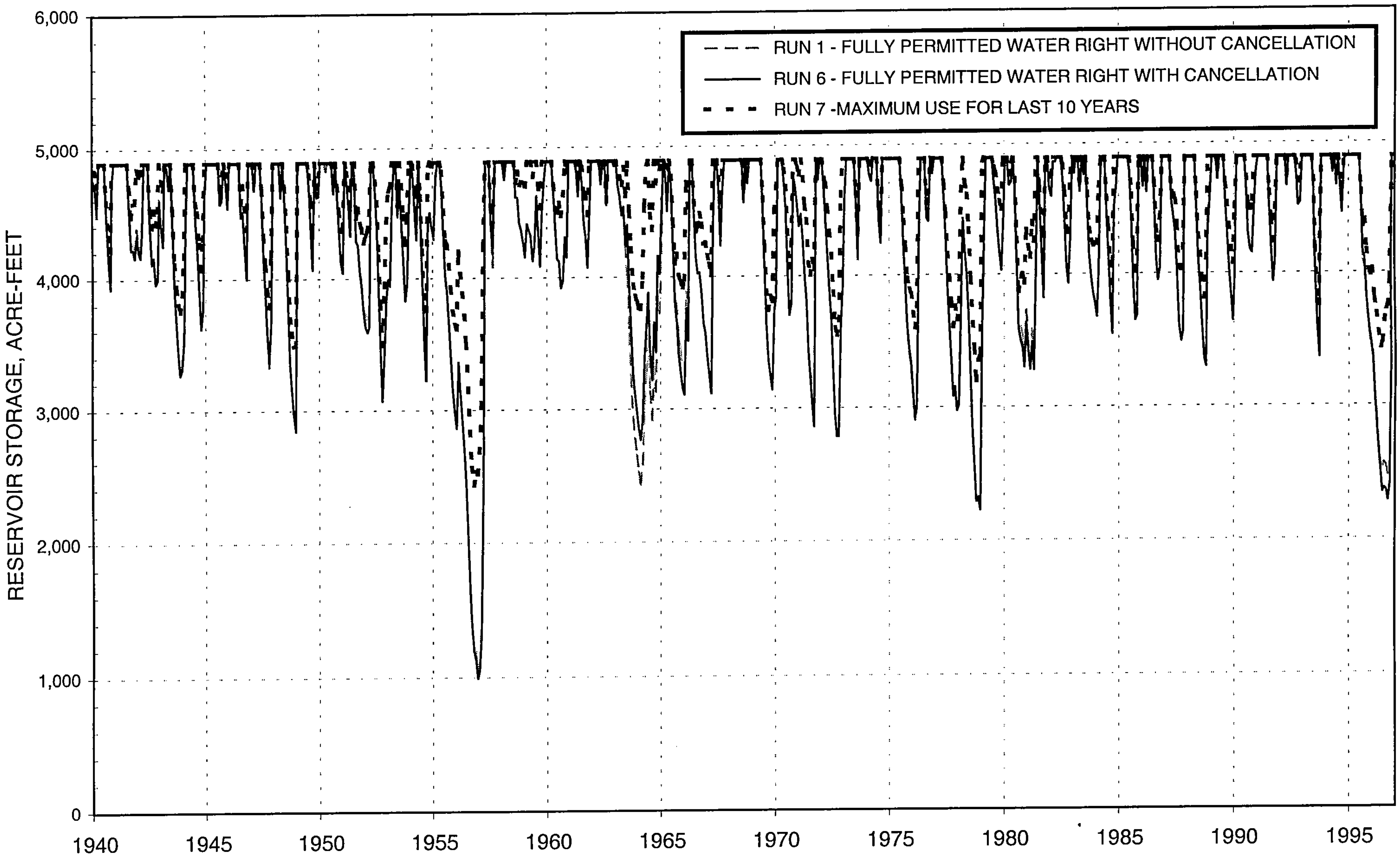


FIGURE A4-25
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS FOR WATER RIGHT 4148B, SARAH M. DUNHAM TRUST (CONTROL POINT C60)

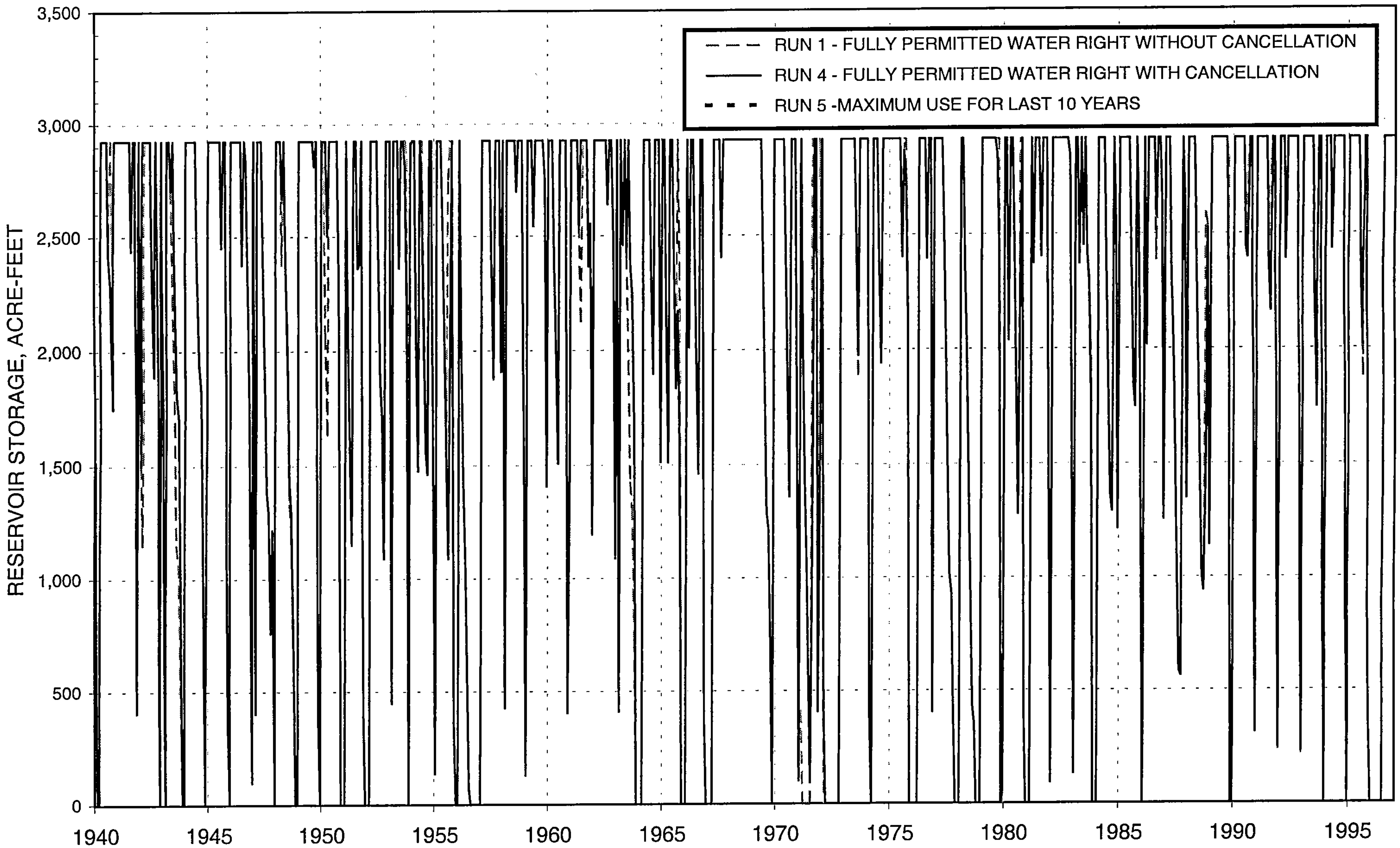


FIGURE A4-26
MONTHLY RESERVOIR STORAGE CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS FOR WATER RIGHT 4148B, SARAH M. DUNHAM TRUST (CONTROL POINT C60)

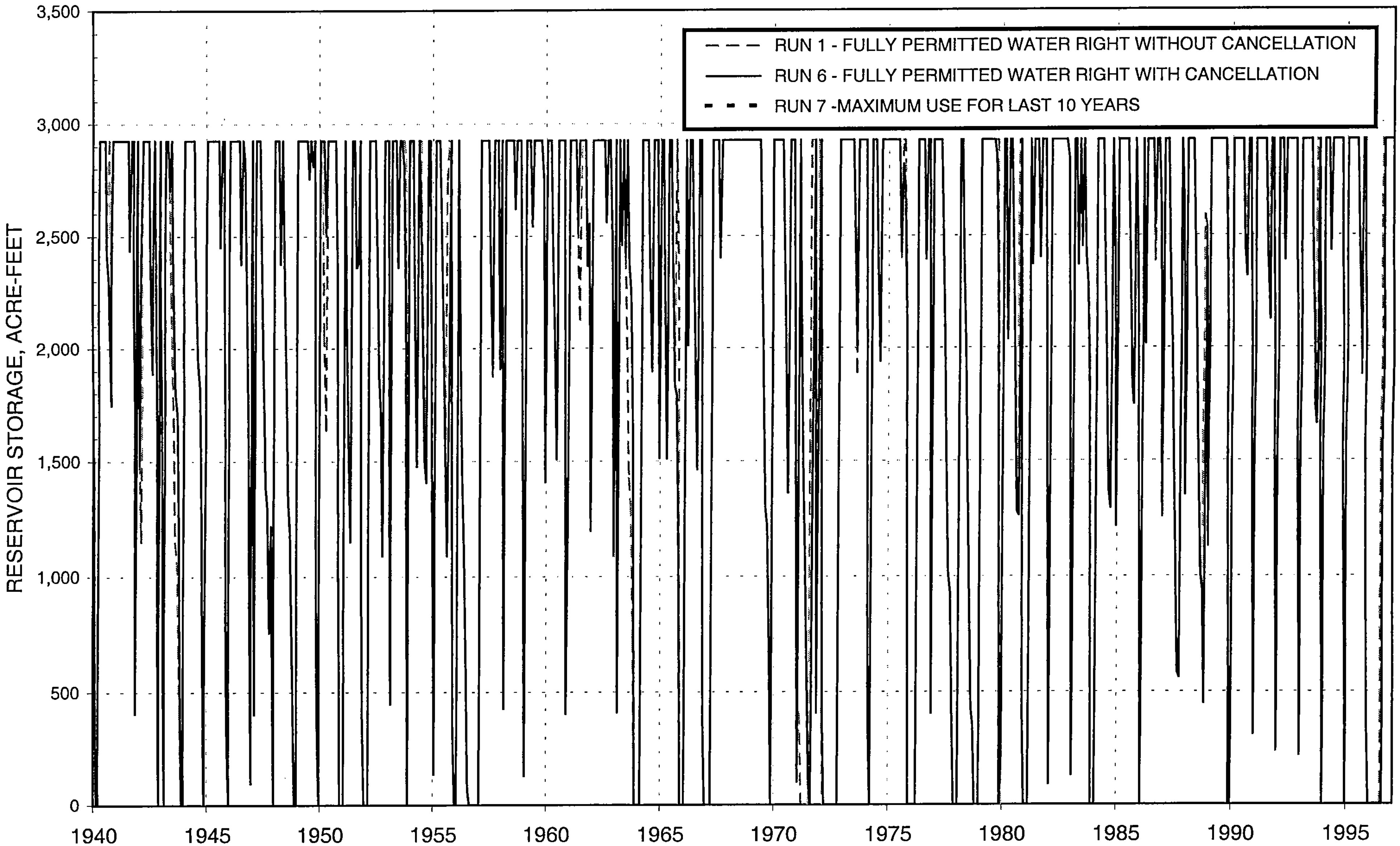


FIGURE A4-27
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

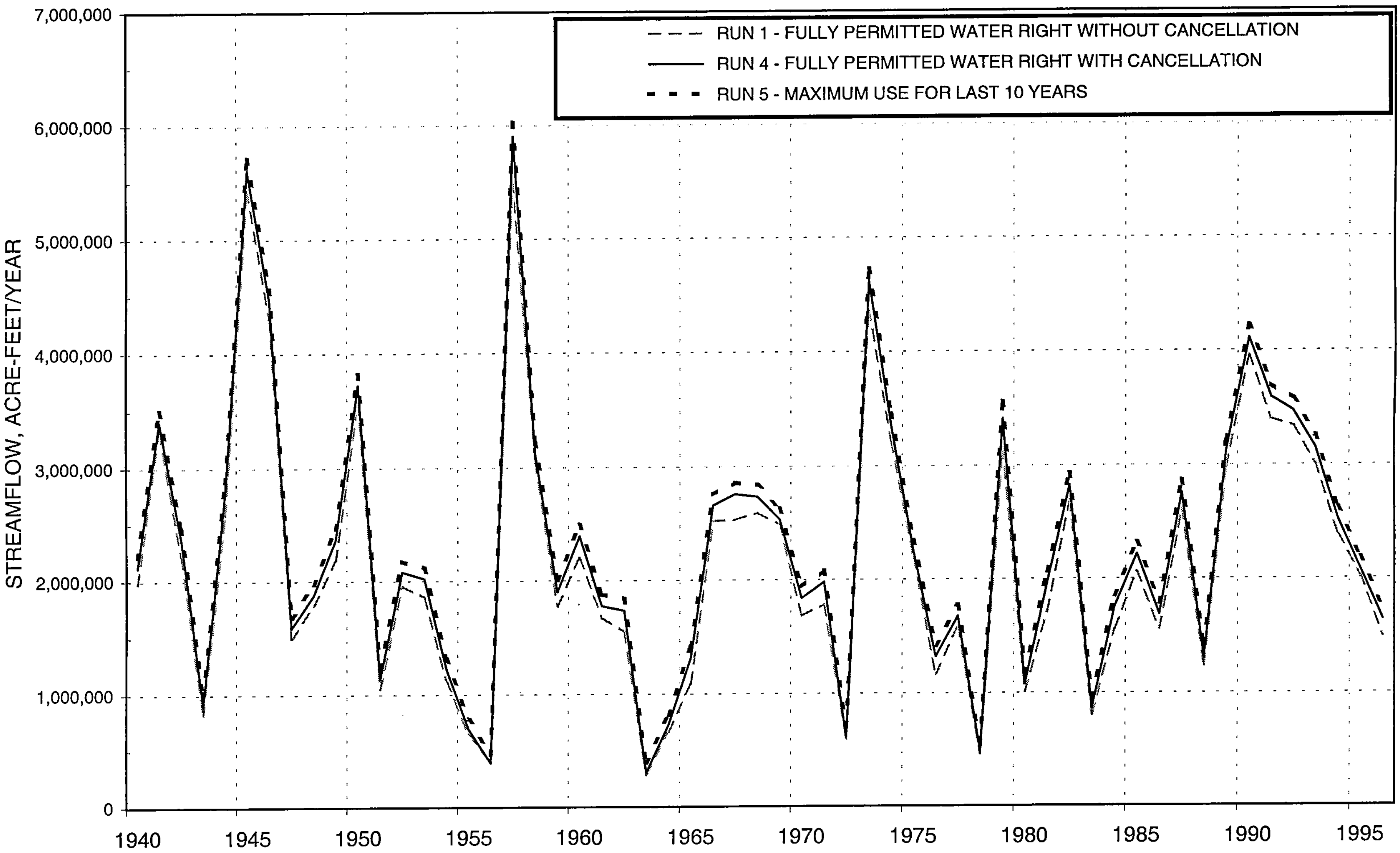


FIGURE A4-28
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

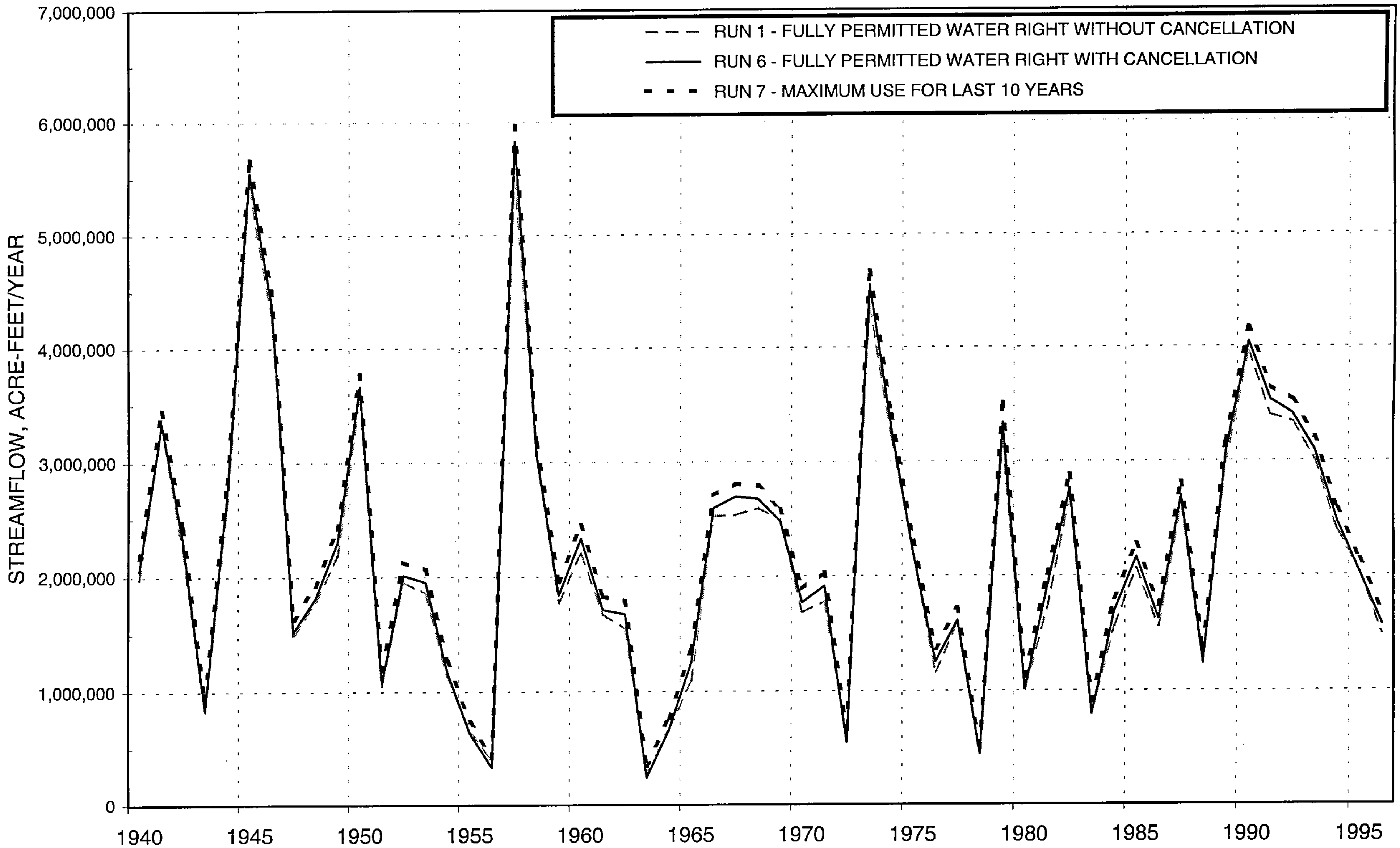


FIGURE A4-29
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

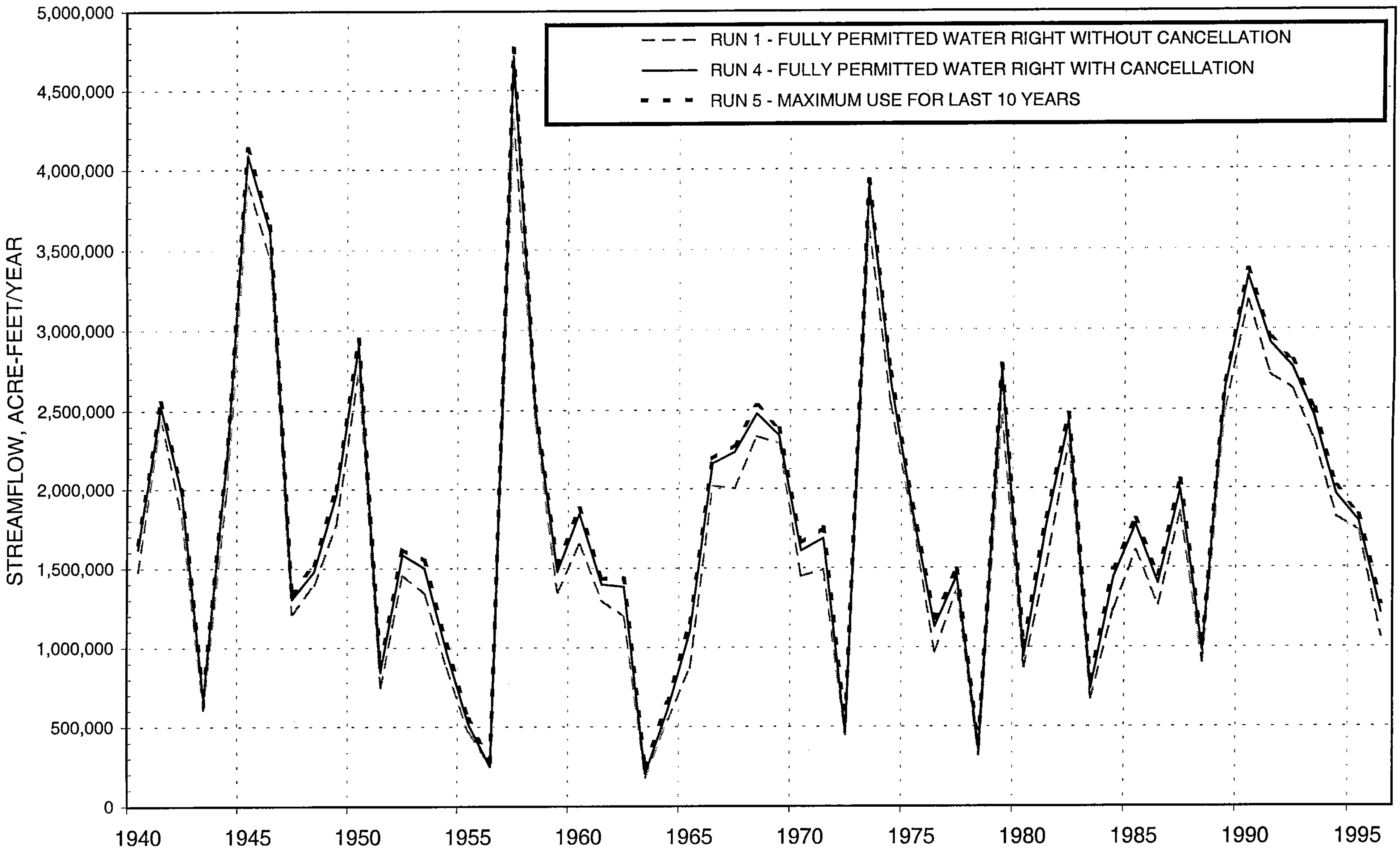


FIGURE A4-30
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

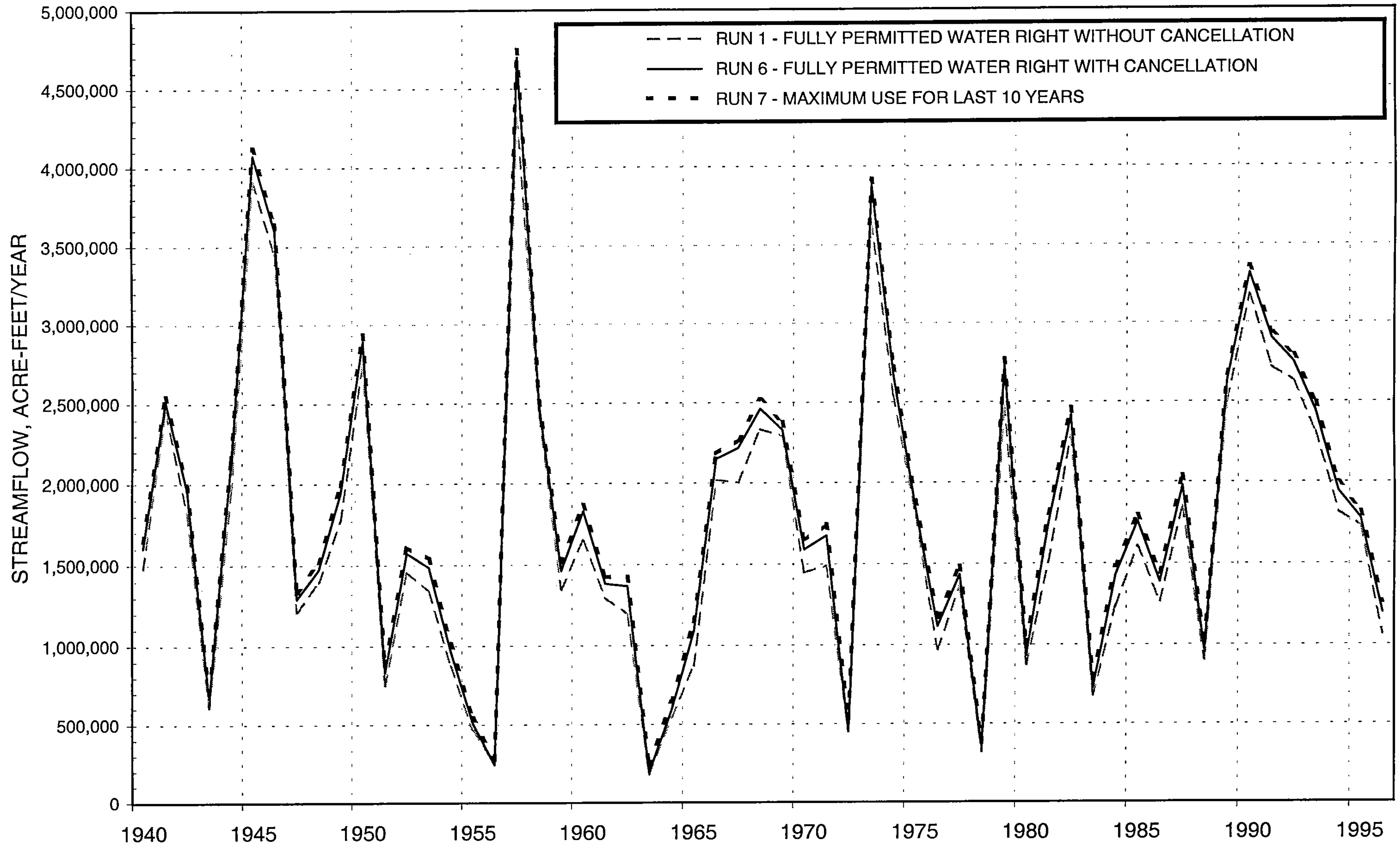


FIGURE A4-31
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

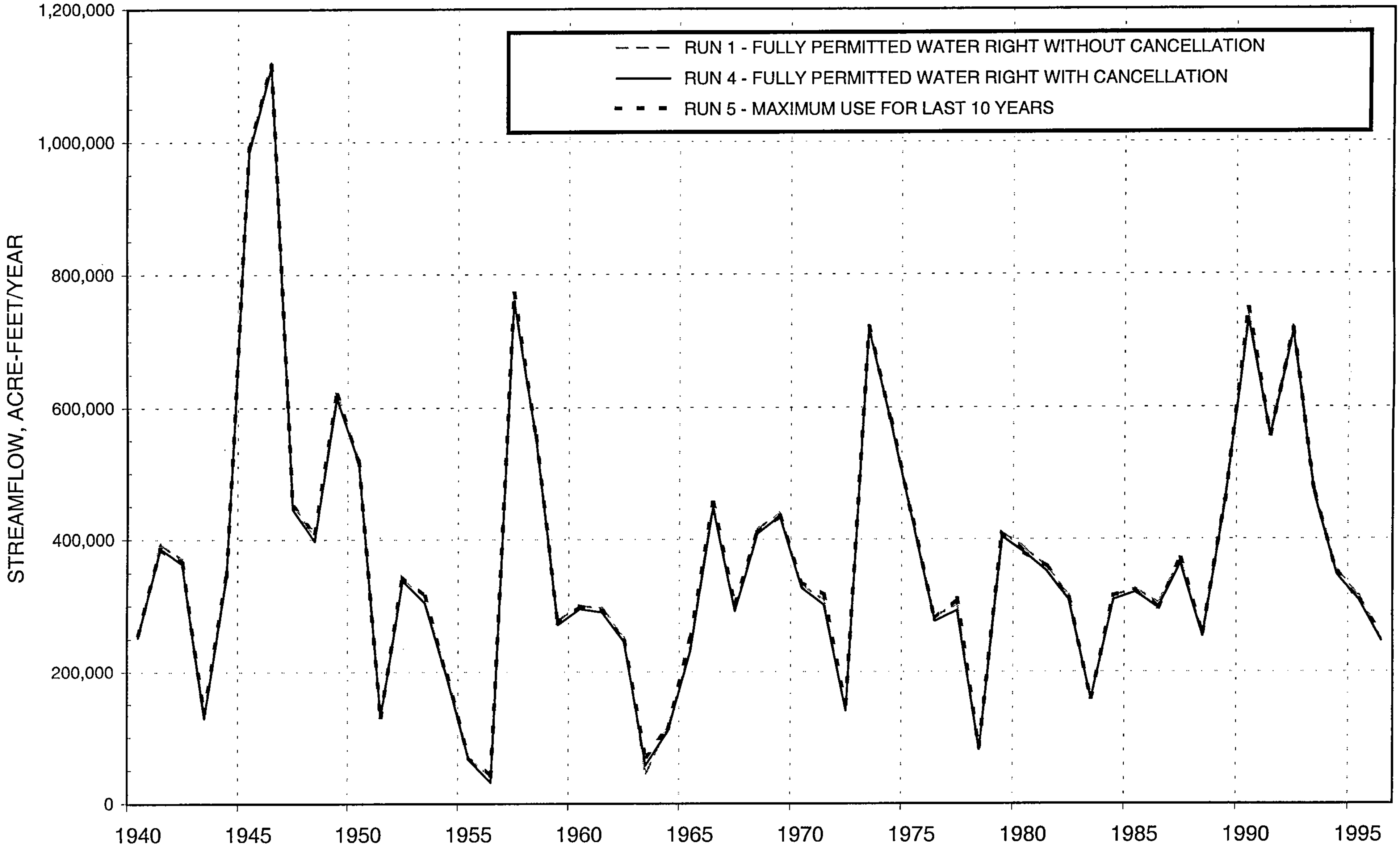


FIGURE A4-32
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

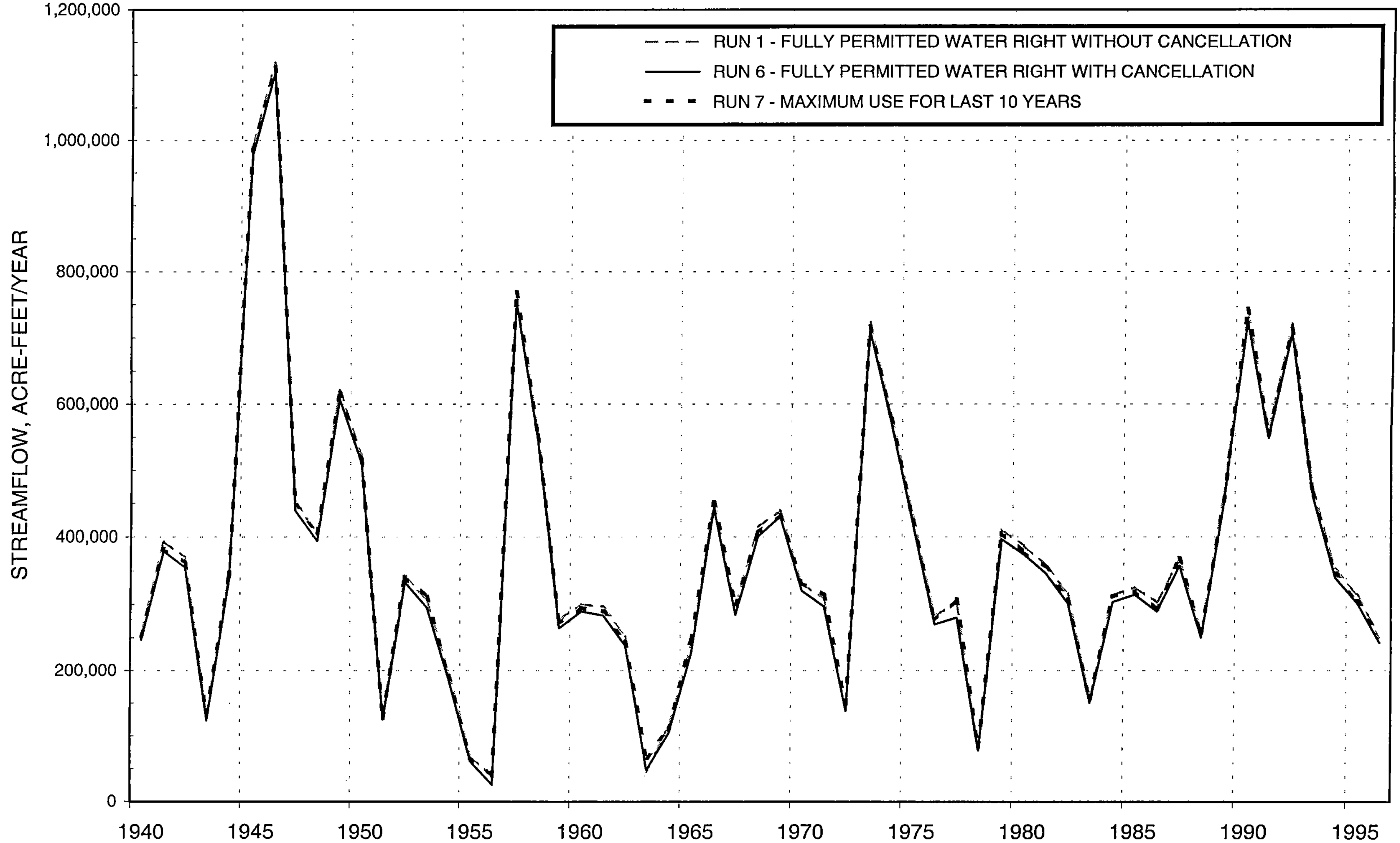


FIGURE A4-33
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

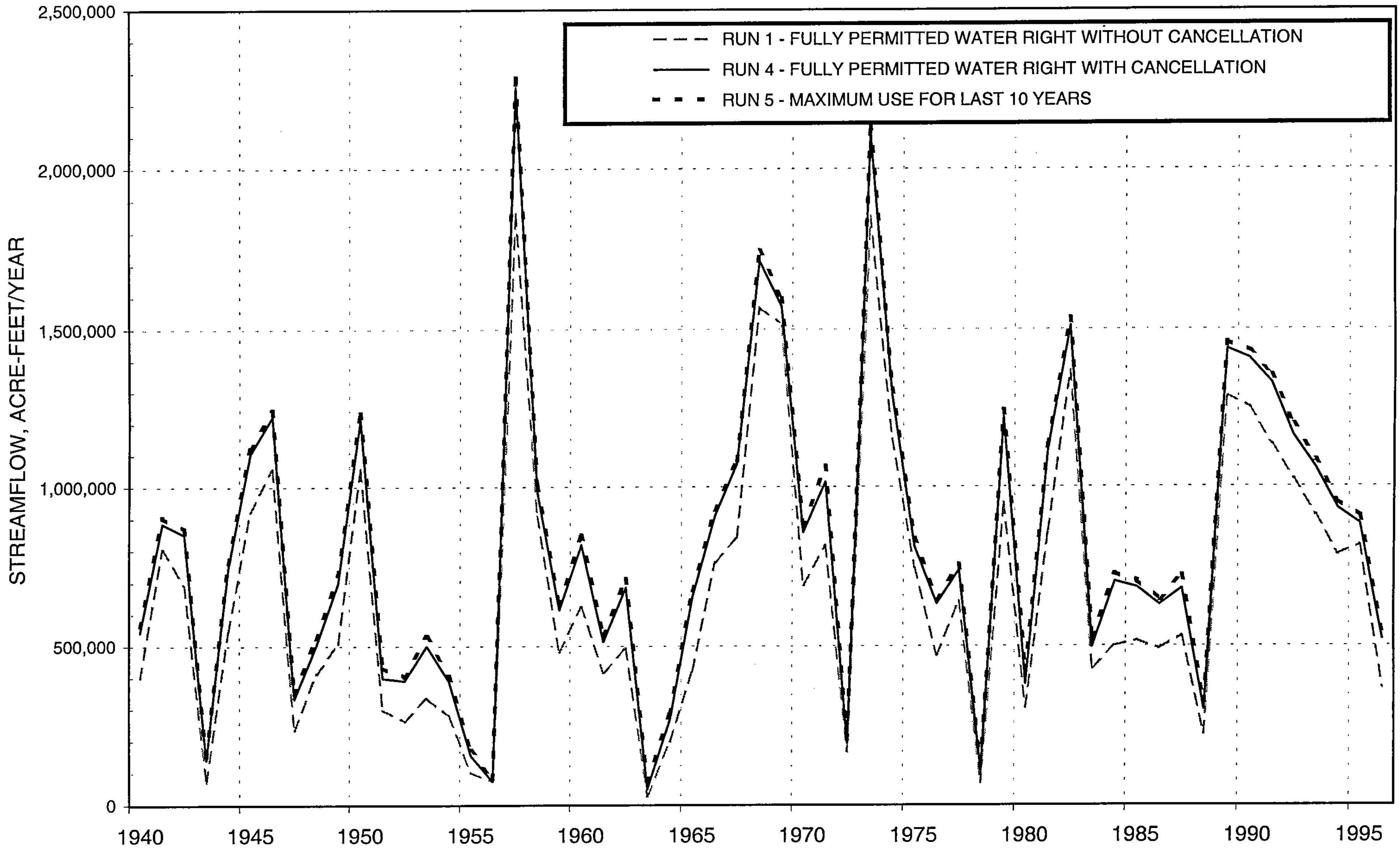


FIGURE A4-34
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

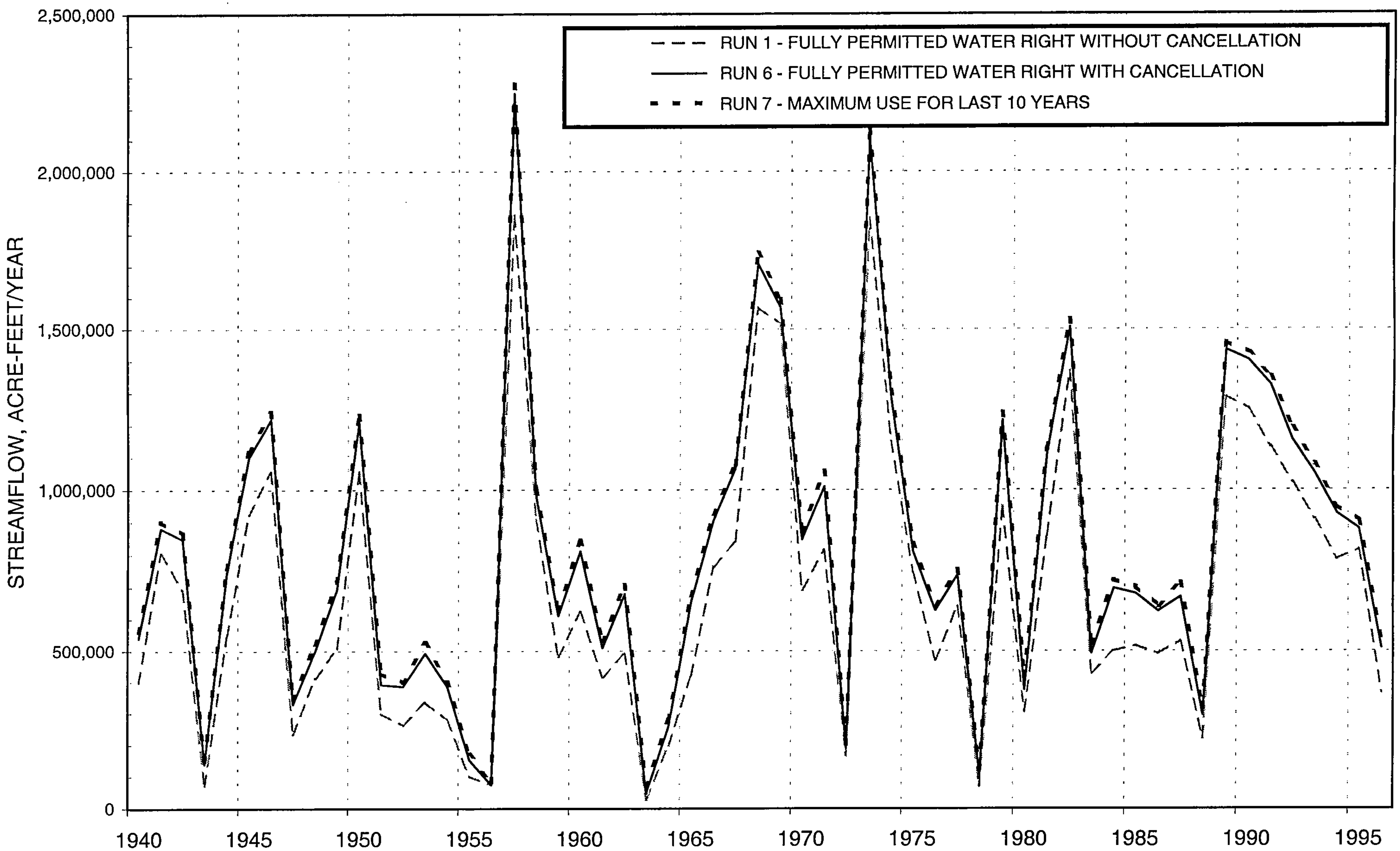


FIGURE A4-35
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

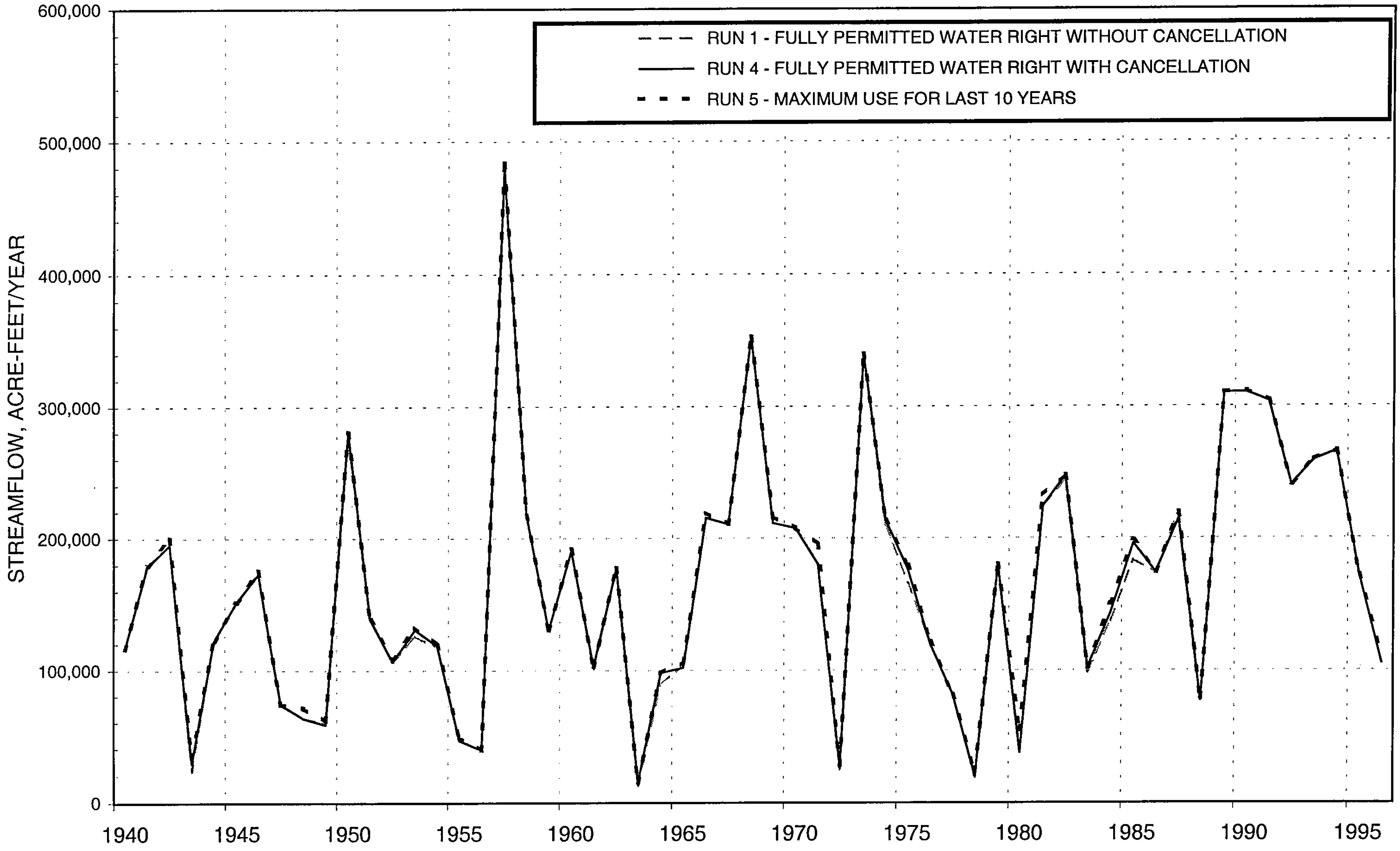


FIGURE A4-36
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

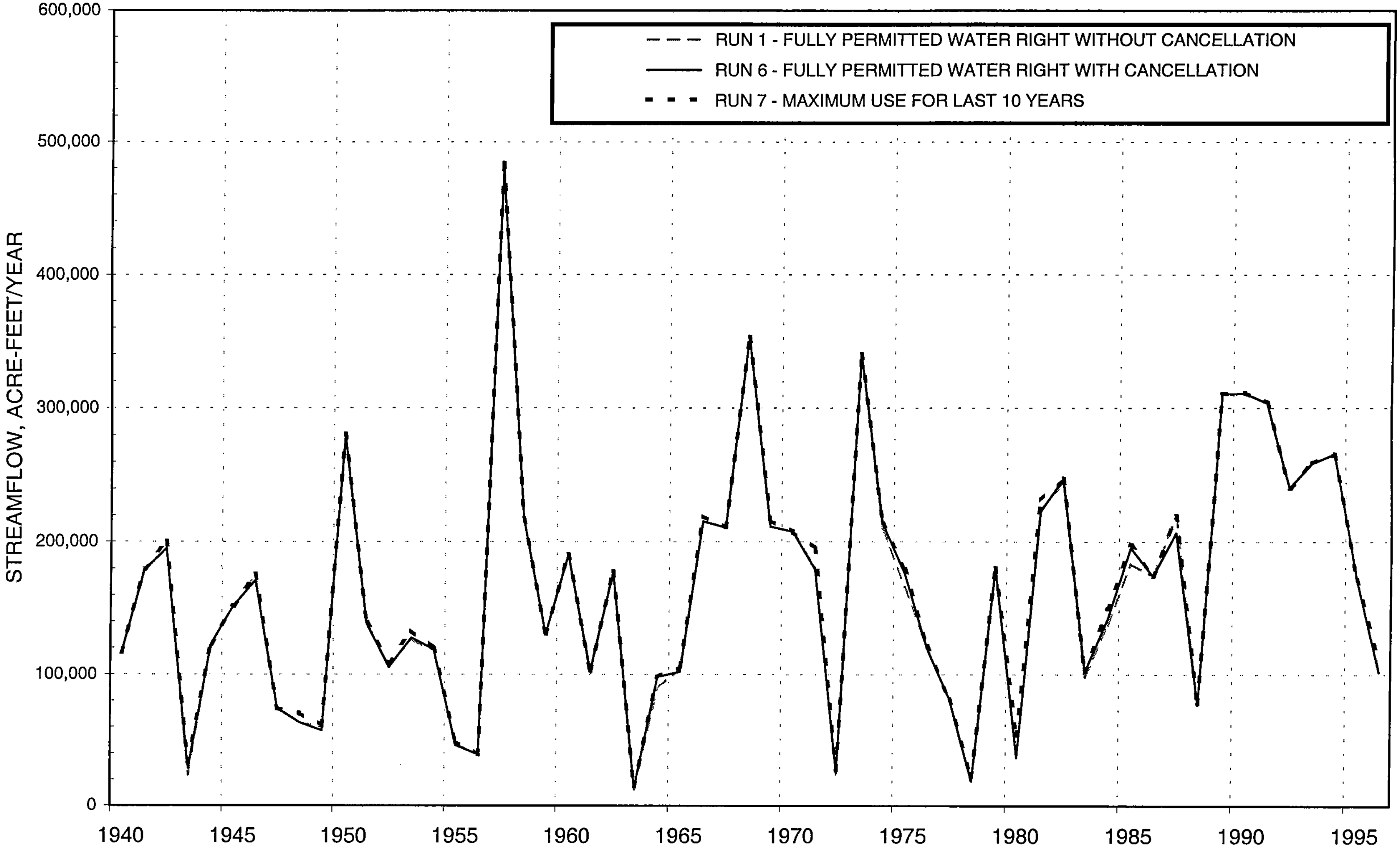


FIGURE A4-37

ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

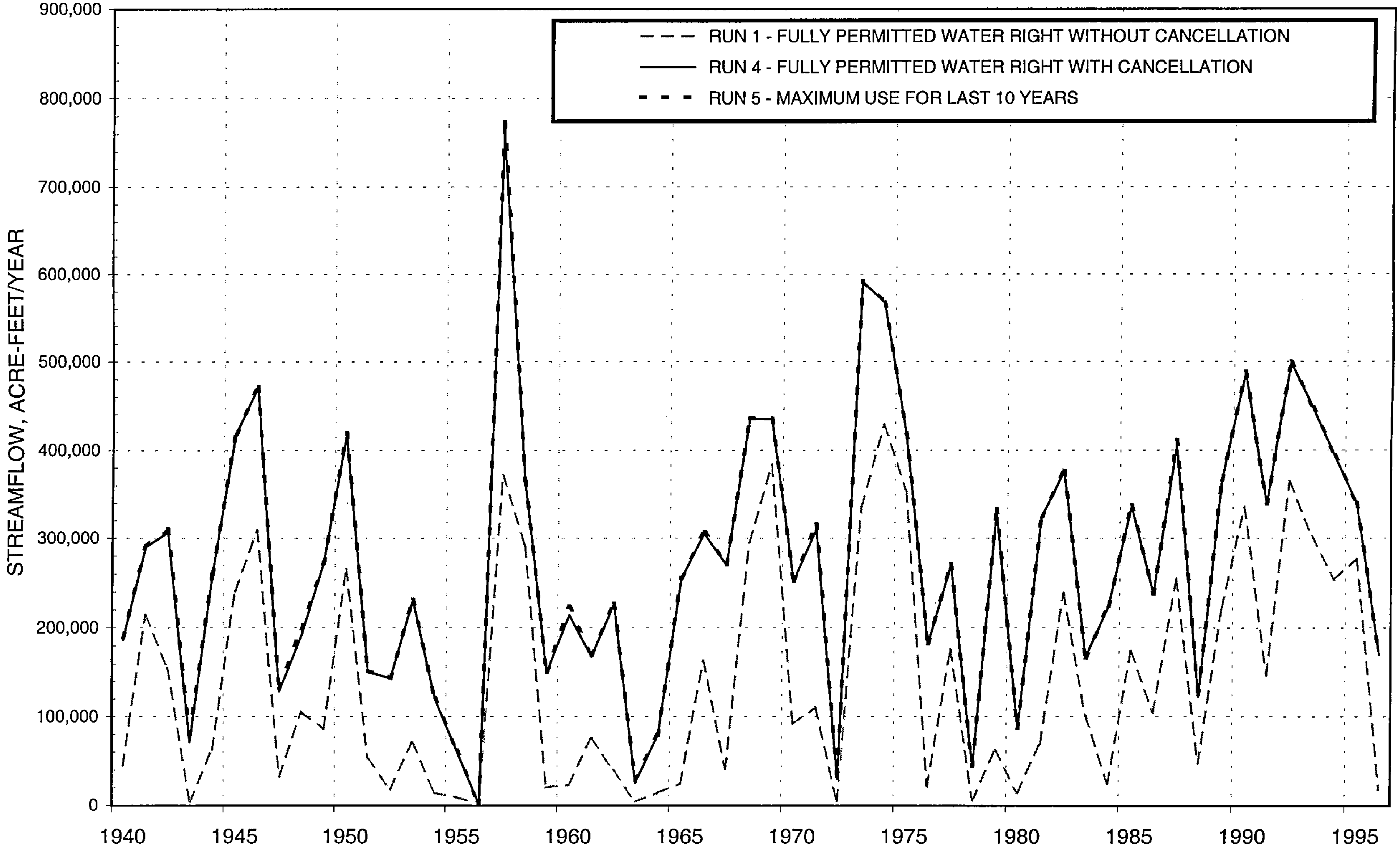


FIGURE A4-38
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

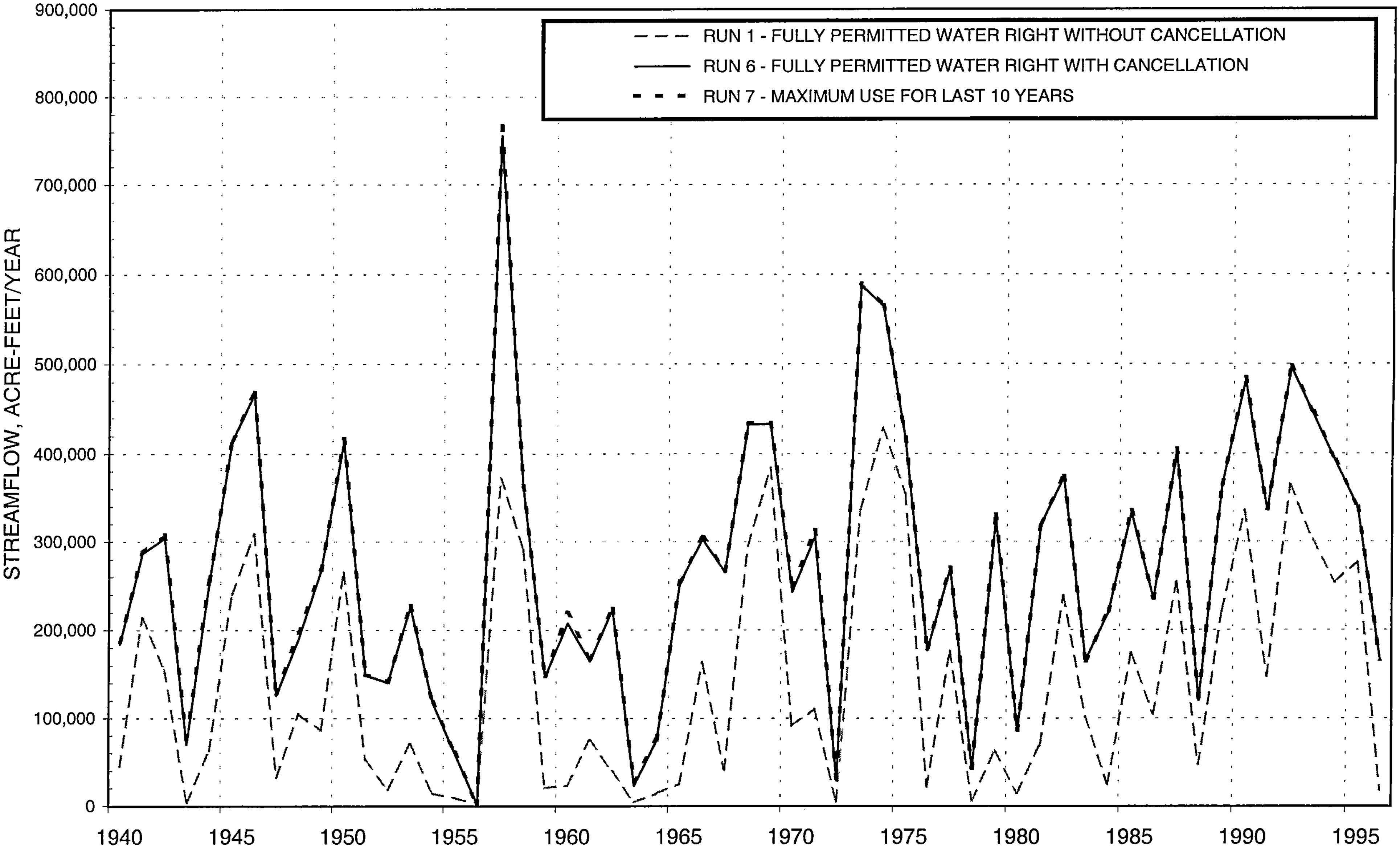


FIGURE A4-39
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

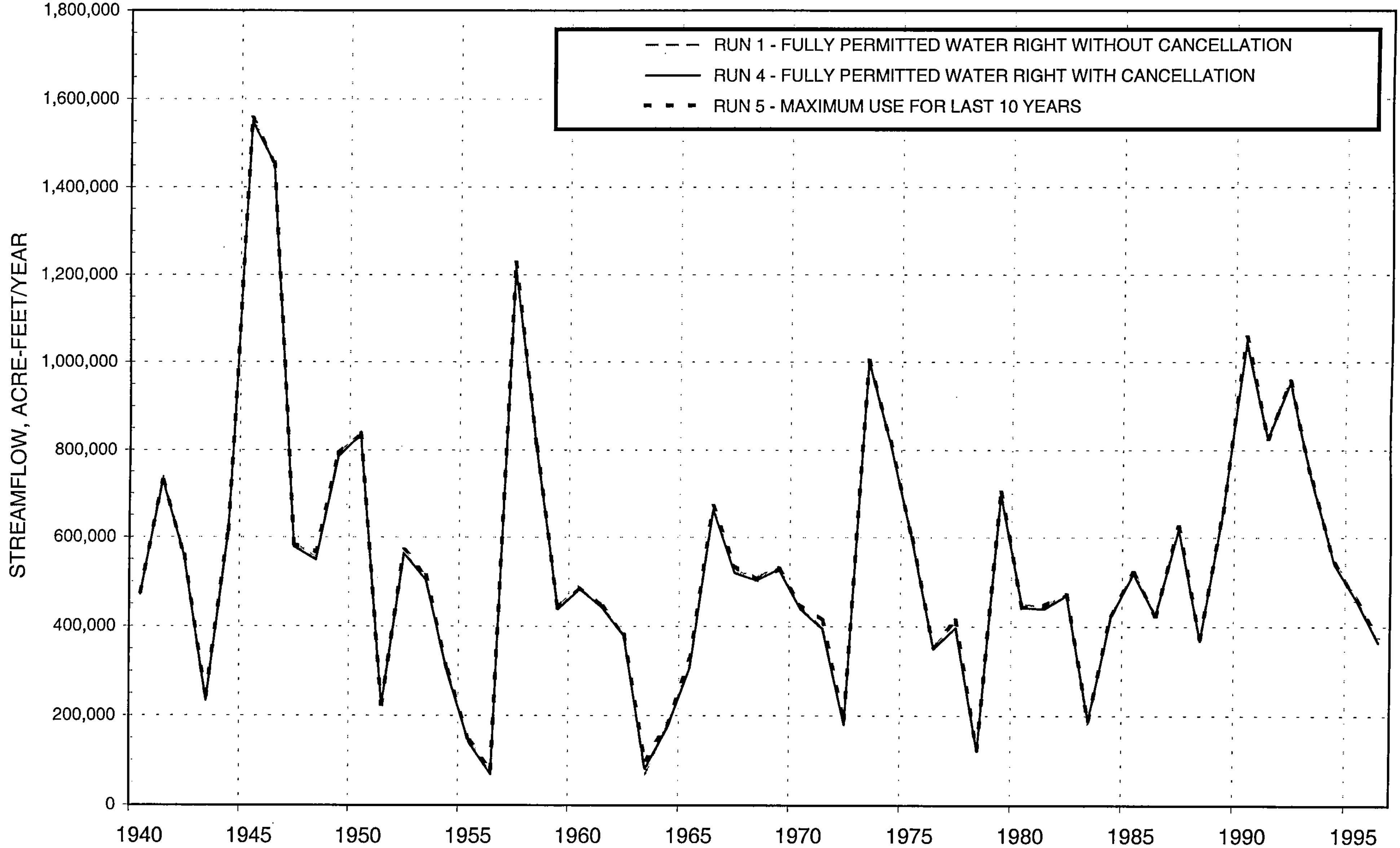


FIGURE A4-40
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

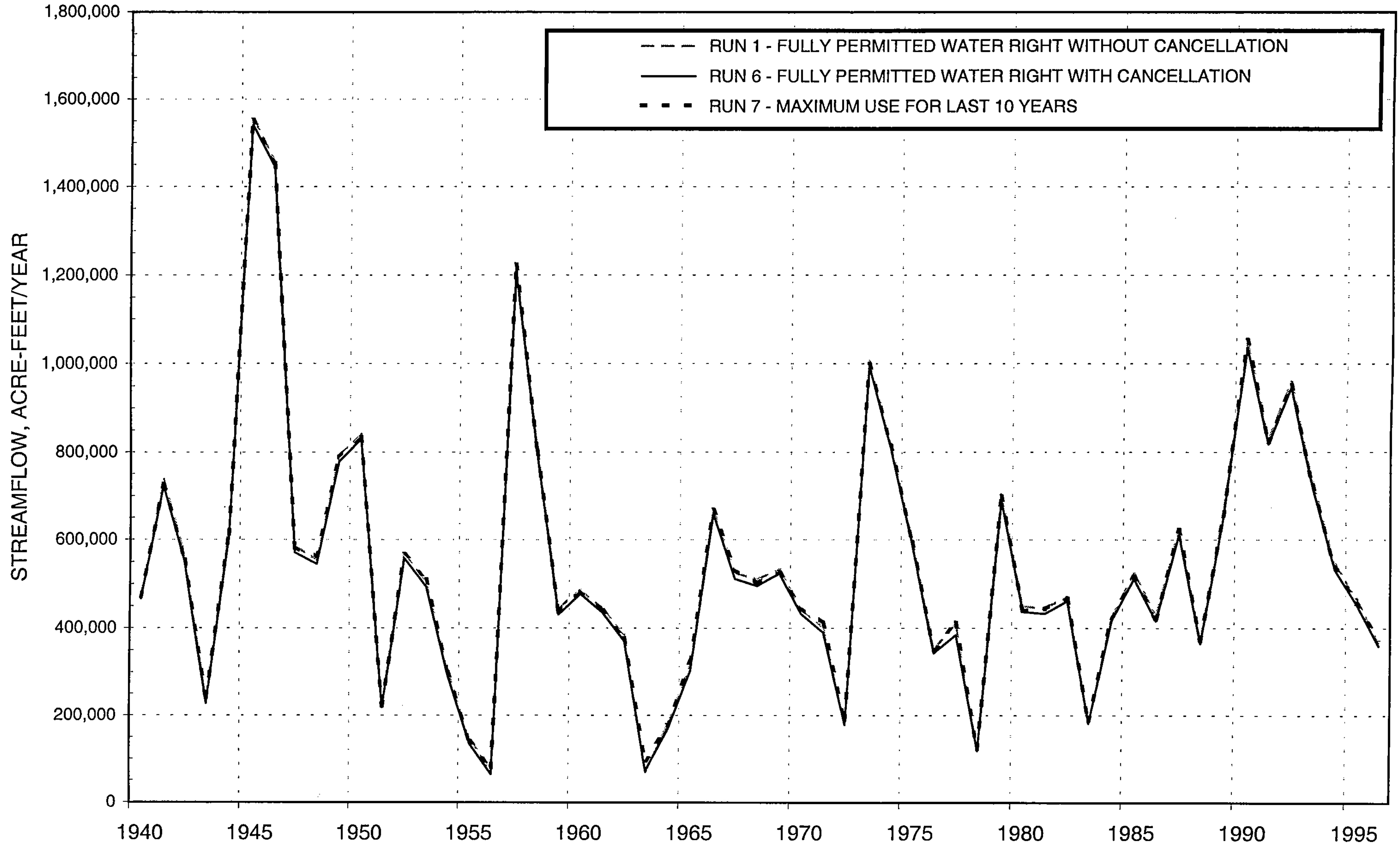


FIGURE A4-41
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

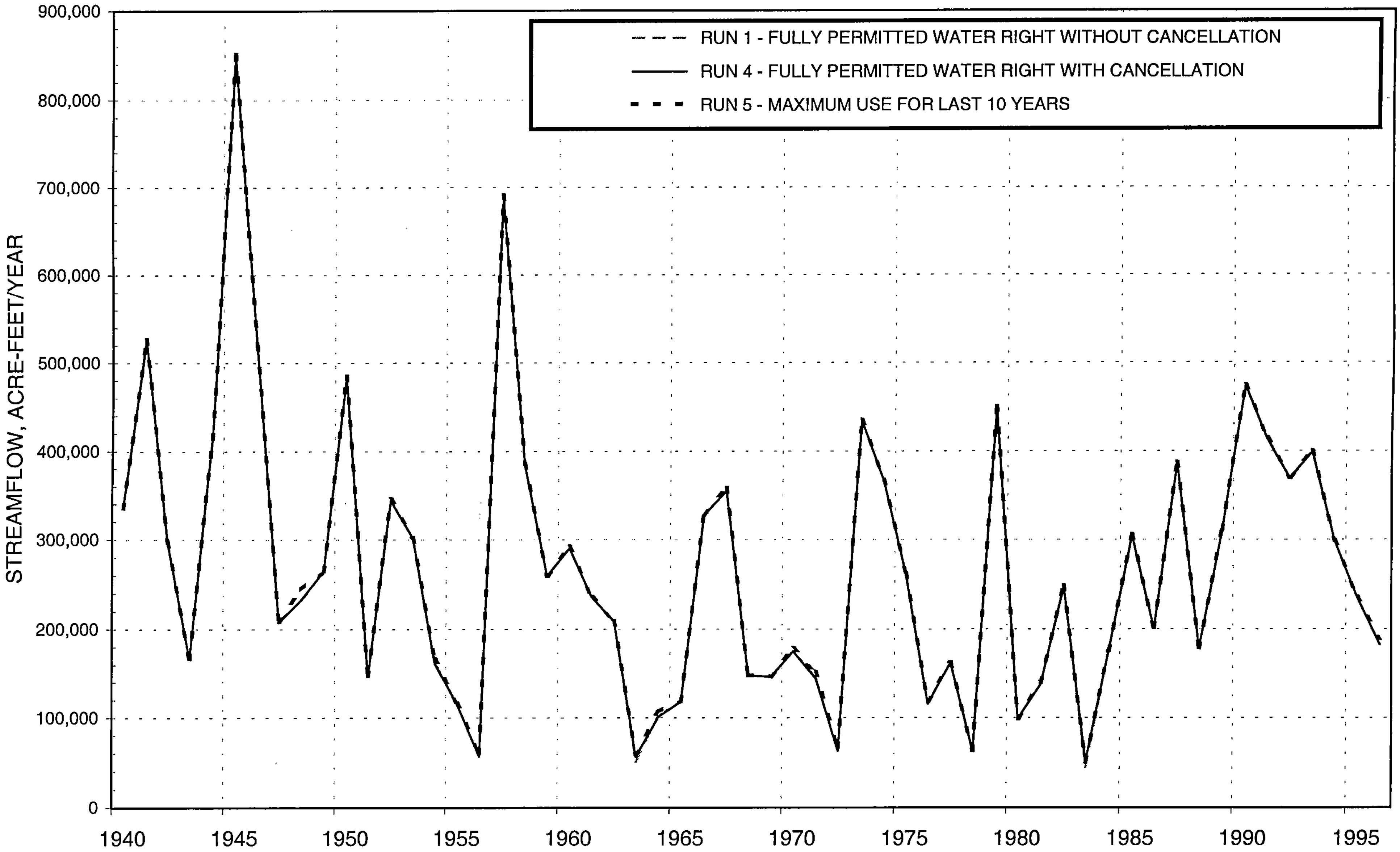


FIGURE A4-42
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

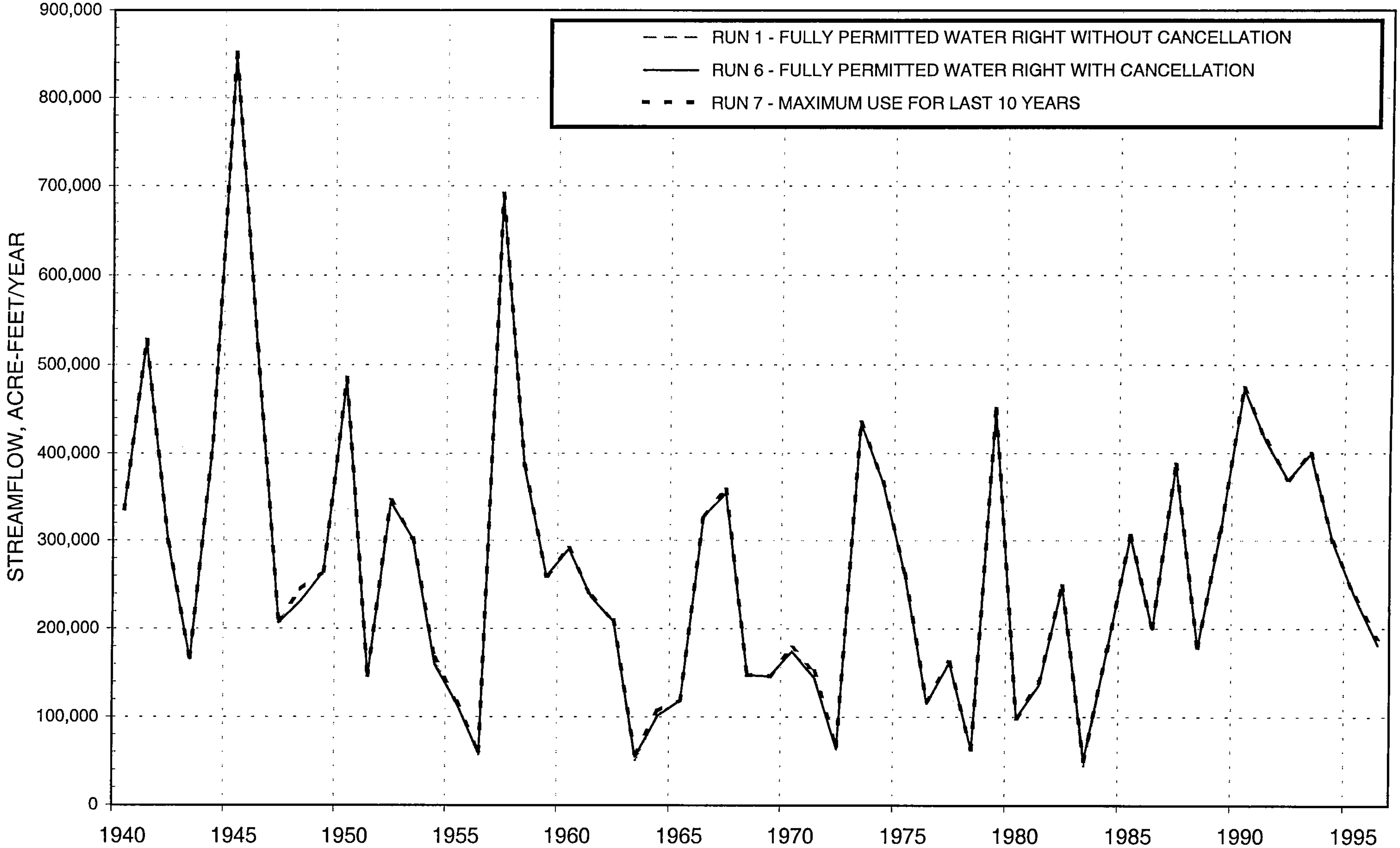


FIGURE A4-43
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT C90, NORTH SULPHUR RIVER

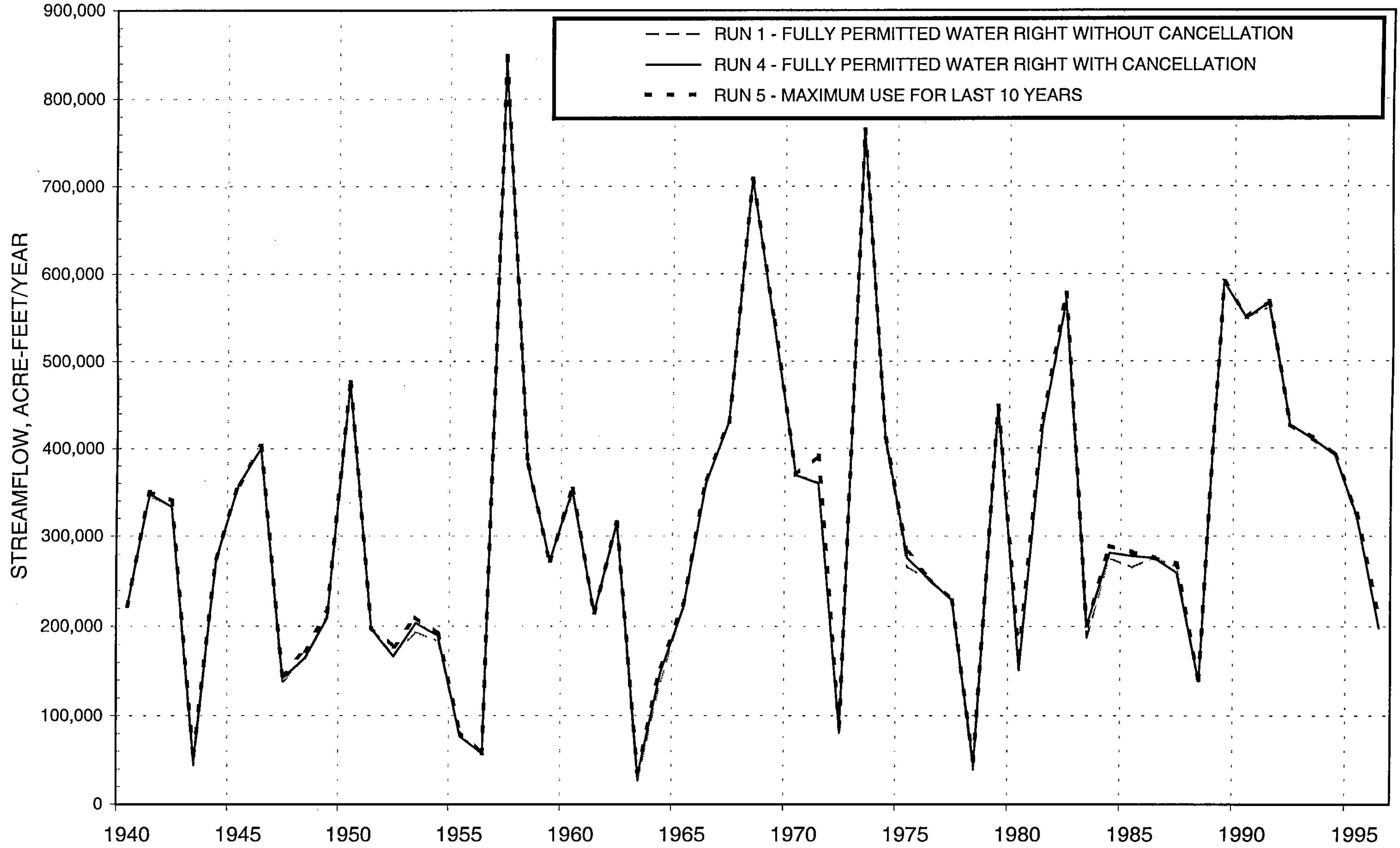


FIGURE A4-44
ANNUAL UNAPPROPRIATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT C90, NORTH SULPHUR RIVER

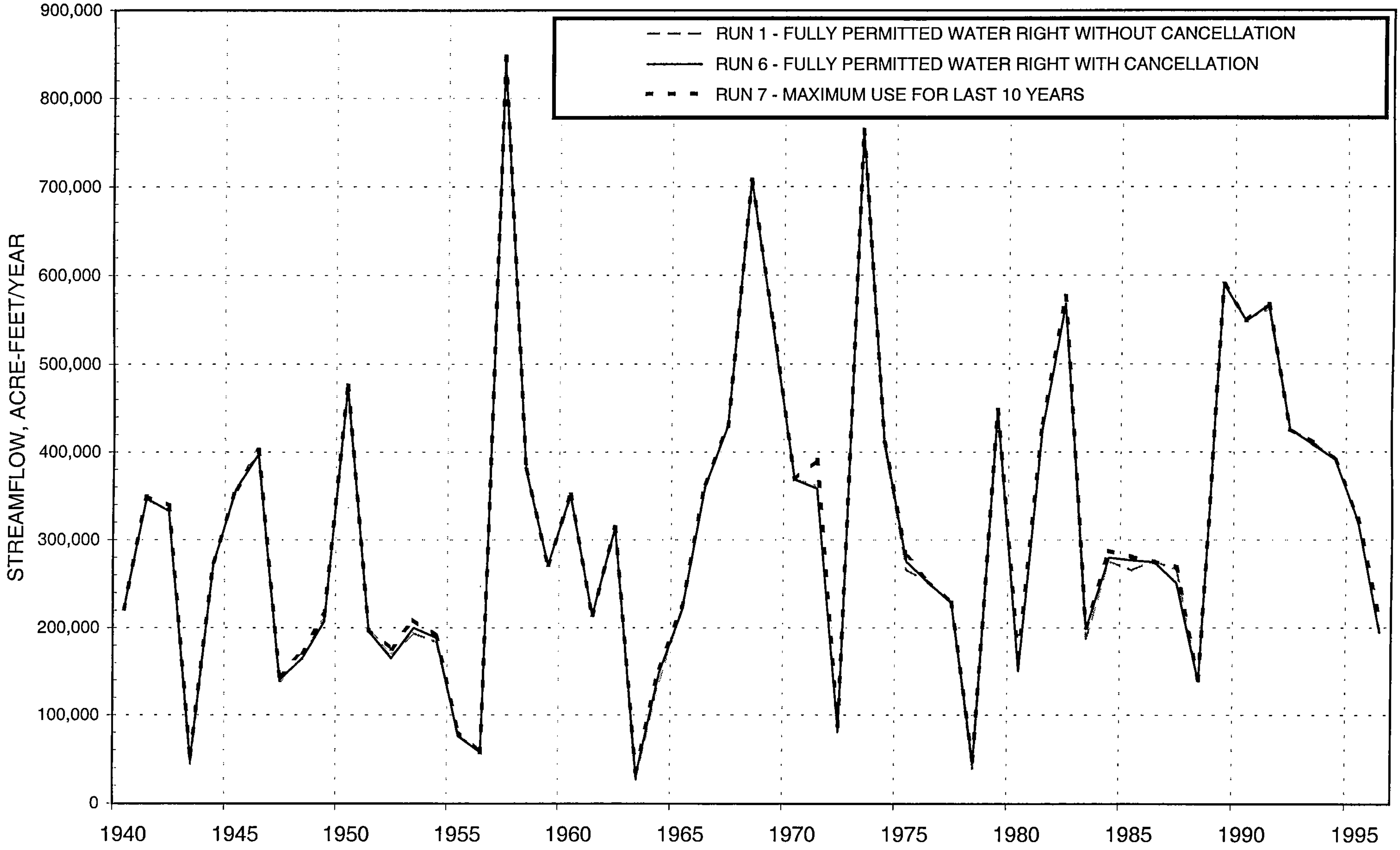


FIGURE A4-45
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

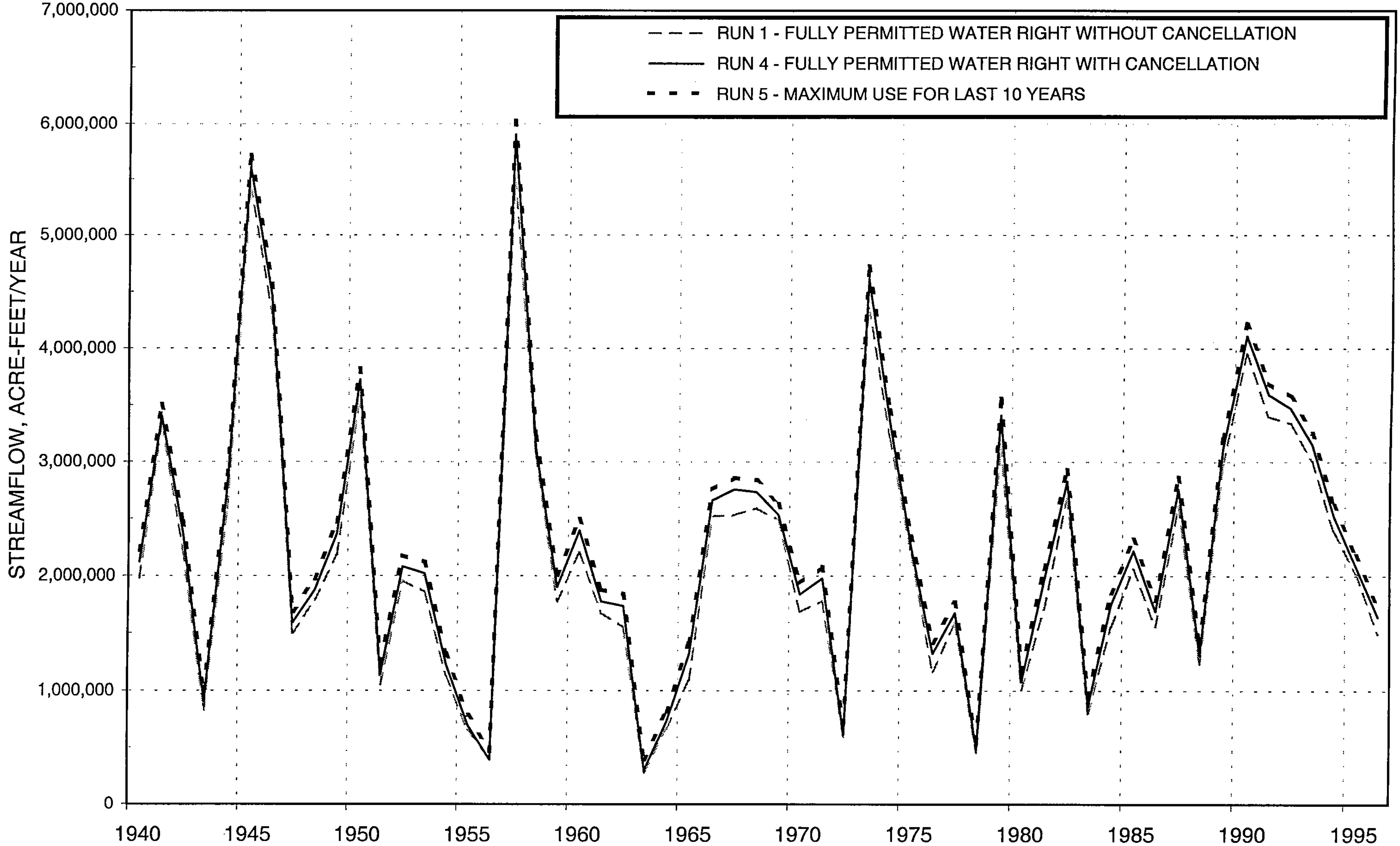


FIGURE A4-46
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

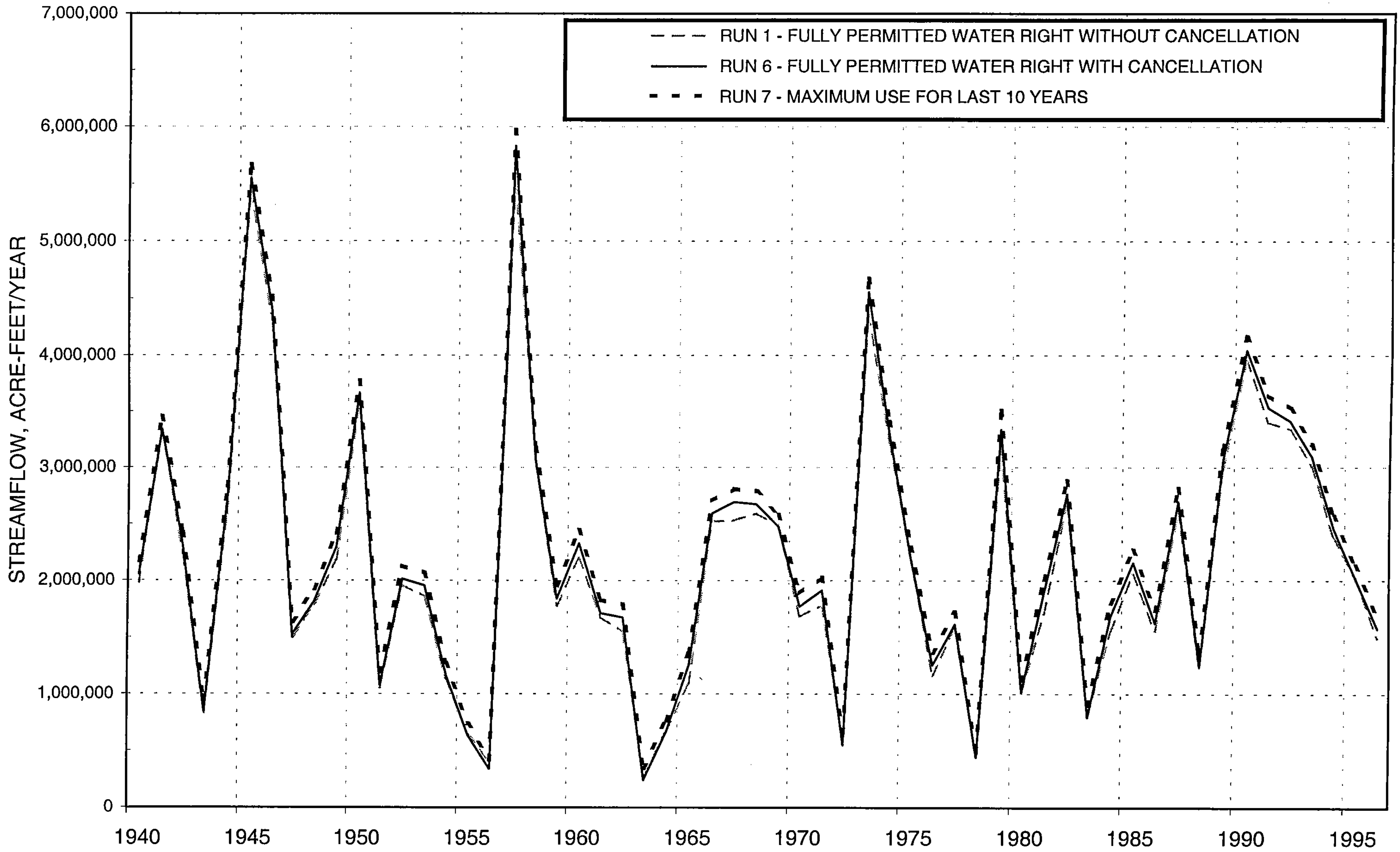


FIGURE A4-47
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

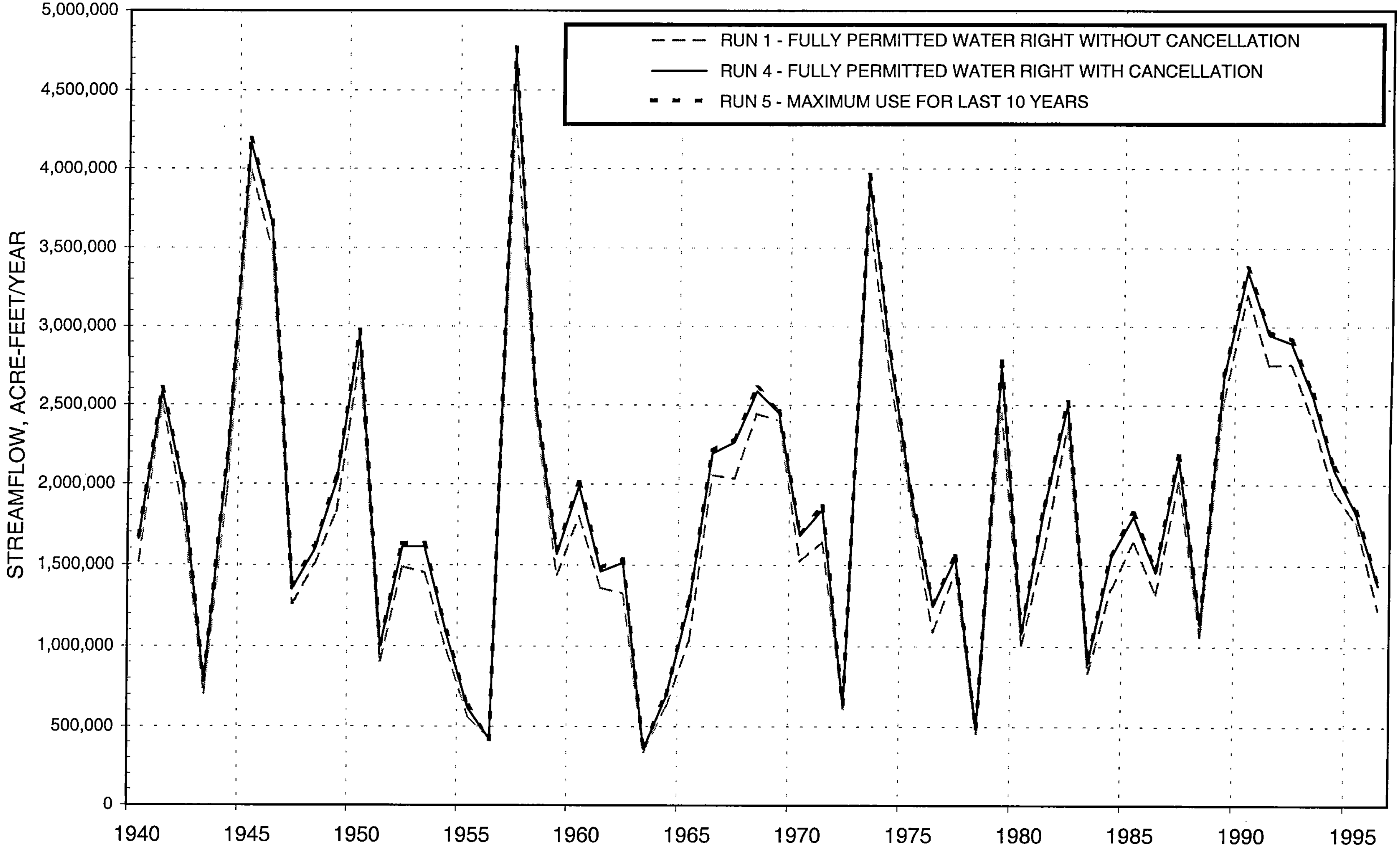


FIGURE A4-48
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

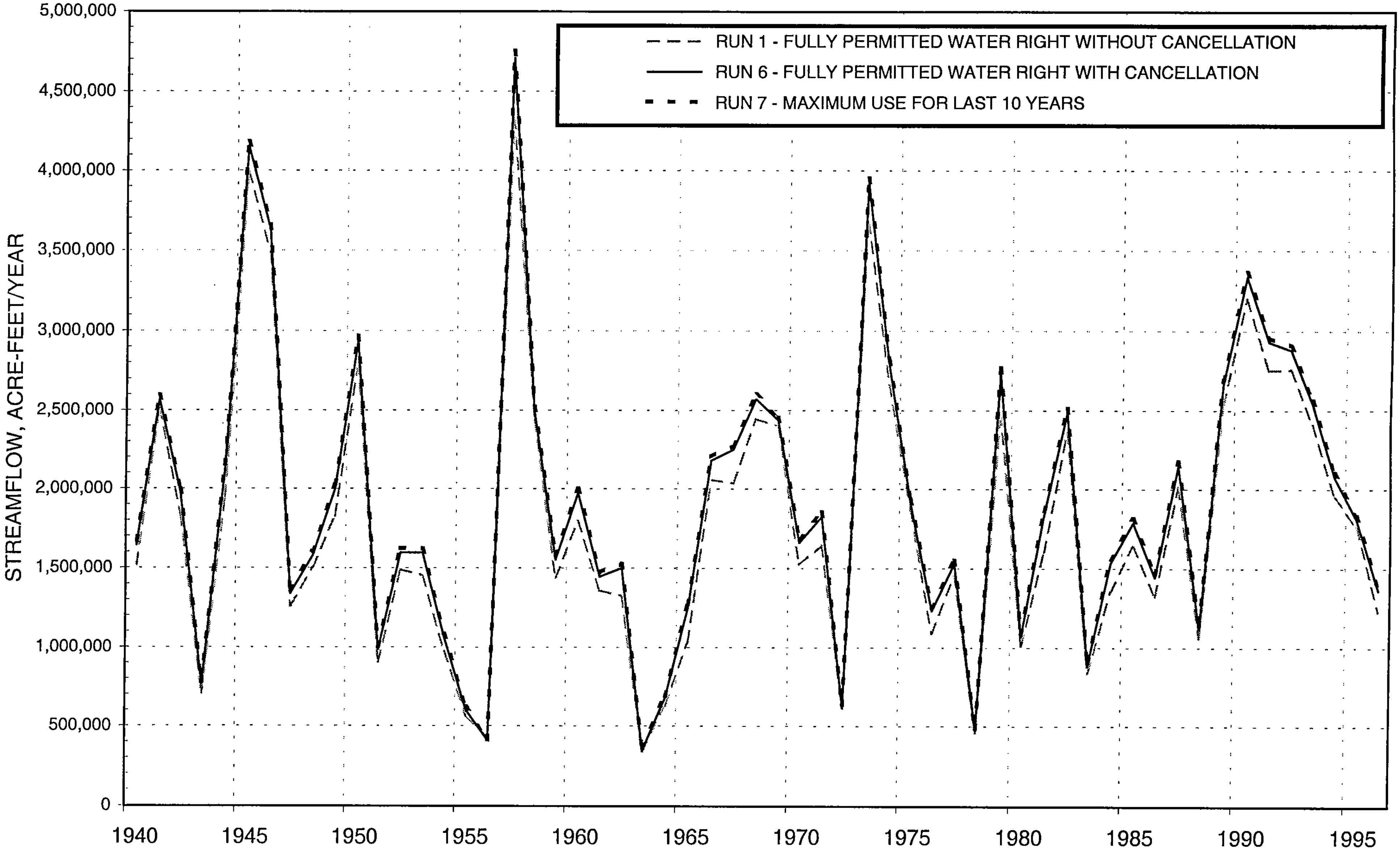


FIGURE A4-49
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

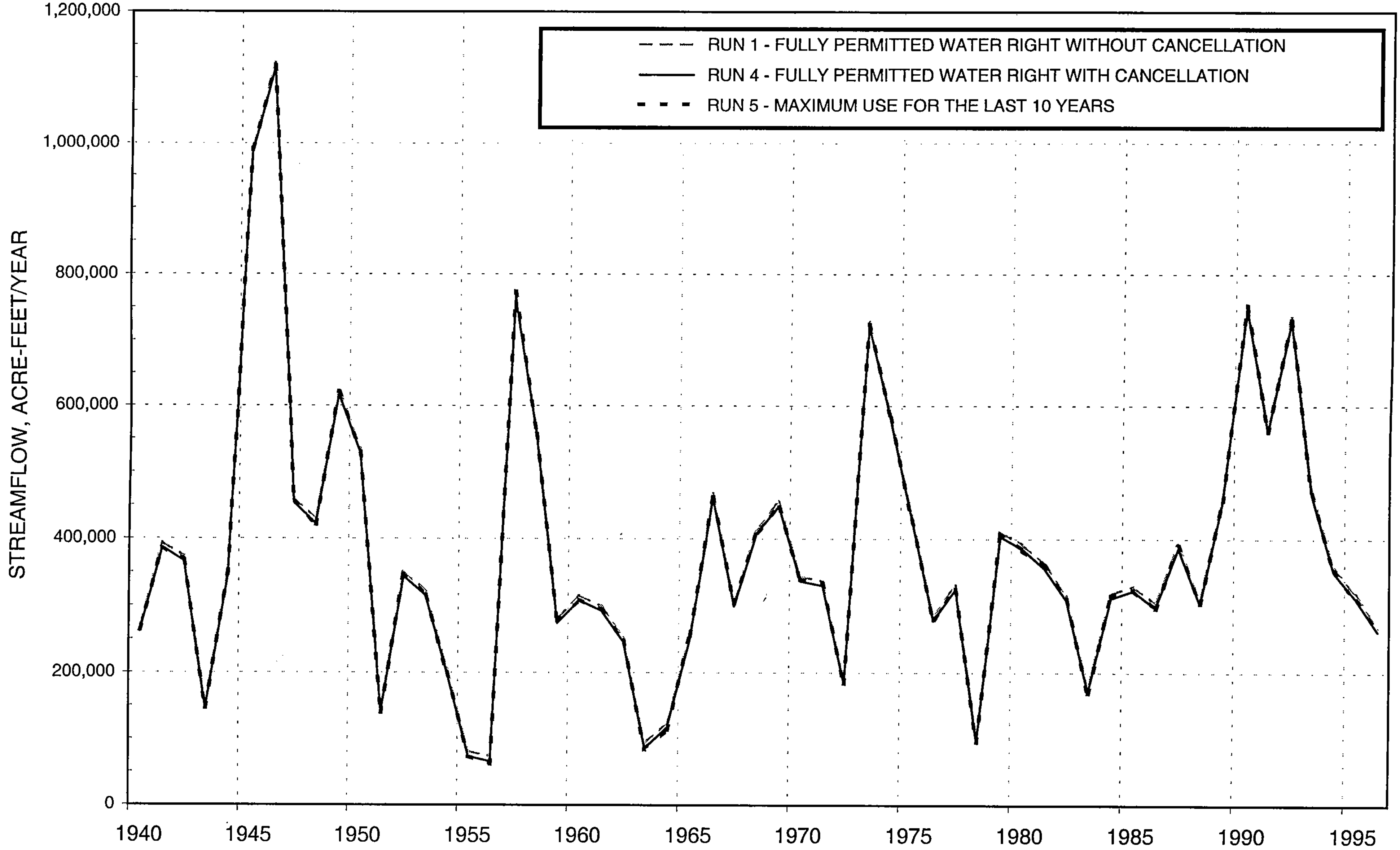


FIGURE A4-50
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

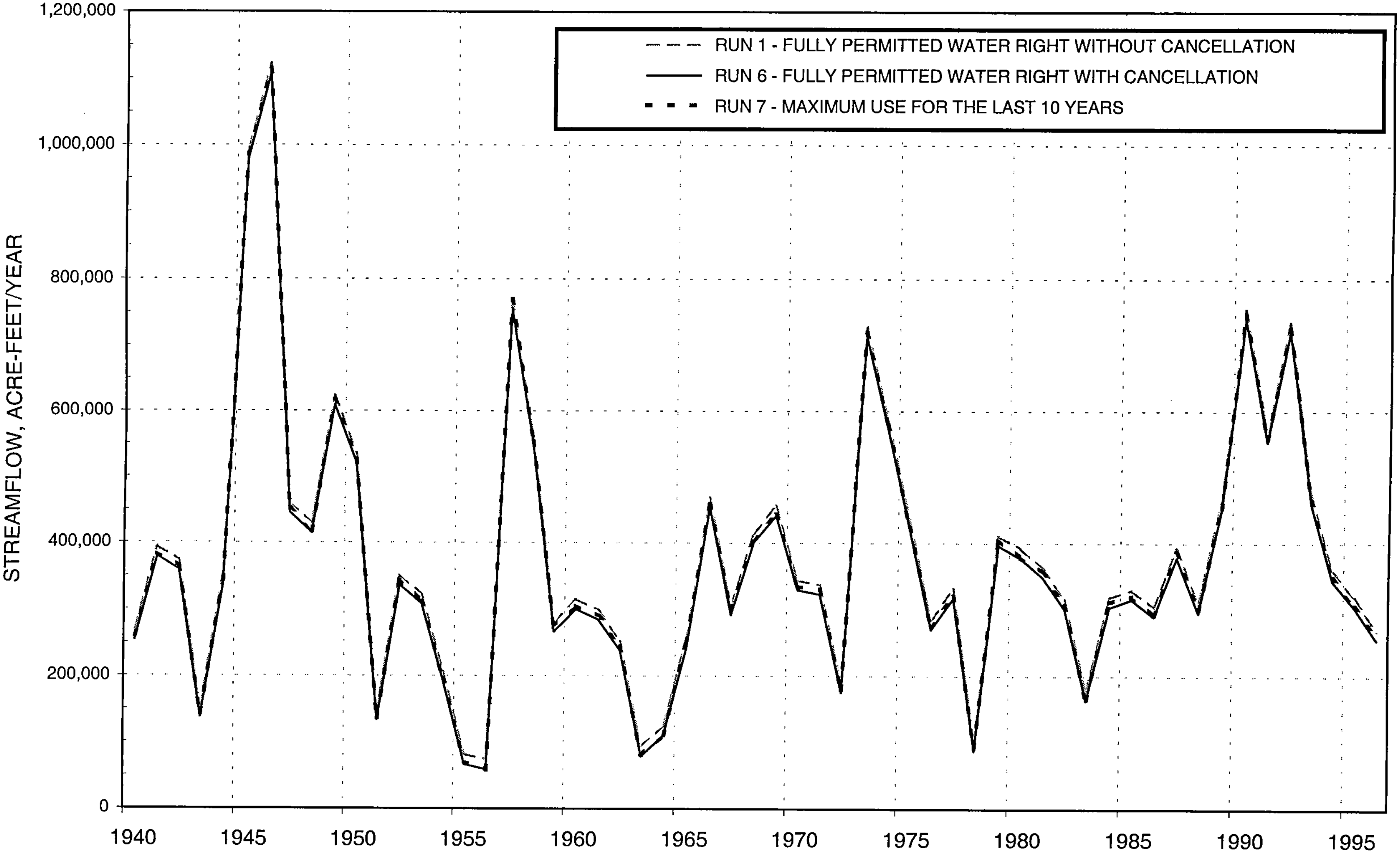


FIGURE A4-51
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

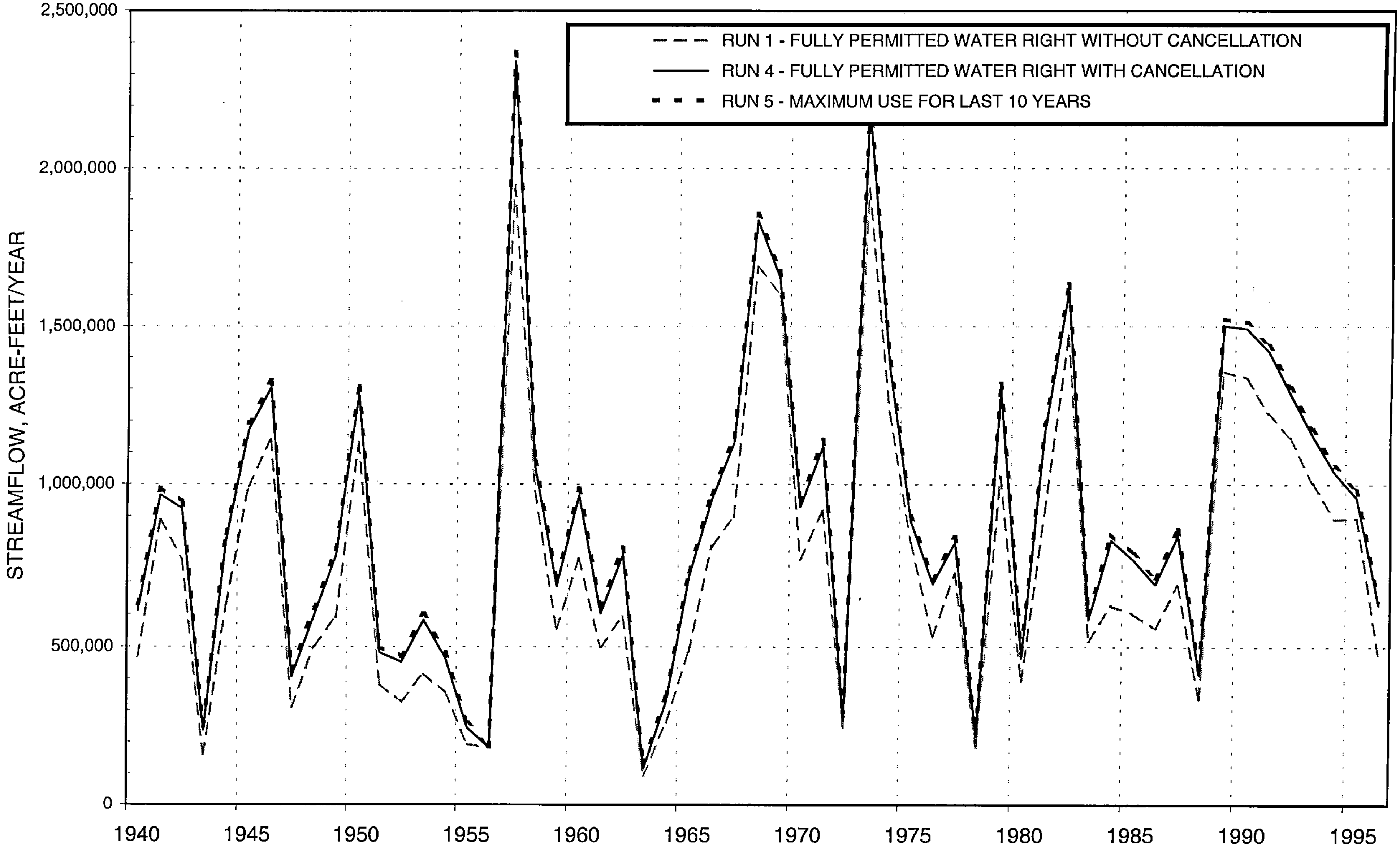


FIGURE A4-52
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

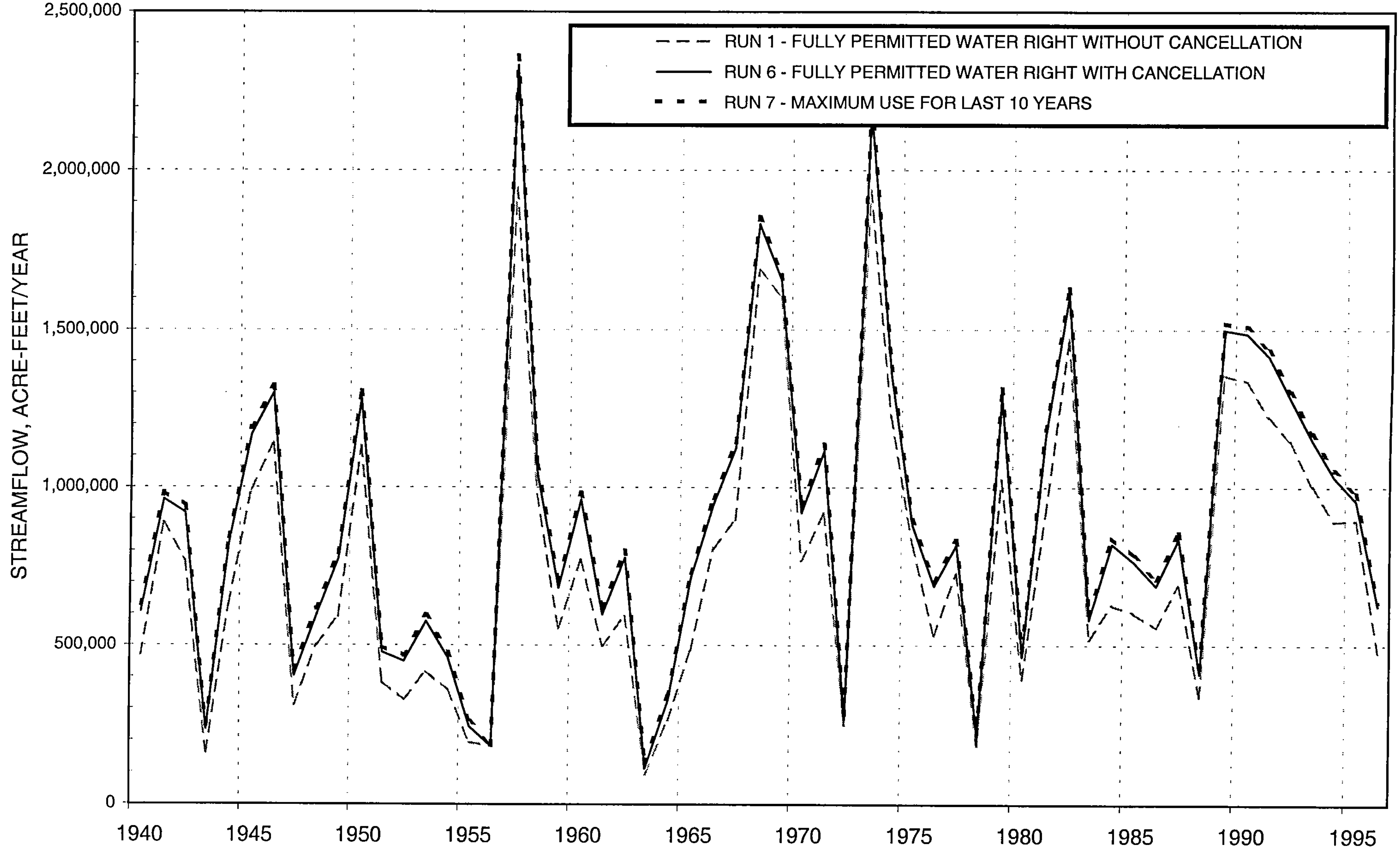


FIGURE A4-53
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

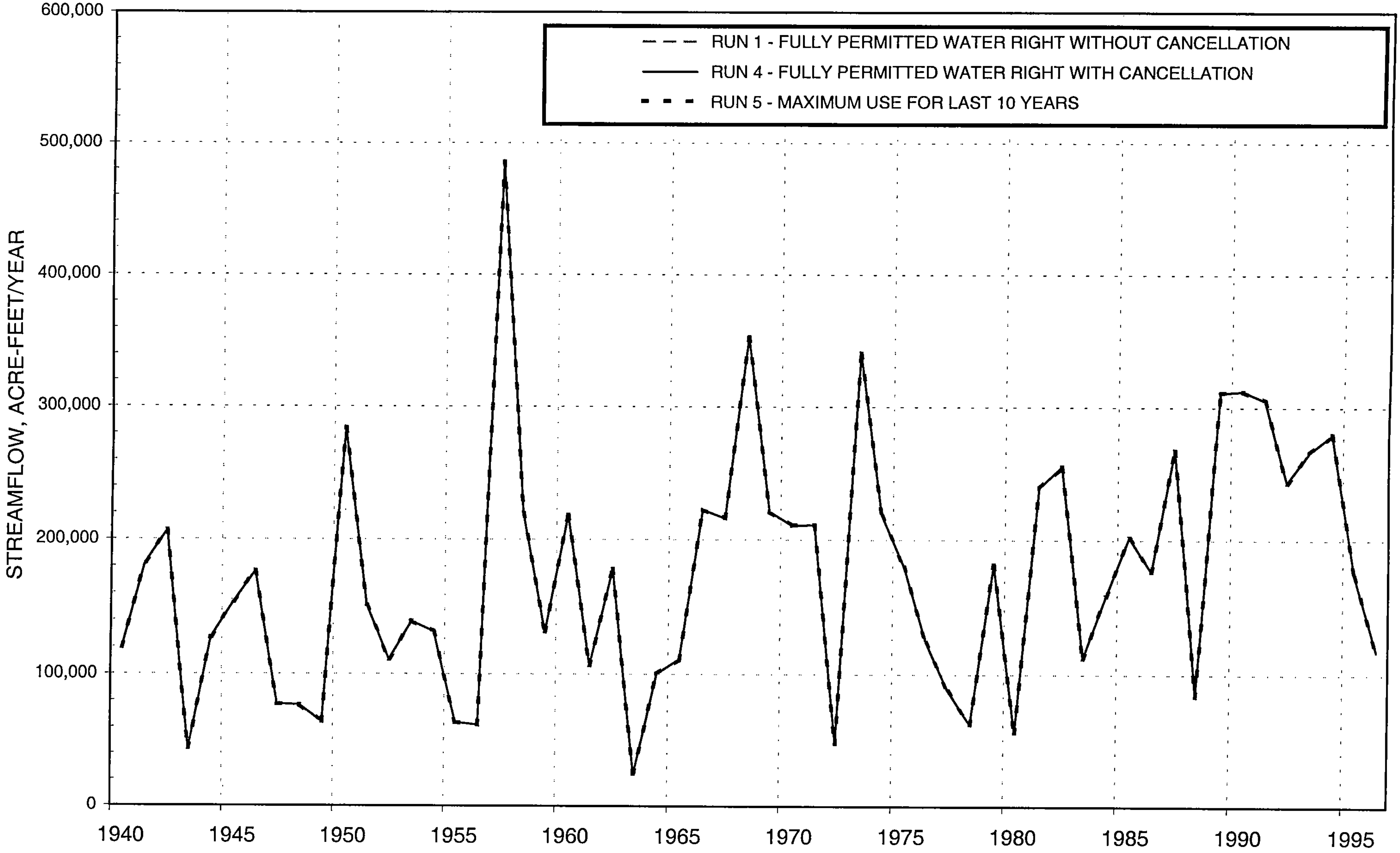


FIGURE A4-54
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

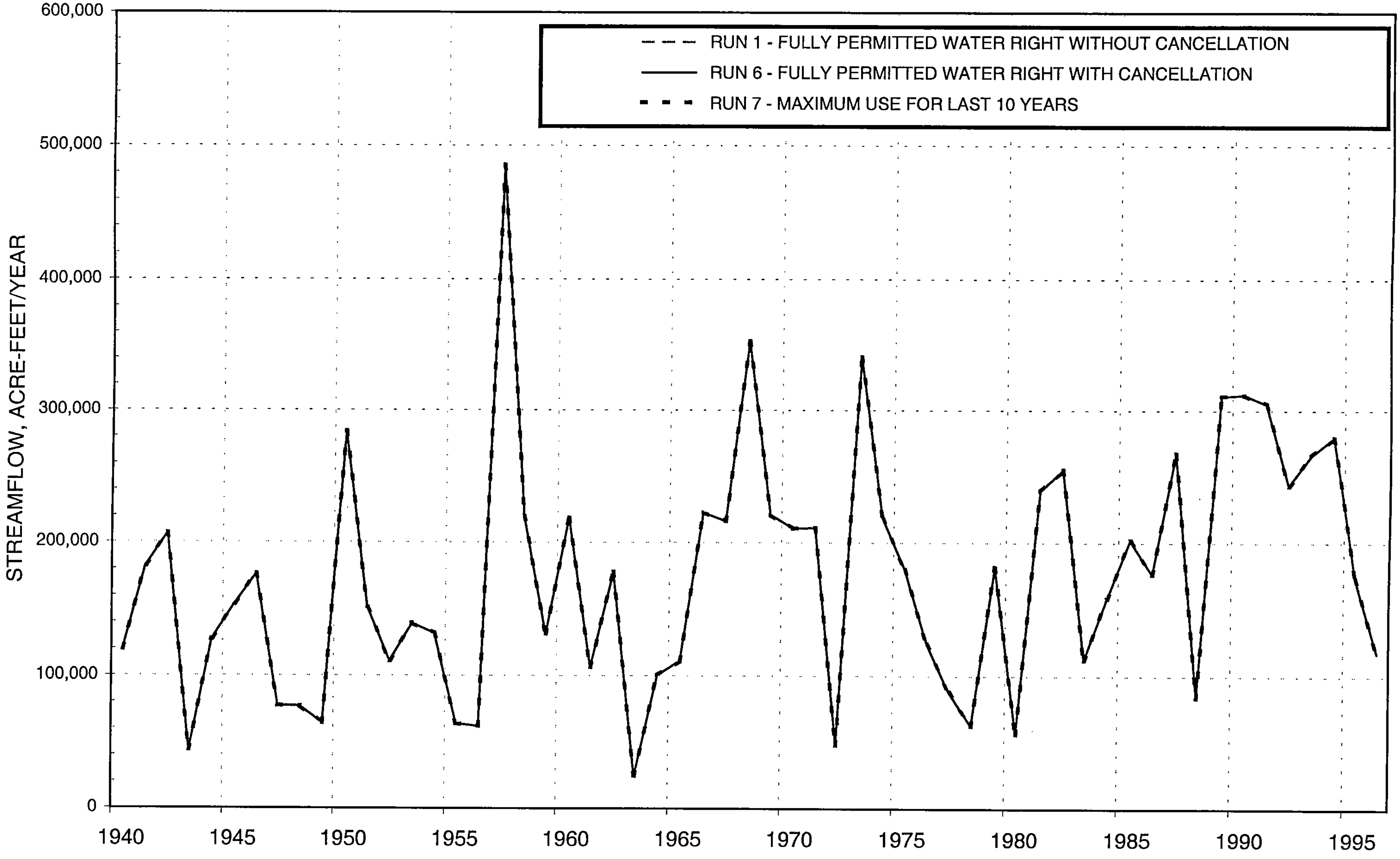


FIGURE A4-55
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

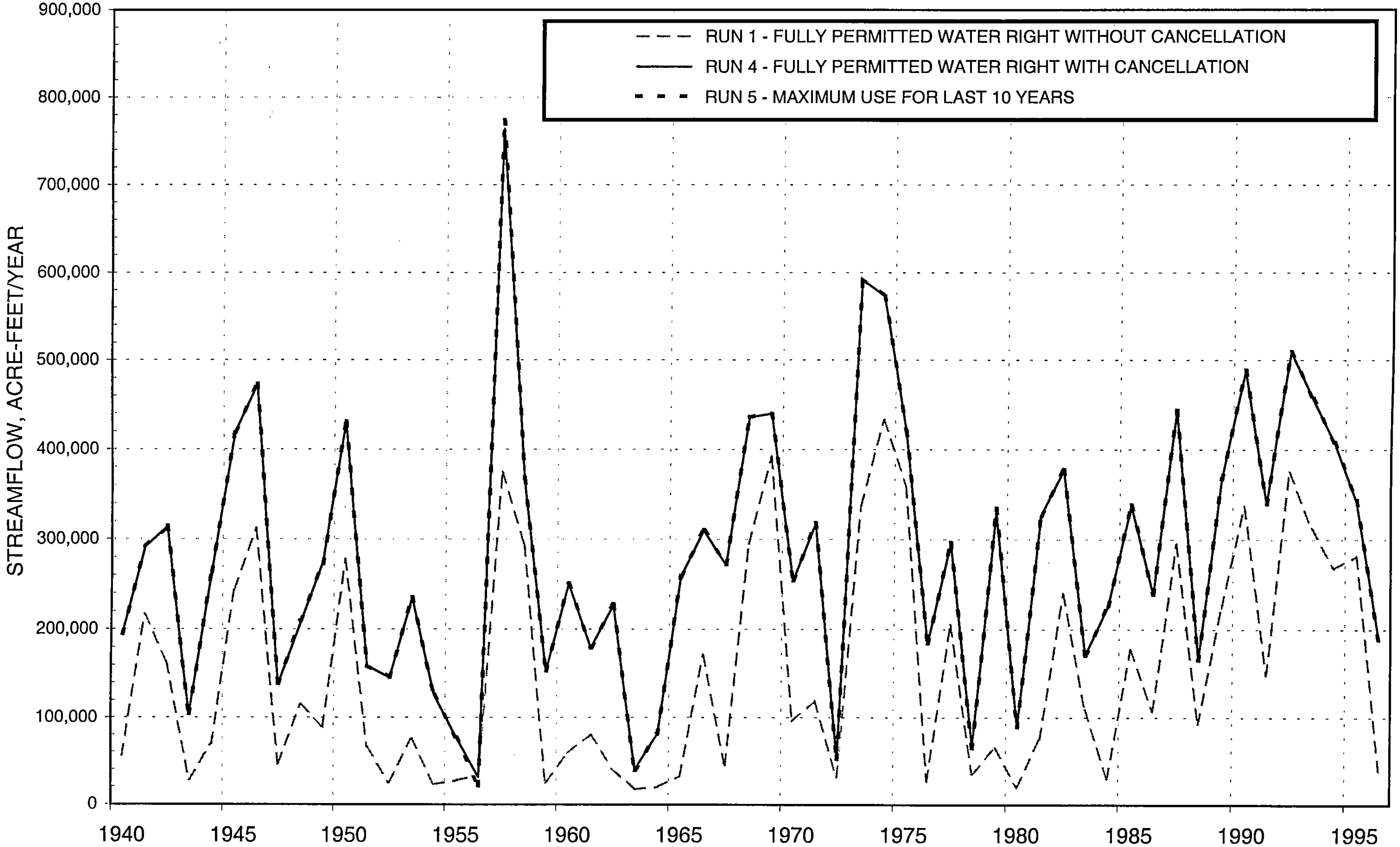


FIGURE A4-56
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

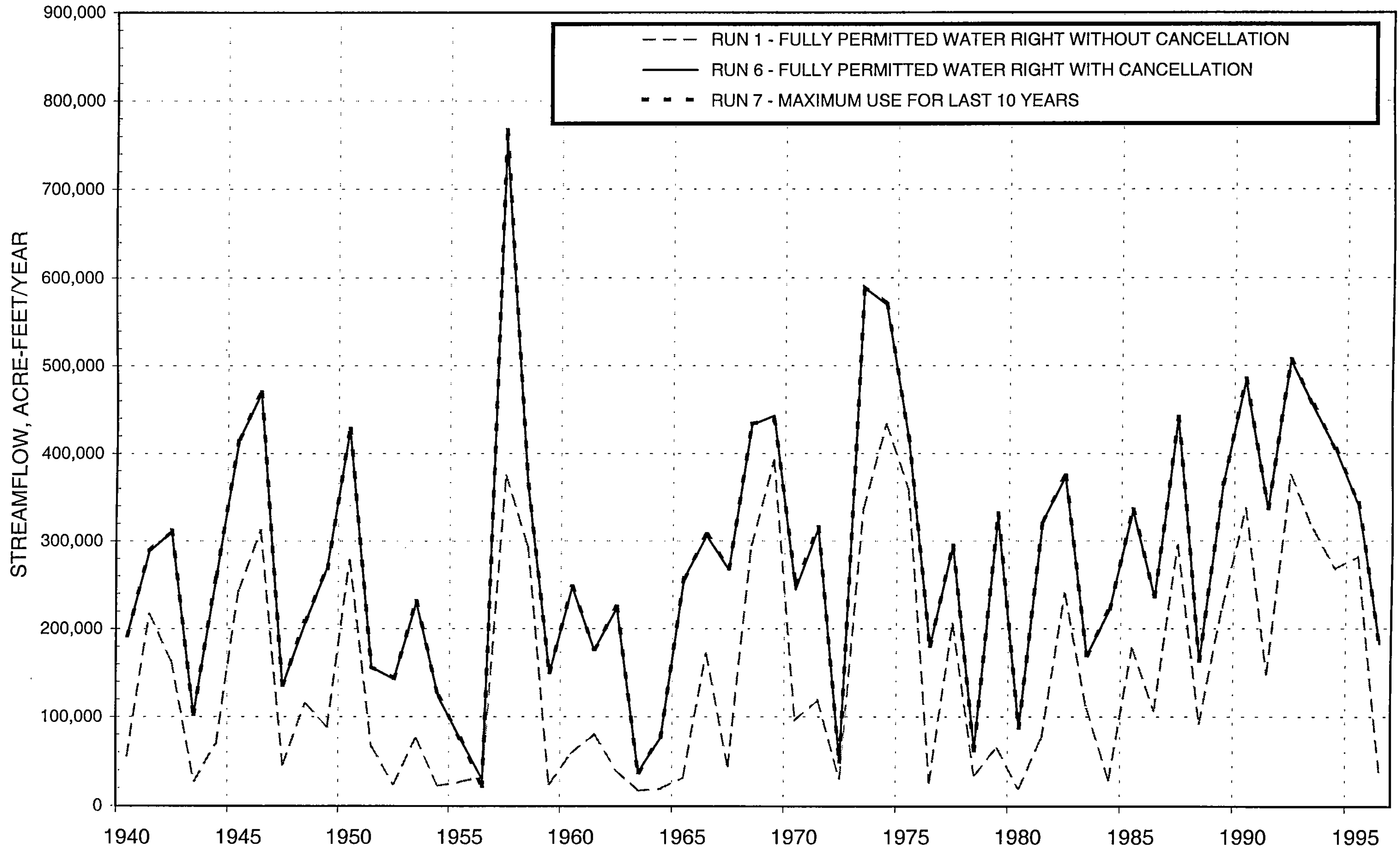


FIGURE A4-57
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

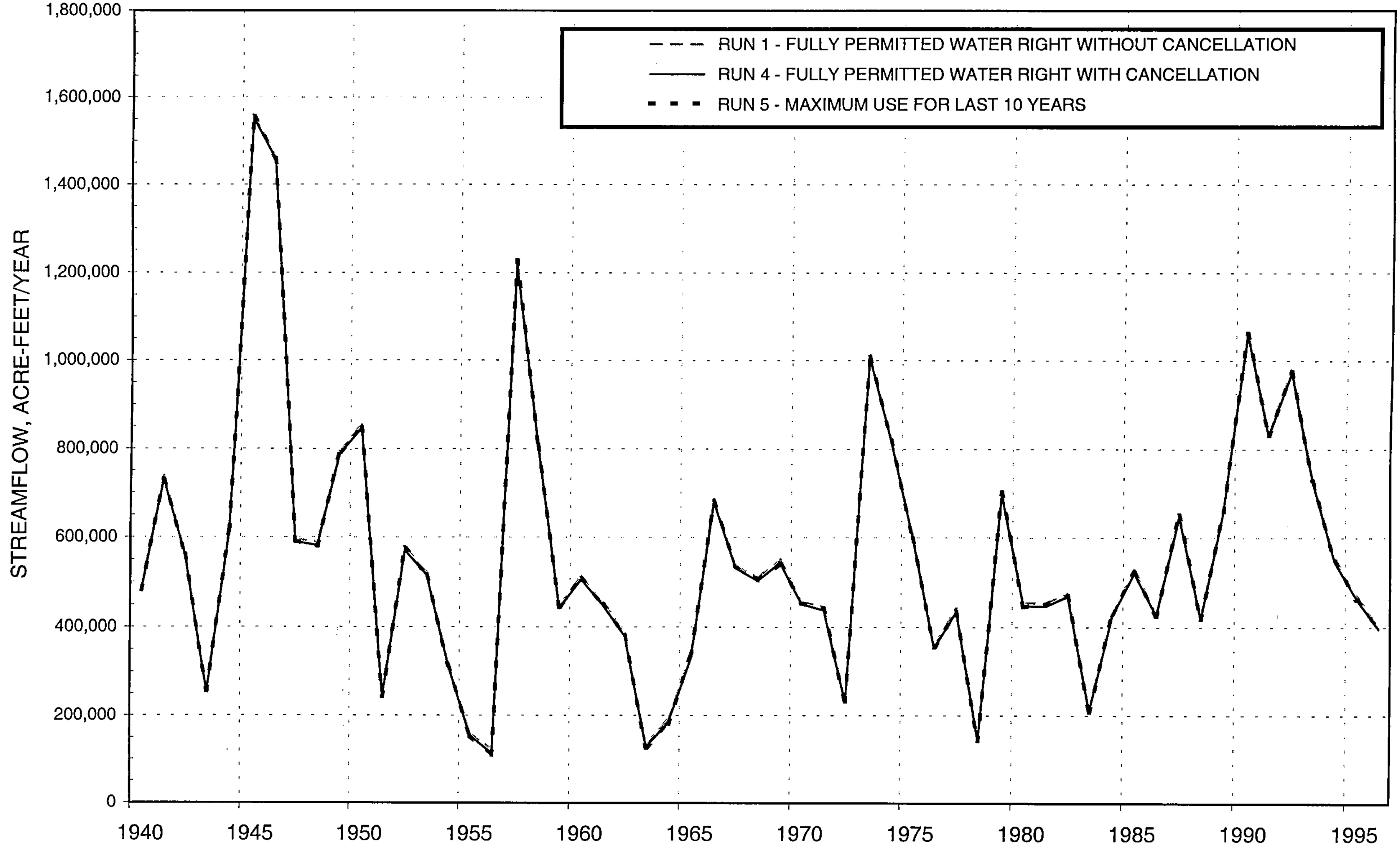


FIGURE A4-58
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

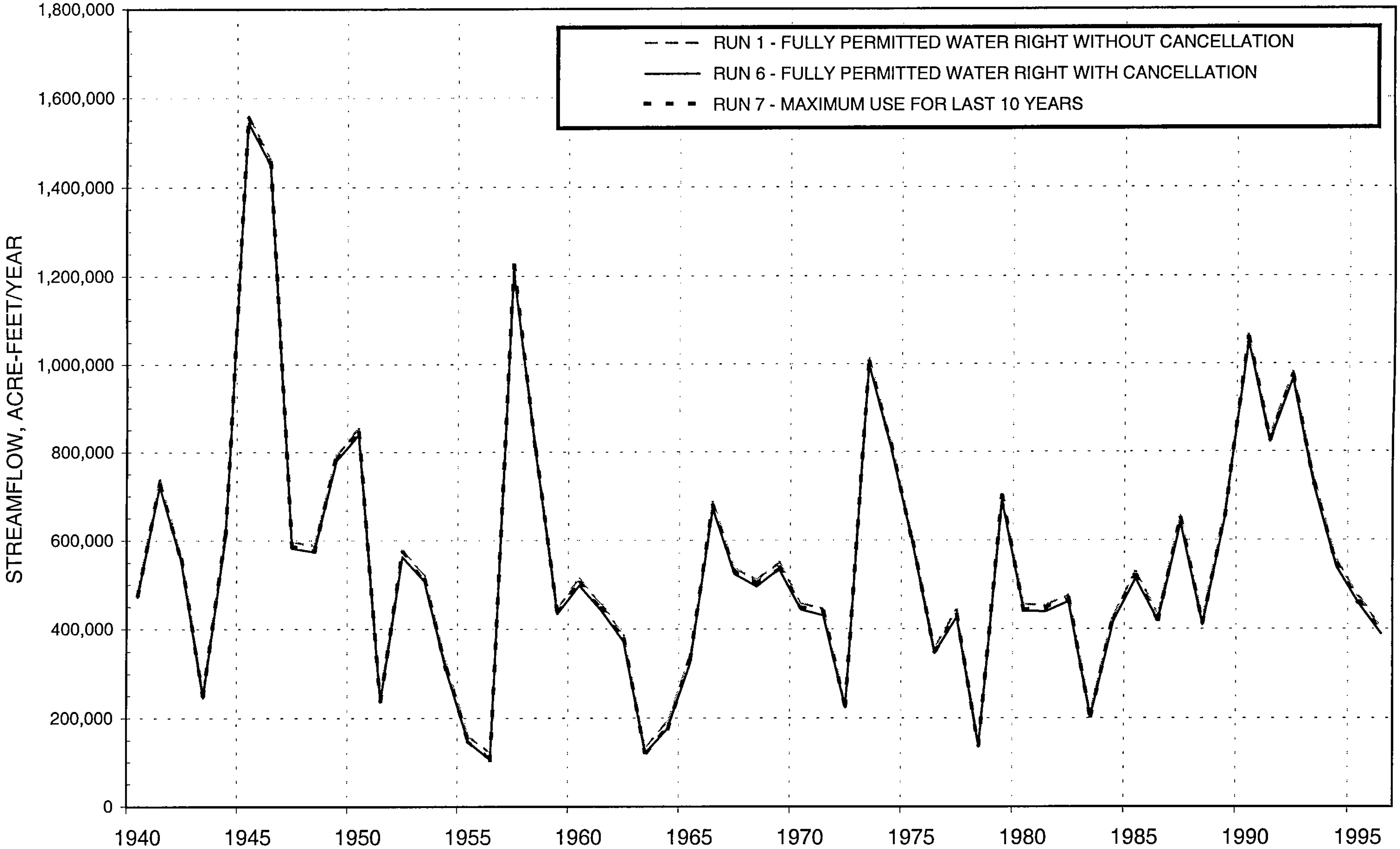


FIGURE A4-59
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

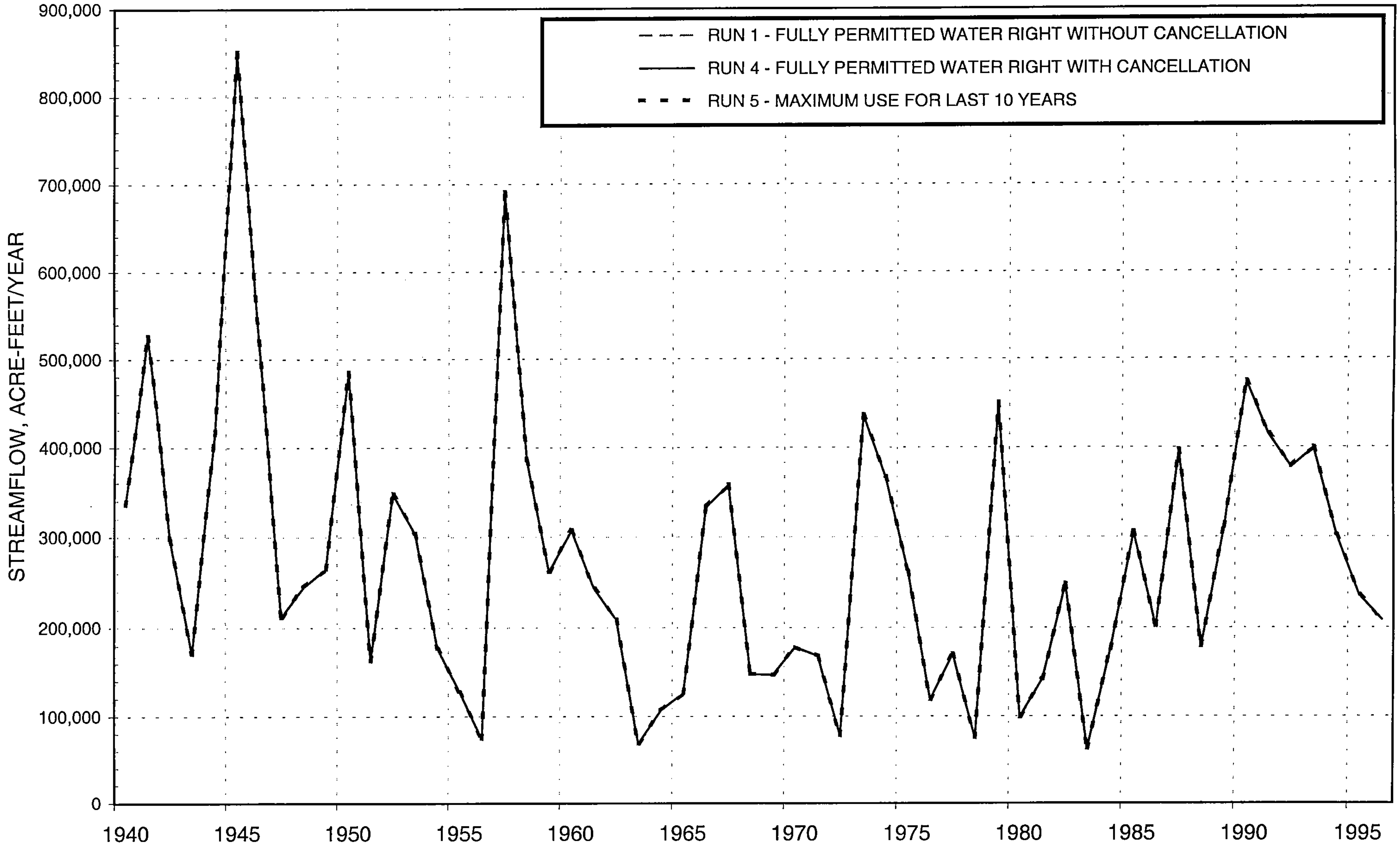


FIGURE A4-60
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

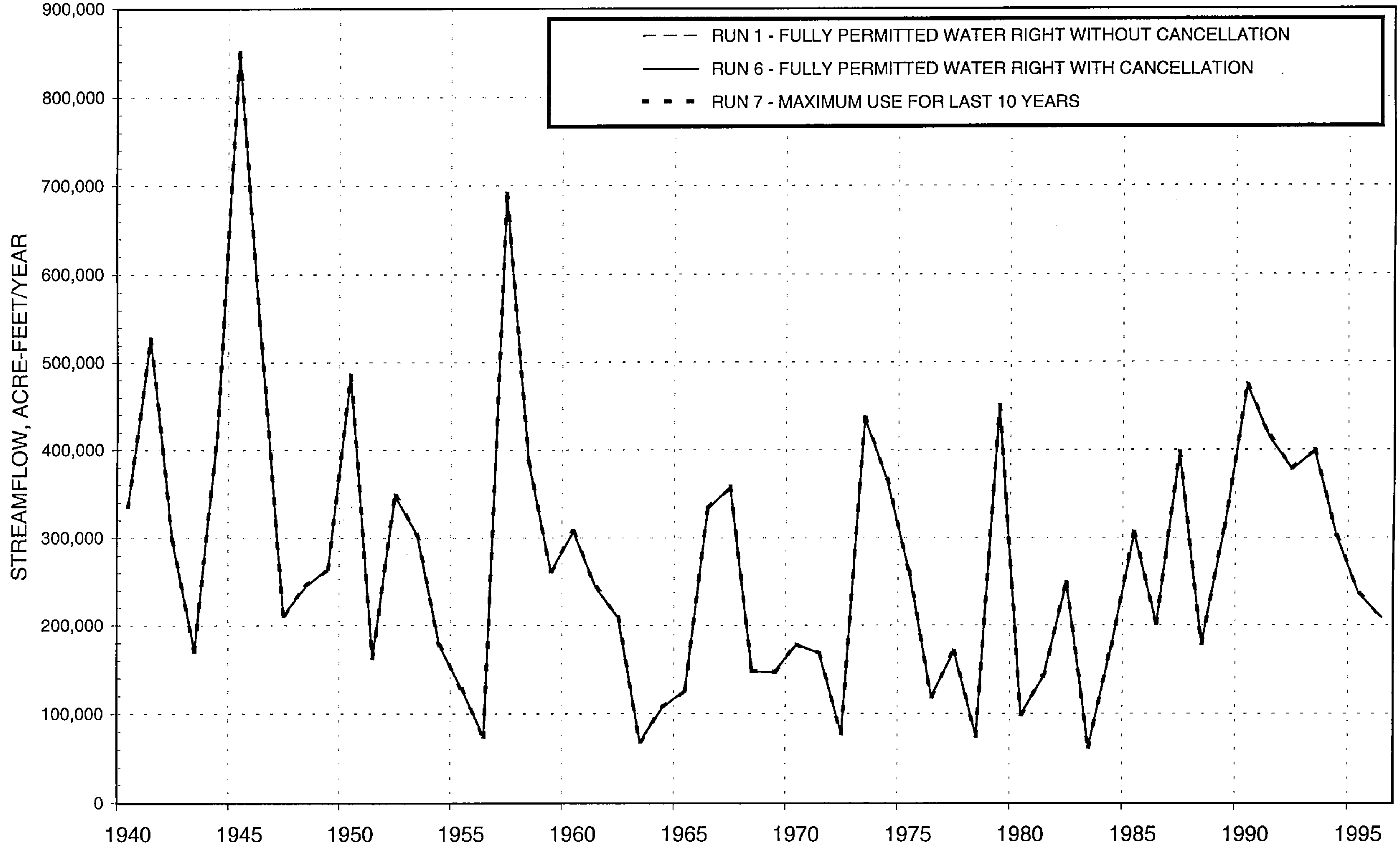


FIGURE A4-61
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH 100% OF ASSUMED RETURN FLOWS AT CONTROL POINT C90, NORTH SULPHUR RIVER

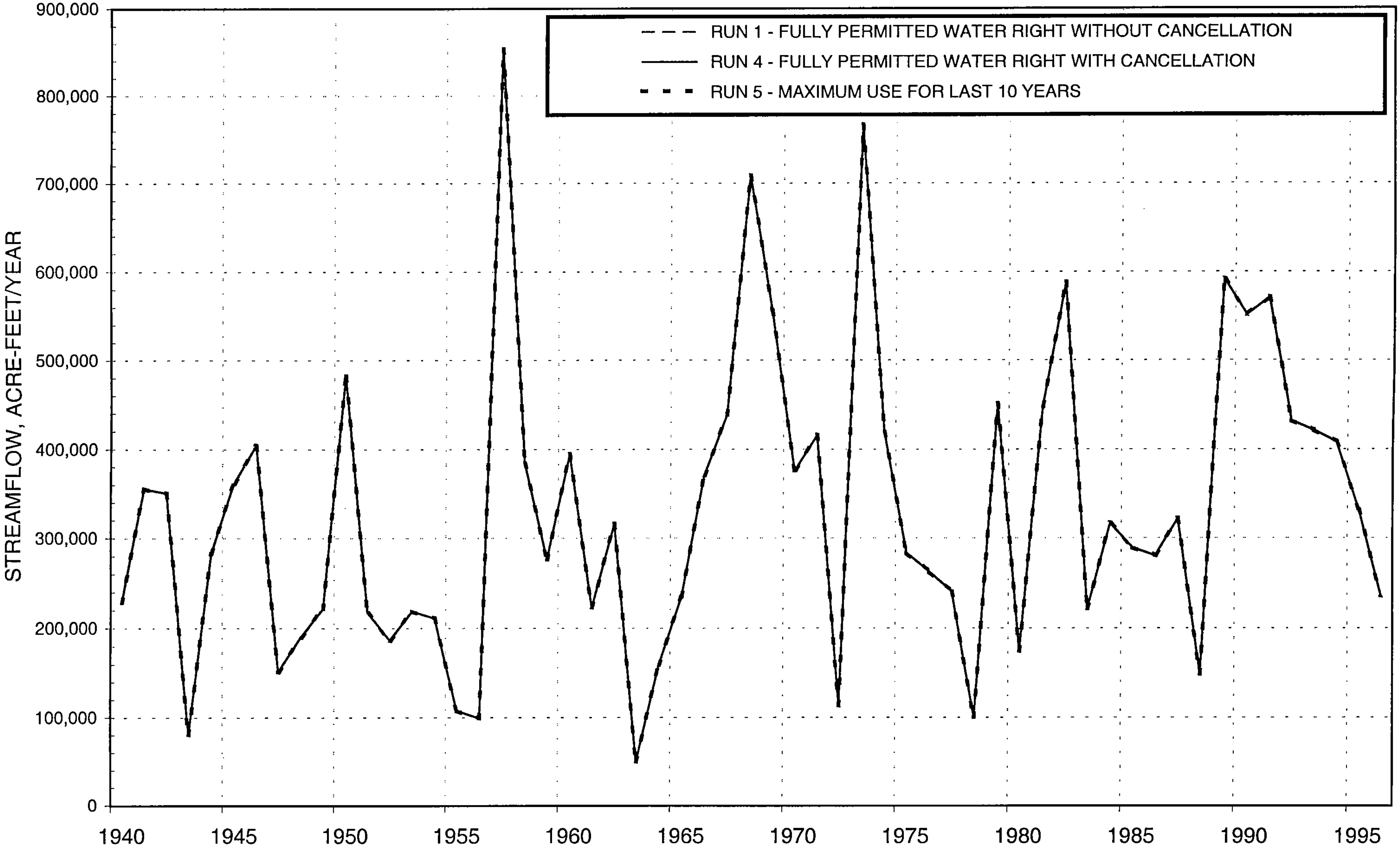
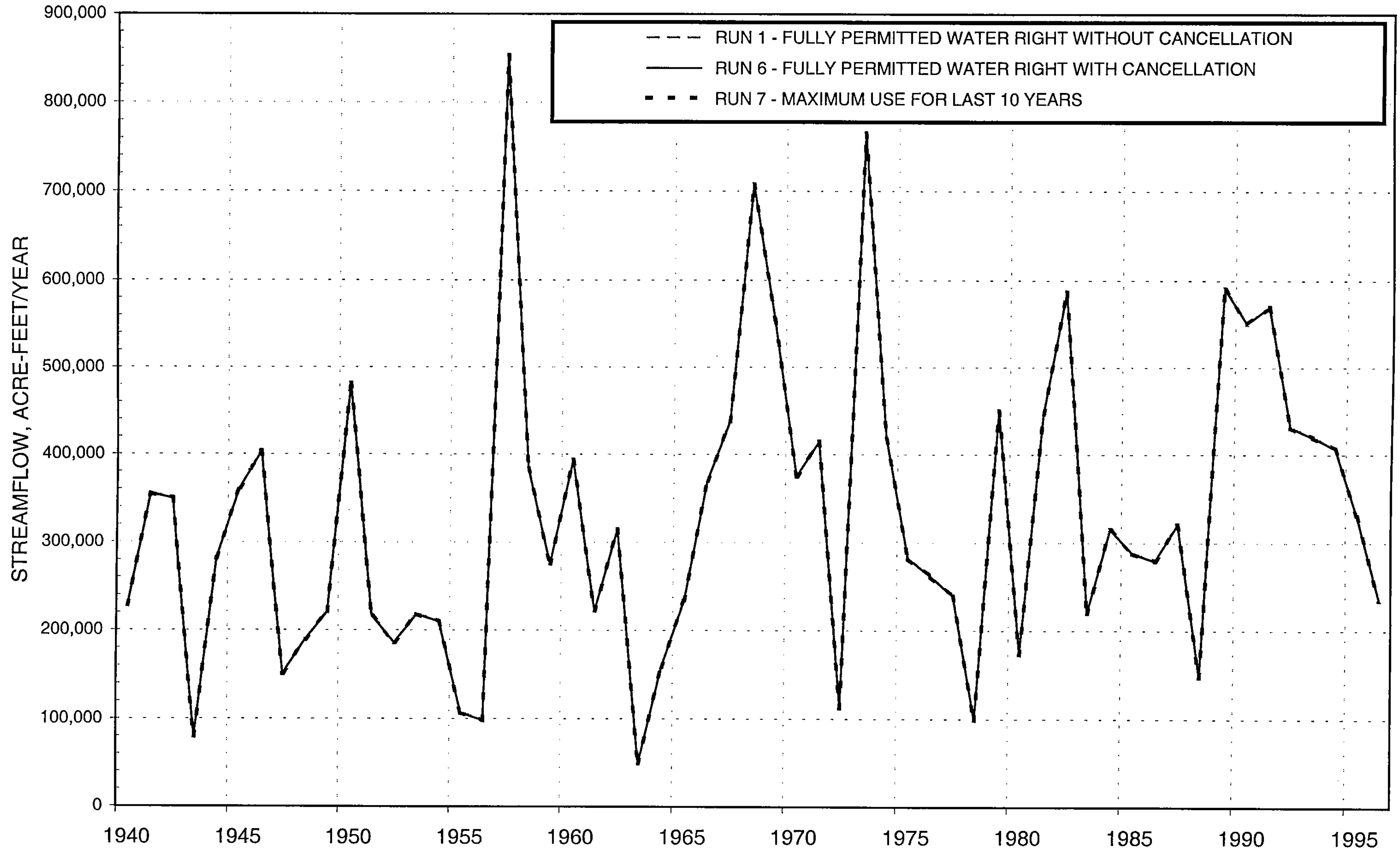


FIGURE A4-62
ANNUAL REGULATED FLOWS CONSIDERING CANCELLATION WITH ZERO ASSUMED RETURN FLOWS
AT CONTROL POINT C90, NORTH SULPHUR RIVER



APPENDIX 5

SELECTED WRAP RESULTS FROM CURRENT CONDITIONS ANALYSES RUNS 1 AND 8

Diversions:	Figures A5-1 through A5-8
Reservoir Storage:	Figures A5-9 through A5-13
Unappropriated Flows:	Figures A5-14 through A5-22
Regulated Flows:	Figures A5-23 through A5-31

FIGURE A5-1
ANNUAL DIVERSIONS AVAILABLE UNDERCURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4836, WRIGHT PATMAN LAKE (CONTROL POINT F60)

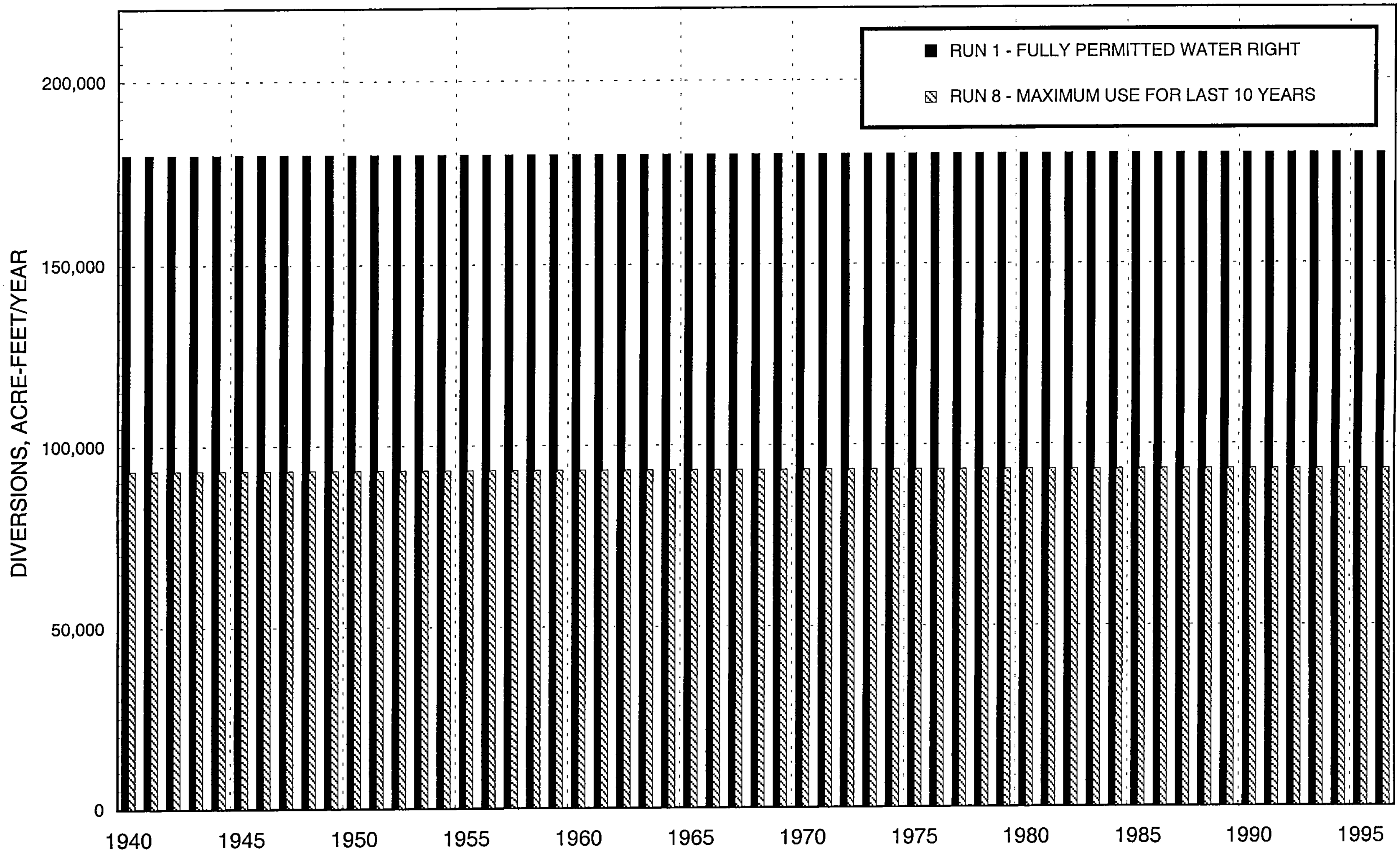


FIGURE A5-2
ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

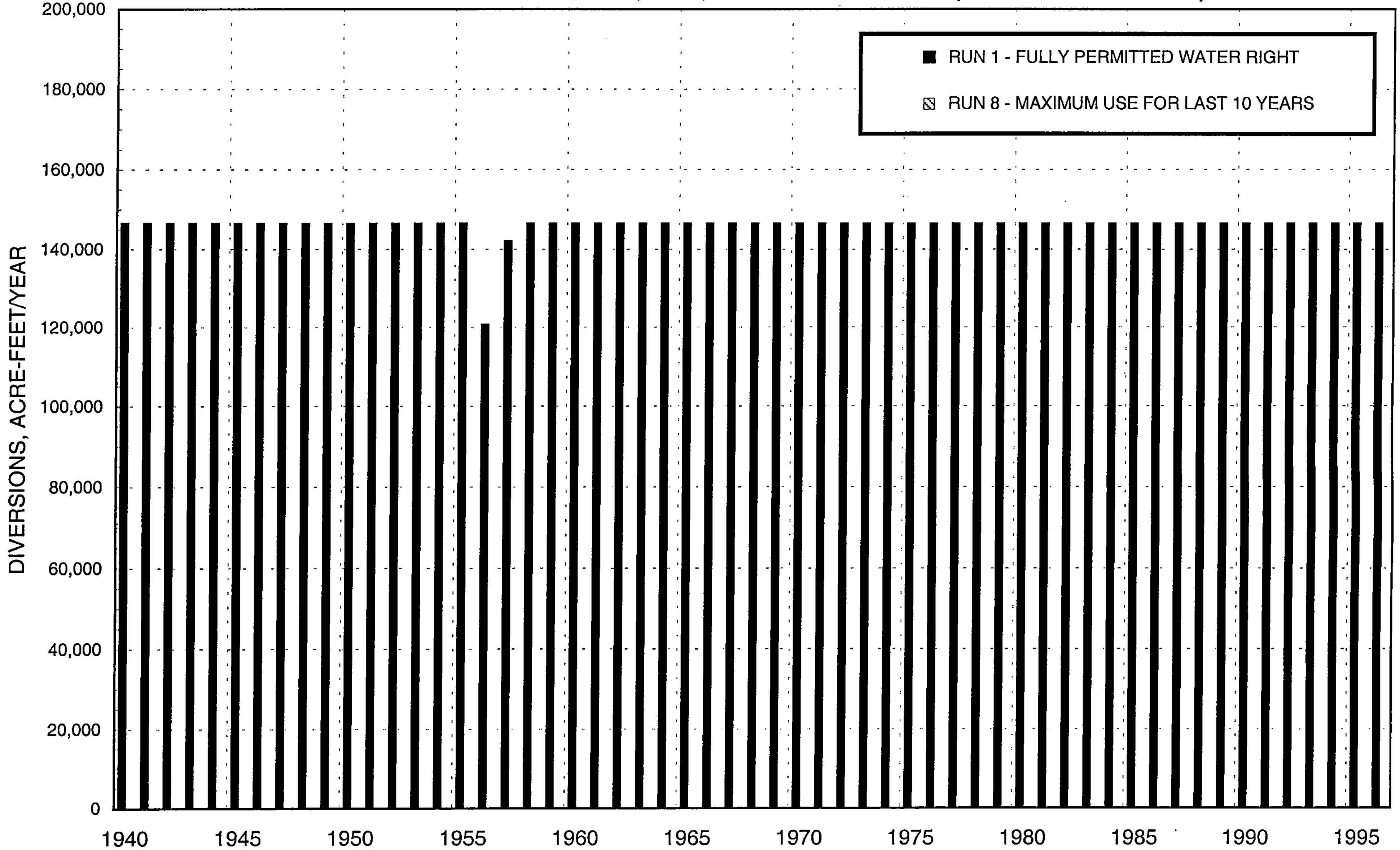


FIGURE A5-3
ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

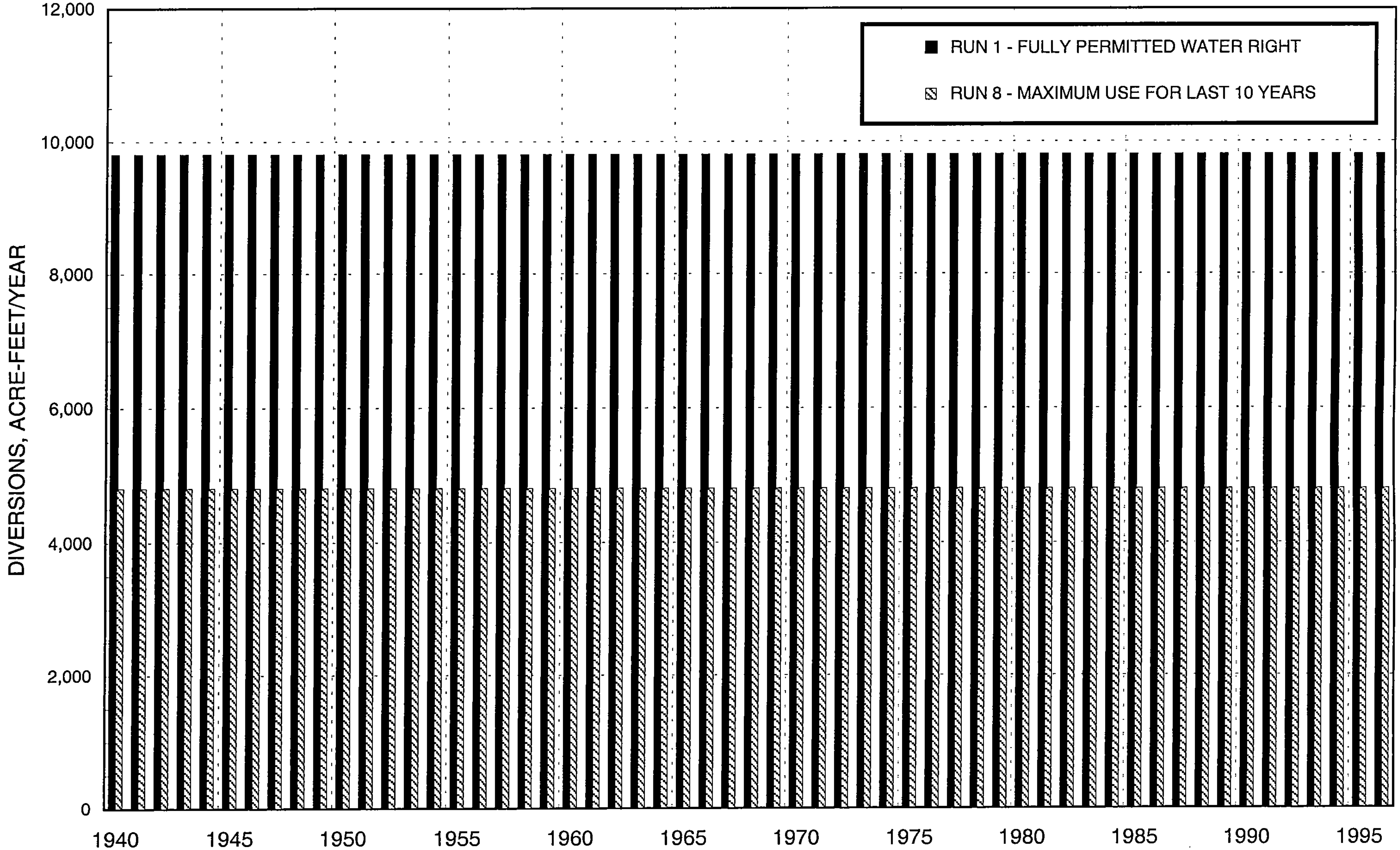


FIGURE A5-4

ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

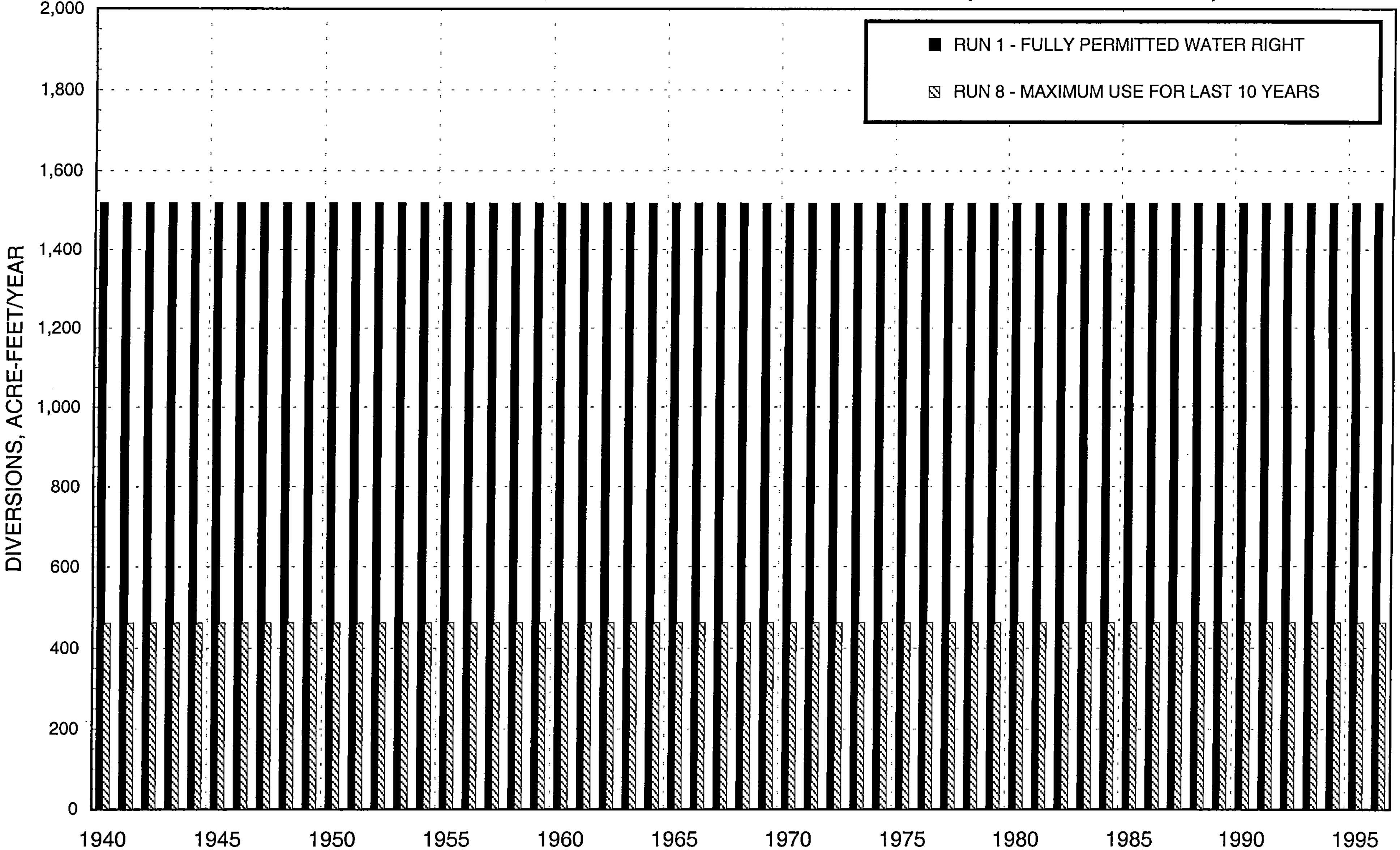


FIGURE A5-5
ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4830, WILLIAM E. JOHNSON, JR., ET AL (CONTROL POINT F110)

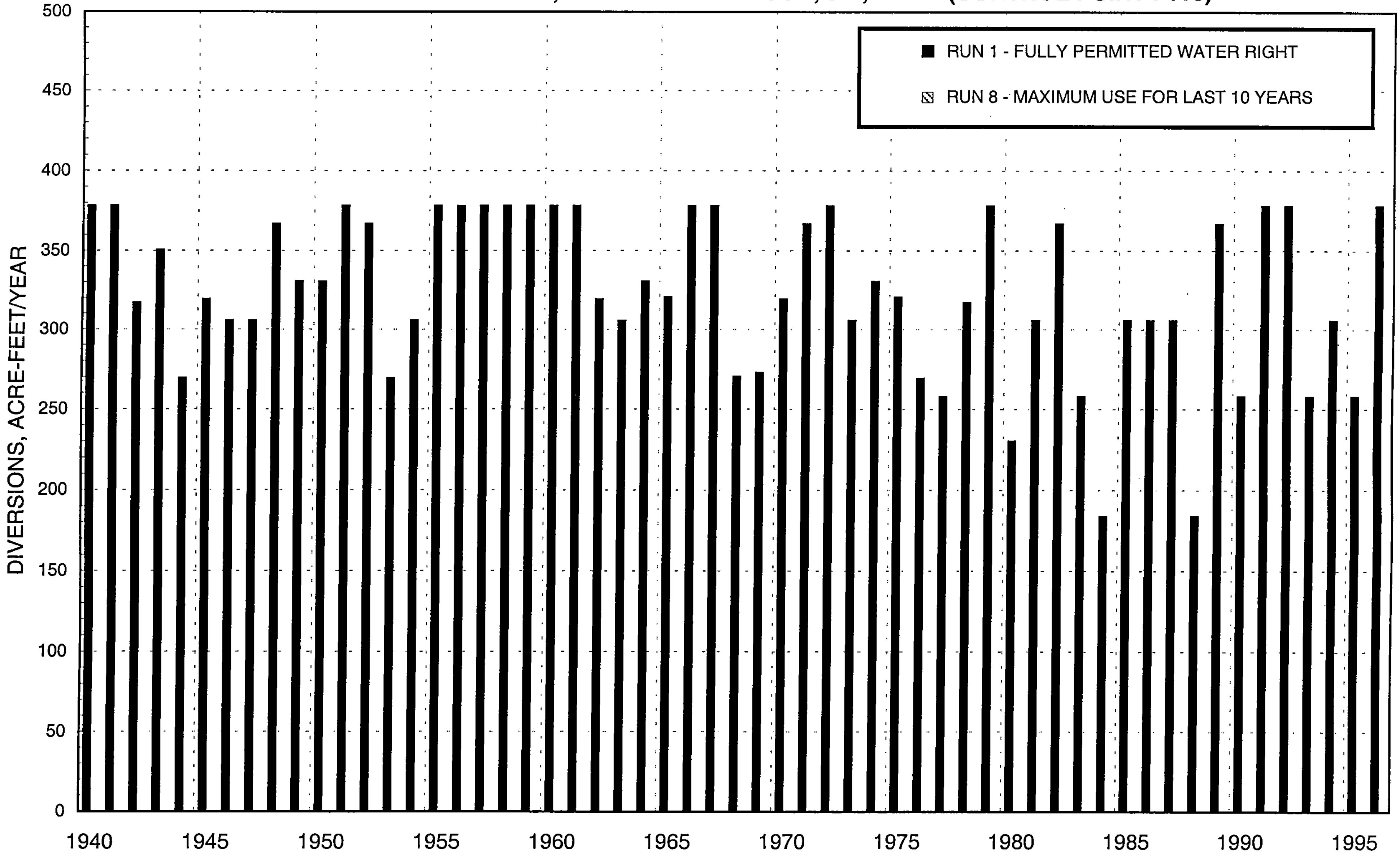


FIGURE A5-6
ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4804, TEXAS UTILITIES ELECTRIC RIVER CREST PLANT (CONTROL POINT C20)

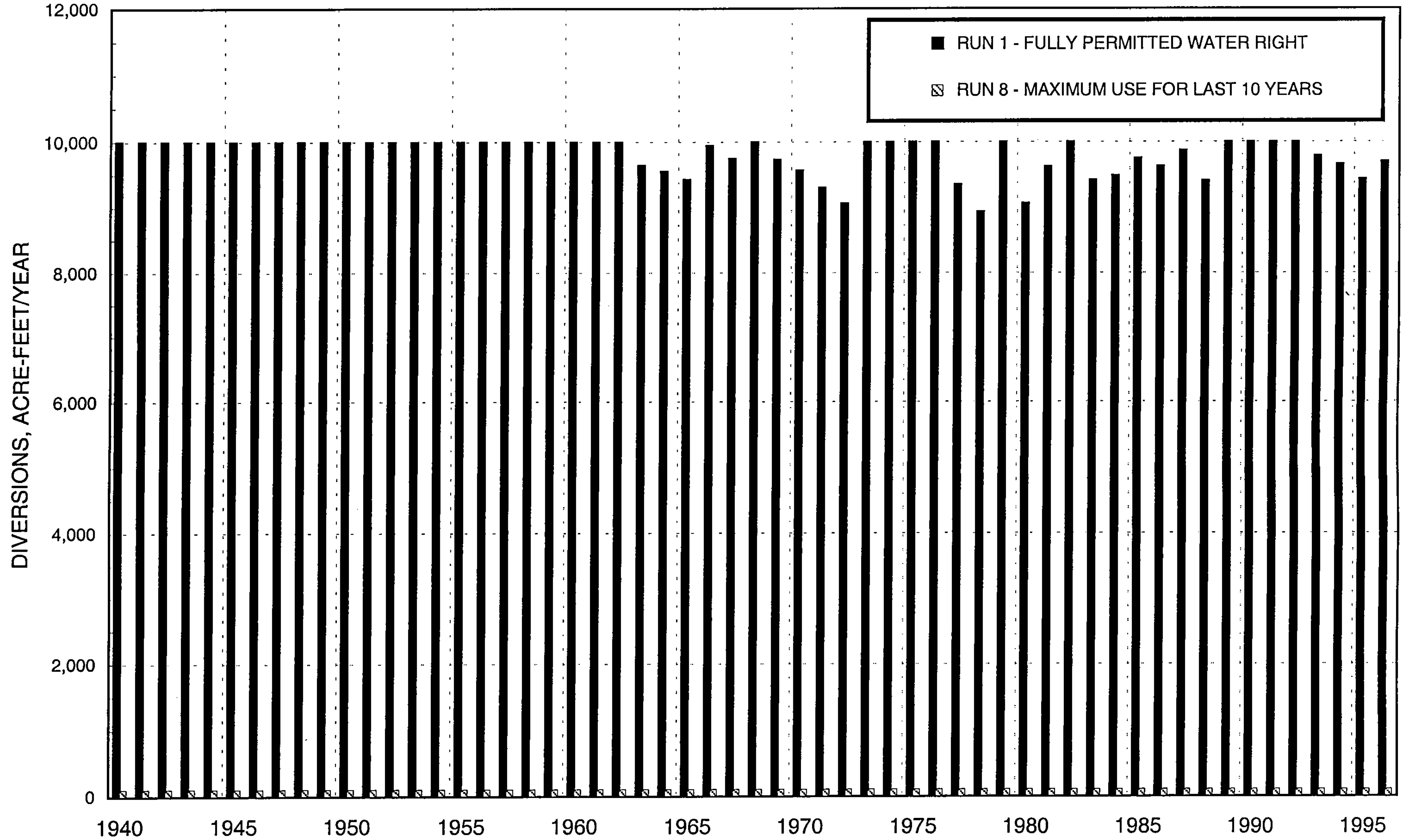


FIGURE A5-7
ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4817, HANS WEISS (CONTROL POINT D40)

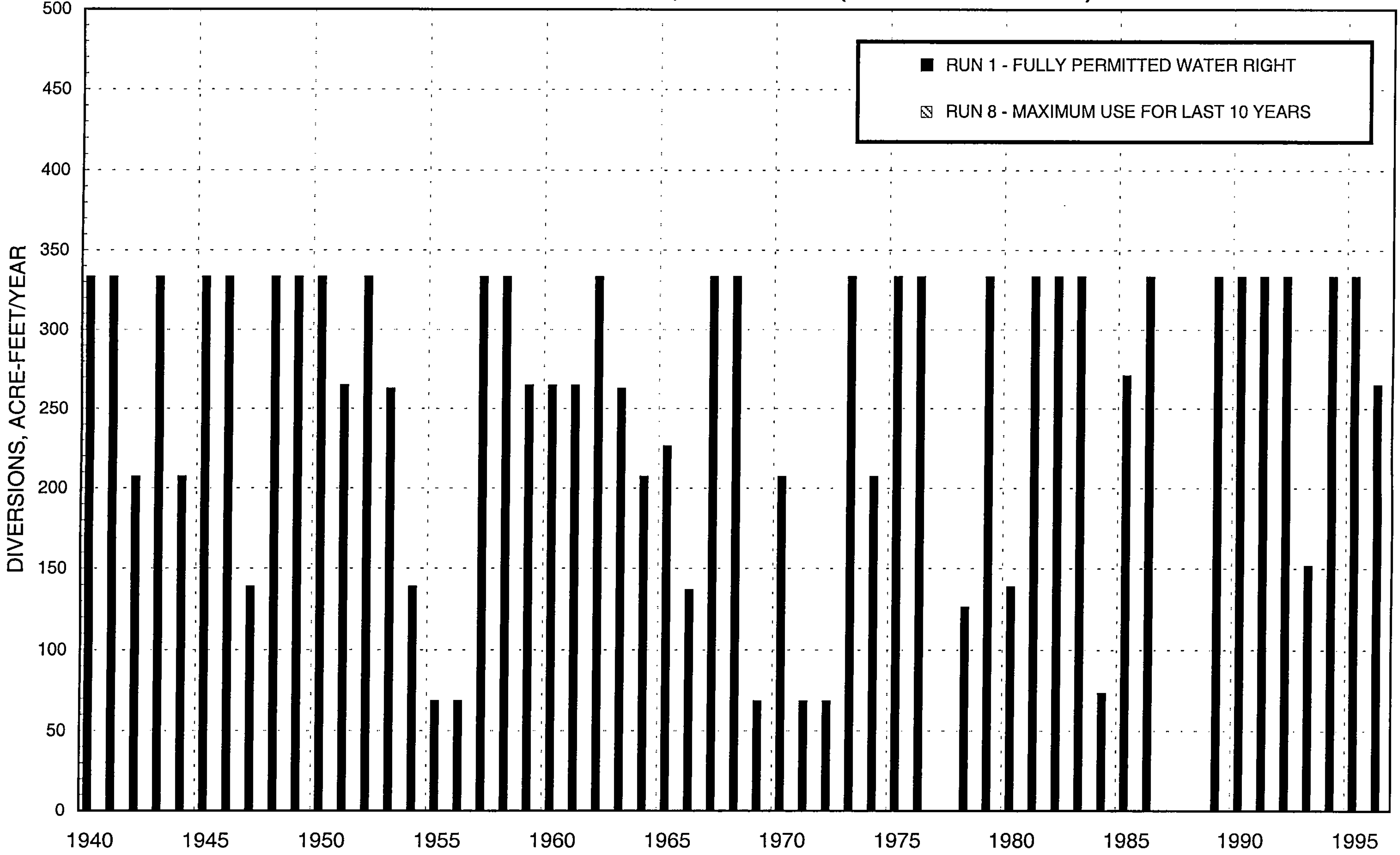


FIGURE A5-8
ANNUAL DIVERSIONS AVAILABLE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4148B, SARA M. DUNHAM TRUST RESERVOIR DIVERSIONS (CONTROL POINT C60)

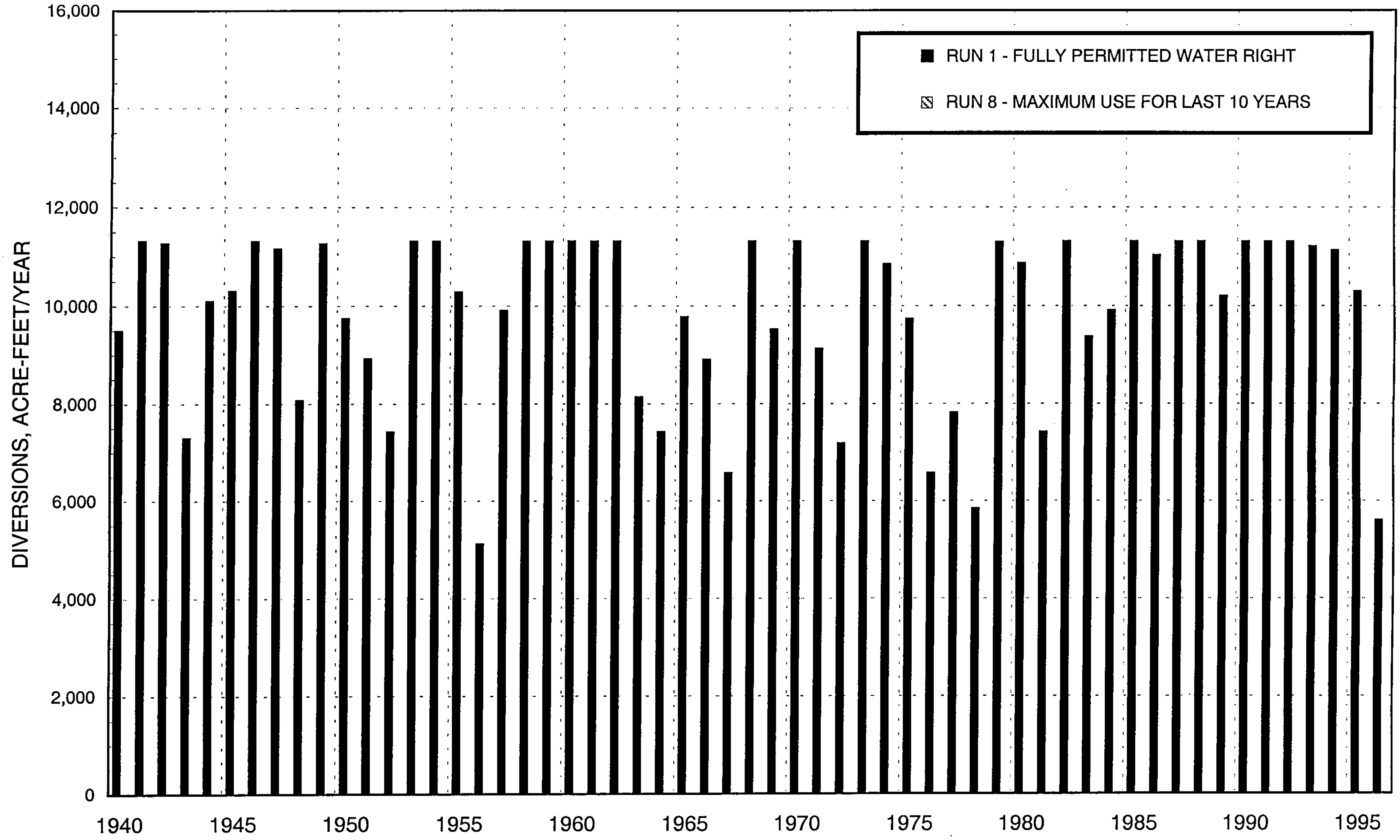


FIGURE A5-9
MONTHLY RESERVOIR STORAGE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4830, WRIGHT PATMAN LAKE (CONTROL POINT F60)

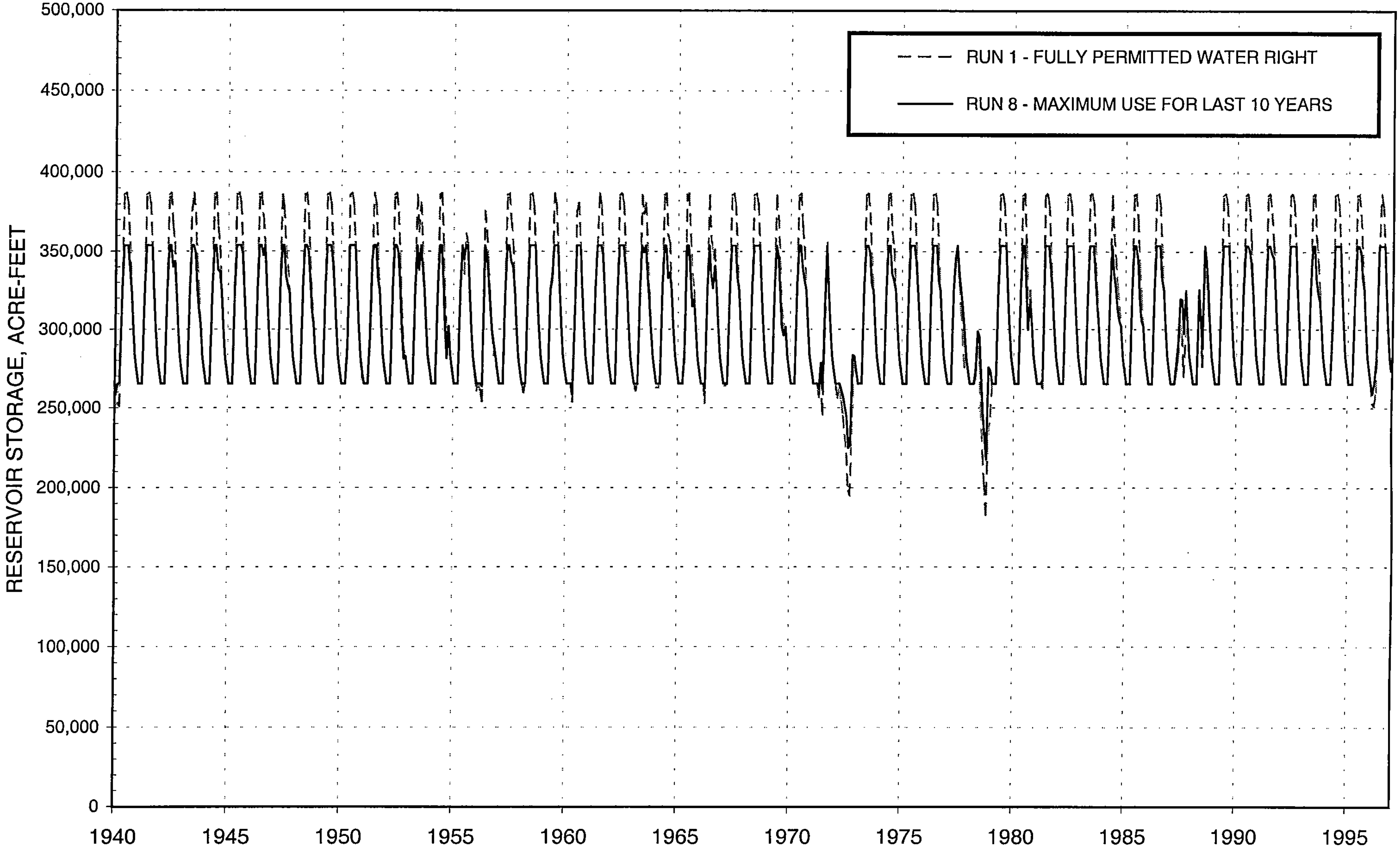


FIGURE A5-10
MONTHLY RESERVOIR STORAGE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHTS 4797, 4798, 4799; JIM CHAPMAN LAKE (CONTROL POINT A40)

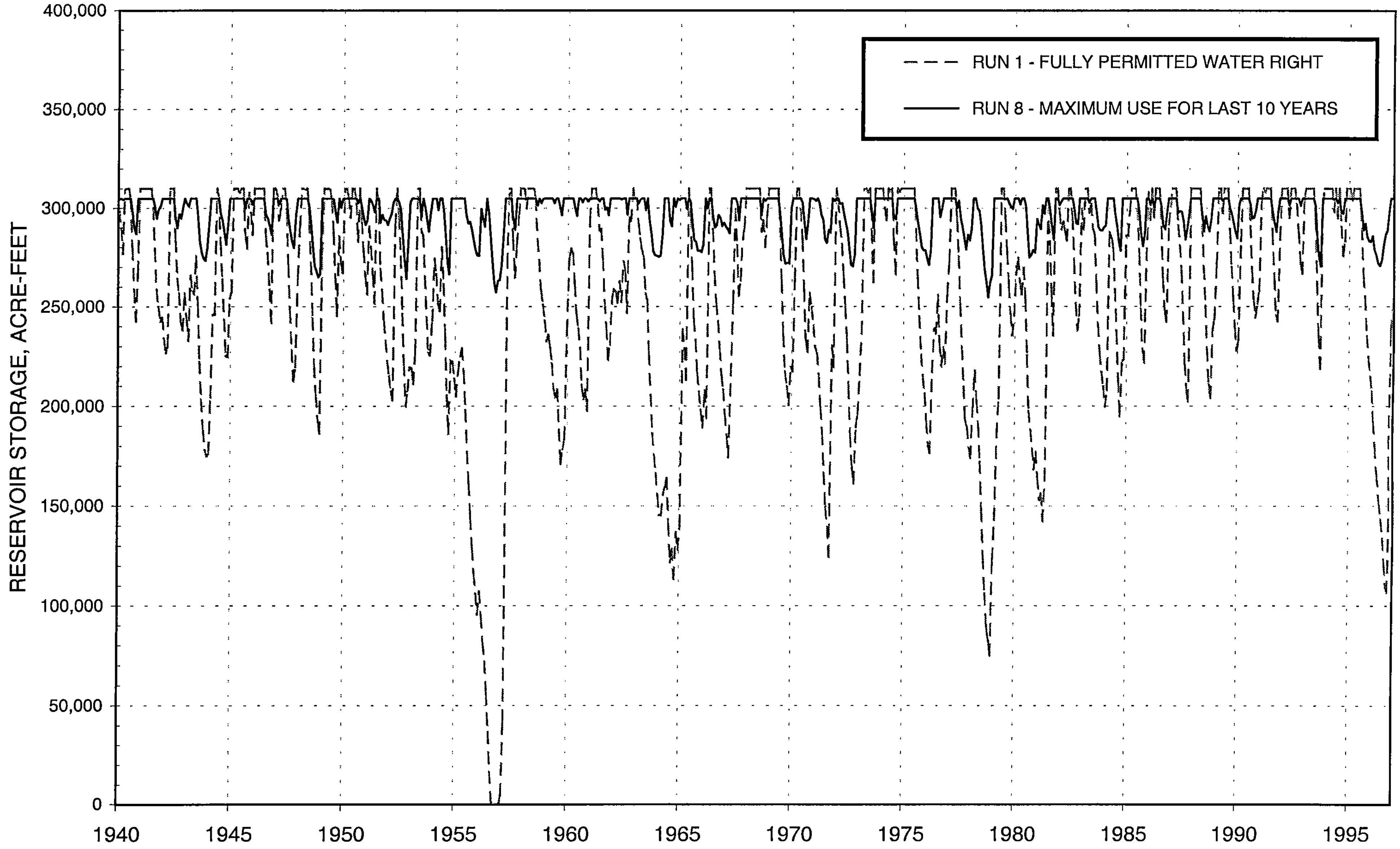


FIGURE A5-11
MONTHLY RESERVOIR STORAGE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4811, LAKE SULPHUR SPRINGS (CONTROL POINT D120)

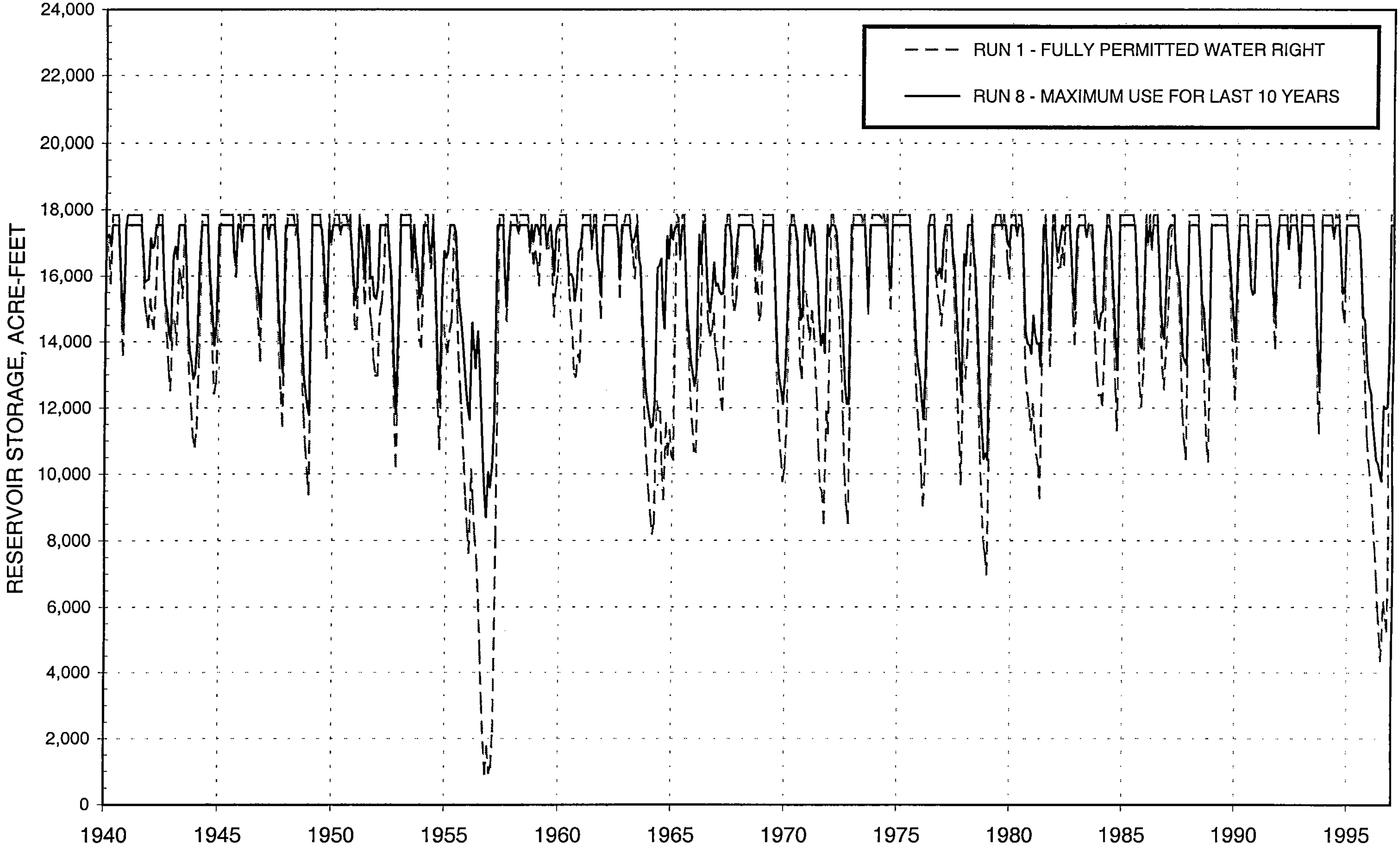


FIGURE A5-12
MONTHLY RESERVOIR STORAGE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4395, CITY OF COOPER BIG CREEK LAKE (CONTROL POINT A30)

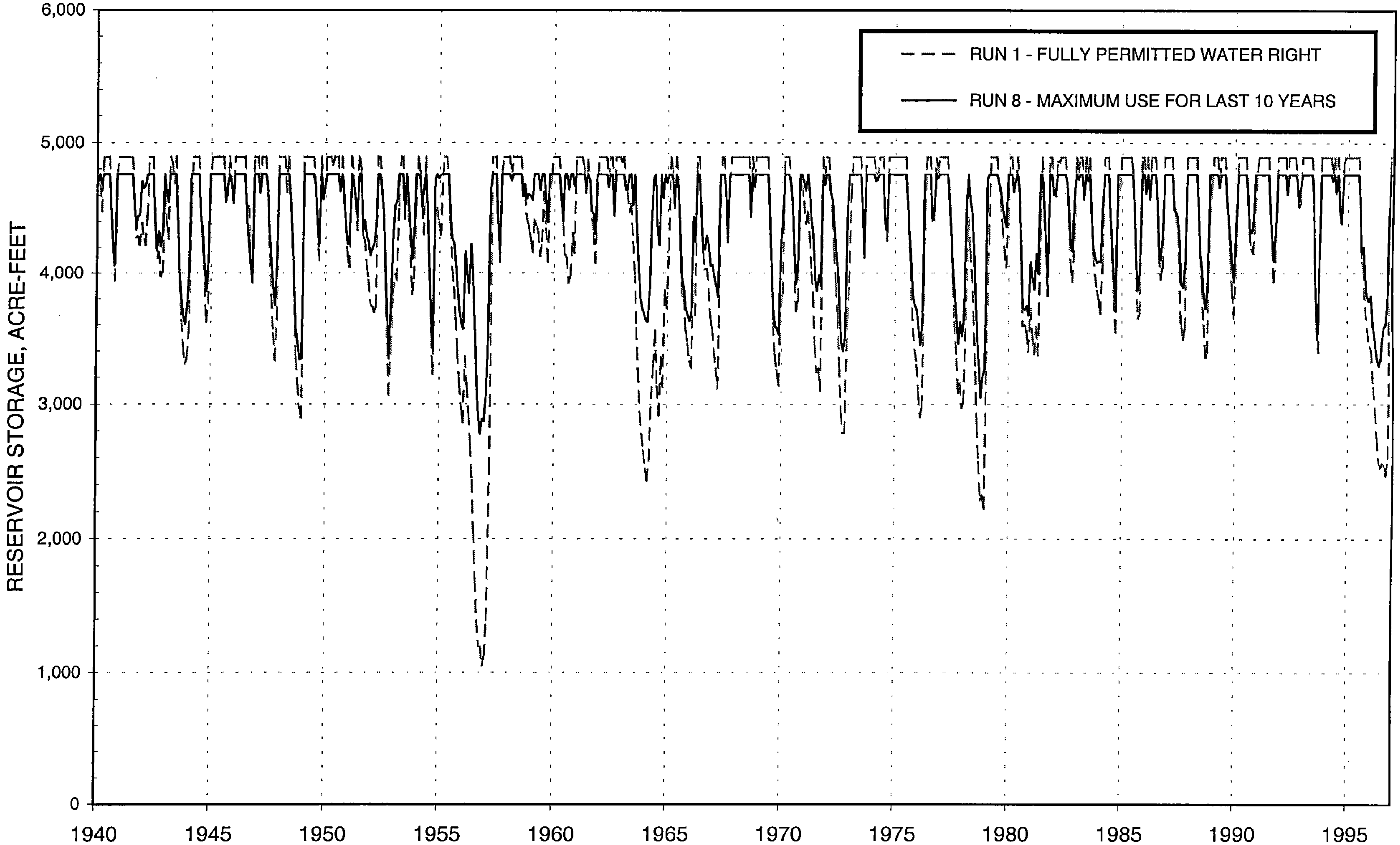


FIGURE A5-13
MONTHLY RESERVOIR STORAGE UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW FOR WATER RIGHT 4148B, SARAH M. DUNHAM TRUST (CONTROL POINT C60)

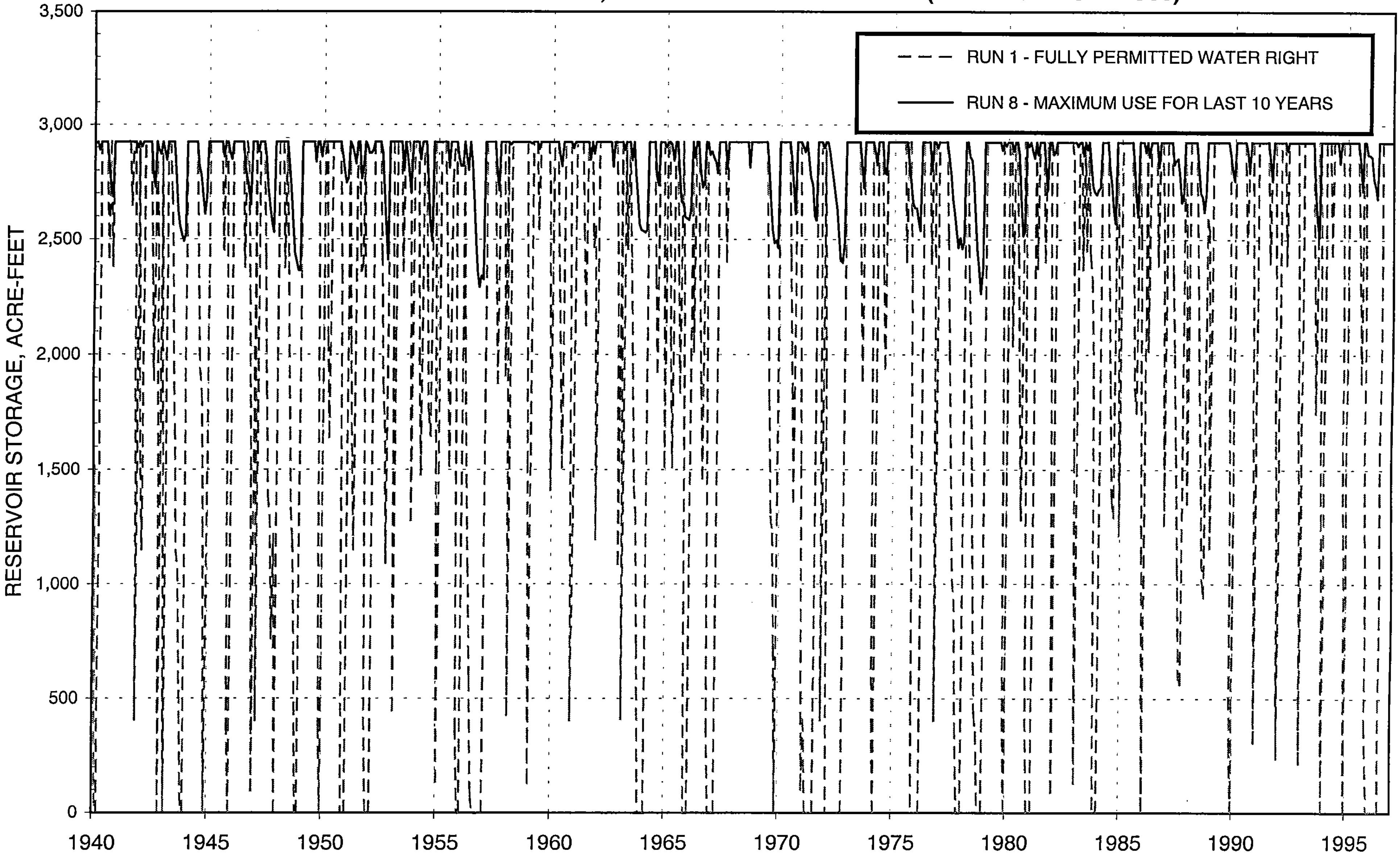


FIGURE A5-14
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

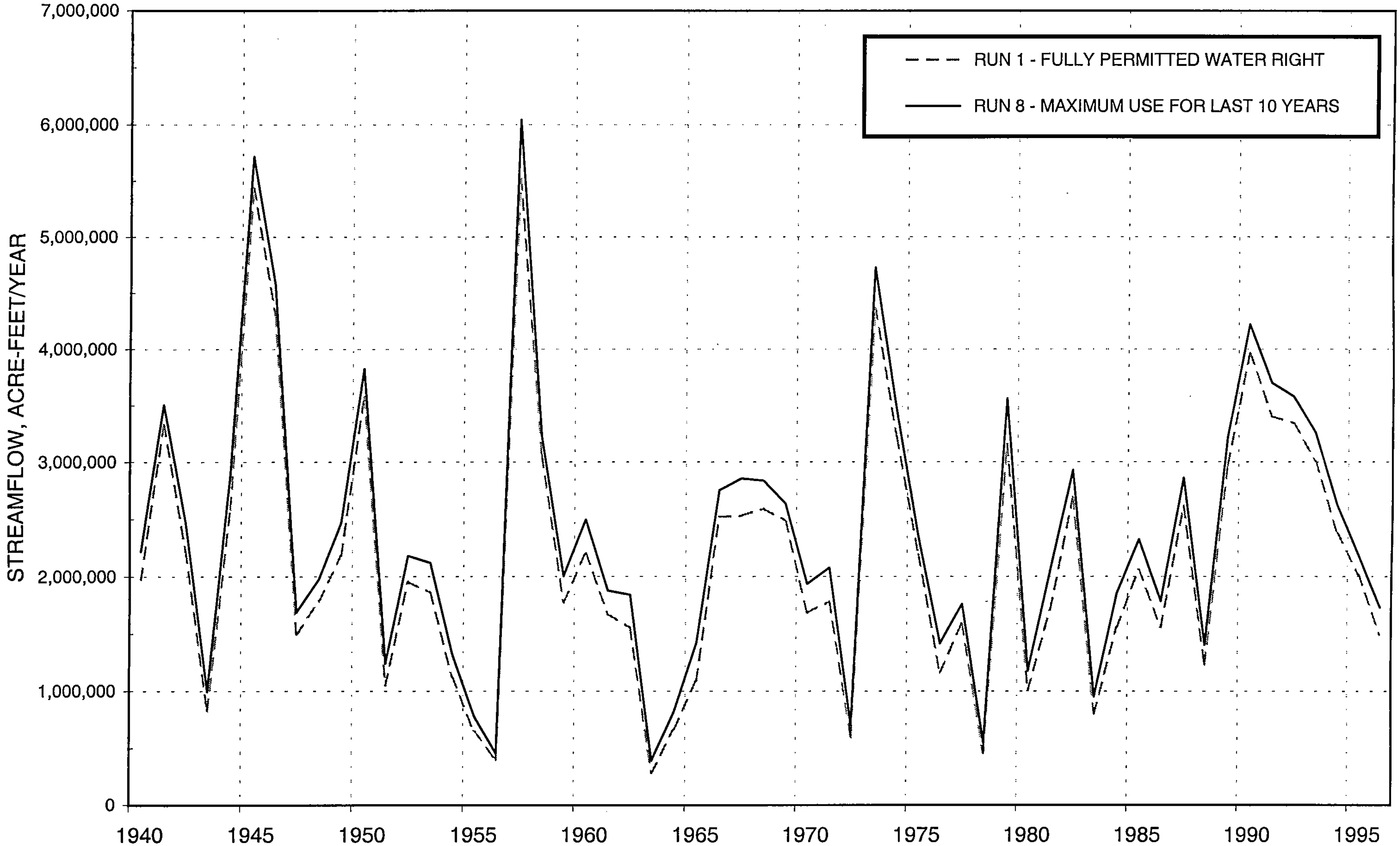


FIGURE A5-15
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

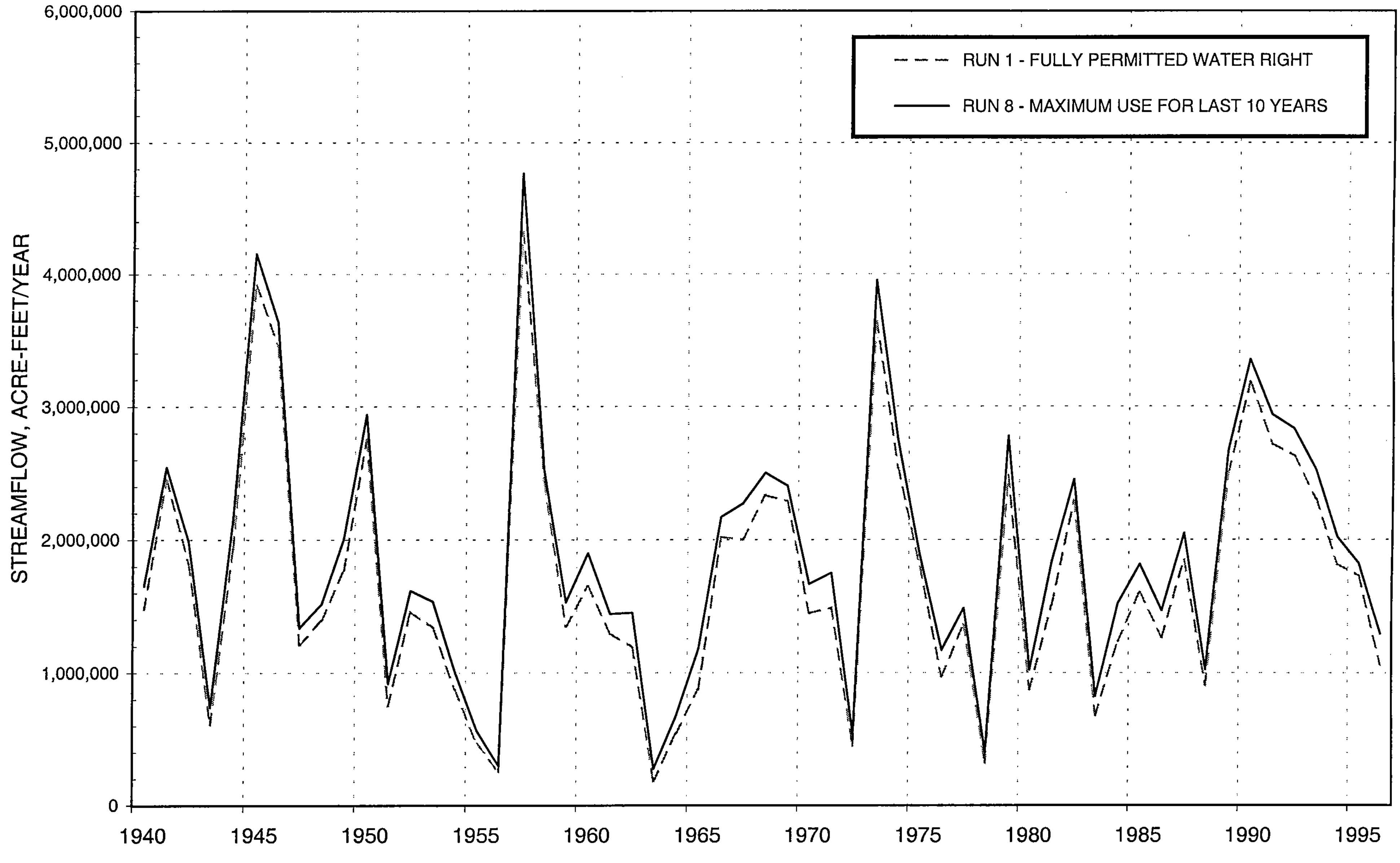


FIGURE A5-16
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

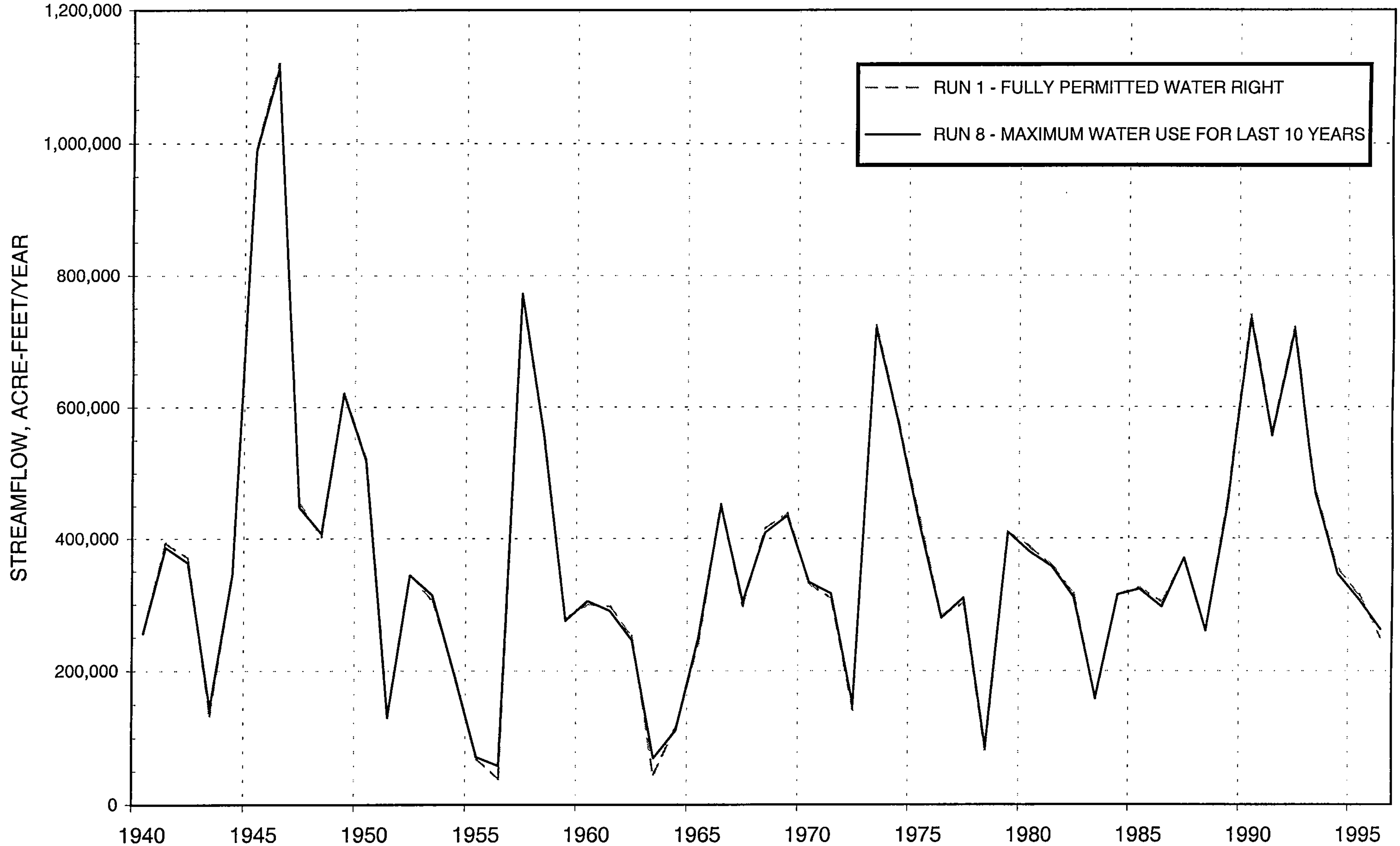


FIGURE A5-17
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

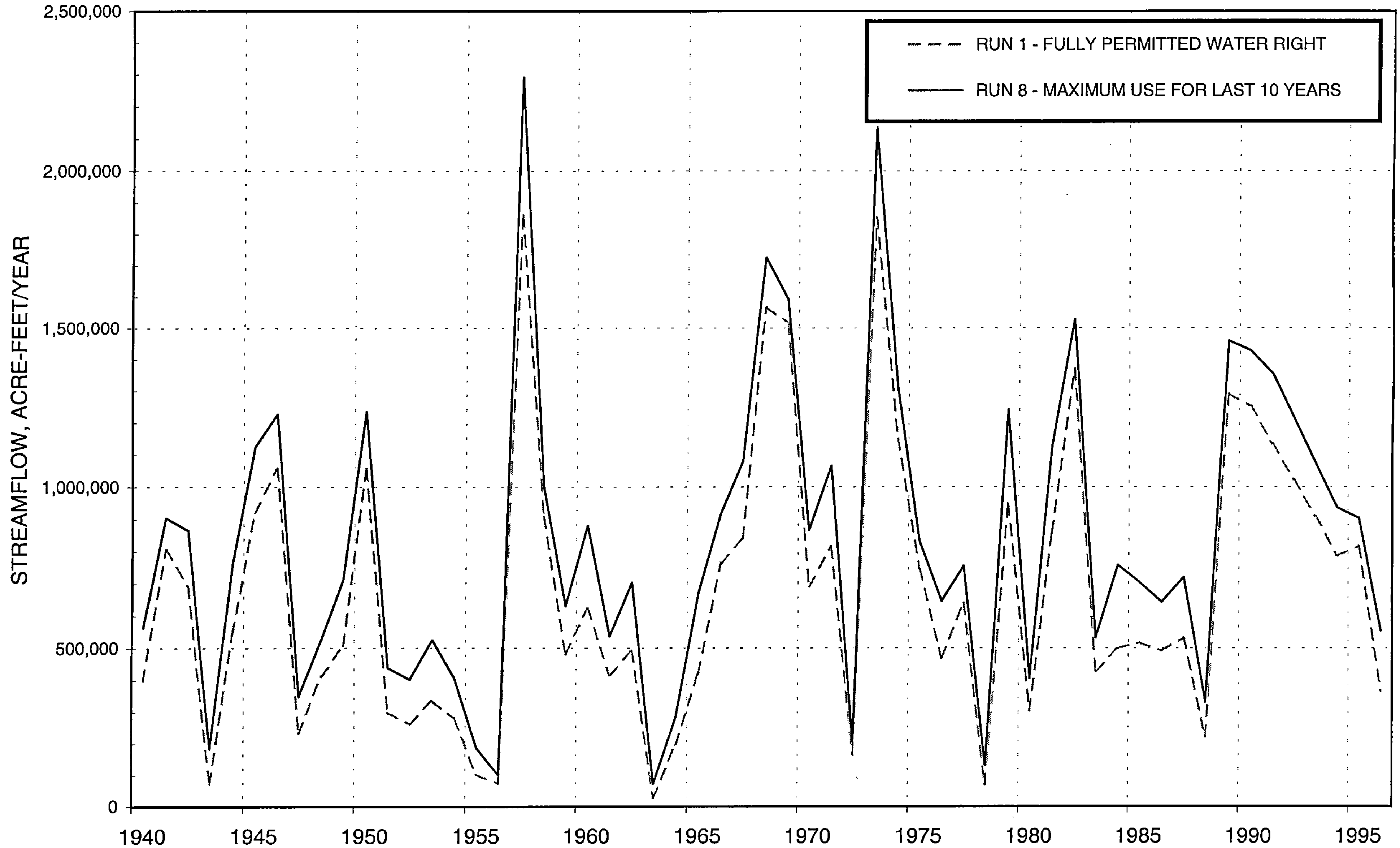


FIGURE A5-18
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

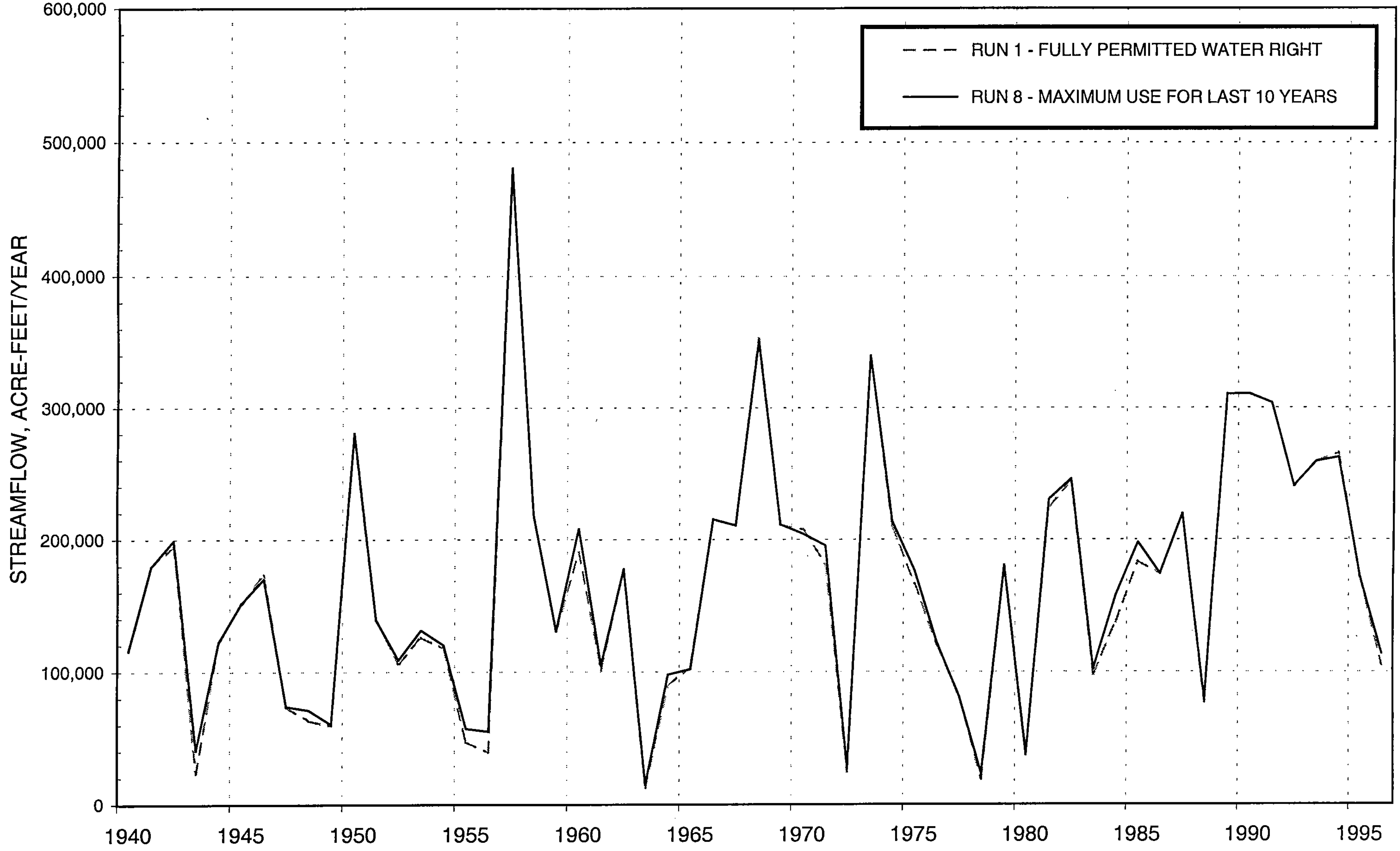


FIGURE A5-19

ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

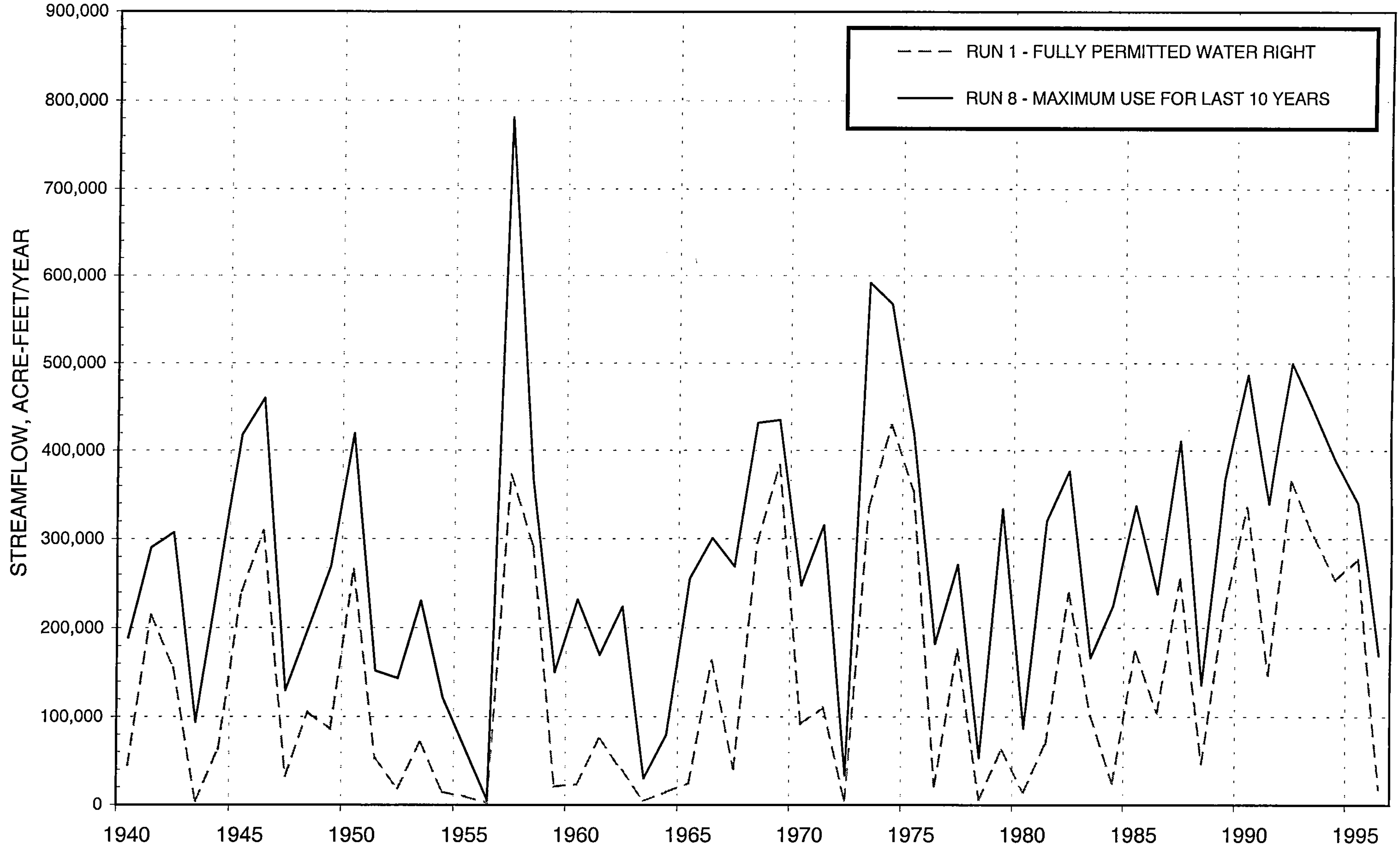


FIGURE A5-20
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

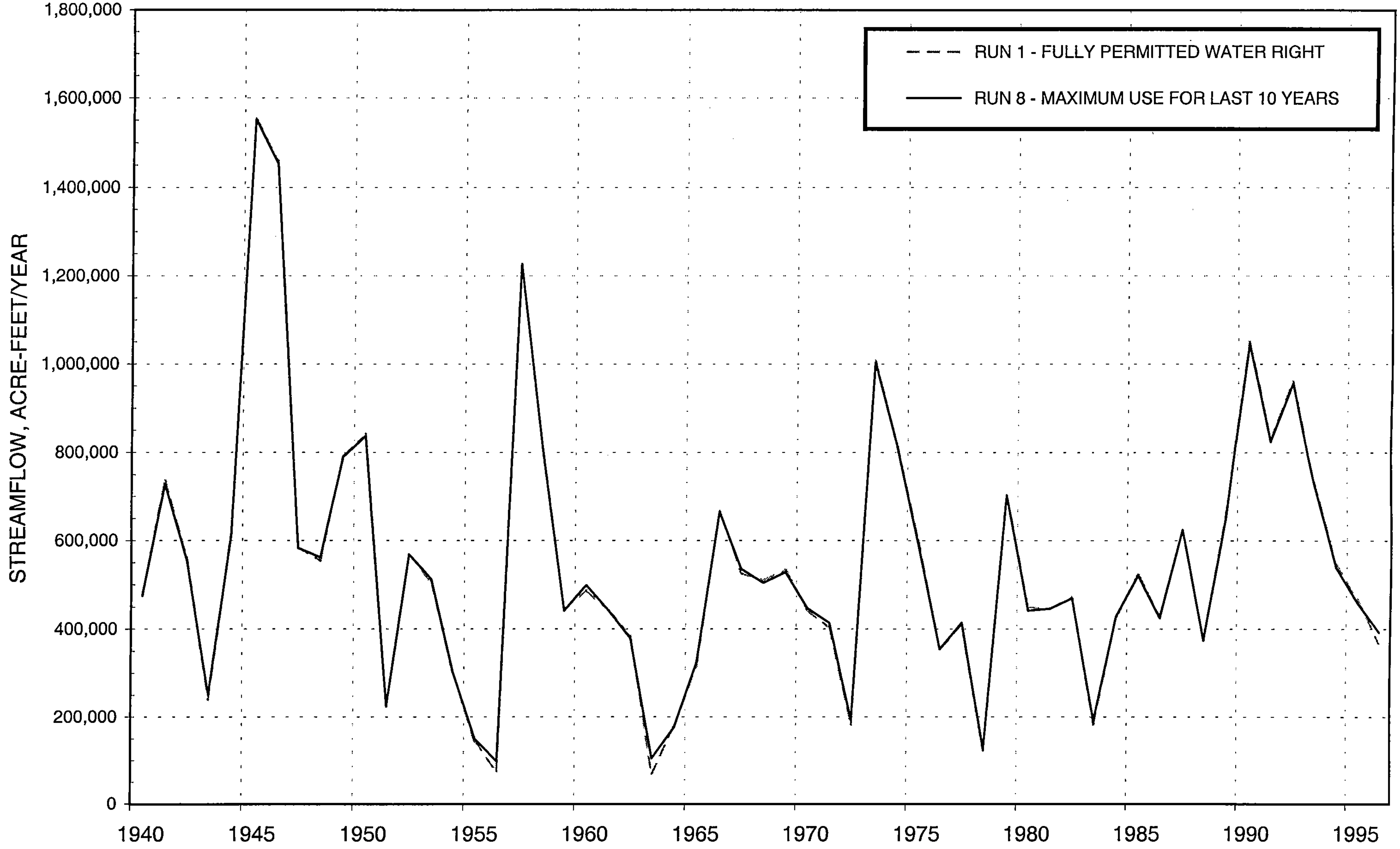


FIGURE A5-21
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

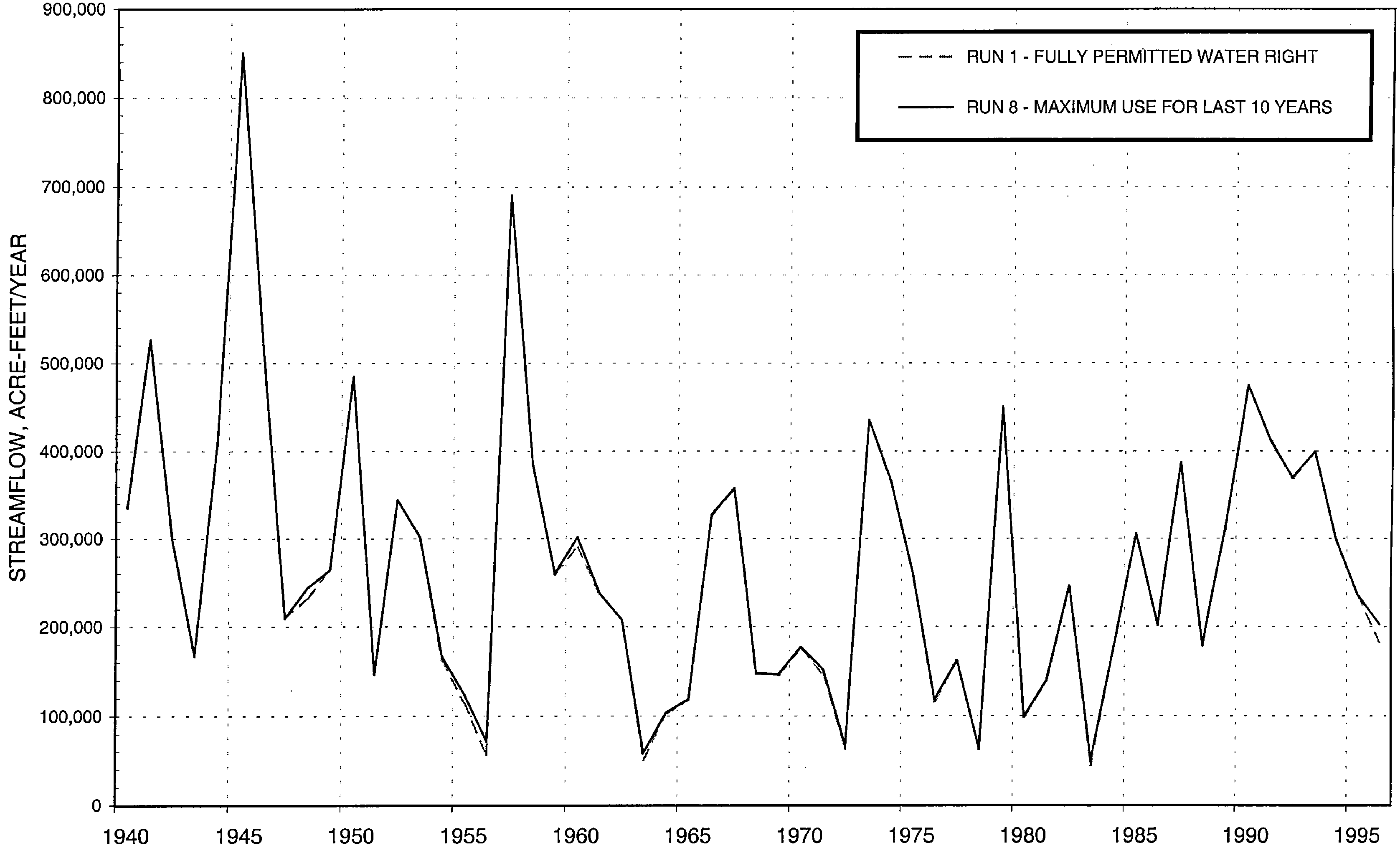


FIGURE A5-22
ANNUAL UNAPPROPRIATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT C90, NORTH SULPHUR RIVER

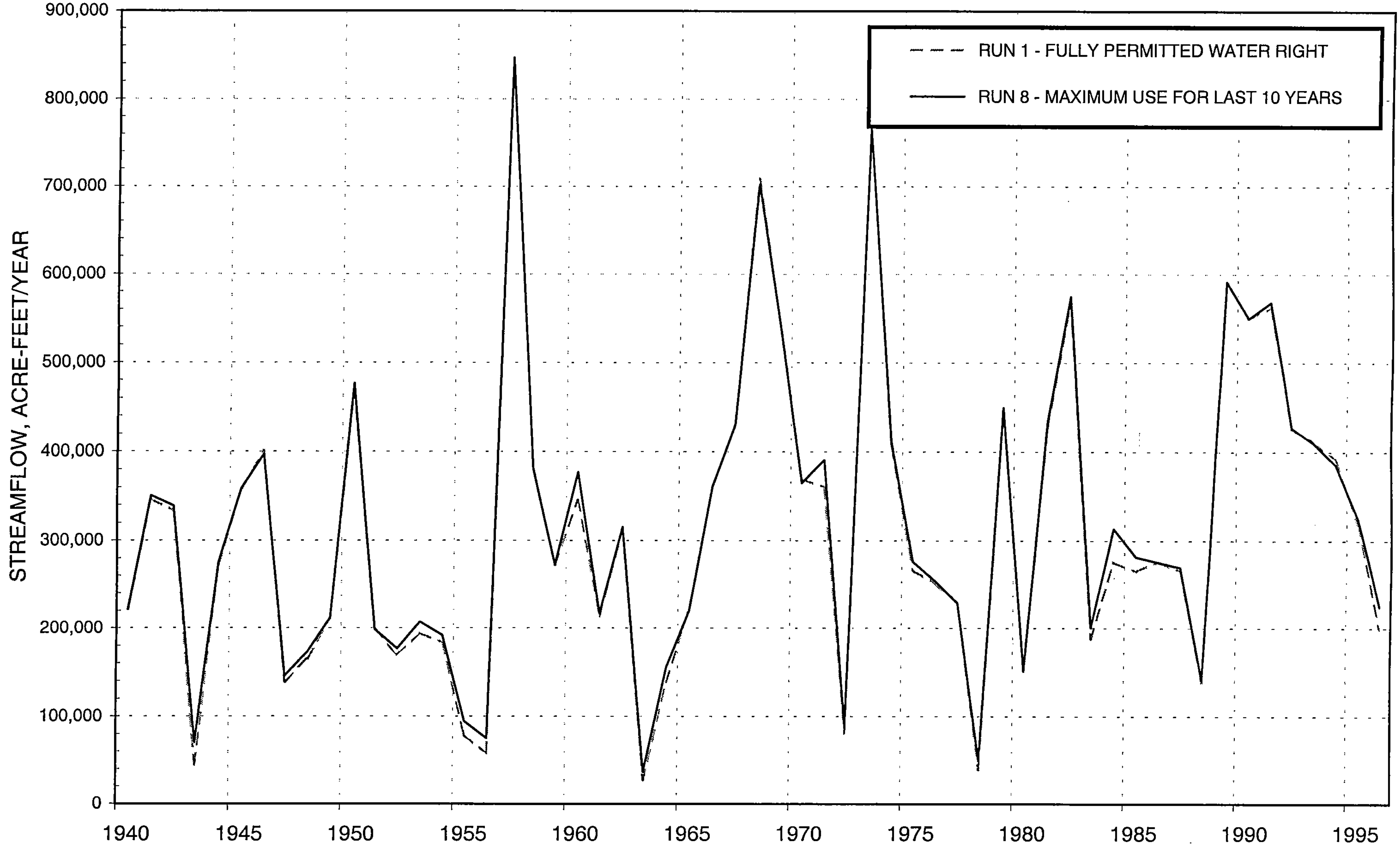


FIGURE A5-23
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT F10, DOWNSTREAM END OF SUBWATERSHED F

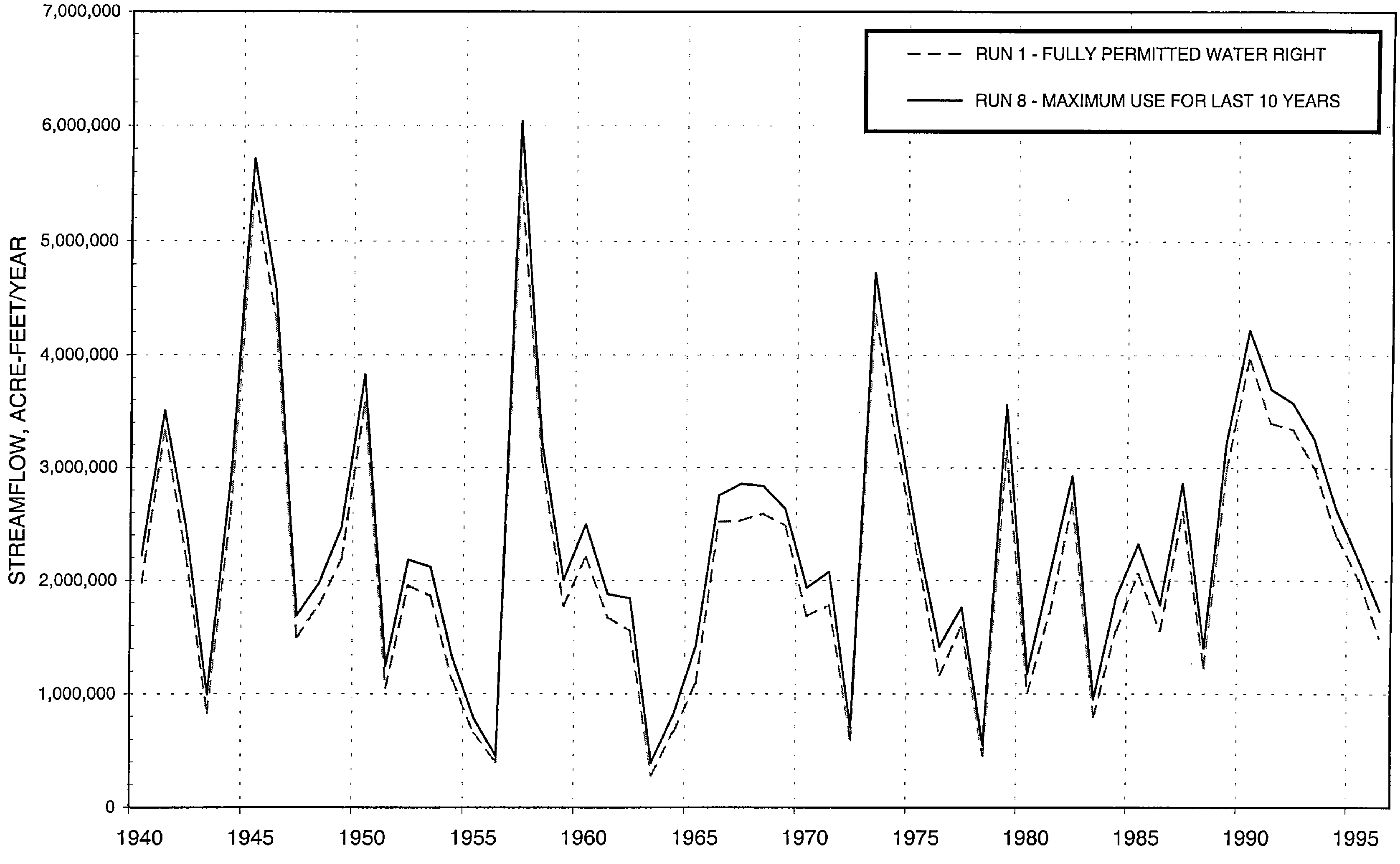


FIGURE A5-24
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT E10, DOWNSTREAM END OF SUBWATERSHED E

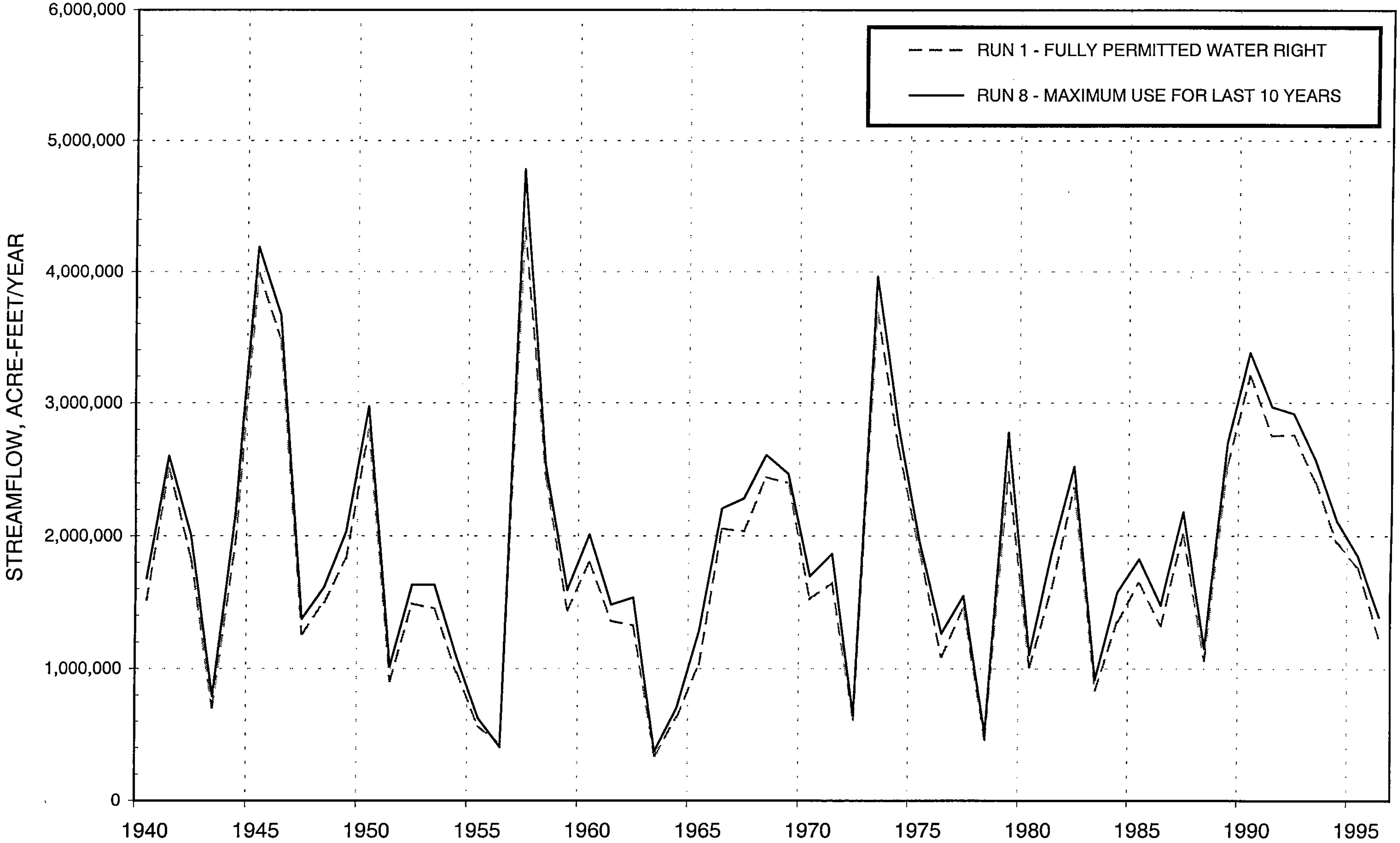


FIGURE A5-25
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT D10, DOWNSTREAM END OF SUBWATERSHED D

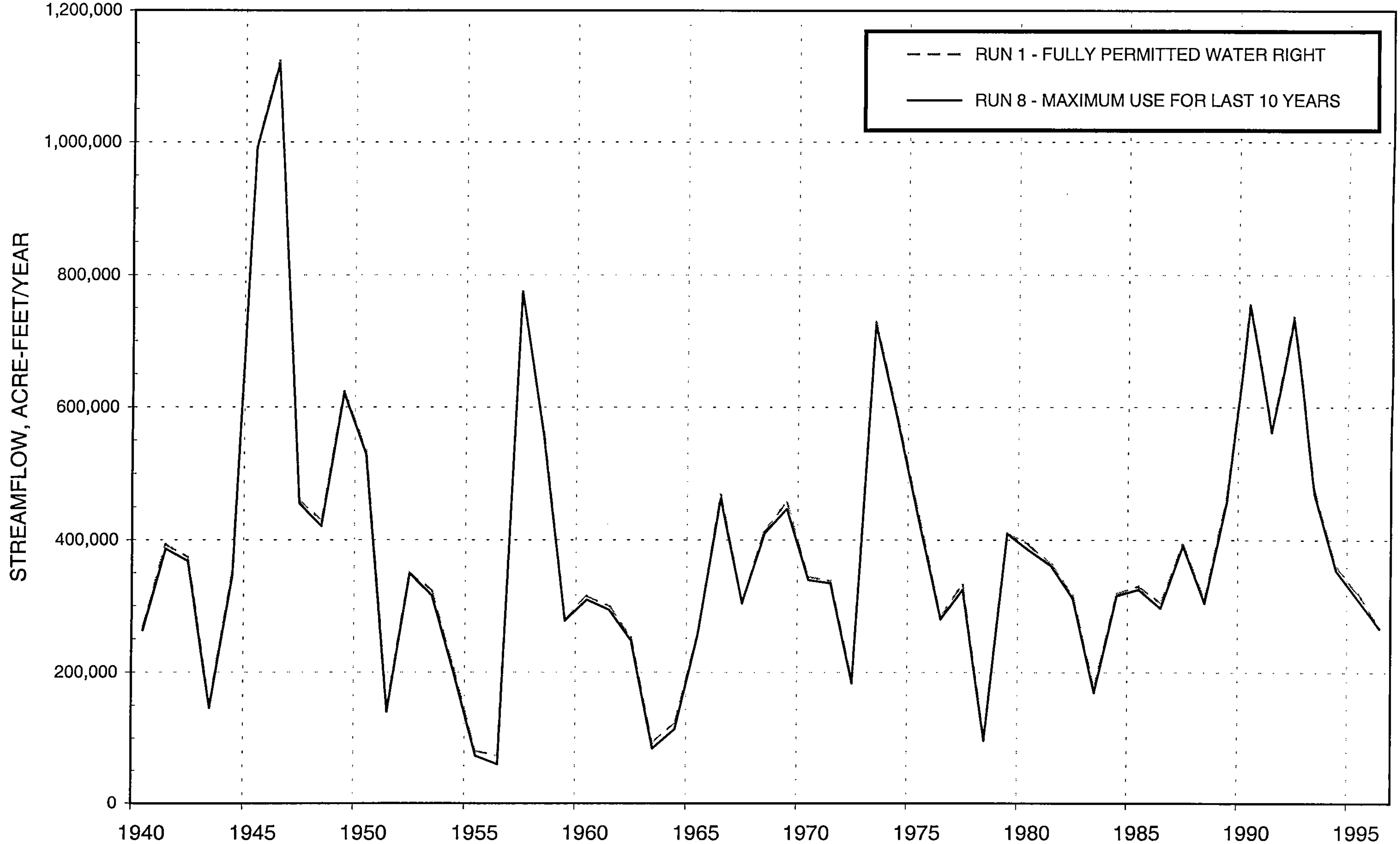


FIGURE A5-26
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT C10, DOWNSTREAM END OF SUBWATERSHED C

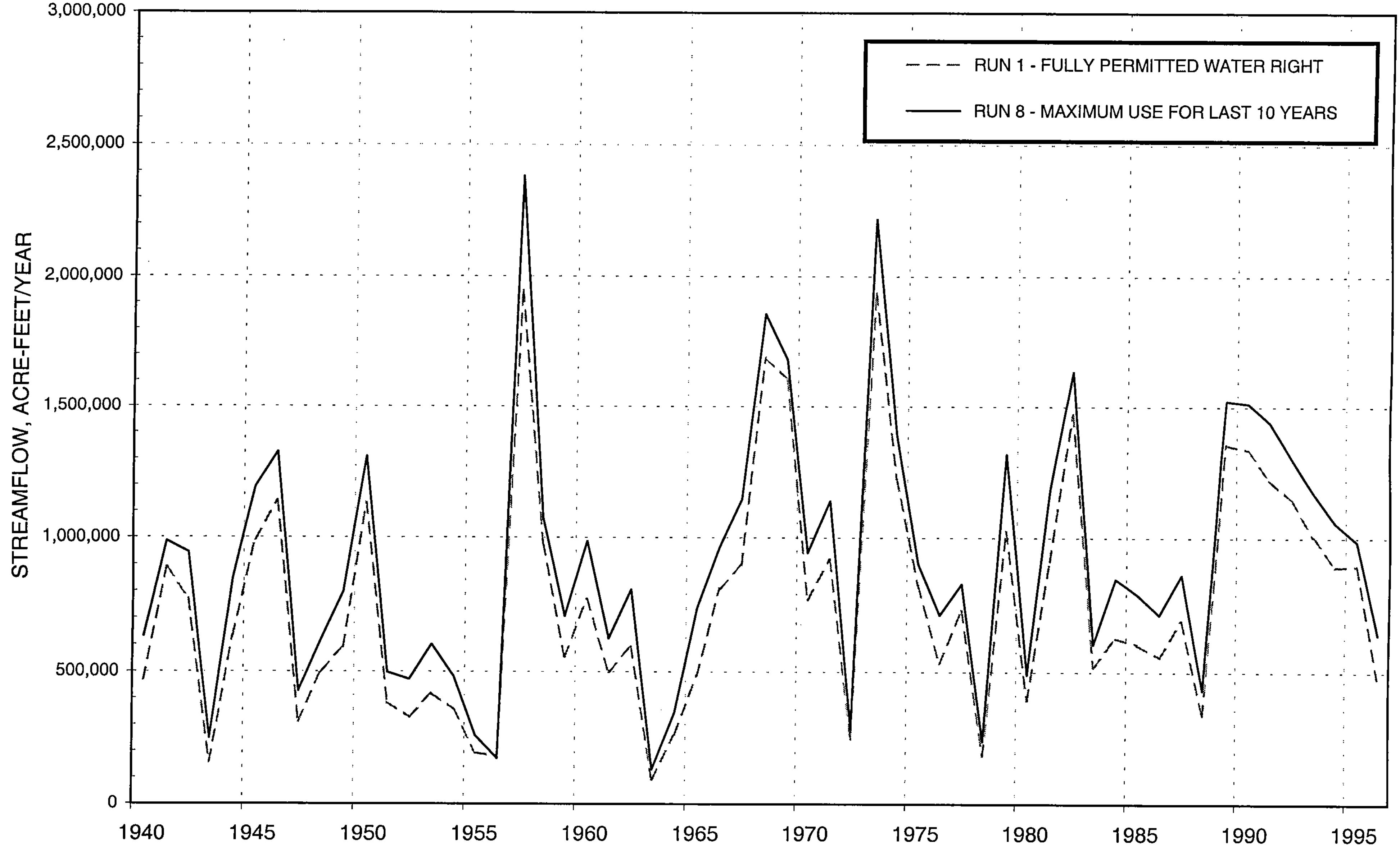


FIGURE A5-27
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT B10, DOWNSTREAM END OF SUBWATERSHED B

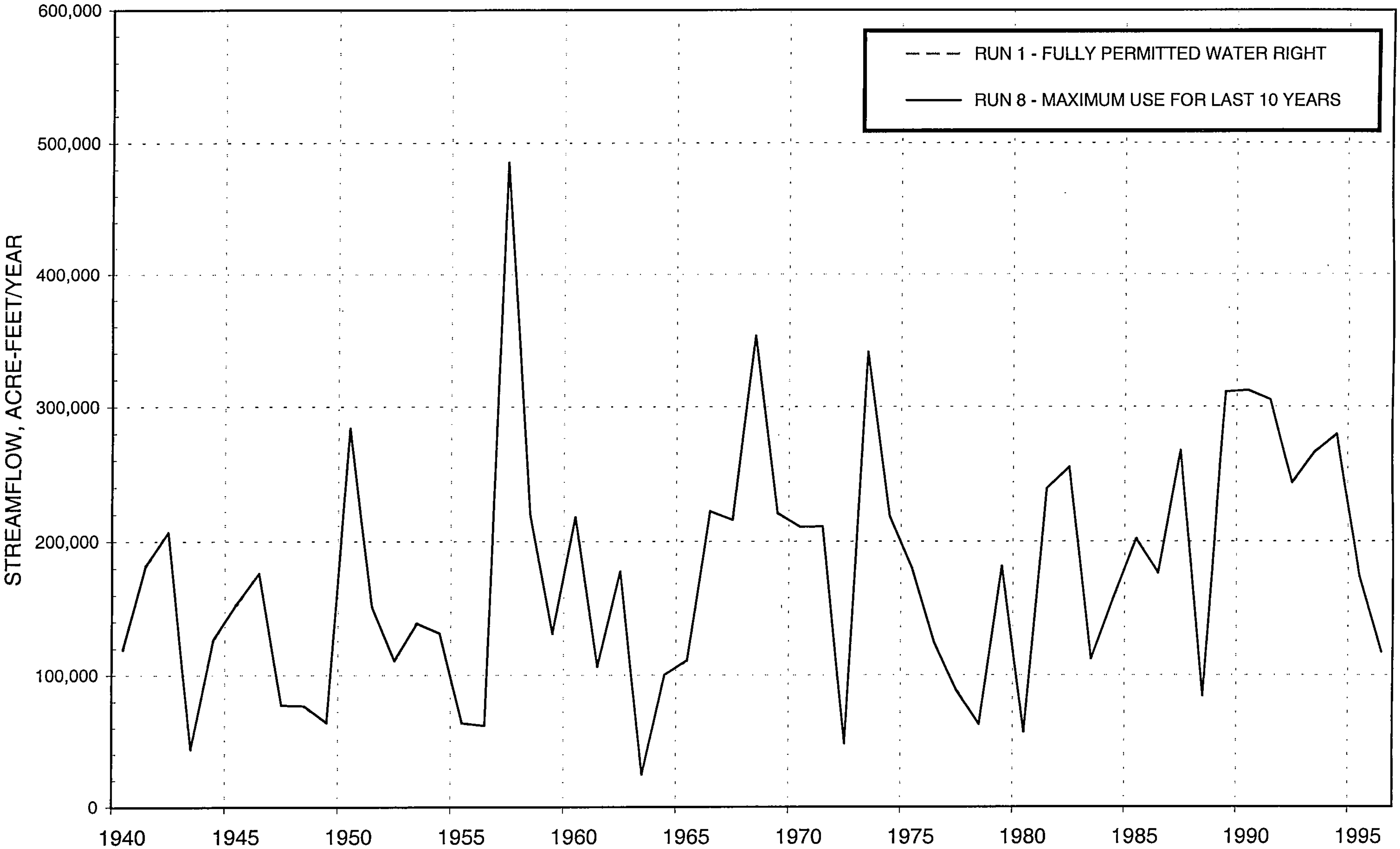


FIGURE A5-28
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT A10, DOWNSTREAM END OF SUBWATERSHED A

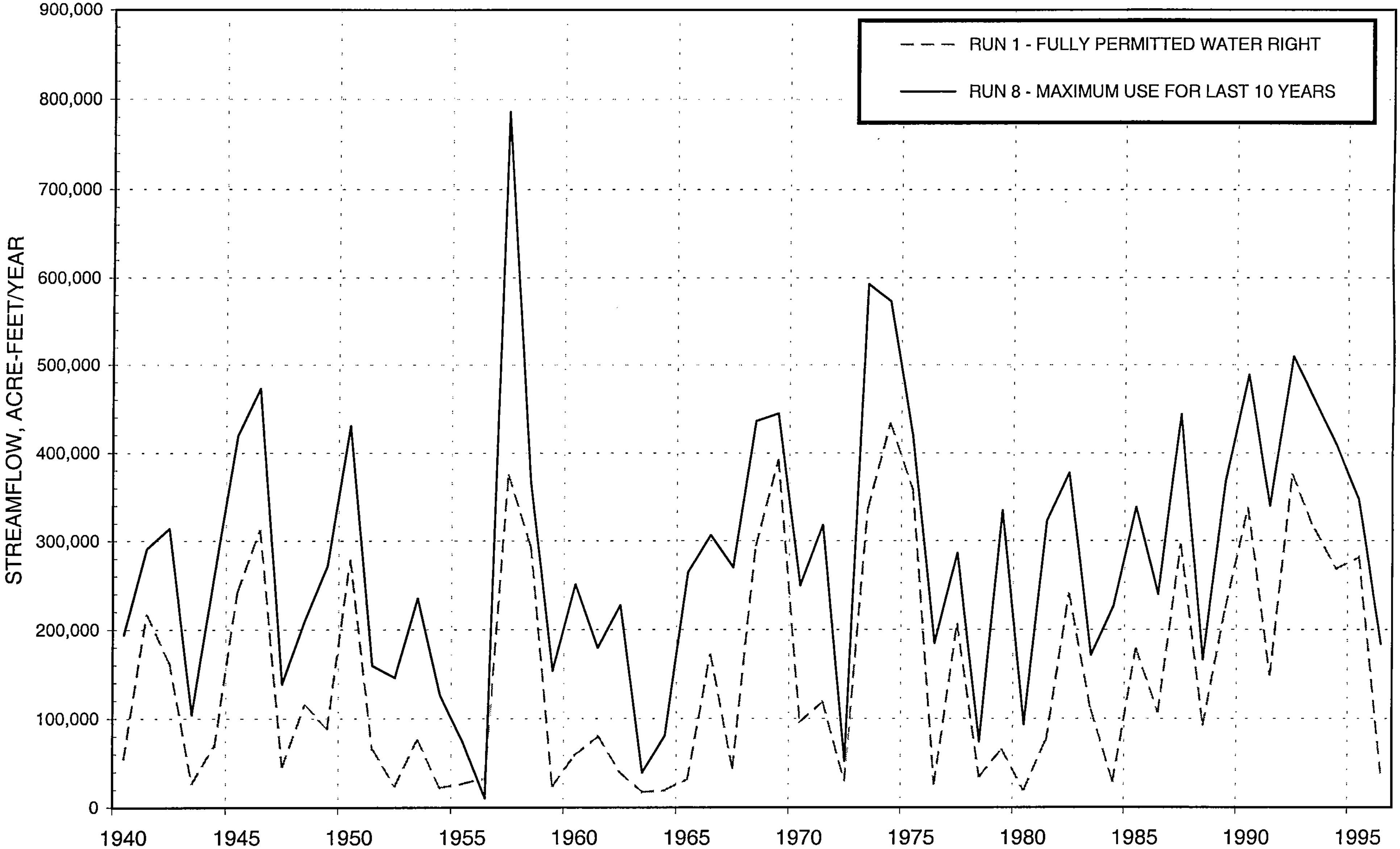


FIGURE A5-29
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT E20, MOUTH OF WHITE OAK CREEK

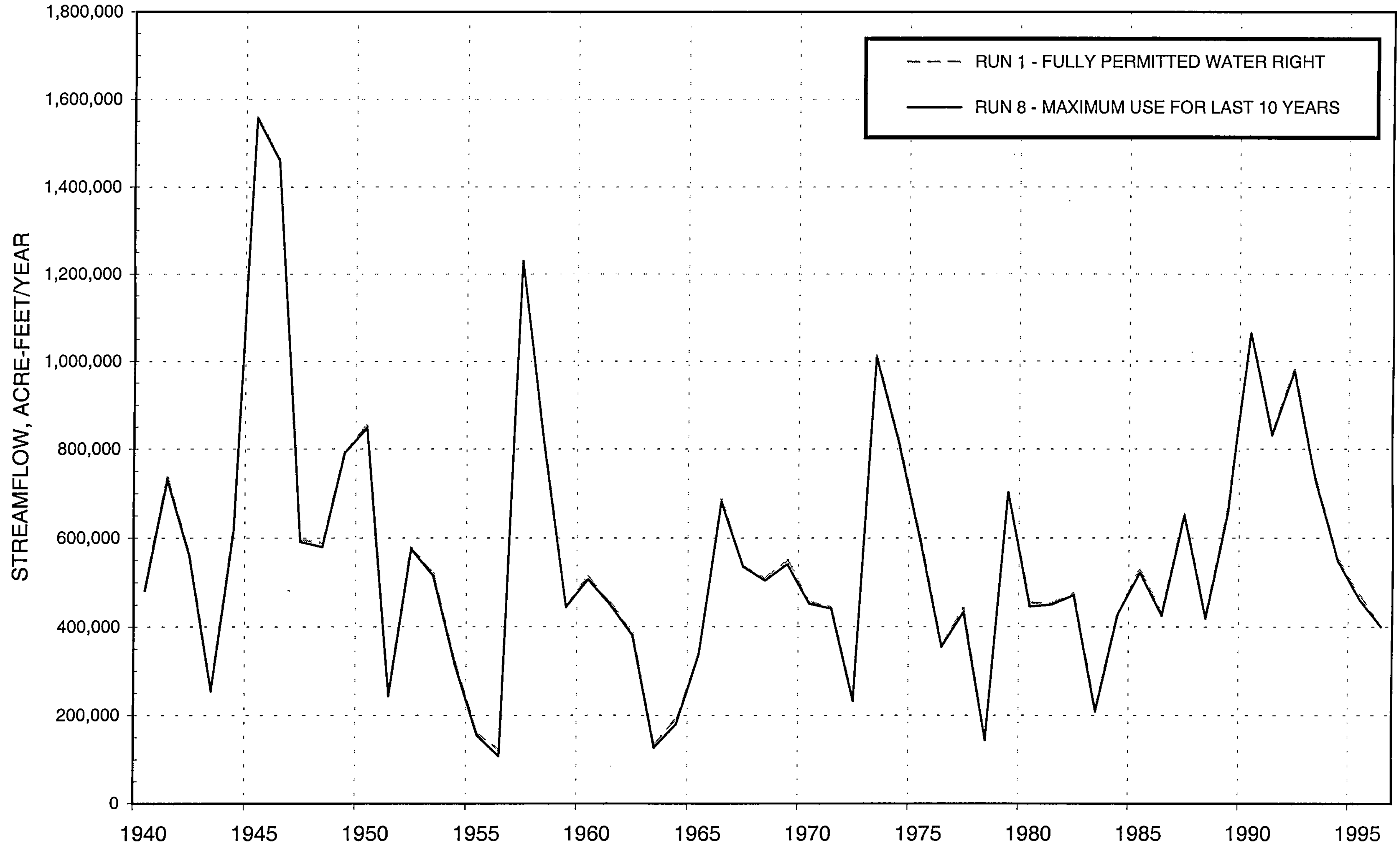


FIGURE A5-30
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT E180, MOUTH OF CUTHAND CREEK

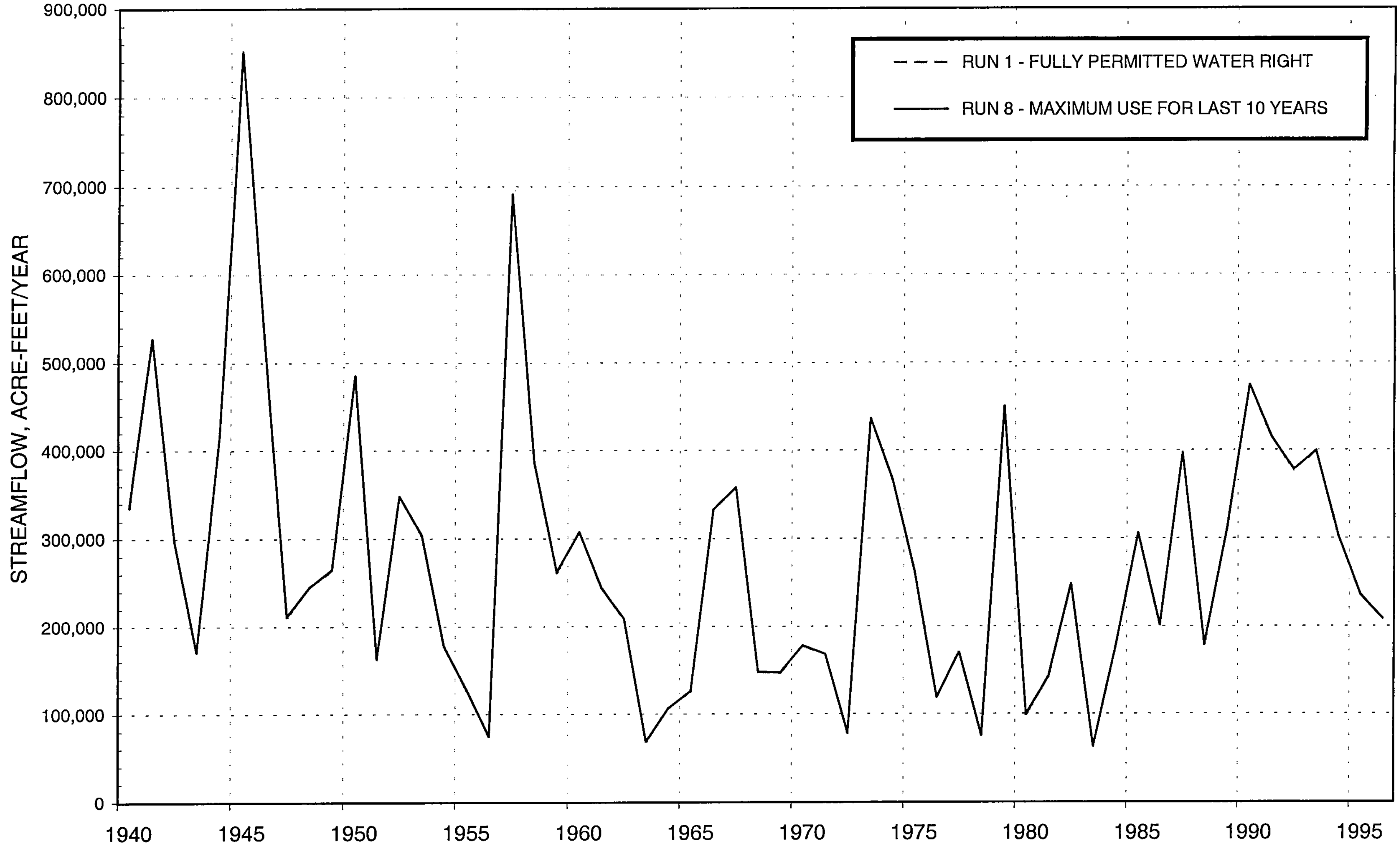


FIGURE A5-31
ANNUAL REGULATED FLOWS UNDER CURRENT CONDITIONS WITH 100% OF ASSUMED RETURN FLOW AT CONTROL POINT C90, NORTH SULPHUR RIVER