DANIEL B. STEPHENS & ASSOCIATES, INC.
ENVIRONMENTAL SCIENTISTS AND ENGINEERS

LITTLE COLORADO RIVER BASIN
PHASE II PROGRESS REPORT

Prepared for

The Hopi Tribe

Kykotsmovi, Arizona

January 9, 1995

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1. INTRODUCTION

In 1982 the Department of the Interior initiated the Glen Canyon Environmental Studies (GCES) with the directive to scientifically quantify the impacts to the resources of the Grand Canyon caused by Glen Canyon Dam operations. The Bureau of Reclamation manages the operations of the Glen Canyon Dam and the releases of water for the Colorado River through the Grand Canyon. In 1991 the Bureau of Reclamation and the Hopi Tribe entered into Cooperative Agreement No. 1-FC-40-10560 entitled *Cooperative Agreement for Hopi Tribe Coordination with the Glen Canyon Environmental Studies and the Glen Canyon Environmental Impact Statement.* Work item (f) for fiscal year 1994, as identified by this agreement, required coordination of the Hopi Tribe's hydrology concerns into the Glen Canyon Dam Environmental Impact Statement (GCD-EIS) and the GCES technical programs.

The Hopi Tribe retained Daniel B. Stephens & Associates, Inc. (DBS&A) to conduct surface water analyses in support of selected requirements of the cooperative agreement. The first portion of work conducted by DBS&A (Phase I) was completed in the spring of 1994 and consisted of an (1) evaluation of LCR basin streamflow characteristics and the (2) reconstruction of missing hydrologic data for selected U.S. Geological Survey (USGS) streamflow gages for a 53-year base period (DBS&A, 1994). The primary objective of DBS&A's second portion of work (Phase II) was to (3) develop a streamflow and sediment transport model for the Little Colorado River (LCR) basin in northern Arizona. The model will be used to evaluate sediment contributions from the LCR, which are necessary to maintain the habitat of the endangered humpback chub. Additional model refinement is scheduled to be completed in 1995 (Phase III).

This progress report summarizes the work completed during Phase II of the LCR basin study. The work consisted of a continued evaluation of basin hydrology and development of a streamflow and suspended sediment model for the LCR basin. Specifically, the following tasks were undertaken by DBS&A to meet the fiscal year 1994 objectives of both the Hopi Tribe and GCES:

- Conduct an analysis of the fluvial geomorphology using aerial photographs

- Conduct a field reconnaissance study to evaluate physical features that control basin hydrology
- Develop a conceptual model that incorporates information obtained from various data sources
- Develop precipitation/runoff relationships for the LCR and the major tributaries
- Construct monthly and event-driven precipitation/runoff models
- Construct a monthly sediment transport model

Detailed discussion of the work is provided in the remainder of this report. Data collection and analyses pertaining to model development are provided in Section 2 of this report. Precipitation and runoff relationships for each of the main tributaries of the LCR are summarized in Section 3. Section 4 discusses the streamflow and sediment transport models. Finally, the summary and conclusions drawn from Phase II of the GCES project are included in Section 5.

Focus is on Hopi issues & sources.

2. OVERVIEW OF LCR BASIN HYDROLOGY

As described in the Phase I progress report (DBS&A, 1994), the LCR Basin encompasses an area of approximately 27,000 square miles (Figure 1). From its forested headwaters near Springerville, Arizona, the main-stem of the LCR flows into a broad, gently sloping basin covered with grasses. Numerous tributaries, which drain the northern and southern highlands of the basin, join the LCR along its length. Near Grand Falls, the LCR leaves the broad valleys and floodplains of the central portion of the basin and becomes constricted within a gradually deepening canyon until it merges with the Colorado River.

In order to identify the physical characteristics that control streamflow and sediment transport throughout this immense basin, DBS&A has obtained hydrological information from several databases, reviewed relevant background materials, and completed several field reconnaissance trips. The information gathered from these efforts is summarized in this section. Section 2.1 summarizes the available hydrologic data for the basin. Section 2.2 describes DBS&A's analyses of Landsat images and aerial photographs, while Section 2.3 describes information gathered during field reconnaissance trips. Finally, Section 2.4 describes an integrated conceptual model on which the computer model was built.

2.1 Data Sources

During the course of Phases I and II, DBS&A has obtained relevant hydrologic information from various governmental agencies and private businesses. Streamflow and sediment transport data were obtained directly from the USGS Water Resource Division (WRD) and from a private company called Earthinfo, Inc., which maintains government databases for private users. Measured and reconstructed precipitation data were obtained directly from the Hopi Tribe and Earthinfo, Inc. The locations of surface-water and precipitation gages used in this study are given in Figure 2.

Data from the following streamflow gaging stations, listed in order from upstream to downstream, were used during this study:

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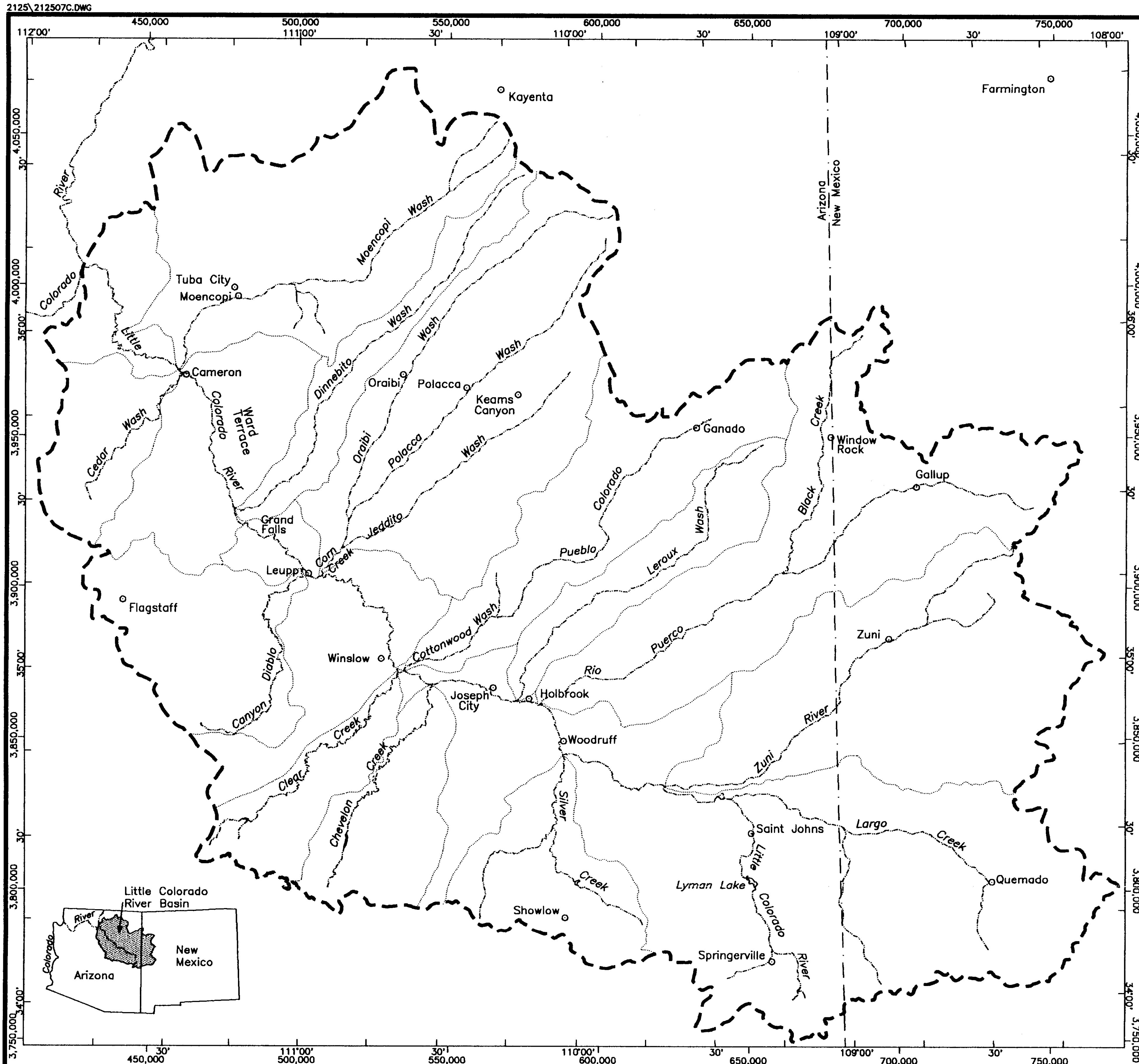

Note: Numbered lines indicate the 50,000 meter Universal Transverse Mercator Grid.

N

10 0 20 Miles

Explanation

LCR Watershed Boundary ?

Sub-Basin Boundary

Surface Drainage

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Little Colorado River Basin

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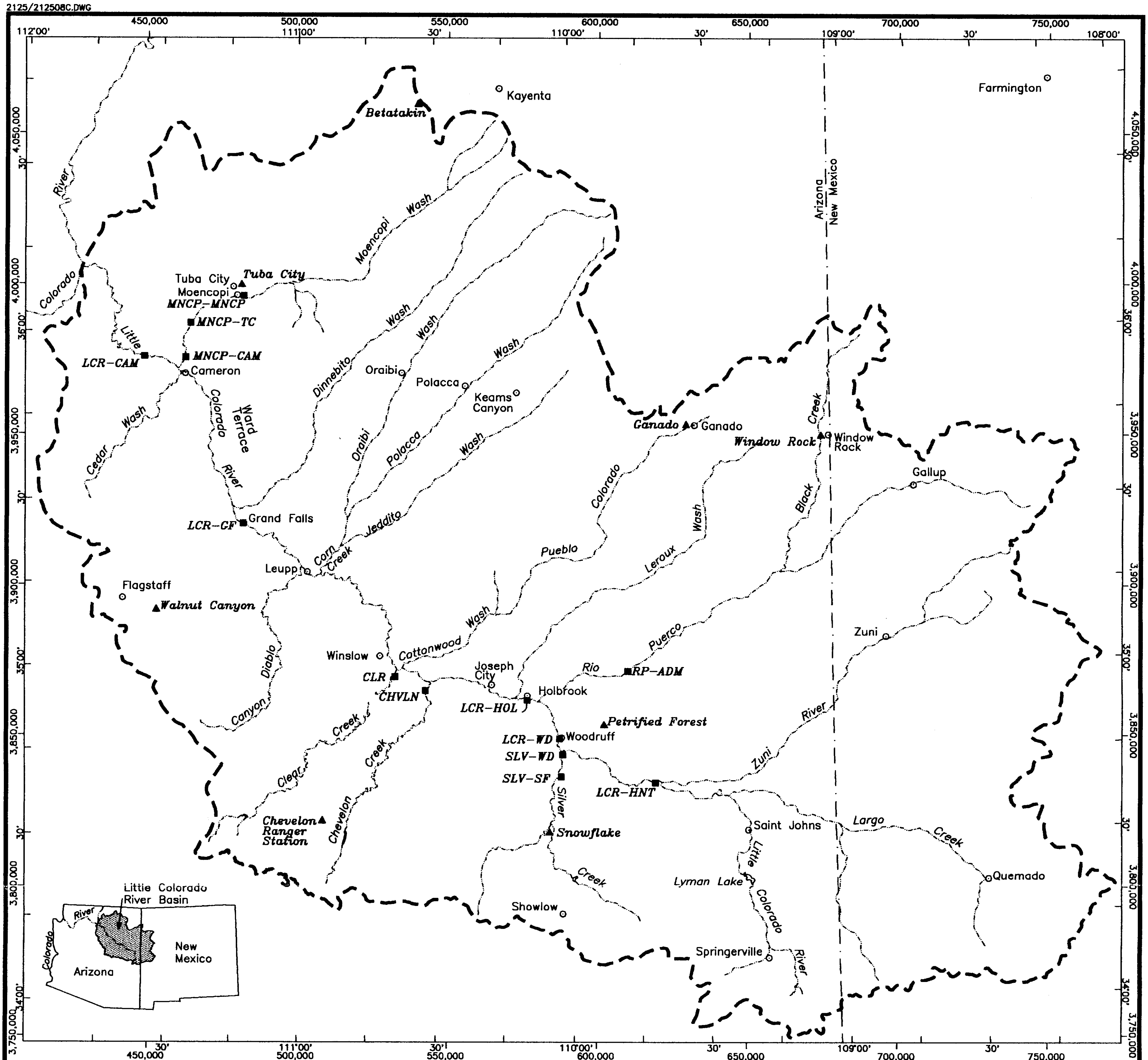
Figure 1

2125/212508C.DWG



Explanation

LCR Watershed Boundary	▲ Climatological Station
Surface Drainage	■ Surface Water Gaging Station

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Location of Selected Surface-Water and Precipitation Gages

Figure 2

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- LCR at Hunt *(LCR-HNT)*
- Silver Creek near Snowflake *(SLV-SF)*
- Silver Creek near Woodruff *(SLV-WD)*
- LCR at Woodruff *(LCR-WD)*
- Rio Puerco at Adamana *(RP-ADM)*
- LCR at Holbrook *(LCR-HOL)*
- Chevelon Creek near Winslow *(CHVLN)*
- Clear Creek near Winslow *(CLR)*
- LCR at Grand Falls *(LCR-GF)*
- Moencopi Wash near Cameron *(MNCP-CAM)*
- LCR near Cameron *(LCR-CAM)*

A review of the measured streamflow and sediment transport records obtained from the USGS indicates that monitoring has been sporadic over time at these primary gaging stations within the LCR basin (Figures 3 and 4). The USGS has also monitored streamflow along Black Creek, the Rio Puerco, the Zuni River, the LCR at Joseph City (LCR-JOE), and at several crest stage gages within the basin. These partial records were helpful when developing transfer relationships to estimate streamflows and sediment transport within ungaged subwatersheds.

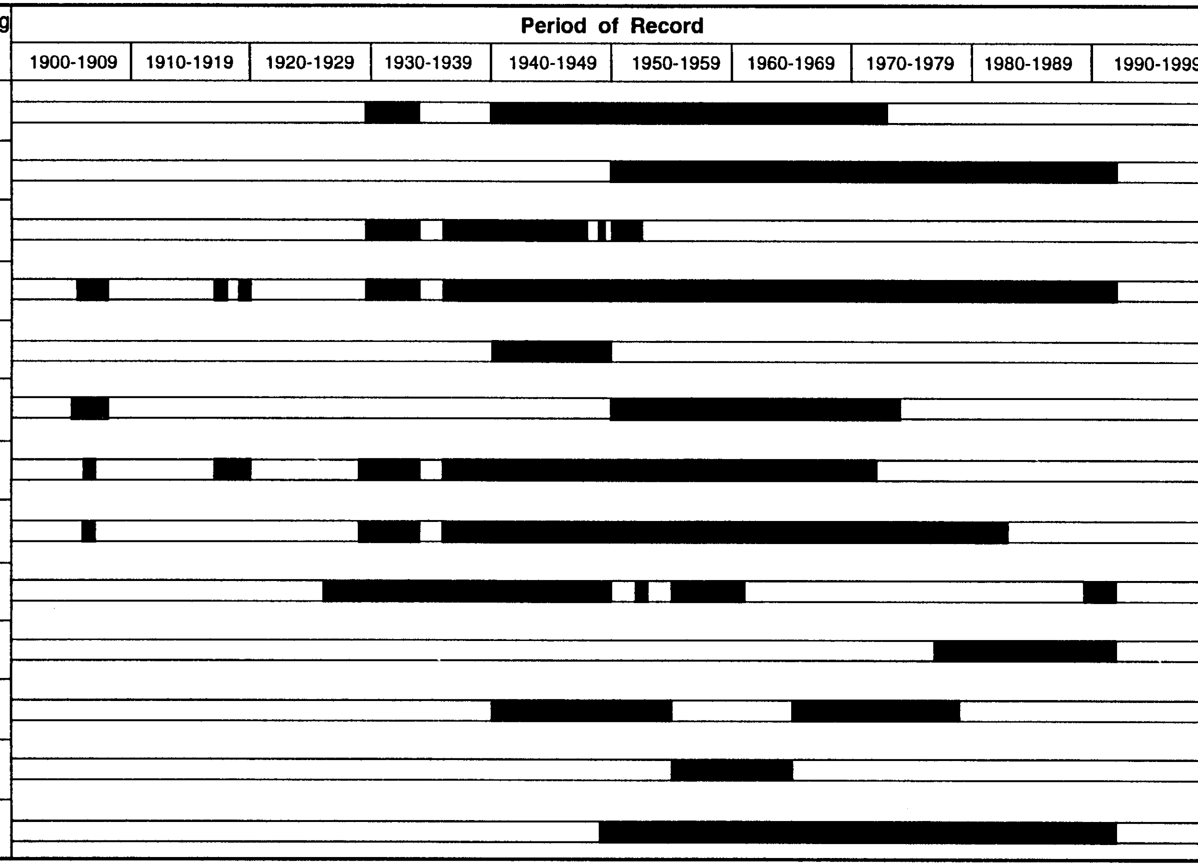
Information on physical characteristics such as watershed geometry, soil types, and vegetative cover was compiled from numerous sources (Sections 2.2 and 2.3). This information was used to assist with the development of a conceptual model of streamflow and sediment transport within the LCR basin.

2.2 Landsat and Aerial Photograph Analysis

In order to evaluate basin characteristics related to streamflows and sediment yields from the major tributaries identified during Phase I, DBS&A obtained contact prints of Landsat images of the entire length of the LCR and aerial photographs showing the confluence of 13 tributaries with the LCR main-stem. The following sources were contacted during this effort: Earth Observation Satellite Company (EROS), Bureau of Land Management Aerial Photograph Laboratory, the Earth Data Analysis Center, IntraSearch, and the USGS. Table 1 summarizes the contact prints obtained for the analysis.

1\WINDOWS\REPORTS\2125\TIME1.CDR

USGS Gaging Station		Drainage Area (mi²)	Contributing Area (mi²)
Number	Location		
09388000	LCR near Hunt (LCR-HNT)	6,383	6,173
09393500	Silver Creek near Snowflake (SLV-SF)	925	846
09394000	Silver Creek near Woodruff (SLV-WD)	966	887
09394500	LCR at Woodruff (LCR-WD)	8,072	7,775
09396500	Rio Puerco near Adamana (RP-ADM)	2,654	2,604
09397000	LCR at Holbrook (LCR-HOL)	11,462	11,115
09398000	Chevelon Creek near Winslow (CHVLN)	785	781
09399000	Clear Creek near Winslow (CLR)	621	621
09401000	LCR at Grand Falls (LCR-GF)	21,068	20,700
09401260	Moencopi Wash at Moencopi (MNCP-MNCP)	1,629	1,629
09401400	Moencopi Wash near Tuba City (MNCP-TC)	2,492	2,492
09401500	Moencopi Wash near Cameron (MNCP-CAM)	2,700	2,700
09402000	LCR near Cameron (LCR-CAM)	26,459	26,091



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Period of Streamflow Records for Selected USGS Gaging Stations Within Little Colorado River Basin

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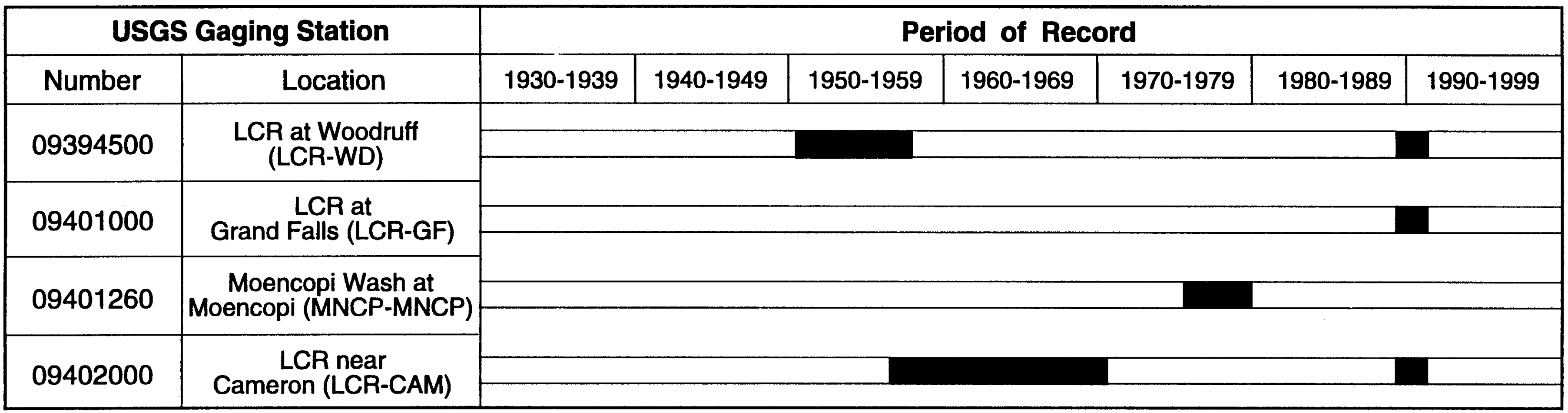
Figure 3



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Period of Sediment Transport Records for Selected USGS Gaging Stations Within Little Colorado River Basin

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Figure 4

Table 1. Summary of Landsat Images and Aerial Photographs Obtained for the LCR Basin

Contact Print	Date Flown	Film Type	Approx. Scale	Source
Landsat Images Showing Various Portions of the LCR Basin				
Headwaters to Woodruff	06/02/92	B&W	1:70,000	EROS
Woodruff to Leupp	10/07/92	B&W	1:70,000	EROS
Leupp to Colorado River	08/27/92	B&W	1:70,000	EROS
Aerial Photographs Showing the Tributary Confluence with LCR				
Zuni River	10/27/73	Color	1:24,000	IntraSearch
Zuni River	04/08/92	B&W	1:40,000	USGS
Silver Creek	10/26/73	Color	1:24,000	IntraSearch
Silver Creek	04/29/92	B&W	1:40,000	USGS
Rio Puerco	10/12/92	B&W	1:40,000	USGS
Leroux Wash	04/29/92	B&W	1:40,000	USGS
Chevelon Creek	10/06/78	Color	1:24,000	IntraSearch
Chevelon Creek	04/29/92	B&W	1:40,000	USGS
Cottonwood Wash	10/06/78	Color	1:24,000	IntraSearch
Cottonwood Wash	04/28/92	B&W	1:40,000	USGS
Clear Creek	10/06/78	Color	1:24,000	IntraSearch
Clear Creek	04/28/92	B&W	1:40,000	USGS
Corn Creek	04/28/92	B&W	1:40,000	USGS
Corn Creek	09/22/92	B&W	1:40,000	USGS
Canyon Diablo	04/28/92	B&W	1:40,000	USGS
Dinnebito Wash	04/17/92	B&W	1:40,000	USGS
Cedar Wash	05/01/92	B&W	1:40,000	USGS
Moencopi Wash	05/01/92	B&W	1:40,000	USGS

B&W = Black and white

EROS = Earth Observation Satellite Company
USGS = U.S. Geological Survey

Using these contact prints, DBS&A evaluated the confluence of each tributary with the LCR to determine geomorphological changes with the basin related to streamflow and sediment transport potential. Sections 2.2.1 and 2.2.2 describe the analyses of the Landsat images and aerial photographs, respectively.

2.2.1 Landsat Images

The three Landsat images obtained (Table 1), which cover the entire length of the LCR main-stem and the southern highlands, allow for a general interpretation of the basin morphology. The prints indicate that the LCR main-stem closely parallels the outline of the southern highlands. Landsat images of the northernmost highlands were not obtained from EROS.

2.2.1.1 Headwaters to Woodruff. The upper portion of the LCR basin is characterized by small drainage networks. The density of small washes is greatest within the Zuni River and Largo Creek sub-basins, and as a result, those areas may have higher erosion rates. In this region, vegetative cover is concentrated along the south side of the LCR main-stem as evidenced by the darker shading on the print. Vegetative cover provides slope stability. Several small reservoirs are present within the headwaters of the LCR.

2.2.1.2 Woodruff to Leupp. Along the south side of the LCR, Chevelon and Clear Creeks are readily distinguishable from the other southern tributaries due to their incised meanders within the Permian Kaibab Limestone. In comparison, the two remaining major tributaries, Silver Creek and Canyon Diablo, are only slightly incised and originate within areas of previous volcanic activity.

The drainage system within the Canyon Diablo sub-basin drains subparallel, as opposed to perpendicular, to the LCR, thus reducing the gradient of the drainage. This decrease in slope may allow for greater infiltration within the Canyon Diablo sub-basin. Greater vegetative cover within the Chevelon and Clear Creek headwaters may be an indication of greater elevation and precipitation in those areas.

On the north side of the LCR, Leroux and Cottonwood Washes contain significant quantities of sediment within their channels. Immediately upstream of Leupp, the LCR spreads out into a large floodplain called Tucker Flats on USGS topographic maps. The Corn Creek confluence with the LCR is difficult to locate.

2.2.1.3 Leupp to Colorado River. The most noticeable features within the lower reaches of the LCR are the San Francisco Peak volcanic field near Flagstaff and the confluence of the LCR with the Colorado River within the Grand Canyon. Two major drainages, Dinnebito and Moencopi Washes, enter the LCR from the north in this region (Figure 1). Highly eroded terraces are present east of the LCR between Dinnebito and Moencopi Washes and within the Moencopi Wash sub-basin.

The LCR floodplain is much smaller through this reach as compared to the reaches upstream of Leupp, because the channel becomes deeply incised within a narrow canyon. Cedar Wash flows north from the San Francisco Peak volcanic field and joins the LCR just west of Cameron (Figure 1).

2.2.2 Aerial Photographs

The aerial photographs obtained by DBS&A (Table 1) were used to evaluate the morphological characteristics throughout the LCR basin as represented by the confluence of each major tributary with the main-stem of the LCR. The morphology of these confluences, which gives an indication of the type of sediment transport that may be occurring, is discussed in the following subsections.

2.2.2.1 Zuni River. The LCR above the confluence with the Zuni River (Figure 1) is slightly sinuous[1], narrow, and has minimal sediment storage within the channel system (e.g., point bars, channel bars, and floodplains). In contrast, the Zuni River is highly sinuous, has a slightly wider channel, and contains deposition point bars caused by lateral migration of the channel system. Vegetation exists along the banks of both channel systems. Below the confluence, the LCR channel characteristics are a mixture of the two upstream morphologies: the channel becomes wider, contains more vegetation, and is slightly to moderately sinuous.

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[1] Sinuosity is the distance measured along a channel within a reach divided by the straight line distance connecting the beginning and ending points of the reach. Values can range from 1 (straight) to values greater than 2 for highly sinuous channel reaches.

Erosion, and thus sediment supply, appears to be greater within the Zuni River drainage, based on the amount of sediment within the channels and erosion of the surrounding contributing slopes. This observation is consistent with the greater density of dry washes and eroded lands noted on the Landsat image. In addition, Lyman Reservoir on the LCR main-stem (Figure 1) serves as a sediment trap above the LCR confluence with the Zuni River.

The surrounding area is vegetated with native grasses and some piñon and juniper. Vegetation density, and thus slope stability, appears to be greatest along the south side of the LCR within this reach.

2.2.2.2 Silver Creek. At the Silver Creek confluence with the LCR (Figure 1), both channels are of similar width and overall size. The LCR above the Silver Creek confluence has greater sediment storage along its channel and is moderately sinuous. In comparison, Silver Creek has greater vegetative growth, minimal sediment storage, and is straight to slightly sinuous. The aerial photographs indicate that an earthen dam controls streamflows out of the mouth of Silver Creek. Below the confluence, the LCR is approximately twice the upstream width, slightly sinuous, and contains stable point bars within each meander belt.

The surrounding area is covered by native grasses, and hill-slope erosion is slight to moderate. The black and white photograph (Table 1) shows the community of Woodruff north of the confluence. The community uses water from the LCR for irrigation of crops.

2.2.2.3 Rio Puerco. A significant change in the LCR channel morphology occurs below the LCR's confluence with the Rio Puerco (Figure 1). Above the confluence the LCR channel is approximately 60 feet wide, relatively straight, and heavily vegetated. Below the confluence the LCR floodplain is approximately 4 to 5 times the upstream width, and the LCR meanders within a braided channel containing abundant sediment. Sediment deposition at the confluence indicates that the main-stem occasionally becomes a backwater due to higher streamflows in the Rio Puerco.

The Rio Puerco morphology is similar to that of the LCR below their confluence in that the Rio Puerco contains abundant sediment, and meander belts are contained within a larger, relatively straight, braided channel that is approximately equal in width to the LCR's below the confluence.

Below the confluence, the LCR's active channel is contained within a well developed, vegetated floodplain.

2.2.2.4 Leroux Wash. Leroux Wash enters the LCR west of Holbrook (Figure 1). The wash is similar to the Rio Puerco in that the channel is braided, contains abundant sediment, and is of similar width. However, the channel is straighter and appears to be less stable, as evidenced by large channel bars and minimal bank vegetation. Below the confluence, significant quantities of sediment are stored along the LCR floodplain.

2.2.2.5 Chevelon Creek. Chevelon Creek enters the LCR from the south between Joseph City and Winslow (Figure 1) and has a slightly sinuous, confined channel. The creek emerges from a vertical-walled bedrock canyon approximately 3 miles above the confluence and then flows into an open plain where the channel banks are stabilized with vegetation. Minimal sediment storage locations exist along the lower reaches of Chevelon Creek.

2.2.2.6 Clear Creek. Clear Creek enters the LCR from the south a few miles southeast of Winslow (Figure 1). The 1978 color aerial photograph obtained by DBS&A (Table 1) shows the channel outlet prior to construction of a reservoir immediately above the confluence with the LCR, whereas the reservoir is present on the 1992 black and white aerial photograph (Table 1). Both photographs show that the creek is contained within a stable channel lined with vegetation and/or bedrock walls. The creek character is similar to Chevelon Creek in respect to channel width (each is approximately 50 feet wide), sinuosity, and sediment storage.

The morphology of the LCR is relatively constant throughout the reach between the Rio Puerco and Clear Creek. Many abandoned meandering belts are present within the well developed, vegetated floodplain. The active channel width of the LCR in this reach is approximately 200 to 300 feet. At low streamflows the LCR meanders from bank to bank within the larger braided channel system, which is only slightly sinuous.

2.2.2.7 Cottonwood Wash. Cottonwood Wash enters the LCR from the north near (southeast of) the city of Winslow (Figure 1). The channel is slightly to moderately sinuous and approximately 50 feet wide, and it contains many deposition point bars along its course. The sediment storage sites have been stabilized by vegetation.

2.2.2.8 Corn Creek. Corn Creek joins the LCR just east of the community of Leupp (Figure 1). There appears to be no distinct outlet for Corn Creek; its streamflows seem to disperse across an open alluvial plain north of the LCR floodplain. The Corn Creek channel above the outlet is narrow and moderately sinuous, and it contains some point bar development. The LCR above the confluence is highly sinuous and contains multiple channels without connections (referred to as anastomosing). The reach contains multiple abandoned meanders and point bars formed within a floodplain, which is approximately four times greater in width than the LCR floodplain near Winslow. This area is approximately 10 miles downstream of the Tucker Flats area.

2.2.2.9 Canyon Diablo. Canyon Diablo enters the LCR from the south near Leupp (Figure 1) at the point that marks the transition of the LCR floodplain from the large expanses in the Corn Creek area (Section 2.2.2.8) to a relatively narrow floodplain. Canyon Diablo is moderately sinuous, narrow, and devoid of significant sediment storage sites. An earthen dam crosses the drainage approximately 1 mile above its confluence with the LCR. The LCR channel below Canyon Diablo is straight to slightly sinuous.

2.2.2.10 Dinnebito Wash. Dinnebito Wash joins the LCR from the north a few miles northwest of Grand Falls (Figure 1). Dinnebito Wash is moderately sinuous and narrow, and its channel contains some point bar development. The wash is lined with some vegetation and is contained within a narrow valley.

The LCR through this reach is relatively straight and confined within a narrow canyon. Moderate sediment storage occurs along this reach.

2.2.2.11 Cedar Wash. Cedar Wash joins the LCR from the south near Cameron (Figure 1). The Cedar Wash channel is highly sinuous and relatively narrow. This channel appears to be relatively shallow, allowing streamflows to spread laterally outside the active channel during high streamflow events. The channel becomes entrenched within a canyon approximately 1.5 miles from its confluence with the LCR.

2.2.2.12 Moencopi Wash. Moencopi Wash joins the LCR from the north near Cameron (Figure 1). The Moencopi Wash channel is highly sinuous and relatively narrow. Substantial terrace development has occurred within the confining vertical-walled canyon surrounding the wash. The LCR channel in this area is also confined within a vertical-walled canyon, but is only slightly sinuous.

2.3 Review of Resource Maps and Field Reconnaissance Trips

In order to confirm the features identified from the analysis summarized in Section 2.2, DBS&A analyzed basin characteristics using soil, geologic, and topographic maps and information gathered during several field reconnaissance trips. The analysis provided an avenue to evaluate streamflow and sediment yields with respect to basin characteristics such as sub-basin area, channel slope, channel width, channel cross-sectional area, and potential sediment sources.

Sub-basins account for the runoff and sediment transported from tributary systems into the main channel system. To represent the drainage basin, each of the major tributaries identified by aerial photographs analysis was delineated on 1:100,000 scale USGS topographic maps to allow calculation of sub-basin areas and channel slopes. Geologic and soils maps were consulted to develop a qualitative understanding of areas of potentially high sediment yield.

From the aerial photograph analysis, the Rio Puerco was determined to have significant control over the LCR channel morphology downstream of the confluence of the two rivers. The Rio Puerco was further divided to allow calculation of contributing areas of subwatersheds, lengths, slopes, vegetative cover, and soil types. The information obtained from the Rio Puerco analysis was used to construct an event-driven mathematical model for the Rio Puerco watershed. The methods used to construct the detailed physical representation of the Rio Puerco basin are similar to those outlined in the software documentation (Riggins et al., 1989a, 1989b).

During the field reconnaissance trips, DBS&A photographically documented each drainage basin identified during the aerial analysis, measured active cross sections, identified vegetative covers and soil types, and collected bed-material samples. Channel geometries provide a simple diagnostic predictor of stream discharge potential. Over 220 photographs were taken in order to develop a photographic log of each location for future examination. Physical parameters determined from the map analysis and cross section measurements are summarized in Table 2.

Table 2. Summary of Sub-Basin Physical Characteristics Within the Little Colorado River Watershed

Location	Drainage Basin (mi^2)	Channel Slope at Outlet	Approximate Channel Width (ft)	Approximate Cross-Sectional Area (ft^2)
Zuni River	2,810	0.0015	NM	NM
LCR below Zuni River	6,380	NM	15	45
Silver Creek	1,010	0.0028	20	80
LCR at Woodruff	8,072	0.0028	50	200
Rio Puerco	3,150	0.0012	175	440
LCR near Joseph City	12,384	NM	230	925
Leroux Wash	858	0.0014	120	265
Chevelon Creek	810	0.0018	50	225
Cottonwood Wash	1,700	0.0015	55	210
Clear Creek	640	0.0022	40	180
Corn Creek[1]	3,020	0.0028	34	112
Canyon Diablo	1,240	0.0030	35	140
LCR at Grand Falls	21,068	0.0008	105	306
Dinnebito Wash	660	0.0031	48	144
Cedar Wash	665	0.0231	40	100
Moencopi Wash	2,650	0.0031	35	140
LCR near Cameron	26,460	0.0012	104	485

[1] Cross section was measured above State Highway 87 bridge

NM = Not measured

The bed-material samples collected by DBS&A and the Hopi Tribe were sieved by the DBS&A soil testing laboratory and the USGS Flagstaff office, respectively, to determine grain-size distributions. Table 3 provides a summary of the completed sieve analyses for bed-material samples. Appendix A contains the sieve analyses and data plots.

2.4 Conceptual Hydrologic Models

This section provides the conceptual framework on which the LCR streamflow and sediment transport models were built. The conceptual framework is based on analyses conducted during Phases I and II of the GCES study. Sections 2.4.1 and 2.4.2 describe basin streamflow and sediment transport, respectively.

2.4.1 Streamflow

In addition to physical characteristics such as basin size, soil types, and relief, the distribution of precipitation controls the runoff process. Within the LCR basin, annual precipitation is bimodally distributed between winter frontal storms and summer monsoons. Winter storms concentrate precipitation along the southern highlands in the form of snowfall, and in spring, the accumulated snow is delivered to the main-stem of the LCR through several north-draining tributaries. During the monsoon season, runoff occurs across the basin in direct response to rainfall from subtropical Gulf of California moisture or tropical Pacific Ocean moisture crossing the normally dry plateau (Hereford, 1989).

During Phase I of the LCR basin study, an inspection of annual median streamflows for the LCR-WD, LCR-HOL, LCR-GF, and LCR-CAM gages revealed, as expected, that as the drainage area above the measuring gage increases, the corresponding stream discharge also increases. However, the relationship between drainage area and stream discharge is not uniform. For example, between Grand Falls and Cameron the drainage area of the LCR nearly doubles in size, but the median flow only slightly increases. The decrease in unit runoff (defined as the stream discharge divided by the drainage area above the measuring point) in the downstream direction results from less precipitation, increased evapotranspiration, and increased channel losses along the lower-middle to lower reaches of the LCR.

Table 3. Grain-Size Distributions From Selected Sediment Sample Locations Along the Little Colorado River and Tributary Drainages

Location	Grain Diameter (mm)[1]			
	D_{10}	D_{30}	D_{50}	D_{90}
Rio Puerco at bridge, Navajo, Arizona	0.02	0.06	0.12	0.57
Little Colorado River at old bridge, Holbrook, Arizona	0.08	0.13	0.17	0.32
Leroux Wash at Broadcast Ave., Holbrook, Arizona	0.13	0.16	0.22	0.44
Chevelon Creek above Little Colorado River	0.06	0.08	0.10	0.22
Clear Creek below Clear Creek Reservoir, Winslow, Arizona	0.05	0.09	0.13	5.00
Jacks Canyon Wash at Highway 99	0.10	0.26	0.51	2.00
Cottonwood Wash at I-40	0.02	0.12	0.14	0.26
Jeddito Wash at Highway 87	0.09	0.15	0.22	0.73
Polacca Wash above Highway 264	0.12	0.16	0.22	0.43
Wepo Wash above Highway 264	0.00	0.13	0.31	0.90
Polacca Wash above Highway 87	0.00	0.01	0.06	43.00
Oraibi Wash at old house, 10 mi south of Kykotsmovi, Arizona	0.08	0.14	0.18	0.42
Corn Creek Wash above Highway 15 bridge	0.21	0.32	0.41	0.84
San Francisco Creek at Turkey Flats, Leupp Road	0.14	0.32	0.44	1.10
Canyon Diablo at Two Guns, I-40	0.06	0.11	0.15	0.42
Little Colorado River, 200 yds above Grand Falls	0.03	0.07	0.11	0.31
Dinnebito Wash near Sand Springs	0.13	0.20	0.30	2.70
Little Colorado River above bridge, Cameron, Arizona	0.06	0.11	0.15	0.23
Moencopi Wash above Highway 89 bridge	0.05	0.10	0.15	0.26

[1] Subscripted number (e.g., in D_{10}) refers to the percentage of sediment that is less than or equal to the indicated grain diameter.

Annual and average monthly streamflows indicate that the duration, periods, and magnitude of runoff vary greatly within the LCR basin, as described below:

- The upper reaches, represented by the LCR-WD gage, have distinct spring snowmelt and late summer thunderstorm runoff events.

- The upper-middle reaches represented by the LCR-HOL gage, have a spring snowmelt of similar magnitude to that of the upper reaches, but the average annual runoff is dominated by the late summer thunderstorm streamflows originating within the Rio Puerco drainage.

- The lower-middle to lower reaches of the LCR basin, represented by the LCR-GF and LCR-CAM gages, respectively, have a snowmelt pulse approximately 5 to 10 times greater than the streamflow magnitude measured at the LCR-HOL gage. However, streamflow resulting from summer thunderstorms closely approximates the magnitude of streamflows measured at the LCR-HOL gage during the summer.

- Water balance calculations indicate that, on average, the LCR main-stem gains significant volumes of water between the LCR-WD and LCR-HOL gages, loses water between and the LCR-HOL and LCR-GF gages, and gains slightly between the LCR-GF and LCR-CAM gages.

The duration and magnitude of runoff events appear to be controlled by basin characteristics such as vegetative cover and watershed geomorphology. The upper reaches respond nearly equally to winter and summer precipitation events, the upper-middle reaches are dominated by late summer storms, and the lower-middle to lower reaches are dominated by snowmelt runoff from the southern highlands and late summer thunderstorm runoff.

Measured streamflow and channel dimensions were used to evaluate streamflow contributions from each tributary. On average, the major contributing drainages can be divided into three classifications based on annual discharge:

- Discharges greater than 30,000 acre-feet per year (ac-ft/yr) (Rio Puerco, Chevelon Creek, Clear Creek, and Cottonwood Wash)

- Discharges between 20,000 and 30,000 ac-ft/yr (Leroux Wash and Silver Creek)

- Discharges less than 15,000 ac-ft/yr (Canyon Diablo, Moencopi Wash, Cedar Wash, LCR above Hunt, and Dinnebito Wash)

Corn Creek, which drains Jeddito, Polacca, and Oraibi Washes, does not appear to contribute significant quantities of water to the LCR main-stem. As described in Section 2.2, the Corn Creek outlet is not distinguishable on aerial photographs, whereas distinct outlets are present for the other major tributaries.

2.4.2 Sediment

The exposed bedrock within the basin consists primarily of late Paleozoic limestones and Mesozoic sandstones, siltstones, and to a lesser extent, shales. Cenozoic deposits consisting of consolidated and unconsolidated clays, silts, and sands, as well as lava flows and unconsolidated pyroclastics, are also present. The sandstones, siltstones, shales, and unconsolidated strata that cover approximately 70 percent of the basin weather rapidly and provide abundant sediment for transport from surrounding hill slopes to channel systems within the LCR basin. In contrast, the limestones, lava flows, and pyroclastic materials concentrated along the southern portion of the basin are more resistant to erosion.

Erosion has carved deeply incised channels within the LCR basin and has removed large quantities of sediment in the process (USDA SCS, 1981). The initial widespread incision observed during the late 19th century, attributable to higher precipitation, resulted in increased sediment yield from the LCR basin. Beginning in the early 1940s, reduced peak streamflows resulted in the stabilization of the main LCR channel system with vegetation (Hereford, 1984), and since the 1940s, sediment transport has been relatively constant throughout the basin (DBS&A, 1994). This relatively stable period of balanced erosion and sediment transport suggests that sediment transported through the LCR should be roughly equal to the sum of the yields from its sub-basins.

The sediment carried through the LCR basin is derived principally from erosion of weathered bedrock at the head of the various tributaries. Spatial variability of sediment storage sites most likely results from the non-linear downstream distribution of stream power and sediment-transport capacity within the channel system (Hereford, 1987). Sub-basins with steeper slopes and narrower channels have a higher sediment-transport capacity. Along the main-stem, the sediment-transport capacity diminishes somewhat due to decreased slopes and wider channels. This reduced carrying capacity results in the storage of sediment within floodplains.

Highly variable discharges within the Rio Puerco, Leroux Wash, and the LCR main-stem below the Rio Puerco confluence has promoted the development of meandering channels within braided channel systems. Braided channels are well suited to highly variable discharges since they accommodate large events without significant changes in channel morphology. At high streamflows, the braided channel can transport greater quantities of sediment due to the straighter stream course adopted during bank-to-bank streamflows. The straighter streamflow path results in a corresponding increase in channel slope, which can create greater shear stress on the channel bed (Graf, 1988).

The wide floodplains along the LCR between Holbrook and Leupp (Section 2.2) indicate a decreased sediment-transport capacity through this reach. In comparison, relatively little sediment is stored along the LCR between Leupp and the LCR confluence with the Colorado River, suggesting that there is an increase in sediment-transport capacity through this reach.

Sediment-transport relationships developed during Phase I of the LCR study indicate that the relative sediment loads carried by the LCR increase substantially between Woodruff and Holbrook, decrease slightly between Holbrook and Grand Falls, and increase substantially again between Grand Falls and Cameron. These relationships are consistent with channel morphological observations described in Section 2.2.

Suspended sediment samples collected during the USGS Rio Puerco study (Graf et al., 1993) contained more than 90 percent silt- and clay-sized materials, while bed material consisted of medium-grained sands with minor amounts of silt and clay. Bed material samples collected by DBS&A and the Hopi Tribe indicate that, on average, only 10 percent of the LCR main-stem bed material is smaller than very fine sand (0.05 mm) (Table 3). According to the suspended sediment data collected by the USGS study, approximately 55 percent of the sediment transported along the main-stem was finer than medium clay (0.002 mm).

The suspended sediment grain-size distributions indicate that silt- and clay-size fractions, which likely originate from the surrounding hill slopes, are readily transported out of the LCR basin during streamflow events. The suspended sediment size fraction finer than 0.002 mm is referred to as wash load for the purposes of this study. Wash load probably accounts for a large component of the increase in sediment load between LCR-GF and LCR-CAM. Multiple minor tributaries of short length and high slope drain the highly eroded Triassic Chinle Formation through this reach. A significant quantity of wash load probably originates from the erosion of Ward Terrace, located east of the LCR between LCR-GF and LCR-CAM. The Soil Conservation Service (SCS) reported an average erosion rate for Ward Terrace of 3 to 9 tons per acre per year (USDA SCS, 1981).

3. PRECIPITATION/RUNOFF RELATIONSHIPS

DBS&A identified precipitation/runoff relationships for selected tributaries of the LCR for incorporation into the LCR streamflow model. The relationships were developed using linear regression analysis of recorded rainfall data at one or more precipitation gages (independent variable) versus recorded streamflow for a given tributary (dependent variable). Where records from multiple discharge gages were available for a tributary, the record for the gage closest to the tributary's confluence with the LCR was selected for analysis. The precipitation/runoff relationships identified for each tributary of the LCR represented in the streamflow model are presented in this section in a logical sequence of upstream to downstream.

Where possible, monthly relationships for precipitation versus runoff were derived. If satisfactory monthly relationships could not be identified, seasonal relationships were investigated. For this investigation the four annual seasons are defined as the following grouping of months: January and February, March through June, July through October, and November and December. The November through December and January through February seasons are referred to as the winter months, the March through June period is referred to as the spring runoff season, and the July through October period is referred to as the monsoon season.

There are several months for which significant precipitation/runoff relationships could not be identified for each tributary. For these months, the mean and standard deviation of the recorded discharge were computed and are presented herein. This situation was generally encountered for months that have relatively low and highly sporadic discharge.

Stacked-bar graphs of average monthly precipitation for several key precipitation stations are presented in Appendix B. Stacked-bar graphs of average monthly discharge for the tributaries discussed in this section are presented in Appendix C. The stacked-bar graphs are divided into three four-month groupings (November through February, March through June, and July through October) to facilitate seasonal comparisons. For each tributary where significant regression relationships were identified, monthly or seasonal scatter plots are provided in Appendix D.

3.1 LCR at Hunt to LCR at Woodruff

The uppermost reach of the LCR streamflow model is discussed in this section. The upstream extent of this reach begins at the LCR-HNT gage, which is downstream of the confluence of the Zuni River with the LCR. Within this reach only one main tributary, Silver Creek, enters the LCR.

3.1.1 LCR at Hunt

The LCR-HNT gage is the first point at which streamflow in the LCR is considered in the streamflow model (Section 4.1). Unsuccessful attempts were made to identify precipitation/runoff relationships for the Zuni River, which enters the LCR upstream of Hunt, and for the headwaters portion of the LCR in the vicinity of Springerville and areas farther upstream. Since the average volume of water passing the LCR-HNT gage is small compared to the average discharge at Cameron, it was determined that investigation of the portion of the LCR basin above the LCR-HNT gage was not a wise application of time and resources. The average monthly streamflow for the LCR-HNT gage for the period of record (1941 to 1972) is presented in Table 4.

3.1.2 Silver Creek

Silver Creek enters the LCR about 4 miles upstream of Woodruff; it is the only major tributary within the Hunt-to-Woodruff reach (Figure 1). Records are available for two gages on this tributary: SLV-WD and SLV-SF (Figure 2) for the periods 1930 to 1952 (partial) and 1951 to 1991, respectively. The SLV-SF gage was selected for analysis since it has the most complete record and is still operational. However, monthly streamflows for each gage were plotted against each other for the two years of overlap (1951 to 1952); the slope of the regression line was 1.04 with a correlation coefficient (R^2) of 0.99. It would seem, therefore, that discharges recorded at the SLV-SF gage are effectively transmitted to the SLV-WD gage.

The Silver Creek stacked-bar discharge plots (Appendix C) indicate that significant discharge can occur in Silver Creek in the winter, spring runoff, and monsoon seasons. Significant runoff generally occurs during the winter months of December through February if heavy rains occur. Spring runoff occurs primarily during March and sometimes April, whereas the May through June period is very dry. The monsoon season is characterized by relatively consistent runoff from year

Table 4. Average Monthly Discharge at LCR-HNT

Period	Average Monthly Flow (ac-ft)*
January	326.3
February	259.4
March	581.2
April	728.7
May	490.9
June	44.1
July	392.2
August	3,476.1
September	1,281.5
October	486.0
November	154.8
December	240.3

* Based on observed monthly values for 1941 to 1972.

to year, although the peak discharges recorded during this season are generally less than those recorded during the winter months.

Silver Creek discharge correlates best with the Snowflake and Chevelon ranger station precipitation gages (Figure 2). A summary of the developed regression relationships is presented in Table 5. Significant regression relationships were determined for the winter months, the primary spring runoff month of March, and the monsoon season. For the November through December and January through February periods, suitable regression relationships were obtained only when the monthly observations for both precipitation and discharge were summed. For the November through December period, 16 percent of the discharge occurs in November on average and the remaining 84 percent occurs in December. For the January through February period, 52 percent of the discharge occurs in January on average and 48 percent occurs in February.

Table 5. Silver Creek Discharge Regression Equations

Period	Regression Equation	R^2	Standard Error of Q	Mean Discharge (ac-ft)	Standard Deviation (ac-ft)	Number of Observations
Summed January-February	$Q = 9{,}709.8\ P_1 - 3{,}059.8$	0.71	5,387.1	1,585.0	4,532.0	13
March	$Q = 4{,}936.2\ P_2 - 1{,}955.1$	0.47	2,736.4	1,971.5	3,149.5	18
April	Random	NA	NA	648.15	1,997.6	41
May	Random	NA	NA	291.8	672.1	41
June	Random	NA	NA	238.2	326.8	41
July-October	$Q = 915.8\ P_3 - 606.0$	0.61	1,121.2	1,203.3	1,561.0	80
Summed November-December	$Q = 2{,}926\ P_4 - 4{,}783.2$	0.88	2,469.4	965.0	2,518.1	10

Q = SLV-SF discharge (ac-ft)
P_1 = Summed January-February precipitation at Snowflake corrected for snowfall (inches)
P_2 = Average March precipitation at Snowflake/Chevelon ranger station (inches)
P_3 = Average precipitation at Snowflake/Chevelon ranger station (inches)
P_4 = Summed November-December precipitation at Chevelon ranger station corrected for snowfall (inches)
NA = Not applicable

To obtain average monthly precipitation, the arithmetic average of the observed values for the two stations was computed. Precipitation corrected for snowfall was obtained by subtracting precipitation depths recorded during snowfall events from the monthly total.

3.2 LCR Below Woodruff to LCR at Joseph City

The reach between LCR-WD and LCR-JOE is a short but important reach in which the Rio Puerco enters the LCR. Leroux Wash also joins the LCR within this reach and is potentially a significant source of sediment to the LCR main-stem. The rainfall/runoff relationships identified for each of these tributaries are presented in Sections 3.2.1 and 3.2.2.

3.2.1 Rio Puerco

The Rio Puerco enters the LCR about 3 miles east (upstream) of Holbrook (Figure 1). Discharge measurements are not available for the Rio Puerco near its confluence with the LCR. A gage was operational on the Rio Puerco from 1940 through 1949 at Adamana, which is about 18 miles upstream of the confluence. Due to the limited duration of this gage record, as well as the fact that streamflows passing Adamana do not record the contribution of about 16 percent of the Rio Puerco drainage basin (Table 2), it was decided that the best approach would be to determine Rio Puerco discharge based upon the LCR-HOL and LCR-WD gages. These gages have coincident records for 1950 to 1973; therefore, the discharge of the Rio Puerco for this period was obtained by subtracting LCR-WD discharge from LCR-HOL discharge. Where the subtraction resulted in a negative number (i.e., the upstream streamflow was greater than the downstream streamflow), Rio Puerco discharge was set to zero.

Stacked-bar graphs of the Rio Puerco discharge thus obtained are presented in Appendix C. Significant discharge occurs sporadically during the winter months in the Rio Puerco. Very little streamflow occurs during the period from March through June. During the monsoon season, substantial quantities of water are produced.

Table 6 presents the precipitation/runoff relationships identified for the Rio Puerco. Significant relationships were found for the months of February and June through October. Rio Puerco discharge was found to be best correlated with the average precipitation observed at the Window Rock and Petrified Forest gages (Figure 2).

3.2.2 Leroux Wash

Leroux Wash enters the LCR about 2 miles downstream from Holbrook (Figure 1). Although a continuous stage recorder has never been installed on this tributary, a peak streamflow gage has been operational since 1980. Since the Leroux Wash drainage basin adjoins the Rio Puerco discharge basin and has a similar morphology, the Leroux Wash peak streamflows were compared against the Rio Puerco peak streamflows recorded at Adamana (RP-ADM on Figure 2) to determine if a scaling relationship based upon the areas of the two basins could be applied. The peak streamflows at Adamana were used because they were readily available and because they should be more accurate than peak streamflows determined by subtracting discharge at LCR-WD from the discharge at LCR-HOL.

Table 6. Rio Puerco Discharge Regression Equations

Period	Regression Equation	R^2	Standard Error of Q	Mean Discharge (ac-ft)	Standard Deviation (ac-ft)	Number of Observations
January	Random	NA	NA	3,001.5	7,842.5	16
February	Q = 4,314.9 P – 878.9	0.41	1,533.6	1,634.7	2,633.5	18
March	Random	NA	NA	3,348.7	11,232.5	20
April	Random	NA	NA	1,944.0	7,369.8	16
May	Random	NA	NA	385.4	1,385.2	17
June	Q = 1,970.9 P – 27.9	0.41	1,069.9	539.6	1,054.6	12
July	Q = 8,420.5 P – 5,674.2	0.44	7,474.4	6,647.8	9,051.7	18
August	Q = 28,476.5 P – 31,360.2	0.78	15,890.3	24,773.3	30,809.9	19
September	Q = 11,366.3 P + 166.3	0.54	9,949.8	10,603.5	13,034.0	18
October	Q = 7,907.7 P – 2,524.7	0.70	6,128.2	6,099.8	10,148.2	19
November	Random	NA	NA	934.4	1,486.4	20
December	Random	NA	NA	1,425.0	4,749.4	18

Q = Rio Puerco monthly discharge (ac-ft)
P = Average precipitation at Window Rock and Petrified Forest (inches)
NA = Not applicable

The comparison procedure is as follows. First, the logarithms of the peak streamflows recorded for the Rio Puerco at Adamana (10 values over the period from 1940 through 1949) and those recorded at Leroux Wash (12 values over the period from 1980 through 1991) were computed. Next, the mean and the standard deviation of the log-transformed peak streamflows were determined, and these values were used to estimate the 100-year peak streamflow using the following equations:

$$\log Q_{p100} = \mu_L + 2.33\,\sigma_L \quad (1)$$

$$Q_{p100} = 10^{(\log Q_{p100})} \quad (2)$$

where log = Logarithm to the base 10

Q_{p100} = Estimated 100-year peak streamflow

μ_L = Mean of the log-transformed peak streamflows

σ_L = Standard deviation of the log-transformed peak streamflows

Finally, the 100-year peak, the mean, the mean plus one standard deviation, and the mean minus one standard deviation peak streamflows were tabulated and divided by the area of their respective drainage basin. These results are presented in Table 7.

Table 7. Summary of Peak Discharge Comparison Calculations for the Rio Puerco and Leroux Wash

Discharge (cfs)	Rio Puerco		Leroux Wash		$\frac{Q_p/A_p}{Q_L/A_L}$
	Q_p	Q_p/A_p	Q_L	Q_L/A_L	
Q_{p100}	60,388	23.2	16,209	18.9	1.20
$10^{(\mu_L)}$	11,447	4.4	3,498	4.1	1.06
$10^{(\mu_L + \sigma_L)}$	23,371	9.0	6,755	7.9	1.12
$10^{(\mu_L - \sigma_L)}$	5,607	2.2	1,811	2.1	1.00

cfs = cubic feet per second
Q_p = Rio Puerco discharge (cfs)
A_p = Rio Puerco drainage basin area (mi²)
Q_L = Leroux Wash discharge (cfs)
A_L = Leroux Wash drainage basin area (mi²)

The values in the last column of Table 7 should be close to 1.0 if the basins have a hydrologic response proportional to their respective areas. As shown in Table 7, these ratios are all reasonably close to 1.0, and the average of the four ratios is 1.1. It seems appropriate, therefore, based upon this analysis and qualitative physical reasoning, that the hydrologic response of Leroux Wash may be estimated from that of the Rio Puerco through the use of area scaling.

Accordingly, discharge estimates for Leroux Wash were obtained based upon the precipitation/runoff relationships identified for the Rio Puerco (Table 6). However, rather than using the Window Rock and Petrified Forest precipitation gages identified in the Rio Puerco regressions, the Ganado gage was substituted since it is likely to be more indicative of precipitation that occurred in the Leroux Wash basin (Figure 2). Finally, monthly discharge estimates obtained in this manner were multiplied by a factor of 0.27, which is equal to the Leroux Wash basin area divided by the Rio Puerco basin area (Table 2).

3.3 LCR Below Joseph City to LCR at Grand Falls

The reach between LCR-JOE and LCR-GF is the longest reach within the LCR streamflow model. Five major tributaries—Chevelon Creek, Cottonwood Wash, Clear Creek, Corn Creek, and Canyon Diablo—enter the LCR within this reach. It is within this reach that large spring runoff contributions from Chevelon and Clear Creeks occur.

3.3.1 Chevelon Creek

Chevelon Creek enters the LCR from the south about 12 miles downstream of Joseph City, or about midway between Holbrook and Winslow (Figure 1). This tributary, along with Clear Creek (Section 3.3.3), is distinctly different from others in the LCR basin. For the majority of its length, Chevelon Creek discharge flows through an incised bedrock channel that drains the forested uplands of the Mogollon Rim. Although significant streamflows may occur in December, January, and February, the largest volumes of water are produced annually during the spring runoff season, primarily during March and April (Appendix C). Monsoon season streamflows are generally quite small (well below 5,000 acre-feet) on Chevelon Creek.

Table 8 presents the precipitation runoff relationships identified for Chevelon Creek. Significant regression relationships were found for Chevelon Creek discharge during the winter months of January, November, and December using the Chevelon ranger station (Figure 2) precipitation record. Note that the precipitation variable in the regression equations for the winter months is precipitation at Chevelon ranger station corrected for snowfall, which means that recorded daily precipitation attributable to snowfall was subtracted from the monthly totals for these months. This procedure was conducted to obtain an estimate of the rainfall that occurred during a given month. The months of November and December were summed for each year to obtain a regression relationship; on average, November accounts for 14 percent of the summed streamflow and December accounts for 86 percent of the summed streamflow.

Table 8. Chevelon Creek Discharge Regression Equations

Period	Regression Equation	R^2	Standard Error of Q	Mean Discharge (ac-ft)	Standard Deviation (ac-ft)	Number of Observations
January	$Q = 8{,}618.4\ P_1 + 1{,}503.6$	0.76	6,436.1	3,733	8,469	14
February	Random	NA	NA	3,657	4,960	45
March-May	$Q = 4{,}967.3\ P_2 - 7{,}356.7$	0.72	8,178.6	20,556	15,305	31
June	Random	NA	NA	299	187	46
July	Random	NA	NA	439	257	46
August	Random	NA	NA	1,180	1,974	46
September	Random	NA	NA	874	1,801	47
October	Random	NA	NA	823	2,311.4	48
November-December	$Q = 3{,}614.4\ P_3 - 1{,}149.4$	0.50	5,336.2	1,607	3,605	15

Q = Chevelon Creek discharge (ac-ft)
P_1 = Precipitation at Chevelon ranger station corrected for snowfall
P_2 = Summed November-February precipitation (not corrected for snowfall) at Chevelon ranger station
P_3 = Summed November-December precipitation at Chevelon ranger station corrected for snowfall
NA = Not applicable

The best relationships were obtained for the spring runoff season when the most significant discharge months (March, April, and May) were summed and were regressed against the summed preceding winter precipitation (November through February) at the Chevelon ranger station. It makes physical sense that the spring runoff from Chevelon Creek would be related to precipitation (snowfall) that occurred during the winter months. On average, 53 percent, 40 percent, and 7 percent of the total discharge observed for this three-month period occurs during March, April, and May, respectively.

3.3.2 Cottonwood Wash

Cottonwood Wash enters the LCR from the north side of the basin about 5 miles east of Winslow (Figure 1). No recorded discharge data are available for this tributary. In terms of the morphology of its drainage area, Cottonwood Wash is probably more similar to the Leroux Wash basin than it is to any other tributaries of the LCR. As discussed in Section 3.2.2, Leroux Wash discharge may be estimated based upon Rio Puerco relationships scaled by the ratio of the areas of the two drainages. By analogy, therefore, discharge was estimated for Cottonwood Wash based upon the Rio Puerco precipitation/runoff relationships, and the resulting values were multiplied (scaled) by a factor of 0.54, which is the ratio of the two drainage areas. As was done for Leroux Wash, the precipitation gage at Ganado (Figure 2) replaced the Window Rock and Petrified Forest gages in the equation.

3.3.3 Clear Creek

Clear Creek enters the LCR about 1 mile downstream from the confluence of the LCR and Cottonwood Wash (Figure 1). Clear Creek is very similar to Chevelon Creek in terms of its channel morphology and hydrologic response. The general overview provided for Chevelon Creek in Section 3.3.1 applies to Clear Creek as well.

The regression relationships identified for Clear Creek are presented in Table 9. On average, of the total March through May discharge, 39 percent, 52 percent and 9 percent is attributable to the months of March, April, and May, respectively. Of the summed November and December discharge, an average of 26 percent occurs in November and 74 percent occurs in December.

3.3.4 Corn Creek

Three of the main washes that occur on the Hopi Indian Reservation—Oraibi Wash, Polacca Wash, and Jeddito Wash—are Corn Creek tributaries (Figure 1). The channel of Corn Creek approaches the LCR about 5 miles east (upstream) of the town of Leupp. As detailed in Section 2.2.2, aerial photographs and field reconnaissance indicate that the channel of Corn Creek undergoes a transition into a broad alluvial plain covered with vegetation about 2 miles north of the LCR main-stem. Corn Creek discharges that do occur are generally insufficient in magnitude to reach the LCR. Accordingly, Corn Creek discharge to the LCR was considered to be zero.

Table 9. Clear Creek Discharge Regression Equations

Period	Regression Equation	R^2	Standard Error of Q	Mean Discharge (ac-ft)	Standard Deviation (ac-ft)	Number of Observations
January	$Q = 9,850.2\ P_1 + 1,462.5$	0.69	9,220.1	4,548	10,645	9
February	Random	NA	NA	4,411	8,867	32
March-May	$Q = 11,225.2\ P_2 - 23,197.0$	0.67	24,862.6	14,001	19,292	29
June	Random	NA	NA	130	285	32
July	Random	NA	NA	125	221	32
August	Random	NA	NA	946	2,783	32
September	Random	NA	NA	912	2,363	32
October	Random	NA	NA	1,069	3,916	32
November-December	$Q = 8,345.6\ P_3 - 6,475.1$	0.80	12,106.5	2,969	10,168	8

Q = Clear Creek discharge (ac-ft)
P_1 = Precipitation at Chevelon ranger station corrected for snowfall
P_2 = Summed November-February precipitation at Chevelon ranger station (not corrected for snowfall).
P_3 = Summed November-December precipitation at Chevelon ranger station corrected for snowfall
NA = Not applicable

3.3.5 Canyon Diablo

Canyon Diablo enters the LCR at Leupp. No discharge data are available for this tributary, and its physical characteristics are somewhat different from other tributaries in the LCR basin that have been gaged (Section 2). An initial estimate of discharge for Canyon Diablo was based upon an area scaling with Silver Creek, since Canyon Diablo does not produce the large volumes of water that Clear and Chevelon Creeks do. Further, since Canyon Diablo's drainage basin consists largely of volcanic rocks that lie at or near the surface, a large potential for high channel transmission losses exists, thus leading to relatively low discharges at the confluence of Canyon Diablo with the LCR. The Walnut Canyon gage was used for the precipitation input.

3.4 LCR Below Grand Falls to LCR at Cameron

Several estimation methods were used to develop precipitation/runoff relationships for tributaries within the reach between LCR-GF and LCR-CAM. Relationships were developed on the basis of geomorphological considerations and measured streamflow data. Measured streamflows indicate that the reach between LCR-GF and LCR-CAM gains slightly on average, and that the greatest increase in streamflow occurs during the summer monsoon season.

3.4.1 Dinnebito Wash

Dinnebito Wash enters the LCR from the north approximately 5 miles downstream of Grand Falls (Figure 1). No recorded discharge data are available for this tributary. In terms of channel morphology and hydrologic response, Dinnebito Wash is probably more similar to Moencopi Wash than to any of the other gaged tributaries. Discharge estimates for Dinnebito Wash were based upon an area-scaling with Moencopi Wash (Section 3.4.3).

3.4.2 Cedar Wash

Cedar Wash enters the LCR from the south approximately 2 miles west of Cameron (Figure 1). Again, no recorded discharge data are available for this tributary. In terms of drainage basin morphology, Cedar Wash is most like Canyon Diablo; like Canyon Diablo, the Cedar Wash drainage basin consists largely of volcanic rocks. Therefore, monthly relationships used at Canyon Diablo were area-scaled to generate Cedar Wash streamflows (Section 3.3.5). Data from the Walnut Canyon gage (Figure 2) were used for the precipitation input.

3.4.3 Moencopi Wash

Moencopi Wash enters the LCR from the north approximately 4 miles west of Cameron. Streamflow has been monitored on a long-term basis at three separate locations along Moencopi Wash (Figure 2). The MNCP-CAM gage was used for the development of precipitation/runoff relationships since it recorded streamflows closest to the LCR confluence and thus most likely represents streamflow inputs to the LCR.

Table 10 presents the precipitation/runoff relationships developed for Moencopi Wash. Significant monthly relationships were found for the months of January, March, and August through November. Moencopi Wash discharge was found to correlate best with the average precipitation observed at the Betatakin and Tuba City gages (Figure 2).

Table 10. Moencopi Wash Discharge Equations

Period	Regression Equation	R^2	Standard Error of Q	Mean Discharge (ac-ft)	Standard Deviation (ac-ft)	Number of Observations
January	Q = 115.9 P + 91.1	0.59	61.1	172.3	88.6	11
February	Random	NA	NA	165.7	135.9	9
March	Q = 521.9 P − 33.4	0.77	201.3	248.9	363.0	8
April	Random	NA	NA	35.0	42.1	8
May	Q = 49.3 P + 15.1	0.60	28.8	23.9	37.2	5
June	Random	NA	NA	213.7	569.8	7
July	Random	NA	NA	1,987.9	3,774.3	9
August	Q = 4,699.4 P − 1,381.4	0.69	1,576.1	4,189.2	3,879.5	9
September	Q = 1,372.0 P − 48.1	0.51	950.2	1,602.8	2,003.6	7
October	Q = 1,071.9 P + 6.9	0.68	591.1	904.0	1,274.8	8
November	Q = 769.1 P − 212.8	0.82	163.5	251.7	362.4	11
December	Random	NA	NA	113.9	63.0	11

Q = Moencopi Wash discharge (ac-ft)
P = Average precipitation at Betatakin and Tuba City (inches)
NA = Not applicable

4. LCR BASIN STREAMFLOW AND TRANSPORT MODELS

Based on information discussed in Sections 2 and 3, DBS&A developed a streamflow model for the LCR basin and a sediment transport model for selected portions of the LCR basin. The purpose of each model is not to exactly match observed streamflows or suspended sediment loads for a given historical month, but rather to mimic the flow and transport characteristics of the LCR over the long term. Simulated streamflows obtained from the streamflow model were used as input to the sediment transport model. Sections 4.1 and 4.2 describe the streamflow model and the sediment transport model, respectively.

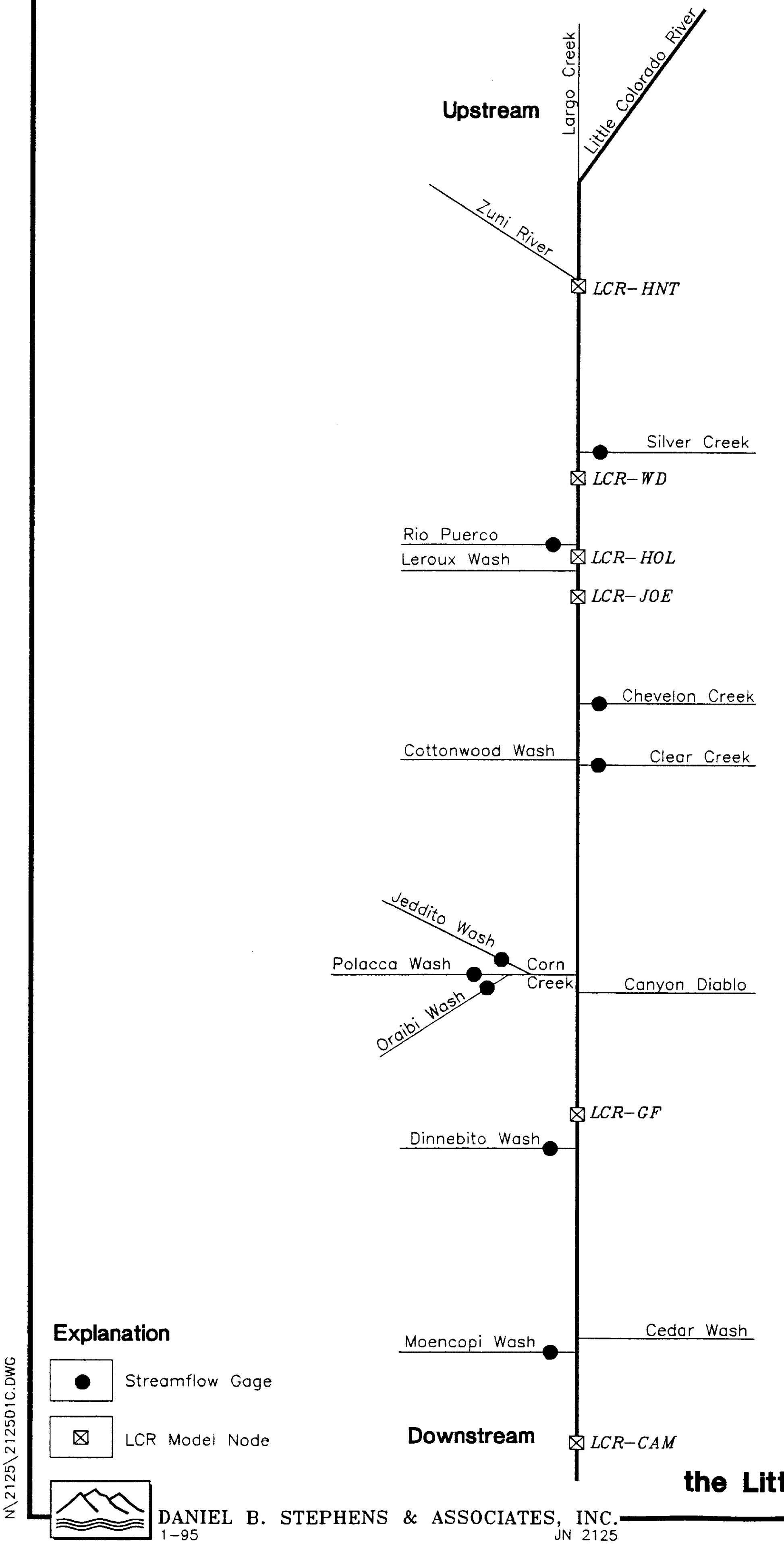
4.1 LCR Streamflow Model

Based upon the empirical relationships presented in Section 3, a streamflow model was constructed for the LCR. The uppermost node, or point of computation, for the model is the LCR at Hunt below the Zuni River (LCR-HNT), while the lowermost node is the LCR at Cameron (LCR-CAM). The streamflow model is constructed on a monthly basis for the period from 1940 to 1990 (calendar years).

4.1.1 Streamflow Model Conceptualization

The streamflow model developed for the LCR between Hunt and Cameron is a cascade-type empirical model where streamflows are determined at an upstream node first and are then routed to the adjoining downstream node based on transfer functions. The transfer functions are themselves functions of streamflow at the upstream node and tributary inflows within the reach of concern (Section 3.4). A reach is the section of the LCR main-stem between two model nodes. A schematic diagram of the LCR and its major tributaries is presented in Figure 5.

Monthly tributary discharges are based on the regression relationships presented in Section 3. The precipitation gages used in the regression relationships are shown in Figure 2. Where monthly or seasonal regression relationships could not be determined for a certain month for a given tributary, the tributary discharge for that month was randomly generated from an assumed normal distribution with a mean and standard deviation as documented in Section 3. For example, the May discharge for Silver Creek for any given year was obtained by drawing a



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Modeling Schematic for the Little Colorado River Basin

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Figure 5

random sample from a normal distribution with a mean of 291.8 acre-feet and a standard deviation of 672.1 acre-feet (Table 5).

Each of the regression relationships developed for use in the streamflow model have an R^2, or goodness of fit, and standard deviation parameter associated with them. Higher R^2 values and lower standard deviation values indicate that the fitted linear regression model is capable of explaining more of the variation in the observed data. For lower R^2 values and higher standard deviation values, the opposite is true. The unexplained variance in the observed data is addressed using a stochastic approach. This approach is designed to account for the observation that a certain degree of randomness is typical of hydrologic events in the LCR basin.

A stochastic (random) component was incorporated in the LCR streamflow model by the addition of a stochastic term to each regression equation. The stochastic term is directly related to the error inherent in an individual regression equation and takes the following form:

$$\varepsilon = t\sigma_e\sqrt{1-R^2} \tag{7}$$

where ε = Stochastic error term

t = Random normal deviate (a random sample from a normal probability distribution with a mean of 0.0 and a standard deviation of 1.0)

σ_e = Standard deviation of the error of the regression

R^2 = Correlation coefficient of the regression

Note that ε can be positive or negative (depending on t), and the magnitude of the error term increases with greater standard deviations and smaller correlation coefficients. The random normal deviate, *t*, is generated using

$$t = \left(\sum_{i=1}^{12} U\right) - 6 \tag{8}$$

where U = Uniform random number from the interval 0.0 to 1.0

An example of the stochastic simulation procedure based on the July Rio Puerco regression equation (Table 6) is outlined below:

$$Q = \underbrace{8420.5P - 5674.2}_{\text{deterministic component}} + \underbrace{t(7474.4)\sqrt{1 - 0.44}}_{\text{stochastic component}}$$

where Q = July Rio Puerco discharge (acre-feet)
P = Average precipitation at Window Rock and Petrified Forest (inches)
t = Random normal deviate (as defined above)

The simulated discharge, therefore, is a function of the observed precipitation at the appropriate rain gages and the stochastic error term. Each time a July discharge value for the Rio Puerco is simulated, a different value of *t* is applied.

Finally, the approach outlined above to generate a random normal deviate was also applied to simulate discharge values during months for which significant regression relationships could not be identified. Discharges for these months were determined as follows:

$$Q_M = \sigma_q t + \mu_q$$

where Q_M = Tributary discharge for a month M where a regression relationship was not identified
σ_q = Standard deviation of the observed discharge values for month M
μ_q = Mean of the observed discharge values for month M

The required means and standard deviations are tabulated in Tables 5, 6, 8, 9, and 10. Where negative discharges were simulated due to the stochastic component or due to negative *y* intercepts in a regression equation, the discharge was set to zero in the model.

4.1.2 Streamflow Model Structure

The streamflow model structure is represented schematically in Figure 5. The streamflows at the model nodes indicated in that figure are solved consecutively for each month of each simulation year. For example, a simulation begins with a prescribed input (discharge) for the LCR-HNT node. Next, the discharge at LCR-HNT is used in conjunction with simulated discharge for Silver Creek in a routing equation (regression) to determine LCR discharge at the LCR-WD node. Discharge is then simulated for the LCR-HOL node using simulated Rio Puerco and LCR-WD discharge, and this process continues until the final LCR-CAM node is reached. The model simulation period consists of 51 calendar years, beginning in 1940 and ending in 1990.

The LCR streamflow model was developed in spreadsheet form using Quattro® Pro software. The model consists of three main spreadsheets and two supporting spreadsheets. The model is divided among the main spreadsheets into three portions: from LCR-HNT to LCR-JOE, below LCR-JOE to LCR-GF, and below LCR-GF to LCR-CAM. The two supporting spreadsheets contain the precipitation data for the precipitation gages used in the model and the random normal deviates (*t*'s) used in the stochastic portion of the regression equations.

4.1.3 Transfer Functions

Transfer functions (regression equations) were developed to route water from upstream to downstream nodes for two reaches of the LCR streamflow model: from LCR-HNT to LCR-WD and from LCR-JOE to LCR-GF (Figure 5). The transfer functions are functions of the inflow at the upstream node and tributary inflows within a given reach. In some cases the statistical correlation between inflow for a given tributary and streamflow at the downstream node is insignificant, and that tributary therefore is not used in the routing equations. The transfer functions were developed based upon observed or estimated discharge for the period from 1950 through 1973, since during this period observed discharge data at Holbrook, and data for most other key stations, are available.

4.1.3.1 LCR-HNT to LCR-WD. The monthly transfer functions developed for the LCR-HNT to LCR-WD reach are presented in Table 11. Estimated discharge at LCR-WD is a function of discharge at LCR-HNT (upstream node) and the discharge of Silver Creek, which is the only major tributary in this reach. The transfer functions for this reach, therefore, take the general form:

$$Q_{WD} = a + b_1 Q_{HNT} + b_2 Q_{SLV}$$

where Q_{WD} = Monthly discharge at LCR-WD (ac-ft)

Q_{HNT} = Monthly discharge at LCR-HNT (ac-ft)
Q_{SLV} = Monthly discharge at SLV-SF (ac-ft)
a, b_1, b_2 = Multiple regression constants

Table 11. Transfer Functions for LCR-HNT to LCR-WD Reach

Period	Regression Equation Constants[1]			R^2	Number of Observations
	a	b_1	b_2		
January	142.00	1.76	1.05	0.99	22
February	56.68	2.06	1.07	0.98	22
March	164.04	1.90	0.96	0.97	22
April	78.66	0.62	1.62	0.91	22
May	36.53	1.17	1.14	0.61	22
June	-334.60	7.15	2.51	0.75	22
July	267.75	2.39	1.89	0.88	22
August	693.33	1.25	2.55	0.94	22
September	1,420.22	0.98	1.20	0.86	22
October	-170.83	0.00	3.41	0.91	22
November	151.08	1.13	1.45	0.95	22
December	105.02	1.95	0.87	0.98	22

[1] Regression constants used in the monthly transfer function calculations: $Q_{WD} = a + b_1 Q_{HNT} + b_2 Q_{SLV}$

4.1.3.2 LCR-WD to LCR-JOE. Transfer functions were not developed for the LCR-WD to LCR-JOE reach because (1) this reach is relatively short, (2) inflows to this reach are highly variable due to Rio Puerco and Leroux Wash discharge, and (3) Rio Puerco streamflows were estimated using the LCR at Holbrook and LCR at Woodruff records. Rather, the discharge at Joseph City (LCR-JOE) was computed in the model as the discharge at LCR-WD plus the simulated discharge for the Rio Puerco and Leroux Wash.

4.1.3.3 LCR-JOE to LCR-GF. Discharge at LCR-GF is a function of the upstream tributary inputs and accordingly can be estimated using the following water balance:

$$\text{LCR-GF} = (\text{LCR-HOL} + \text{CHVLN} + \text{CLR})$$

On average, the measured streamflows used in this water balance resulted in an annual estimated water loss of approximately 19,000 ac-ft without incorporating unmeasured streamflows originating from Leroux Wash, Cottonwood Wash, Corn Creek, and Canyon Diablo (DBS&A, 1994). The water loss through this reach is the result of relatively flat, sandy channels that encourage transmission losses and high evaporation rates.

Monthly transfer functions were developed to route simulated streamflows from LCR-JOE and the major tributaries to the LCR-GF gage (Table 12). Monthly statistical correlations were determined using each node as a separate variable in a multiple linear regression equation. Nodal points that were insignificant in the equation were removed from the final regression equations. Four general regression equations of the following form were developed:

$$Q_{GF} = a + b_1 Q_{JOE} + b_2 Q_{SOUTH}$$
$$Q_{GF} = a + b_1 Q_{COT} + b_2 Q_{SOUTH}$$
$$Q_{GF} = a + b_1 Q_{JOE}$$
$$Q_{GF} = a + b_1 Q_{SOUTH}$$

where Q_{JOE} = Monthly discharge at LCR-JOE (ac-ft)

Q_{SOUTH} = The sum of monthly discharges from Chevelon Creek, Clear Creek, and Canyon Diablo (ac-ft)

Q_{COT} = Monthly discharge from Cottonwood Wash (ac-ft)

4.1.3.4 LCR-GF to LCR-CAM. Due to the lack of measured data for tributary streamflows, no attempt was made to develop monthly routing equations for this reach. Rather, simulated streamflows from each of the three tributaries were added to the streamflows simulated at LCR-GF to obtain discharge at LCR-CAM.

4.1.4 Simulation Results

The streamflow simulation results presented in this section are for a single model run (or realization). In other words, the stochastic component of simulated discharge was only generated one time. The monthly simulated and observed streamflows for the model run presented herein are provided in Appendix E.

Table 12. Transfer Functions for LCR-JOE to LCR-GF Reach

Period	Regression Equation Constants[1]			R^2	Number of Observations
	a	b_1	b_2		
January[2]	438.7	0.02	1.02	0.93	22
February[2]	-799.8	0.85	1.01	0.94	22
March[3]	-4,131.4	2.19	1.02	0.97	22
April[2]	-3,341.6	0.57	1.10	0.99	22
May[2]	-1,478.1	1.28	1.07	0.96	22
June[4]	-809.2	1.49	NA	0.87	23
July[4]	-724.0	0.56	NA	0.77	23
August[2]	-1,295.5	0.44	1.63	0.83	23
September[3]	3,933.4	0.96	0.78	0.63	23
October[2]	-14.0	0.11	2.04	0.94	22
November[2]	-2,240.7	1.03	1.44	0.87	22
December[5]	159.01	0.51	NA	0.84	22

[1] Regression constants used in the monthly transfer calculations
[2] Regression equation: $Q_{GF} = a + b_1Q_{JOE} + b_2Q_{SOUTH}$
[3] Regression equation: $Q_{GF} = a + b_1Q_{COT} + b_2Q_{SOUTH}$
[4] Regression equation: $Q_{GF} = a + b_1Q_{JOE}$
[5] Regression equation: $Q_{GF} = a + b_1Q_{SOUTH}$

NA = Not applicable

The streamflow model simulation results were compared against observed data at three key model nodes (stations): LCR-HOL, LCR-GF, and LCR-CAM. The average annual discharge, the standard deviation of average annual discharge, the average monthly peak for each year, and the standard deviation of the average annual peak streamflow were selected as comparison statistics. At LCR-HOL, the gage record for October 1949 to June 1972 was used for the comparison with simulation results. At LCR-GF and LCR-CAM, the reconstructed record for 1940 to 1990 (DBS&A, 1994), which includes observed data where available, was used to compare the simulation results. To obtain the simulation results presented in this section, the initial simulated discharge for Canyon Diablo was reduced by 50 percent.

The comparison statistics are presented in Table 13. At LCR-HOL, the average annual simulated discharge is 32 percent higher than the observed average annual discharge. The overprediction occurs primarily as a result of higher than observed simulated discharge during the winter months. The average of the peak monthly simulated streamflows at Holbrook is 7 percent higher than the observed average, which is a good match.

At LCR-GF, the simulated average annual discharge is 17 percent higher than the reconstructed (observed) average annual discharge, but the average simulated peak monthly discharge is 28 percent lower than the observed average. The standard deviations of the simulated streamflows (annual and monthly peak) are also lower than those of the reconstructed data. These results indicate that the simulated average annual discharge at LCR-GF is in reasonable agreement with the reconstructed data set, although the simulated discharges are not as variable as those observed in the field. This result is not surprising, since it is often very difficult to simulate the extreme events that occur in natural systems.

The simulation results for LCR-CAM are similar to those obtained for LCR-GF. At LCR-CAM, the average annual simulated discharge is 26 percent higher than the annual average of the reconstructed (observed) data, and the average simulated peak monthly discharge is 29 percent lower than the observed average. The standard deviations of the simulated streamflows (annual and monthly peak) are significantly lower than those of the observed data.

The bottom two sections of Table 13 present the simulated and observed increases in discharge between the LCR-HOL and LCR-GF and between the LCR-GF and LCR-CAM stations. These data are presented to illustrate the point that, when examined as a percentage of total streamflow at a downstream gage, the simulated increase in discharge between gages on the LCR main-stem are reasonable. It would seem that the overestimation of average discharge at Grand Falls and Cameron is due, at least in part, to the overestimation of discharge at Holbrook.

Time series of the simulated and observed discharge for LCR-HOL, LCR-GF, and LCR-CAM are presented in Figures 6, 7, and 8 respectively. These plots indicate that the simulation results mimic the natural behavior of the LCR streamflow system relatively well, although the extreme discharge events tend to be underestimated, and periods of observed no-flow or very small flow tend to be overestimated.

Table 13. Summary Statistics of Simulated and Observed Discharge for the LCR at Holbrook, Grand Falls, and Cameron

Type of Discharge	Average Annual Discharge (ac-ft)	Standard Deviation (ac-ft)	Average Peak Monthly Discharge (ac-ft)	Standard Deviation (ac-ft)
LCR at Holbrook				
Observed	90,376.6	56,979.5	45,829.7	33,140.9
Simulated	119,254.1	67,246.1	49,074.0	55,887.4
Percent difference	32	NA	7	NA
LCR at Grand Falls				
Observed	163,024.8	116,323.7	65,077.0	47,325.0
Simulated	191,054.6	57,747.9	46,573.0	19,396.9
Percent difference	17	NA	-28	NA
LCR at Cameron				
Observed	173,166.1	118,758.3	69,499.5	50,942.5
Simulated	217,848.4	62,893.0	53,076.4	19,822.0
Percent difference	26	NA	-24	NA
Increase from Holbrook to Grand Falls				
Observed	61,948.0	NA	11,950.2	NA
Simulated	71,800.6	NA	-2,501.0	NA
Percent difference[1]	6	NA	-9	NA
Increase from Grand Falls to Cameron				
Observed	10,141.3	NA	4,422.5	NA
Simulated	26,793.7	NA	6,503.4	NA
Percent difference[1]	10	NA	1	NA

[1] As a percentage of observed average annual discharge at the downstream gage

NA = Not applicable

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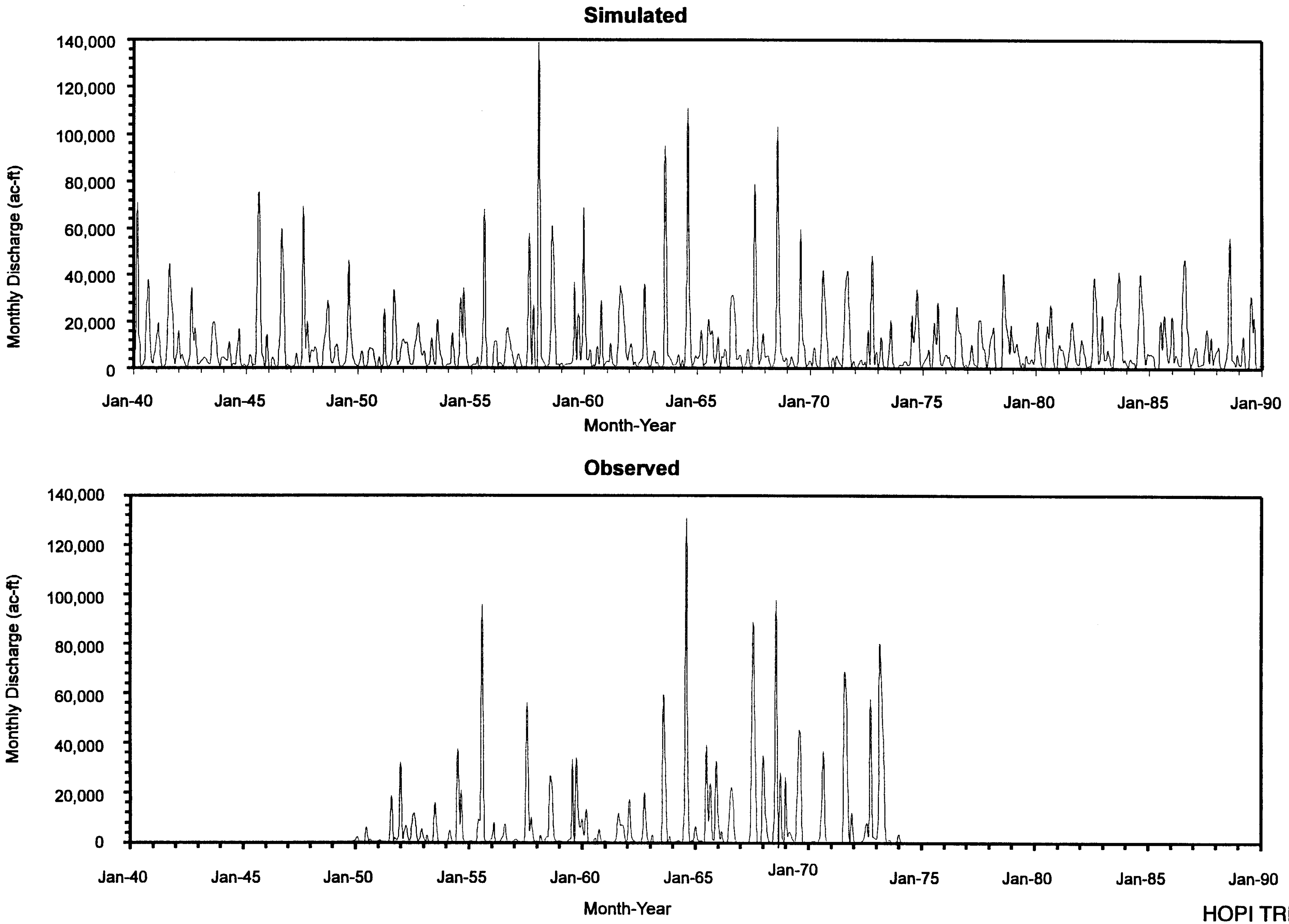

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LCR at Holbrook Monthly Discharge

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Figure 6

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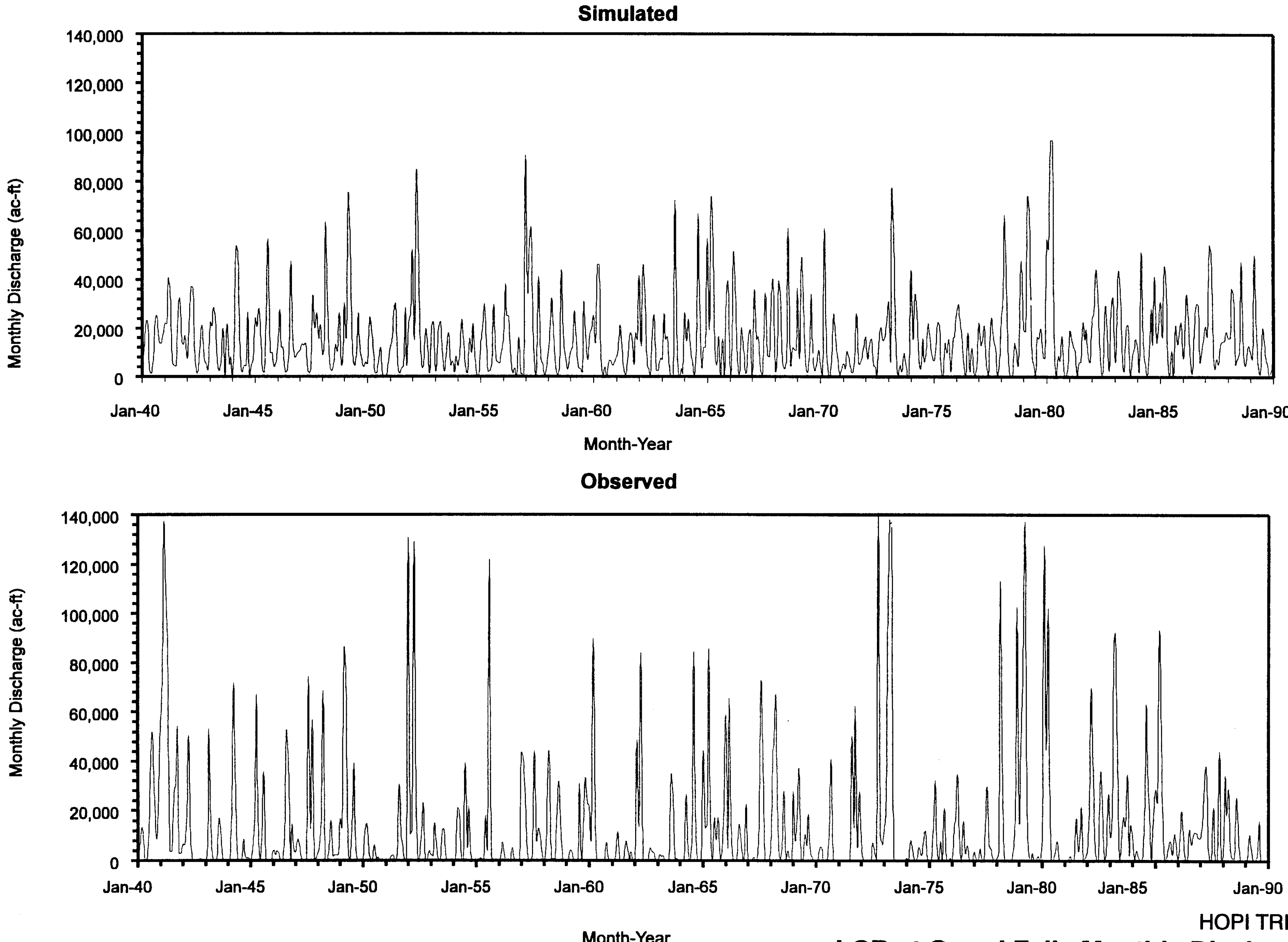

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LCR at Grand Falls Monthly Discharge

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Figure 7

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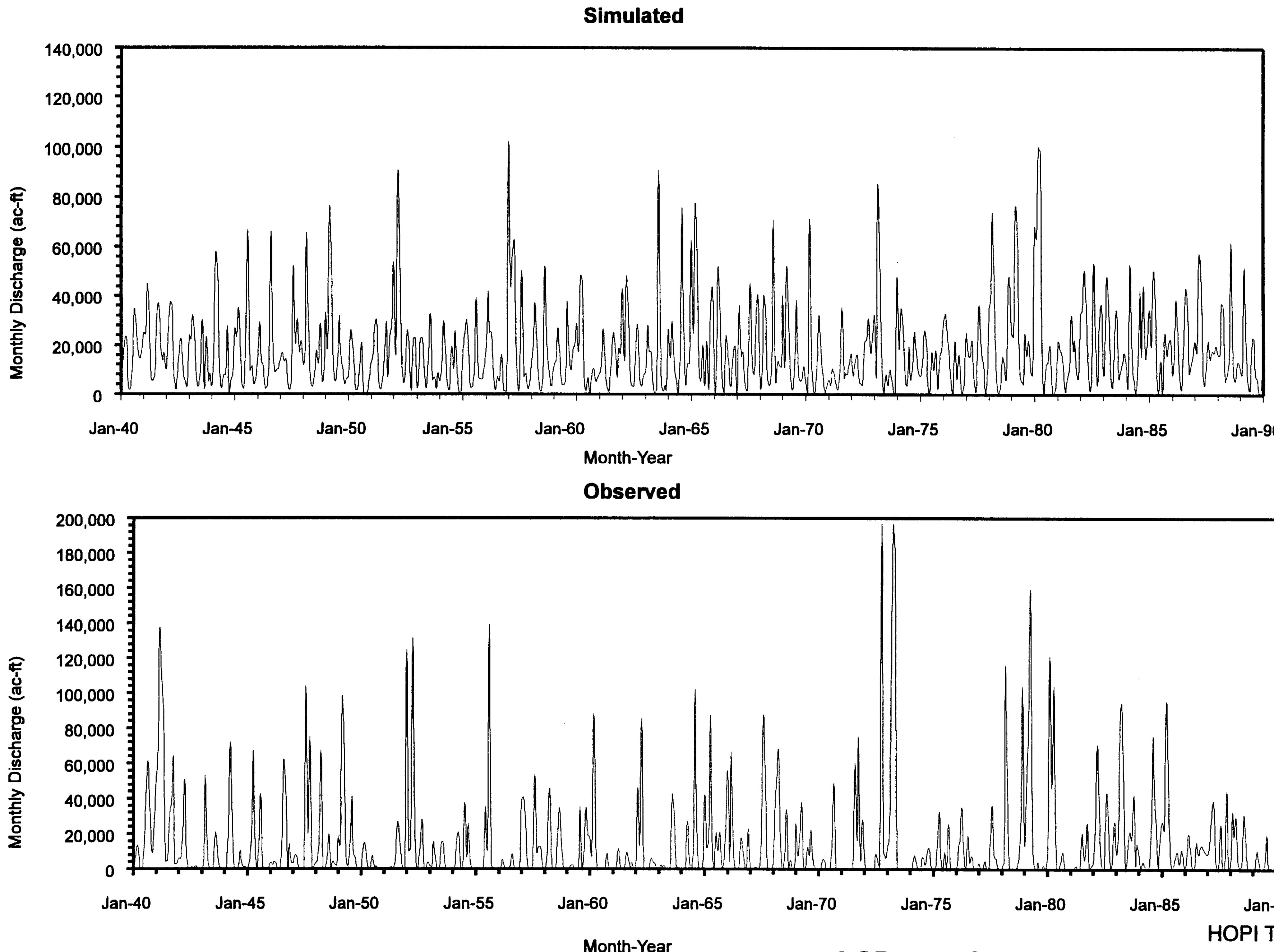

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LCR near Cameron Monthly Discharge

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Figure 8

4.2 Sediment Transport Model

The simulation results obtained from the streamflow model described in Section 4.1 were used as input to a monthly sediment transport model developed for selected nodal points. To date, simulated monthly sediment yields have been produced for LCR-GF, Dinnebito Wash, Cedar Wash, Moencopi Wash, and LCR-CAM. In addition, an event-driven model was developed for the Rio Puerco in order to evaluate sediment contributions and concentrations for a range of streamflow events.

4.2.1 Sediment Model Conceptualization

For the dry washes, the maximum 3-day discharge events contribute the majority of the measured monthly discharge and, consequently, the majority of the sediment yield for each respective tributary. Since the Rio Puerco exhibits significant controls over the discharge and sediment loads transported through the LCR main-stem, an event-driven model was developed for the Rio Puerco watershed. The runoff and sediment yield computer program called ARMSED, developed by the U.S Army Corps of Engineers for semi-arid, event-driven systems, was used to estimate streamflow and sediment yields from specific storms. ARMSED characterizes each runoff event with a set of mathematical equations that approximate physical processes such as infiltration, runoff, erosion, and sediment transport. Preliminary model runs confirmed that short duration runoff events can produce the majority of the monthly sediment load delivered from a tributary to the main-stem.

In order to develop relationships between mean daily discharge (in cubic feet per second [cfs]) and sediment loads, the USGS data set from the Rio Puerco study (Graf et al., 1993) was evaluated for correlations between mean daily discharge and sediment load. Measured data from the Rio Puerco at Chambers (RP-CHM), LCR-WD, LCR-JOE, LCR-GF, and LCR-CAM were plotted, and regression models of discharge versus sediment transport were developed. Statistical correlation did not improve significantly by performing log transformations of the data set. Linear relationships suggest that sediment concentrations are relatively constant for the ranges of stream discharge and suspended sediment measured.

Since discharge and sediment loads appear to be linearly correlated (DBS&A, 1994), monthly simulated streamflow volumes obtained from the LCR streamflow model were used as input to a sediment transport model. Monthly sediment loads were generated following the general procedure outlined below:

1. Divide the monthly total discharge by 30 days to determine mean daily discharge.

2. Calculate the daily sediment load transported through a given node using the appropriate mathematical equations and input parameters for that node, as described in Section 4.2.2.

3. Multiply the simulated daily sediment loads by 30 days to determine monthly sediment loads.

4.2.2 Sediment Transport Model Structure

The sediment transport routines within the ARMSED computer code were modified to accept monthly discharge, channel geometric parameters, grain-size distributions, and erosion and transport parameters directly from the user and to provide monthly sediment load output for the nodal point of interest. Mathematical equations developed by Einstein and by Meyer-Peter and Muller are used to approximate sediment transport (Riggins et al., 1989a, 1989b).

The program was constructed to read two input files, which contain information for a maximum of 15 stations. The first input file contains the physical and model-related input parameters for each station (e.g., channel slope, particle size distribution, etc.), and the second input file contains the monthly discharge values for each station. Model output is run through a postprocessor which provides sediment load distributions based on grain-size and average monthly sediment load, average monthly discharge, and suspended sediment concentration for the period of interest. The sediment transport routines extracted from the ARMSED code and subsequently modified were linked in a computer code called LCRTRAN.FOR. Both LCRTRAN.FOR and the postprocessor, POST.FOR, are written in the FORTRAN 77 programming language.

The channel geometric parameters were determined from regression relationships developed for discharge and cross-sectional area (A), discharge and average channel width (W), and discharge and average channel depth. Linear and log-log relationships were generated for each of these relationships. Log-log relationships consistently provided the best correlation between the variables of interest (Table 14). Graphical plots of discharge versus cross-sectional area for selected stations are provided in Appendix F.

Ten grain-size distribution intervals were input for each nodal point using the distribution determined from sieved bed material samples and USGS wash load data measured during the USGS Rio Puerco study (Graf et al., 1993). Each grain-size division is based upon 10 percent of the sediment (by weight) being contained within the designated grain-size interval. The sediment loads were lumped in the following classes for purposes of calibration: coarse load (percentage of sediment greater than 0.125 mm), suspended load (percentage of sediment between 0.125 and 0.002 mm), and wash load (percentage of sediment less than 0.002 mm).

4.2.3 Simulation Results

The final input parameters for the LCR sediment transport model are provided in Table 15. Although up to 15 stations, or points at which sediment transport is simulated, can be entered into the model at once, the sediment transport at each station is simulated independently within the model. In the LCR sediment transport model, 5 stations (2 along the LCR main-stem and 3 on tributaries) were initially considered: LCR-GF, Dinnebito Wash, Cedar Wash, Moencopi Wash, and LCR-CAM.

In order to calibrate the sediment transport model, the input grain-size distribution was first developed for each station based on the values presented in Table 3. Along the LCR main-stem and the Rio Puerco, the sampled grain-size distributions are very similar. The geometric mean of the observed grain sizes, therefore, for the Rio Puerco at Navajo, the LCR at Holbrook, the LCR above Grand Falls, and the LCR above Cameron were computed and used as model input for the LCR-GF and LCR-CAM stations. Based upon USGS suspended sediment concentration data for Grand Falls and Cameron, a minimum grain size of 0.002 mm was selected (the USGS data indicate that, on the main-stem, about 55 percent of the suspended sediment has a grain size less than 0.002 mm). This portion of the suspended sediment is called wash load. The grain size for percentage intervals not tabulated in Table 3 was obtained through linear interpolation of the tabulated values. A maximum grain size of 0.5 mm was selected based on the sieve analyses results presented in Appendix A.

Table 14. Channel Cross-Sectional Relationships for Selected Gages

USGS Gaging Station	Regression Evaluation[1]	R^2	Number of Observations
Silver Creek near Snowflake	log (A) = 0.35 + 0.72 log (Q)	0.99	4
	log (W) = 0.94 + 0.26 log (Q)	0.95	4
	log (D) = -0.57 + 0.47 log (Q)	1.00	4
LCR at Woodruff	log (A) = 0.35 + 0.68 log (Q)	0.98	17
	log (W) = 1.10 + 0.23 log (Q)	0.93	17
	log (D) = -0.62 + 0.41 log (Q)	0.94	17
LCR near Joseph City	log (A) = 0.66 + 0.58 log (Q)	0.98	18
	log (W) = 1.33 + 0.28 log (Q)	0.75	18
	log (D) = -0.52 + 0.26 log (Q)	0.80	18
LCR at Grand Falls	log (A) = 0.69 + 0.58 log (Q)	0.91	9
	log (W) = 1.02 + 0.33 log (Q)	0.87	9
	log (D) = 0.28 + 0.25 log (Q)	0.90	9
Moencopi Wash at Moencopi	log (A) = 0.18 + 0.69 log (Q)	0.98	13
	log (W) = 0.84 + 0.37 log (Q)	0.93	13
	log (D) = -0.52 + 0.26 log (Q)	0.91	13
LCR near Cameron	log (A) = 0.46 + 0.66 log (Q)	0.97	18
	log (W) = 0.91 + 0.37 log (Q)	0.86	18
	log (D) = -0.41 + 0.29 log (Q)	0.89	18

[1] Regression equation variables: A = Channel cross-sectional area (square feet)
W = Channel width (ft)
D = Channel depth (ft)
Q = Discharge (cubic feet per second)

Table 15. Sediment Transport Model Input Parameters

Model Input Parameter	LCR-GF	Dinnebito Wash	Cedar Creek	Moencopi Wash	LCR-CAM
Detachment coefficient	1.0	1.0	1.0	1.0	1.0
DELTS	0.03	0.03	0.03	0.03	0.03
AGB regression coefficient	7.5	13.5	13.5	13.5	10.3
Wash load sediment concentration	24.7	90.0	6.6	162.0	35.4
Channel slope	0.0007	0.0031	0.0231	0.0031	0.0012
Regression line intercept[1]	0.69	0.18	0.35	0.18	0.46
Regression line slope[1]	0.58	0.69	0.72	0.69	0.66
Regression line intercept[2]	−0.28	−0.52	−0.57	−0.52	−0.41
Regression line slope[2]	0.25	0.26	0.47	0.26	0.29
Grain-size distribution (mm)[3]: D_0	0.002	0.002	0.002	0.002	0.002
D_{10}	0.00256	0.00256	0.06	0.00256	0.00256
D_{20}	0.00412	0.00412	0.085	0.00412	0.00412
D_{30}	0.09	0.09	0.11	0.09	0.09
D_{40}	0.1125	0.1125	0.13	0.1125	0.1125
D_{50}	0.135	0.135	0.15	0.135	0.135
D_{60}	0.17225	0.17225	0.2175	0.17225	0.17225
D_{70}	0.2095	0.2095	0.285	0.2095	0.2095
D_{80}	0.24675	0.24675	0.3525	0.24675	0.24675
D_{90}	0.284	0.284	0.42	0.284	0.284
D_{100}	0.50	0.50	0.50	0.50	0.50

[1] Regression of log-discharge (cfs) versus log-cross-sectional area (ft^2)
[2] Regression of log-discharge (cfs) versus log-flow depth (ft)
[3] Subscripted number (e.g., in D_{10}) refers to the percentage of sediment that is less than or equal to the indicated grain diameter

DELTS = Shield's dimensionless critical shear stress (model results are not sensitive to this parameter)
AGB = Empirical regression coefficient in Meyer-Peter and Muller sediment transport equation

The input grain-size distributions listed in Table 15 are divided into 10 percent intervals by weight. For example, for LCR-GF, 10 percent of the sediment is prescribed to have a grain size greater than 0.002 mm but less than 0.00256 mm (the D_0 to D_{10} interval), the next 10 percent of the sediment has a grain size greater than 0.00256 mm but less than 0.00412 mm (the D_{10} to D_{20} interval), and so on for the remaining intervals. The input grain-size distributions are indicative of the sediment found in the channel only.

Once the grain-size distributions for the main-stem stations (LCR-GF and LCR-CAM) were decided upon, the model was run iteratively in an attempt to match observed and reconstructed suspended load sediment concentrations at LCR-GF and LCR-CAM. The periods for which observed suspended sediment loads are available are provided in Figure 4. The methods used to reconstruct suspended sediment loads for the LCR-GF and LCR-CAM gages is documented in DBS&A's previous progress report (1994). For simplicity, the terms "observed sediment concentration" or "load" as used in the remainder of this section refer to both the observed and reconstructed sediment transport records.

The observed sediment concentrations were matched primarily through adjustment of the AGB model input parameter, which is a regression coefficient in the Meyer-Peter and Muller sediment transport equations. During the calibration process, it was assumed (based on the USGS data) that 55 percent of the total suspended load was wash load. Wash load is not simulated explicitly in the model since this sediment is not derived solely from the stream channel. Therefore, the suspended sediment simulated by the model, which is that portion of the sediment load between 0.002 mm and 0.125 mm, was divided by a factor of 0.45 (i.e., 1.0 – 0.55) to obtain an estimate of the wash load sediment mass. The estimated wash load was then added to the suspended load simulated by the model to obtain the total suspended sediment load.

The model simulation results are summarized in Table 16, and time series plots of the simulated and observed suspended sediment at LCR-GF and LCR-CAM are presented in Figures 9 and 10, respectively. The simulated and observed monthly sediment discharges for LCR-GF and LCR-CAM are provided in Appendix E. As indicated in Table 16, the simulated and observed suspended sediment concentrations match very well. Once an average wash load sediment concentration was determined through model calibration, that concentration was prescribed as a model input so that predictive simulations could be conducted in the future.

Table 16. Summary of Sediment Transport Modeling Results

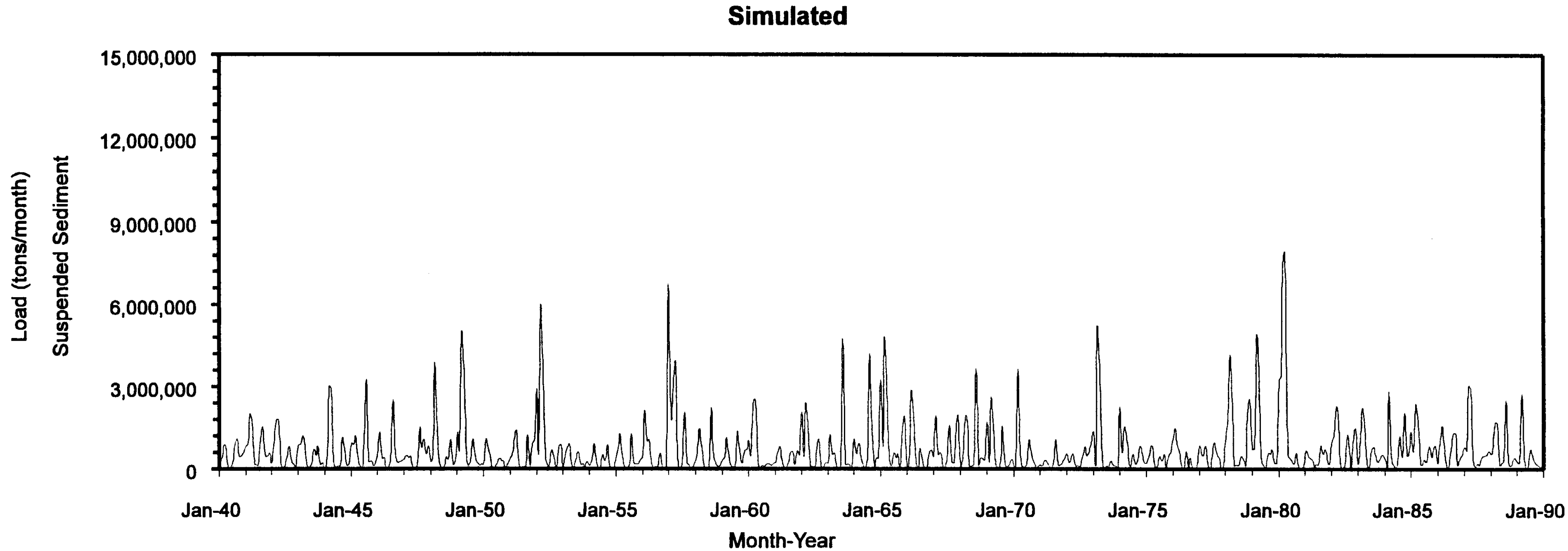
Station/Tributary	Simulation Results				Observed Suspended Sediment Concentration (tons/ac-ft)
	Average Suspended Sediment Load (tons/month)	Average Bed Load Sediment (tons/month)	Average Discharge (ac-ft/month)	Average Suspended Sediment Concentration (tons/ac-ft)	
LCR-GF	718,224	7,838	15,921	45	44.5
Dinnebito Wash	60,794	587	585	104	NA
Cedar Wash	7,339	298	736	10	NA
Moencopi Wash	177,207	1,856	912	194	185.7
LCR-CAM	1,160,380	22,383	18,154	64	64.7

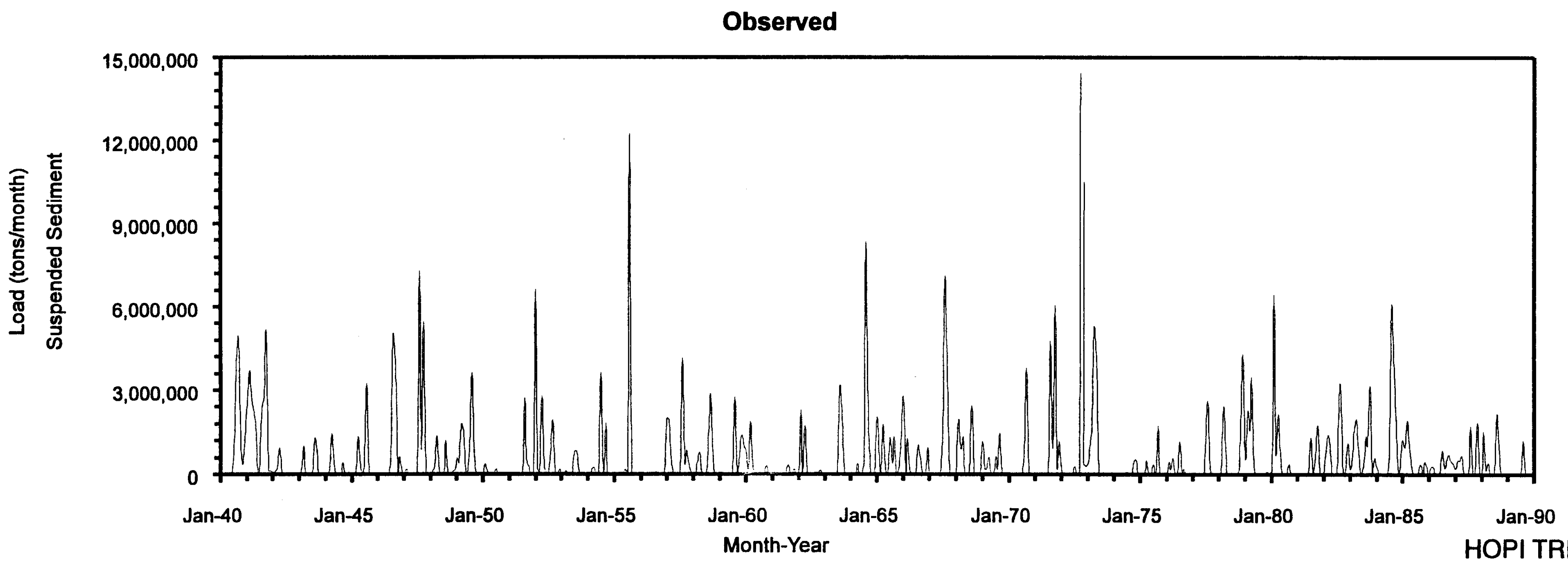
NA = Not available

Once the sediment transport model was calibrated for the two LCR main-stem stations, sediment transport was simulated for three tributary stations within the LCR-GF to LCR-CAM reach. Of these tributaries, suspended sediment concentration was available only for Moencopi Wash. The Moencopi Wash station, therefore, was calibrated to the available data, and the model input parameters for Moencopi Wash were transferred to Dinnebito Wash, which has a similar morphology. For Cedar Wash, the observed grain-size distribution and model input parameters that maximize the transport of sediment were applied. The sediment transport modeling results for each of the tributaries are also presented in Table 16.

A sediment mass balance calculation can be made based upon the summary data in Table 16. The average suspended sediment load increases between LCR-GF and LCR-CAM by 442,156 tons per month. However, the contribution of the increased sediment load attributable to the three tributaries is only 245,340 tons per month. On average, therefore, the transport model results indicate that about 200,000 tons per month of suspended sediment is contributed to the LCR main-stem within the LCR-GF to LCR-CAM reach by numerous small tributaries that were not incorporated into the model.

2\2125\212512F.CDR





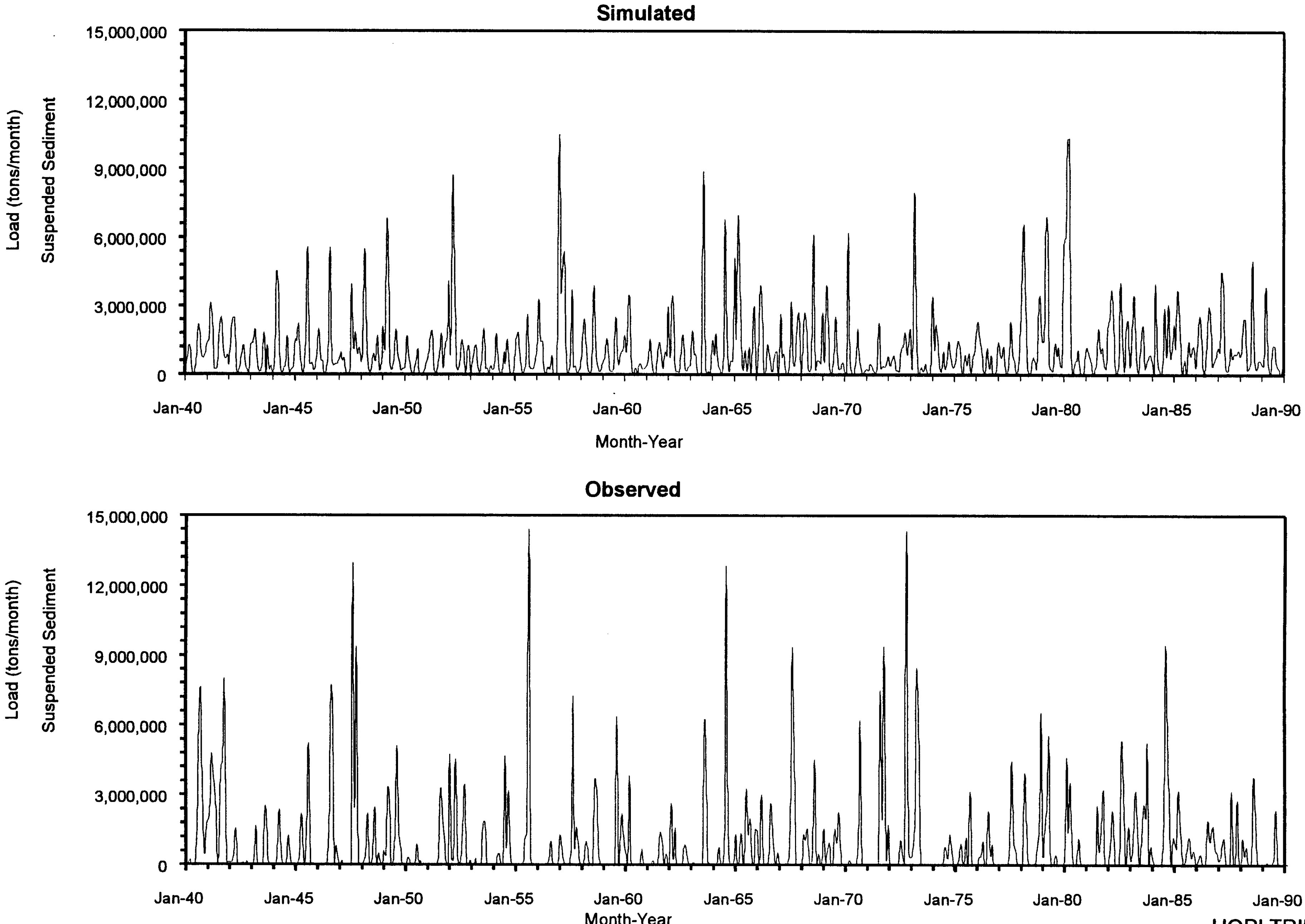
HOPI TRIBE

LCR at Grand Falls Monthly Suspended Sediment Load

DANIEL B. STEPHENS & ASSOCIATES, INC.
12-94 JN 2125

Figure 9

2\2125\212513F.CDR



HOPI TRIBE

LCR Near Cameron Monthly Suspended Sediment Load

DANIEL B. STEPHENS & ASSOCIATES, INC.

12-94 JN 2125

Figure 10

5. SUMMARY AND CONCLUSIONS

This progress report summarizes the LCR streamflow and sediment transport models developed by DBS&A in support of Phase II of the Little Colorado River Basin study. The purpose of this study is to produce a management tool which can be used by the Hopi Tribe and the Glen Canyon Environmental Studies to evaluate the hydrologic character of the LCR basin. During Phase II of the study, background data and information were reviewed, basin geomorphology was analyzed using aerial photographs, several field reconnaissance trips were completed, a basin-wide precipitation/runoff model was developed, and a sediment transport model, which can use measured or simulated streamflows, was constructed for the LCR-GF to LCR-CAM reach.

Based on Phases I and II of the study, the following preliminary conclusions can be made regarding basin hydrology and the current predictive capabilities of the model:

- The bimodal distribution of precipitation within the LCR basin controls the runoff process. Winter storms concentrate precipitation along the southern highlands, which produce winter streamflows and spring runoff in response to snowmelt. Summer monsoonal storms create runoff throughout the basin in direct response to the rainfall inputs.

- Annual and average monthly streamflows indicate that the duration, period, and magnitude of runoff events vary greatly within the LCR basin. Streamflow characteristics appear to be controlled by basin characteristics such as vegetative cover and watershed geomorphology.

- A significant change in the LCR channel morphology occurs below its confluence with the Rio Puerco. The Rio Puerco above the confluence is similar to the morphology of the LCR below the confluence in that the Rio Puerco contains abundant sediment and the meander belts are contained in larger, relatively straight and braided channels which are approximately equal in width to the LCR below the confluence.

- The wide floodplains along the LCR between Holbrook and Leupp indicate a decrease in sediment transport capacity through this reach. In comparison, relatively little sediment is stored along the reach between Leupp and the LCR confluence with the Colorado River, suggesting an increase in sediment transport capacity through this reach.

- According to the USGS Rio Puerco study (Graf et al., 1993), approximately 55 percent of the sediment transported along the main-stem was finer than medium clay (0.002 mm). In contrast, bed-material samples collected along the main-stem consisted of only 10 percent particles that are finer than very-fine sand (0.05 mm). The size fraction that is finer than 0.002 mm is referred to as wash load. Wash load is a large component of the measured increase in sediment load between the LCR at Grand Falls and the LCR near Cameron.

- Monthly precipitation/runoff relationships were developed for each of the major tributaries within the LCR basin. For those months in which significant precipitation/runoff relationships could not be identified, the mean and the standard deviation of the measured streamflow record were determined. For tributary streams where measured streamflow data were sparse or non-existent, an area-scaling approach was used to transfer relationships generated for similar, gaged tributaries to the ungaged watershed.

- Based on the empirical precipitation/runoff relationships, a streamflow model was constructed on a monthly basis for the time period of 1940 to 1990. In order to simulate the unexplained variance in the empirical relationships, a stochastic component was incorporated into the LCR streamflow model. Summary statistics developed from the model output indicate that the model consistently overpredicts streamflows by approximately 10 to 30 percent and results in less variance than measured streamflows.

- On average, the major contributing streamflow drainages are the Rio Puerco, Clear Creek, Chevelon Creek, Silver Creek, the LCR above Hunt, Cottonwood Wash, Leroux Wash, Canyon Diablo, Moencopi Wash, Cedar Wash, and Dinnebito Wash. Corn Creek does not appear to contribute significant quantities of water to the LCR main-stem.

- The simulated streamflows were used in a sediment transport model developed for nodal points within the basin. The model output provides the user with sediment load (in tons per month) based on user-specified grain-size distributions. A preliminary model calibration was performed for the reach between LCR at Grand Falls and LCR near Cameron using inputs from the major tributaries of Dinnebito, Cedar, and Moencopi Washes. Simulation results indicate that substantial sediment wash loads must be contributed to the LCR main-stem directly from short tributaries currently not incorporated into the model.

Additional model refinement is scheduled to be completed in 1995. During this period the streamflow overprediction and sediment contribution from the remaining major tributaries and minor tributaries along the lower reaches of the LCR will be investigated. DBS&A has submitted to the Hopi Tribe a proposal that outlines a scope of work for Phase III of the LCR Basin study.

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APPENDIX A

SIEVE ANALYSES

File

SIEVE ANALYSIS

Sample ID: CHEVELON CR
Location: ABOVE LITTLE COLORADO RIVER
Date/Time: Jul 28, 1993 00:00

Sample submitted by: SM
Date/Time:

Analyzed by: AMW
Date/time: Oct 7, 1993 00:00

Gross weight: 3860.2
Tare weight: 13.2
Net weight: 3847.0

Gravel weight: 1.5
Sand weight: 3845.5

Portion analyzed: 48.6

Remarks:

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	−8					
128	−7					
64	−6					
32	−5					
16	−4					100.0
8	−3	0.0	0.0	.0	.0	100.0
4	−2	1.5	1.5	.0	.0	100.0
<4		3845.5				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	−1	0.1	9.4	.2	.2	99.8
1.00	0	0.3	33.2	.9	.6	99.1
.500	1	0.8	96.5	2.5	1.6	97.5
.250	2	2.3	278.4	7.2	4.7	92.8
.125	3	11.7	1204.2	31.3	24.1	68.7
.0625	4	28.7	3475.1	90.3	59.0	9.7
<.0625		4.7				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	49.0	3664.8	95.3	4.9	4.7
.016	6	27.3	3745.5	97.4	2.1	2.6
.008	7	17.9	3780.4	98.3	.9	1.7
.004	8	12.9	3799.0	98.8	.5	1.2
.002	9	11.2	3805.3	98.9	.2	1.1
<.002	>9					

File

SIEVE ANALYSIS

Sample ID: CD@2G,I 40

Location: CANYON DIABLO @ 2 GUNS, I 40

Date/Time: Jul 28, 1993 00:00

Sample submitted by: SM

Date/Time:

Analyzed by: AMW

Date/time: Oct 7, 1993 00:00

Gross weight: 3083.6

Tare weight: 183.9

Net weight: 2899.7

Gravel weight: 0.0

Sand weight: 2899.7

Portion analyzed: 84.2

Remarks:

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					
16	-4					
8	-3					100.0
4	-2	0.0	0.0	.0	.0	100.0
<4		2899.7				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.1	3.4	.1	.1	99.9
1.00	0	1.0	37.9	1.3	1.2	98.7
.500	1	3.1	144.6	5.0	3.7	95.0
.250	2	16.1	699.1	24.1	19.1	75.9
.125	3	36.0	1938.9	66.9	42.8	33.1
.0625	4	20.0	2627.6	90.6	23.8	9.4
<.0625		7.9				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	72.6	2702.2	93.2	2.6	6.8
.016	6	44.0	2780.0	95.9	2.7	4.1
.008	7	25.4	2830.6	97.6	1.7	2.4
.004	8	15.1	2858.6	98.6	1.0	1.4
.002	9	10.5	2871.1	99.0	.4	1.0
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	LEROUX WASH [
Location:	@ BROADCAST AVE., HOLBROOK
Date/Time:	Jul 28, 1993 00:00
Sample submitted by:	SM
Date/Time:	
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	4128.4
Tare weight:	12.6
Net weight:	4115.8
Gravel weight:	1.6
Sand weight:	4114.2
Portion analyzed:	62.8
Remarks:	

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	−8					
128	−7					
64	−6					
32	−5					100.0
16	−4	0.0	0.0	.0	.0	100.0
8	−3	0.8	0.8	.0	.0	100.0
4	−2	0.8	1.6	.0	.0	100.0
<4		4114.2				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	−1	0.1	8.2	.2	.2	99.8
1.00	0	0.3	27.8	.7	.5	99.3
.500	1	3.0	224.3	5.5	4.8	94.5
.250	2	24.8	1849.1	44.9	39.5	55.1
.125	3	30.9	3873.4	94.1	49.2	5.9
.0625	4	3.3	4089.6	99.4	5.3	.6
<.0625		0.4	4115.8	100.0	.6	−.0

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	[				
.016	6					
.008	7					
.004	8					
.002	9					
<.002	>9					

File

SIEVE ANALYSIS

Sample ID: CLEAR CREEK

Location: BELOW CLEAR CREEK RES.,WINSLOW

Date/Time: Jul 28, 1993 00:00

Sample submitted by: SM

Date/Time:

Analyzed by: AMW

Date/time: Oct 7, 1993 00:00

Gross weight: 3584.0

Tare weight: 0.0

Net weight: 3584.0

Gravel weight: 418.5

Sand weight: 3165.5

Portion analyzed: 95.7

Remarks:

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					100.0
64	-6	0.0	0.0	.0	.0	100.0
32	-5	96.6	96.6	2.7	2.7	97.3
16	-4	11.8	108.4	3.0	.3	97.0
8	-3	124.5	232.9	6.5	3.5	93.5
4	-2	185.6	418.5	11.7	5.2	88.3
<4		3165.5				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	1.3	461.5	12.9	1.2	87.1
1.00	0	11.4	838.6	23.4	10.5	76.6
.500	1	5.8	1030.4	28.8	5.4	71.2
.250	2	4.3	1172.7	32.7	4.0	67.3
.125	3	23.6	1953.3	54.5	21.8	45.5
.0625	4	35.8	3137.5	87.5	33.0	12.5
<.0625		13.5				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	45.1	3382.6	94.4	6.8	5.6
.016	6	27.3	3462.1	96.6	2.2	3.4
.008	7	22.2	3484.9	97.2	.6	2.8
.004	8	18.0	3503.6	97.8	.5	2.2
.002	9	15.6	3514.5	98.1	.3	1.9
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	SFO CREEK
Location:	@TURKEY FLATS, LEUPP ROAD
Date/Time:	Jul 29, 1993 00:00
Sample submitted by:	SM
Date/Time:	
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	2758.5
Tare weight:	12.6
Net weight:	2745.9
Gravel weight:	15.8
Sand weight:	2730.1
Portion analyzed:	79.4
Remarks:	

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					100.0
16	-4	0.0	0.0	.0	.0	100.0
8	-3	7.7	7.7	.3	.3	99.7
4	-2	8.1	15.8	.6	.3	99.4
<4		2730.1				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	1.1	53.6	2.0	1.4	98.0
1.00	0	7.5	311.5	11.3	9.4	88.7
.500	1	27.3	1250.2	45.5	34.2	54.5
.250	2	32.1	2353.9	85.7	40.2	14.3
.125	3	4.8	2519.0	91.7	6.0	8.3
.0625	4	5.6	2711.5	98.7	7.0	1.3
<.0625		1.0	2745.9	100.0	1.3	-.0

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5					
.016	6					
.008	7					
.004	8					
.002	9					
<.002	>9					

File

SIEVE ANALYSIS

Sample ID: JEDDITO WASH
Location: @ HWY 87
Date/Time: Jul 27, 1993 00:00

Sample submitted by: SM
Date/Time:

Analyzed by: AMW
Date/time: Oct 7, 1993 00:00

Gross weight: 3185.4
Tare weight: 13.5
Net weight: 3171.9

Gravel weight: 12.2
Sand weight: 3159.7

Portion analyzed: 98.3

Remarks:

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					100.0
16	-4	0.0	0.0	.0	.0	100.0
8	-3	3.4	3.4	.1	.1	99.9
4	-2	8.8	12.2	.4	.3	99.6
<4		3159.7				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.6	31.5	1.0	.6	99.0
1.00	0	3.7	150.4	4.7	3.7	95.3
.500	1	12.3	545.8	17.2	12.5	82.8
.250	2	27.7	1436.2	45.3	28.1	54.7
.125	3	36.4	2606.2	82.2	36.9	17.8
.0625	4	15.0	3088.3	97.4	15.2	2.6
<.0625		2.6	3171.9	100.0	2.6	-.0

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5					
.016	6					
.008	7					
.004	8					
.002	9					
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	ORAIBI WASH [
Location:	OLD HOUSE, 10 MI.SO. OF KYKOTS
Date/Time:	
Sample submitted by:	SM
Date/Time:	
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	2915.1
Tare weight:	13.3
Net weight:	2901.8
Gravel weight:	0.0
Sand weight:	2901.8
Portion analyzed:	88.0
Remarks:	KYKOTSMOUI ??

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	–8					
128	–7					
64	–6					
32	–5					
16	–4					
8	–3					100.0
4	–2	0.0	0.0	.0	.0	100.0
<4		2901.8				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	–1	0.0	0.0	.0	.0	100.0
1.00	0	0.2	6.6	.2	.2	99.8
.500	1	3.3	115.4	4.0	3.7	96.0
.250	2	21.9	837.6	28.9	24.9	71.1
.125	3	47.0	2387.4	82.3	53.4	17.7
.0625	4	11.1	2753.4	94.9	12.6	5.1
<.0625		4.5	2901.8	100.0	5.1	–.0

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5					
.016	6					
.008	7					
.004	8					
.002	9					
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	WW-HWY264
Location:	WEPO WASH ABV HWY 264
Date/Time:	Jul 27, 1993 13:45
Sample submitted by:	SM
Date/Time:	Jul 27, 1993 13:45
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	3509.2
Tare weight:	13.3
Net weight:	3495.9
Gravel weight:	73.6
Sand weight:	3422.3
Portion analyzed:	104.6
Remarks:	

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					100.0
32	-5	43.3	43.3	1.2	1.2	98.8
16	-4	12.4	55.7	1.6	.4	98.4
8	-3	8.6	64.3	1.8	.2	98.2
4	-2	9.3	73.6	2.1	.3	97.9
<4		3422.3				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.8	99.8	2.9	.7	97.1
1.00	0	3.9	227.4	6.5	3.6	93.5
.500	1	24.6	1032.2	29.5	23.0	70.5
.250	2	33.5	2128.3	60.9	31.4	39.1
.125	3	12.1	2524.2	72.2	11.3	27.8
.0625	4	1.9	2586.3	74.0	1.8	26.0
<.0625		27.8				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	81.0	2759.2	78.9	4.9	21.1
.016	6	69.0	2868.3	82.0	3.1	18.0
.008	7	56.9	2978.4	85.2	3.1	14.8
.004	8	43.4	3101.2	88.7	3.5	11.3
.002	9	34.2	3184.8	91.1	2.4	8.9
<.002	>9					

File

SIEVE ANALYSIS

Sample ID: CW@I40

Location: COTTONWOOD WASH @ I40

Date/Time: Jul 28, 1993 07:00

Sample submitted by: SM

Date/Time: Jul 28, 1993 00:00

Analyzed by: AMW

Date/time: Oct 7, 1993 00:00

Gross weight: 2890.7

Tare weight: 13.3

Net weight: 2877.4

Gravel weight: 0.0

Sand weight: 2877.4

Portion analyzed: 80.7

Remarks:

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					
16	-4					
8	-3					100.0
4	-2	0.0	0.0	.0	.0	100.0
<4		2877.4				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.0	0.0	.0	.0	100.0
1.00	0	0.0	0.0	.0	.0	100.0
.500	1	0.1	3.6	.1	.1	99.9
.250	2	9.4	338.7	11.8	11.6	88.2
.125	3	46.3	1989.6	69.1	57.4	30.9
.0625	4	8.8	2303.3	80.0	10.9	20.0
<.0625		16.1				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	53.5	2570.3	89.3	9.3	10.7
.016	6	43.5	2627.7	91.3	2.0	8.7
.008	7	38.3	2657.5	92.4	1.0	7.6
.004	8	30.9	2700.0	93.8	1.5	6.2
.002	9	25.4	2731.6	94.9	1.1	5.1
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	L. COLORADO [
Location:	ABOVE GRAND FALLS
Date/Time:	Jul 29, 1993 00:00
Sample submitted by:	SM
Date/Time:	
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	2211.7
Tare weight:	0.0
Net weight:	2211.7
Gravel weight:	0.0
Sand weight:	2211.7
Portion analyzed:	133.0
Remarks:	

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					
16	-4					
8	-3					100.0
4	-2	0.0	0.0	.0	.0	100.0
<4		2211.7				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.0	0.0	.0	.0	100.0
1.00	0	0.1	1.7	.1	.1	99.9
.500	1	0.2	5.2	.2	.2	99.8
.250	2	19.6	331.1	15.0	14.7	85.0
.125	3	40.3	1001.2	45.3	30.3	54.7
.0625	4	41.8	1696.2	76.7	31.4	23.3
<.0625		31.0				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	36.8	2022.0	91.4	14.7	8.6
.016	6	18.1	2118.4	95.8	4.4	4.2
.008	7	12.3	2148.3	97.1	1.4	2.9
.004	8	9.5	2162.7	97.8	.7	2.2
.002	9	9.5	2162.7	97.8	.0	2.2
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	PUERCO RIVER
Location:	@ BRIDGE NAVAHO, ARIZONA
Date/Time:	Jul 28, 1993 00:00
Sample submitted by:	SM
Date/Time:	
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	4349.9
Tare weight:	13.4
Net weight:	43336.5
Gravel weight:	5.8
Sand weight:	43330.7
Portion analyzed:	60.1
Remarks:	

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					100.0
16	-4	0.0	0.0	.0	.0	100.0
8	-3	2.0	2.0	.0	.0	100.0
4	-2	3.8	5.8	.0	.0	100.0
<4		43330.7				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.1	77.9	.2	.2	99.8
1.00	0	1.5	1159.4	2.7	2.5	97.3
.500	1	5.8	5341.0	12.3	9.6	87.7
.250	2	9.9	12478.7	28.8	16.5	71.2
.125	3	12.9	21779.3	50.3	21.5	49.7
.0625	4	10.9	29637.9	68.4	18.1	31.6
<.0625		19.0				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	39.4	37939.3	87.5	19.2	12.5
.016	6	20.0	40596.8	93.7	6.1	6.3
.008	7	13.5	41487.2	95.7	2.1	4.3
.004	8	9.9	41980.3	96.9	1.1	3.1
.002	9	9.8	41994.0	96.9	.0	3.1
<.002	>9					

File

SIEVE ANALYSIS

Sample ID:	PW-HWY87
Location:	POLACCA WASH ABV HWY 87
Date/Time:	Jul 27, 1993 19:25
Sample submitted by:	SM
Date/Time:	Jul 27, 1993 19:25
Analyzed by:	AMW
Date/time:	Oct 7, 1993 00:00
Gross weight:	
Tare weight:	
Net weight:	1909.5
Gravel weight:	617.1
Sand weight:	1292.4
Portion analyzed:	134.4
Remarks:	

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	−8					
128	−7					
64	−6					100.0
32	−5	375.8	375.8	19.7	19.7	80.3
16	−4	152.5	528.3	27.7	8.0	72.3
8	−3	49.3	577.6	30.2	2.6	69.8
4	−2	39.5	617.1	32.3	2.1	67.7
<4		1292.4				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	−1	1.1	627.7	32.9	.6	67.1
1.00	0	2.9	655.6	34.3	1.5	65.7
.500	1	4.1	695.0	36.4	2.1	63.6
.250	2	16.8	856.5	44.9	8.5	55.1
.125	3	9.4	946.9	49.6	4.7	50.4
.0625	4	0.8	954.6	50.0	.4	50.0
<.0625		99.3				

sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5	71.2	1229.6	64.4	14.4	35.6
.016	6	64.7	1291.7	67.6	3.3	32.4
.008	7	59.0	1346.1	70.5	2.9	29.5
.004	8	50.4	1428.2	74.8	4.3	25.2
.002	9	40.5	1522.8	79.7	5.0	20.3
<.002	>9					

File

SIEVE ANALYSIS

Sample ID: POLACCA WASH

Location: ABOVE HWY 264

Date/Time: Jul 27, 1993 00:00

Sample submitted by: SM

Date/Time:

Analyzed by: AMW

Date/time: Oct 7, 1993 00:00

Gross weight: 2066.3

Tare weight: 13.3

Net weight: 2053.0

Gravel weight: 3.6

Sand weight: 2049.4

Portion analyzed: 127.0

Remarks:

Save the data in the database table (F8)

Restore previously entered data by Sample ID (F10)

Clear all fields (F11)

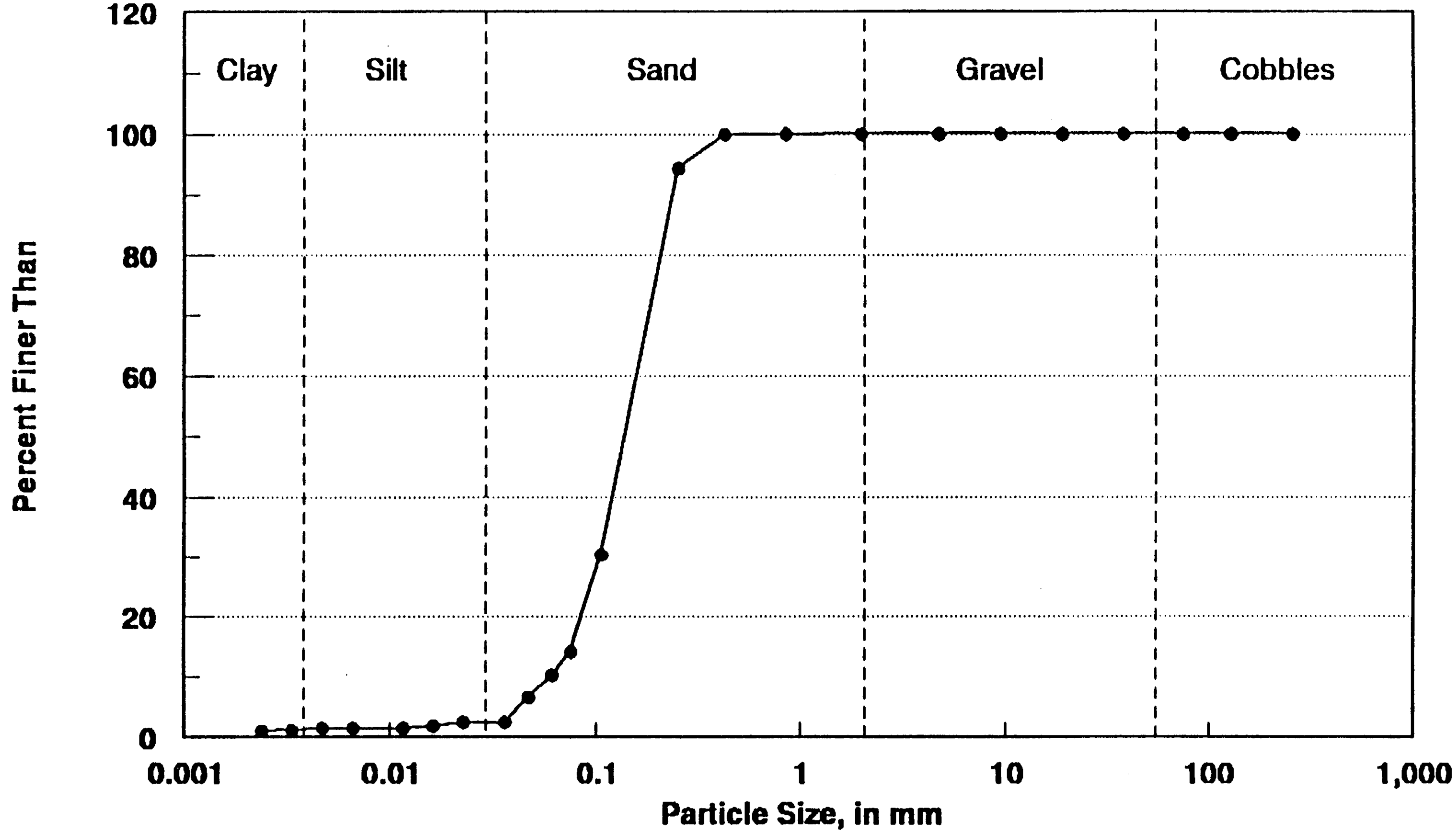
QUIT (F12)

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
256	-8					
128	-7					
64	-6					
32	-5					
16	-4					100.0
8	-3	0.0	0.0	.0	.0	100.0
4	-2	3.6	3.6	.2	.2	99.8
<4		2049.4				

sieve (mm) size	phi size	net weight (g)	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
2.00	-1	0.3	8.4	.4	.2	99.6
1.00	0	0.6	18.1	.9	.5	99.1
.500	1	1.8	47.2	2.3	1.4	97.7
.250	2	52.6	896.0	43.6	41.3	56.4
.125	3	61.1	1881.9	91.7	48.0	8.3
.0625	4	7.7	2006.2	97.7	6.1	2.3
<.0625		2.9	2053.0	100.0	2.3	.0

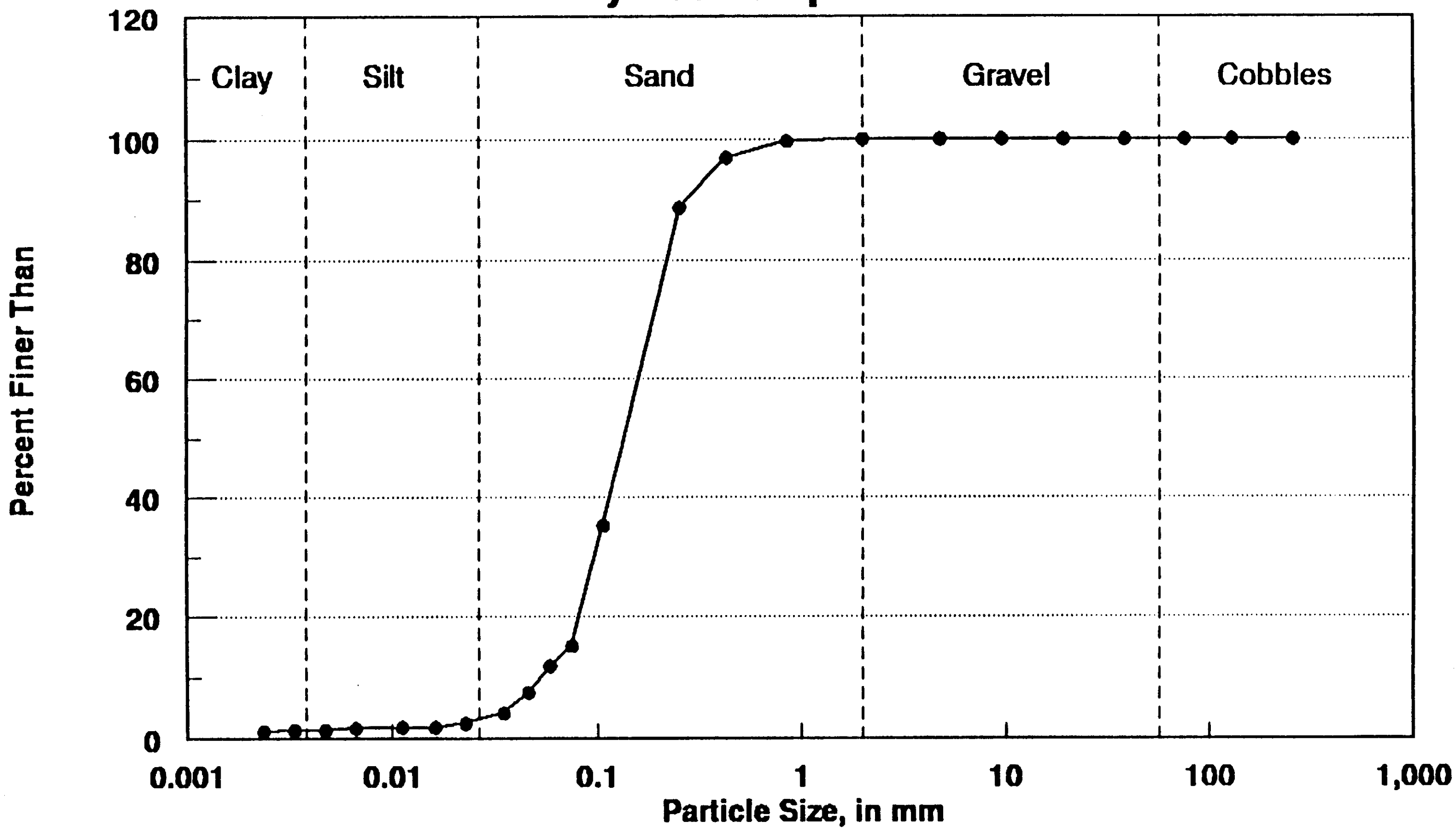
sieve (mm) size	phi size	Percent silt finer than	Cumulative weight (g)	Cumulative percent	Percent in class	Percent finer than
.031	5					
.016	6					
.008	7					
.004	8					
.002	9					
<.002	>9					

Little Colorado River at Cameron
Particle Size Distribution Analysis
Dry Bed Sample



Sampled by R. Marley, Analysis by D.B. Stephens
Sample Date: / /93

Moenkopi Wash at Highway 89
Particle Size Distribution Analysis
Dry Bed Sample

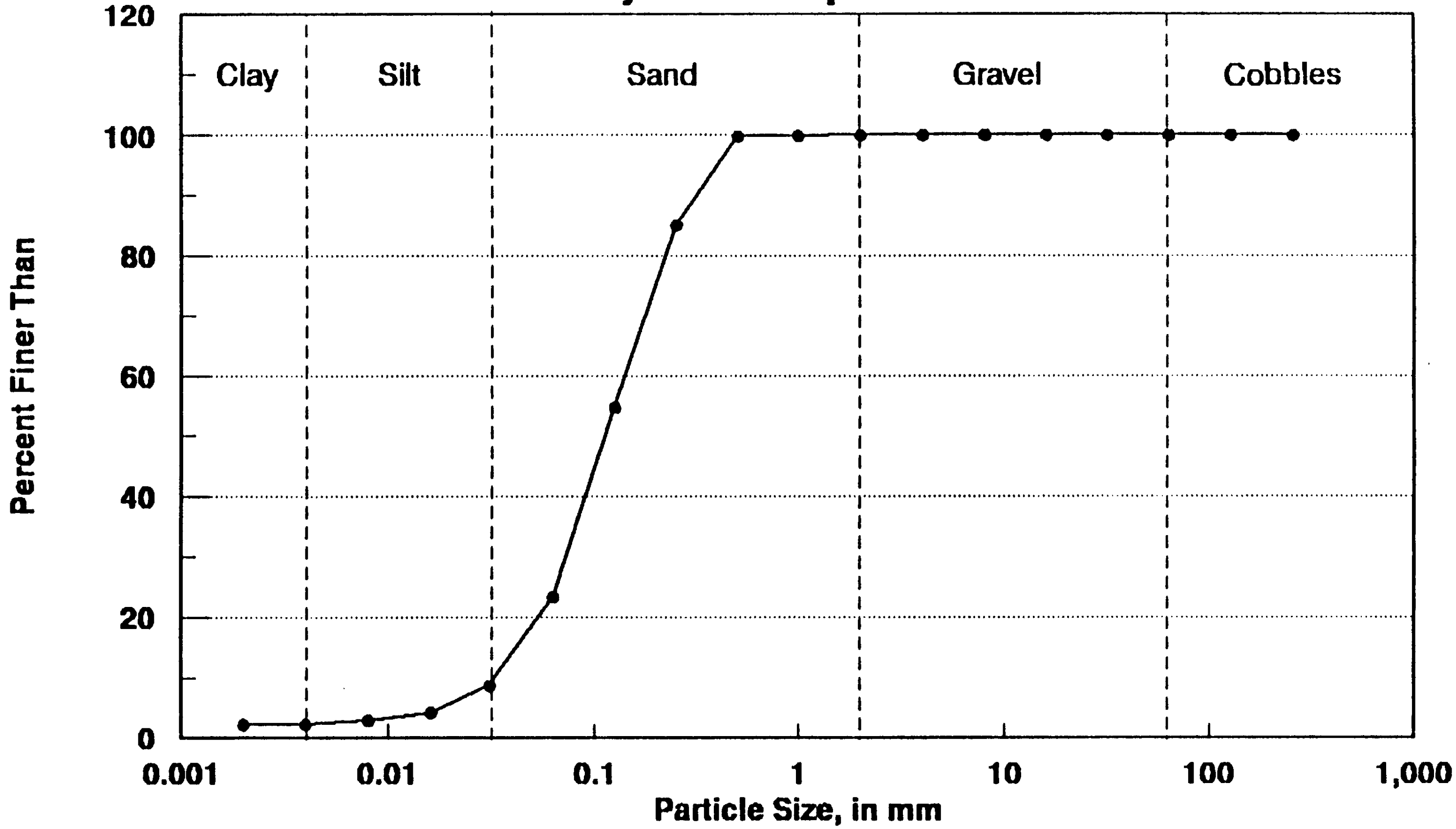


Sampled by R. Marley, Analysis by D.B. Stephens
Sample Date: / /93

Little Colorado River above Grand Falls

Particle Size Distribution Analysis

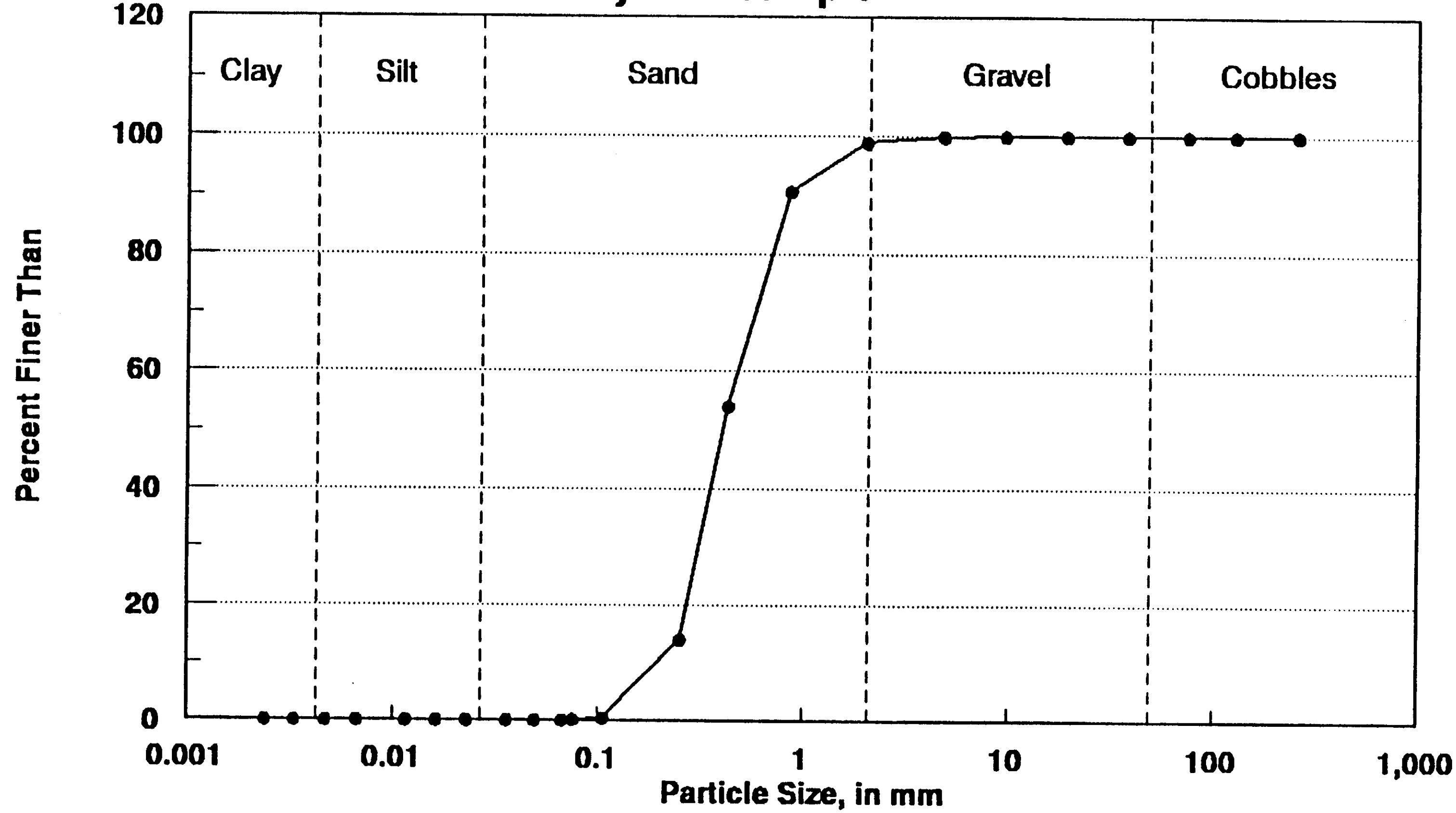
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS

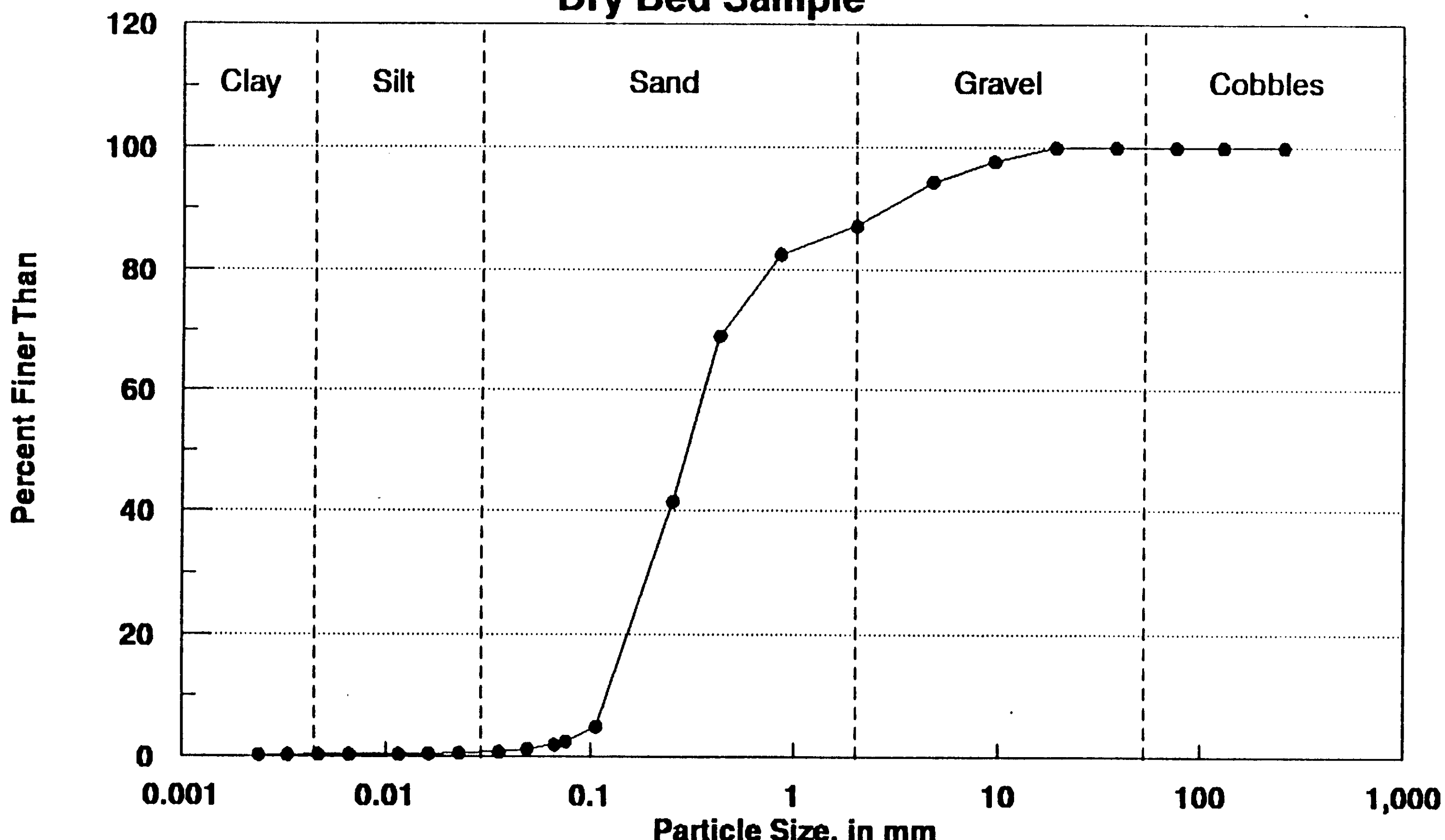
Sample Date: 7/27/93

Corn Creek Wash near Highway 15
Particle Size Distribution Analysis
Dry Bed Sample



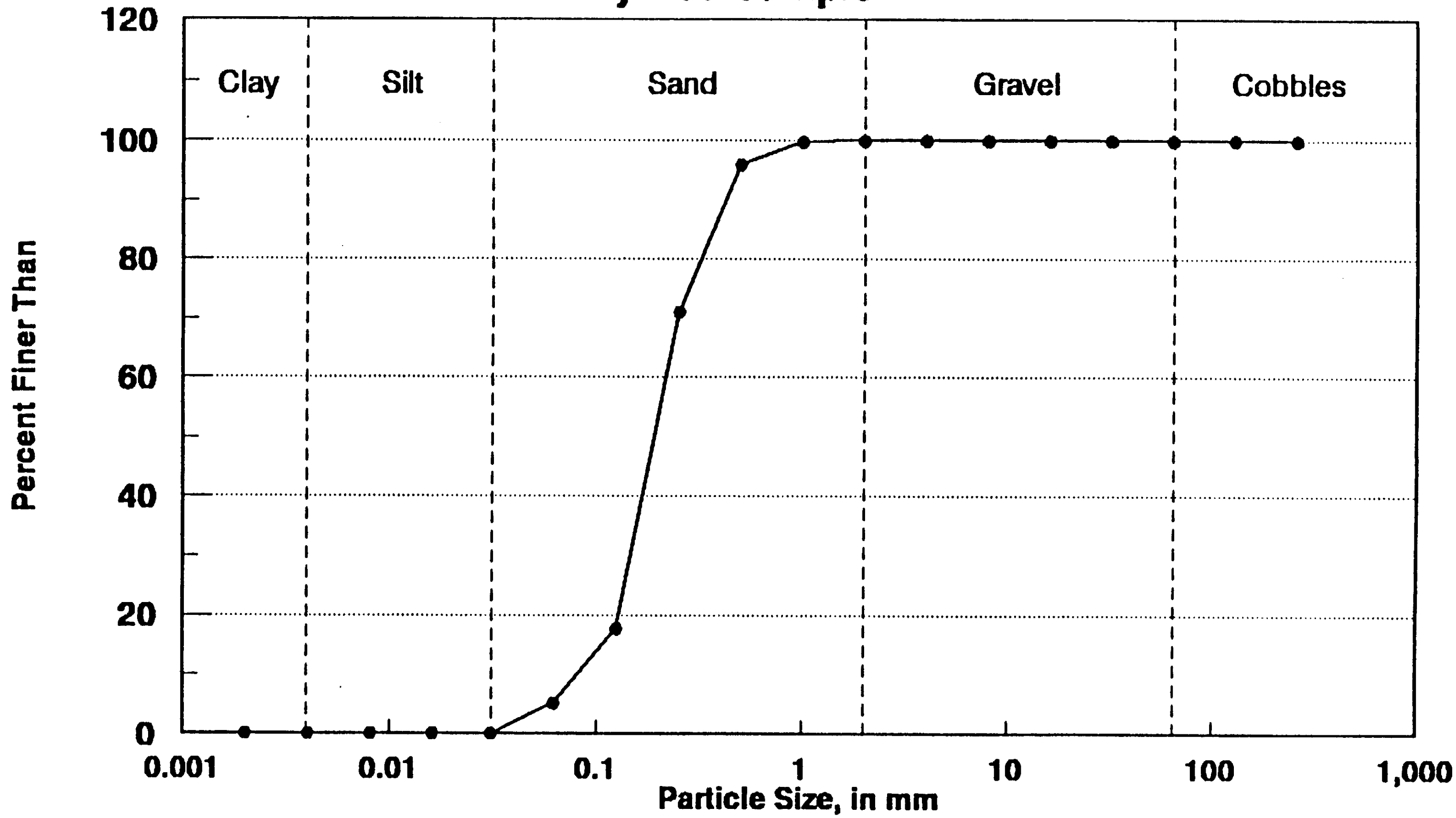
Sampled by R. Marley, Analysis by D.B. Stephens
Sample Date: / /93

Dinnebito Wash near Sand Springs
Particle Size Distribution Analysis
Dry Bed Sample



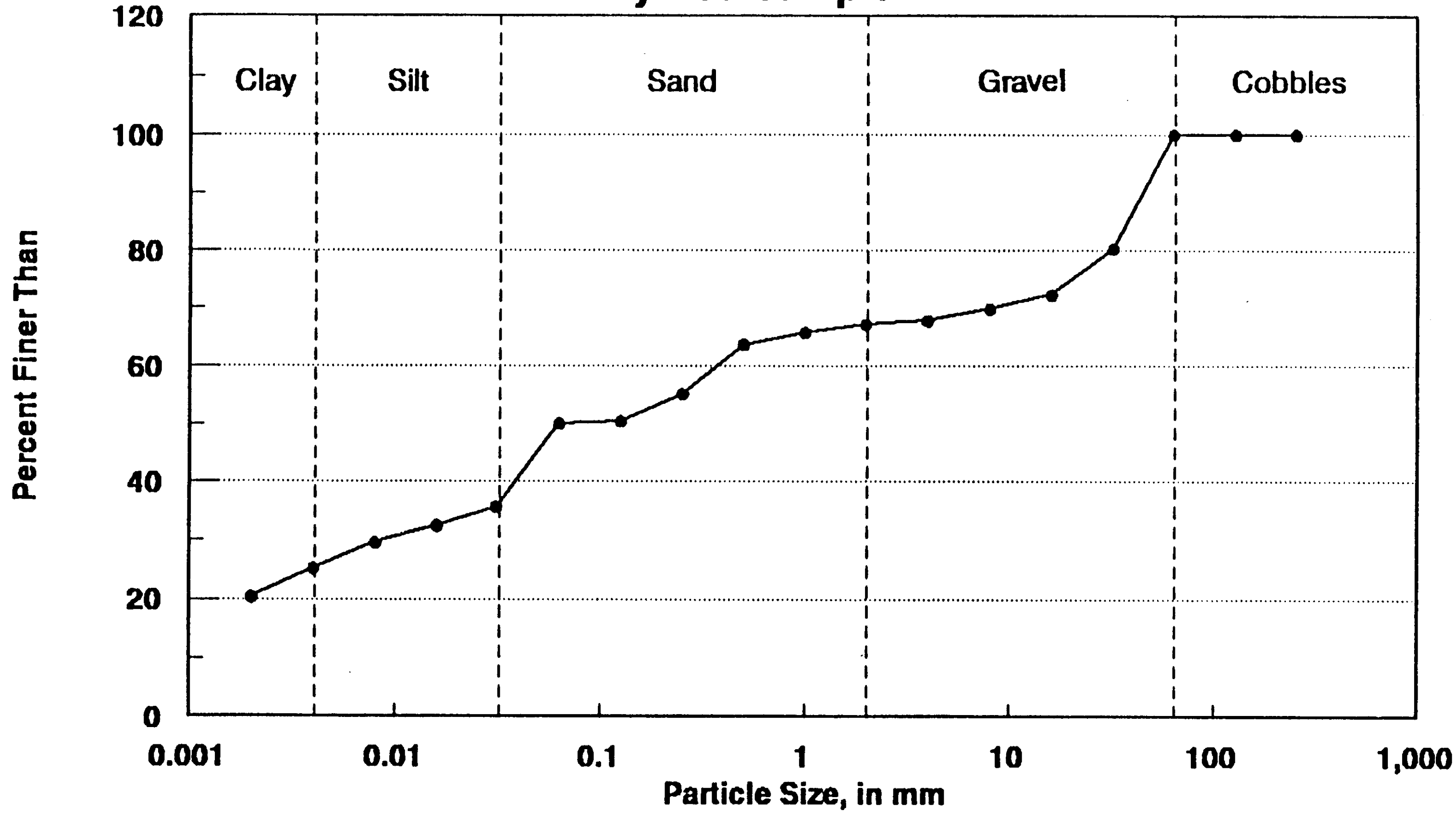
Sampled by R. Marley, Analysis by D.B. Stephens
Sample Date: / /93

Oraibi Wash, Old House, 10 mi. S. of Kykotsmovi
Particle Size Distribution Analysis
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/29/93

Polacca Wash above Highway 87
Particle Size Distribution Analysis
Dry Bed Sample

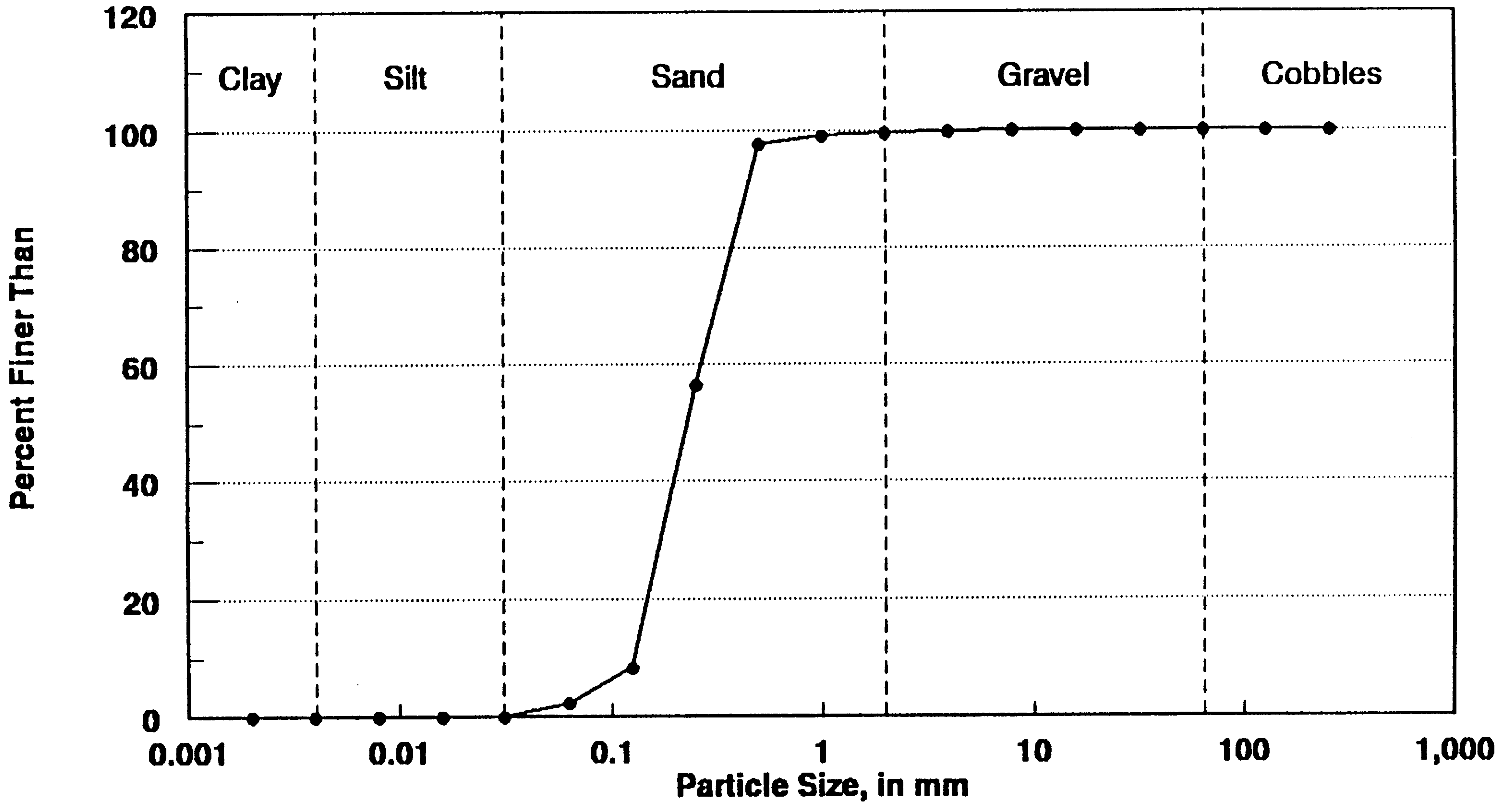


Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/27/93

Polacca Wash above Highway 264

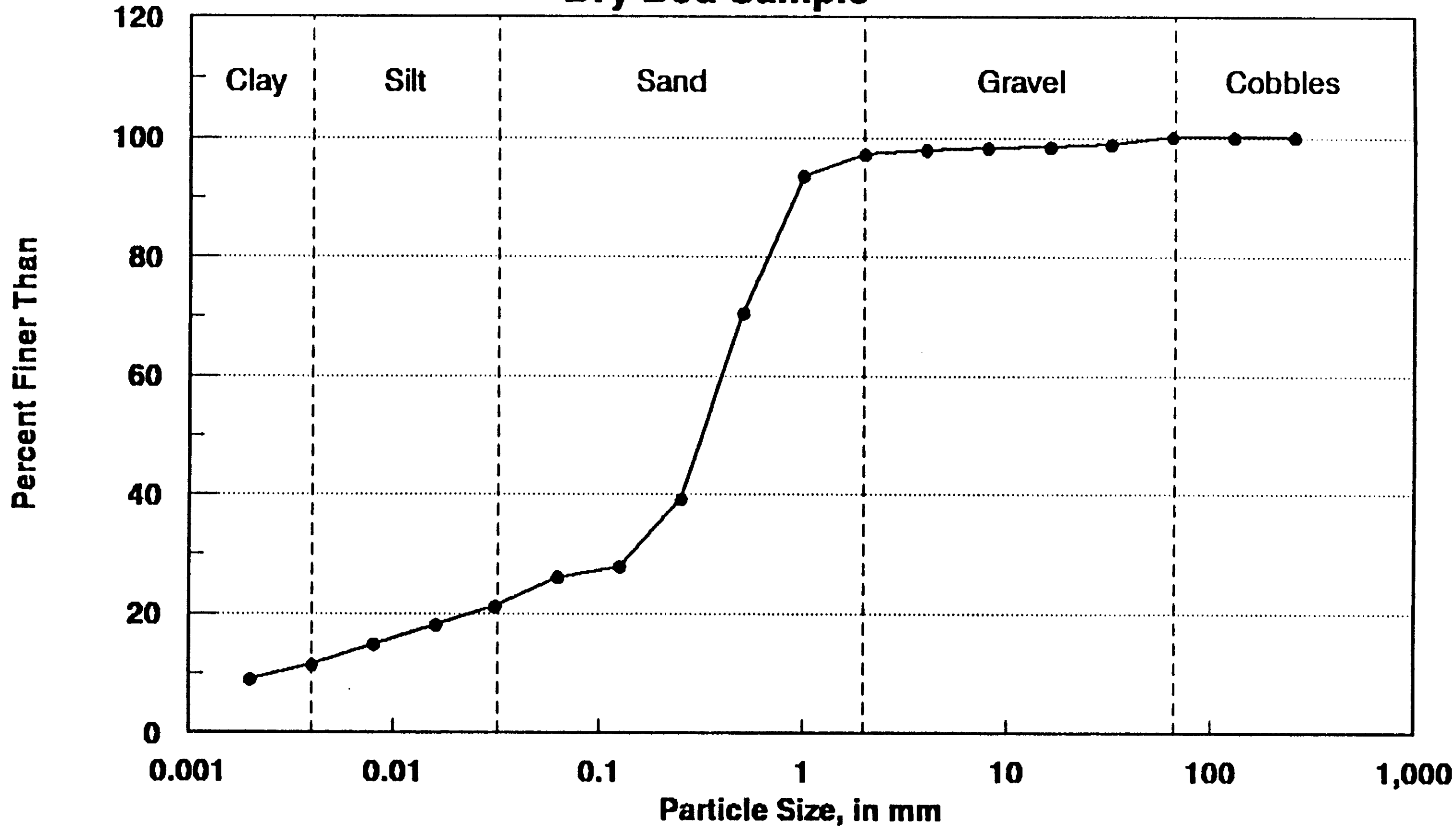
Particle Size Distribution Analysis

Dry Bed Sample



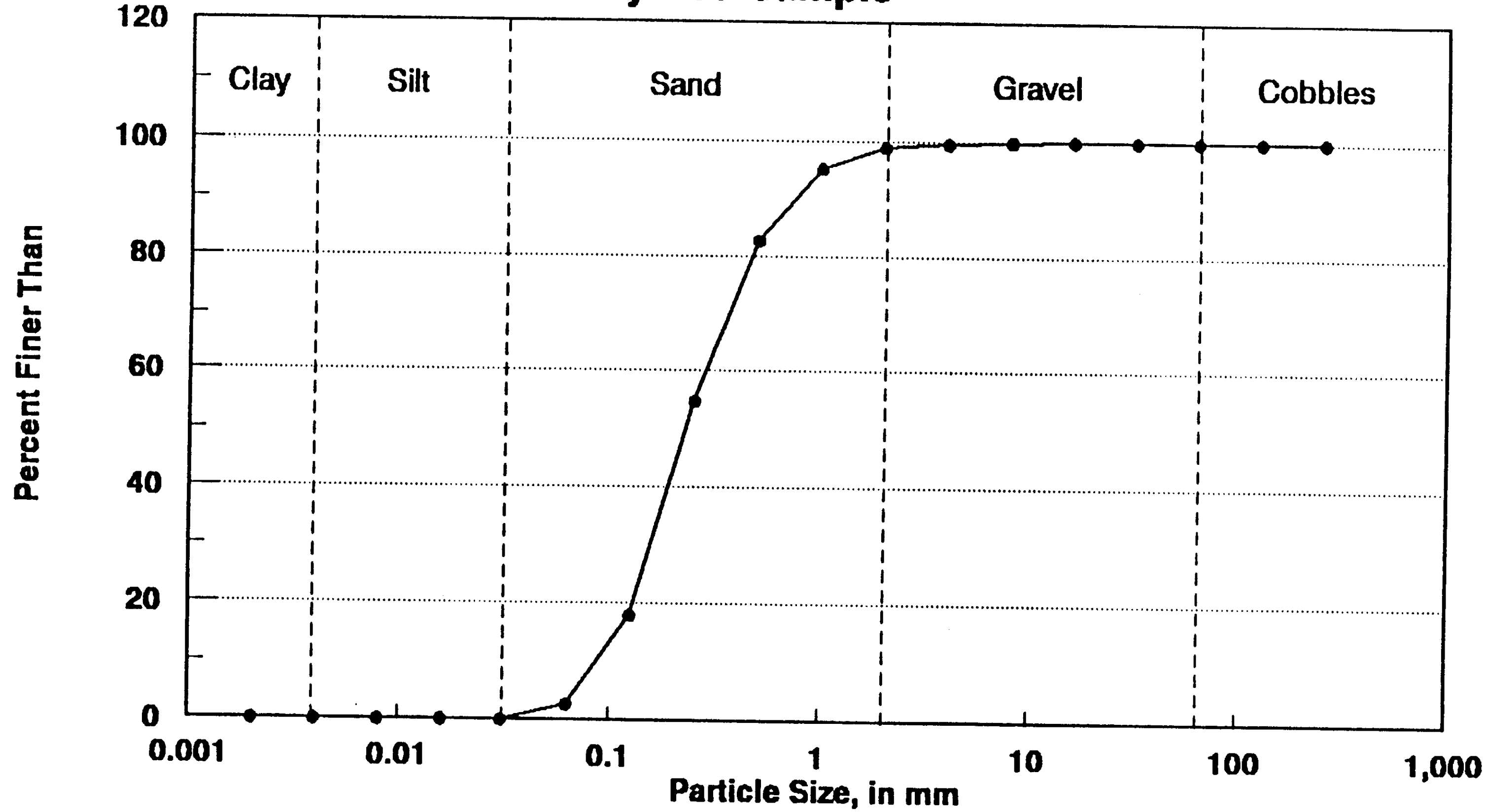
Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/27/93

Wepo Wash above Highway 264
Particle Size Distribution Analysis
Dry Bed Sample



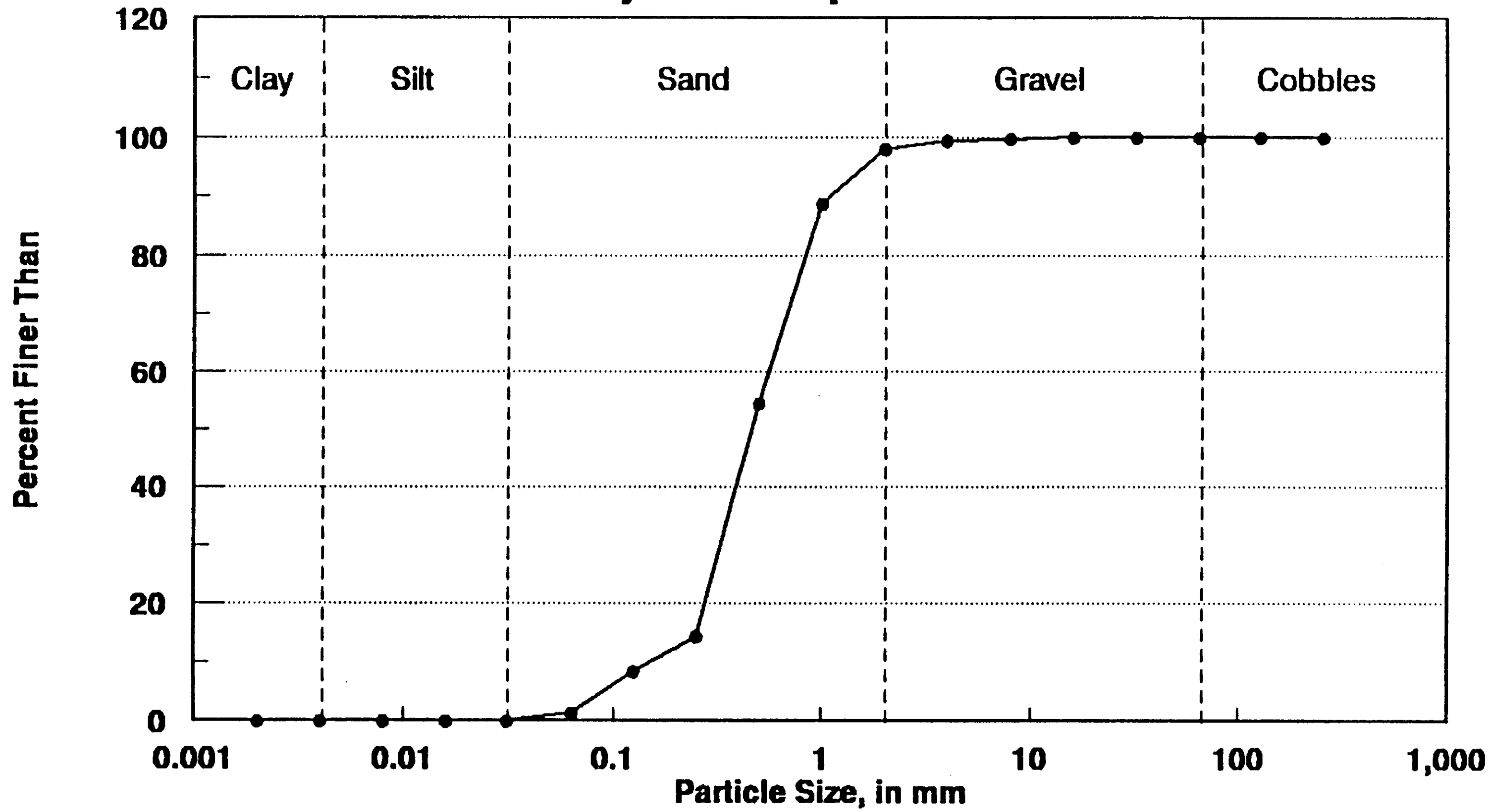
Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/27/93

Jeddito Wash at Highway 87
Particle Size Distribution Analysis
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/27/93

San Francisco Creek at Turkey Flats, Leupp Road
Particle Size Distribution Analysis
Dry Bed Sample

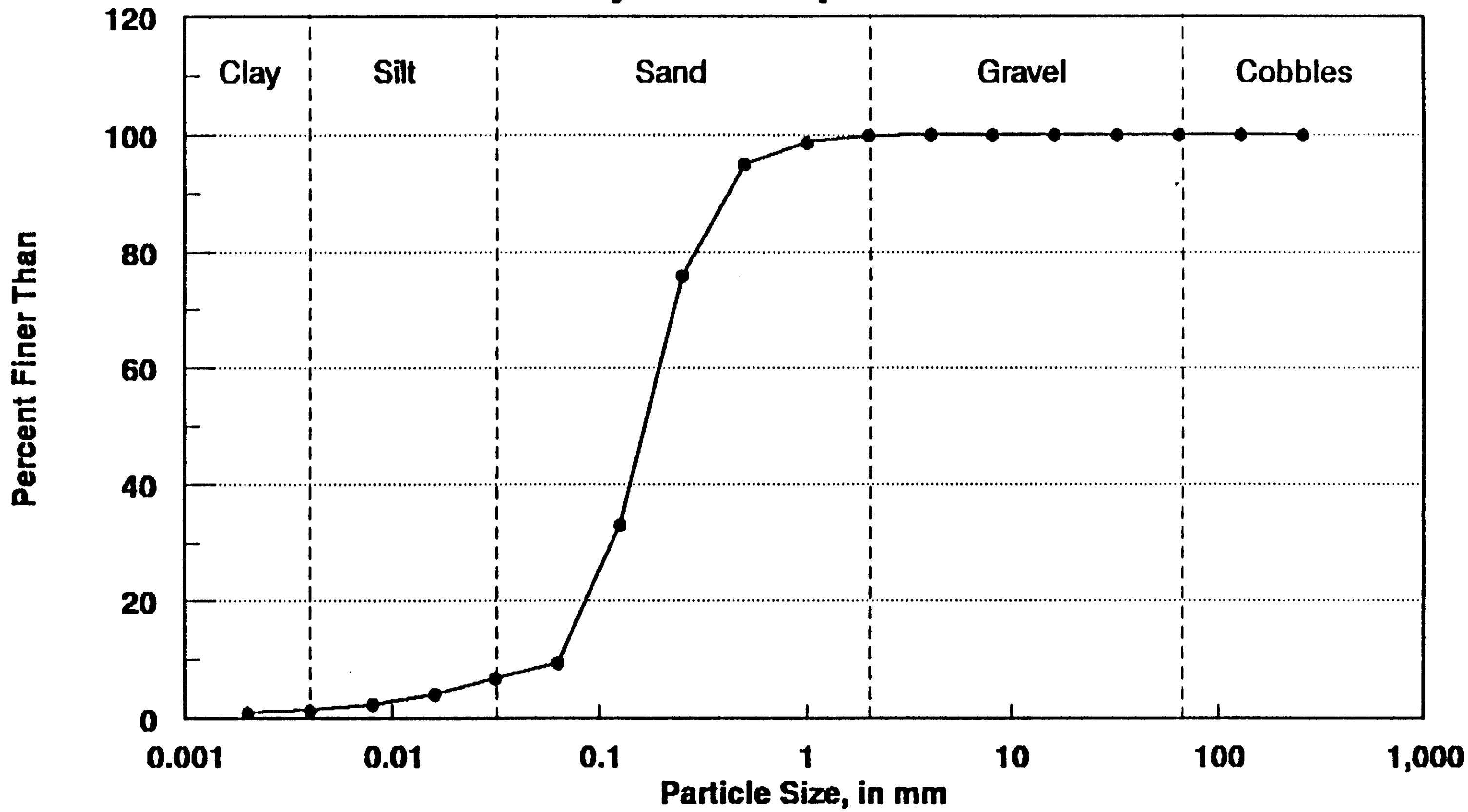


Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/29/93

Canyon Diablo at Two Guns, near Interstate 40

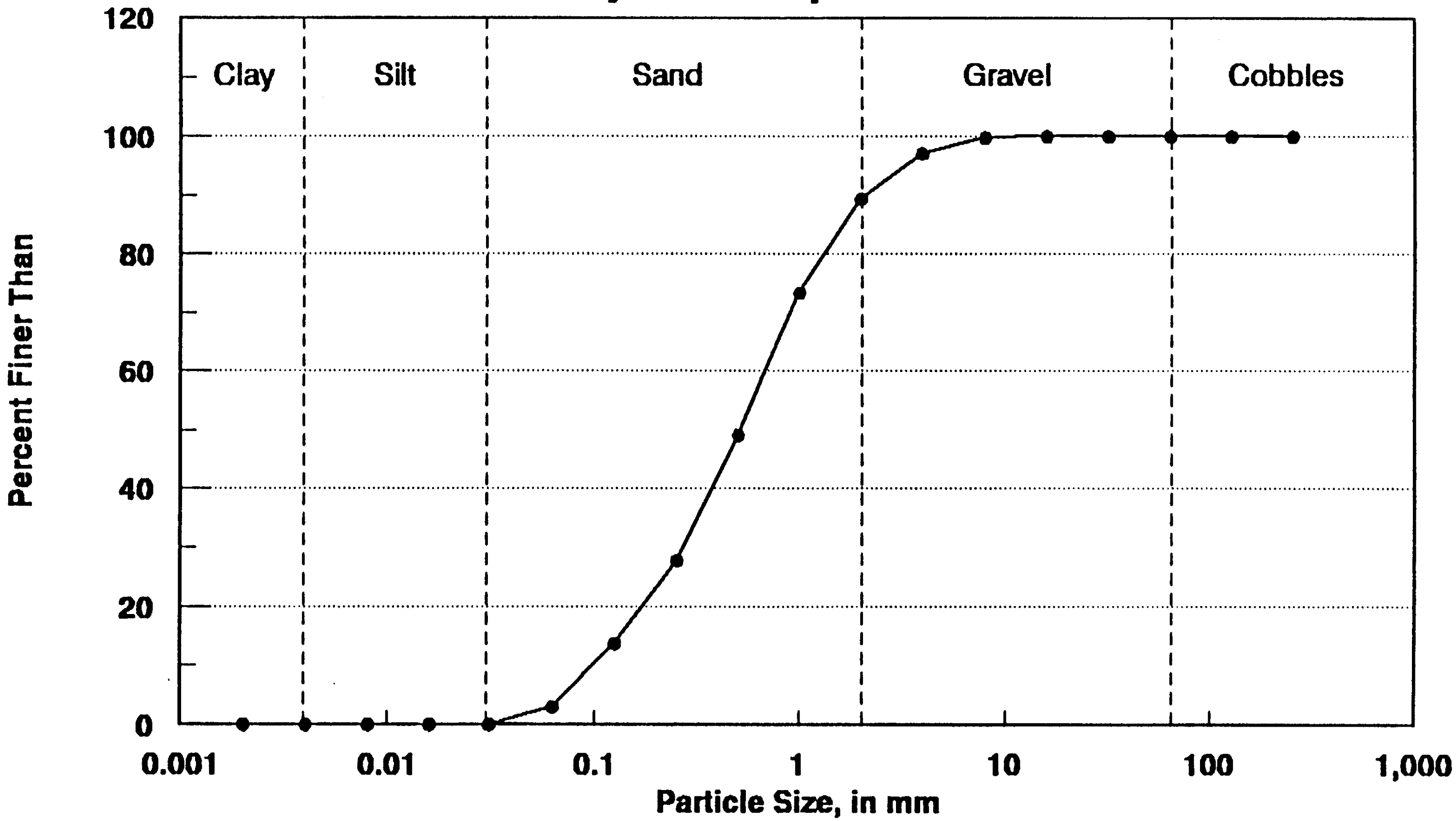
Particle Size Distribution Analysis

Dry Bed Sample



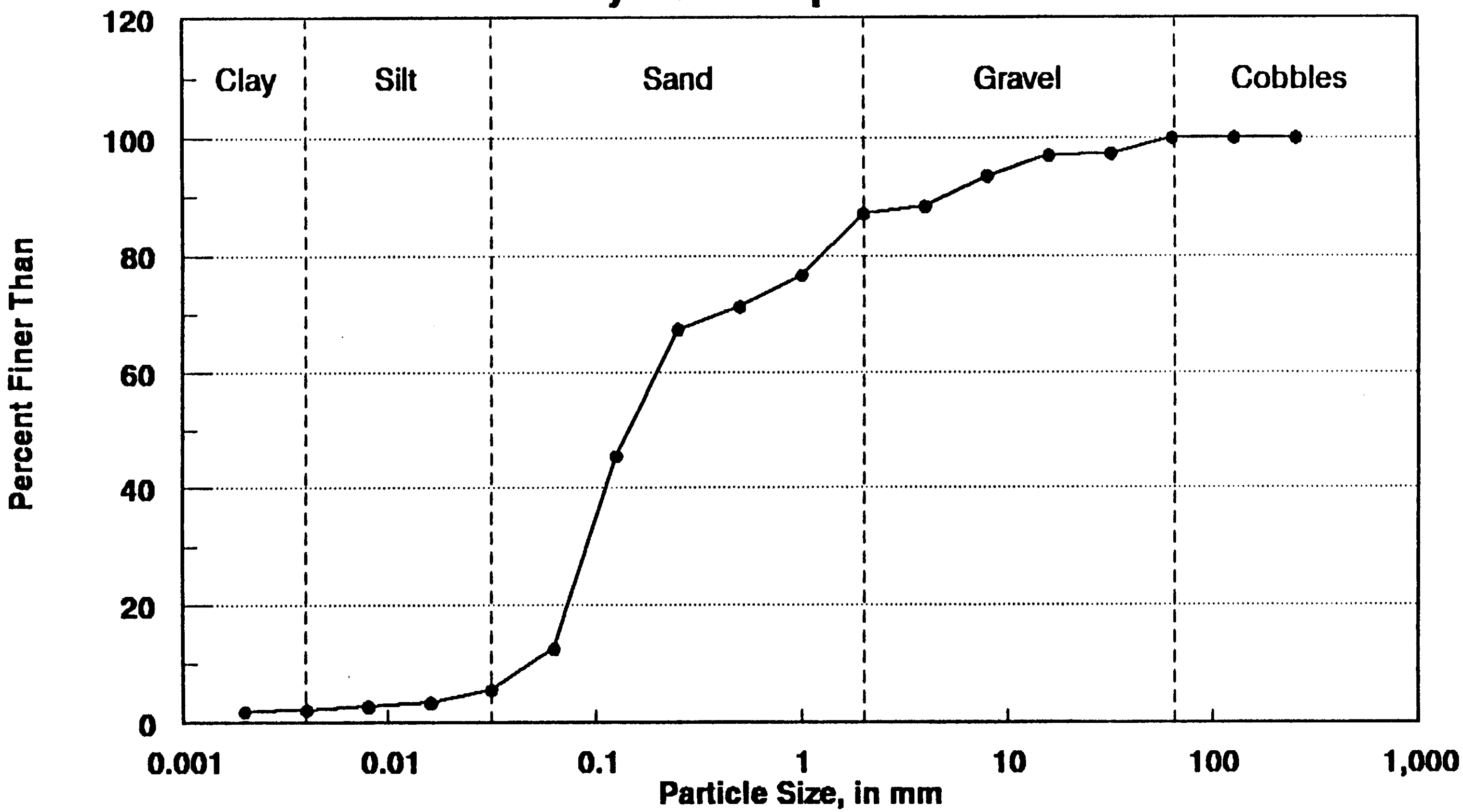
Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/28/93

Jacks Canyon Wash at Highway 99
Particle Size Distribution Analysis
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/28/93

Clear Creek below Clear Creek Resererervoir, near Winslow
Particle Size Distribution Analysis
Dry Bed Sample

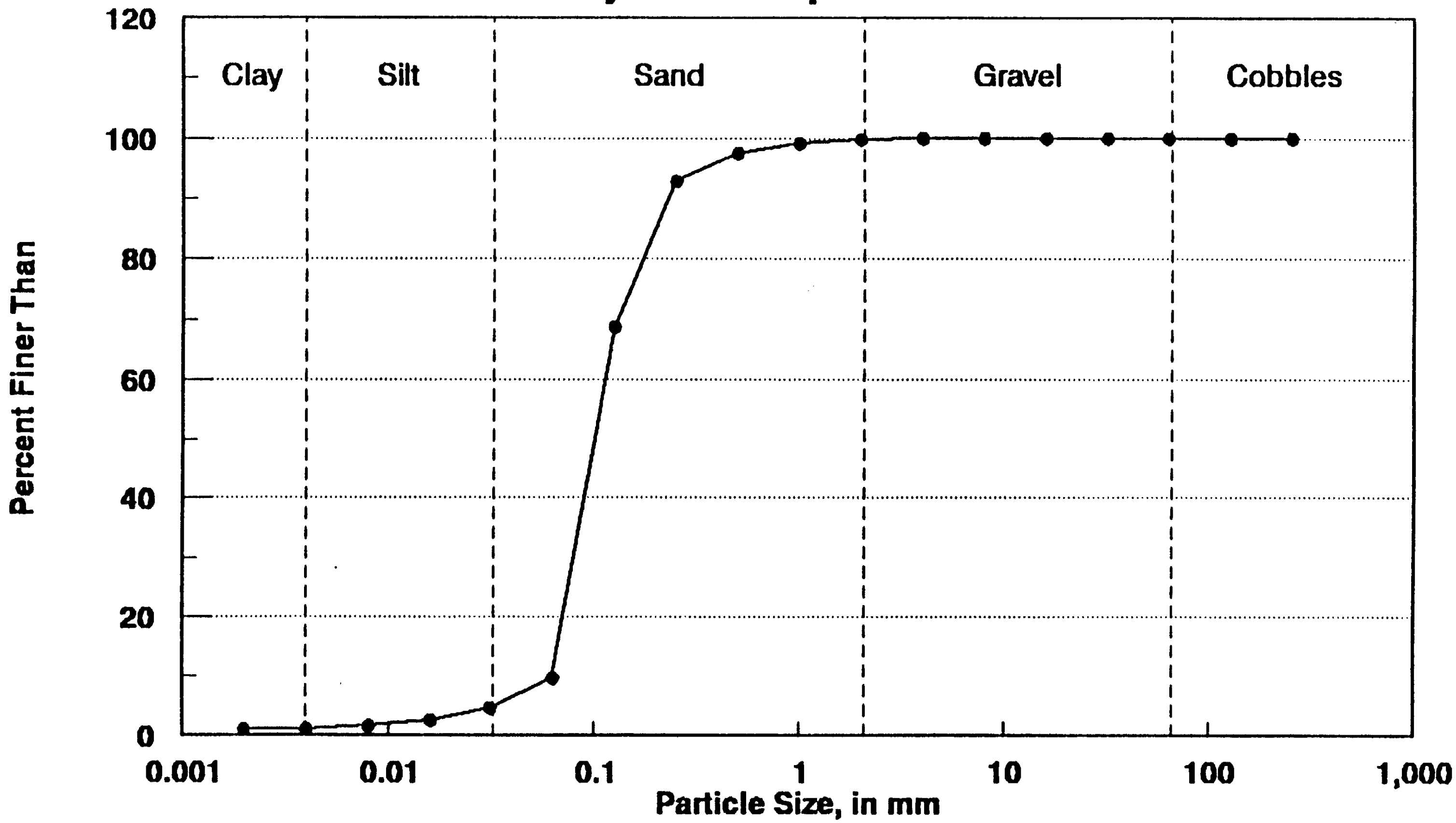


Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/28/93

Chevelon Creek above Confluence with Little Colorado River

Particle Size Distribution Analysis

Dry Bed Sample



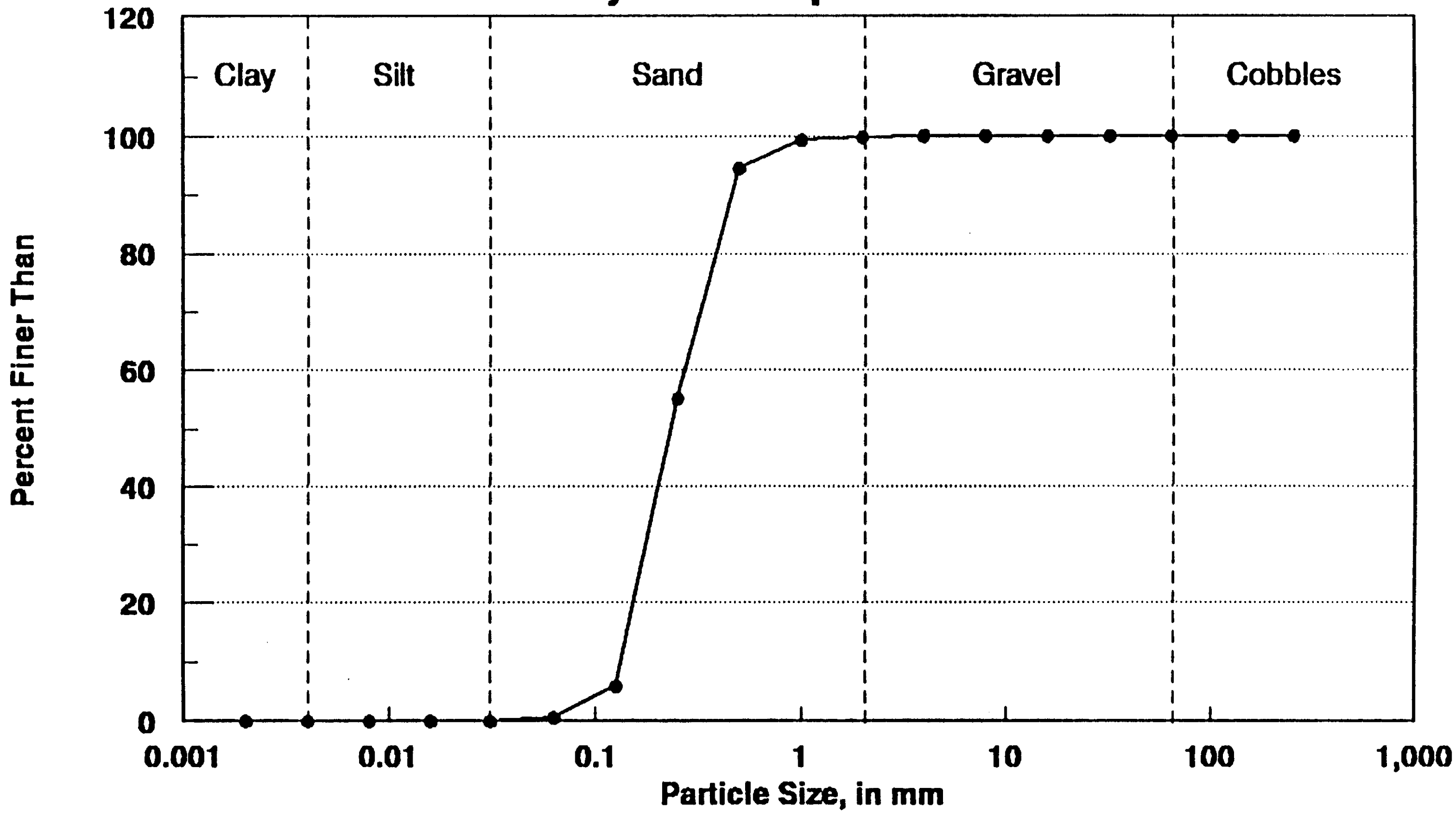
Sampled by RPM, Hopi Tribe, Analysis by USGS

Sample Date: 7/28/93

Leroux Wash at Broadcast Avenue, Holbrook

Particle Size Distribution Analysis

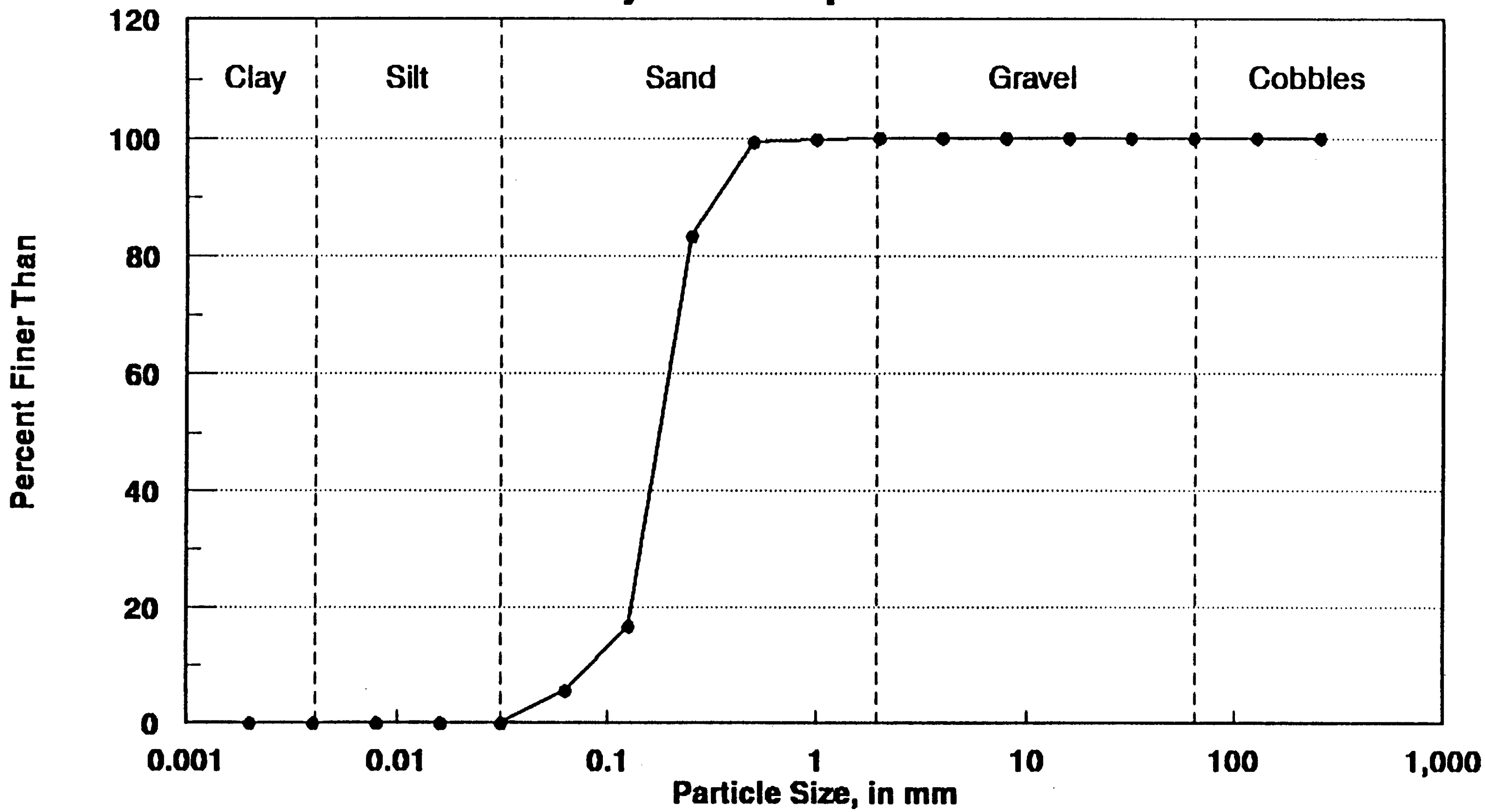
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/28/93

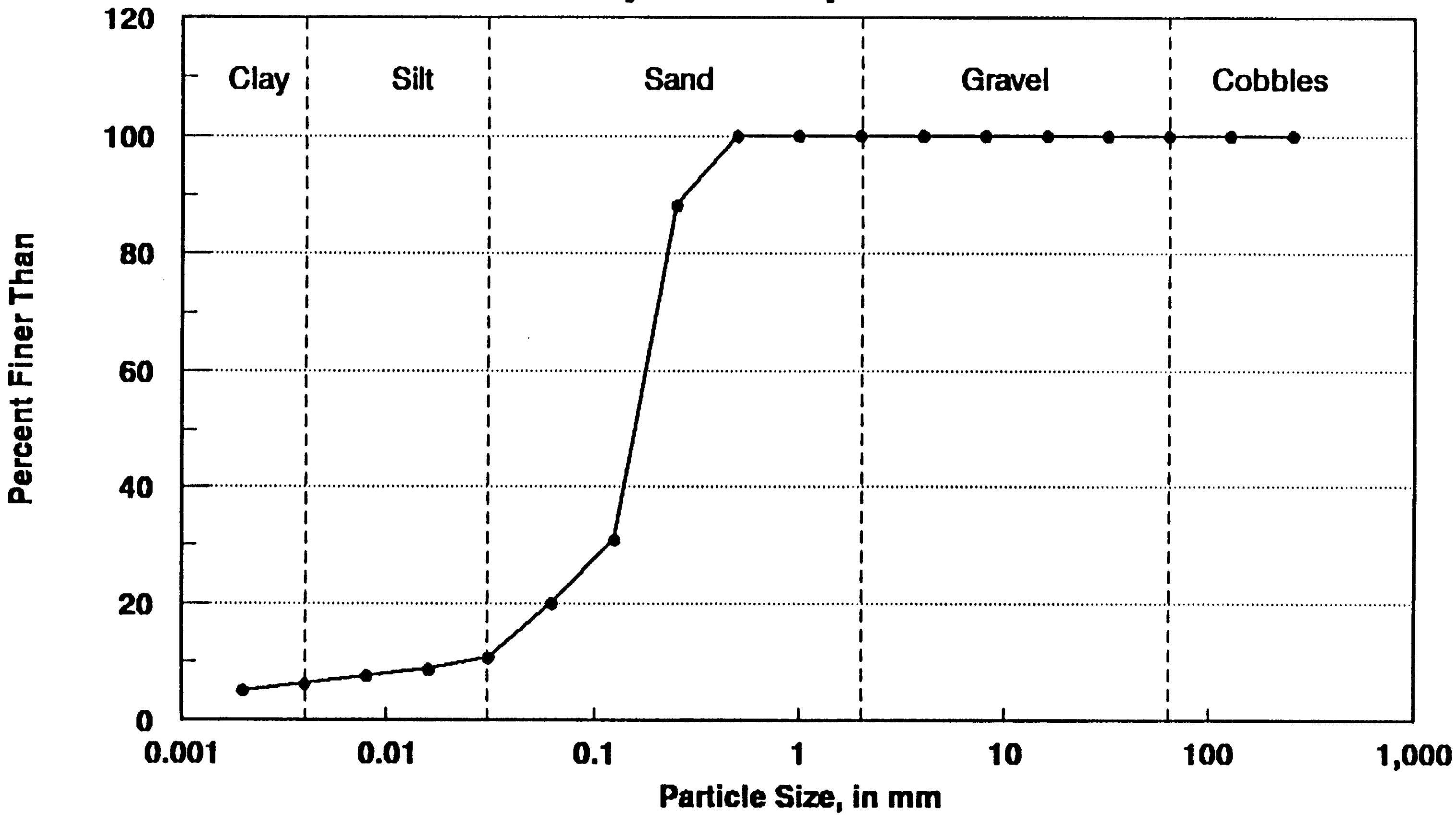
Little Colorado River at Holbrook, Old Bridge, Highway 180

Particle Size Distribution Analysis
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/28/93

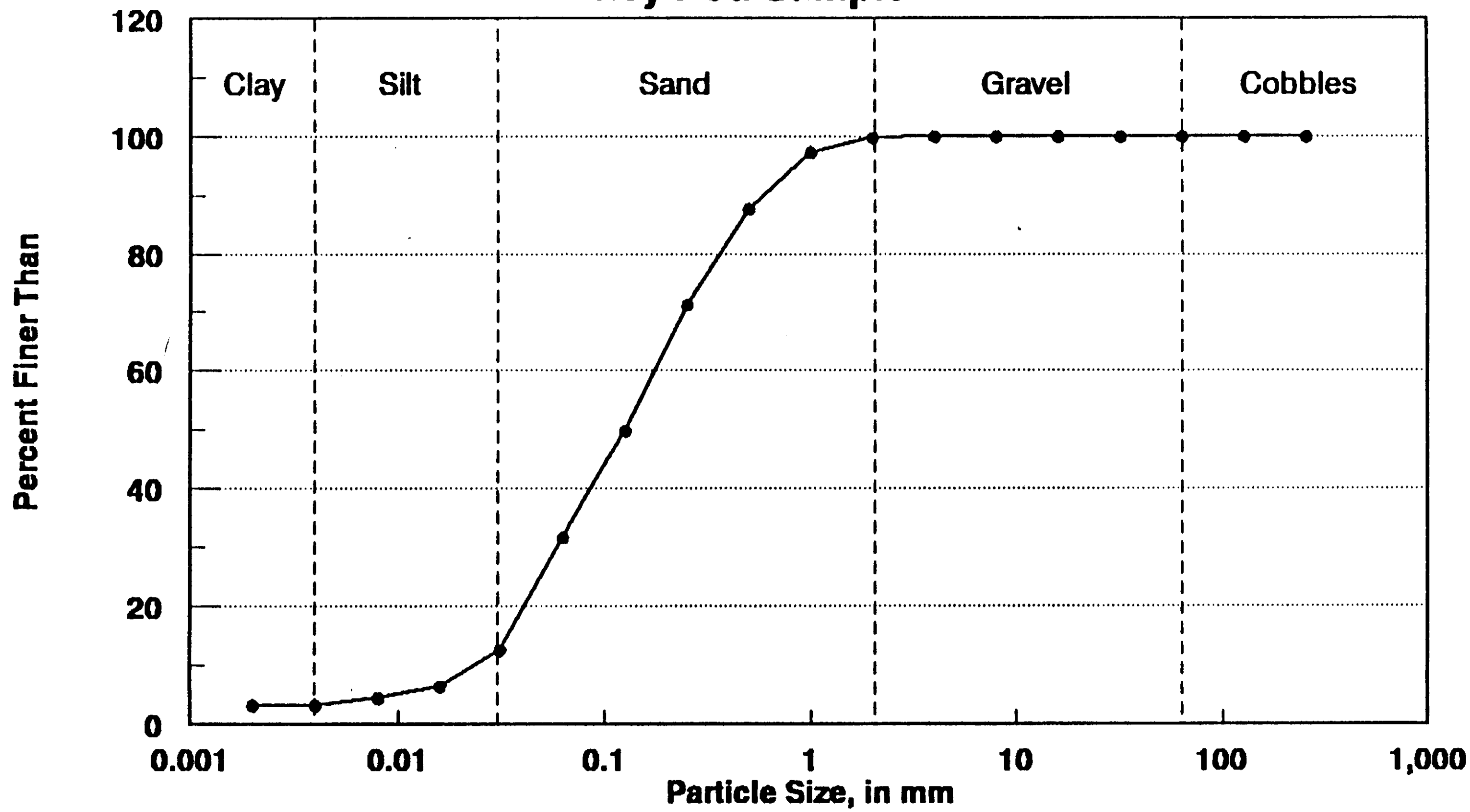
Cottonwood Wash at Interstate 40
Particle Size Distribution Analysis
Dry Bed Sample



Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Data: 7/28/93

Puerco River at Bridge, Navajo, Arizona

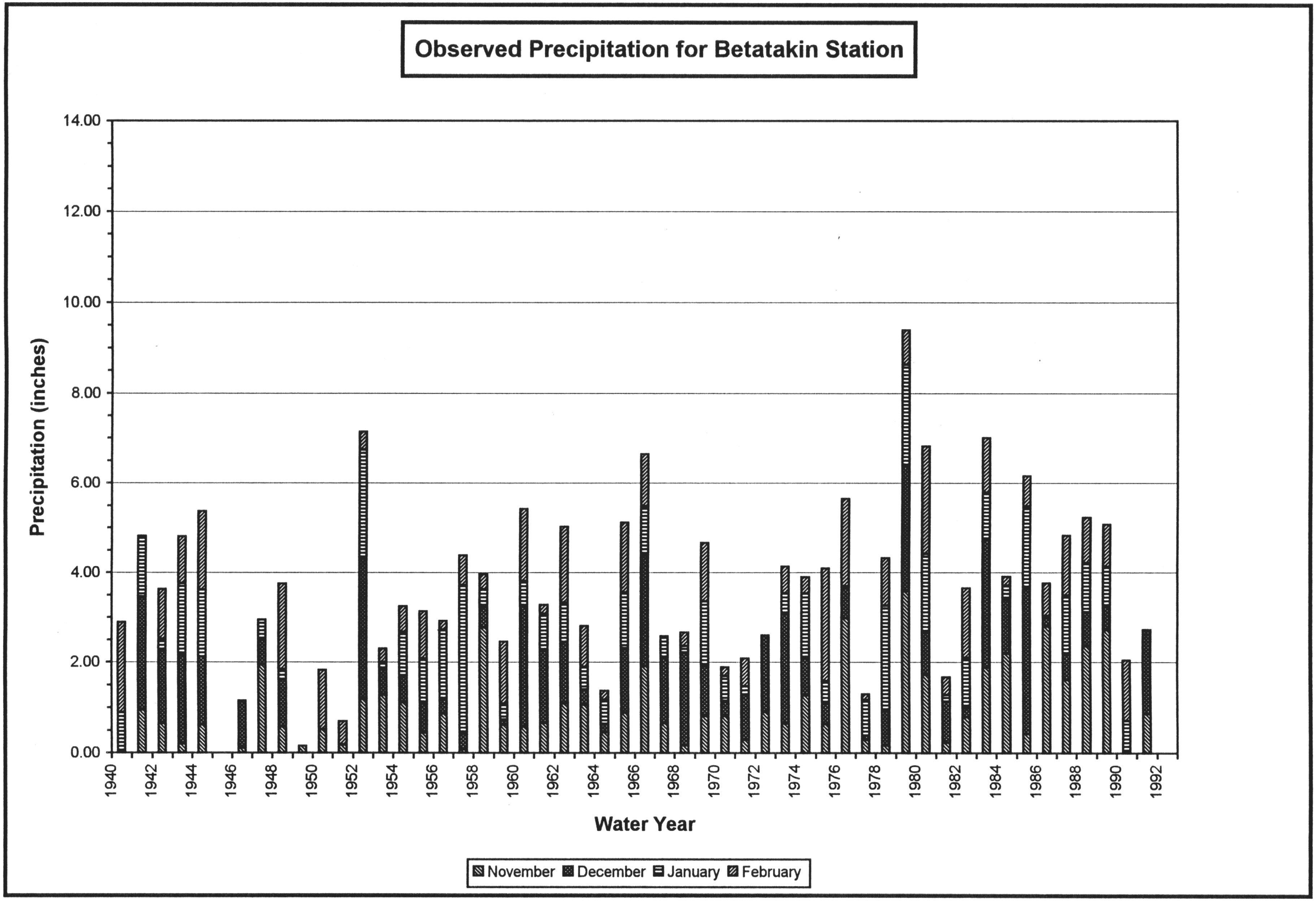
Particle Size Distribution Analysis
Dry Bed Sample

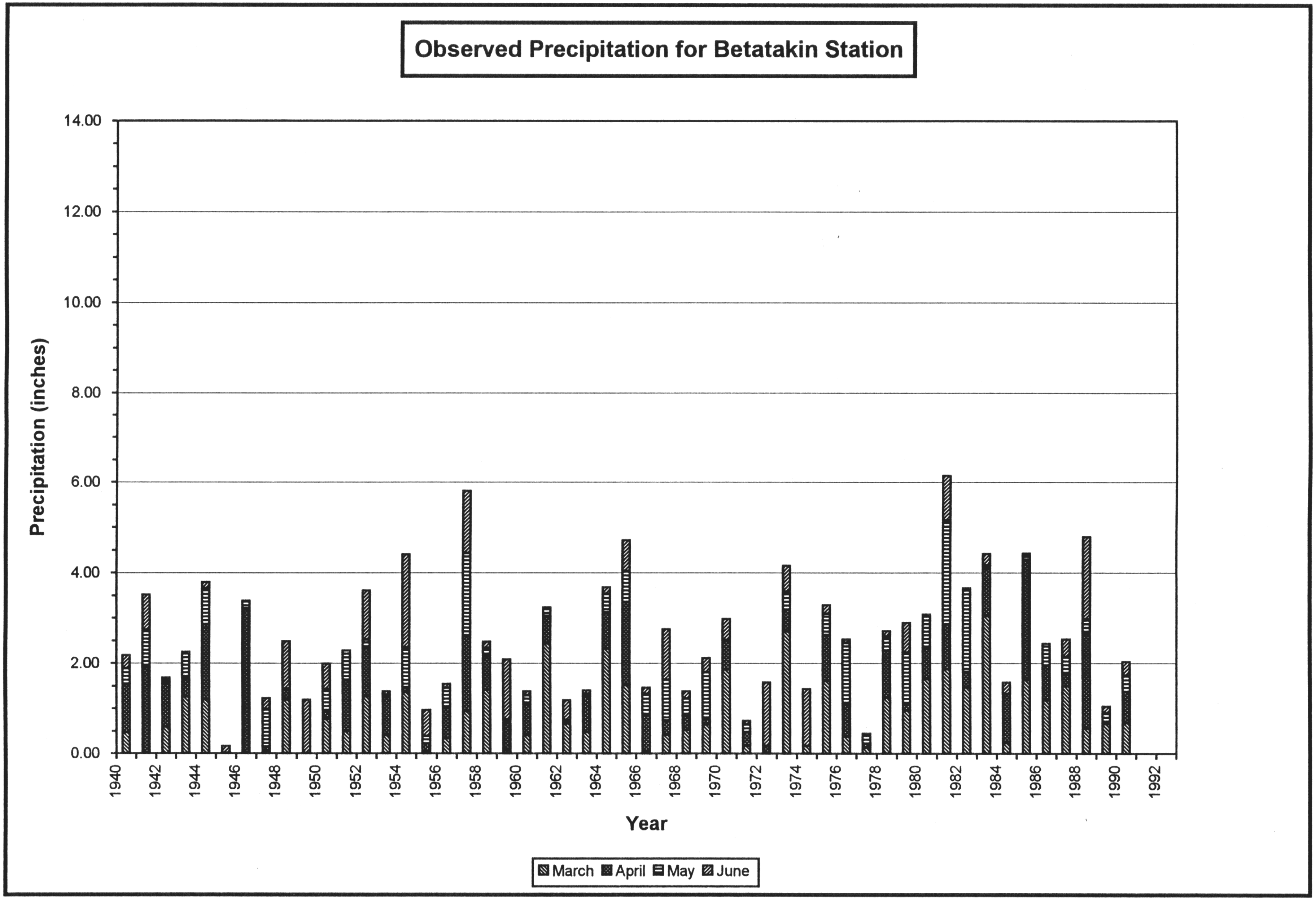


Sampled by RPM, Hopi Tribe, Analysis by USGS
Sample Date: 7/28/93

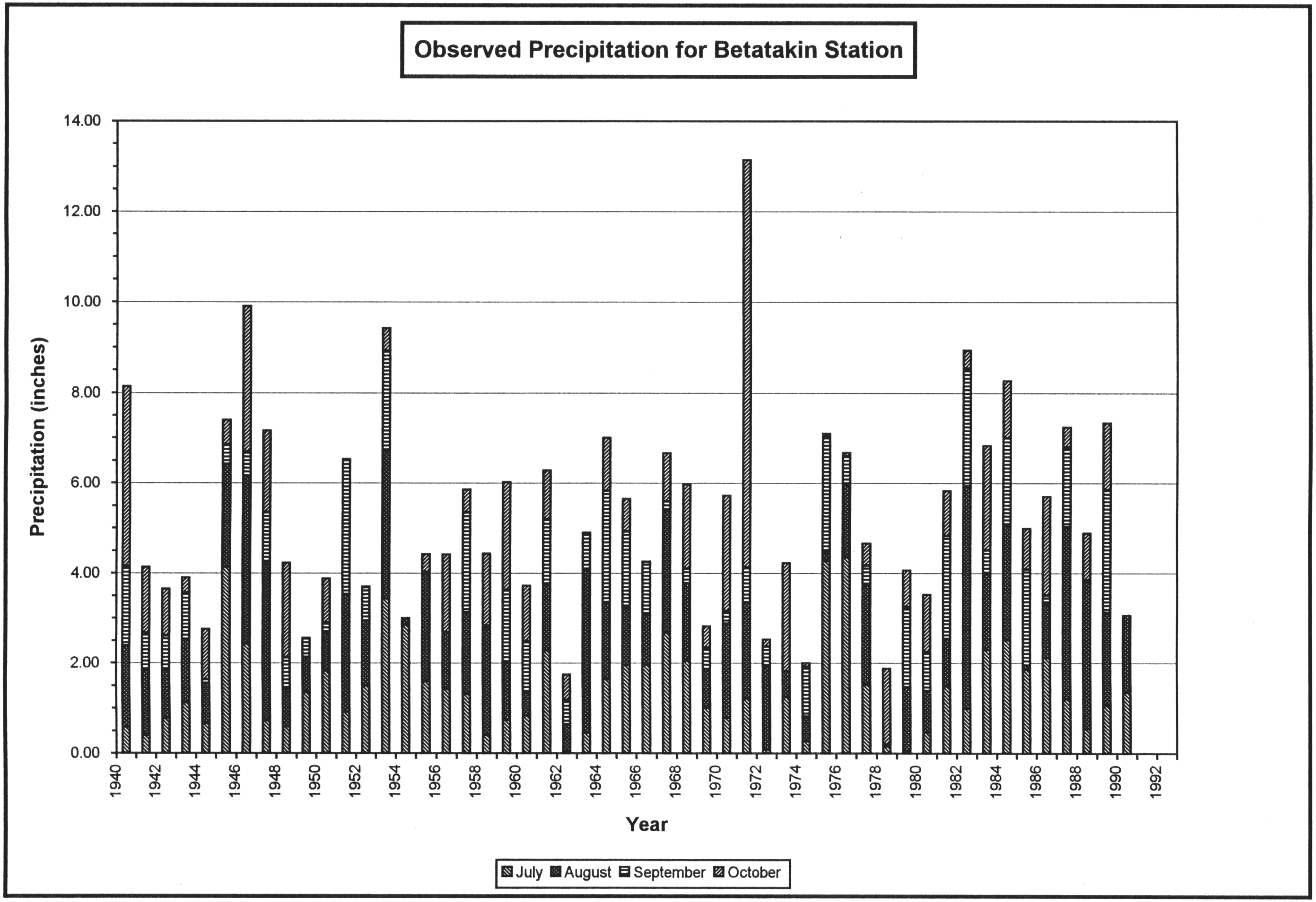
APPENDIX B

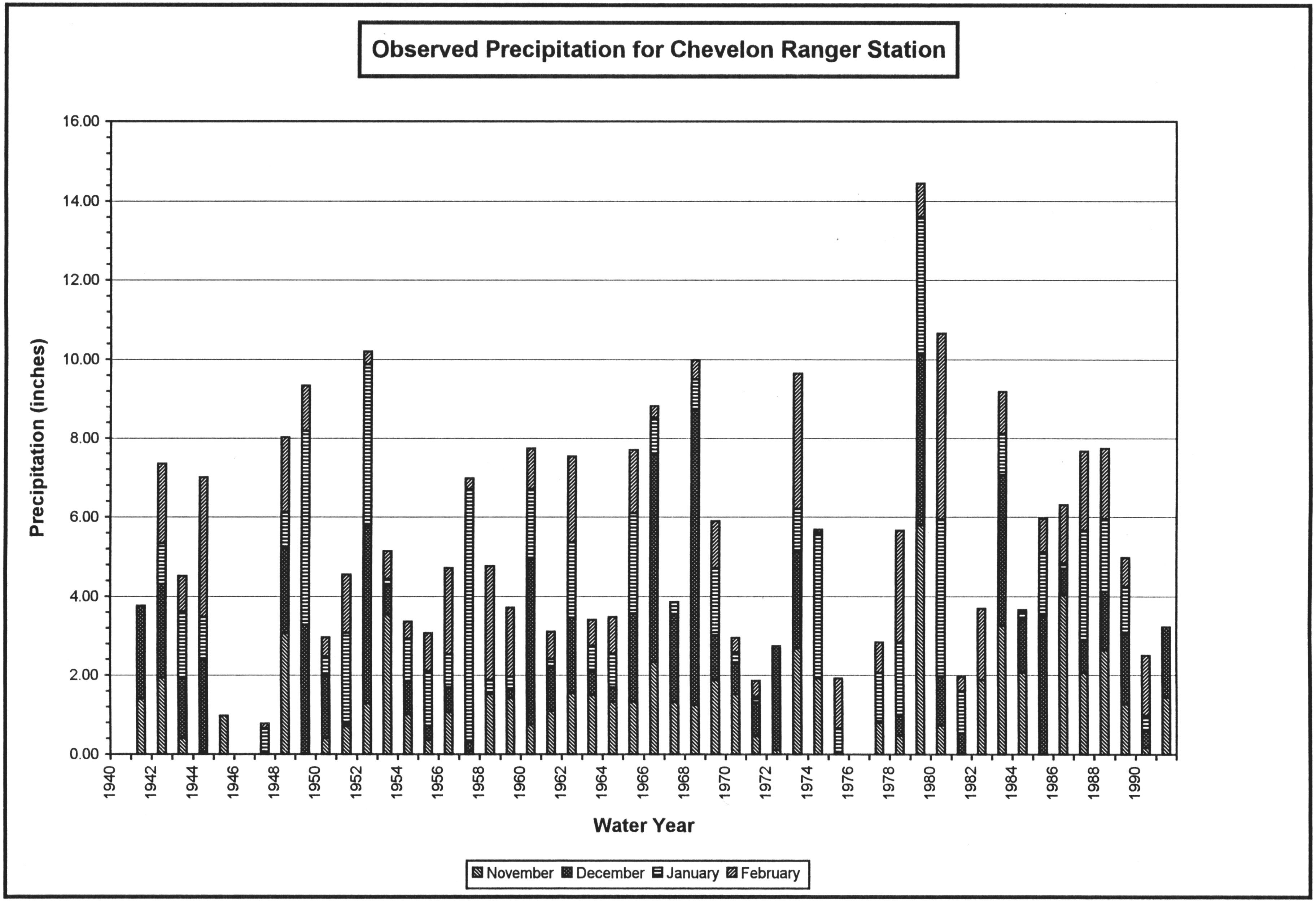
STACKED BAR GRAPHS FOR KEY PRECIPITATION STATIONS

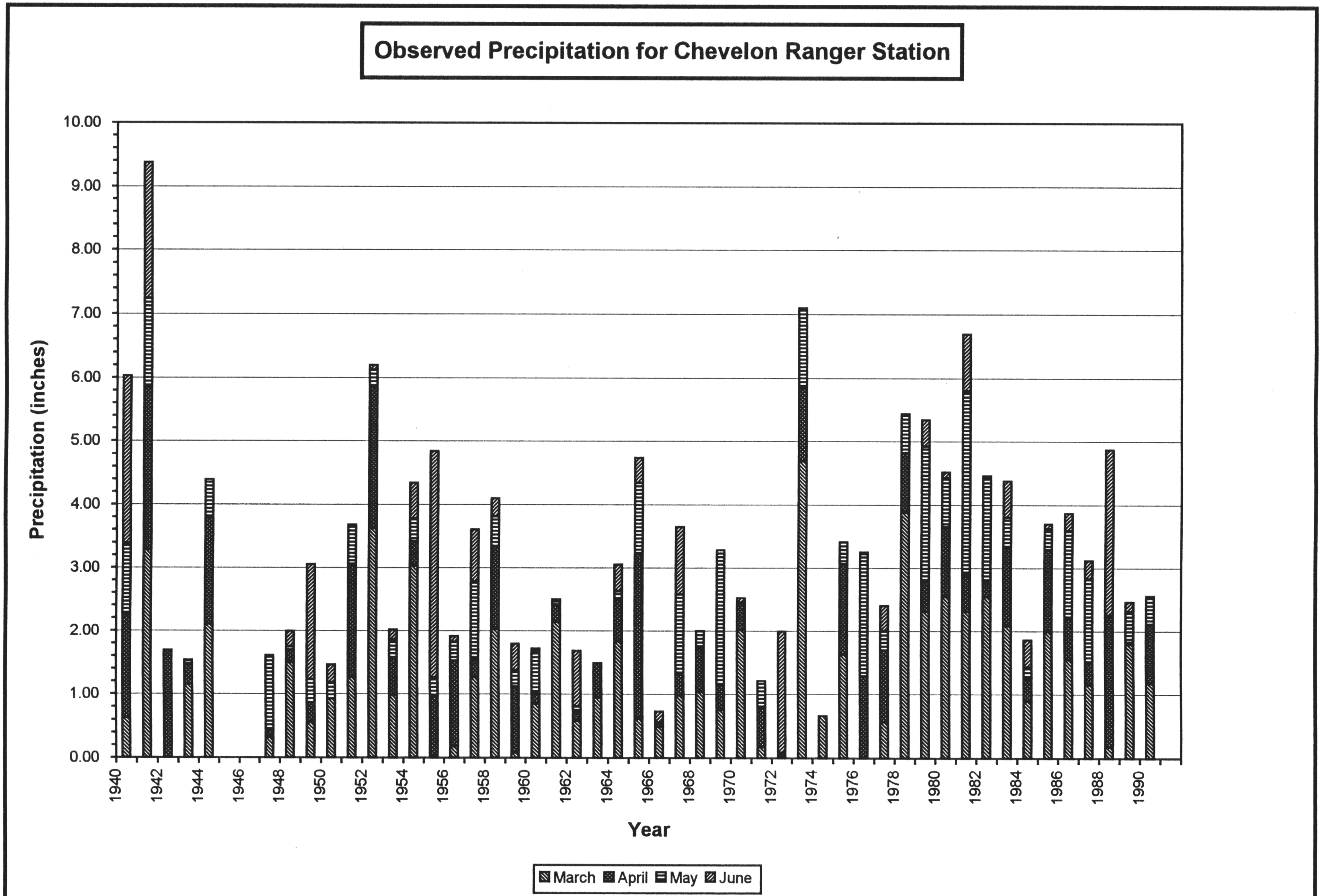

Observed Precipitation for Betatakin Station
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Precipitation (inches)
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Water Year
November
December
January
February

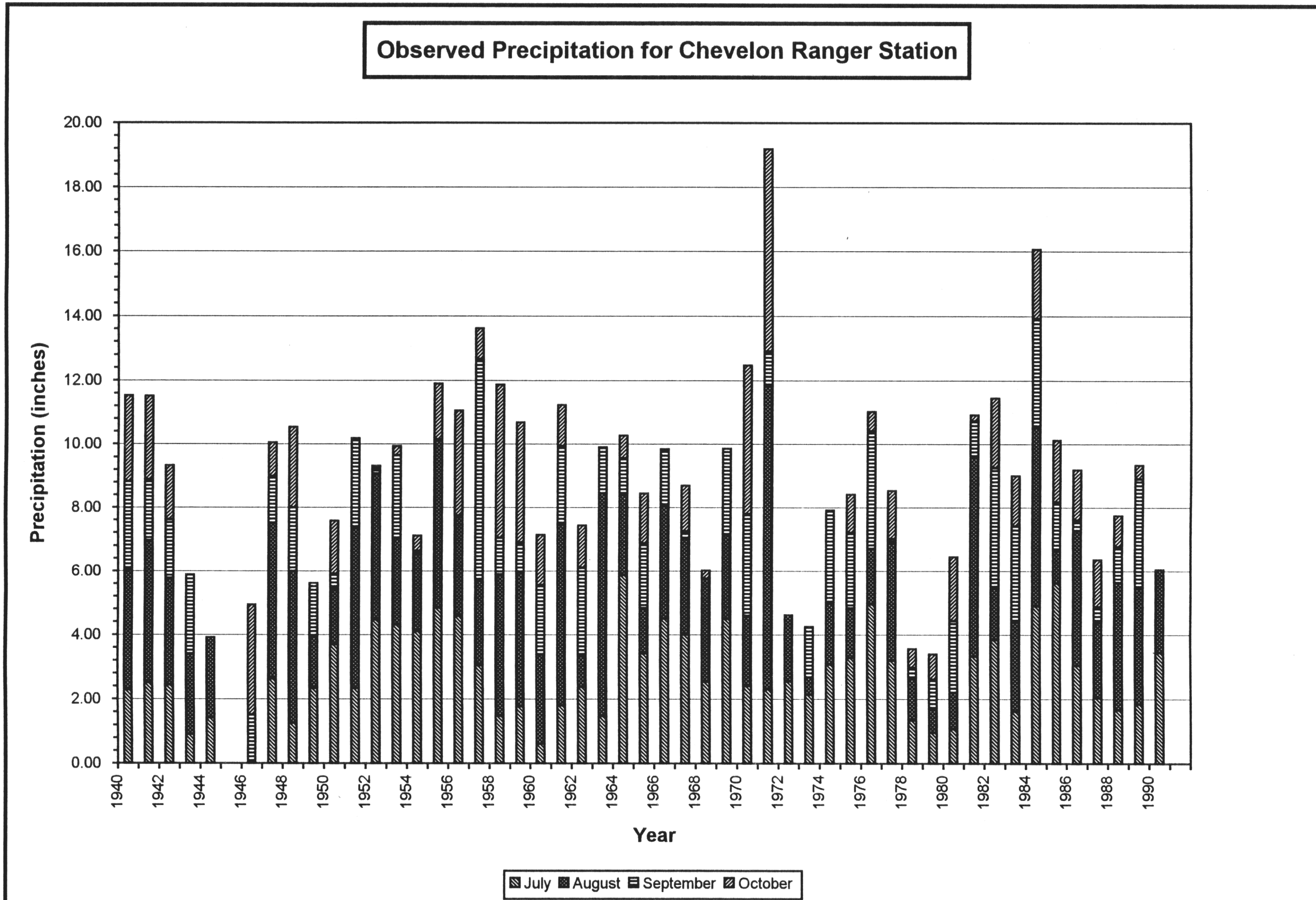


Observed Precipitation for Betatakin Station
Precipitation (inches)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Year
March
April
May
June

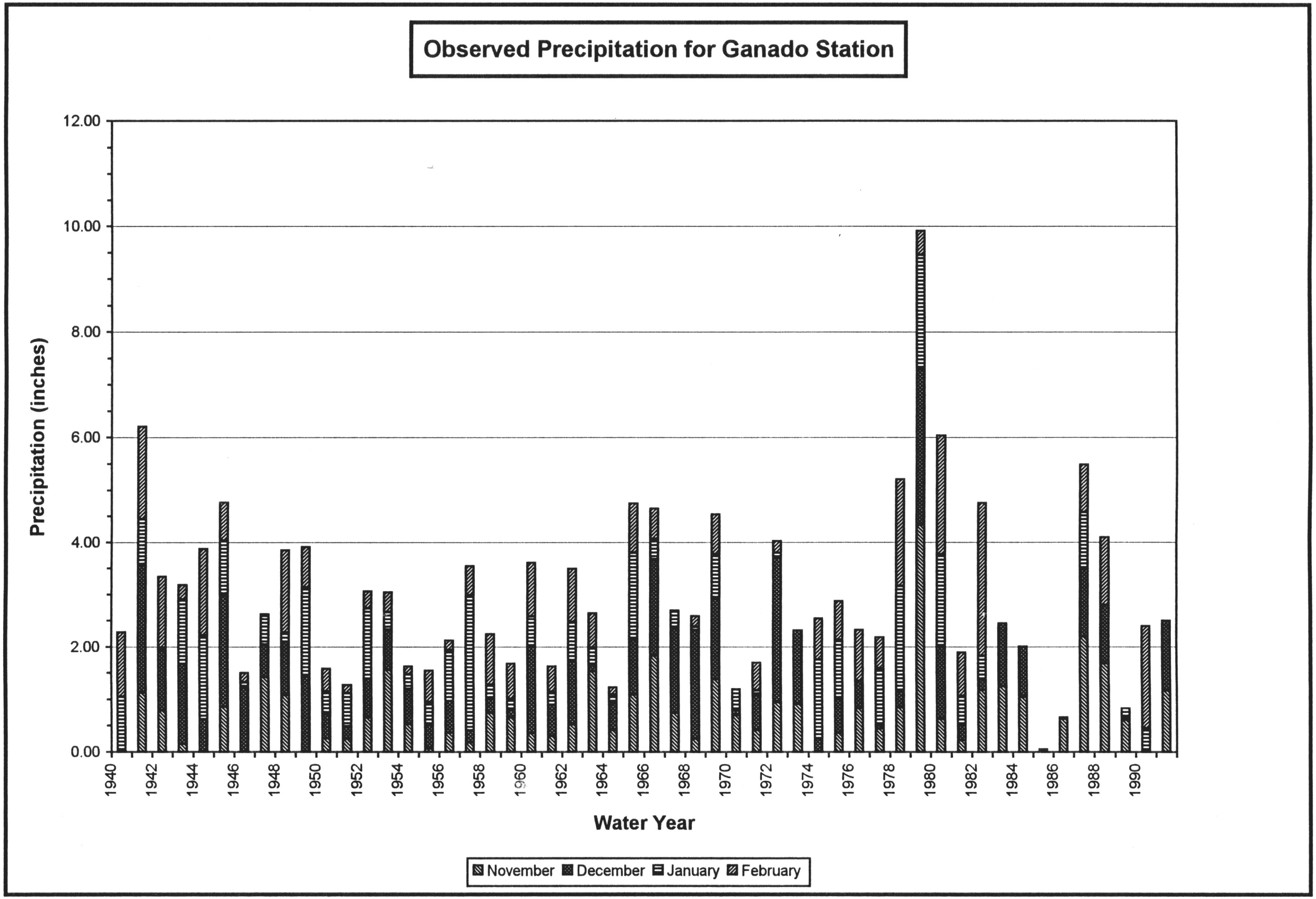

Observed Precipitation for Betatakin Station
Precipitation (inches)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
Year
July
August
September
October

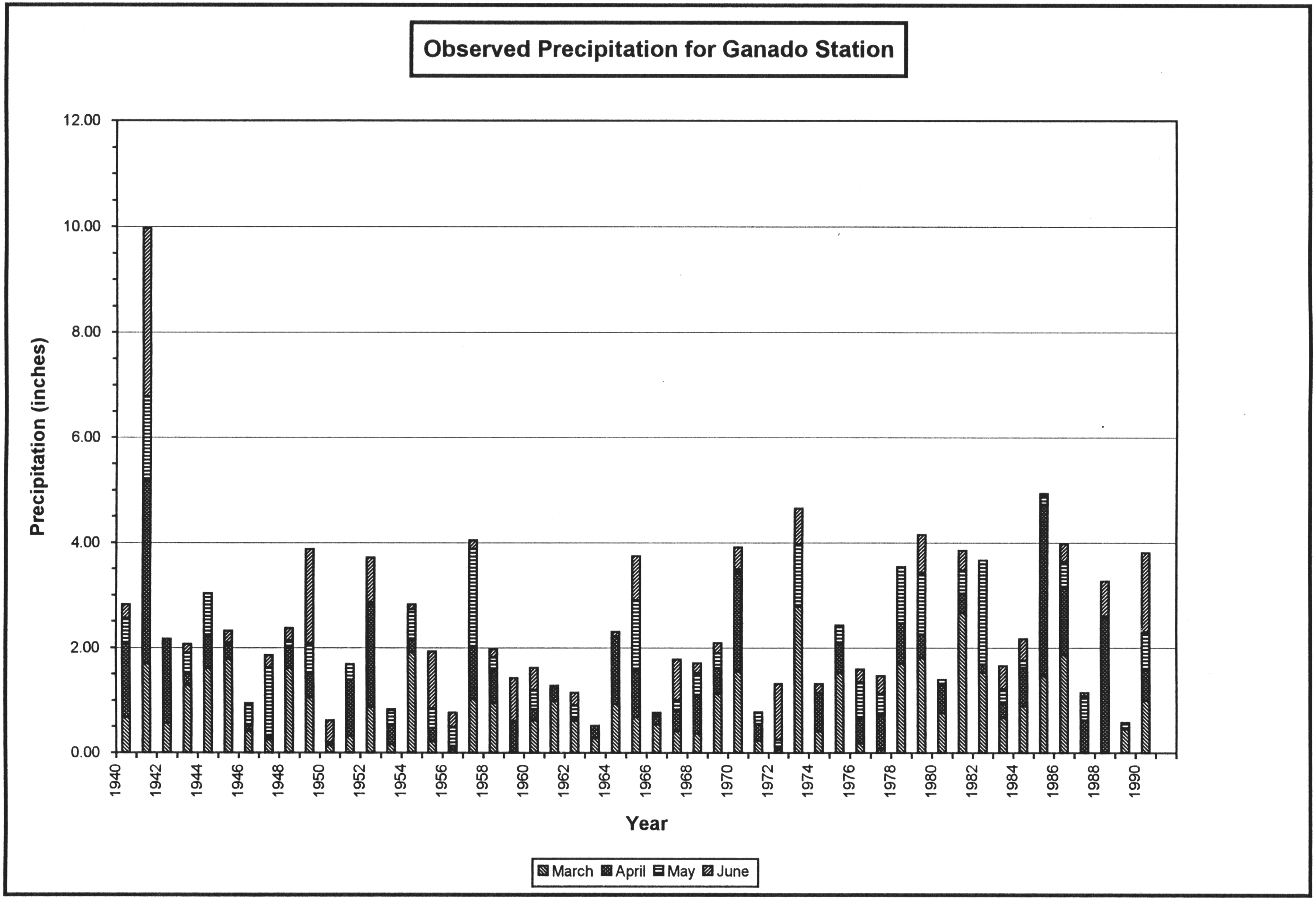

Observed Precipitation for Chevelon Ranger Station
Precipitation (inches)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February

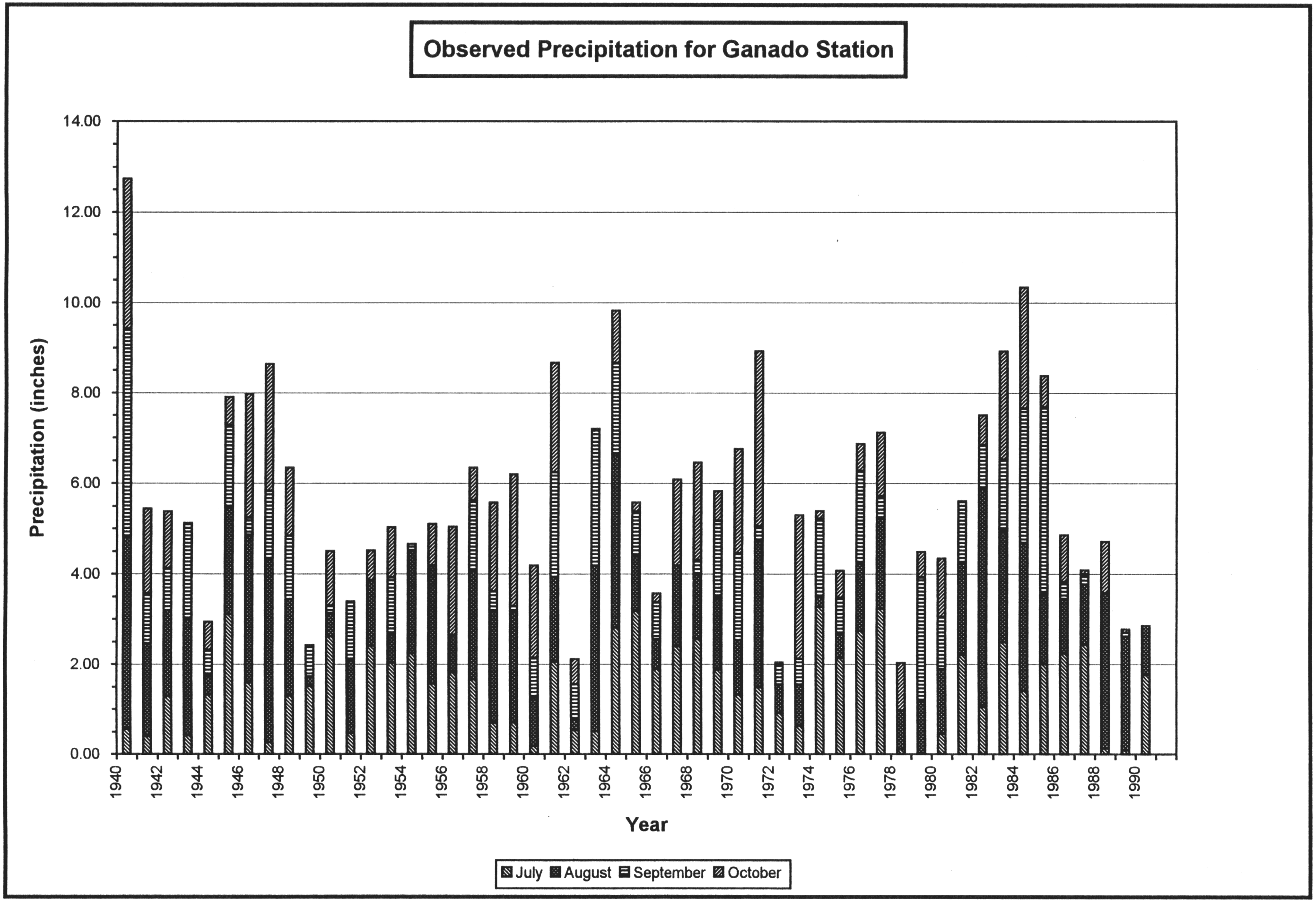

Observed Precipitation for Chevelon Ranger Station
Precipitation (inches)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
March
April
May
June



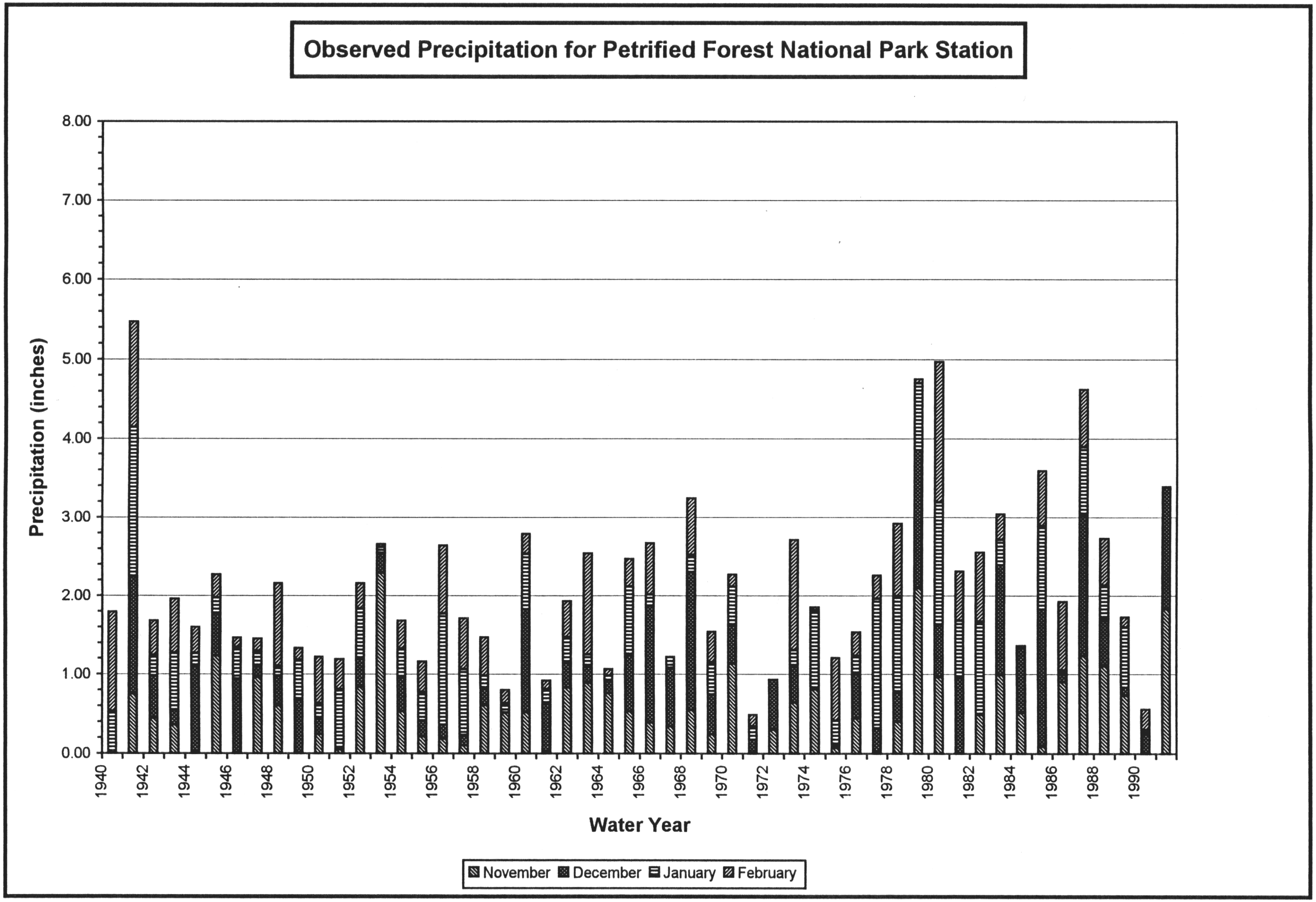
Observed Precipitation for Chevelon Ranger Station
Precipitation (inches)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October

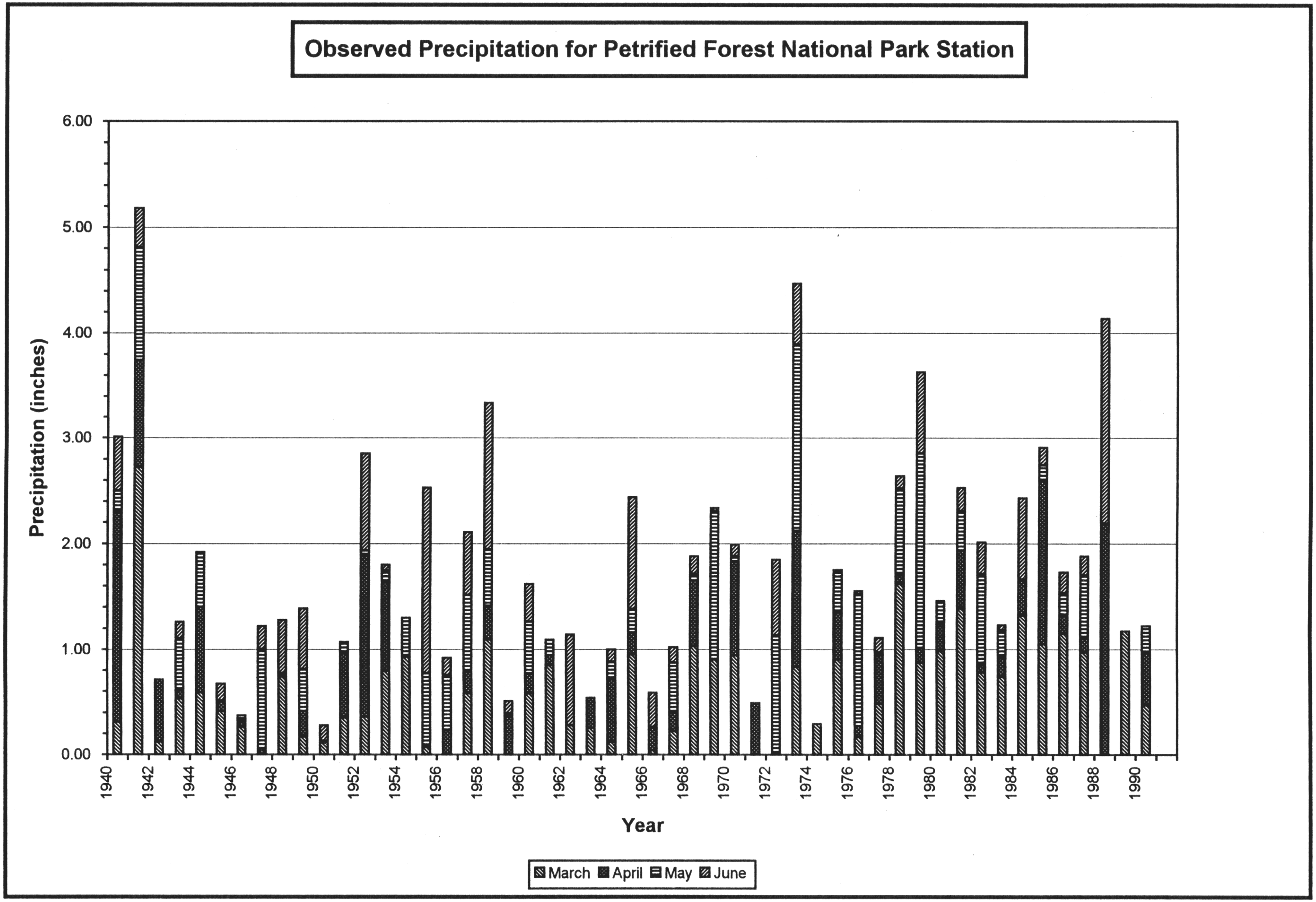

Observed Precipitation for Ganado Station
Precipitation (inches)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February

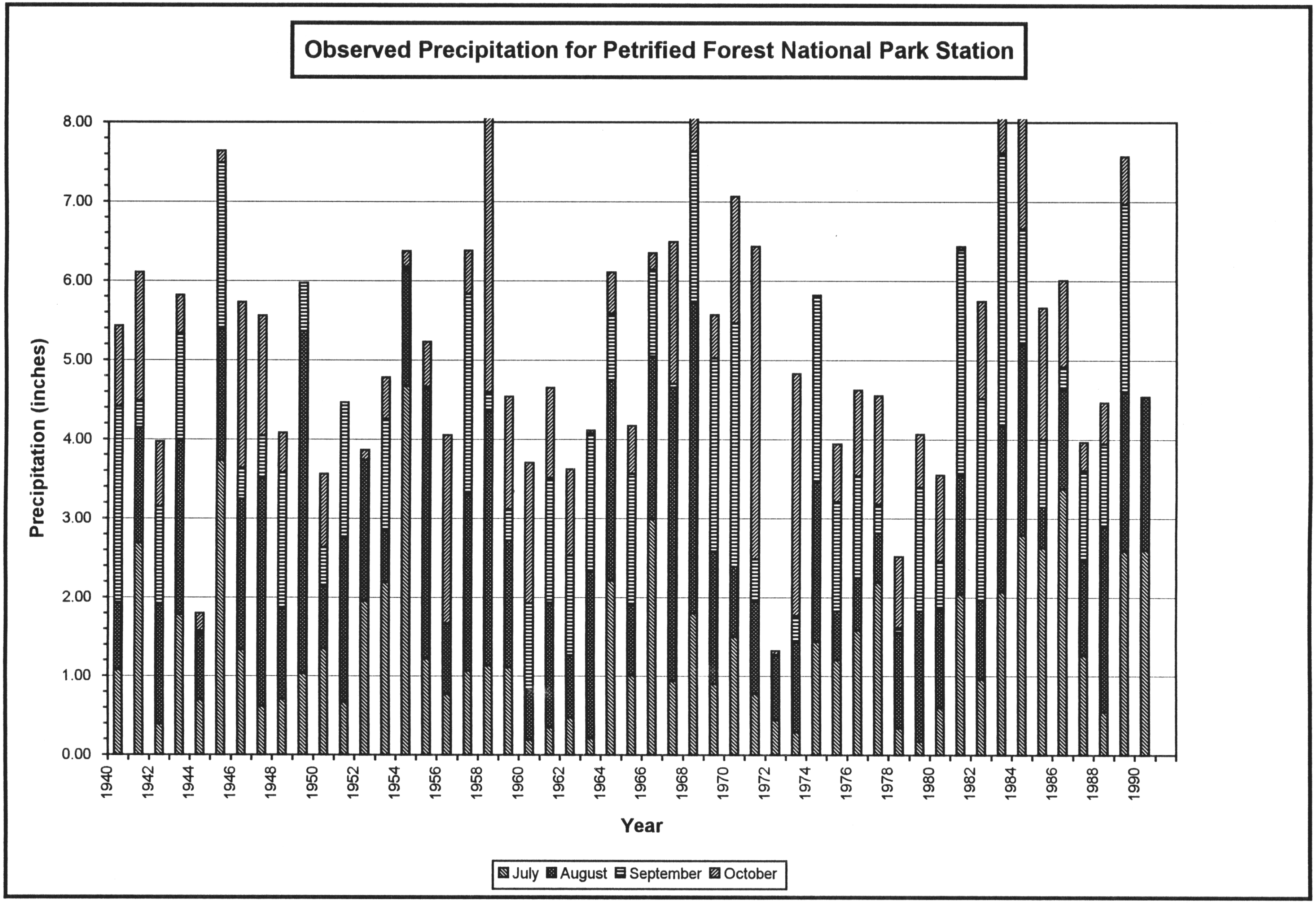

Observed Precipitation for Ganado Station
Precipitation (inches)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
March
April
May
June



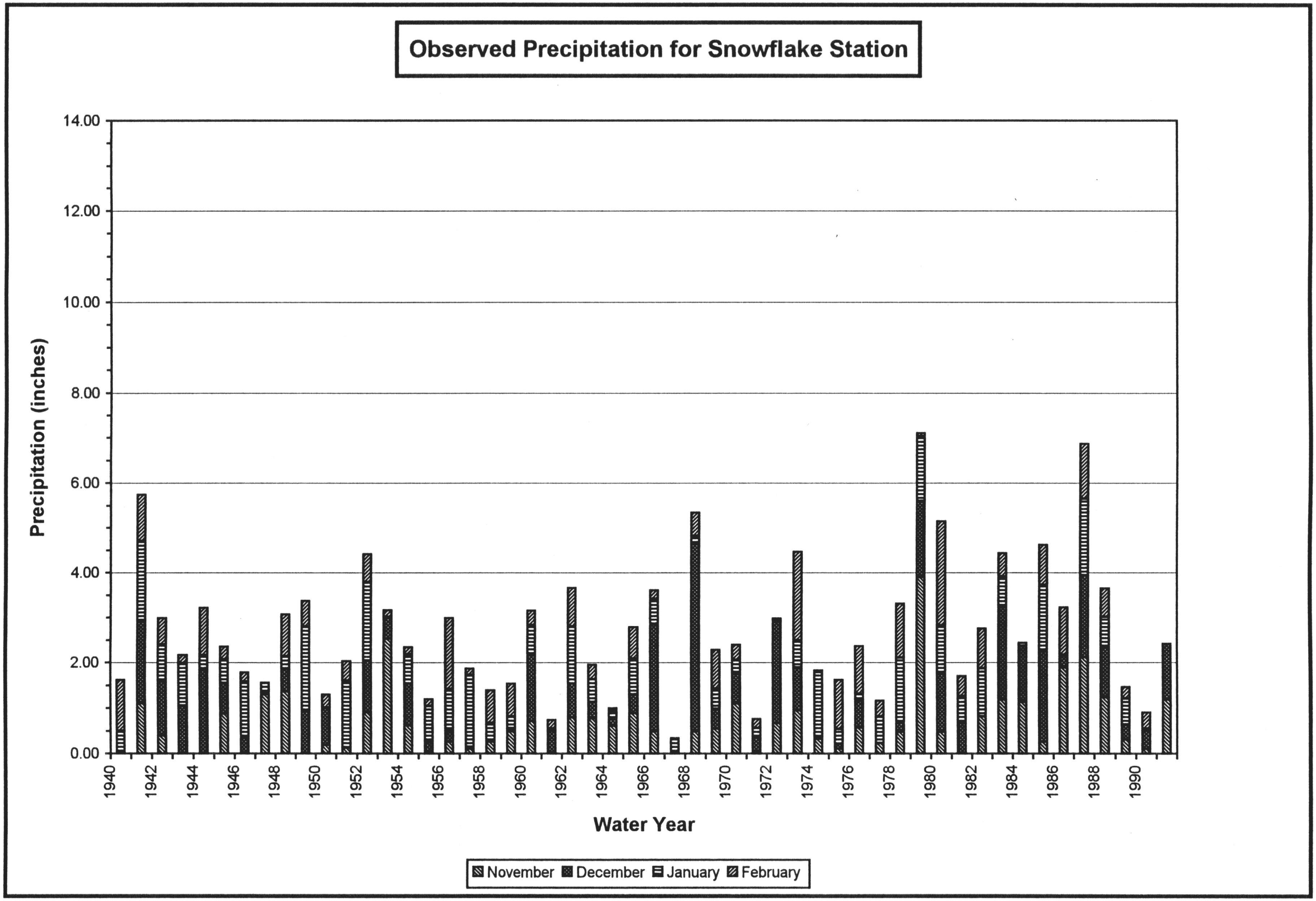
Observed Precipitation for Ganado Station
Precipitation (inches)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October


Observed Precipitation for Petrified Forest National Park Station
Precipitation (inches)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February

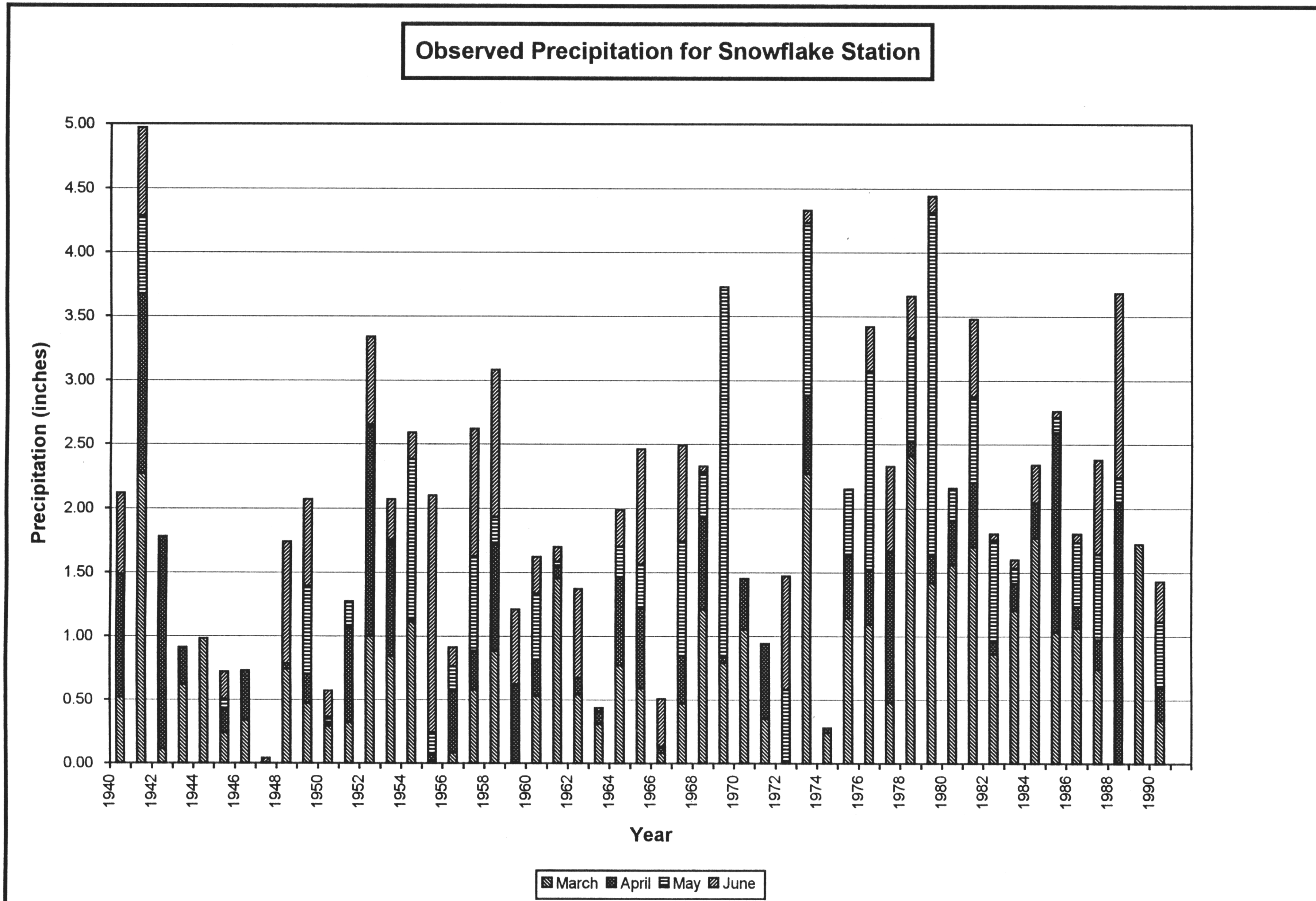

Observed Precipitation for Petrified Forest National Park Station
Precipitation (inches)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
March
April
May
June



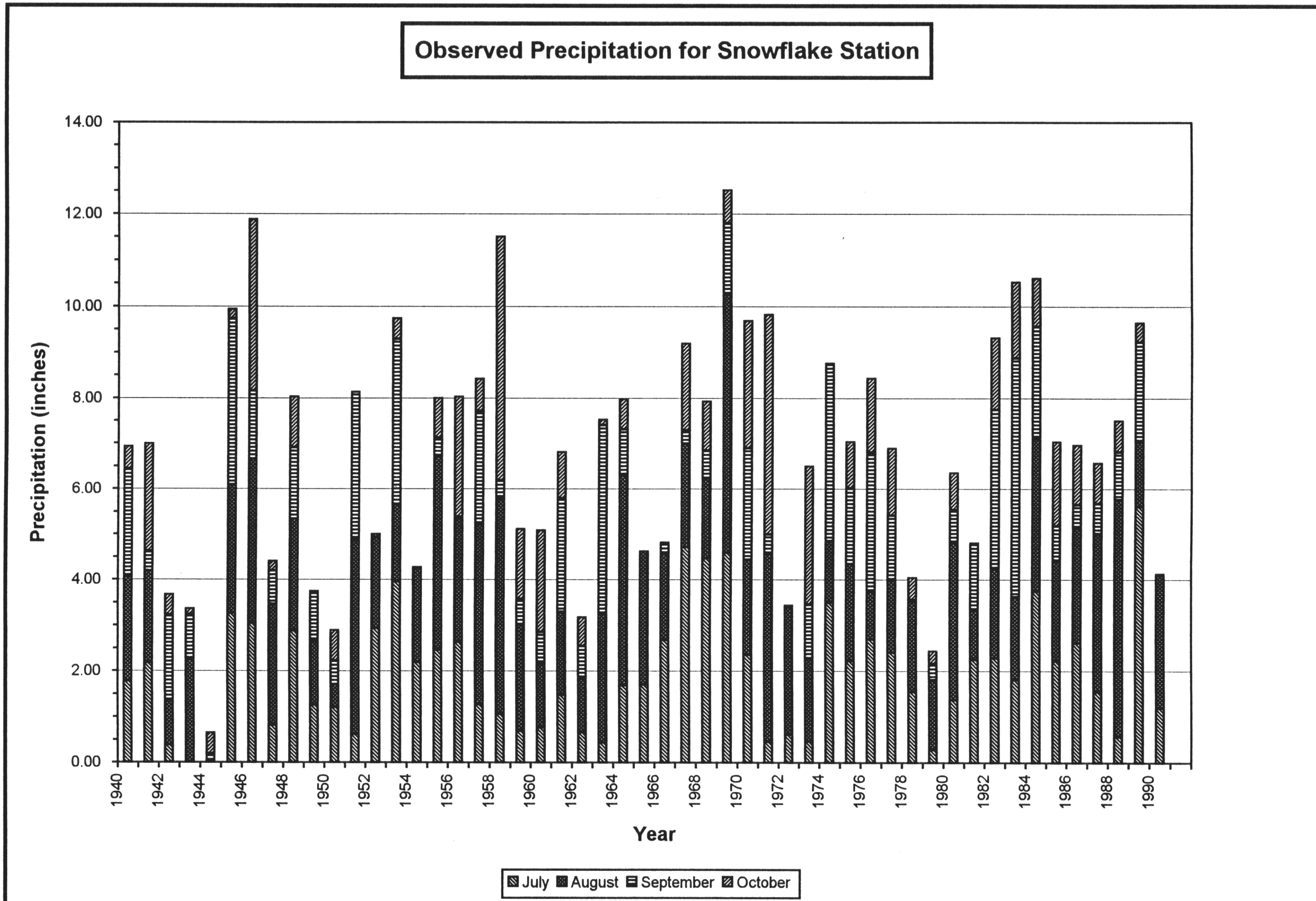
Observed Precipitation for Petrified Forest National Park Station
Precipitation (inches)
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October



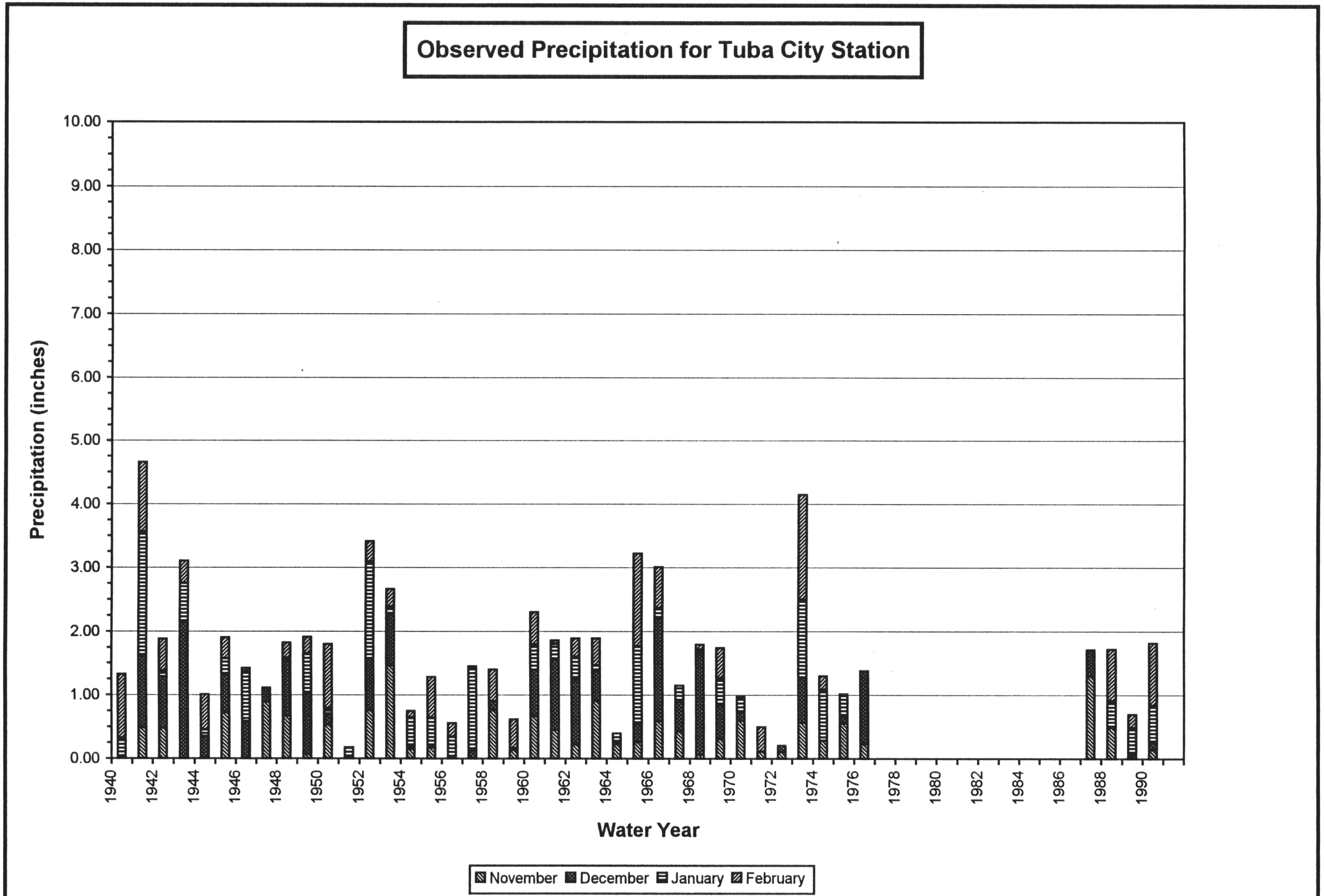
Observed Precipitation for Snowflake Station
Precipitation (inches)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February

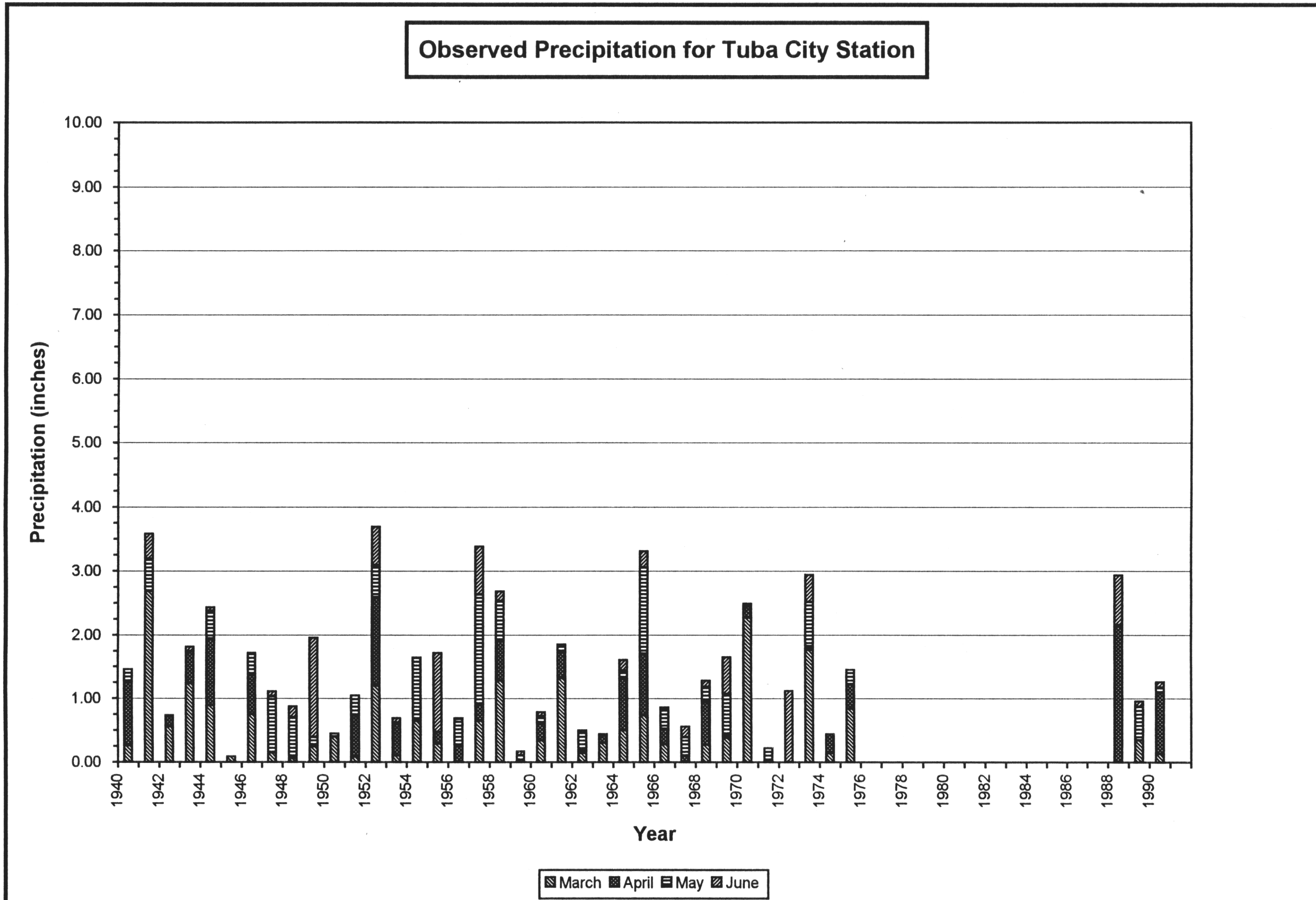


Observed Precipitation for Snowflake Station
Precipitation (inches)
5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
March April May June



Observed Precipitation for Snowflake Station
Precipitation (inches)
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October


Observed Precipitation for Tuba City Station
Precipitation (inches)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February



Observed Precipitation for Tuba City Station
Precipitation (inches)
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
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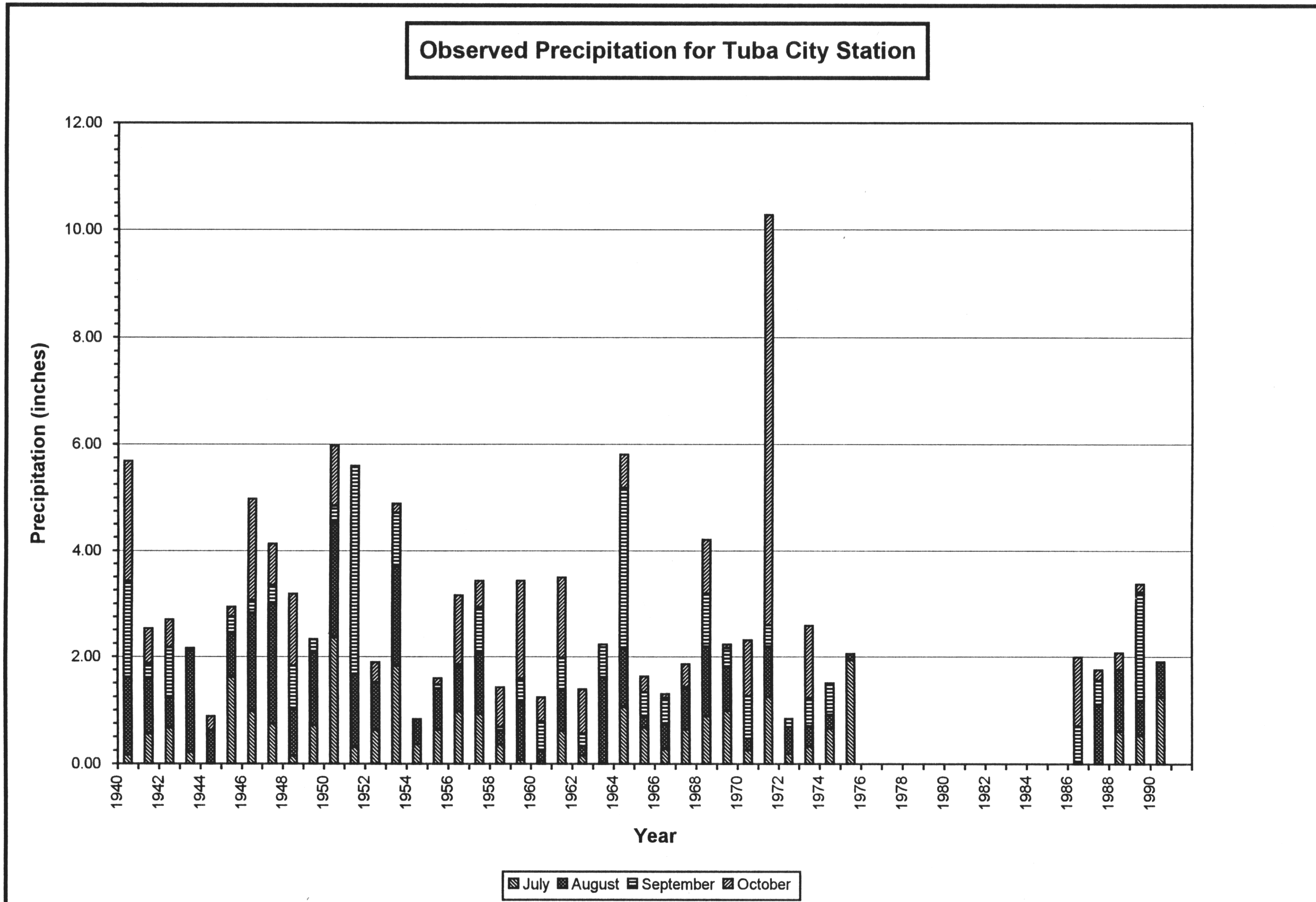
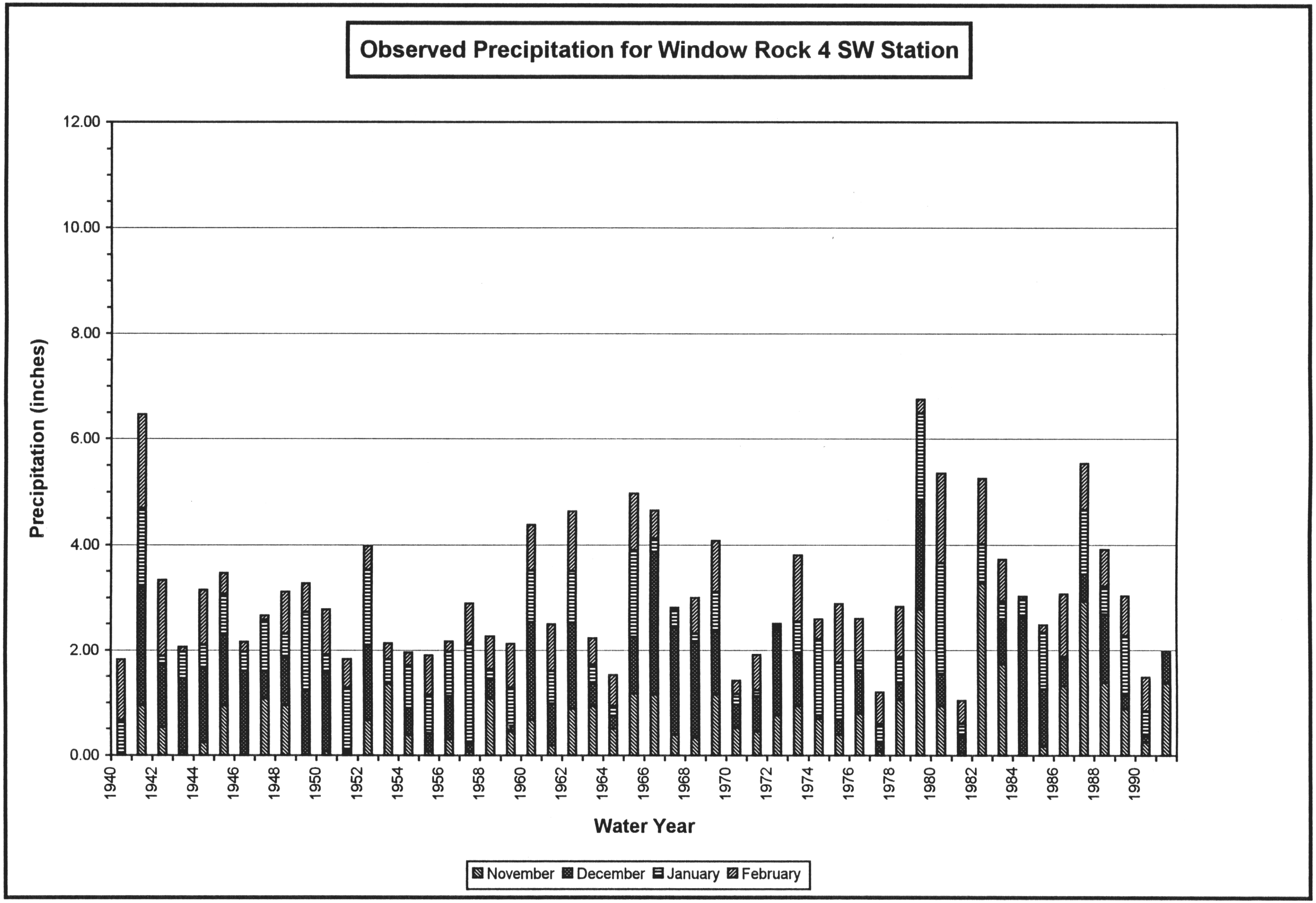
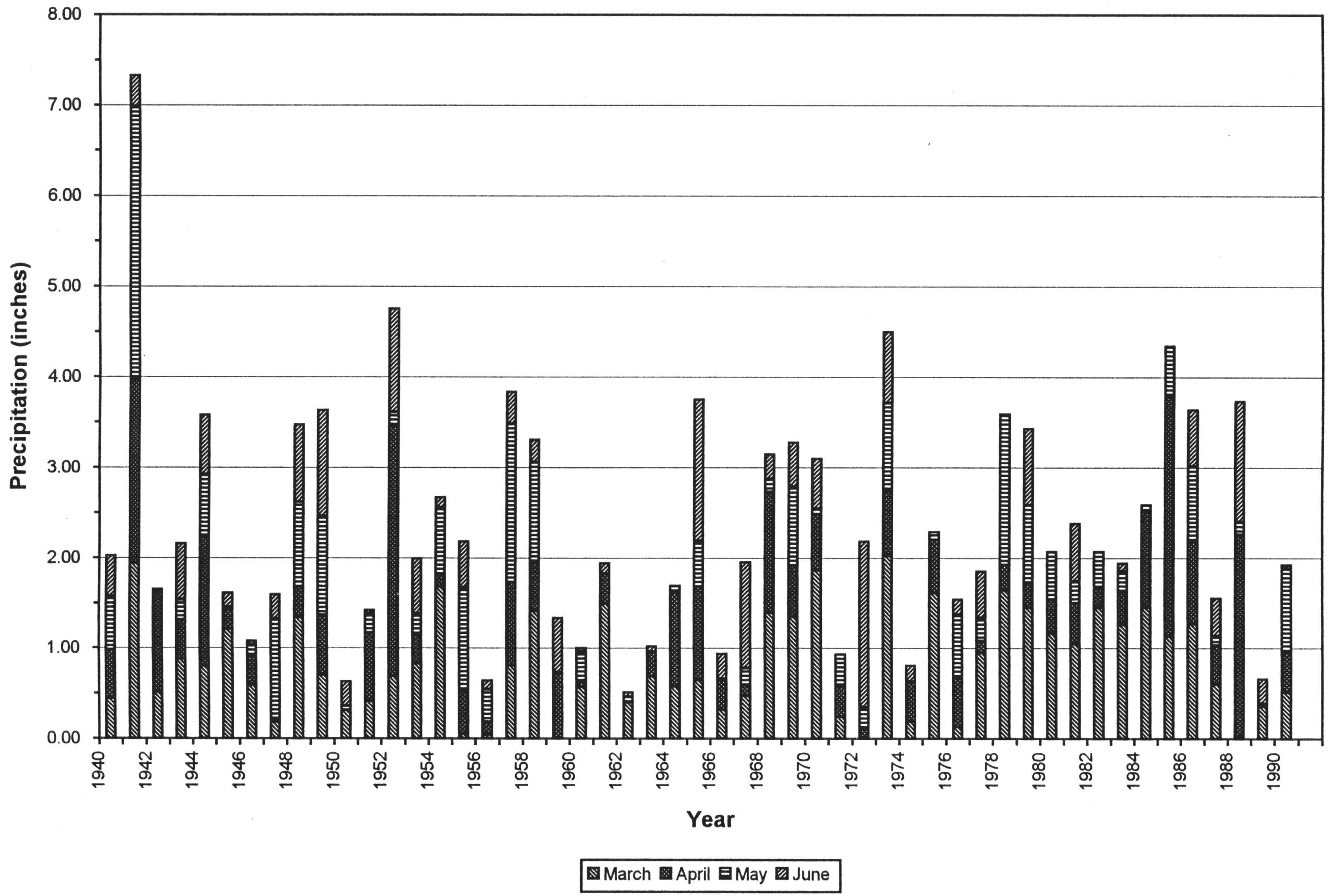
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
March
April
May
June

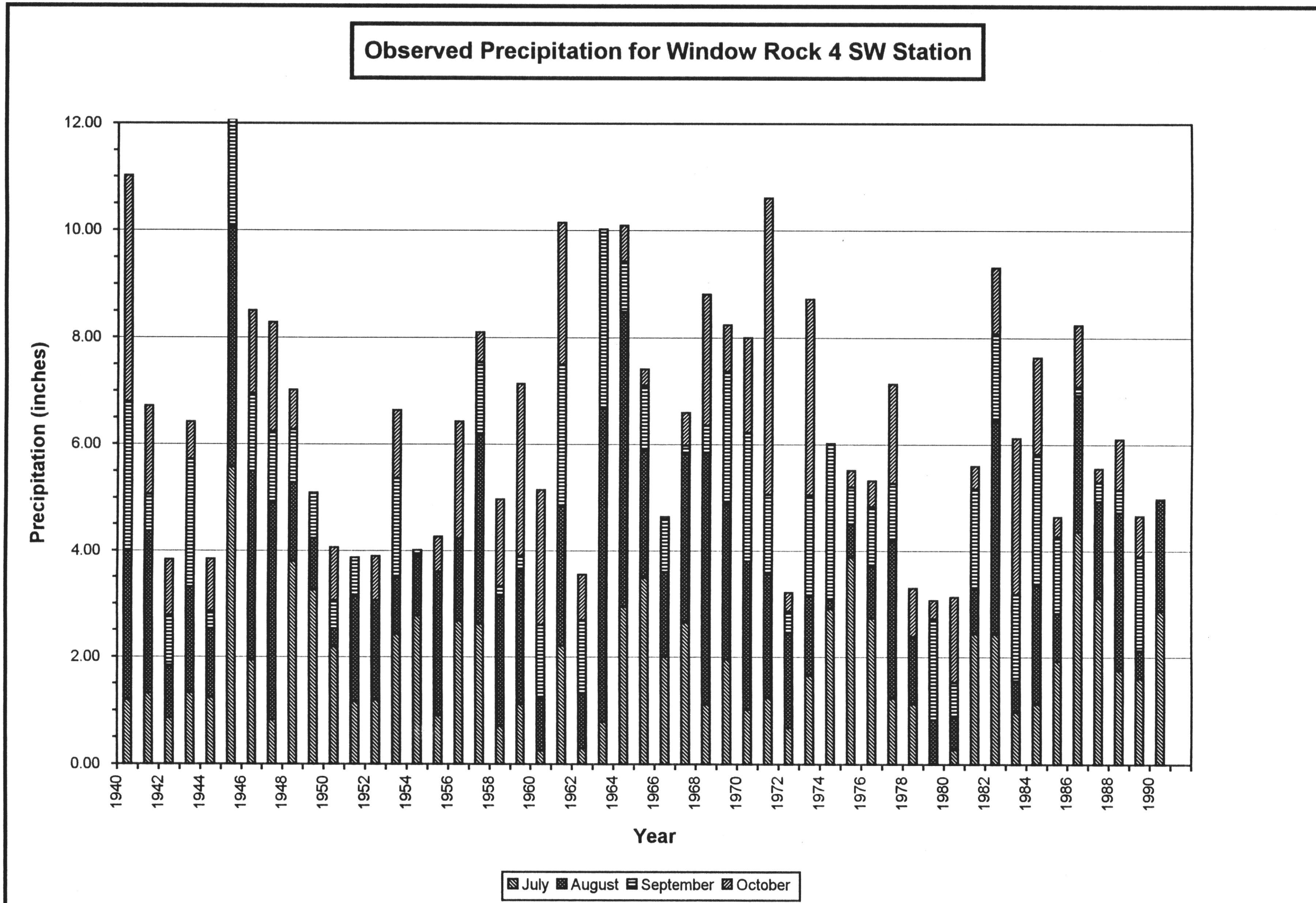


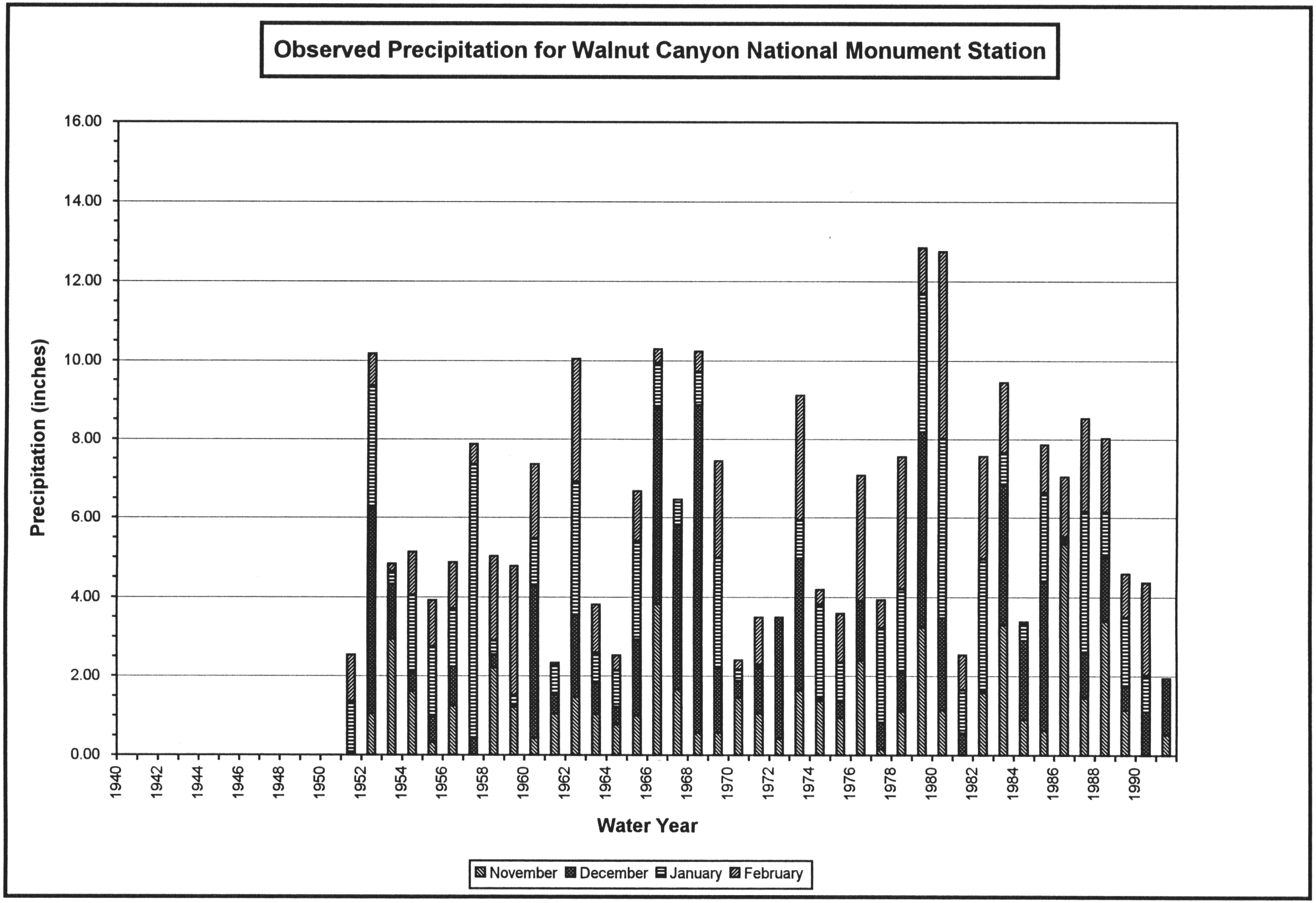
Observed Precipitation for Tuba City Station
Precipitation (inches)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October

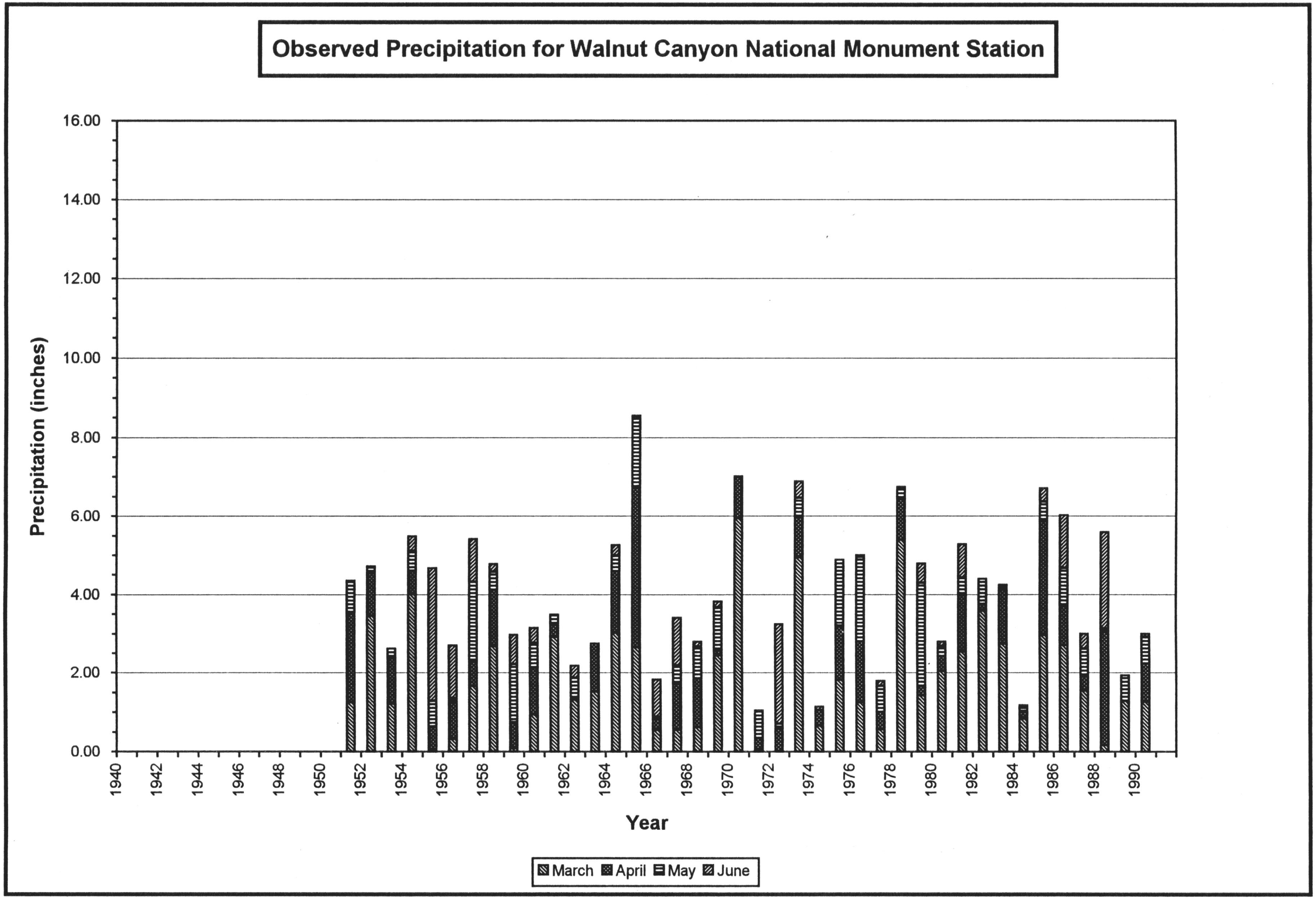

Observed Precipitation for Window Rock 4 SW Station
Precipitation (inches)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February

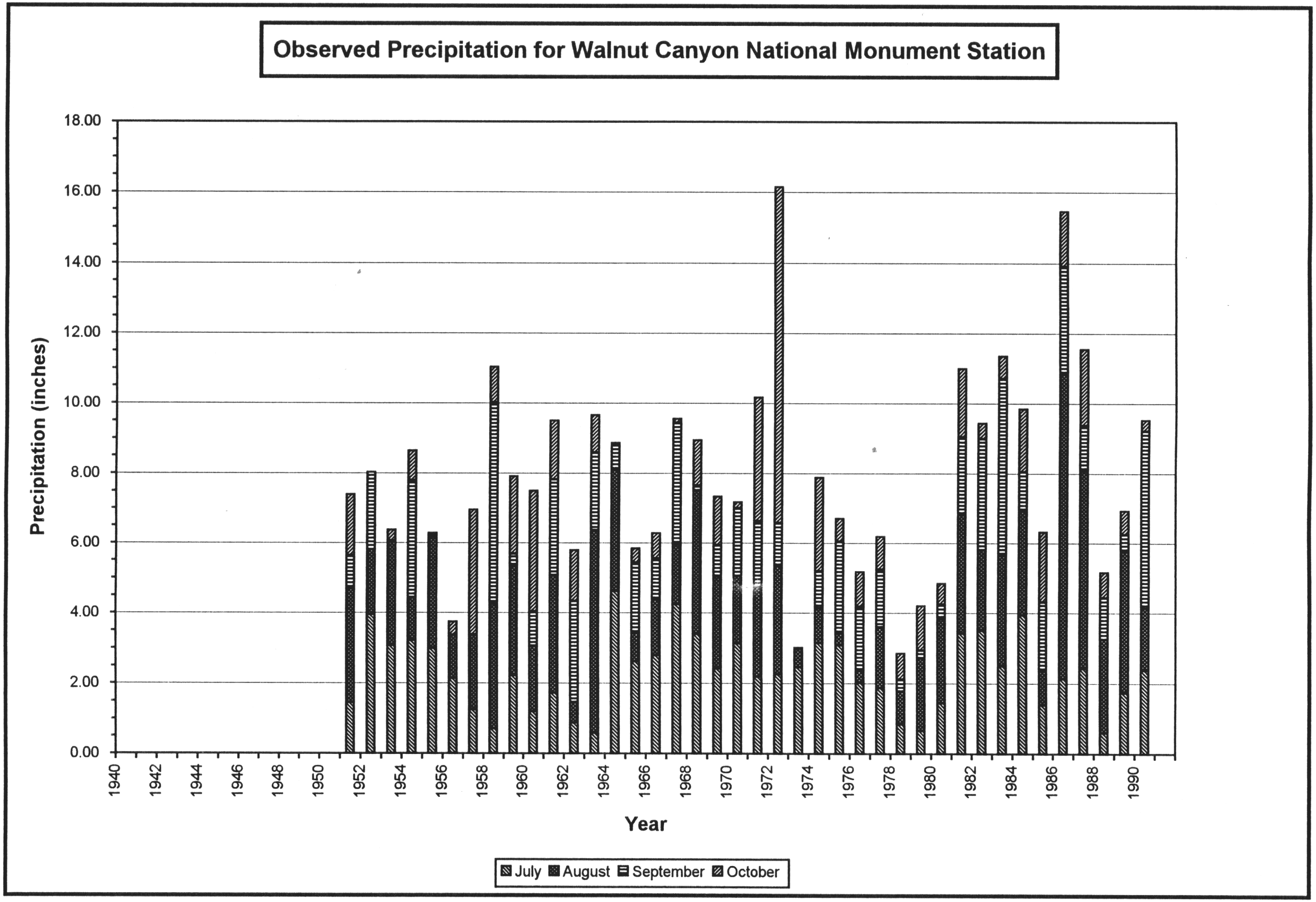
Observed Precipitation for Window Rock 4 SW Station




Observed Precipitation for Window Rock 4 SW Station
Precipitation (inches)
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October


Observed Precipitation for Walnut Canyon National Monument Station
Precipitation (inches)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Water Year
November
December
January
February


Observed Precipitation for Walnut Canyon National Monument Station
Precipitation (inches)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
March
April
May
June



Observed Precipitation for Walnut Canyon National Monument Station
Precipitation (inches)
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
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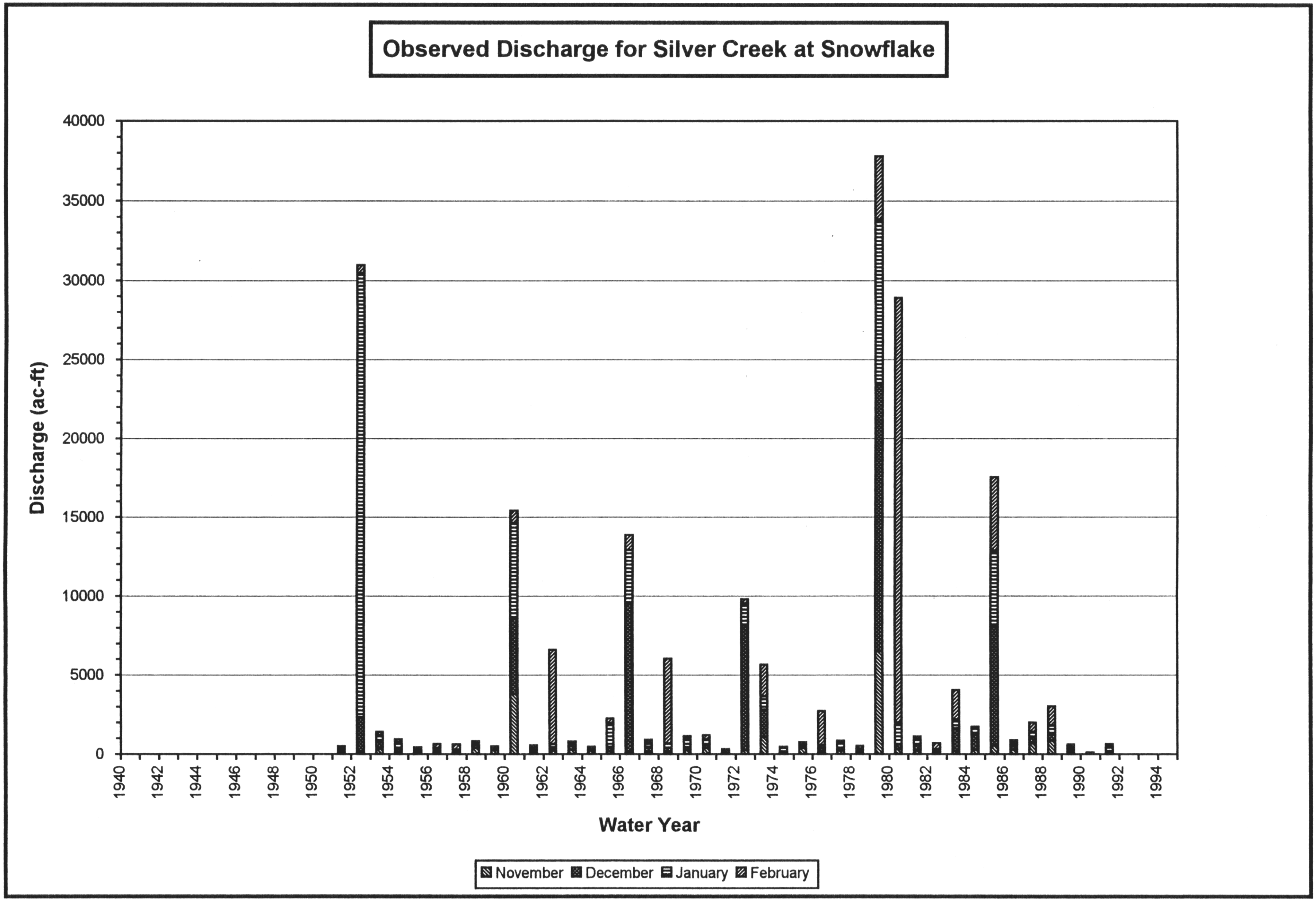
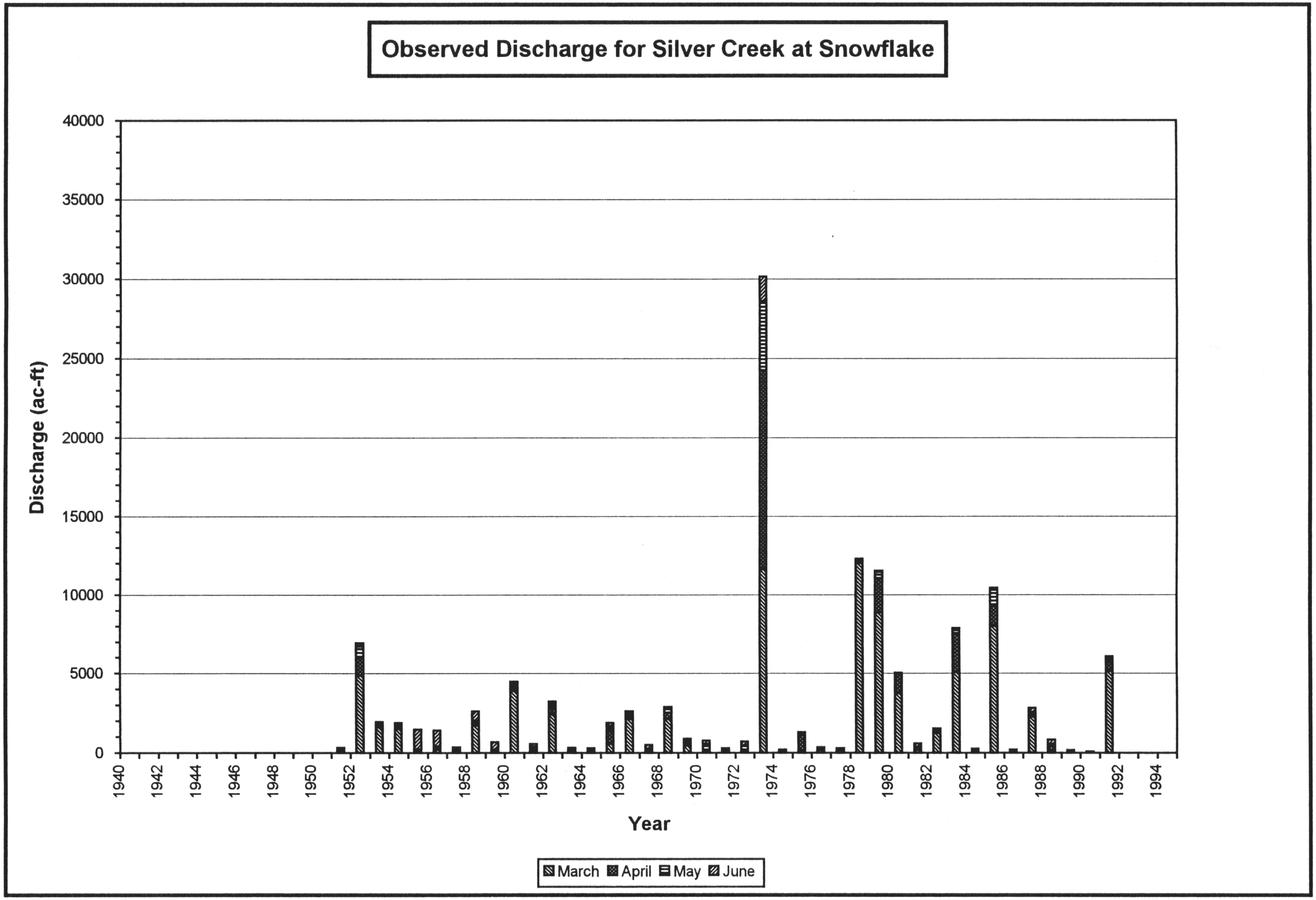
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Year
July
August
September
October

APPENDIX C

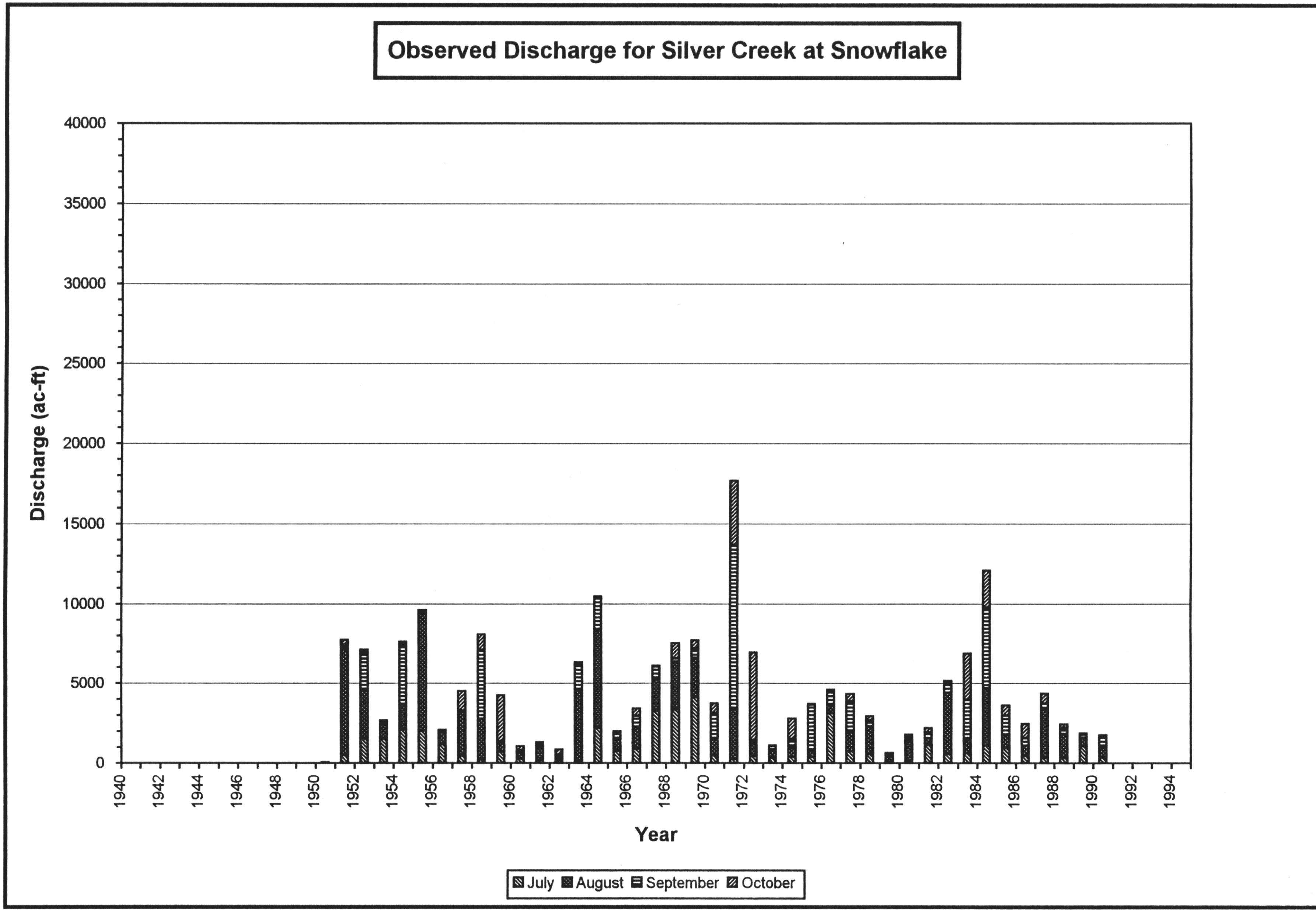
STACKED BAR GRAPHS FOR LCR TRIBUTARY DISCHARGE

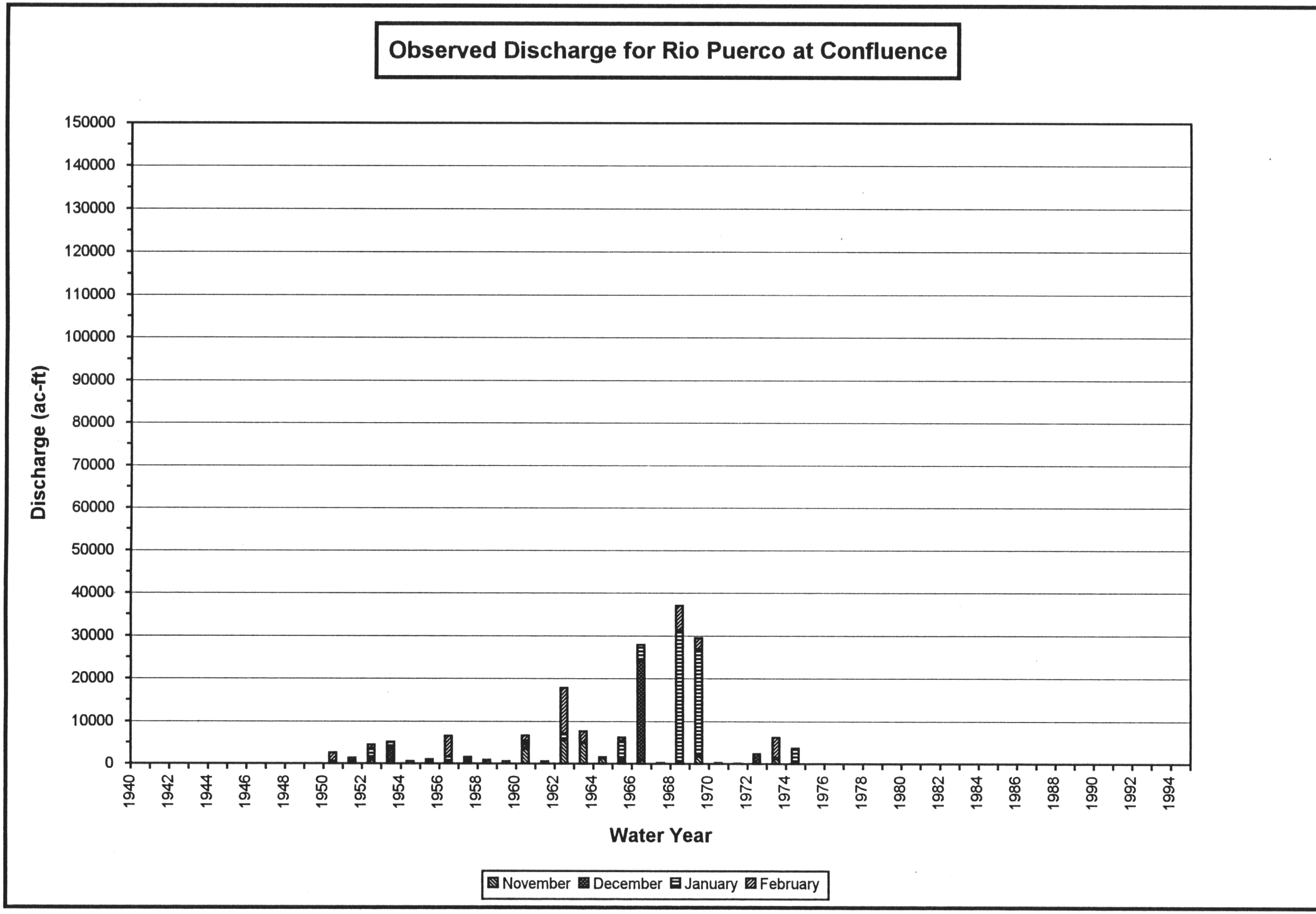


Observed Discharge for Silver Creek at Snowflake
Discharge (ac-ft)
0
5000
10000
15000
20000
25000
30000
35000
40000
1940 1942 1944 1946 1948 1950 1952 1954 1956 1958 1960 1962 1964 1966 1968 1970 1972 1974 1976 1978 1980 1982 1984 1986 1988 1990 1992 1994
Water Year
November December January February

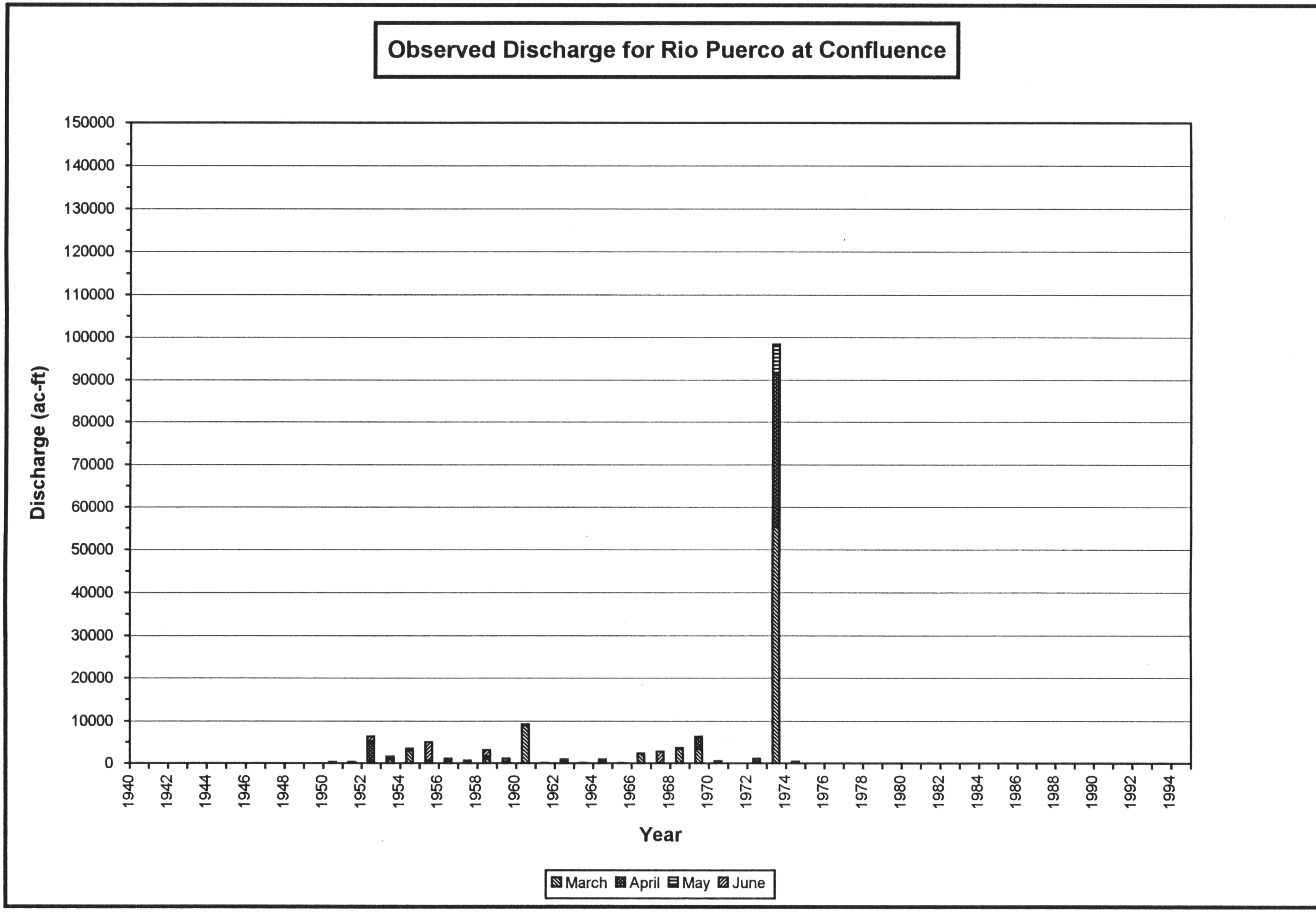


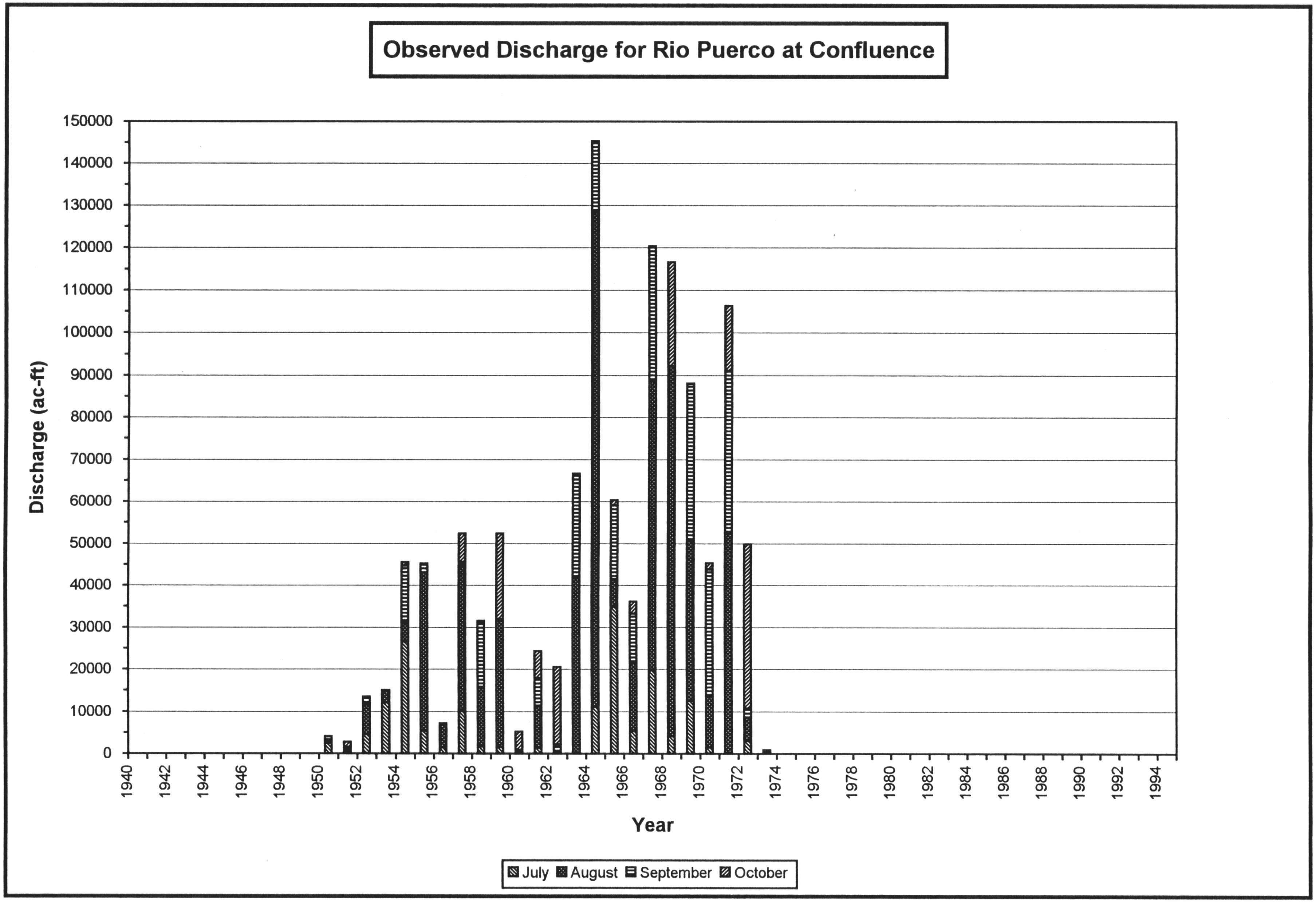
Observed Discharge for Silver Creek at Snowflake
Discharge (ac-ft)
40000
35000
30000
25000
20000
15000
10000
5000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
March
April
May
June

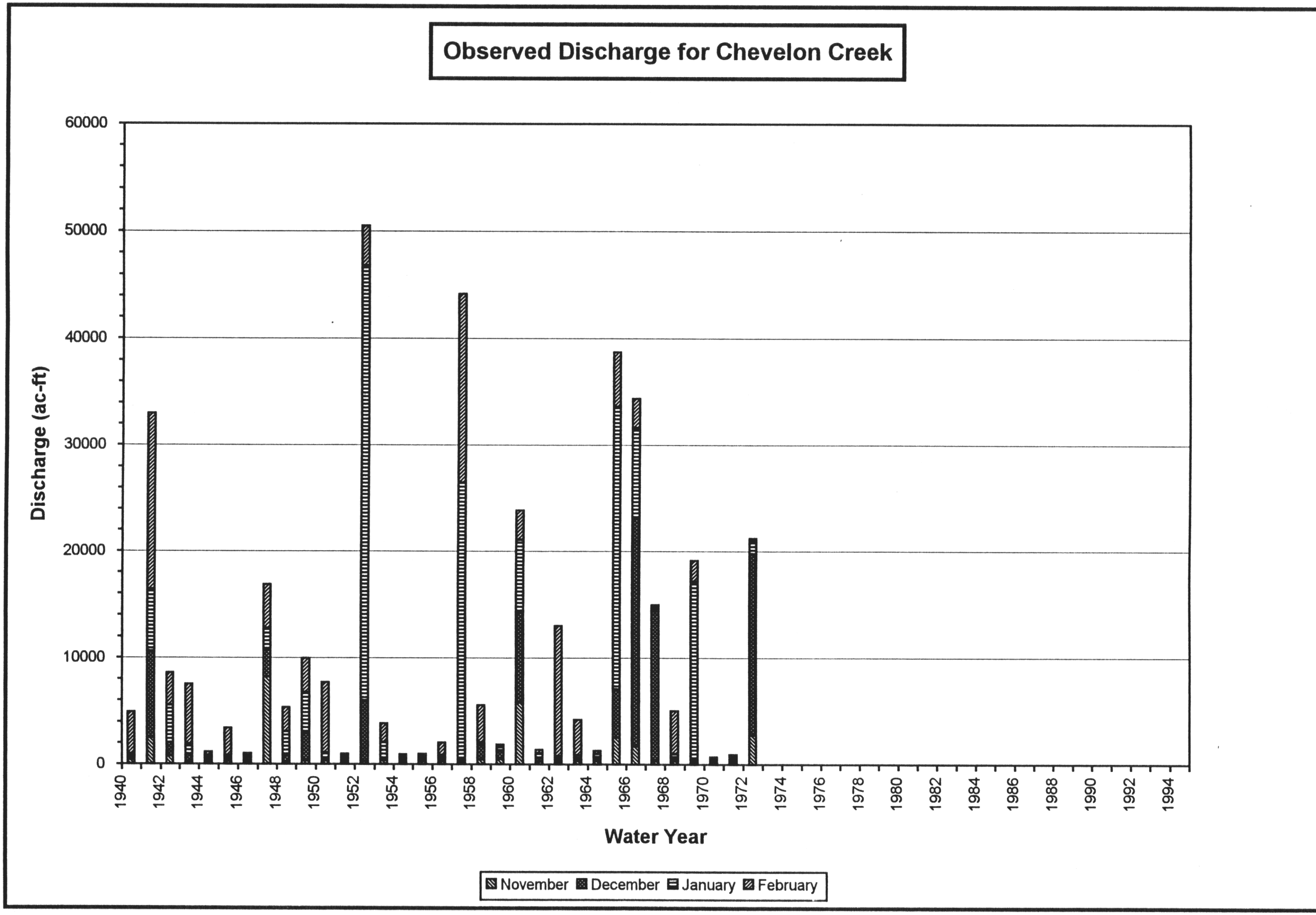

Observed Discharge for Silver Creek at Snowflake
Discharge (ac-ft)
40000
35000
30000
25000
20000
15000
10000
5000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
July
August
September
October

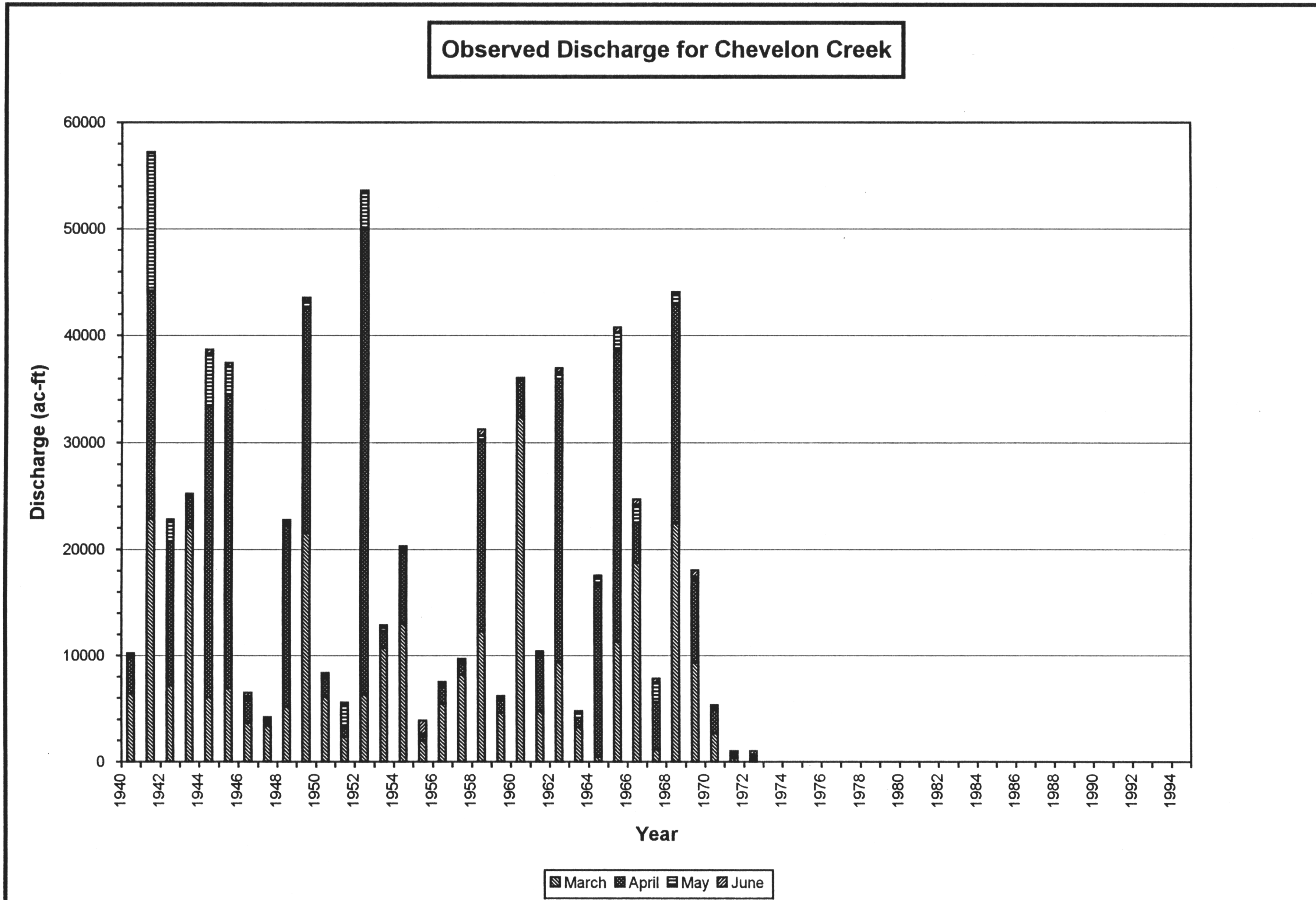


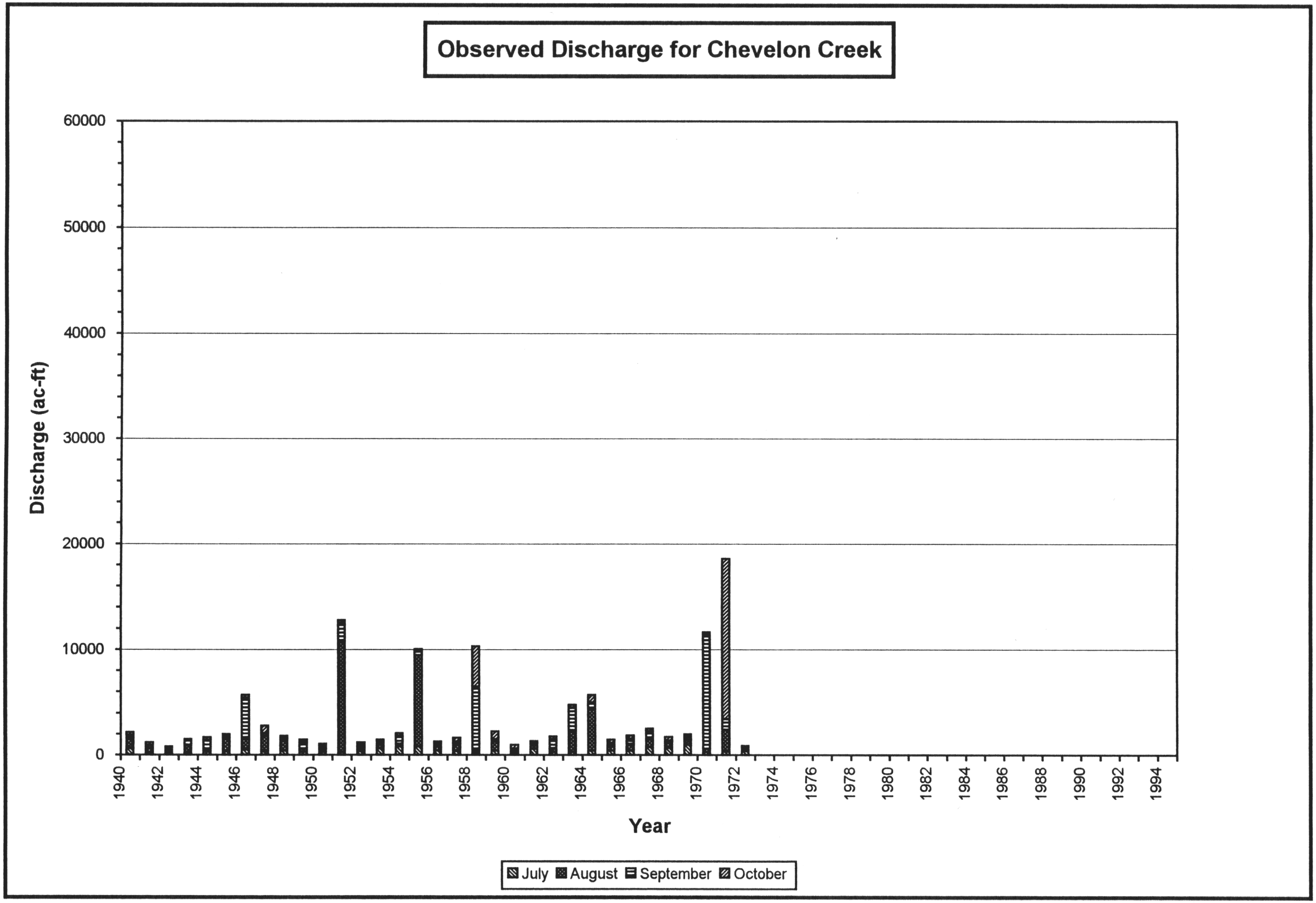
Observed Discharge for Rio Puerco at Confluence
Discharge (ac-ft)
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Water Year
November
December
January
February


Observed Discharge for Rio Puerco at Confluence
Discharge (ac-ft)
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
March
April
May
June

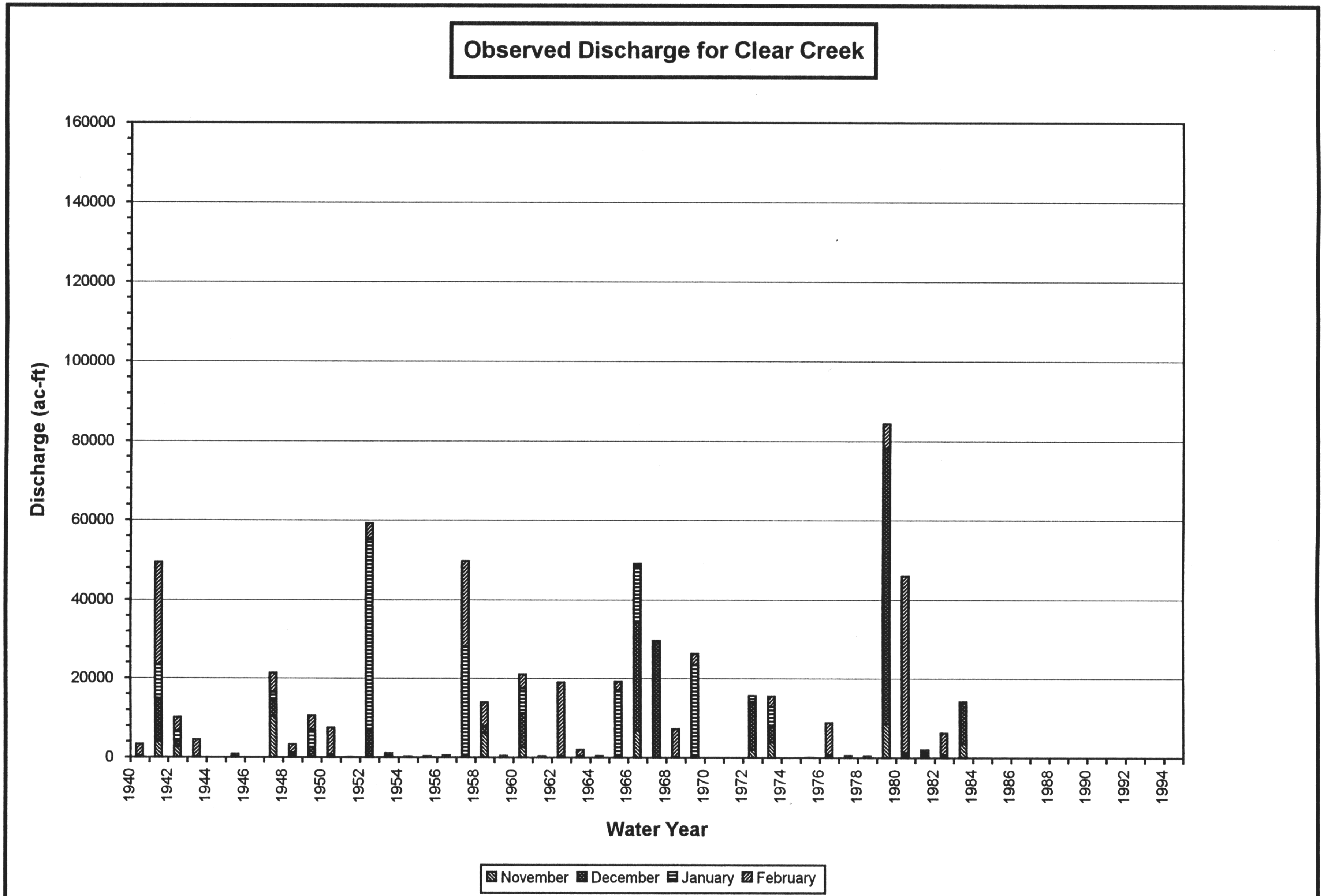

Observed Discharge for Rio Puerco at Confluence
Discharge (ac-ft)
150000
140000
130000
120000
110000
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
July
August
September
October


Observed Discharge for Chevelon Creek
Discharge (ac-ft)
60000
50000
40000
30000
20000
10000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Water Year
November
December
January
February

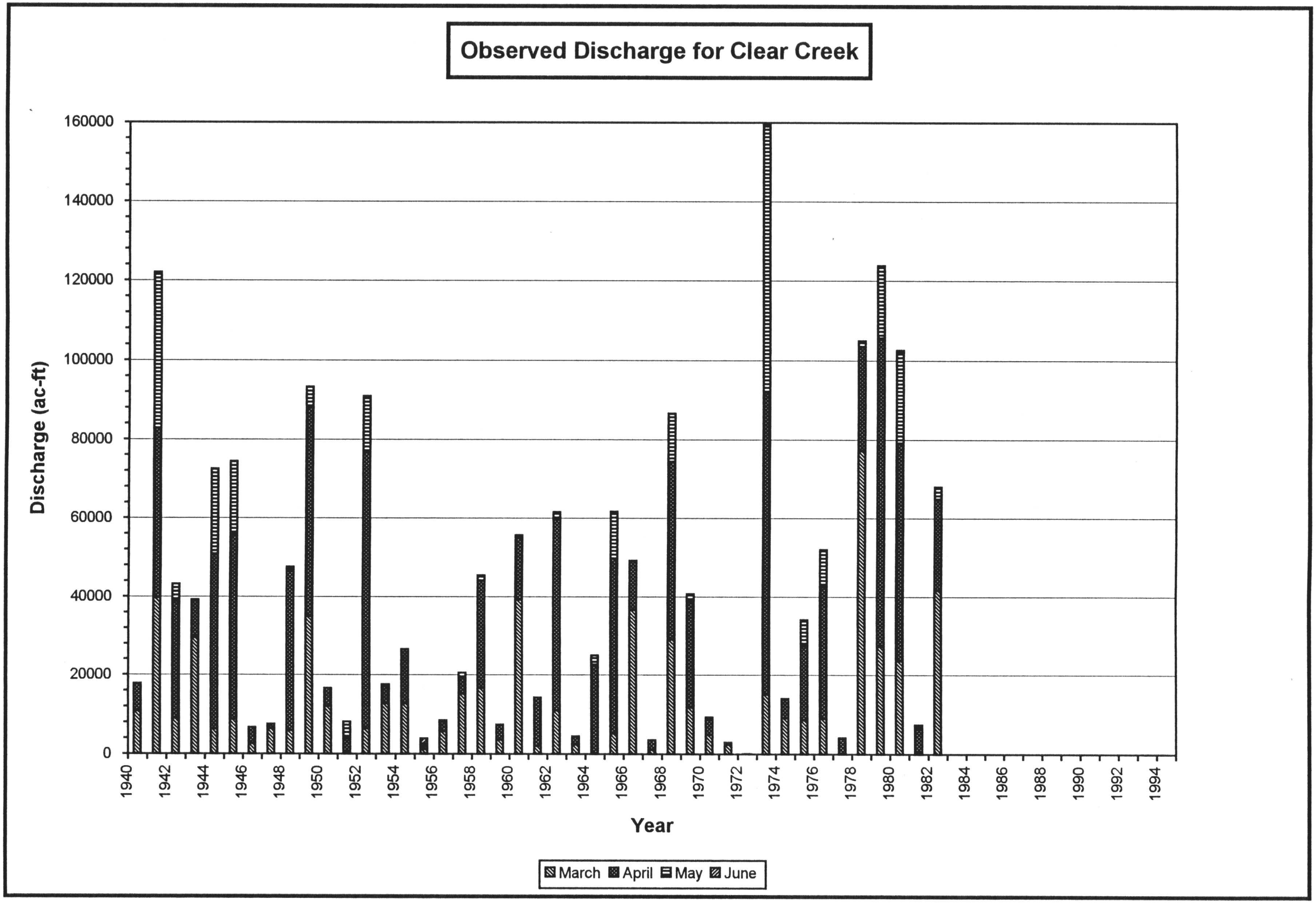

Observed Discharge for Chevelon Creek
60000
50000
40000
30000
20000
10000
0
Discharge (ac-ft)
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
March
April
May
June

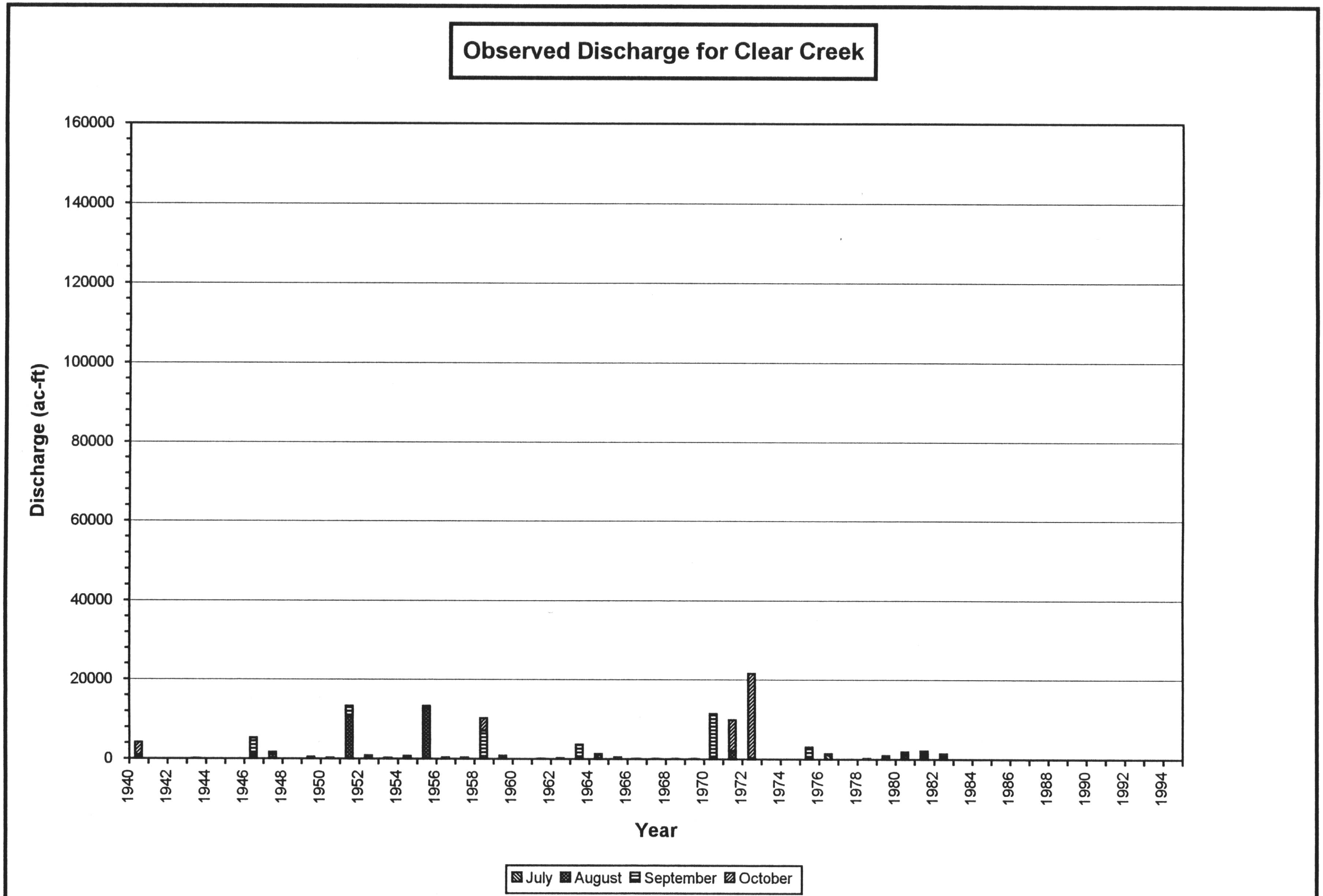


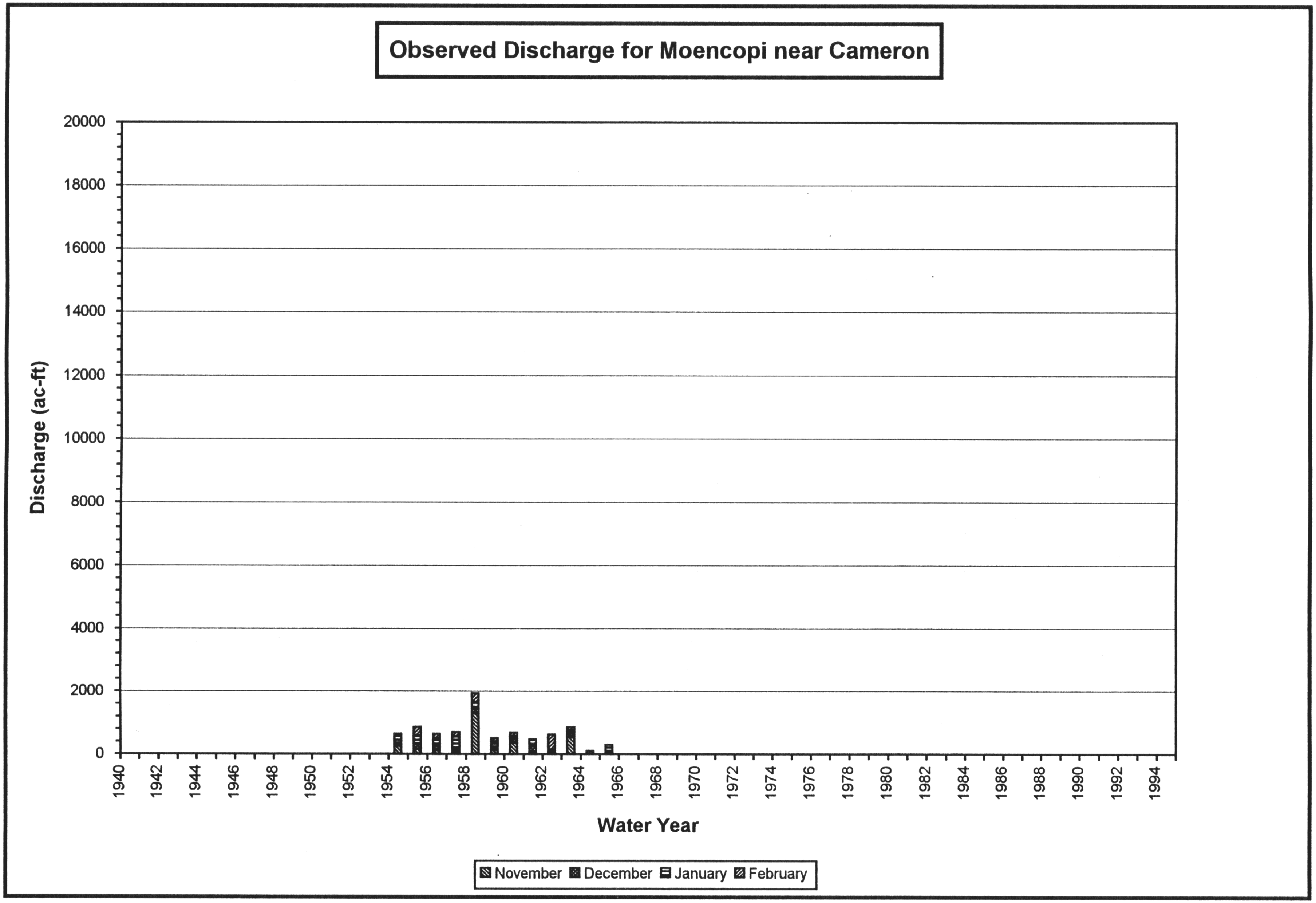
Observed Discharge for Chevelon Creek
Discharge (ac-ft)
60000
50000
40000
30000
20000
10000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
July
August
September
October



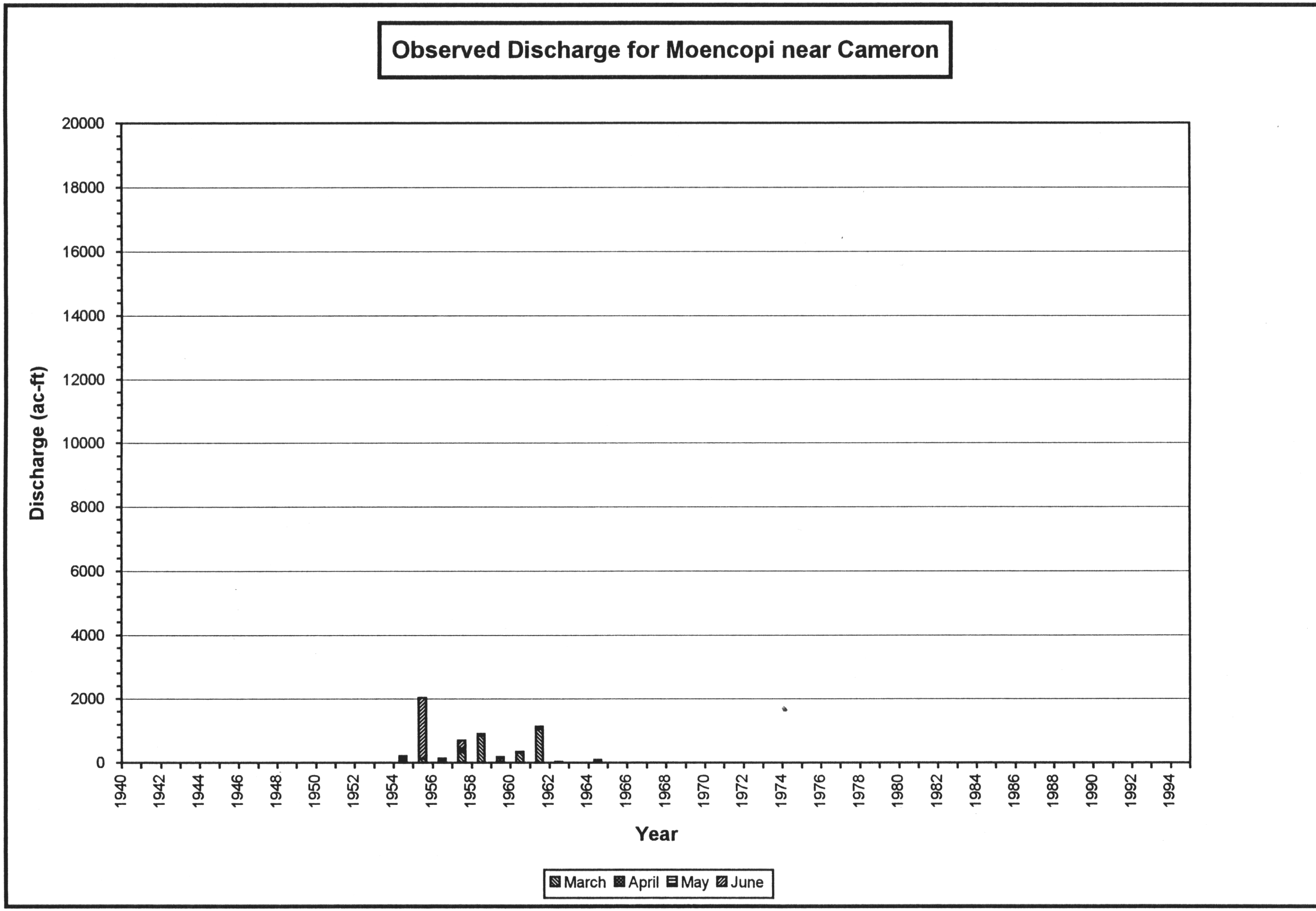
Observed Discharge for Clear Creek
Discharge (ac-ft)
160000
140000
120000
100000
80000
60000
40000
20000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Water Year
November
December
January
February

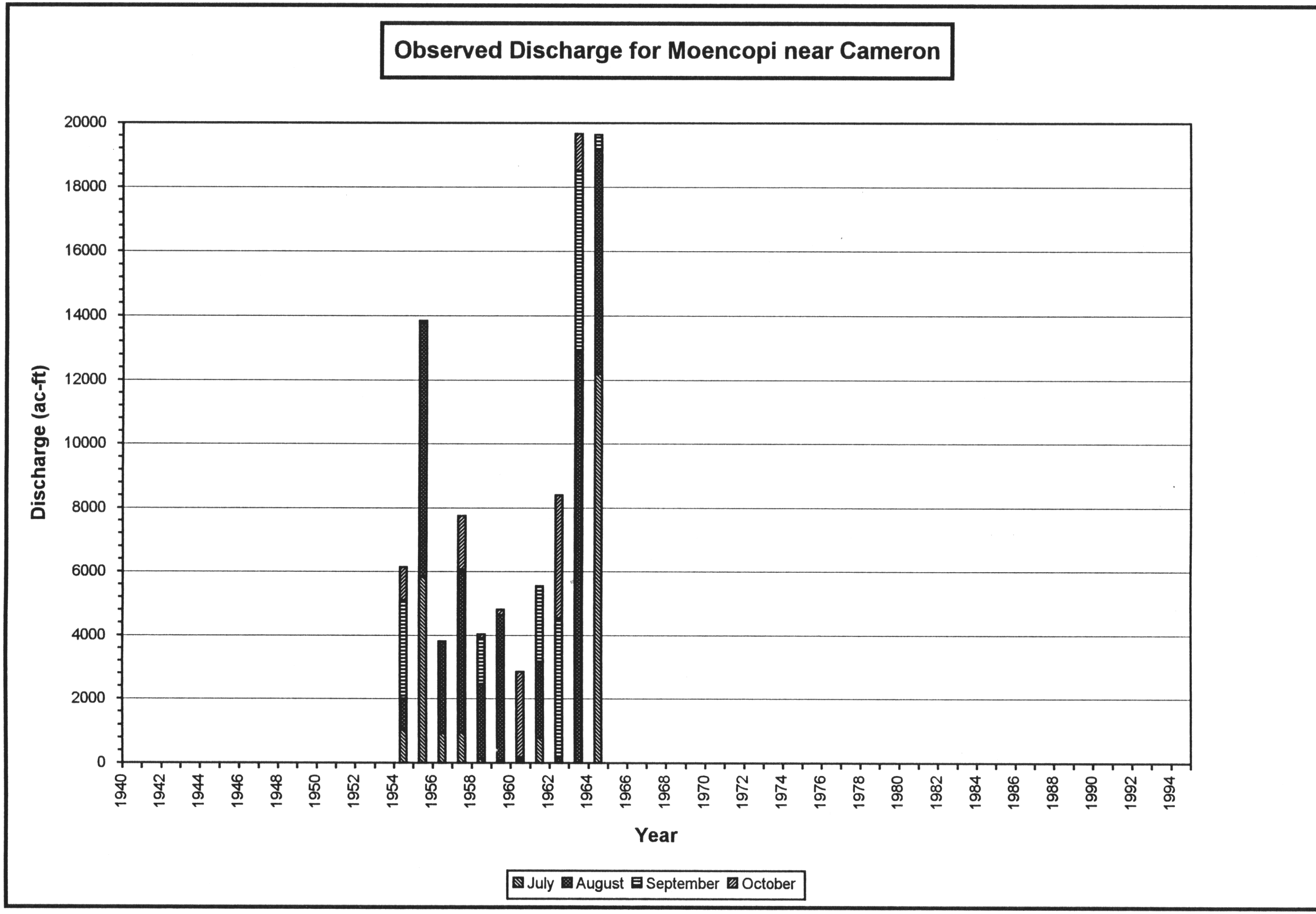

Observed Discharge for Clear Creek
Discharge (ac-ft)
160000
140000
120000
100000
80000
60000
40000
20000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
March
April
May
June


Observed Discharge for Clear Creek
Discharge (ac-ft)
160000
140000
120000
100000
80000
60000
40000
20000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
July
August
September
October



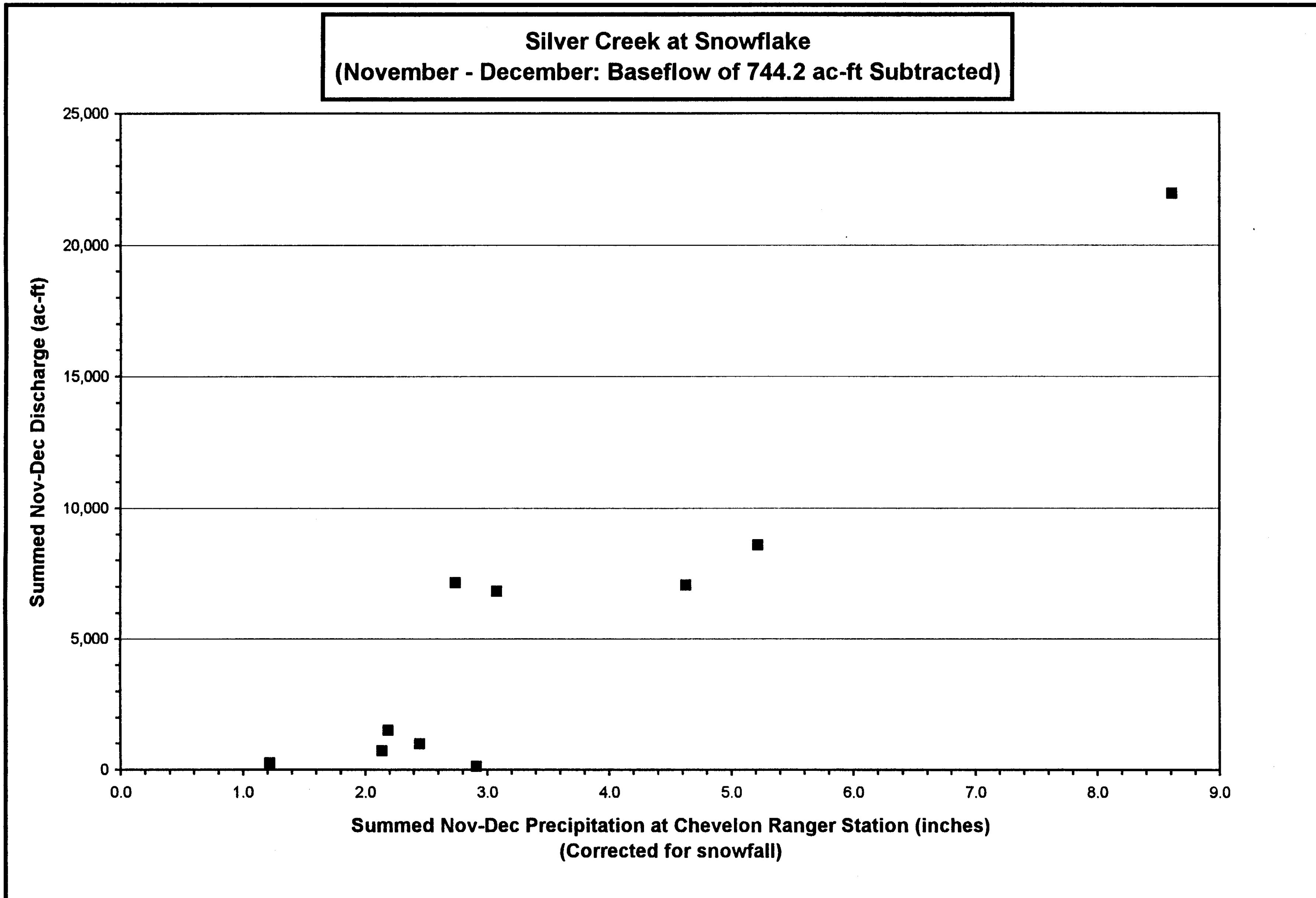
Observed Discharge for Moencopi near Cameron
Discharge (ac-ft)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Water Year
November
December
January
February

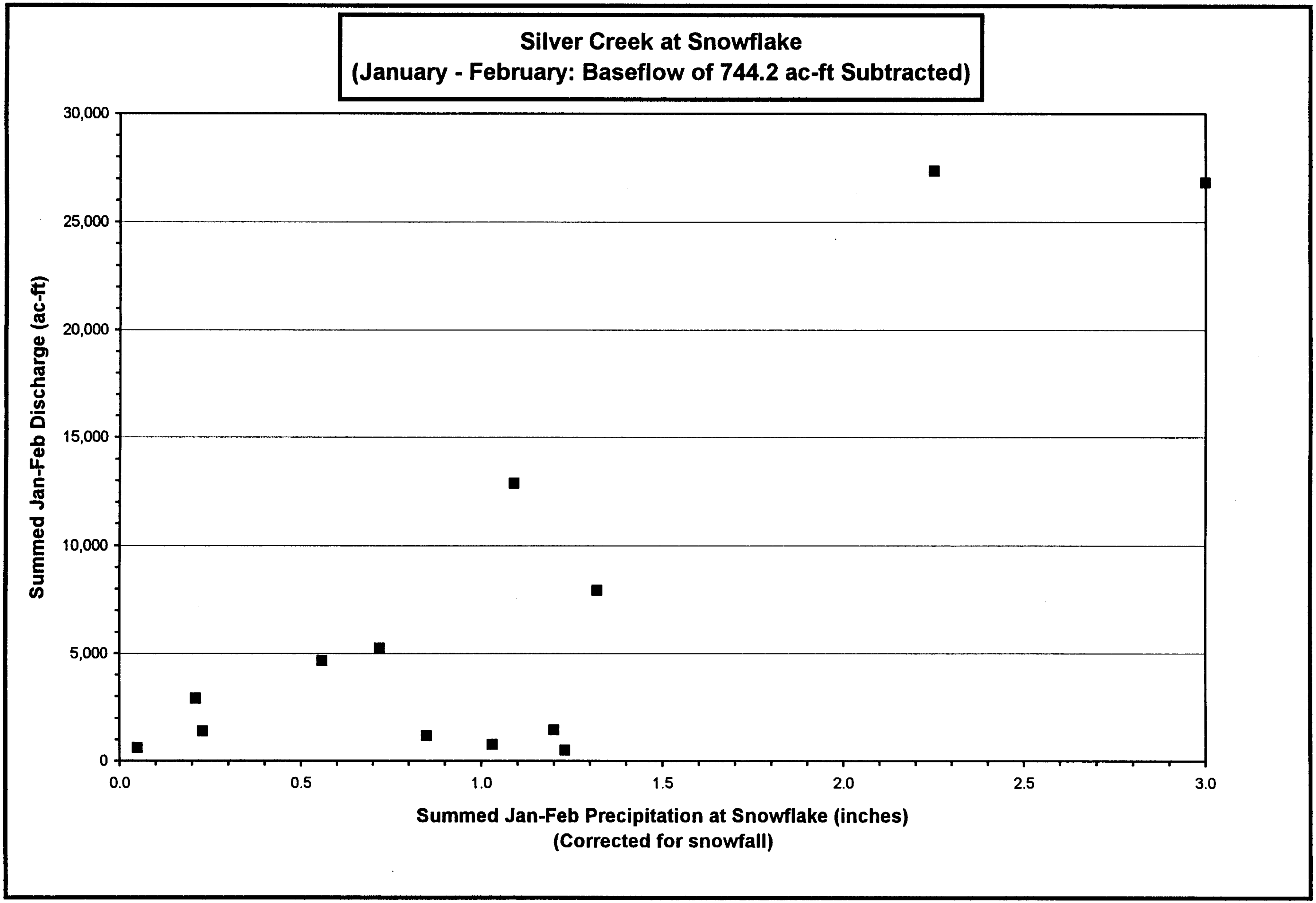

Observed Discharge for Moencopi near Cameron
Discharge (ac-ft)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
March
April
May
June

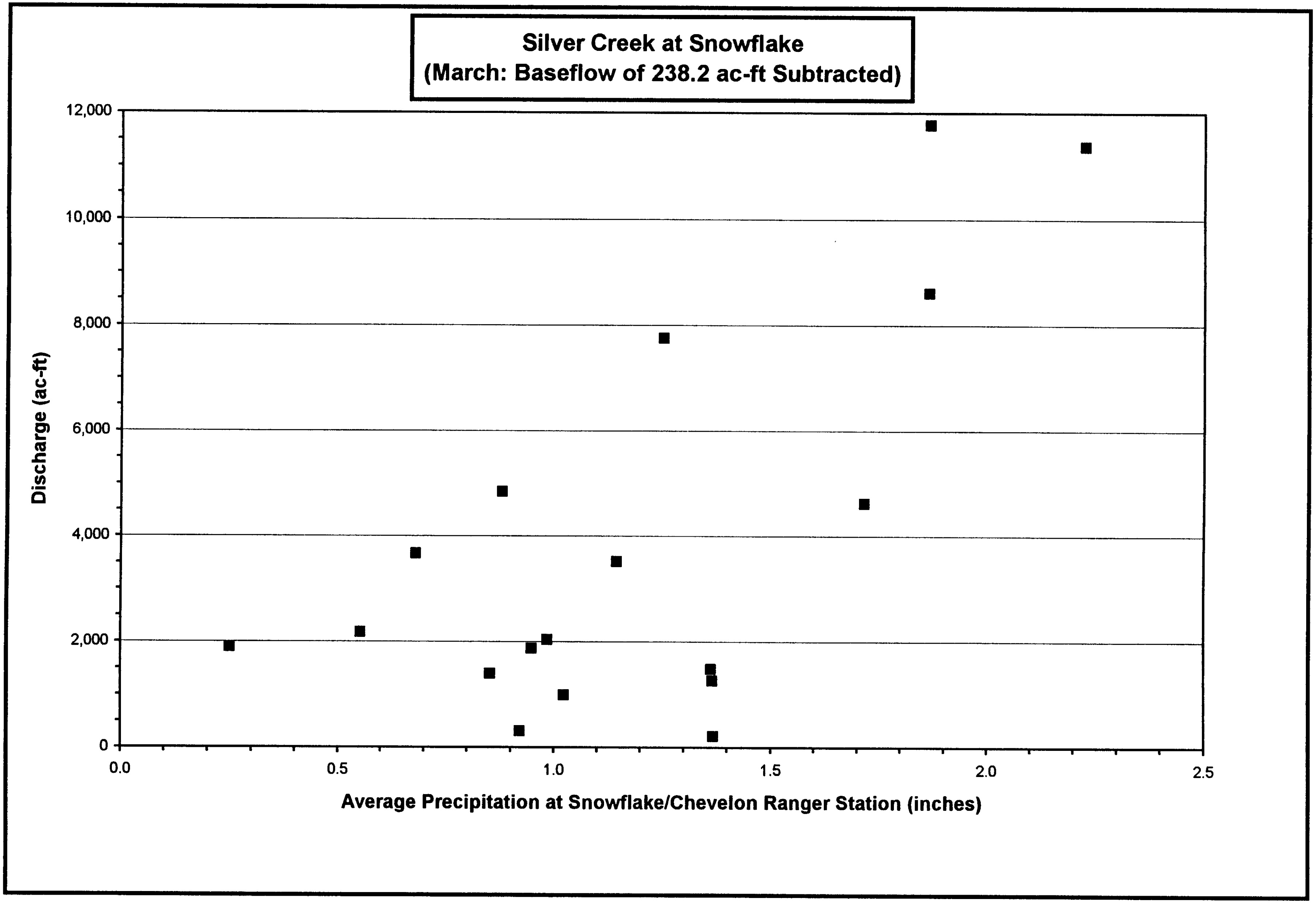

Observed Discharge for Moencopi near Cameron
Discharge (ac-ft)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
Year
July
August
September
October

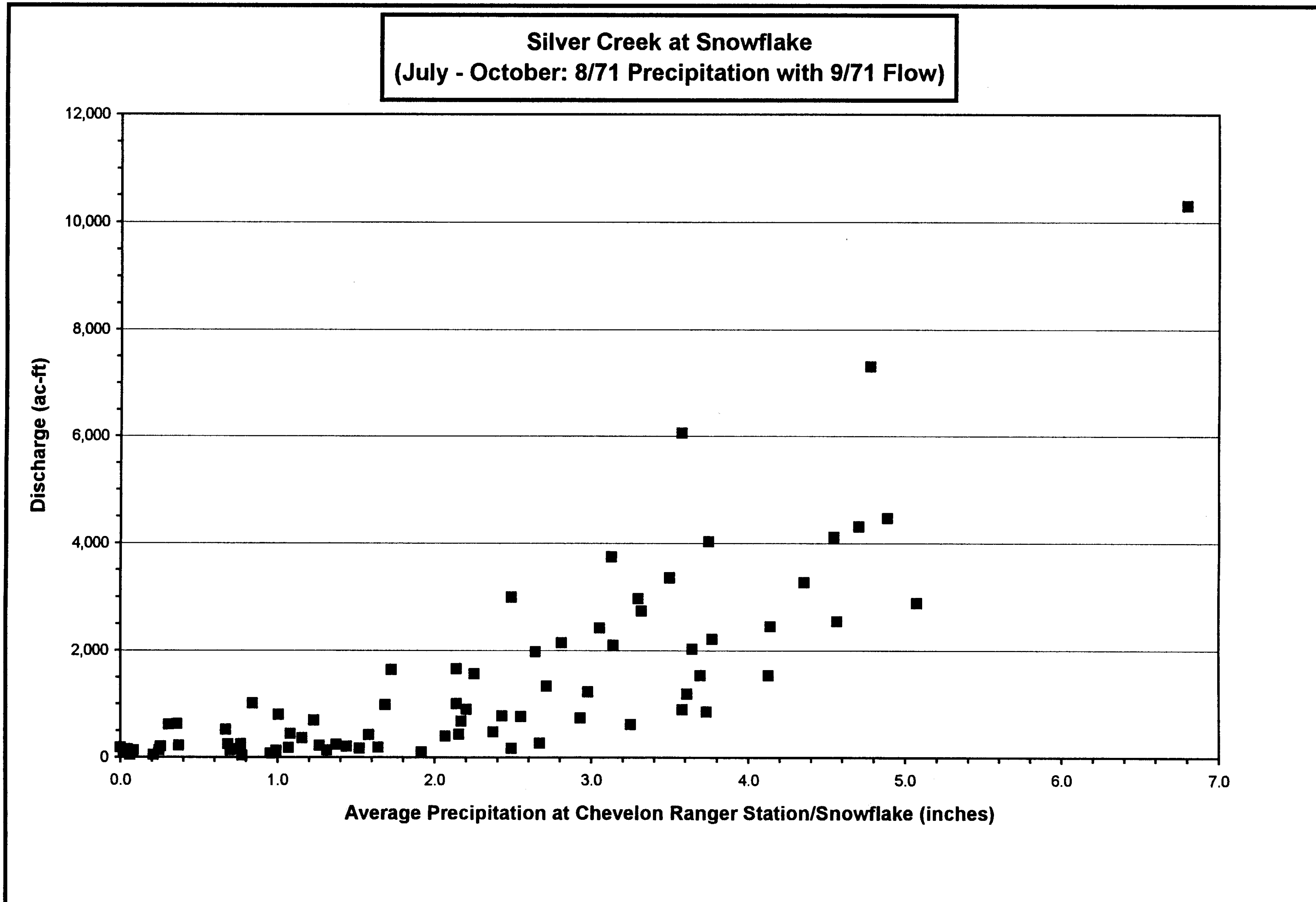
APPENDIX D

SCATTER PLOTS FOR PRECIPITATION/RUNOFF RELATIONSHIPS

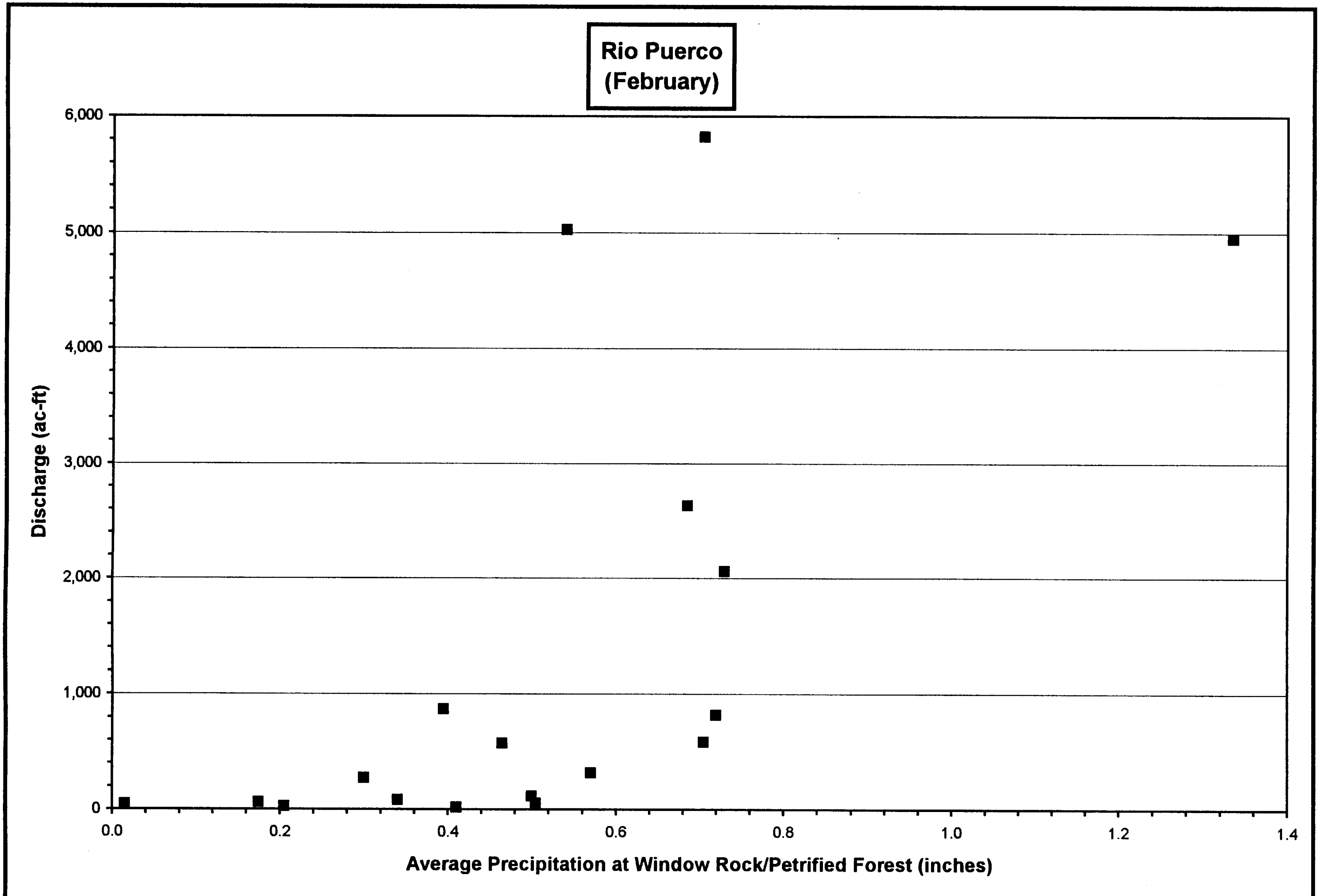

Silver Creek at Snowflake
(November - December: Baseflow of 744.2 ac-ft Subtracted)
Summed Nov-Dec Discharge (ac-ft)
25,000
20,000
15,000
10,000
5,000
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Summed Nov-Dec Precipitation at Chevelon Ranger Station (inches)
(Corrected for snowfall)


Silver Creek at Snowflake
(January - February: Baseflow of 744.2 ac-ft Subtracted)
Summed Jan-Feb Discharge (ac-ft)
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Summed Jan-Feb Precipitation at Snowflake (inches)
(Corrected for snowfall)

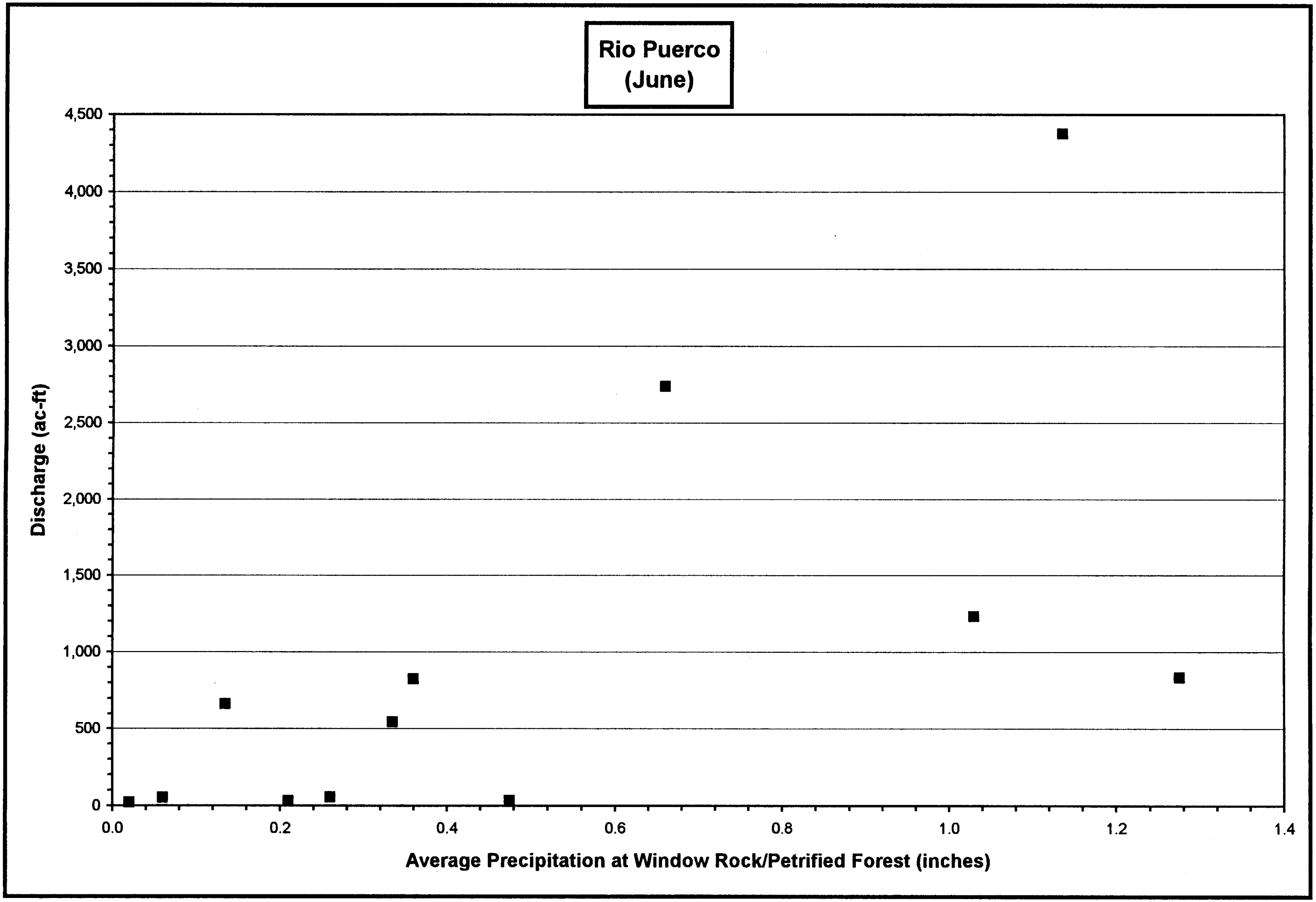

Silver Creek at Snowflake
(March: Baseflow of 238.2 ac-ft Subtracted)
Discharge (ac-ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
0.0
0.5
1.0
1.5
2.0
2.5
Average Precipitation at Snowflake/Chevelon Ranger Station (inches)

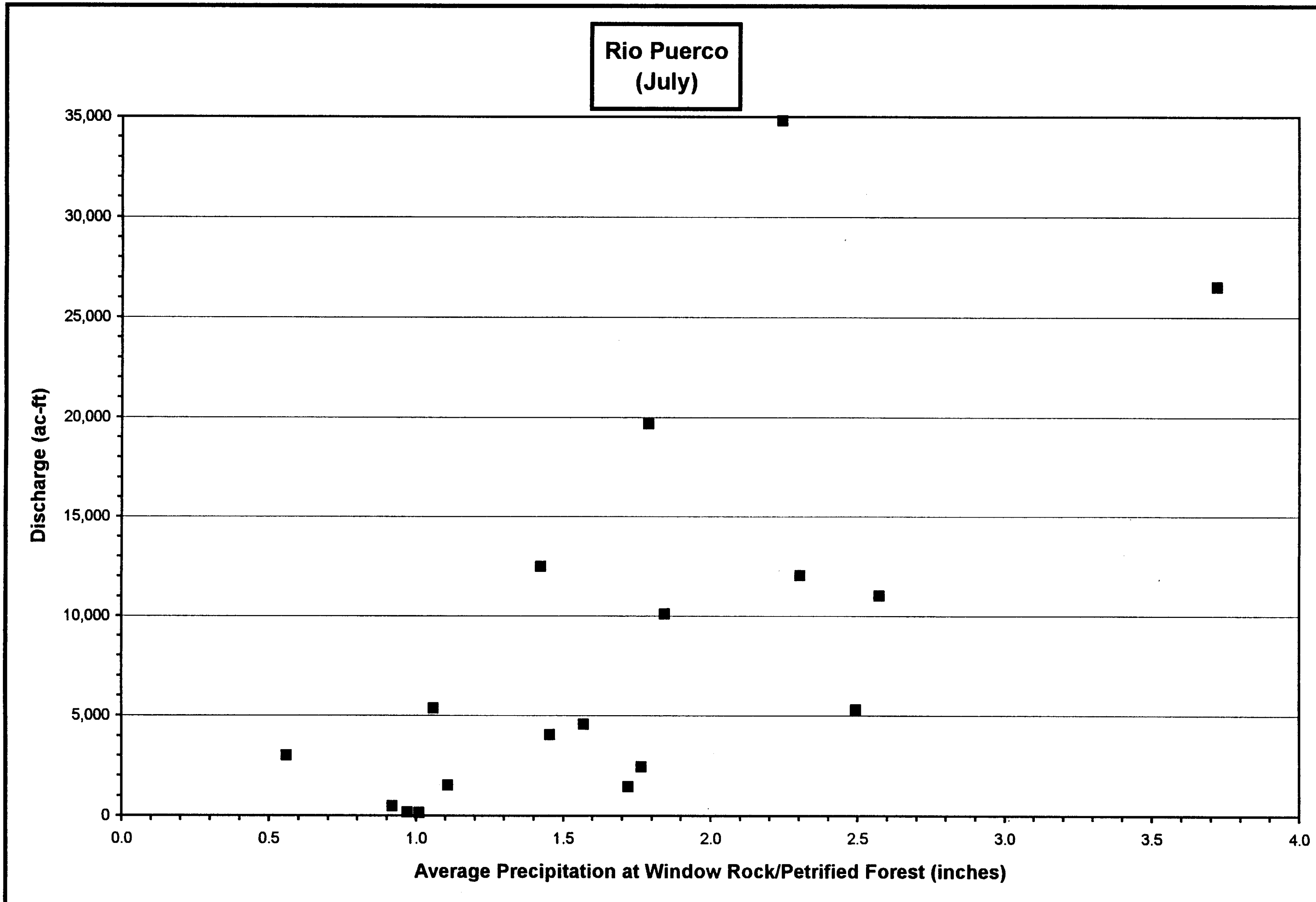


Silver Creek at Snowflake
(July - October: 8/71 Precipitation with 9/71 Flow)
Discharge (ac-ft)
12,000
10,000
8,000
6,000
4,000
2,000
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Average Precipitation at Chevelon Ranger Station/Snowflake (inches)

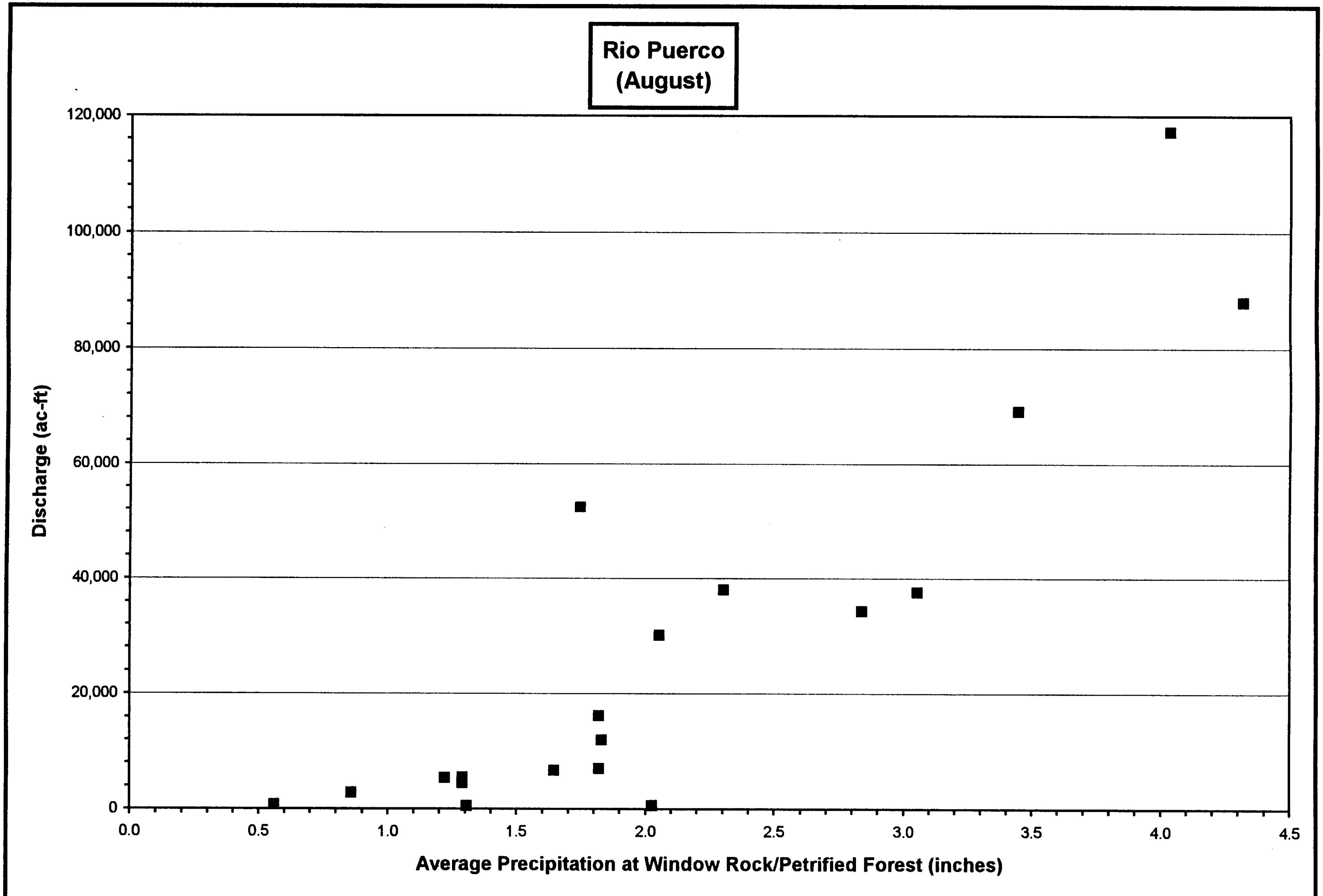


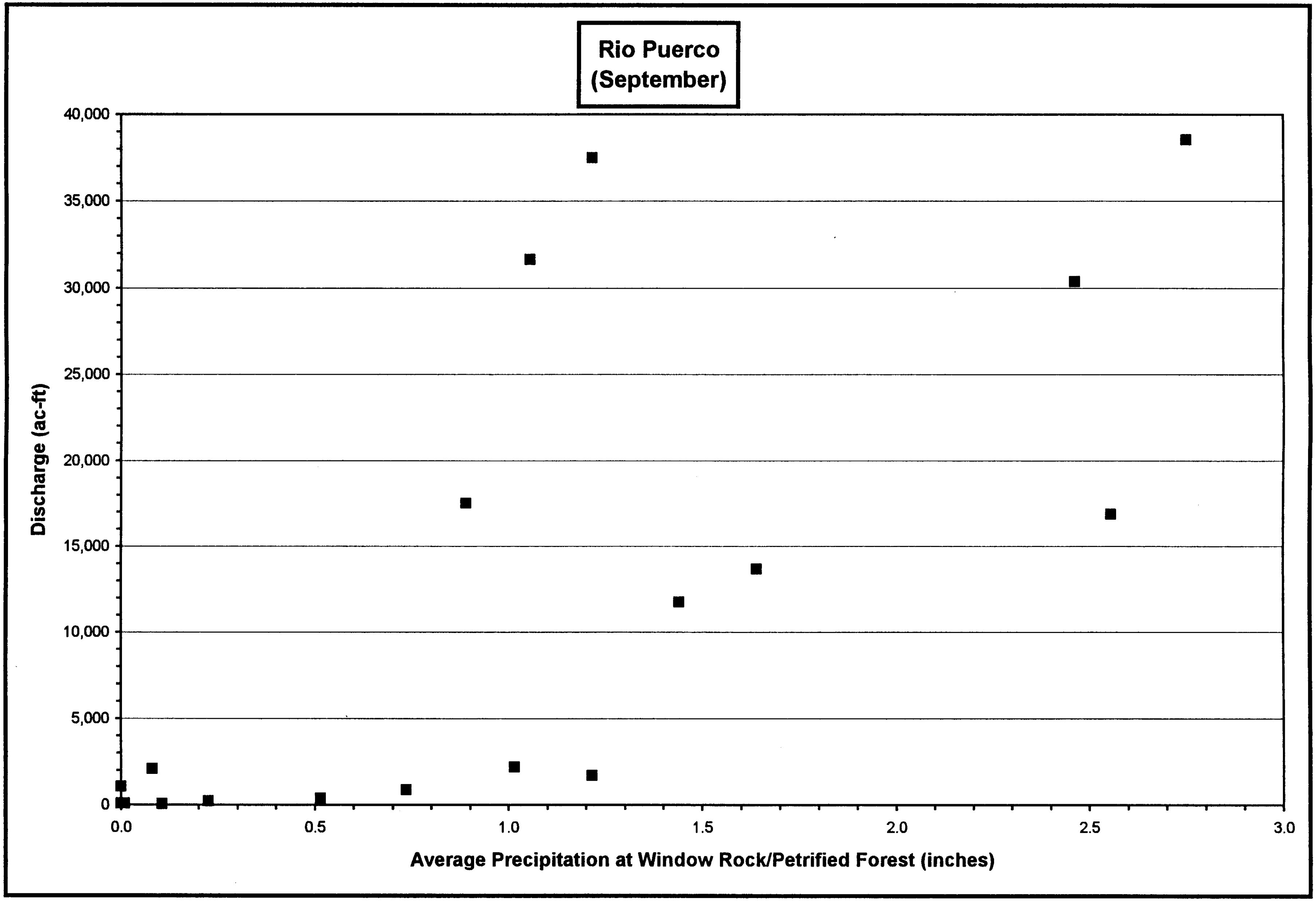
Rio Puerco
(February)
Discharge (ac-ft)
6,000
5,000
4,000
3,000
2,000
1,000
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Average Precipitation at Window Rock/Petrified Forest (inches)


Rio Puerco
(June)
Discharge (ac-ft)
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Average Precipitation at Window Rock/Petrified Forest (inches)

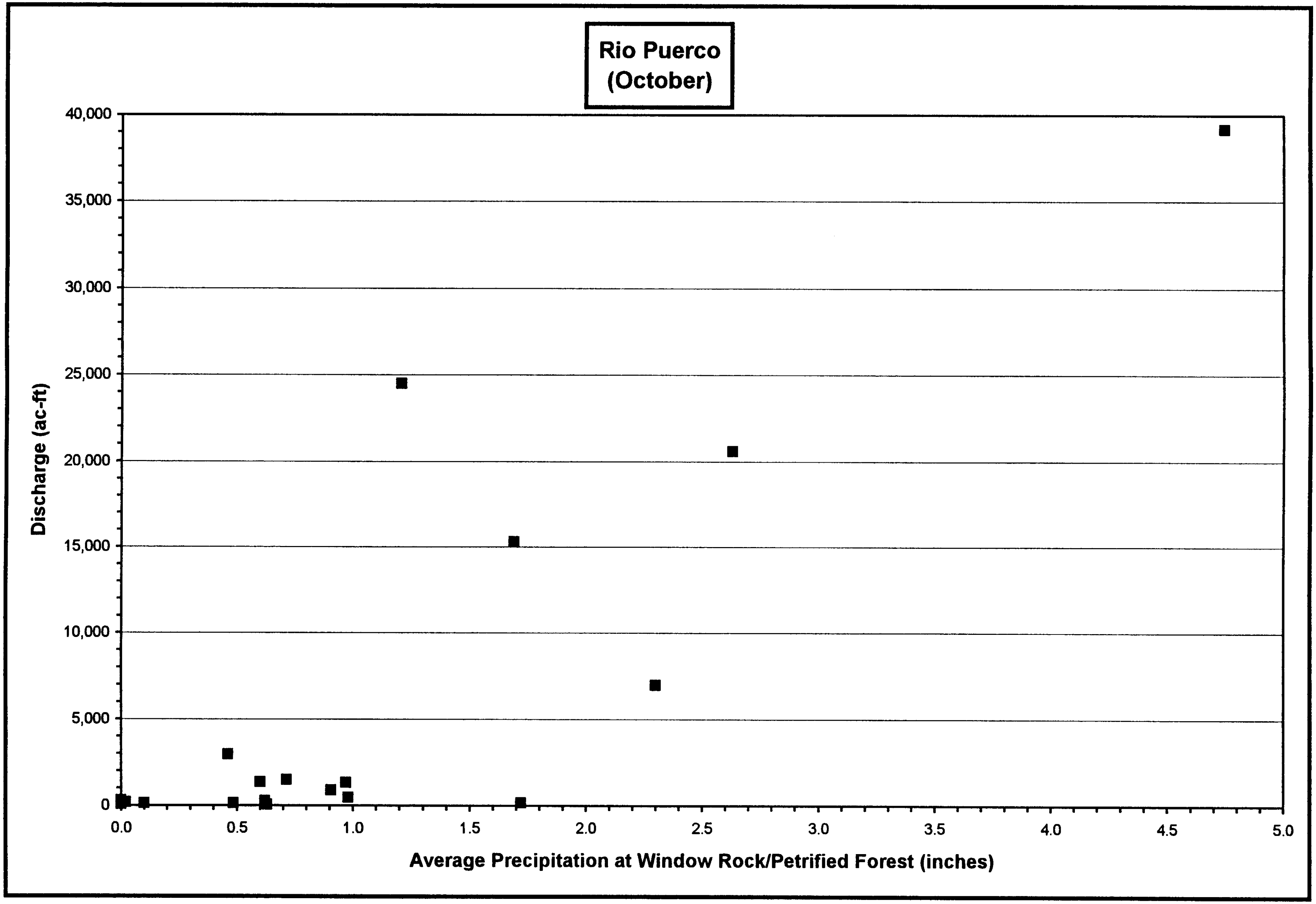


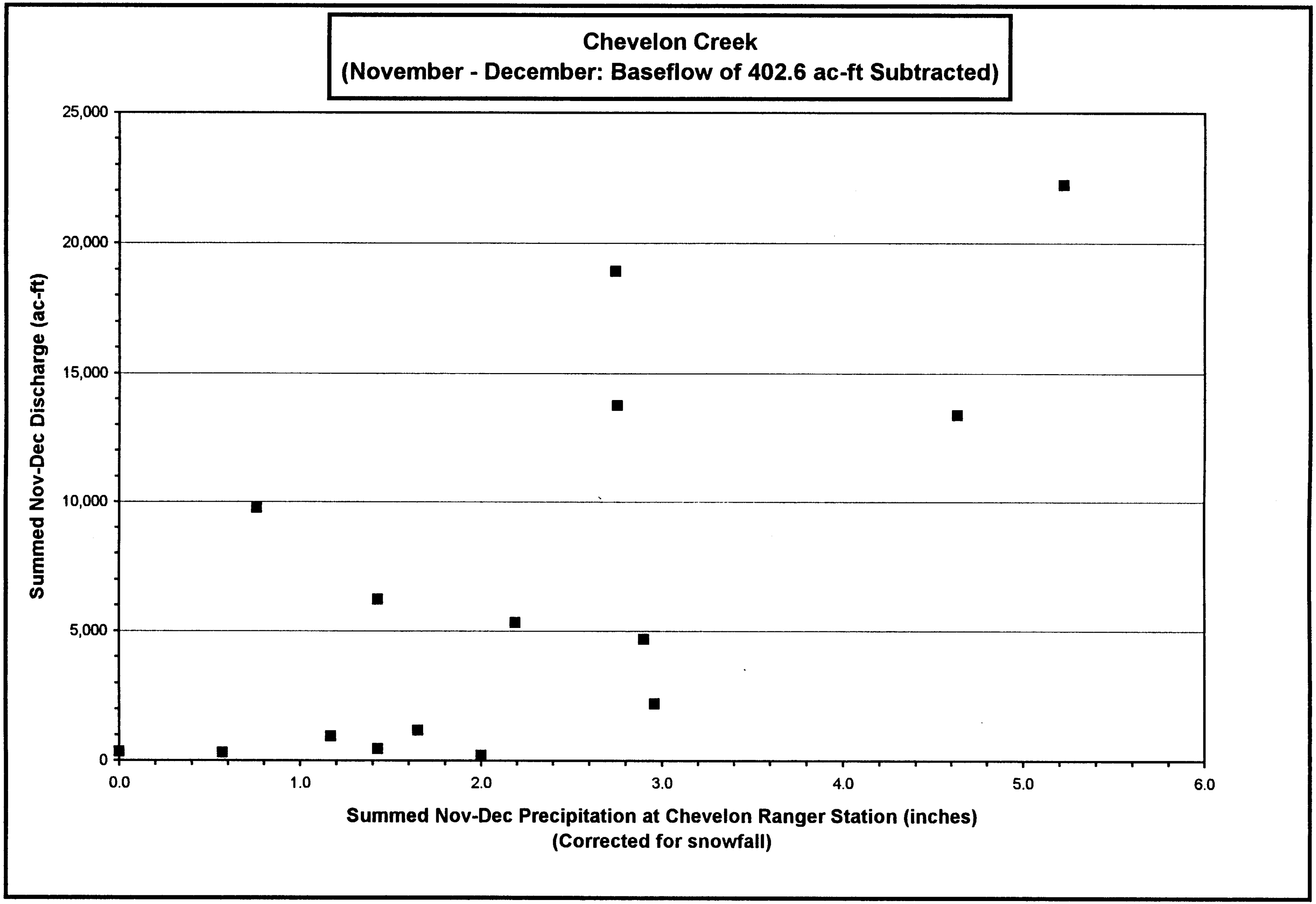
Rio Puerco
(July)
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Discharge (ac-ft)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Average Precipitation at Window Rock/Petrified Forest (inches)

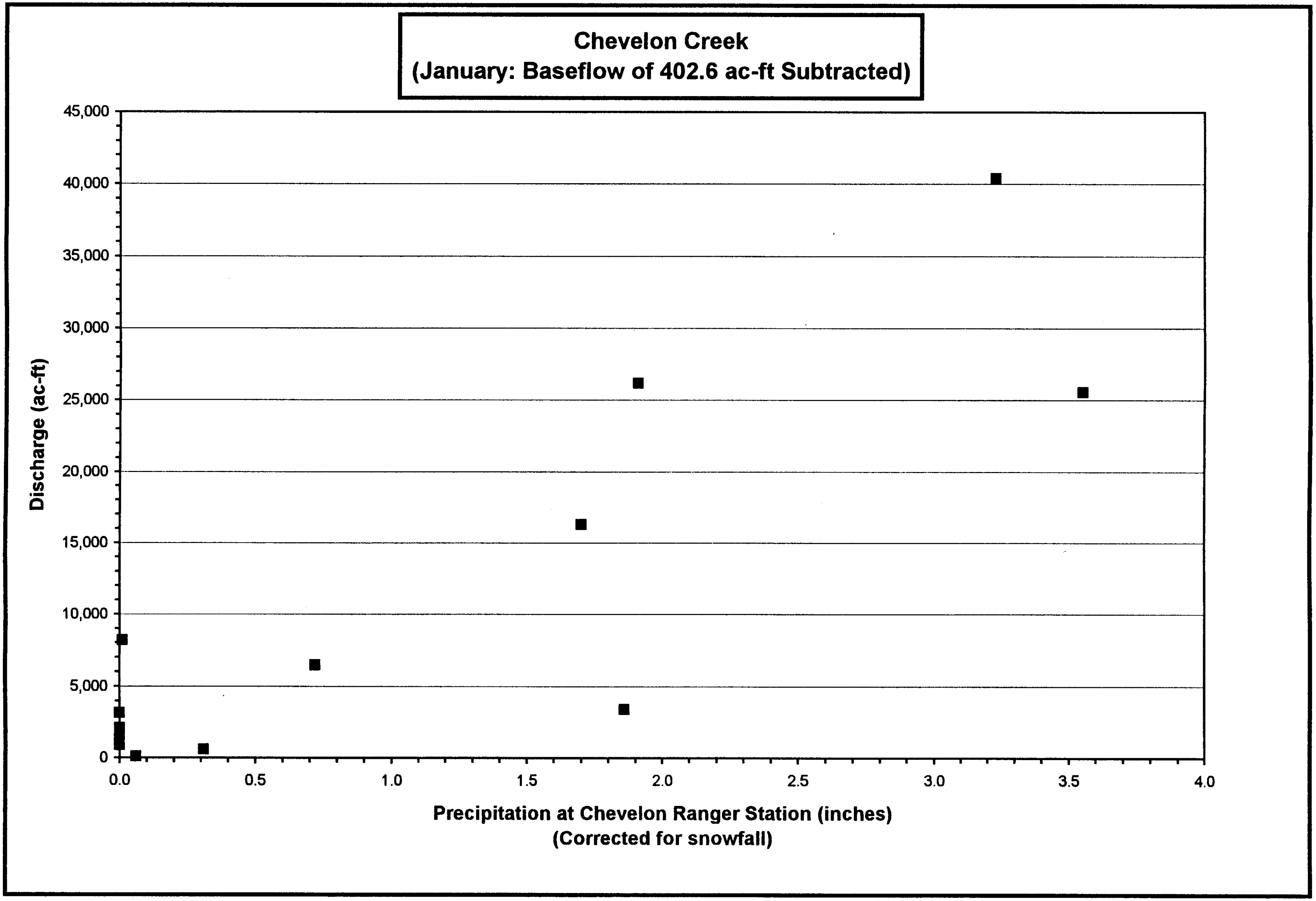

Rio Puerco
(August)
Discharge (ac-ft)
120,000
100,000
80,000
60,000
40,000
20,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Average Precipitation at Window Rock/Petrified Forest (inches)



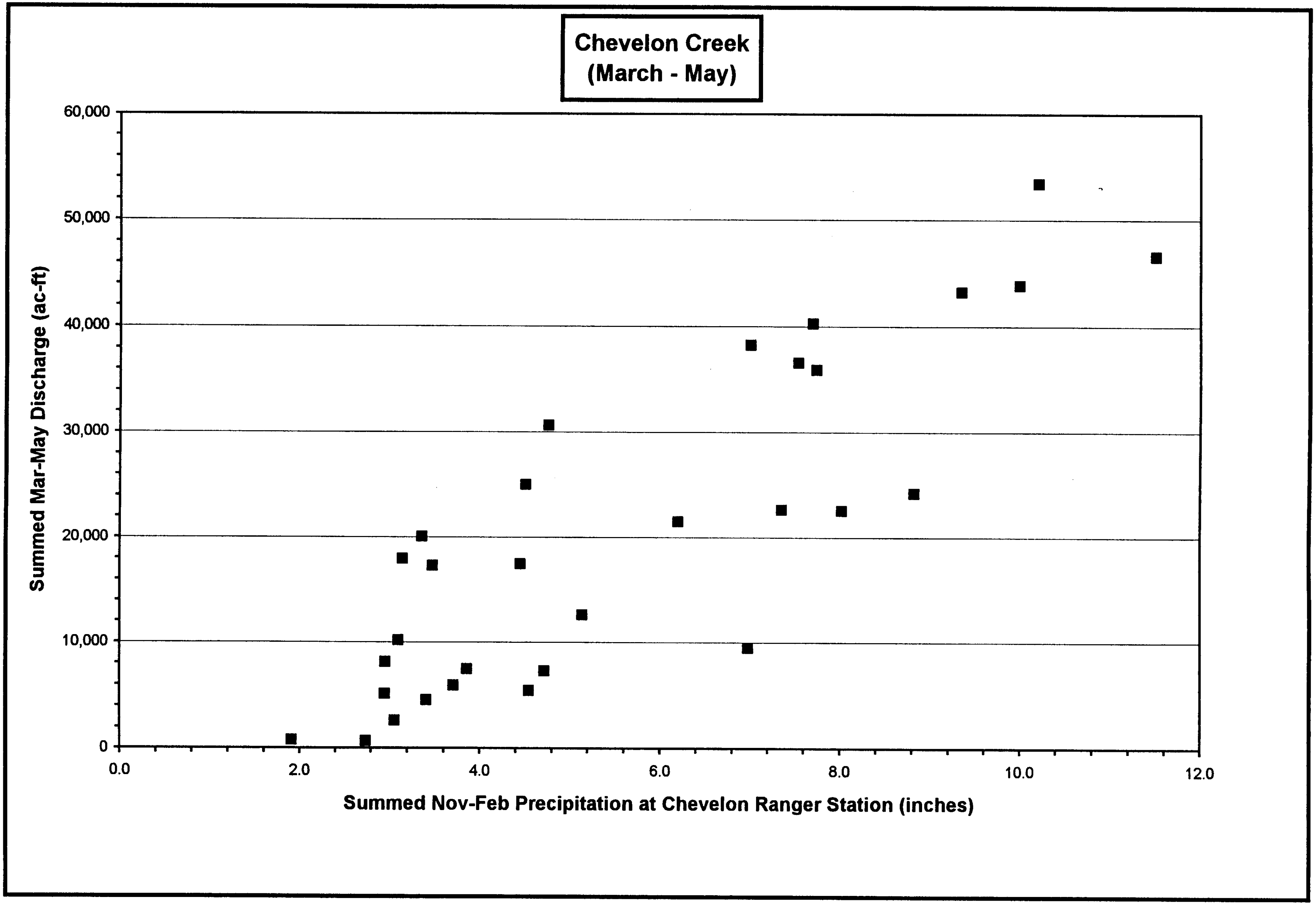
Rio Puerco
(September)
Discharge (ac-ft)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Average Precipitation at Window Rock/Petrified Forest (inches)

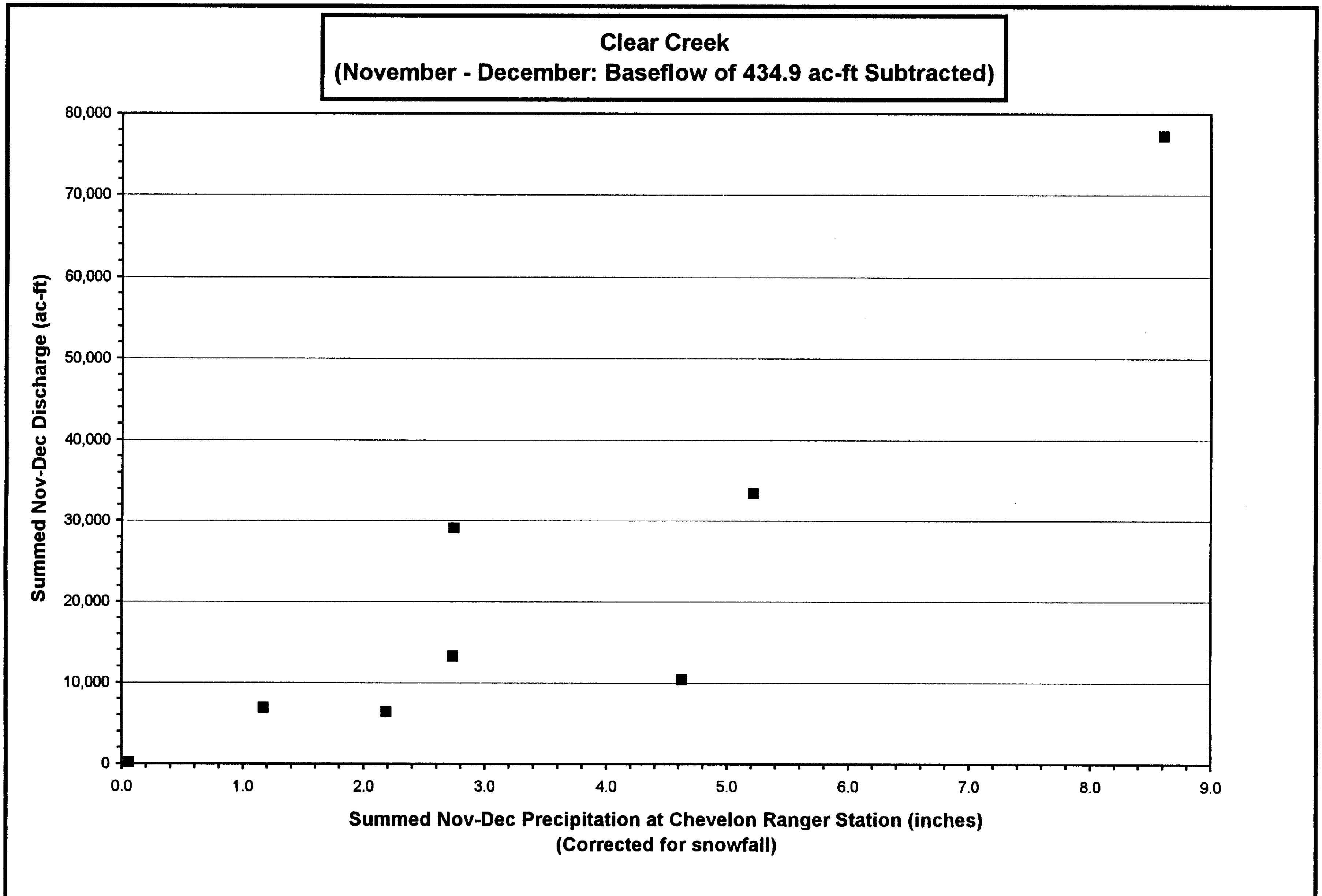

Rio Puerco
(October)
Discharge (ac-ft)
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Average Precipitation at Window Rock/Petrified Forest (inches)


Chevelon Creek
(November - December: Baseflow of 402.6 ac-ft Subtracted)
Summed Nov-Dec Discharge (ac-ft)
25,000
20,000
15,000
10,000
5,000
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
Summed Nov-Dec Precipitation at Chevelon Ranger Station (inches)
(Corrected for snowfall)

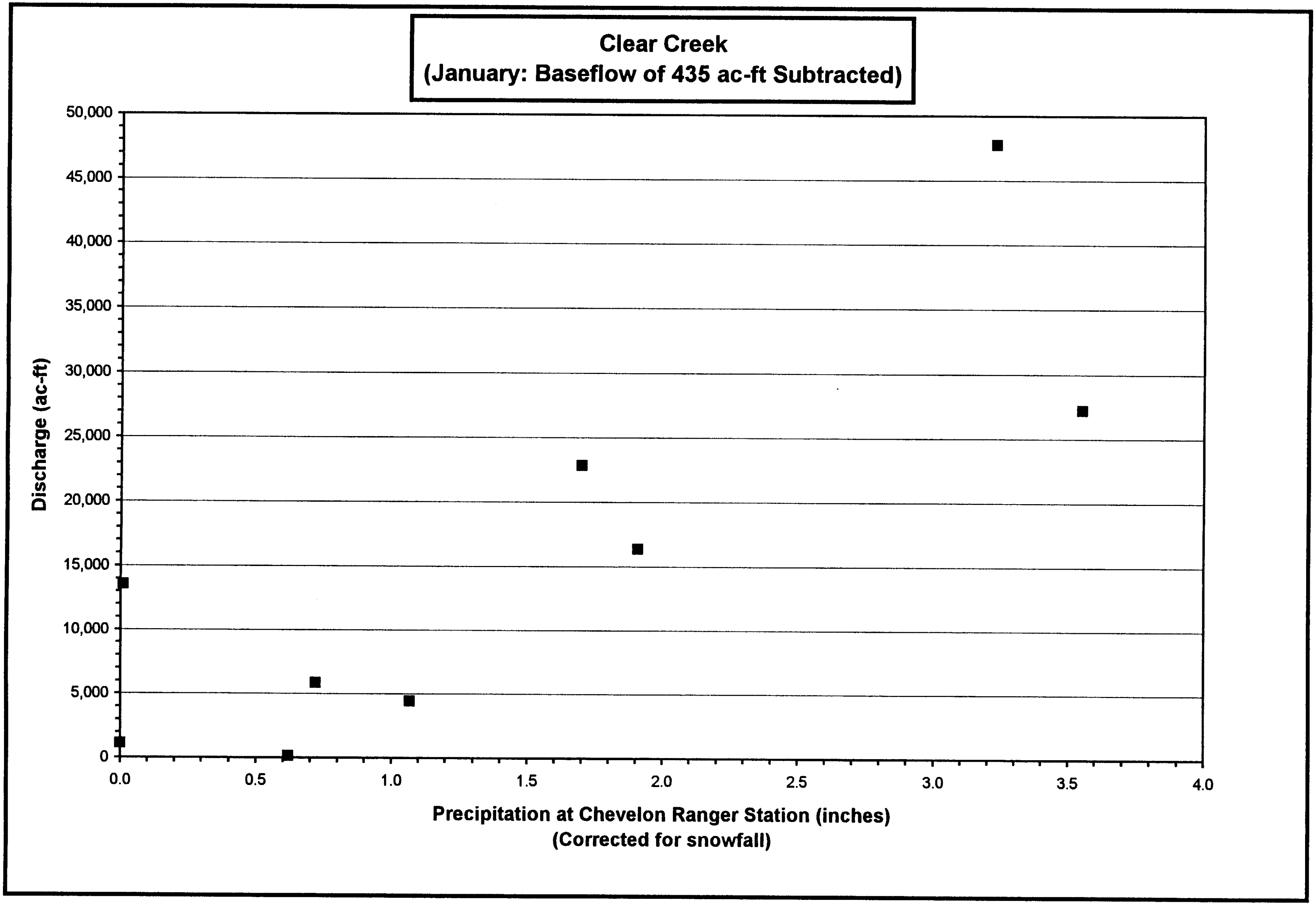


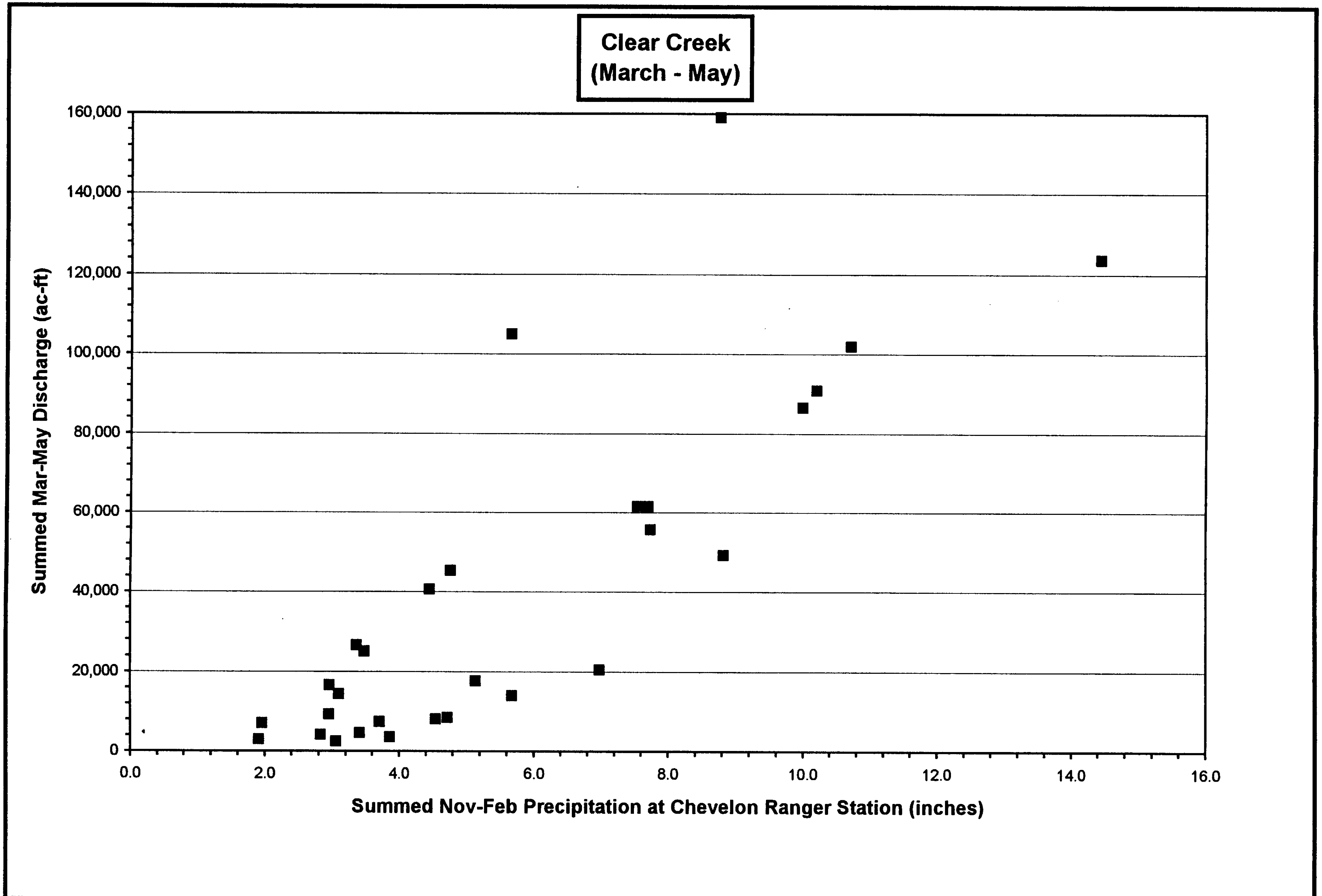
Chevelon Creek
(January: Baseflow of 402.6 ac-ft Subtracted)
Discharge (ac-ft)
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Precipitation at Chevelon Ranger Station (inches)
(Corrected for snowfall)


Chevelon Creek
(March - May)
60,000
50,000
40,000
30,000
20,000
10,000
0
Summed Mar-May Discharge (ac-ft)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
Summed Nov-Feb Precipitation at Chevelon Ranger Station (inches)

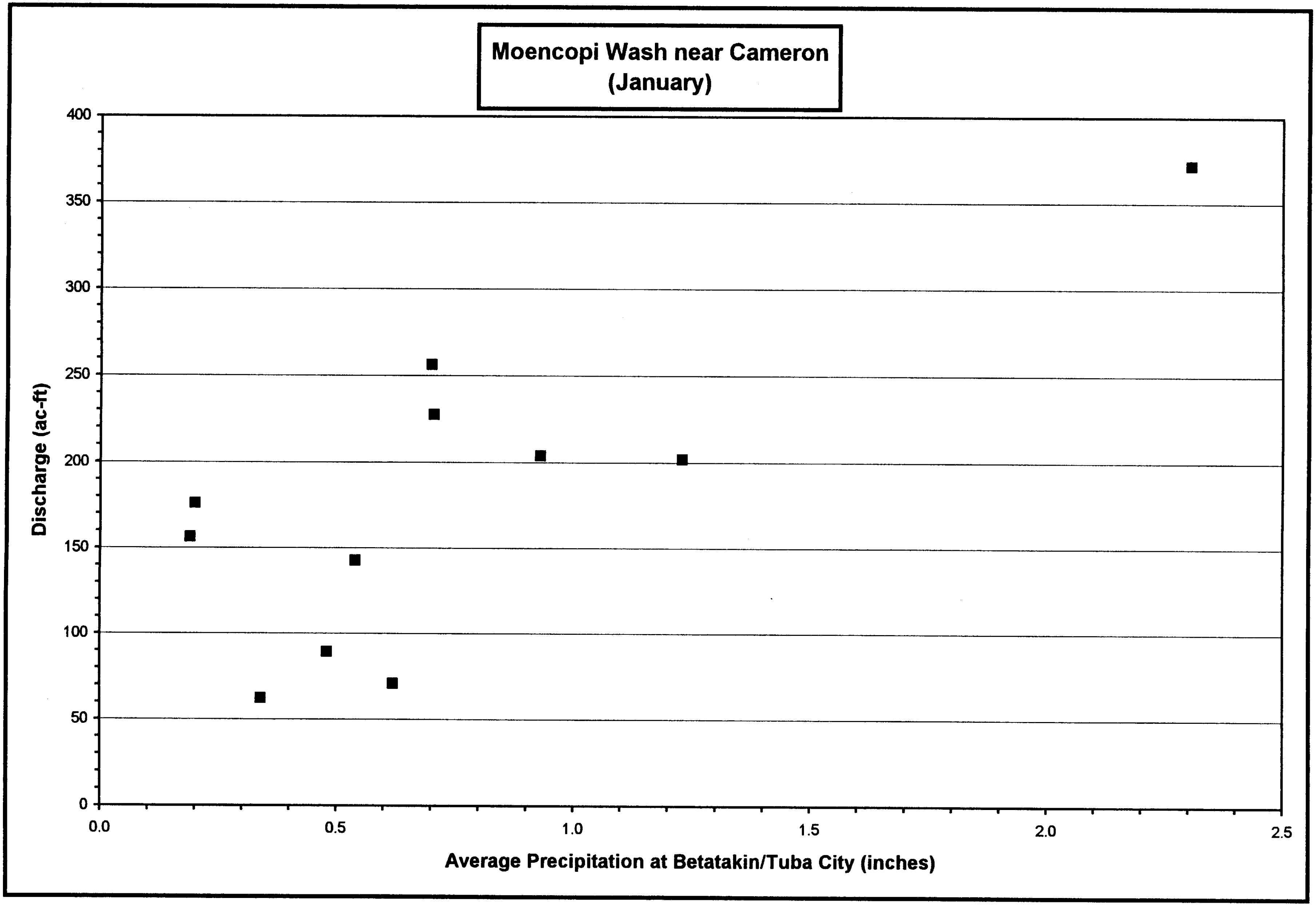


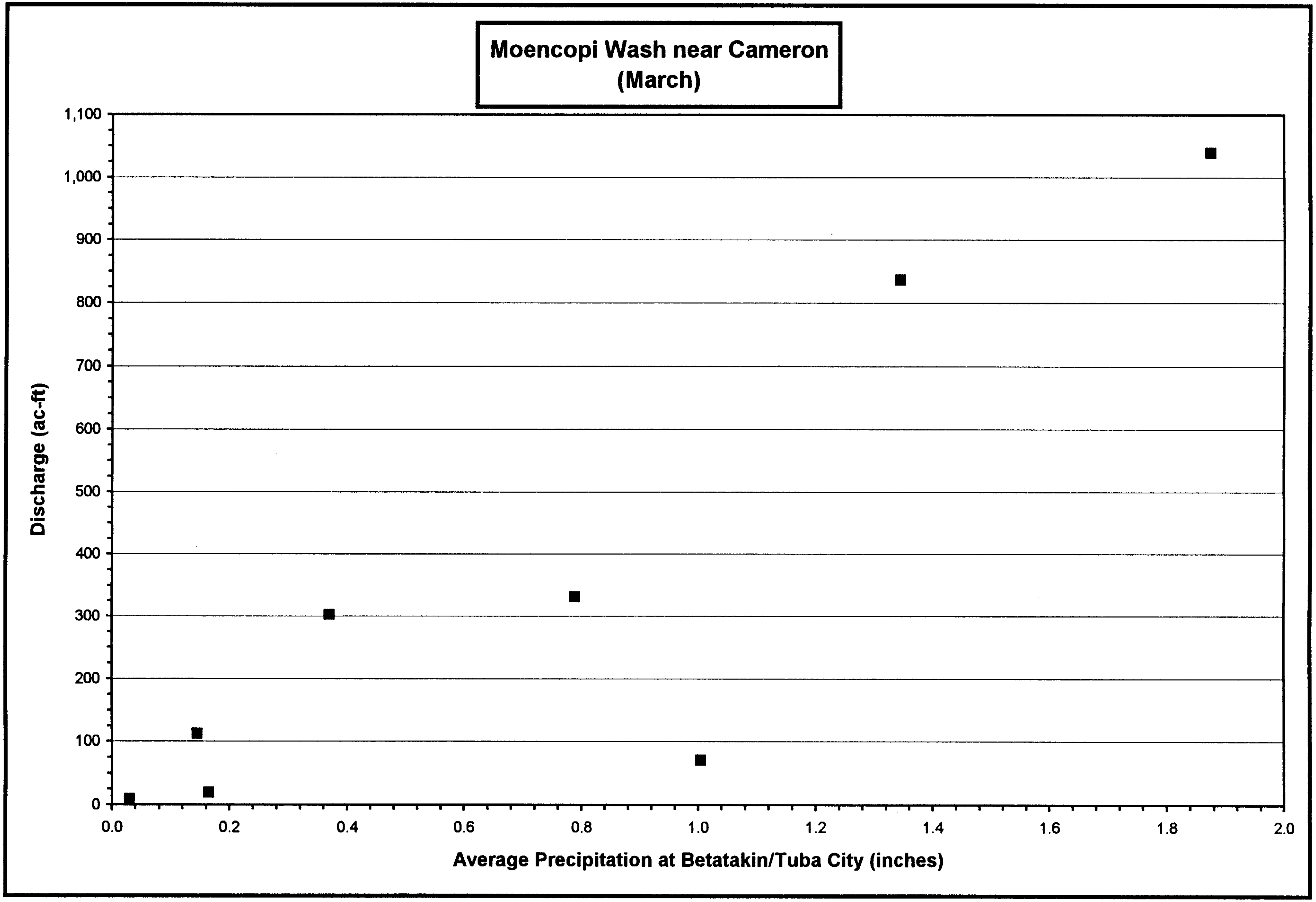
Clear Creek
(November - December: Baseflow of 434.9 ac-ft Subtracted)
Summed Nov-Dec Discharge (ac-ft)
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
Summed Nov-Dec Precipitation at Chevelon Ranger Station (inches)
(Corrected for snowfall)

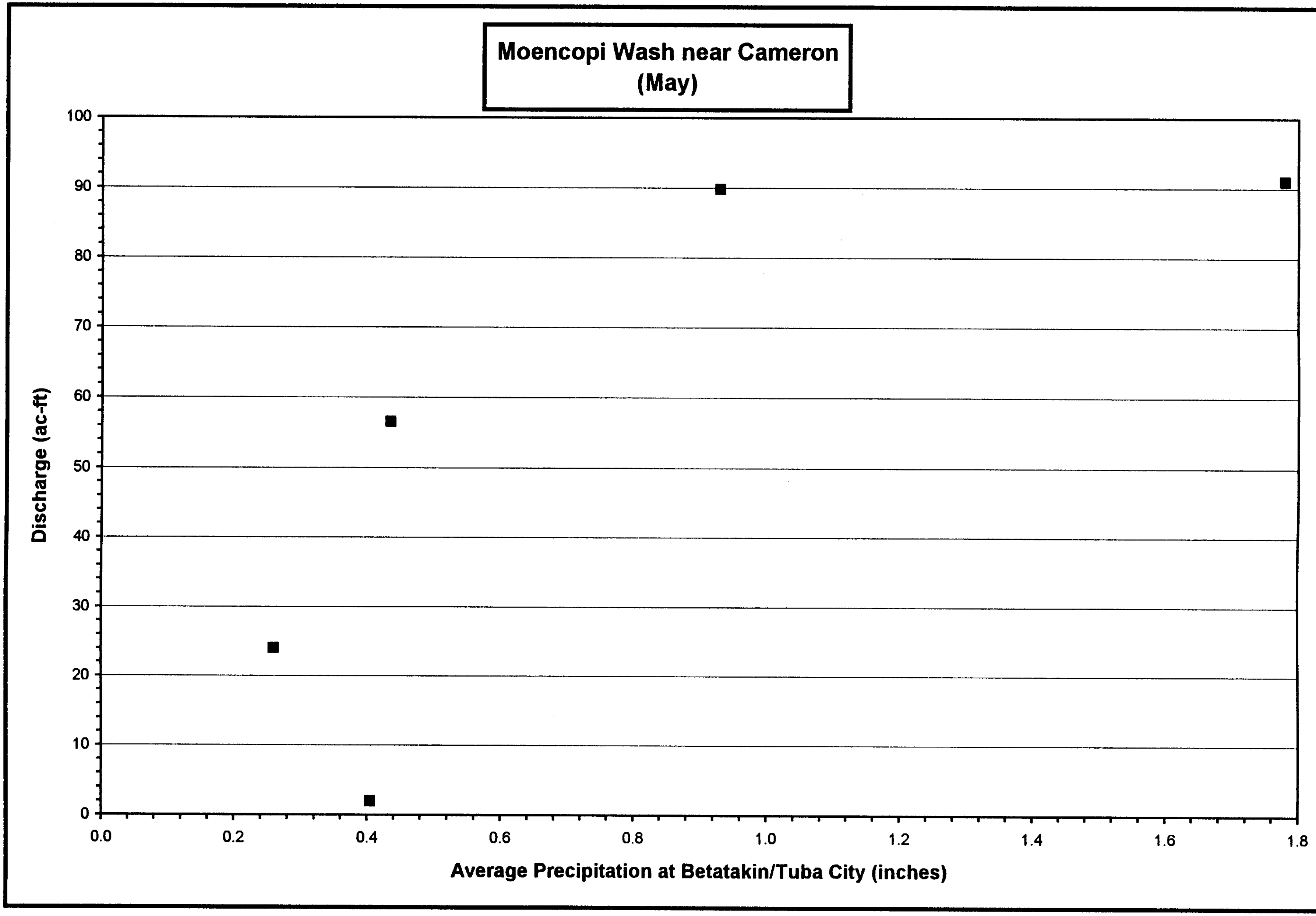

Clear Creek
(January: Baseflow of 435 ac-ft Subtracted)
Discharge (ac-ft)
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Precipitation at Chevelon Ranger Station (inches)
(Corrected for snowfall)

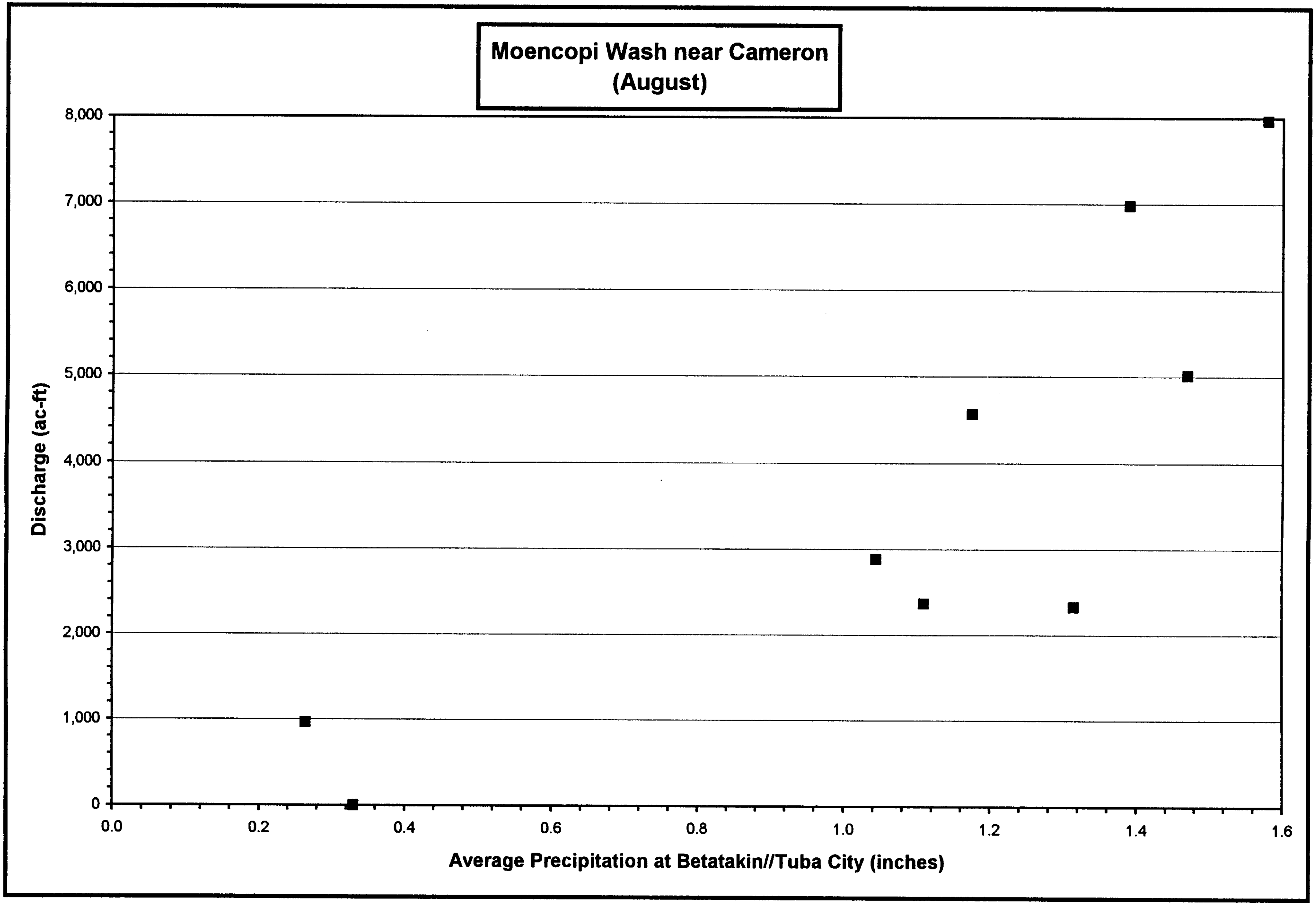


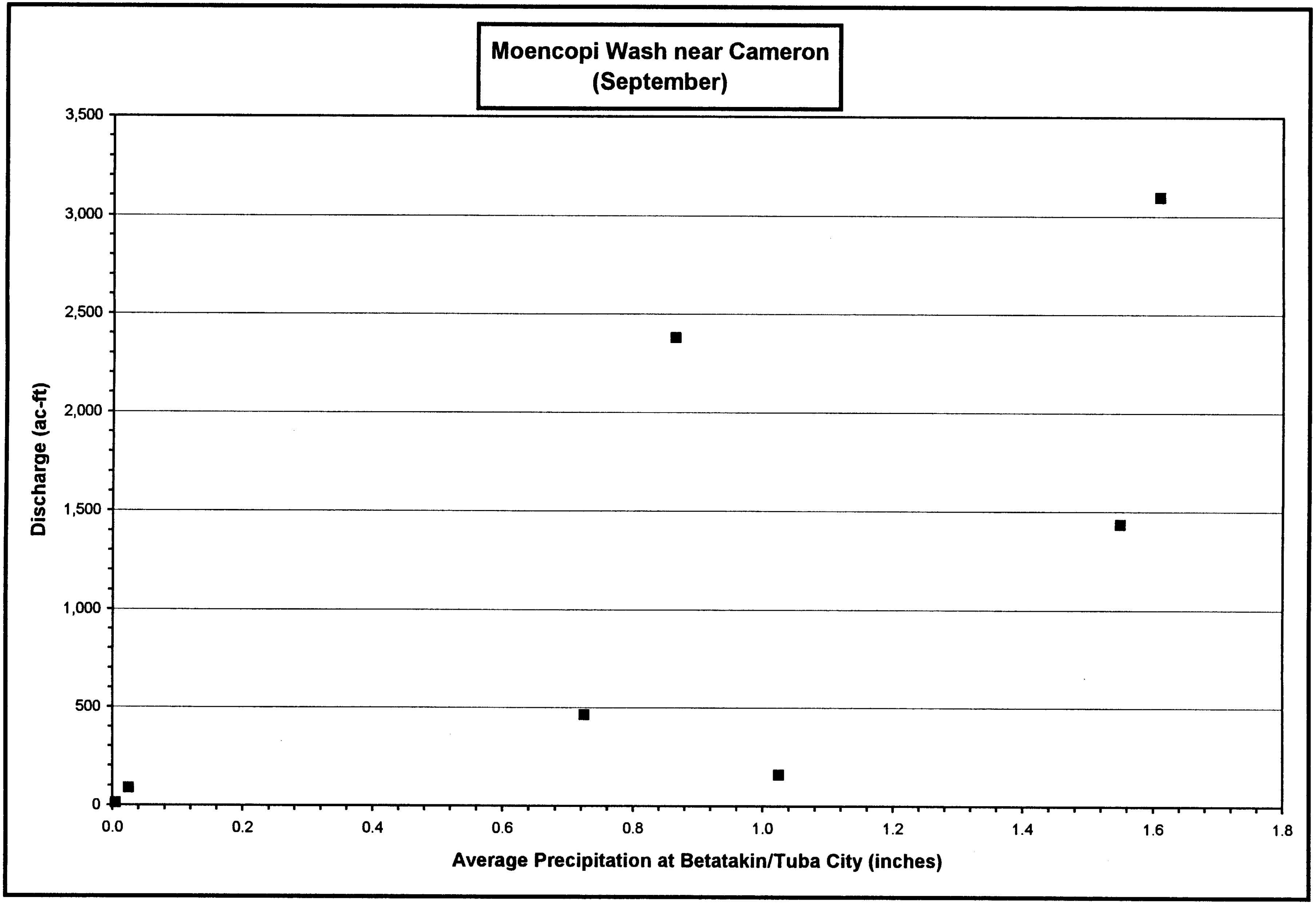
Clear Creek
(March - May)
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Summed Mar-May Discharge (ac-ft)
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
Summed Nov-Feb Precipitation at Chevelon Ranger Station (inches)

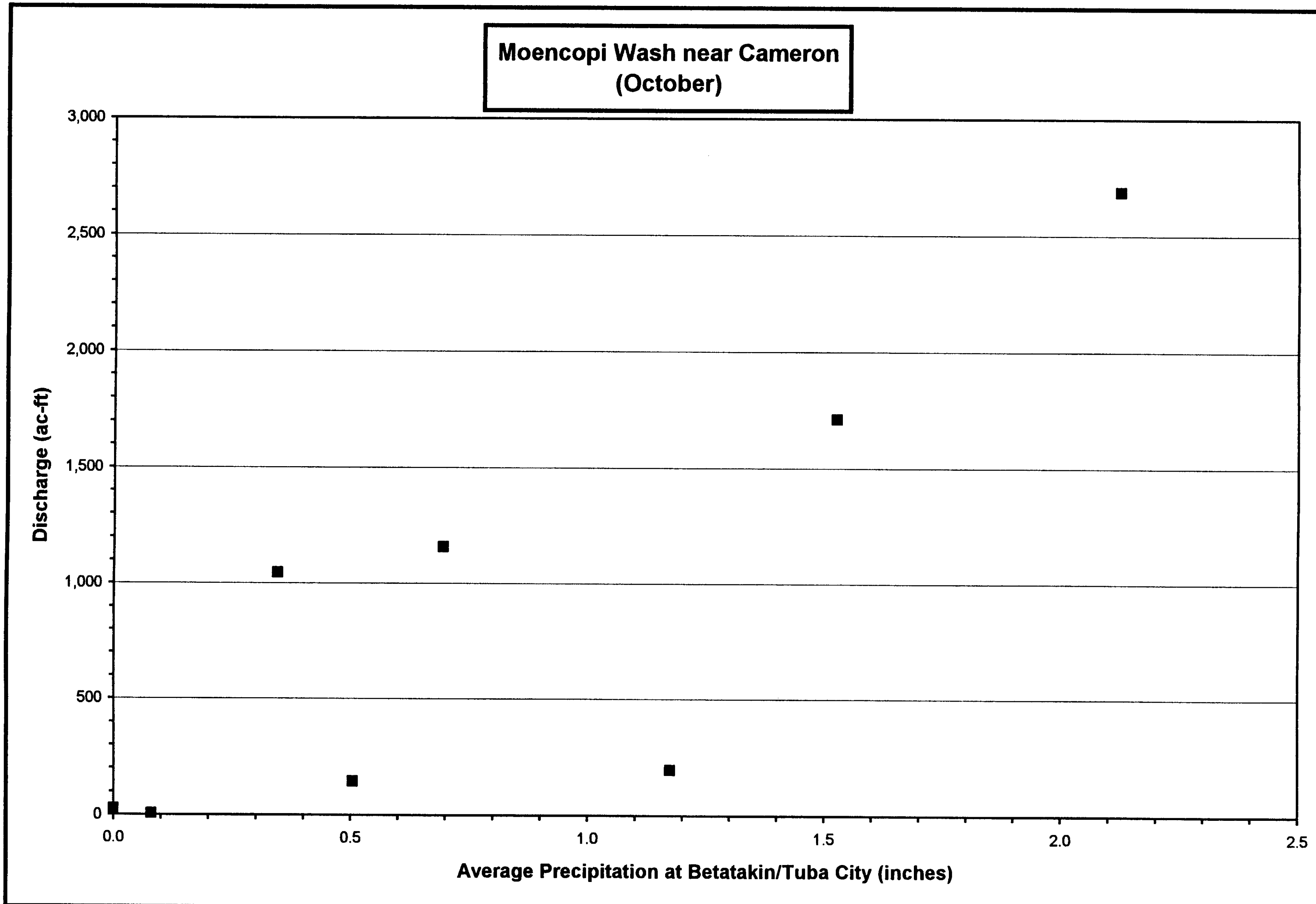

Moencopi Wash near Cameron
(January)
Discharge (ac-ft)
400
350
300
250
200
150
100
50
0
0.0
0.5
1.0
1.5
2.0
2.5
Average Precipitation at Betatakin/Tuba City (inches)


Moencopi Wash near Cameron
(March)
Discharge (ac-ft)
1,100
1,000
900
800
700
600
500
400
300
200
100
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Average Precipitation at Betatakin/Tuba City (inches)

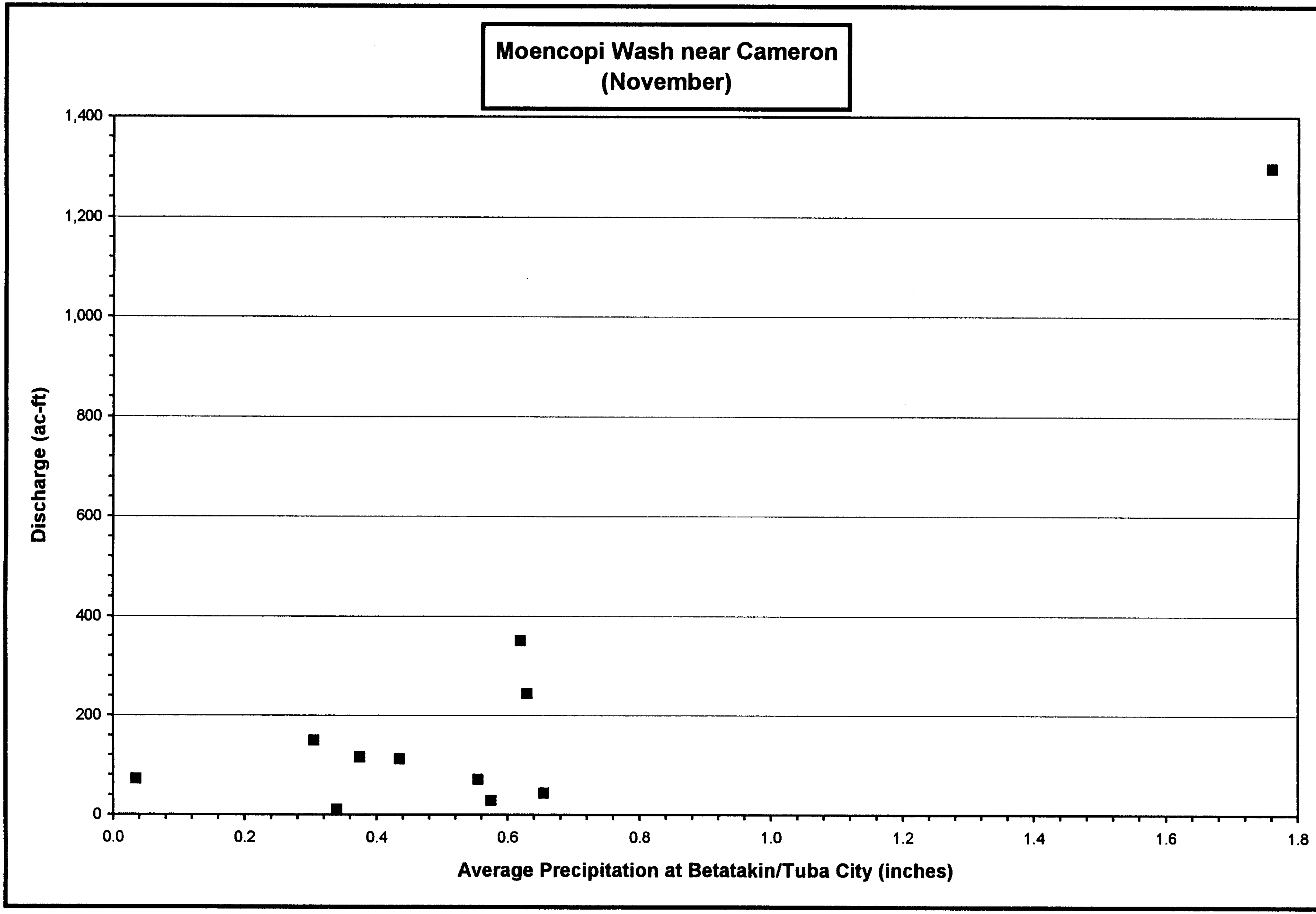

Moencopi Wash near Cameron
(May)
Discharge (ac-ft)
100
90
80
70
60
50
40
30
20
10
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Average Precipitation at Betatakin/Tuba City (inches)


Moencopi Wash near Cameron
(August)
Discharge (ac-ft)
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
Average Precipitation at Betatakin//Tuba City (inches)


Moencopi Wash near Cameron
(September)
Discharge (ac-ft)
3,500
3,000
2,500
2,000
1,500
1,000
500
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Average Precipitation at Betatakin/Tuba City (inches)



Moencopi Wash near Cameron
(October)
3,000
2,500
2,000
1,500
1,000
500
0
Discharge (ac-ft)
0.0
0.5
1.0
1.5
2.0
2.5
Average Precipitation at Betatakin/Tuba City (inches)


Moencopi Wash near Cameron
(November)
Discharge (ac-ft)
1,400
1,200
1,000
800
600
400
200
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
Average Precipitation at Betatakin/Tuba City (inches)

APPENDIX E

SIMULATED AND OBSERVED STREAMFLOW AND SEDIMENT LOAD VALUES

Simulated and Observed Discharge

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
1940	Jan	NA	6,667	818	5,875	618	7,805
	Feb	NA	9,078	5,344	10,651	4,883	12,565
	Mar	NA	71,022	13,472	23,172	13,596	23,522
	Apr	NA	3,799	6,676	21,221	6,789	21,766
	May	NA	553	2	2,619	104	2,778
	Jun	NA	1,860	0	1,257	102	1,790
	Jul	NA	4,004	12,230	7,498	14,937	10,761
	Aug	NA	25,699	42,046	23,983	49,806	34,126
	Sep	NA	37,408	51,448	25,360	60,801	30,394
	Oct	NA	7,255	21,650	14,218	25,954	17,832
	Nov	NA	2,133	8,598	13,772	8,522	14,405
	Dec	NA	7,125	28,770	17,361	28,601	17,650
1941	Jan	NA	13,227	56,692	22,093	53,271	25,013
	Feb	NA	19,470	74,921	21,661	70,449	24,220
	Mar	NA	11,104	136,689	40,653	137,018	44,680
	Apr	NA	512	107,645	35,580	107,925	36,818
	May	NA	688	86,391	6,205	86,637	6,548
	Jun	NA	1,900	3,963	4,691	4,071	5,337
	Jul	NA	16,677	3,818	4,694	5,100	7,897
	Aug	NA	44,471	26,778	27,227	31,951	34,303
	Sep	NA	29,325	31,008	32,363	36,897	36,947
	Oct	NA	15,804	53,833	13,846	63,591	20,038
	Nov	NA	2,263	3,070	13,276	3,020	13,700
	Dec	NA	6,662	2,970	16,533	2,920	16,921
1942	Jan	NA	16,274	6,721	7,285	6,180	9,838
	Feb	NA	4,408	6,454	20,769	5,928	23,229
	Mar	NA	5,791	19,043	37,207	19,176	37,727
	Apr	NA	2,745	50,603	36,221	50,789	36,390
	May	NA	889	5,983	6,572	6,095	6,841
	Jun	NA	1,278	0	1,395	102	1,872
	Jul	NA	8,712	0	3,806	635	7,242
	Aug	NA	34,813	371	14,117	1,068	18,403
	Sep	NA	12,457	0	21,147	635	22,333
	Oct	NA	17,291	664	7,688	1,411	9,552
	Nov	NA	1,752	595	5,344	556	5,460
	Dec	NA	1,858	0	2,860	0	3,148
1943	Jan	NA	3,216	291	22,238	122	23,782
	Feb	NA	4,324	6,731	20,730	6,190	22,107
	Mar	NA	4,703	53,120	28,413	53,310	32,096
	Apr	NA	3,803	12,782	24,689	12,905	25,052
	May	NA	2,173	0	5,587	102	5,747
	Jun	NA	2,074	0	2,415	102	3,017
	Jul	NA	17,110	0	6,170	635	9,298
	Aug	NA	19,736	16,731	19,907	20,201	30,396

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	Sep	NA	11,691	12,080	0	14,761	1,841
	Oct	NA	2,613	713	21,698	1,469	23,343
	Nov	NA	1,036	29	5,102	0	5,260
	Dec	NA	4,424	58	8,284	22	8,586
1944	Jan	NA	4,505	192	288	28	3,283
	Feb	NA	4,021	354	13,236	180	16,005
	Mar	NA	3,258	22,708	53,415	22,847	57,393
	Apr	NA	11,646	71,763	50,936	71,984	51,504
	May	NA	804	24,675	8,242	24,818	8,510
	Jun	NA	2,231	0	1,964	102	2,403
	Jul	NA	1,521	0	4,519	635	7,941
	Aug	NA	8,194	0	4,632	635	8,044
	Sep	NA	17,003	8,521	26,627	10,600	27,803
	Oct	NA	2,438	2,201	0	3,209	447
	Nov	NA	796	1,023	4,582	983	5,696
	Dec	NA	1,733	1,119	7,097	1,078	7,658
1945	Jan	NA	658	508	23,974	326	26,647
	Feb	NA	1,685	4,904	20,553	4,468	23,069
	Mar	NA	5,905	16,817	28,162	16,947	35,055
	Apr	NA	1,143	67,300	12,858	67,514	13,479
	May	NA	1,810	19,584	3,278	19,718	3,480
	Jun	NA	1,472	0	1,881	102	2,504
	Jul	NA	42,165	9,623	24,732	11,888	28,518
	Aug	NA	74,762	35,805	56,471	42,507	66,481
	Sep	NA	11,031	666	9,676	1,414	9,802
	Oct	NA	4,442	34	10,010	674	11,456
	Nov	NA	886	0	3,918	0	4,034
	Dec	NA	14,542	432	6,062	394	6,351
1946	Jan	NA	791	4,329	14,848	3,926	16,599
	Feb	NA	578	2,510	27,575	2,213	29,220
	Mar	NA	4,558	3,978	12,074	4,087	13,177
	Apr	NA	3,448	3,172	11,997	3,279	12,166
	May	NA	667	0	1,925	102	2,370
	Jun	NA	1,587	0	2,480	102	3,082
	Jul	NA	17,584	9,611	10,310	11,874	14,080
	Aug	NA	59,542	52,001	47,456	61,448	66,328
	Sep	NA	36,158	40,374	12,977	47,851	14,189
	Oct	NA	43	658	7,915	1,404	8,948
	Nov	NA	1,522	14,543	8,501	14,439	9,956
	Dec	NA	1,158	4,925	9,964	4,866	10,320
1947	Jan	NA	768	3,536	10,848	3,179	14,342
	Feb	NA	717	8,420	13,559	7,781	16,880
	Mar	NA	1,439	6,622	12,870	6,735	13,174
	Apr	NA	6,454	815	13,709	918	14,168

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	May	NA	721	422	2,133	525	2,414
	Jun	NA	1,210	0	1,318	0	1,757
	Jul	NA	6,556	0	4,919	0	8,083
	Aug	NA	69,351	74,463	33,362	104,261	52,612
	Sep	NA	9,540	12,669	20,005	20,168	20,916
	Oct	NA	20,207	57,000	26,261	75,390	30,623
	Nov	NA	2,679	702	15,517	710	17,297
	Dec	NA	7,927	1,021	21,587	1,019	21,876
1948	Jan	NA	6,968	3,511	8,993	3,304	11,938
	Feb	NA	9,125	7,915	15,663	6,462	18,492
	Mar	NA	7,342	19,867	63,707	19,069	65,821
	Apr	NA	1,113	68,312	29,152	67,365	29,367
	May	NA	600	996	5,285	857	5,625
	Jun	NA	1,526	62	2,463	879	3,046
	Jul	NA	12,599	4,962	4,527	5,242	7,655
	Aug	NA	16,973	16,171	13,278	20,187	17,762
	Sep	NA	28,732	1,726	10,495	602	12,568
	Oct	NA	7,951	2,115	26,284	4,443	28,937
	Nov	NA	2,098	2,017	4,876	2,176	4,992
	Dec	NA	4,687	3,277	10,542	2,071	10,830
1949	Jan	NA	9,265	16,872	30,659	18,337	33,443
	Feb	NA	9,910	13,146	16,991	13,640	19,342
	Mar	NA	1,491	85,531	74,406	97,142	75,124
	Apr	NA	692	75,988	54,848	77,887	55,017
	May	NA	989	6,069	9,479	6,011	9,646
	Jun	NA	2,439	4	4,479	1,686	5,024
	Jul	NA	7,542	13,337	9,147	11,758	12,642
	Aug	NA	46,371	39,291	26,430	41,372	32,094
	Sep	NA	19,859	10,747	14,054	10,745	16,249
	Oct	600	8,592	163	7,216	6,488	10,890
	Nov	505	2,932	445	3,927	252	4,337
	Dec	785	1,469	77	6,000	30	6,313
1950	Jan	948	1,206	462	5,122	188	6,955
	Feb	2,490	2,870	12,115	23,812	11,308	25,579
	Mar	459	7,259	14,433	19,174	14,555	20,379
	Apr	137	816	3,982	9,634	3,870	10,623
	May	122	824	197	1,713	0	1,872
	Jun	66	1,393	197	1,465	0	1,927
	Jul	6,353	8,702	6,249	7,037	7,690	10,874
	Aug	908	8,227	686	11,789	998	20,776
	Sep	1,412	7,856	1,250	0	1,676	942
	Oct	148	2,385	0	0	0	126
	Nov	421	358	0	1,067	22	1,183
	Dec	519	4,819	0	6,747	94	7,035

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
1951	Jan	775	864	0	12,532	152	13,439
	Feb	931	1,501	158	16,001	14	16,890
	Mar	476	25,281	253	26,656	0	28,027
	Apr	159	2,690	1,833	29,894	454	30,079
	May	127	641	2,183	4,874	1,312	5,164
	Jun	22	1,480	0	1,251	0	1,769
	Jul	1,821	4,583	1,918	3,498	3,971	6,641
	Aug	18,765	33,442	30,597	4,390	26,269	17,059
	Sep	866	15,080	9,253	28,483	17,915	29,241
	Oct	2,103	1,602	7,377	4,303	9,048	6,746
	Nov	974	3,223	201	22,677	103	23,910
	Dec	2,713	9,388	245	25,873	147	27,754
1952	Jan	32,025	12,434	130,992	52,497	124,746	53,779
	Feb	1,712	10,530	10,947	15,278	10,193	16,274
	Mar	5,274	11,115	12,827	83,503	12,912	89,334
	Apr	6,698	3,954	129,159	57,263	131,841	57,675
	May	1,172	1,461	20,807	10,406	21,070	10,688
	Jun	1,794	2,478	358	3,511	165	4,216
	Jul	7,451	9,491	1,447	5,421	1,913	9,665
	Aug	11,937	13,259	10,293	19,304	12,556	25,954
	Sep	7,513	19,417	22,982	12,792	27,821	20,569
	Oct	562	8,923	0	1,243	114	1,370
	Nov	1,771	5,260	580	21,338	488	22,273
	Dec	5,504	7,224	3,959	22,437	3,919	22,726
1953	Jan	1,906	727	1,986	2,372	1,642	2,649
	Feb	576	1,533	1,755	12,145	1,422	12,512
	Mar	2,893	1,314	15,169	20,799	15,306	22,483
	Apr	229	12,914	5,806	22,319	5,735	22,488
	May	257	2,892	197	6,888	0	7,194
	Jun	698	1,633	197	2,224	0	2,825
	Jul	16,053	20,757	12,237	11,341	14,894	15,225
	Aug	4,363	8,032	12,369	17,878	15,054	32,751
	Sep	161	4,206	45	4,937	227	5,858
	Oct	223	0	0	6,469	0	6,920
	Nov	350	320	0	1,723	130	2,250
	Dec	480	1,348	0	8,448	27	8,737
1954	Jan	652	1,568	0	4,328	135	5,146
	Feb	670	2,135	0	9,675	26	10,449
	Mar	4,886	15,372	20,838	23,561	17,556	29,918
	Apr	365	1,765	19,976	12,929	20,200	13,098
	May	162	652	0	2,335	120	2,543
	Jun	54	1,721	0	1,579	270	2,019
	Jul	37,608	30,263	39,310	15,645	37,862	19,449
	Aug	7,306	12,992	5,399	9,790	6,286	10,155

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	Sep	21,159	34,376	21,987	22,030	25,945	26,055
	Oct	1,589	12,802	2,712	7,878	4,158	8,565
	Nov	502	1,793	0	748	68	897
	Dec	579	629	0	511	63	800
1955	Jan	657	986	25	13,523	113	18,649
	Feb	668	1,541	78	20,355	176	25,106
	Mar	522	1,431	1,156	29,767	473	29,947
	Apr	198	4,718	525	12,372	22	12,991
	May	240	641	0	2,268	0	2,585
	Jun	9,602	1,911	18,078	2,451	35,380	2,891
	Jul	8,582	12,907	5,276	5,031	12,317	8,569
	Aug	96,083	68,038	122,116	29,792	139,198	39,501
	Sep	3,035	2,425	2,344	7,531	3,598	7,647
	Oct	288	0	0	5,919	0	6,202
	Nov	409	314	0	5,729	0	6,085
	Dec	905	863	121	10,831	69	11,416
1956	Jan	2,026	11,419	0	15,708	121	19,840
	Feb	8,041	11,175	3,704	38,271	2,034	42,066
	Mar	563	1,413	7,379	25,003	5,173	25,199
	Apr	178	2,393	2,071	24,812	1,234	24,981
	May	80	1,741	47	6,124	37	6,469
	Jun	1,524	980	0	1,247	0	1,687
	Jul	2,892	10,438	0	3,567	1,980	7,303
	Aug	7,525	17,430	5,337	0	8,694	5,463
	Sep	137	12,123	0	16,038	0	16,195
	Oct	531	7,091	0	978	0	1,235
	Nov	318	4,484	0	1,463	0	1,579
	Dec	488	847	0	0	0	289
1957	Jan	1,061	3,896	43,300	90,524	39,171	101,478
	Feb	1,424	6,307	41,715	35,045	40,875	44,915
	Mar	561	2,542	24,811	56,303	25,755	58,305
	Apr	233	613	2,987	61,089	1,926	62,140
	May	143	692	0	11,010	57	11,499
	Jun	60	409	0	445	263	1,034
	Jul	12,385	12,516	4,470	6,297	4,168	9,425
	Aug	56,281	57,938	44,358	41,383	53,472	50,391
	Sep	5,281	1,965	8,134	7,060	9,266	7,176
	Oct	10,390	27,239	12,857	5,322	12,827	8,545
	Nov	2,169	446	9,592	384	12,423	2,259
	Dec	642	718	2,078	3,734	1,264	4,183
1958	Jan	729	404,876	228	10,632	307	13,895
	Feb	602	4,908	6,498	22,212	4,904	25,324
	Mar	3,024	3,827	29,939	32,606	31,256	37,345
	Apr	694	1,910	43,153	18,303	44,537	19,158

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	May	232	502	1,174	3,548	1,619	3,783
	Jun	2,483	1,003	780	676	165	1,201
	Jul	2,662	9,128	990	3,595	444	6,722
	Aug	26,332	59,832	22,308	43,676	23,088	52,071
	Sep	23,736	39,993	31,472	17,097	34,417	21,802
	Oct	2,467	1,784	8,885	8,341	10,812	9,585
	Nov	698	1,970	0	2,997	63	3,228
	Dec	596	594	0	4,816	29	5,104
1959	Jan	697	2,136	0	10,239	128	11,714
	Feb	561	809	0	12,391	80	13,854
	Mar	368	1,649	4,243	27,093	1,890	27,209
	Apr	394	1,890	3,201	14,066	2,394	14,523
	May	294	1,993	0	3,827	0	4,145
	Jun	1,433	2,187	0	3,233	49	3,847
	Jul	2,734	6,331	354	1,980	96	5,673
	Aug	33,404	36,891	30,892	31,004	35,587	38,330
	Sep	358	3,727	282	16,506	264	16,949
	Oct	33,928	23,457	12,310	6,812	6,581	9,725
	Nov	9,467	3,443	33,204	17,717	34,715	18,233
	Dec	6,002	11,724	22,825	19,686	19,007	19,975
1960	Jan	9,378	69,028	22,044	25,129	18,196	29,131
	Feb	2,826	4,641	8,893	14,132	8,216	17,881
	Mar	13,490	3,496	89,773	46,001	88,475	48,208
	Apr	642	8,192	18,209	45,805	18,557	45,974
	May	294	843	100	6,626	24	6,777
	Jun	248	1,306	2	758	13	1,216
	Jul	483	1,285	0	3,943	0	7,071
	Aug	1,950	9,738	0	0	0	647
	Sep	251	2,416	174	6,456	382	8,629
	Oct	5,517	29,097	7,459	6,436	9,146	10,472
	Nov	432	740	179	4,647	80	5,141
	Dec	543	2,073	222	6,403	124	6,974
1961	Jan	676	2,952	342	8,204	73	8,553
	Feb	373	2,742	278	15,419	13	15,786
	Mar	468	10,755	2,422	21,228	2,275	26,678
	Apr	357	2,359	11,560	11,080	11,618	11,249
	May	369	1,129	197	2,284	0	2,532
	Jun	191	1,417	197	825	0	1,264
	Jul	1,767	12,967	443	8,943	706	12,844
	Aug	11,723	34,648	7,717	17,917	9,457	24,878
	Sep	7,236	30,728	4,235	16,287	5,268	19,110
	Oct	7,086	19,520	281	4,938	510	6,655
	Nov	6,536	11,032	3,753	18,031	3,710	18,794
	Dec	875	3,585	106	15,224	6	16,593

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
1962	Jan	1,430	8,254	362	41,621	93	42,987
	Feb	17,335	10,214	48,779	12,295	46,294	13,589
	Mar	3,269	1,623	13,900	45,477	14,009	47,552
	Apr	1,125	2,571	83,967	32,062	85,640	32,231
	May	410	571	1,367	4,622	1,197	4,776
	Jun	483	2,364	197	2,777	0	3,250
	Jul	299	2,998	0	0	0	3,128
	Aug	275	4,786	0	19,201	167	19,929
	Sep	2,645	36,232	4,952	24,976	6,131	27,927
	Oct	19,912	11,138	3,595	2,821	4,498	5,541
	Nov	5,776	1,001	3,166	2,319	3,114	3,270
	Dec	604	1,194	257	7,627	159	7,966
1963	Jan	570	4,811	280	6,952	14	9,194
	Feb	3,255	7,488	2,496	26,197	2,129	28,350
	Mar	351	2,553	1,476	15,290	1,308	17,143
	Apr	307	2,362	1,911	16,363	1,753	17,138
	May	254	876	197	2,543	0	2,923
	Jun	110	337	197	0	0	496
	Jul	151	2,958	0	0	0	3,128
	Aug	58,894	95,209	34,232	72,487	41,355	90,807
	Sep	27,092	7,556	24,737	6,426	29,933	7,280
	Oct	967	4,473	1,396	0	1,852	1,366
	Nov	2,662	3,230	769	3,536	680	3,726
	Dec	503	1,610	100	1,380	0	1,668
1964	Jan	423	1,475	265	26,188	0	26,501
	Feb	361	2,044	265	14,505	0	14,872
	Mar	354	5,823	197	23,870	0	29,902
	Apr	1,085	724	26,792	11,638	27,189	12,135
	May	350	3,886	3,210	5,872	3,080	6,173
	Jun	156	677	255	300	60	813
	Jul	15,863	23,172	8,123	11,693	9,945	15,724
	Aug	131,082	111,313	84,555	67,043	101,897	75,671
	Sep	27,326	33,863	21,636	29,541	26,201	31,091
	Oct	633	0	313	4,048	549	4,174
	Nov	927	2,322	100	11,960	0	12,424
	Dec	1,027	5,501	100	12,427	0	12,716
1965	Jan	6,591	4,346	44,426	56,584	42,141	62,760
	Feb	1,622	5,728	13,065	18,964	12,214	24,598
	Mar	851	16,291	14,839	72,717	14,969	76,802
	Apr	1,048	995	85,835	52,038	87,550	52,207
	May	515	1,778	16,407	10,501	16,572	10,749
	Jun	375	2,874	197	4,567	0	5,100
	Jul	39,234	20,700	17,160	16,664	20,817	20,299
	Aug	8,904	14,642	8,261	0	10,111	3,363

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	Sep	23,833	15,870	17,286	15,473	20,969	21,501
	Oct	1,848	2,307	202	567	416	2,163
	Nov	1,219	4,547	3,956	33,317	3,916	35,215
	Dec	32,527	13,650	24,217	39,026	24,494	42,715
1966	Jan	7,698	964	58,758	137	55,817	502
	Feb	1,458	5,207	4,807	15,358	4,334	15,725
	Mar	4,632	4,702	65,611	50,932	66,875	51,336
	Apr	737	8,357	16,777	38,194	16,951	38,793
	May	405	932	272	6,146	77	6,485
	Jun	229	1,351	197	441	0	959
	Jul	10,778	30,223	668	19,959	976	23,346
	Aug	22,074	31,363	14,410	12,246	17,508	16,249
	Sep	15,733	22,131	9,094	1,296	11,113	3,610
	Oct	3,782	3,902	3,620	2,245	4,527	3,513
	Nov	419	4,417	142	17,066	43	17,507
	Dec	573	5,686	22,763	18,963	23,017	19,314
1967	Jan	450	742	317	0	50	321
	Feb	368	579	315	35,697	48	36,064
	Mar	295	2,803	197	15,349	0	15,577
	Apr	237	8,391	1,374	16,463	1,204	17,326
	May	242	1,171	197	2,310	0	2,593
	Jun	3,324	317	2,742	844	2,603	1,490
	Jul	30,645	18,071	18,778	10,649	22,763	14,703
	Aug	88,935	78,914	72,414	34,573	87,291	45,339
	Sep	41,973	20,260	40,484	8,879	48,877	11,441
	Oct	496	2,076	231	8,243	450	8,447
	Nov	388	5,154	100	32,697	0	32,813
	Dec	544	15,198	215	39,612	117	39,900
1968	Jan	34,733	4,990	4,395	2,666	3,941	2,937
	Feb	13,071	5,015	42,456	11,010	40,260	11,377
	Mar	7,726	5,288	48,208	39,366	49,083	40,154
	Apr	1,369	1,561	65,842	34,181	67,111	35,049
	May	434	672	12,237	5,764	12,309	5,926
	Jun	253	2,609	197	3,221	0	3,661
	Jul	11,336	13,121	5,320	6,557	6,573	10,094
	Aug	97,986	103,350	28,076	61,006	33,949	70,674
	Sep	374	9,721	0	5,223	1	5,484
	Oct	28,155	5,338	4,144	12,081	5,158	13,434
	Nov	2,012	2,986	276	11,274	179	11,720
	Dec	467	4,671	100	10,710	0	10,998
1969	Jan	26,315	686	28,142	36,467	26,602	40,341
	Feb	2,896	1,600	8,251	7,185	7,620	10,742
	Mar	4,491	5,111	17,688	48,627	17,882	51,843
	Apr	2,882	2,660	37,087	30,300	37,714	30,469

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	May	1,021	762	1,274	5,183	1,101	5,433
	Jun	355	1,160	197	1,504	0	1,944
	Jul	23,925	14,758	10,612	9,907	12,940	13,633
	Aug	45,346	59,727	6,405	34,005	7,879	38,543
	Sep	42,980	12,437	18,786	9,950	22,773	11,604
	Oct	877	9,558	4,555	2,777	5,653	5,694
	Nov	722	1,131	1,213	5,140	1,130	5,792
	Dec	372	1,938	147	11,087	48	11,542
1970	Jan	357	3,281	331	4,171	63	4,492
	Feb	477	1,371	265	796	0	1,163
	Mar	685	9,169	5,359	61,060	5,278	71,410
	Apr	732	2,250	4,724	13,430	4,628	13,942
	May	548	979	197	3,001	0	3,280
	Jun	215	0	197	0	0	440
	Jul	2,012	10,754	463	7,276	729	11,233
	Aug	14,560	41,630	11,150	25,746	13,587	32,355
	Sep	36,455	26,040	41,021	15,400	49,523	16,891
	Oct	2,703	9,118	420	7,633	679	8,206
	Nov	260	353	108	766	8	882
	Dec	240	711	166	3,329	67	3,618
1971	Jan	196	4,739	313	5,318	46	5,588
	Feb	158	727	271	3,483	5	3,850
	Mar	207	5,444	197	10,105	0	10,233
	Apr	163	3,450	197	8,044	0	8,213
	May	245	1,868	197	3,859	0	4,013
	Jun	152	1,063	197	1,665	0	2,190
	Jul	346	16,477	0	6,694	130	10,355
	Aug	67,712	37,946	50,179	26,450	60,540	35,619
	Sep	59,758	41,438	13,300	5,505	16,173	6,810
	Oct	26,853	21,667	62,572	5,066	75,449	8,719
	Nov	564	1,115	6,069	7,636	6,062	8,018
	Dec	12,129	3,115	27,874	12,253	28,209	12,541
1972	Jan	934	755	7,500	16,038	6,904	16,292
	Feb	465	601	603	7,185	322	7,552
	Mar	345	2,286	197	14,051	0	14,167
	Apr	314	3,889	197	15,350	0	15,829
	May	770	1,618	197	4,530	0	4,945
	Jun	1,693	2,940	374	3,756	182	4,241
	Jul	3,700	417	7,152	0	8,777	3,635
	Aug	8,100	16,576	4,175	14,424	5,196	21,266
	Sep	3,070	2,705	1,083	20,536	1,476	21,964
	Oct	57,714	48,341	214,117	14,829	257,766	30,871
	Nov	3,074	2,406	12,015	16,382	12,101	16,892
	Dec	2,148	7,328	6,402	23,413	6,401	23,701

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
1973	Jan	1,680	868	13,152	30,727	12,298	32,028
	Feb	9,537	6,605	26,214	7,169	24,762	8,368
	Mar	77,883	13,363	85,263	76,110	86,965	83,714
	Apr	60,857	1,231	231,253	56,537	236,216	56,706
	May	36,881	731	173,524	9,401	177,197	9,744
	Jun	1,831	834	2,016	230	1,860	749
	Jul	415	8,376	0	4,826	39	8,248
	Aug	1,261	20,842	27	2,225	205	3,630
	Sep	232	2,338	0	9,572	46	10,228
	Oct	462	0	0	4,913	0	5,275
	Nov	355	448	100	0	0	697
	Dec	533	677	100	636	0	924
1974	Jan	3,548	1,571	952	44,179	656	47,671
	Feb	412	1,422	330	15,445	62	18,619
	Mar	368	3,062	8,081	33,915	8,060	34,901
	Apr	349	2,884	4,108	26,525	3,999	27,022
	May	310	1,462	197	6,298	0	6,925
	Jun	39	2,471	197	3,186	0	3,768
	Jul	NA	22,792	5,379	15,955	6,643	19,739
	Aug	NA	11,234	4,878	6,075	6,042	6,191
	Sep	NA	19,532	2,185	9,699	2,801	10,958
	Oct	NA	33,602	9,016	22,032	11,019	25,521
	Nov	NA	9,471	11,763	15,745	11,845	16,232
	Dec	NA	653	100	8,499	0	8,788
1975	Jan	NA	2,054	277	6,811	12	7,616
	Feb	NA	3,750	321	11,792	53	12,600
	Mar	NA	5,238	14,042	22,508	14,155	25,940
	Apr	NA	8,044	32,263	21,240	32,783	21,735
	May	NA	682	6,247	3,161	6,185	3,415
	Jun	NA	490	197	0	0	561
	Jul	NA	19,287	8,055	13,707	9,863	17,331
	Aug	NA	10,480	670	9,611	979	9,732
	Sep	NA	28,189	21,077	15,363	25,529	17,919
	Oct	NA	3,548	3	1,877	177	2,076
	Nov	NA	1,221	100	14,203	0	15,925
	Dec	NA	3,737	978	17,219	892	17,816
1976	Jan	NA	5,999	413	27,028	142	30,175
	Feb	NA	4,710	13,352	29,822	12,489	32,853
	Mar	NA	5,209	17,631	23,217	17,823	25,815
	Apr	NA	1,322	34,925	17,322	35,504	17,577
	May	NA	992	9,713	3,874	9,729	4,542
	Jun	NA	565	197	505	0	1,138
	Jul	NA	26,166	15,752	18,391	19,123	21,902
	Aug	NA	16,156	3,200	1,849	4,022	6,183

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	Sep	NA	14,983	6,230	12,123	7,667	16,555
	Oct	NA	2,648	279	2,398	509	2,752
	Nov	NA	511	176	456	77	572
	Dec	NA	1,798	100	3,988	0	4,276
1977	Jan	NA	778	3,757	22,058	3,332	24,866
	Feb	NA	2,458	852	13,154	560	15,766
	Mar	NA	10,588	225	15,094	29	15,332
	Apr	NA	2,447	5,083	21,036	4,995	21,810
	May	NA	1,617	199	4,702	3	4,864
	Jun	NA	559	197	880	0	1,342
	Jul	NA	20,017	13,521	14,721	16,440	18,212
	Aug	NA	20,713	29,916	24,515	36,163	36,508
	Sep	NA	9,541	6,062	15,162	7,465	16,405
	Oct	NA	8,041	4,864	12,207	6,025	12,794
	Nov	NA	942	695	365	605	569
	Dec	NA	4,904	265	5,401	168	6,045
1978	Jan	NA	12,571	896	24,754	603	33,820
	Feb	NA	15,351	5,773	34,283	5,256	42,460
	Mar	NA	17,481	112,846	66,521	115,164	74,054
	Apr	NA	615	46,240	39,980	47,072	41,759
	May	NA	538	2,432	5,469	2,285	5,630
	Jun	NA	540	394	0	202	440
	Jul	NA	1,694	0	0	0	3,267
	Aug	NA	40,140	58	13,696	243	14,970
	Sep	NA	22,991	864	10,807	1,212	12,377
	Oct	NA	16,019	5,958	4,961	7,341	6,331
	Nov	NA	6,386	35,469	39,998	35,922	43,960
	Dec	NA	18,678	102,358	47,555	103,857	47,965
1979	Jan	NA	10,292	16,413	19,742	15,410	25,305
	Feb	NA	6,980	47,806	18,698	45,366	23,612
	Mar	NA	11,143	77,056	73,743	78,575	76,030
	Apr	NA	5,914	155,409	67,791	158,678	67,960
	May	NA	1,145	21,662	12,366	21,945	12,664
	Jun	NA	2,805	1,789	5,042	1,628	5,482
	Jul	NA	648	0	956	0	4,280
	Aug	NA	5,724	3,170	16,318	3,986	24,718
	Sep	NA	2,819	0	15,453	0	15,687
	Oct	NA	2,394	78	19,709	267	22,040
	Nov	NA	4,210	1,941	8,048	1,870	9,550
	Dec	NA	2,293	482	7,811	388	8,100
1980	Jan	NA	14,046	8,920	56,389	8,259	67,842
	Feb	NA	19,824	127,357	52,778	121,277	63,143
	Mar	NA	8,226	44,923	96,657	45,725	100,280
	Apr	NA	1,736	102,146	96,797	104,225	97,326

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	May	NA	751	36,241	15,985	36,849	16,163
	Jun	NA	233	289	0	94	491
	Jul	NA	18,009	0	8,668	14	12,123
	Aug	NA	13,328	3,739	6,629	4,670	13,116
	Sep	NA	27,368	7,905	16,889	9,683	19,875
	Oct	NA	9,576	0	2,298	0	3,821
	Nov	NA	334	100	0	0	116
	Dec	NA	722	108	3,405	8	3,693
1981	Jan	NA	9,922	334	18,765	65	21,577
	Feb	NA	8,204	342	15,376	73	18,057
	Mar	NA	8,281	243	12,661	47	16,765
	Apr	NA	5,008	1,979	10,526	1,822	11,290
	May	NA	498	271	875	76	1,135
	Jun	NA	4,085	203	5,916	7	6,507
	Jul	NA	10,571	17,169	6,162	20,828	10,166
	Aug	NA	20,137	4,143	22,267	5,157	32,684
	Sep	NA	10,340	10,716	15,232	13,065	18,015
	Oct	NA	5,495	21,476	19,470	26,009	22,128
	Nov	NA	2,018	133	7,428	33	8,321
	Dec	NA	2,186	1,408	6,313	1,329	6,743
1982	Jan	NA	11,997	3,711	24,194	3,288	33,035
	Feb	NA	9,373	23,129	25,996	21,818	34,102
	Mar	NA	4,710	69,761	44,242	71,117	50,527
	Apr	NA	658	31,798	33,328	32,307	33,565
	May	NA	1,395	3,280	7,679	3,152	8,152
	Jun	NA	1,045	197	776	0	1,215
	Jul	NA	10,149	23	3,962	200	8,038
	Aug	NA	38,147	35,172	29,093	42,486	53,511
	Sep	NA	26,596	21,333	18,029	25,837	22,312
	Oct	NA	2,783	185	2,624	395	3,707
	Nov	NA	4,348	3,271	28,031	3,221	30,340
	Dec	NA	23,178	27,031	32,597	27,352	36,309
1983	Jan	NA	3,921	9,535	5,978	8,846	7,801
	Feb	NA	4,442	18,197	25,490	17,111	27,160
	Mar	NA	8,125	81,524	43,762	83,143	48,281
	Apr	NA	4,869	91,737	34,907	93,584	35,131
	May	NA	879	40,988	5,809	41,702	5,955
	Jun	NA	1,271	209	2,534	13	3,037
	Jul	NA	24,639	7,722	20,348	9,463	23,984
	Aug	NA	27,967	17,617	21,122	21,366	33,882
	Sep	NA	41,288	14,056	0	17,083	6,826
	Oct	NA	13,138	35,060	9,000	42,351	10,175
	Nov	NA	2,954	2,573	11,928	2,512	13,682
	Dec	NA	4,013	13,966	15,624	14,083	17,053

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
1984	Jan	NA	2,053	10,340	12,142	9,614	12,447
	Feb	NA	975	802	3,048	513	3,415
	Mar	NA	4,417	4,155	51,528	4,047	53,124
	Apr	NA	2,675	1,614	13,457	1,449	13,900
	May	NA	2,706	197	5,313	0	5,593
	Jun	NA	499	197	625	0	1,065
	Jul	NA	14,258	14,400	9,484	17,496	13,244
	Aug	NA	39,651	62,692	28,160	75,594	42,552
	Sep	NA	33,758	37,119	13,358	44,828	15,288
	Oct	NA	22,080	19,313	41,283	23,407	44,336
	Nov	NA	2,599	304	14,631	207	15,388
	Dec	NA	6,597	18,786	19,760	18,978	22,171
1985	Jan	NA	6,047	28,835	31,141	27,263	34,763
	Feb	NA	6,117	23,850	16,518	22,506	19,717
	Mar	NA	5,398	93,099	45,014	94,977	49,738
	Apr	NA	610	48,374	35,413	49,254	35,582
	May	NA	497	19,624	6,312	19,861	6,458
	Jun	NA	0	197	0	0	511
	Jul	NA	20,483	1,527	10,813	2,009	13,958
	Aug	NA	8,265	5,166	0	6,388	639
	Sep	NA	22,972	8,021	20,961	9,822	24,763
	Oct	NA	11,556	2,354	13,524	3,004	15,996
	Nov	NA	3,039	10,821	18,333	10,888	21,248
	Dec	NA	7,249	6,695	21,967	6,698	22,256
1986	Jan	NA	22,267	445	7,426	172	7,688
	Feb	NA	3,350	10,253	23,385	9,531	23,752
	Mar	NA	5,890	20,081	34,203	20,329	38,901
	Apr	NA	4,553	10,030	23,217	10,053	23,386
	May	NA	1,397	197	5,720	0	6,042
	Jun	NA	1,506	197	1,709	0	2,252
	Jul	NA	38,293	12,799	20,197	15,571	23,643
	Aug	NA	46,518	6,647	30,212	8,169	43,043
	Sep	NA	20,774	10,182	28,843	12,422	32,732
	Oct	NA	11,950	11,297	6,496	13,763	8,987
	Nov	NA	1,194	11,109	10,607	11,181	12,106
	Dec	NA	3,071	9,256	15,104	9,300	15,487
1987	Jan	NA	6,780	9,383	21,075	8,701	21,734
	Feb	NA	9,038	14,424	16,935	13,511	17,478
	Mar	NA	1,402	31,353	53,960	31,853	57,203
	Apr	NA	1,673	37,374	50,766	38,007	50,935
	May	NA	2,156	7,939	10,159	7,915	10,337
	Jun	NA	2,321	749	3,180	565	3,620
	Jul	NA	10,371	768	7,436	1,097	10,981
	Aug	NA	16,567	21,331	5,319	25,835	22,169

NA = Not available

Observed and Simulated Discharge for the LCR at Holbrook, Grand Falls and Cameron in ac-ft

Date		LCR at Holbrook		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated	Observed	Simulated
	Sep	NA	2,586	42	13,180	223	14,332
	Oct	NA	13,633	605	14,386	901	17,707
	Nov	NA	2,397	44,221	14,740	44,811	16,897
	Dec	NA	6,216	115	18,497	15	20,029
1988	Jan	NA	7,864	2,501	15,890	2,134	16,275
	Feb	NA	9,461	34,216	16,441	32,398	16,808
	Mar	NA	1,424	18,366	36,382	18,576	37,050
	Apr	NA	566	28,806	34,251	29,248	35,767
	May	NA	728	4,297	5,445	4,192	5,615
	Jun	NA	4,663	1,046	7,430	868	8,005
	Jul	NA	11,584	1,454	10,246	1,922	13,374
	Aug	NA	56,228	25,226	47,467	30,521	61,839
	Sep	NA	4,723	12,774	8,904	15,541	11,841
	Oct	NA	3,323	0	4,692	0	5,338
	Nov	NA	1,418	163	11,071	64	12,729
	Dec	NA	6,480	129	12,829	30	13,118
1989	Jan	NA	2,283	414	9,750	142	10,515
	Feb	NA	1,961	738	7,518	452	8,249
	Mar	NA	14,159	10,535	50,315	10,569	51,827
	Apr	NA	600	3,342	15,539	3,215	15,708
	May	NA	723	197	3,696	0	4,010
	Jun	NA	1,226	197	1,334	0	1,937
	Jul	NA	31,041	1,899	19,483	2,458	23,005
	Aug	NA	16,234	16,100	13,875	19,542	22,545
	Sep	NA	21,493	0	7,914	4	8,148
	Oct	NA	0	0	5,235	155	6,489
	Nov	NA	522	0	0	0	116
	Dec	NA	1,757	0	3,345	0	3,633
1990	Jan	NA	793	0	8,133	21	8,500
	Feb	NA	1,756	0	10,531	515	10,898
	Mar	NA	6,497	0	14,034	14	15,569
	Apr	NA	3,238	649	14,703	135	14,872
	May	NA	2,072	0	5,246	2	5,401
	Jun	NA	22	0	0	0	440
	Jul	NA	15,323	5,761	11,424	7,644	15,273
	Aug	NA	35,980	6,758	35,410	8,723	42,289
	Sep	NA	42,499	8,694	21,533	18,926	27,558
	Oct	NA	250	1,254	21,577	1,781	21,722
	Nov	NA	1,543	1,339	13,212	1,552	13,328
	Dec	NA	4,223	4,575	16,092	2,964	16,380

NA = Not available

Simulated and Observed Sediment Loads

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
1940	Jan	0	159,830	0	332,402
	Feb	13,967	365,888	65,023	664,045
	Mar	59,684	900,771	214,031	1,296,768
	Apr	0	833,187	0	1,222,926
	May	0	66,130	0	104,993
	Jun	0	31,841	0	68,036
	Jul	800,008	211,708	1,816,280	485,996
	Aug	3,910,989	946,348	6,171,971	2,141,070
	Sep	4,907,372	1,075,703	7,547,107	1,910,914
	Oct	1,782,896	464,492	3,192,423	907,005
	Nov	359,298	465,064	477,424	722,716
	Dec	1,206,183	604,539	1,750,480	895,390
1941	Jan	2,698,290	842,379	1,951,397	1,407,592
	Feb	3,690,167	946,542	2,639,437	1,544,317
	Mar	2,982,347	2,007,462	4,737,779	3,124,942
	Apr	2,301,807	1,740,199	3,680,623	2,491,126
	May	1,789,304	170,198	2,891,167	271,770
	Jun	0	128,882	0	223,596
	Jul	0	124,370	587,452	337,411
	Aug	2,317,966	1,135,880	3,941,577	2,158,322
	Sep	2,774,663	1,521,374	4,561,098	2,504,235
	Oct	5,140,882	449,095	7,893,946	1,054,045
	Nov	127,199	443,793	127,967	679,679
	Dec	122,919	566,585	119,482	849,549
1942	Jan	57,965	204,847	102,397	437,175
	Feb	72,603	891,910	106,085	1,461,834
	Mar	191,823	1,770,563	418,558	2,463,899
	Apr	948,801	1,785,552	1,586,417	2,452,778
	May	0	181,852	0	285,937
	Jun	0	35,466	0	71,395
	Jul	0	98,835	29,629	305,374
	Aug	0	460,659	83,794	945,630
	Sep	0	830,176	31,230	1,267,470
	Oct	0	218,231	126,642	422,323
	Nov	23,266	149,205	0	229,666
	Dec	0	72,676	0	120,405
1943	Jan	0	851,035	0	1,318,824
	Feb	87,275	889,952	116,360	1,369,911
	Mar	1,000,117	1,206,777	1,669,649	1,972,234
	Apr	51,690	1,035,902	197,853	1,475,860
	May	0	151,211	0	234,553
	Jun	0	62,895	0	119,130
	Jul	0	169,243	29,629	409,232
	Aug	1,269,638	729,364	2,473,810	1,831,691

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	Sep	799,657	475,840	1,795,888	70,189
	Oct	0	822,322	133,828	1,287,474
	Nov	0	141,674	0	220,262
	Dec	673	238,424	0	372,644
1944	Jan	0	6,917	0	126,076
	Feb	0	483,812	0	901,901
	Mar	278,749	2,991,863	553,103	4,497,420
	Apr	1,450,708	2,927,435	2,363,279	4,027,850
	May	325,420	237,023	625,342	368,829
	Jun	0	50,620	0	93,272
	Jul	0	119,377	29,629	340,208
	Aug	0	122,684	29,629	345,391
	Sep	428,373	1,154,221	1,276,053	1,698,085
	Oct	0	657,690	351,208	15,659
	Nov	41,255	125,705	0	241,150
	Dec	45,211	198,918	2,483	326,178
1945	Jan	0	947,702	0	1,535,242
	Feb	0	879,828	48,752	1,450,929
	Mar	139,026	1,192,668	336,837	2,228,665
	Apr	1,344,851	426,521	2,199,430	667,454
	May	204,658	84,156	438,424	134,418
	Jun	0	48,395	0	97,483
	Jul	527,981	991,231	1,435,415	1,681,842
	Aug	3,259,794	3,251,425	5,260,231	5,593,820
	Sep	0	299,099	128,590	453,457
	Oct	0	299,529	34,551	525,774
	Nov	0	105,823	0	163,921
	Dec	16,374	165,993	0	263,040
1946	Jan	0	492,500	13,895	831,042
	Feb	0	1,337,315	0	1,996,351
	Mar	0	377,868	0	623,631
	Apr	0	390,665	0	588,722
	May	0	47,917	0	88,772
	Jun	0	64,729	0	122,050
	Jul	526,698	310,609	1,433,618	676,761
	Aug	4,949,694	2,515,889	7,626,263	5,576,200
	Sep	3,751,922	431,779	5,929,360	711,628
	Oct	0	226,107	125,743	391,618
	Nov	608,886	255,897	853,212	462,169
	Dec	205,016	297,953	243,090	463,919
1947	Jan	0	330,725	0	692,468
	Feb	176,482	499,770	178,831	966,375
	Mar	0	409,779	0	623,607
	Apr	0	463,468	0	710,438

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	May	0	53,356	0	90,536
	Jun	0	33,479	0	66,898
	Jul	0	131,239	0	347,679
	Aug	7,293,355	1,519,394	12,974,390	3,965,640
	Sep	861,124	769,480	2,471,287	1,165,884
	Oct	5,471,291	1,082,028	9,367,850	1,853,270
	Nov	27,763	545,145	0	913,161
	Dec	41,081	817,530	0	1,184,453
1948	Jan	0	263,272	0	553,057
	Feb	149,820	605,252	127,027	1,086,880
	Mar	211,367	3,900,490	414,623	5,514,970
	Apr	1,368,845	1,312,890	2,193,967	1,830,753
	May	0	142,223	0	229,301
	Jun	0	64,281	0	120,552
	Jul	41,670	119,719	605,216	326,389
	Aug	1,211,255	426,578	2,472,039	906,053
	Sep	0	330,744	27,160	613,005
	Oct	0	1,083,673	505,390	1,716,802
	Nov	82,977	134,839	74,366	208,004
	Dec	135,828	319,410	65,562	491,765
1949	Jan	594,347	1,346,435	579,736	2,090,843
	Feb	426,201	675,955	408,891	1,152,363
	Mar	1,768,886	4,946,950	3,276,240	6,721,720
	Apr	1,550,921	3,272,107	2,579,640	4,441,880
	May	0	280,586	0	428,247
	Jun	0	122,702	0	209,505
	Jul	915,491	268,786	1,419,141	593,209
	Aug	3,623,565	1,092,625	5,118,471	1,976,343
	Sep	660,581	478,929	1,294,231	843,891
	Oct	0	203,039	760,865	495,102
	Nov	16,970	106,172	0	177,776
	Dec	1,478	164,200	0	261,473
1950	Jan	0	137,360	0	292,235
	Feb	371,727	1,088,754	317,304	1,668,097
	Mar	82,484	693,996	249,158	1,080,857
	Apr	0	297,855	0	499,917
	May	0	42,458	0	69,102
	Jun	0	37,353	0	73,785
	Jul	175,891	197,225	910,965	494,288
	Aug	0	367,087	75,063	1,108,251
	Sep	0	281,800	161,377	34,869
	Oct	0	281,800	0	4,369
	Nov	0	26,957	0	44,163
	Dec	0	187,852	0	296,130

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
1951	Jan	0	396,494	0	639,559
	Feb	0	623,293	0	967,873
	Mar	0	1,106,061	0	1,645,086
	Apr	0	1,361,521	0	1,892,366
	May	0	129,984	0	208,327
	Jun	0	31,741	0	67,390
	Jul	0	90,358	446,421	277,167
	Aug	2,716,382	115,775	3,231,801	861,226
	Sep	504,741	1,271,235	2,189,796	1,821,137
	Oct	293,643	113,255	1,080,563	282,206
	Nov	6,717	918,835	0	1,390,679
	Dec	8,504	1,059,711	0	1,623,855
1952	Jan	6,624,011	2,921,355	4,757,842	4,097,000
	Feb	310,007	585,847	273,535	923,178
	Mar	44,380	5,921,130	188,962	8,666,240
	Apr	2,812,112	3,491,768	4,557,226	4,762,570
	May	233,655	314,538	487,970	484,230
	Jun	0	94,012	0	172,349
	Jul	0	146,443	189,384	429,406
	Aug	597,940	700,730	1,518,844	1,484,675
	Sep	1,937,192	424,442	3,427,258	1,141,730
	Oct	0	30,490	0	49,761
	Nov	22,649	843,045	0	1,266,762
	Dec	164,444	864,045	182,953	1,245,906
1953	Jan	0	59,702	0	100,099
	Feb	0	433,858	0	664,010
	Mar	99,926	776,901	276,711	1,228,546
	Apr	0	898,462	0	1,282,877
	May	0	192,465	0	303,927
	Jun	0	57,747	0	111,152
	Jul	800,690	349,894	1,810,865	746,674
	Aug	814,538	631,278	1,830,811	2,032,946
	Sep	0	136,812	0	249,344
	Oct	0	179,042	0	290,617
	Nov	0	44,211	0	87,065
	Dec	0	244,560	0	381,177
1954	Jan	0	114,011	0	207,568
	Feb	0	326,015	0	532,798
	Mar	234,411	926,317	359,153	1,797,148
	Apr	222,333	430,356	465,233	645,329
	May	0	58,728	0	95,839
	Jun	0	40,381	0	77,555
	Jul	3,625,490	528,356	4,679,992	1,018,146
	Aug	87,222	292,027	735,643	455,566

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	Sep	1,833,415	882,155	3,192,967	1,559,346
	Oct	0	225,169	469,810	372,384
	Nov	0	18,766	0	33,163
	Dec	0	12,337	0	28,465
1955	Jan	0	437,140	0	964,821
	Feb	0	869,681	0	1,627,521
	Mar	0	1,292,377	0	1,799,671
	Apr	0	406,894	0	638,917
	May	0	56,959	0	97,521
	Jun	177,308	63,997	1,021,643	113,987
	Jul	74,390	134,724	1,489,012	372,595
	Aug	12,265,536	1,293,978	17,338,611	2,636,415
	Sep	0	221,967	401,416	338,947
	Oct	0	161,797	0	256,401
	Nov	0	161,823	0	260,460
	Dec	3,311	330,578	0	524,354
1956	Jan	0	531,253	0	1,044,660
	Feb	0	2,138,209	0	3,329,543
	Mar	0	1,009,014	0	1,427,856
	Apr	0	1,046,415	0	1,474,384
	May	0	168,203	0	269,042
	Jun	0	31,647	0	64,103
	Jul	0	92,332	197,660	309,282
	Aug	80,806	85,263	1,036,361	222,039
	Sep	0	570,397	0	840,924
	Oct	0	23,854	0	44,650
	Nov	0	37,317	0	59,793
	Dec	0	36,136	0	10,056
1957	Jan	1,990,695	6,725,770	1,276,580	10,459,410
	Feb	1,935,672	1,885,358	714,838	3,658,440
	Mar	328,629	3,243,157	227,638	4,612,660
	Apr	0	3,851,350	2,702	5,319,950
	May	0	337,395	1,905	529,012
	Jun	0	11,091	28,202	38,429
	Jul	0	173,651	687,234	416,927
	Aug	4,152,220	2,067,242	7,246,700	3,729,340
	Sep	388,016	205,829	744,701	314,802
	Oct	865,448	143,508	1,632,257	371,445
	Nov	401,021	9,558	874,157	87,425
	Dec	85,485	97,040	2,696	164,785
1958	Jan	0	323,158	161	666,755
	Feb	74,950	985,341	65,081	1,646,678
	Mar	450,267	1,472,339	990,326	2,437,775
	Apr	772,088	681,796	770,220	1,041,840

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	May	0	91,809	14,042	147,509
	Jun	0	16,934	16,710	44,887
	Jul	0	93,129	55,290	281,159
	Aug	1,851,544	2,234,171	3,660,938	3,910,770
	Sep	2,823,091	621,551	3,254,557	1,232,157
	Oct	450,993	240,981	400,503	425,372
	Nov	0	79,302	140	128,522
	Dec	0	128,353	50	205,713
1959	Jan	0	308,568	300	541,028
	Feb	0	445,444	120	753,818
	Mar	0	1,132,478	10,408	1,581,820
	Apr	0	480,024	11,305	733,590
	May	0	99,681	0	163,137
	Jun	0	86,036	3,823	155,797
	Jul	0	49,407	14,042	231,715
	Aug	2,747,178	1,369,944	6,389,120	2,528,024
	Sep	0	592,887	20,778	890,832
	Oct	808,348	190,110	848,423	432,735
	Nov	1,392,378	652,310	2,203,112	977,716
	Dec	956,537	720,406	1,088,956	1,053,962
1960	Jan	867,574	1,016,684	533,016	1,733,931
	Feb	201,487	528,668	99,708	1,041,880
	Mar	1,869,521	2,408,869	3,836,211	3,498,940
	Apr	180,413	2,511,013	182,926	3,426,030
	May	0	184,141	9	283,784
	Jun	0	19,025	300	45,481
	Jul	0	102,986	0	298,005
	Aug	0	94,250	0	22,903
	Sep	0	185,594	41,525	390,527
	Oct	302,158	178,089	686,400	472,735
	Nov	5,790	127,948	600	215,183
	Dec	7,561	177,047	350	293,317
1961	Jan	0	236,327	200	371,865
	Feb	0	593,626	40	888,474
	Mar	0	799,938	39,060	1,540,770
	Apr	22,721	354,305	175,341	536,015
	May	0	57,399	0	95,377
	Jun	0	20,739	0	47,369
	Jul	0	261,925	100,000	605,293
	Aug	329,166	633,587	1,374,890	1,404,100
	Sep	0	582,455	1,121,390	1,038,538
	Oct	0	132,001	61,818	277,958
	Nov	155,868	668,171	477,878	1,016,489
	Dec	2,658	510,042	50	832,032

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
1962	Jan	0	2,084,862	5,000	2,970,956
	Feb	2,308,908	441,084	2,628,890	735,898
	Mar	69,829	2,369,310	226,377	3,430,880
	Apr	1,740,172	1,506,984	1,594,500	2,080,951
	May	0	122,657	2,631	190,983
	Jun	0	73,103	0	129,464
	Jul	0	68,592	0	119,842
	Aug	0	696,229	21,000	1,050,926
	Sep	56,019	1,056,927	829,112	1,712,087
	Oct	0	71,786	725,390	225,643
	Nov	131,228	60,381	341,974	130,363
	Dec	9,013	216,880	1,073	342,210
1963	Jan	0	194,678	18	404,926
	Feb	0	1,246,465	74,710	1,918,776
	Mar	0	512,981	11,642	867,046
	Apr	0	586,140	17,791	903,518
	May	0	64,296	0	111,362
	Jun	0	60,786	0	18,052
	Jul	0	60,786	0	119,843
	Aug	3,095,689	4,757,760	6,181,000	8,881,720
	Sep	2,120,348	184,627	3,454,900	320,166
	Oct	0	158,720	172,109	49,649
	Nov	30,569	94,804	47,038	150,399
	Dec	2,420	33,971	0	61,211
1964	Jan	0	1,079,669	0	1,527,229
	Feb	0	547,290	0	823,991
	Mar	0	944,428	0	1,796,411
	Apr	384,013	376,841	784,980	587,854
	May	0	160,410	84,241	255,065
	Jun	0	7,455	1,000	29,954
	Jul	371,450	363,800	1,530,650	777,703
	Aug	8,346,441	4,221,670	12,876,300	6,798,270
	Sep	1,796,750	1,340,261	1,667,640	1,980,839
	Oct	0	106,003	20,445	164,412
	Nov	2,478	390,035	0	604,988
	Dec	2,420	392,769	0	597,947
1965	Jan	2,050,183	3,268,722	1,317,200	5,143,100
	Feb	421,917	787,885	65,730	1,583,972
	Mar	92,102	4,781,210	99,590	6,946,620
	Apr	1,784,489	3,030,093	1,384,000	4,117,650
	May	129,287	318,384	191,139	487,781
	Jun	0	125,529	0	213,242
	Jul	1,314,359	574,893	3,270,000	1,076,130
	Aug	385,831	398,320	1,331,433	129,674

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	Sep	1,342,911	544,151	1,957,459	1,210,126
	Oct	0	13,709	38,384	80,607
	Nov	164,379	1,593,246	145,447	2,351,619
	Dec	1,014,990	1,901,931	1,514,480	2,944,343
1966	Jan	2,807,417	3,283	1,450,400	17,672
	Feb	0	590,606	6,148	884,213
	Mar	1,296,395	2,796,584	2,991,760	3,831,430
	Apr	146,459	1,932,599	147,998	2,692,081
	May	0	168,966	28	269,842
	Jun	0	10,992	0	35,527
	Jul	0	734,436	174,000	1,291,192
	Aug	1,027,420	385,575	2,620,100	810,441
	Sep	488,131	32,938	1,464,000	145,281
	Oct	0	56,375	594,753	136,035
	Nov	4,257	620,281	617	928,358
	Dec	953,952	684,558	532,002	1,009,414
1967	Jan	0	453,280	36	11,192
	Feb	0	1,936,497	34	2,677,104
	Mar	0	515,651	0	768,580
	Apr	0	591,019	2,954	916,188
	May	0	58,096	0	97,856
	Jun	0	21,228	296,105	56,268
	Jul	1,483,186	323,937	3,518,779	715,178
	Aug	7,079,641	1,602,972	9,343,100	3,204,923
	Sep	3,763,370	270,173	4,791,980	547,152
	Oct	0	237,715	20,636	366,463
	Nov	2,478	1,550,541	0	2,132,913
	Dec	7,258	1,942,828	2,600	2,674,594
1968	Jan	0	67,605	71,400	111,945
	Feb	1,974,824	383,354	1,287,500	591,045
	Mar	883,597	1,925,660	1,074,100	2,698,439
	Apr	1,310,254	1,651,791	1,546,400	2,336,308
	May	30,390	157,087	113,102	243,515
	Jun	0	85,715	0	147,513
	Jul	79,057	181,994	893,442	452,435
	Aug	2,453,344	3,659,567	4,509,200	6,140,760
	Sep	0	145,848	80	231,452
	Oct	0	379,064	490,123	639,648
	Nov	9,857	362,162	13,019	563,430
	Dec	2,420	326,232	0	501,426
1969	Jan	1,189,801	1,727,778	1,581,989	2,716,175
	Feb	167,565	227,934	122,991	551,144
	Mar	159,687	2,612,901	676,198	3,886,380
	Apr	628,195	1,389,839	928,136	1,926,879

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	May	0	139,367	17,158	220,679
	Jun	0	38,413	0	74,498
	Jul	631,227	296,509	1,532,664	651,361
	Aug	192,251	1,565,209	959,823	2,547,989
	Sep	1,499,386	310,278	2,273,693	556,644
	Oct	0	70,604	717,219	232,721
	Nov	49,191	143,250	57,807	246,280
	Dec	4,405	340,512	115	531,504
1970	Jan	0	109,552	2,002	178,369
	Feb	0	21,455	0	46,641
	Mar	0	3,664,586	210,281	6,237,210
	Apr	0	452,303	82,348	697,352
	May	0	76,699	0	126,220
	Jun	0	71,734	0	15,957
	Jul	0	205,303	90,443	514,326
	Aug	687,307	1,053,468	2,149,947	2,000,082
	Sep	3,819,398	540,829	6,186,902	887,101
	Oct	0	217,124	35,122	354,295
	Nov	2,822	19,233	0	32,575
	Dec	5,200	85,736	0	140,472
1971	Jan	0	143,453	0	227,815
	Feb	0	100,543	0	168,262
	Mar	0	303,772	0	459,892
	Apr	0	240,100	0	368,527
	May	0	100,623	0	157,433
	Jun	0	42,688	0	84,581
	Jul	0	186,383	0	466,457
	Aug	4,759,594	1,095,641	7,512,895	2,282,966
	Sep	927,004	154,766	1,972,278	296,400
	Oct	6,052,645	135,854	9,375,284	380,376
	Nov	253,090	225,774	321,179	358,269
	Dec	1,168,552	385,900	1,725,557	587,943
1972	Jan	99,164	546,453	130,836	813,160
	Feb	0	227,946	0	362,103
	Mar	0	459,625	0	682,999
	Apr	0	538,525	0	817,203
	May	0	119,980	0	198,559
	Jun	0	101,256	0	173,535
	Jul	270,178	92,773	1,046,767	141,193
	Aug	0	475,502	599,369	1,143,075
	Sep	0	799,840	136,352	1,244,316
	Oct	21,864,935	492,955	32,149,805	1,875,950
	Nov	502,736	587,202	704,707	887,137
	Dec	267,022	918,928	340,542	1,317,154

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
1973	Jan	397,775	1,353,141	342,592	1,972,530
	Feb	1,116,662	227,343	845,564	408,611
	Mar	1,762,530	5,130,830	2,903,217	7,879,160
	Apr	5,233,767	3,429,392	8,382,845	4,647,380
	May	3,856,064	278,258	6,210,485	433,802
	Jun	0	5,707	0	27,519
	Jul	0	128,703	0	356,375
	Aug	0	55,852	0	140,996
	Sep	0	295,955	0	477,996
	Oct	0	131,291	0	213,480
	Nov	2,478	117,440	0	25,551
	Dec	2,420	15,400	0	33,072
1974	Jan	0	2,272,686	0	3,443,340
	Feb	0	595,204	0	1,097,840
	Mar	0	1,559,328	11,109	2,219,619
	Apr	0	1,151,579	0	1,637,956
	May	0	173,776	0	290,964
	Jun	0	84,719	0	152,279
	Jul	85,130	542,731	780,241	1,038,088
	Aug	32,937	166,775	705,068	255,931
	Sep	0	300,752	301,912	519,372
	Oct	464,619	843,102	1,326,822	1,452,473
	Nov	492,150	556,983	688,445	843,491
	Dec	2,420	246,550	0	383,915
1975	Jan	0	190,159	0	324,778
	Feb	0	418,262	0	670,087
	Mar	73,207	868,931	234,501	1,484,308
	Apr	513,789	838,587	926,442	1,227,396
	May	0	81,094	0	131,882
	Jun	0	75,558	0	20,477
	Jul	364,397	445,186	1,182,471	879,144
	Aug	0	285,804	72,610	433,171
	Sep	1,738,451	539,151	3,141,009	956,346
	Oct	0	46,741	0	77,178
	Nov	2,478	486,375	0	823,466
	Dec	39,302	600,782	0	910,481
1976	Jan	0	1,129,287	0	1,818,757
	Feb	437,116	1,500,063	363,673	2,350,331
	Mar	158,325	908,033	368,967	1,474,719
	Apr	576,929	632,988	1,026,187	933,163
	May	0	101,055	72,279	180,567
	Jun	0	12,606	0	42,451
	Jul	1,167,449	656,679	2,339,111	1,187,774
	Aug	0	46,014	452,838	255,572

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	Sep	189,270	396,874	909,717	864,774
	Oct	0	60,439	13,913	104,333
	Nov	5,659	11,370	0	20,892
	Dec	2,420	104,306	0	168,892
1977	Jan	0	844,531	0	1,403,252
	Feb	0	481,506	0	887,169
	Mar	0	504,531	0	753,537
	Apr	0	827,301	0	1,232,907
	May	0	125,042	0	194,928
	Jun	0	22,153	0	50,427
	Jul	934,749	488,311	2,003,952	936,343
	Aug	2,645,325	981,537	4,467,703	2,362,429
	Sep	171,758	529,866	884,494	854,912
	Oct	31,458	384,106	702,937	602,449
	Nov	27,478	9,083	0	20,780
	Dec	9,357	145,982	0	249,064
1978	Jan	0	995,354	0	2,125,352
	Feb	36,655	1,828,675	79,692	3,375,160
	Mar	2,416,794	4,172,660	3,936,792	6,588,100
	Apr	845,316	2,063,519	1,450,173	2,987,276
	May	0	148,048	0	229,771
	Jun	0	130,730	0	15,957
	Jul	0	130,730	0	125,656
	Aug	0	444,748	0	731,408
	Sep	0	343,607	103,349	602,219
	Oct	145,614	132,727	867,357	262,528
	Nov	1,487,500	2,064,891	2,217,595	3,213,653
	Dec	4,295,832	2,529,436	6,529,977	3,473,970
1979	Jan	570,088	723,595	464,786	1,436,207
	Feb	2,257,511	772,742	1,654,581	1,499,703
	Mar	1,567,866	4,886,600	2,595,695	6,845,490
	Apr	3,434,760	4,515,630	5,540,857	6,082,340
	May	253,954	390,437	520,038	595,014
	Jun	0	140,201	0	231,346
	Jul	0	23,314	0	169,058
	Aug	0	559,194	448,254	1,392,233
	Sep	0	543,356	0	808,002
	Oct	0	721,939	0	1,197,519
	Nov	79,792	240,262	54,942	440,399
	Dec	18,475	223,109	0	348,928
1980	Jan	174,185	3,252,691	184,036	5,775,630
	Feb	6,460,684	3,430,546	4,635,204	6,041,240
	Mar	805,686	7,466,700	1,391,638	10,282,700
	Apr	2,171,377	7,885,660	3,545,023	10,325,790

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	May	599,747	544,115	1,066,306	805,059
	Jun	0	382,090	0	17,852
	Jul	0	252,415	0	564,170
	Aug	0	184,322	533,760	621,139
	Sep	364,117	611,762	1,161,550	1,092,564
	Oct	0	57,785	0	149,152
	Nov	2,478	54,930	0	4,139
	Dec	2,765	87,856	0	143,687
1981	Jan	0	674,951	0	1,164,823
	Feb	0	591,675	0	1,055,208
	Mar	0	402,272	0	842,994
	Apr	0	332,574	0	538,438
	May	0	21,300	0	40,904
	Jun	0	167,974	0	281,296
	Jul	1,315,357	169,503	2,552,143	456,268
	Aug	0	855,862	594,562	2,027,979
	Sep	657,439	533,117	1,584,023	962,901
	Oct	1,764,724	709,927	3,199,368	1,203,763
	Nov	3,847	218,575	0	374,225
	Dec	57,358	174,268	18,437	282,181
1982	Jan	0	963,162	0	2,057,866
	Feb	953,683	1,233,432	729,990	2,475,560
	Mar	1,394,832	2,277,512	2,322,343	3,744,400
	Apr	502,745	1,594,410	908,994	2,200,558
	May	0	218,688	0	351,562
	Jun	0	19,488	0	45,464
	Jul	0	103,566	0	345,804
	Aug	3,193,744	1,252,332	5,257,594	4,069,300
	Sep	1,765,115	668,352	3,179,414	1,270,233
	Oct	0	66,484	0	144,269
	Nov	135,631	1,244,575	140,727	1,915,870
	Dec	1,133,146	1,472,709	1,671,163	2,344,607
1983	Jan	206,681	163,750	207,081	333,961
	Feb	693,072	1,199,772	545,181	1,810,183
	Mar	1,673,850	2,241,950	2,763,124	3,506,910
	Apr	1,924,481	1,701,696	3,154,988	2,344,035
	May	712,358	158,504	1,244,203	244,846
	Jun	0	66,336	0	120,272
	Jul	329,682	754,500	1,132,471	1,337,885
	Aug	1,362,045	794,738	2,619,388	2,130,756
	Sep	1,005,912	504,880	2,085,930	297,216
	Oct	3,182,046	264,044	5,240,745	456,787
	Nov	106,303	388,835	95,670	681,288
	Dec	584,592	527,963	828,424	861,363

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
1984	Jan	249,183	381,539	237,220	582,571
	Feb	0	87,010	0	147,456
	Mar	0	2,845,618	0	4,026,660
	Apr	0	453,549	0	694,751
	May	0	143,315	0	228,050
	Jun	0	15,644	0	39,608
	Jul	1,026,405	281,257	2,135,964	628,559
	Aug	6,065,203	1,196,139	9,393,370	2,928,637
	Sep	3,412,264	449,253	5,551,811	782,288
	Oct	1,539,025	2,061,445	2,874,294	3,104,453
	Nov	11,054	505,637	0	788,703
	Dec	786,959	724,534	1,139,318	1,206,821
1985	Jan	1,226,395	1,379,364	930,196	2,207,505
	Feb	991,792	651,711	757,014	1,182,602
	Mar	1,948,404	2,335,320	3,196,852	3,660,290
	Apr	895,938	1,736,585	1,530,143	2,385,837
	May	205,596	174,235	443,645	268,568
	Jun	0	150,880	0	18,587
	Jul	0	330,168	201,351	670,597
	Aug	62,975	258,470	748,331	22,599
	Sep	376,194	823,203	1,178,943	1,457,666
	Oct	0	437,597	325,633	794,609
	Nov	452,602	683,788	627,688	1,191,572
	Dec	279,305	839,678	359,412	1,212,858
1986	Jan	0	210,277	0	328,338
	Feb	273,363	1,062,236	247,550	1,511,555
	Mar	216,448	1,578,663	460,787	2,581,198
	Apr	0	951,612	93,329	1,351,247
	May	0	155,755	0	248,928
	Jun	0	43,866	0	87,142
	Jul	859,421	746,770	1,895,456	1,312,893
	Aug	217,432	1,321,134	970,796	2,976,622
	Sep	601,702	1,295,904	1,503,745	2,125,698
	Oct	702,611	180,077	1,669,602	394,206
	Nov	464,711	335,758	646,291	586,110
	Dec	386,861	505,002	524,651	763,103
1987	Jan	198,653	792,280	201,388	1,175,863
	Feb	493,742	674,208	403,828	1,011,864
	Mar	483,823	3,046,567	883,174	4,486,120
	Apr	635,006	2,921,792	1,117,934	3,972,610
	May	0	305,797	5,802	465,505
	Jun	0	84,553	0	145,705
	Jul	0	210,604	87,377	500,498
	Aug	1,749,640	143,494	3,177,644	1,206,690

NA = Not available

Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

Date		LCR at Grand Falls		LCR near Cameron	
		Observed	Simulated	Observed	Simulated
	Sep	0	441,569	0	721,651
	Oct	0	473,929	62,873	903,449
	Nov	1,854,957	510,587	2,782,117	887,478
	Dec	3,043	661,875	0	1,057,777
1988	Jan	0	539,865	0	812,056
	Feb	1,539,483	647,601	1,145,402	962,452
	Mar	175,776	1,722,483	396,535	2,411,335
	Apr	431,787	1,656,859	796,898	2,403,144
	May	0	147,332	0	229,071
	Jun	0	218,644	0	357,603
	Jul	0	309,004	190,400	636,152
	Aug	2,156,031	2,522,709	3,762,971	5,031,960
	Sep	872,162	271,149	1,893,289	570,535
	Oct	0	124,758	0	216,370
	Nov	5,126	354,110	0	623,259
	Dec	3,650	409,071	0	621,227
1989	Jan	0	290,850	0	475,098
	Feb	0	240,524	0	401,778
	Mar	0	2,747,505	103,082	3,884,760
	Apr	0	547,380	0	809,352
	May	0	96,017	0	157,295
	Jun	0	33,939	0	74,218
	Jul	0	710,604	257,347	1,266,549
	Aug	1,203,798	452,269	2,391,465	1,233,529
	Sep	0	235,536	0	365,093
	Oct	0	140,957	569	270,024
	Nov	0	125,130	0	4,139
	Dec	0	86,189	0	141,125
1990	Jan	0	234,011	0	369,175
	Feb	0	362,610	28,590	560,896
	Mar	0	458,968	0	768,156
	Apr	1,152	508,911	0	755,748
	May	0	141,286	0	219,251
	Jun	0	125,400	0	15,957
	Jul	518,850	353,493	394,141	749,895
	Aug	667,010	1,658,001	805,380	2,902,976
	Sep	539,210	855,020	1,972,580	1,681,814
	Oct	61,710	818,815	109,690	1,175,037
	Nov	73,250	442,944	82,210	659,589
	Dec	167,660	548,967	180,210	818,684
1991	Jan	716,089	NA	899,169	NA
	Feb	82,827	NA	71,900	NA
	Mar	707,960	NA	1,459,550	NA
	Apr	1,132,330	NA	2,914,330	NA

NA = Not available

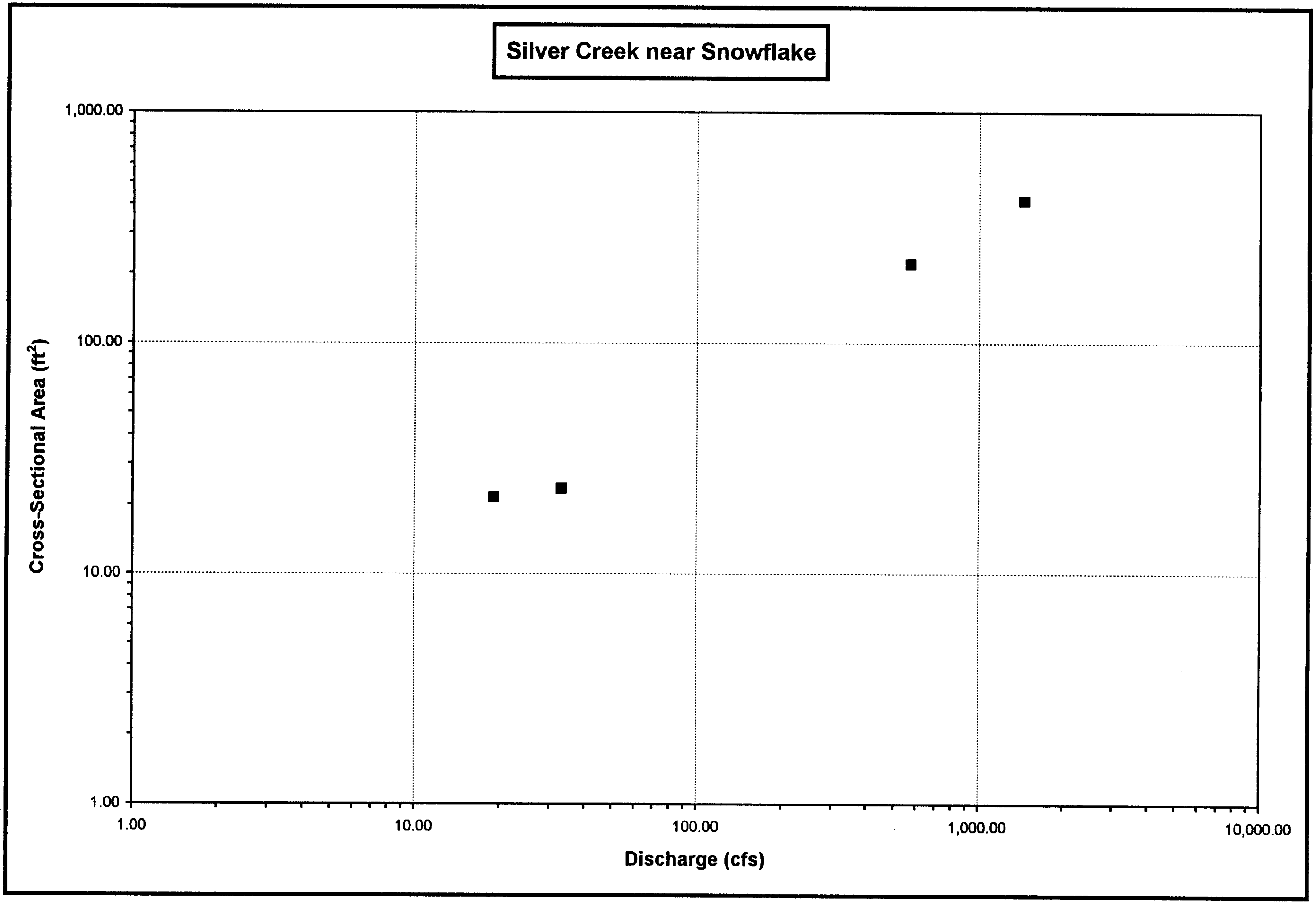
Observed and Simulated Sediment Loads for the LCR at Grand Falls and the LCR near Cameron in tons/month

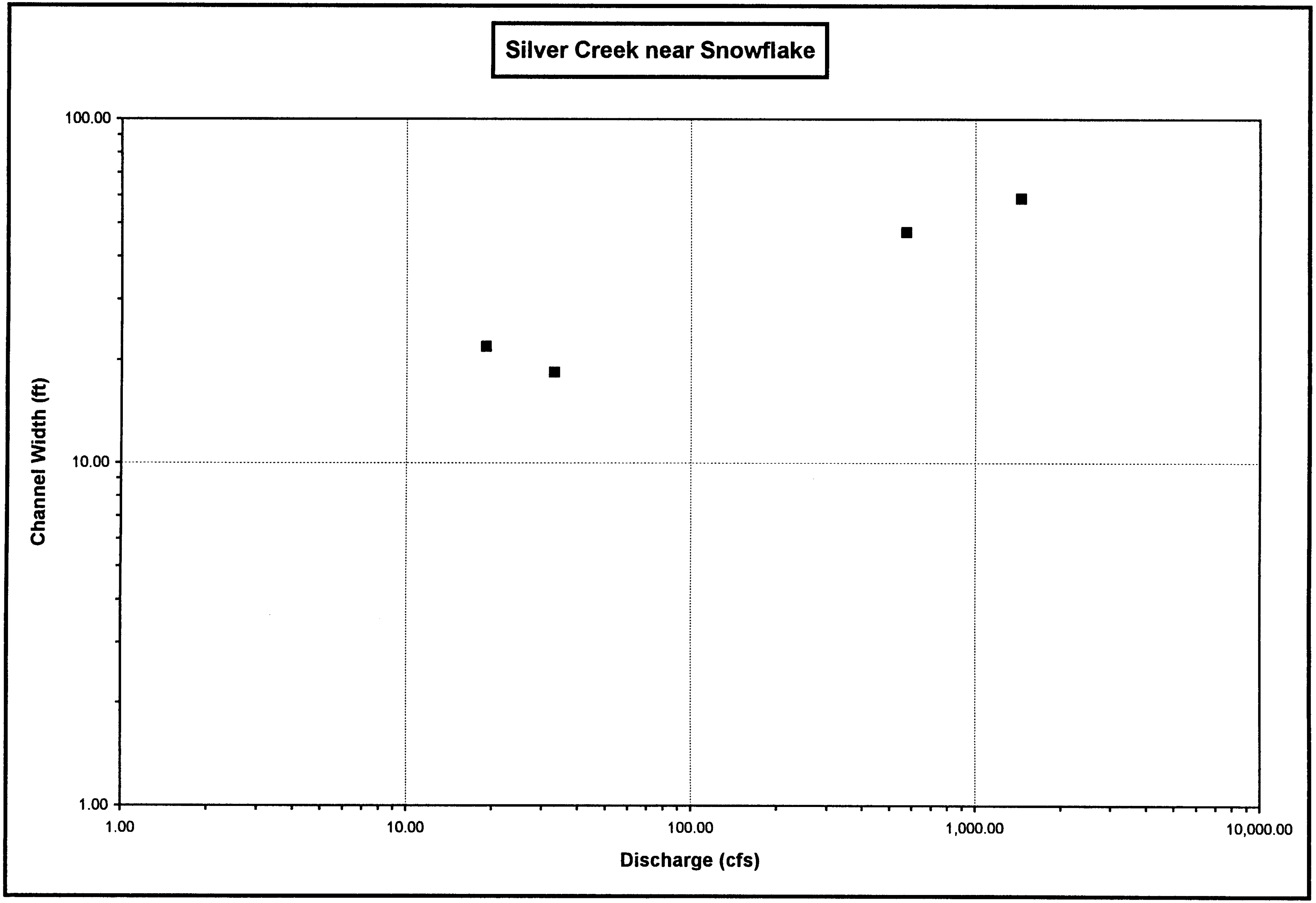
Date	LCR at Grand Falls		LCR near Cameron	
	Observed	Simulated	Observed	Simulated
May	6,184	NA	12,414	NA
Jun	0	NA	0	NA
Jul	0	NA	0	NA
Aug	2,700	NA	111,370	NA
Sep	77,240	NA	758,140	NA
Oct	0	NA	0	NA
Nov	21,018	NA	0	NA
Dec	364,821	NA	565,877	NA

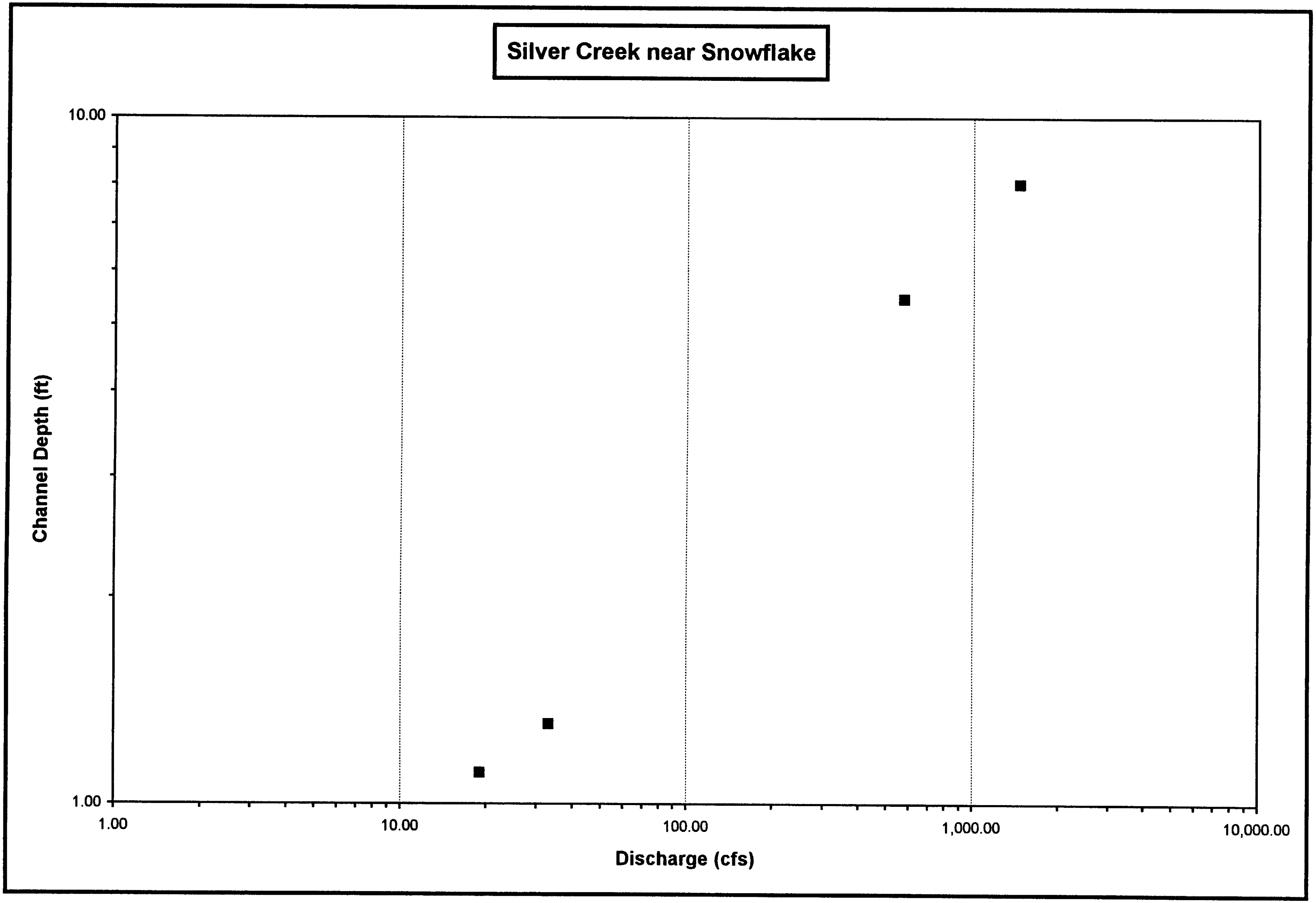
NA = Not available

APPENDIX F

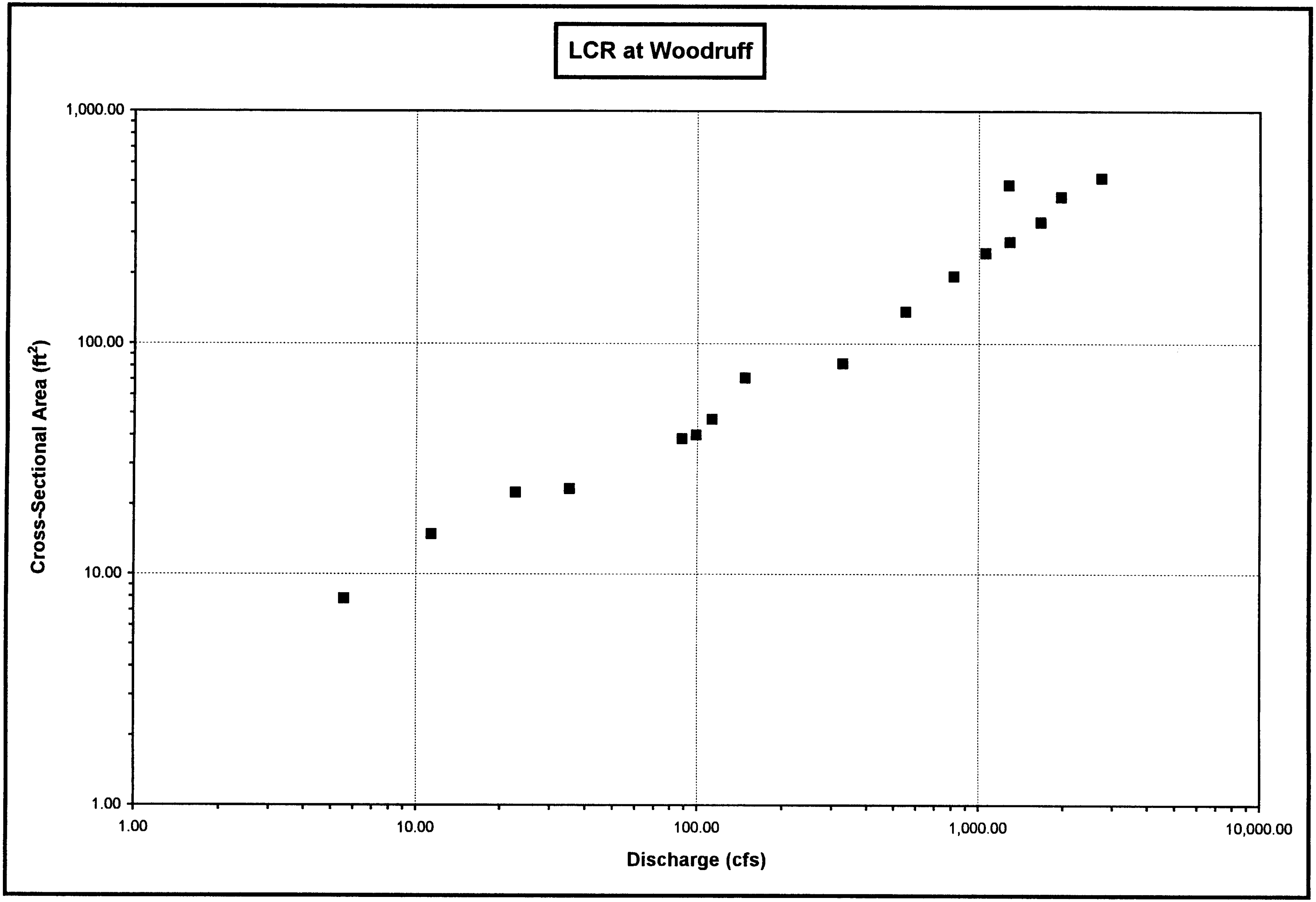
SCATTER PLOTS FOR CHANNEL GEOMETRIES


Silver Creek near Snowflake
1,000.00
100.00
10.00
1.00
Cross-Sectional Area (ft2)
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

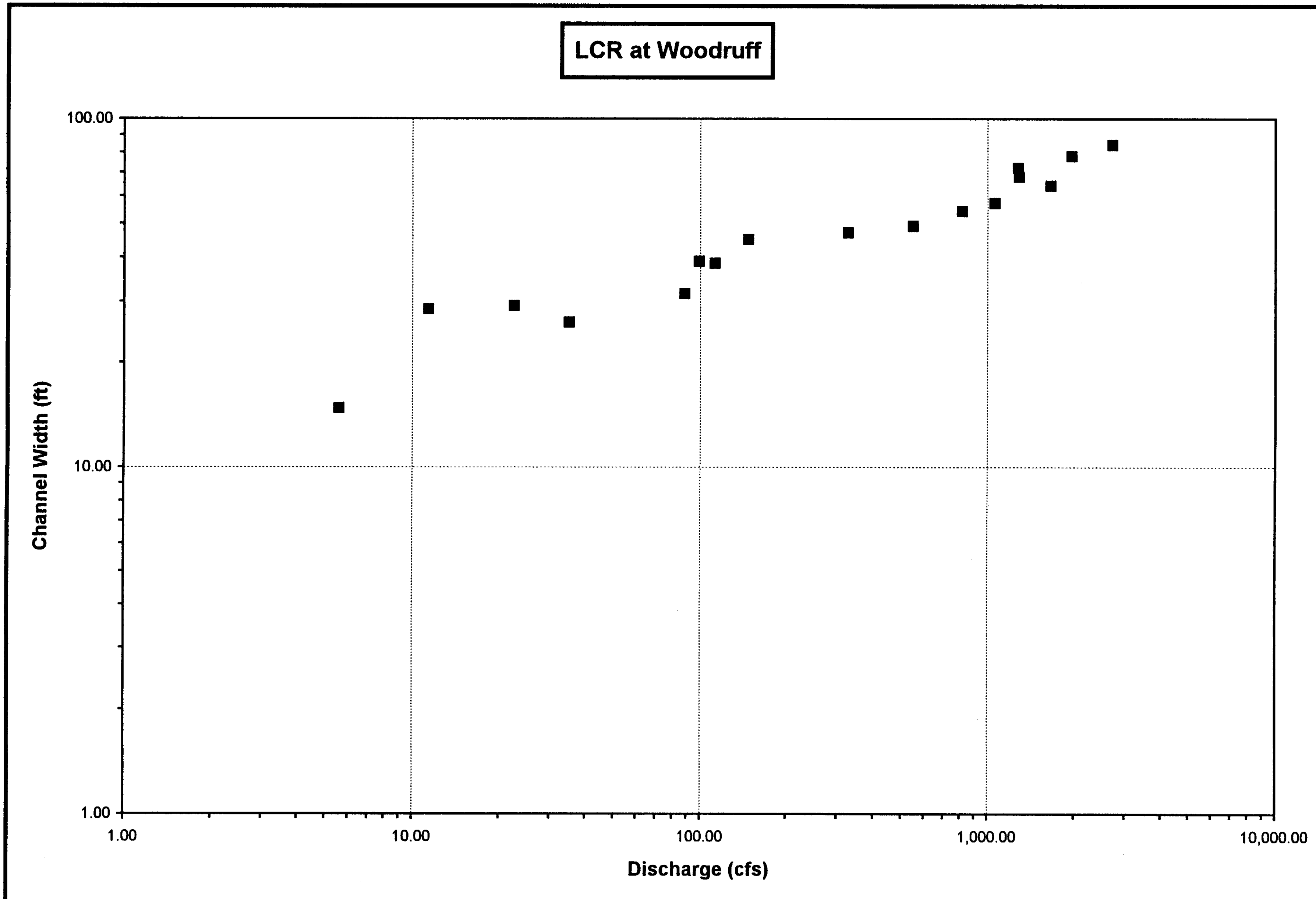

Silver Creek near Snowflake
100.00
10.00
1.00
Channel Width (ft)
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)



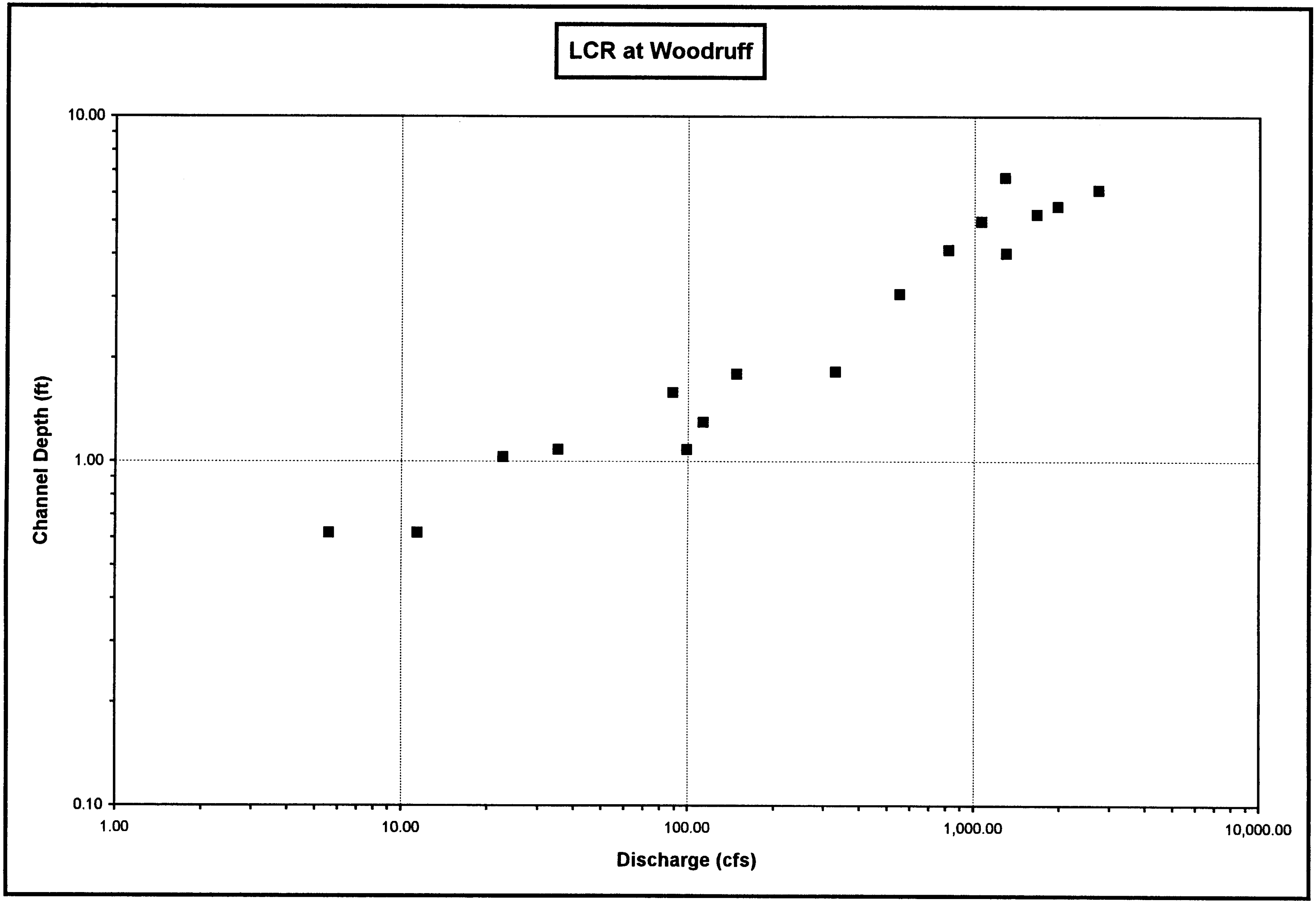
Silver Creek near Snowflake
10.00
1.00
Channel Depth (ft)
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)



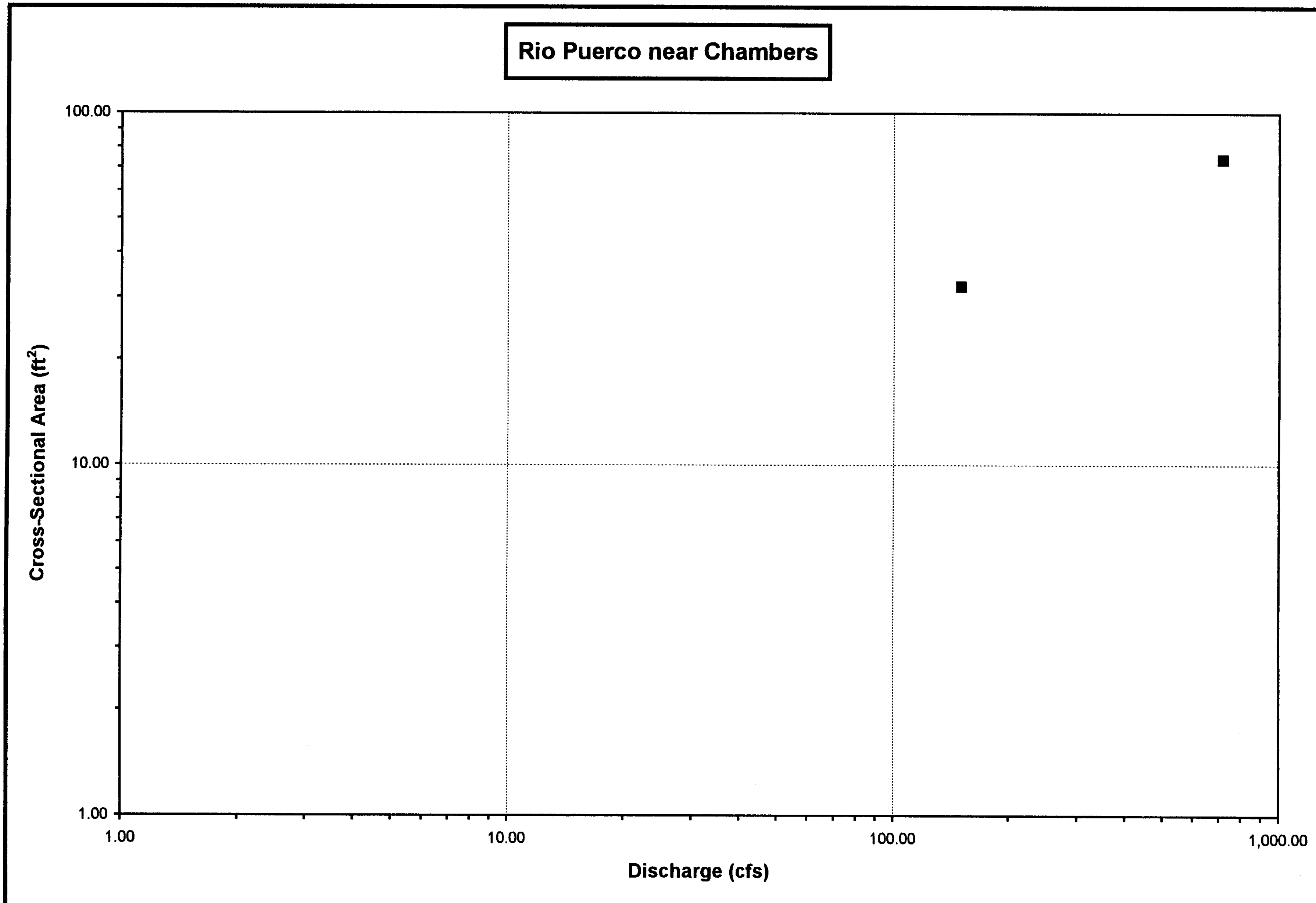
LCR at Woodruff
1,000.00
100.00
10.00
1.00
Cross-Sectional Area (ft²)
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

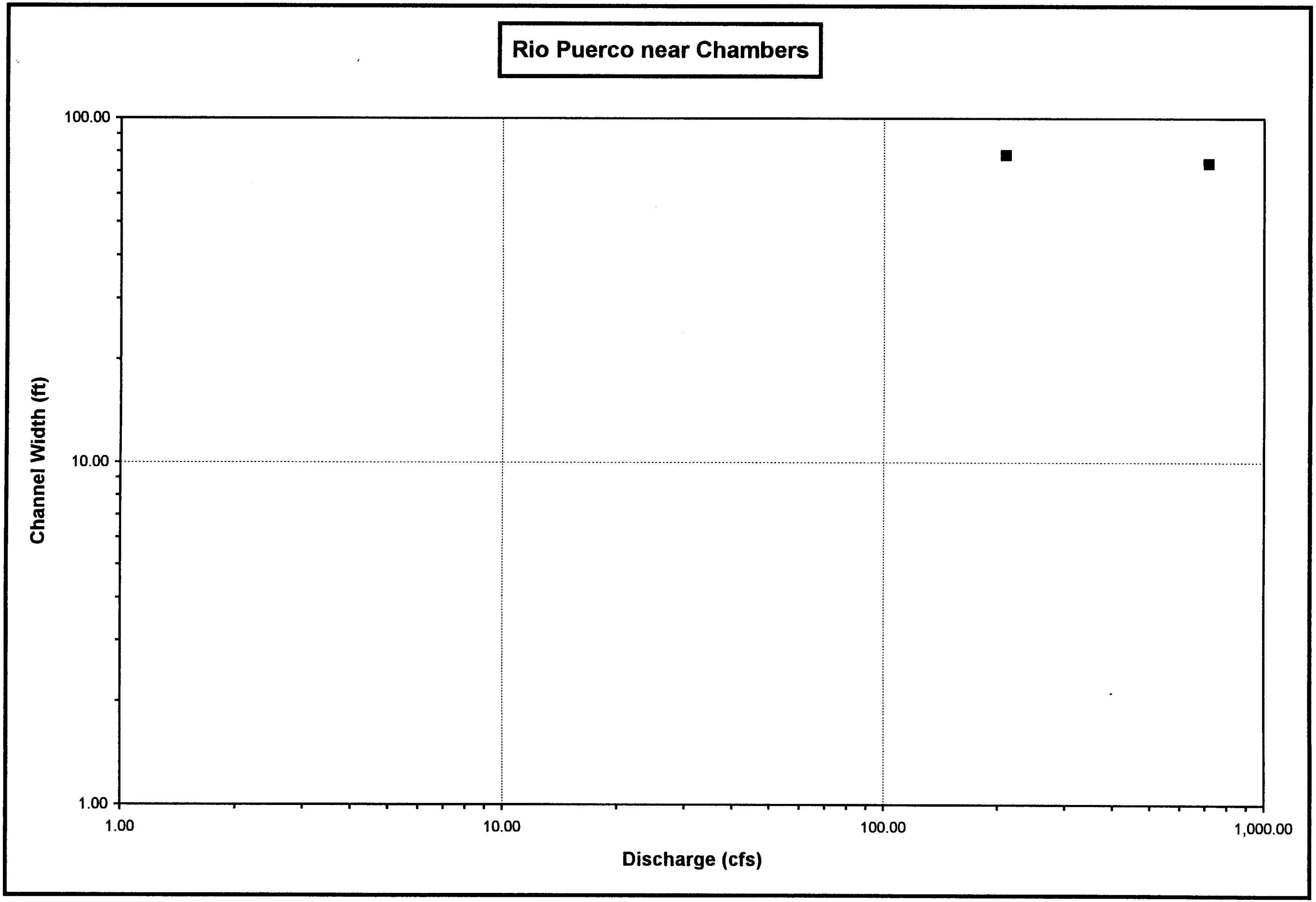


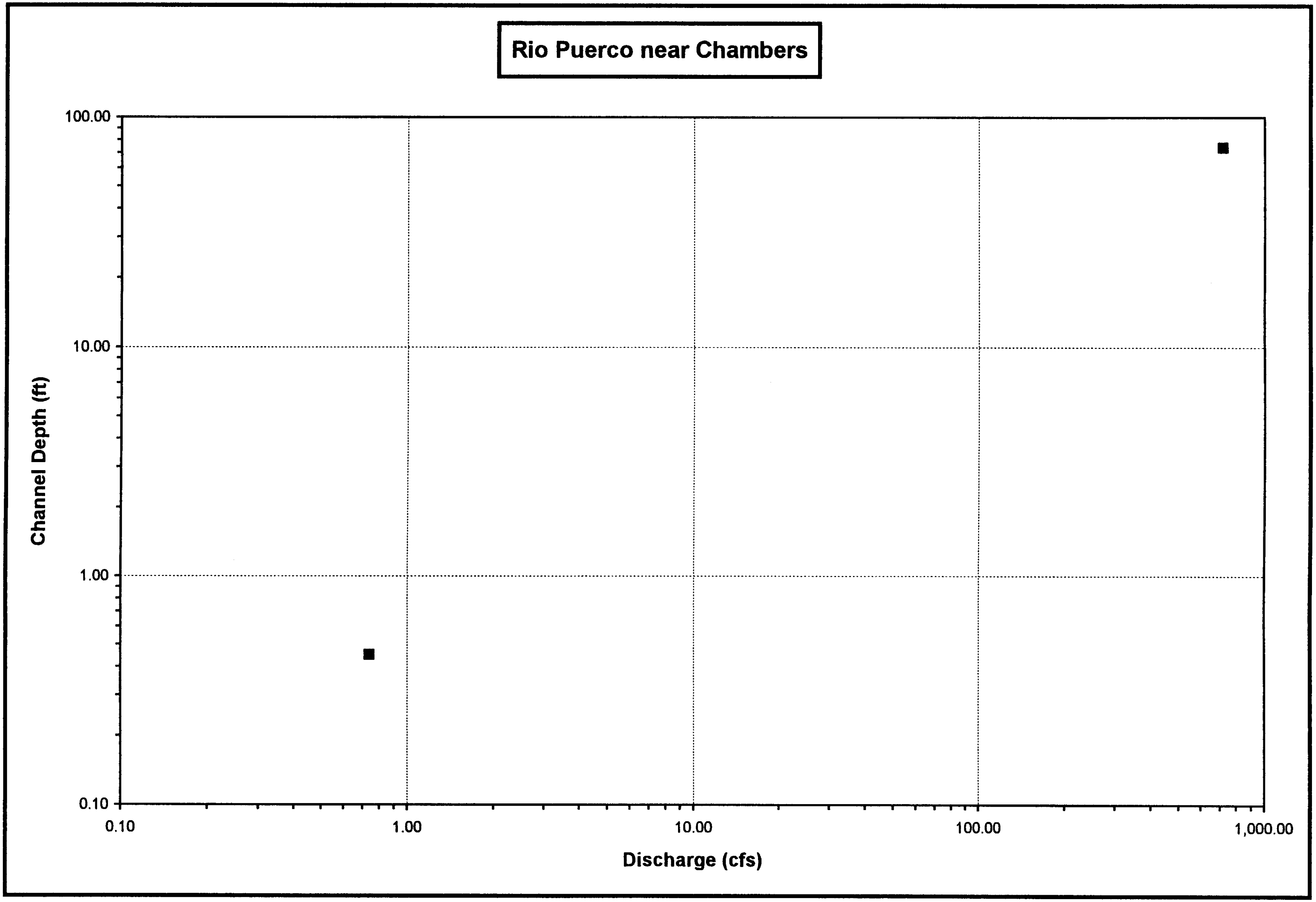
LCR at Woodruff
100.00
10.00
1.00
Channel Width (ft)
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

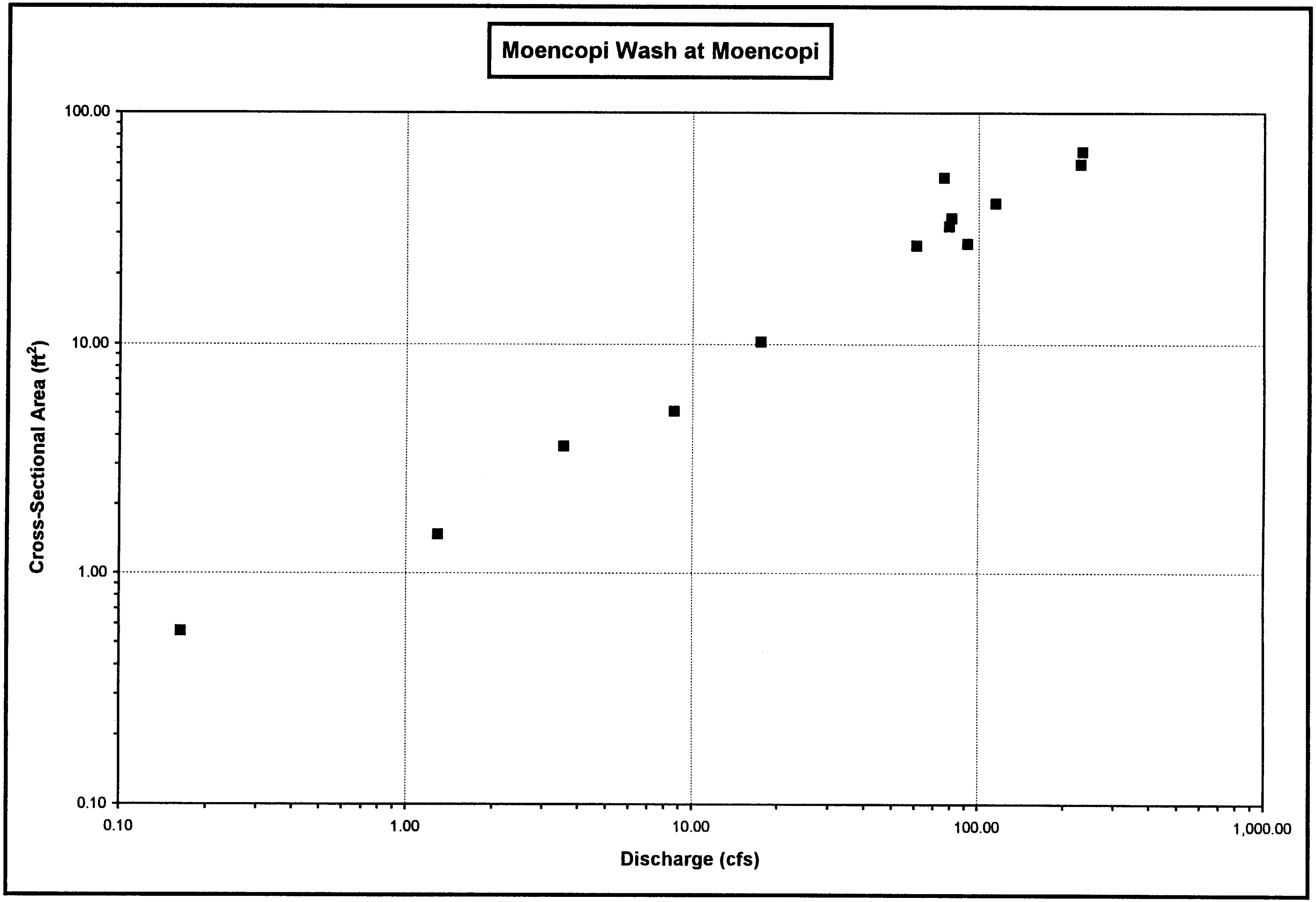


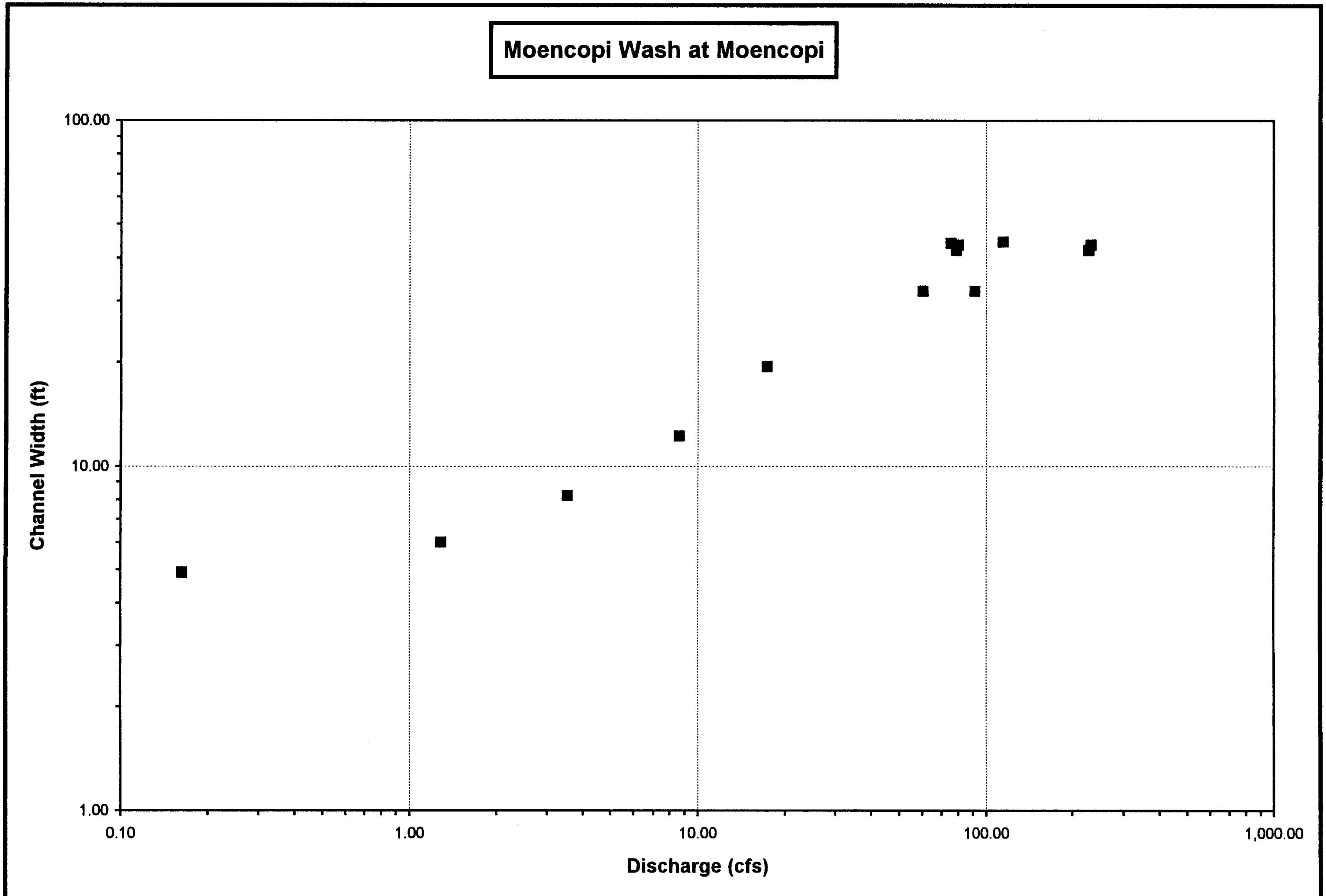
LCR at Woodruff
Channel Depth (ft)
10.00
1.00
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

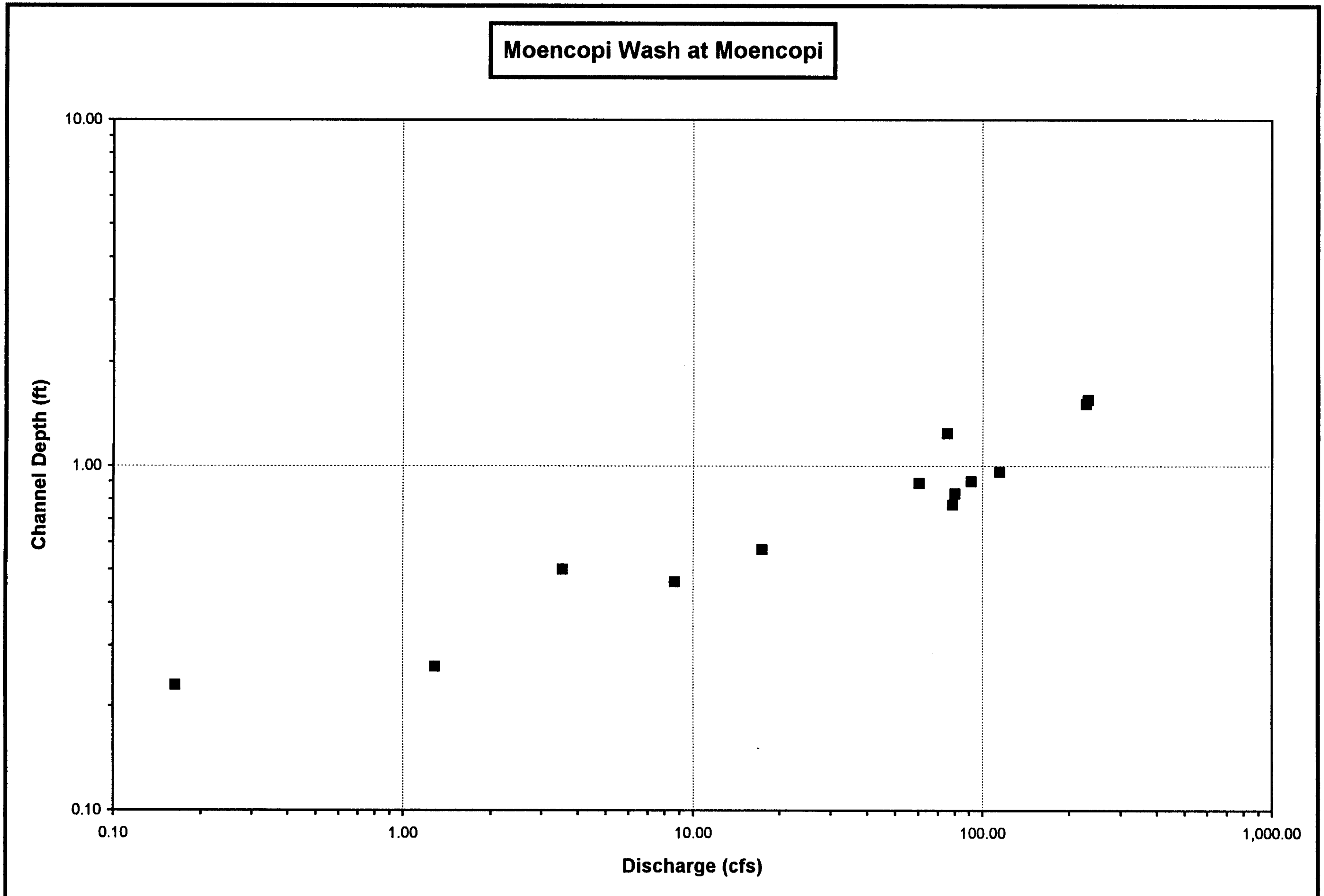

Rio Puerco near Chambers
100.00
10.00
1.00
Cross-Sectional Area (ft2)
1.00
10.00
100.00
1,000.00
Discharge (cfs)


Rio Puerco near Chambers
100.00
10.00
1.00
Channel Width (ft)
1.00
10.00
100.00
1,000.00
Discharge (cfs)

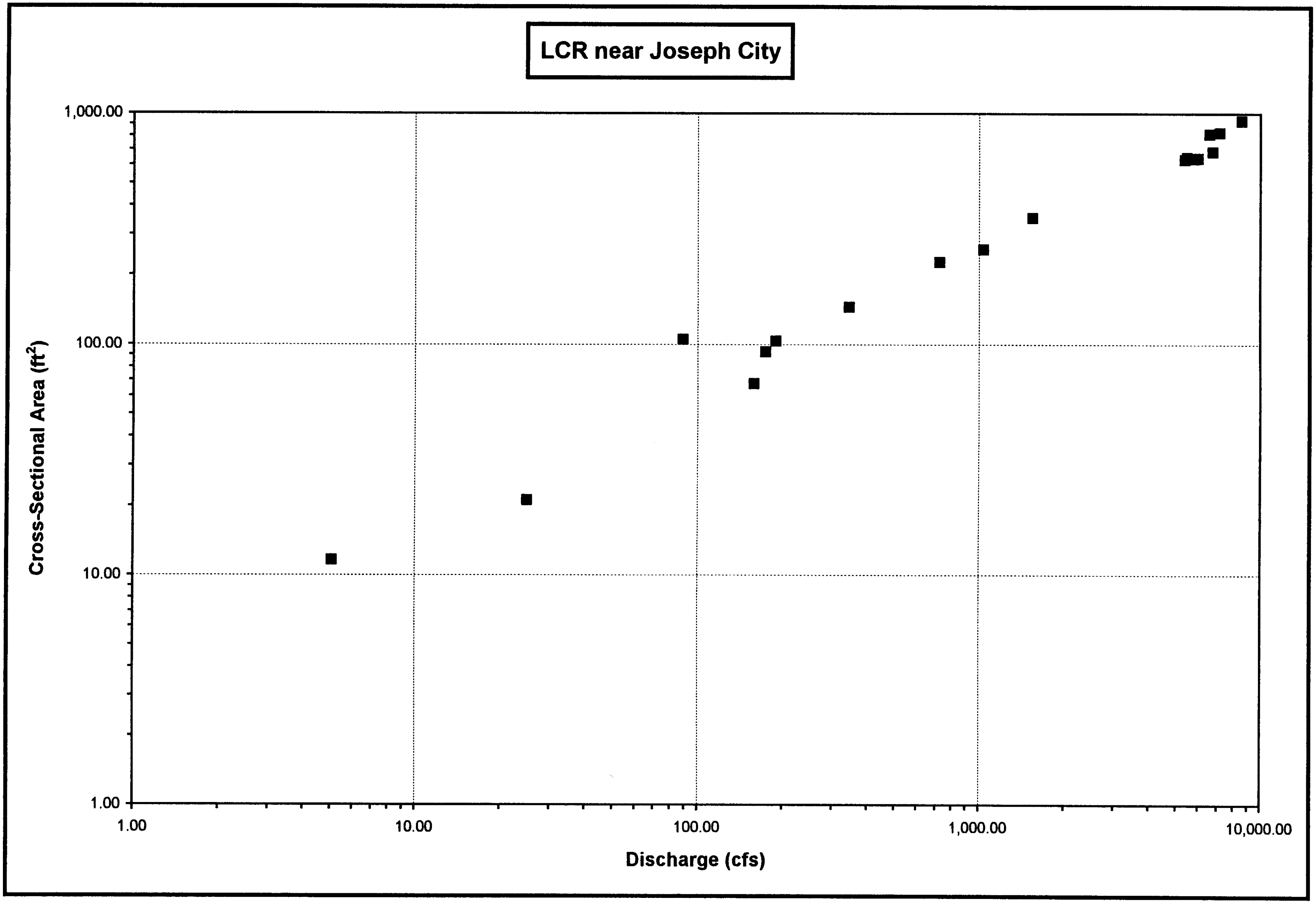

Rio Puerco near Chambers
Channel Depth (ft)
100.00
10.00
1.00
0.10
0.10
1.00
10.00
100.00
1,000.00
Discharge (cfs)


Moencopi Wash at Moencopi
Cross-Sectional Area (ft²)
100.00
10.00
1.00
0.10
0.10
1.00
10.00
100.00
1,000.00
Discharge (cfs)

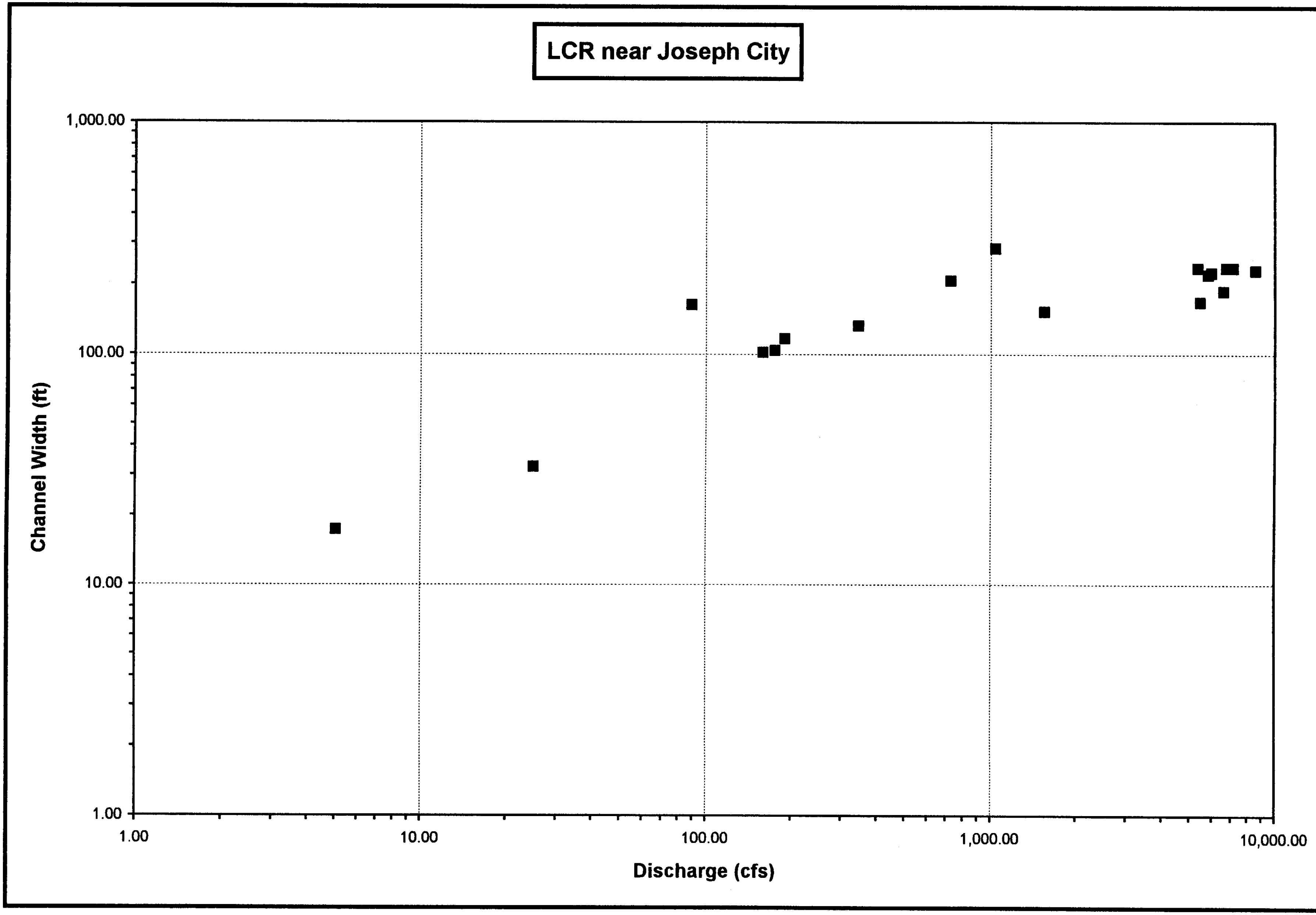

Moencopi Wash at Moencopi
Channel Width (ft)
100.00
10.00
1.00
0.10
1.00
10.00
100.00
1,000.00
Discharge (cfs)



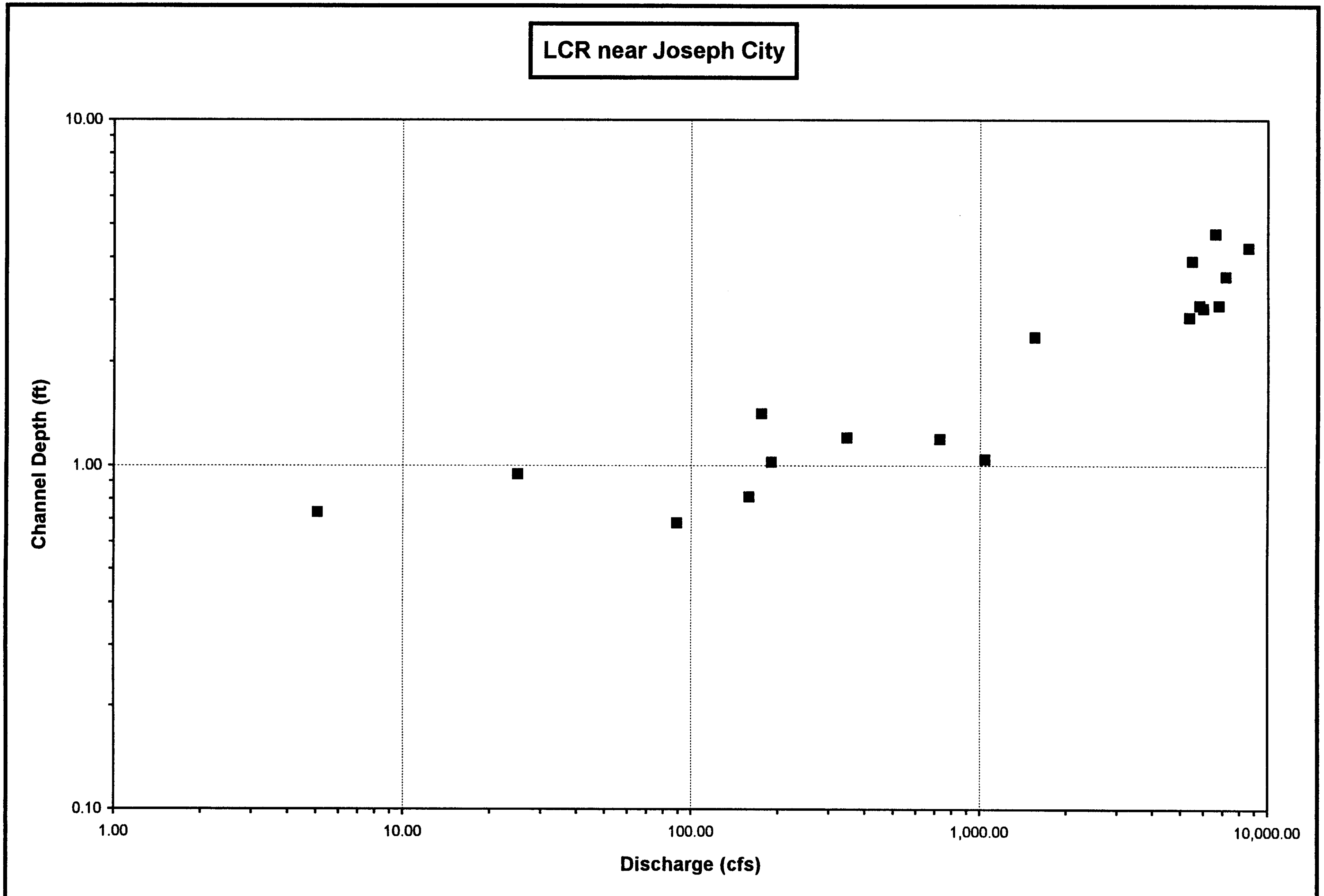
Moencopi Wash at Moencopi
Channel Depth (ft)
10.00
1.00
0.10
0.10
1.00
10.00
100.00
1,000.00
Discharge (cfs)

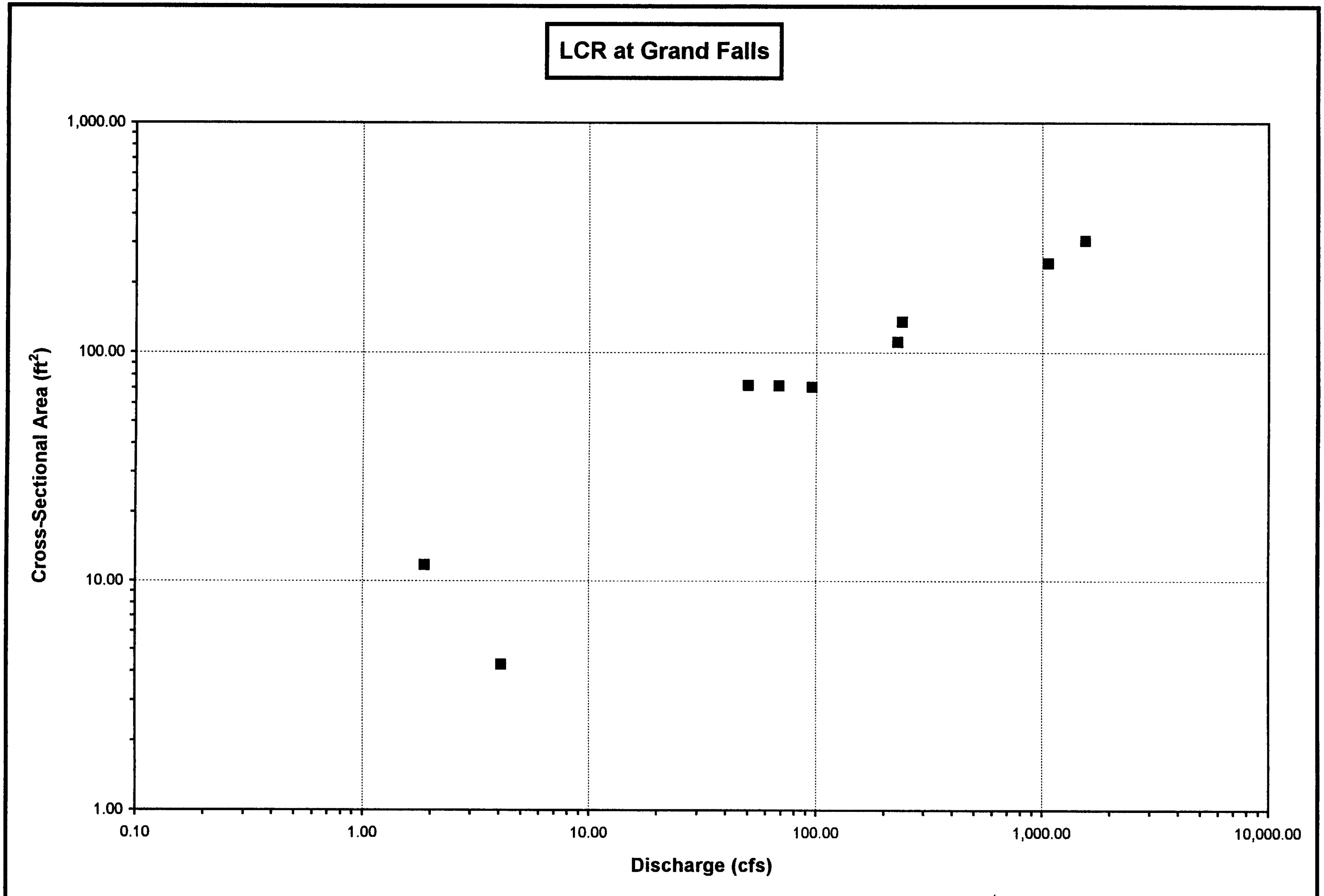


LCR near Joseph City
1,000.00
100.00
10.00
1.00
Cross-Sectional Area (ft^2)
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

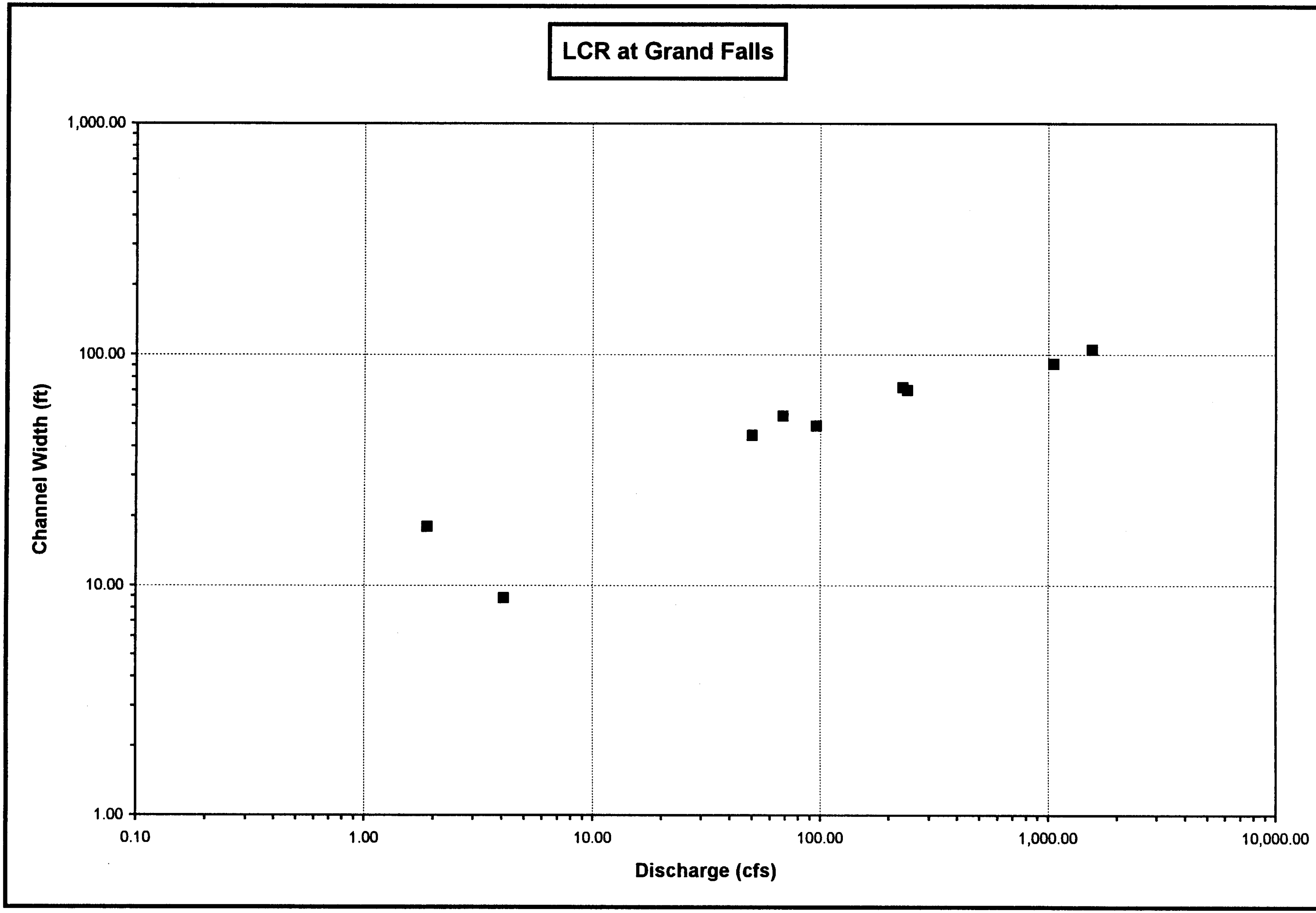


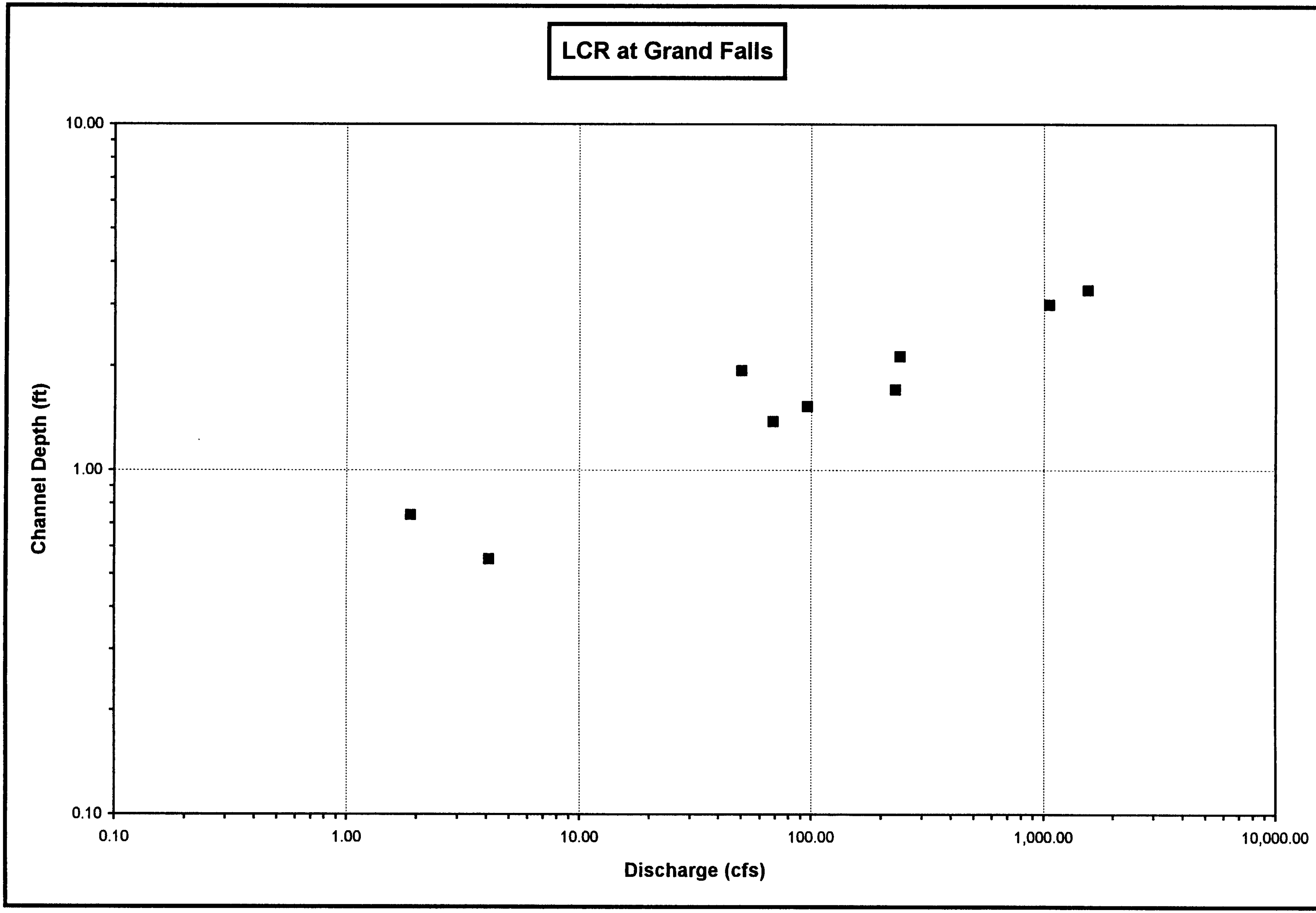
LCR near Joseph City
Channel Width (ft)
1,000.00
100.00
10.00
1.00
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

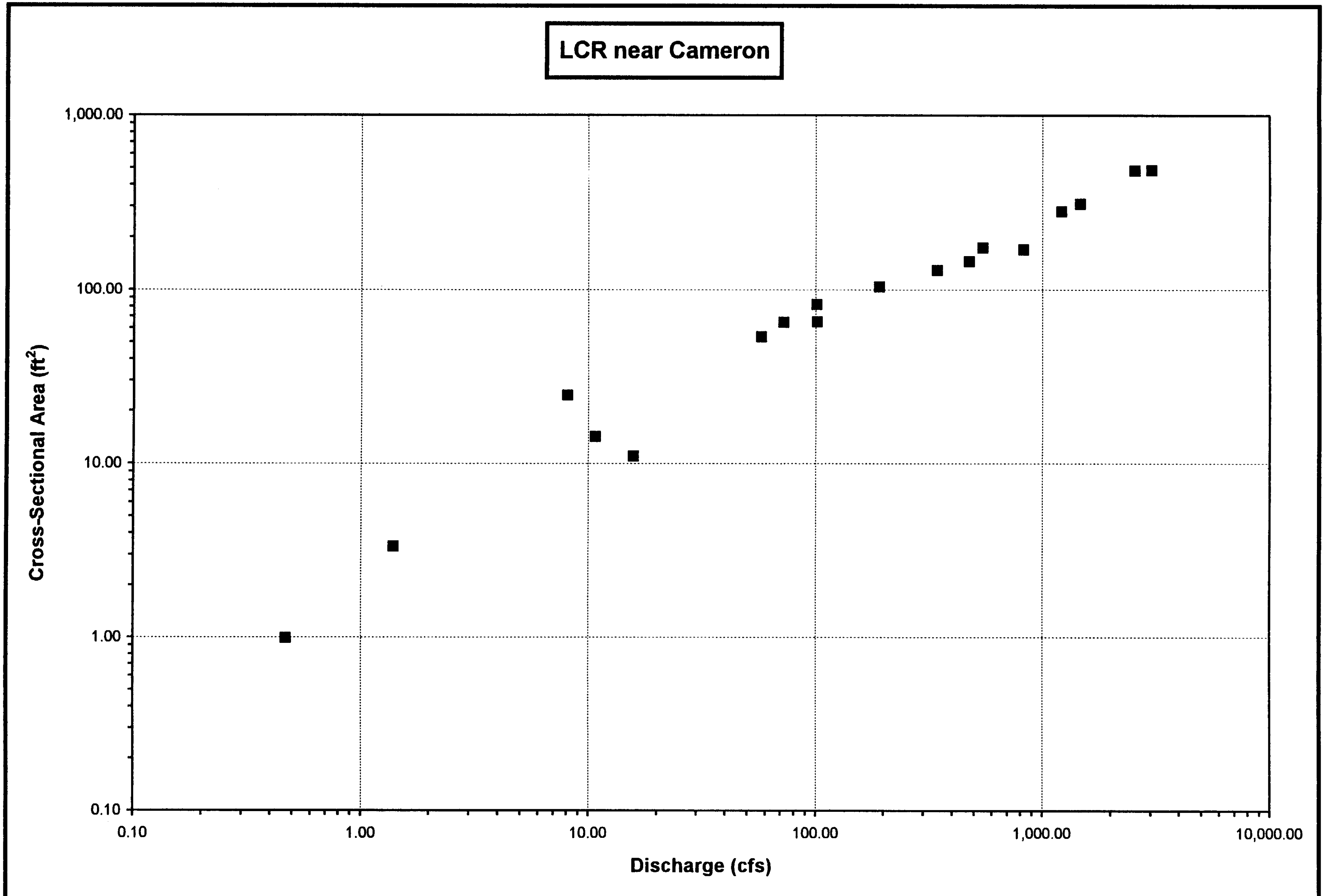

LCR near Joseph City
Channel Depth (ft)
10.00
1.00
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)

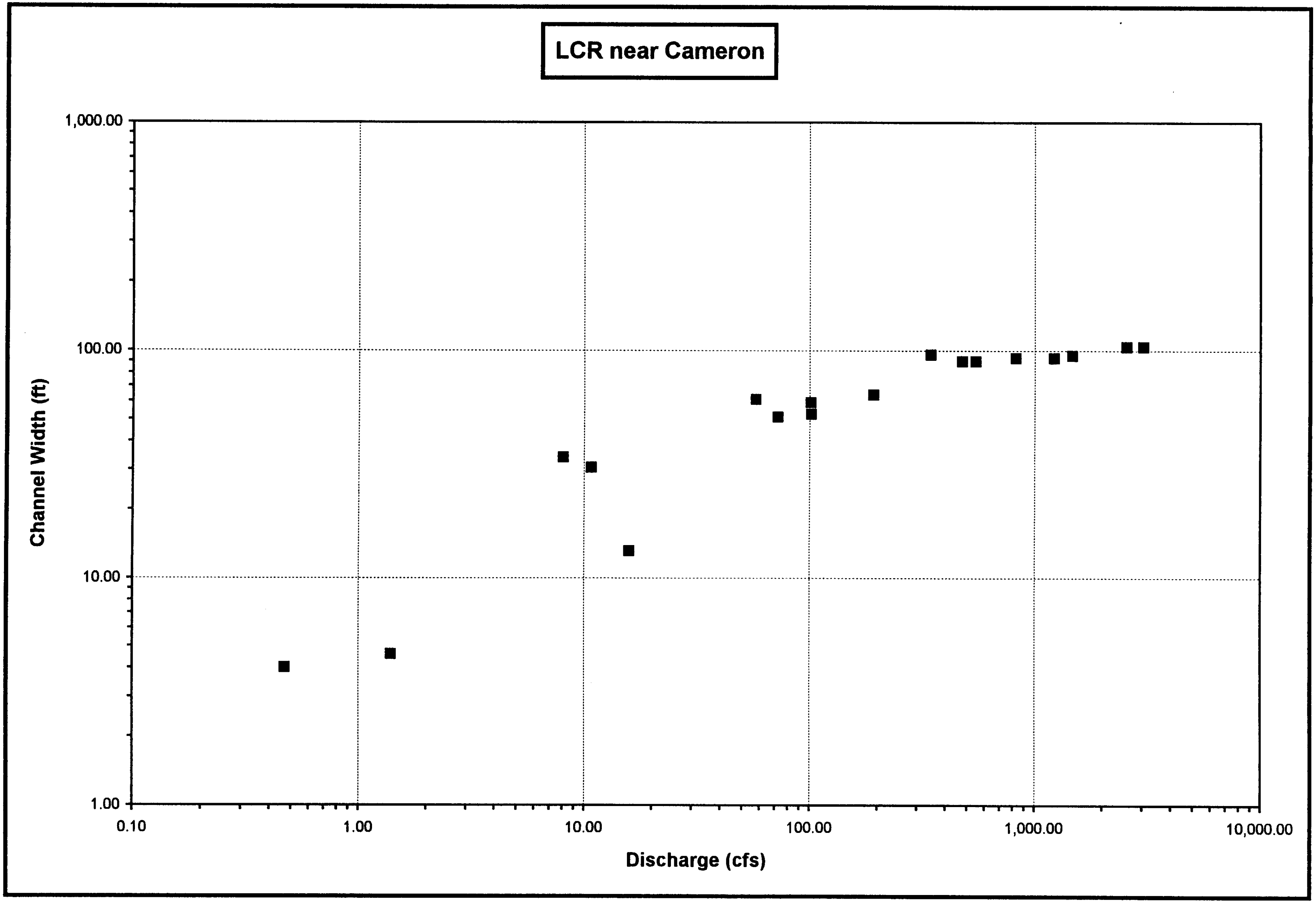


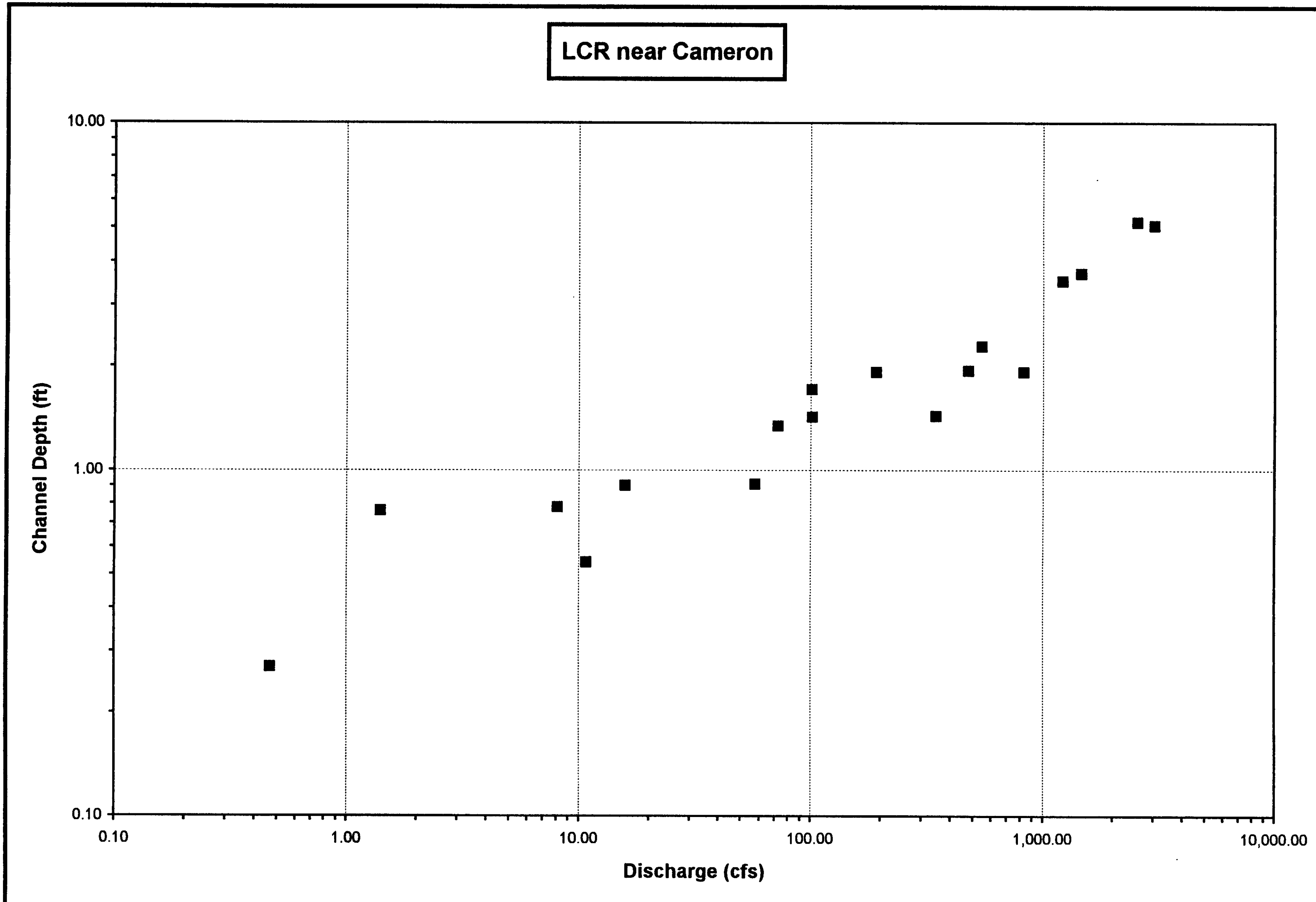
LCR at Grand Falls
Cross-Sectional Area (ft²)
1,000.00
100.00
10.00
1.00
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)


LCR at Grand Falls
Channel Width (ft)
1,000.00
100.00
10.00
1.00
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)


LCR at Grand Falls
10.00
1.00
0.10
Channel Depth (ft)
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)


LCR near Cameron
Cross-Sectional Area (ft^2)
1,000.00
100.00
10.00
1.00
0.10
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)


LCR near Cameron
1,000.00
100.00
10.00
1.00
Channel Width (ft)
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)



LCR near Cameron
Channel Depth (ft)
10.00
1.00
0.10
0.10
1.00
10.00
100.00
1,000.00
10,000.00
Discharge (cfs)