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Extending and Condensing the Brazos River Basin Water Availability Model

By:
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ABSTRACT

The Water Availability Modeling (WAM) System developed and maintained by the Texas Commission on Environmental Quality includes the generalized Water Rights Analysis Package (WRAP) simulation model and WRAP input datasets for all of the river basins of Texas. This report documents an investigation that consisted of developing, testing, and applying procedures for (1) extending WAM hydrology datasets to cover a longer period-of-analysis and (2) condensing WAM water right datasets to focus on a particular water management system while reflecting the effects of all other water rights in the stream flow inflows. The WRAP computer programs *HYD* and *SIM* were expanded to provide the necessary computational capabilities. The procedures were applied to the WRAP input dataset for the Brazos River Basin from the Texas WAM System (Brazos WAM). The modeling methods developed are applicable to other river basins as well.

The Brazos WAM has a 1940-1997 hydrologic period-of-analysis. The research included developing and applying methods to extend the period-of-analysis to 1900-2007 providing a better representation of river basin hydrology. The 1998-2007 extension included adjusting observed flows at gaging stations to develop sequences of monthly naturalized flows and then distributing the naturalized flows to ungaged sites. A new methodology was developed for converting gaged flows to naturalized flows utilizing water management/use information available in the WAM System supplemented with additional observed data. Available gaged stream flows compiled in a previous study were adopted without naturalization adjustments to extend the hydrologic period-of-analysis to cover the period 1900-1939. Monthly flows for 1900-1939 were synthesized for ungaged sites. The impacts on simulation results of lengthening the hydrologic period-of-analysis from 1940-1997 to 1940-2007 and 1900-2007 were evaluated.

The Brazos WAM has 3,830 control points, 670 reservoirs, and hundreds of water rights. The research included developing and applying methods to create a much easier-to-apply condensed dataset with only 48 control points and 14 reservoirs that is focused on a reservoir system operated by the Brazos River Authority and associated water rights. The effects of all of the numerous other reservoirs and water rights in the river basin are incorporated in the stream flow inflows at the 48 selected control points while properly maintaining the priority system reflected in the water right permits. A comparison of simulation results obtained with the condensed versus full WAM datasets confirms that the methodology does properly preserve the effects of the numerous water rights, reservoirs, and control points removed from the WAM dataset in creating the condensed dataset. Modeling applications and issues are explored.

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CHAPTER 1
INTRODUCTION

This report presents procedures for modifying Water Availability Modeling (WAM) System datasets in the following ways.

1. Updating hydrology data by extending the period-of-analysis forward.
2. Lengthening the hydrologic period-of-analysis by extending it backward.
3. Condensing a dataset to focus on a particular water management system.

These three distinctly different tasks represent modifications of existing WAM datasets needed to support evolving applications of the modeling system. The procedures rely upon recently expanded Water Rights Analysis Package (WRAP) computational capabilities.

This report presents an application of the newly developed procedures to the TCEQ WAM System dataset for the Brazos River Basin and San Jacinto-Brazos Coastal Basin, which for brevity is called the Brazos WAM. This initial application provides opportunities to research, develop, test, and further refine the methodologies. The resulting versions of the Brazos WAM dataset will facilitate a broader range of practical applications of the WRAP modeling system.

Water Availability Modeling (WAM) System

Information describing the Water Availability Modeling (WAM) System developed and maintained by the Texas Commission on Environmental Quality (TCEQ) is provided at the WAM website:

http://www.tceq.state.tx.us/permitting/water_supply/water_rights/wam.html

The WAM System consists of the generalized Water Rights Analysis Package (WRAP) simulation model, WRAP input datasets for all of the river basins of Texas, and other supporting software and databases. WRAP is documented by the following reference and users manuals.

Water Rights Analysis Package (WRAP) Modeling System Reference and Users Manuals, TWRI TR-255 and TR-256, Fifth Edition, August 2008.

The March 2008 fourth edition and August 2008 fifth edition of the WRAP manuals incorporate recent additions to the modeling system developed to support the input dataset extension and simplification procedures outlined by this report. These new features are described in Chapter 2 of this report as well as in the WRAP manuals.

Texas has 15 major river basins and eight coastal basins lying between the lower reaches of the major river basins. The Texas WAM System includes 21 WRAP input datasets covering the 23 river basins. Three of the 21 datasets combine two river basins, and one basin is divided into two datasets. The river basins covered by the datasets are delineated in Figure 1.1 and listed in Table 1.1. The map number in the first column of Table 1.1 refers to the river basins shown in Figure 1.1. The water rights in the datasets are updated as the TCEQ approves applications for new permits or revisions to existing permits. Other aspects of the datasets also continue to be refined.

The 21 WAM System input datasets listed in Table 1.1 combined with the generalized WRAP simulation model provide models for each of the river basins of the state. The hydrologic simulation periods currently reflected in each of the river basin models are shown in Table 1.1. The number of primary control points and the total number of control points in each dataset are also listed in Table 1.1. The difference is the number of secondary control points for which naturalized flows are computed within the *WRAP-SIM* simulation model based on flows input for the primary control points. Primary control points are defined as locations at which naturalized flows are provided in the WAM datasets. Primary control points are usually stream gaging stations. This report is concerned with extending the period-of-analysis and reducing the number of control points.

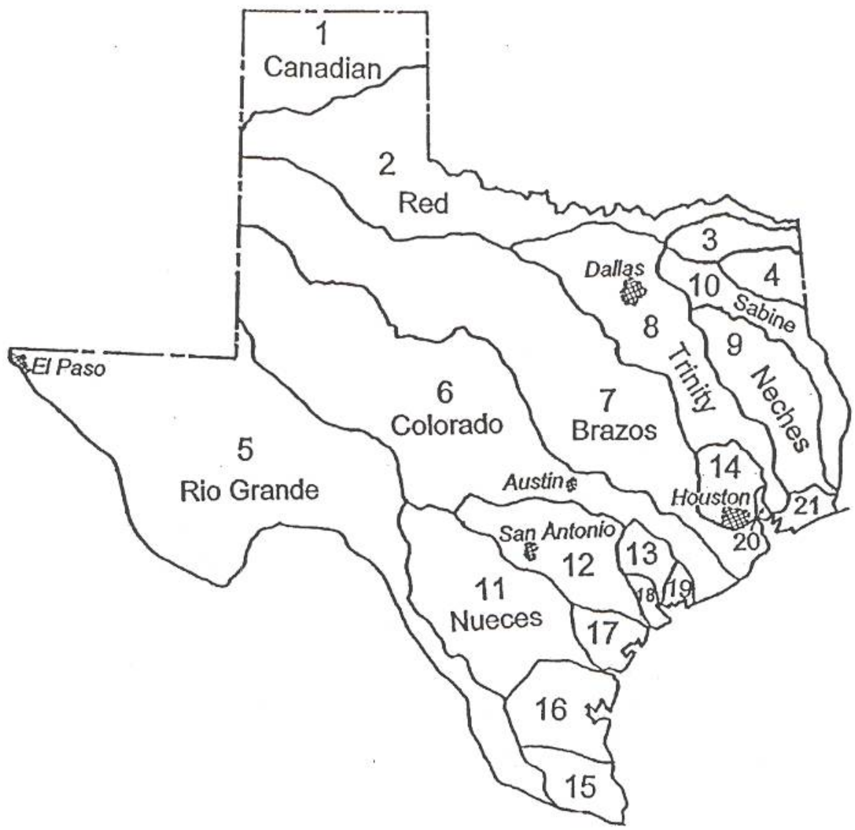

Figure 1.1 WAM System River Basins

Alternative versions of the water rights data files (with filename extension DAT) contained in the TCEQ WAM System datasets represent alternative scenarios reflecting combinations of premises regarding water use, return flows, reservoir sedimentation, and term permits. Several specified scenarios were simulated by TCEQ contractors during 1997-2002 for all of the river basins in conjunction with implementation of the WAM System. The following two scenarios are routinely adopted for water right permit applications and planning studies.

- The authorized use scenario (run 3) is based on the following premises.

  1. Water use targets are the full amounts authorized by the permits.
  2. Full reuse with no return flow is assumed.
  3. Reservoir storage capacities are those specified in the permits, which typically reflect no sediment accumulation.
  4. Term permits are not included.

- The current use scenario (run 8) is based on the following premises.
    1. The water use target for each right is based on the maximum annual amount used in any year during a recent ten year period.
    2. Best estimates of actual return flows are adopted.
    3. Reservoir storage capacities and elevation-area-volume relations for major reservoirs reflect year 2000 conditions of sedimentation.
    4. Term permits are included.

Table 1.1
WAM System Datasets

Fig. 1.1 Map ID	Major River Basin or Coastal Basin	Period of Analysis	Number of Control Points Primary	Number of Control Points Total	Number of Reservoirs
1	Canadian River Basin	1948−1998	12	85	47
2	Red River Basin	1948−1998	47	447	245
3	Sulphur River Basin	1940−1996	8	83	53
4	Cypress Bayou Basin	1948−1998	10	189	91
5	Rio Grande Basin	1940−2000	55	957	113
6	Colorado River Basin and Brazos-Colorado Coastal Basin	1940−1998	45	2,395	511
7	Brazos River Basin and San Jacinto-Brazos Coastal Basin	1940−1997	77	3,830	670
8	Trinity River Basin	1940−1996	40	1,334	703
9	Neches River Basin	1940−1996	20	318	176
10	Sabine River Basin	1940−1998	27	376	207
11	Nueces River Basin	1934−1996	41	542	121
12	Guadalupe and San Antonio River Basins	1934−1989	46	1,349	237
13	Lavaca River Basin	1940−1996	7	185	22
14	San Jacinto River Basin	1940−1996	16	411	114
15	Lower Nueces-Rio Grande	1948−1998	16	119	42
16	Upper Nueces-Rio Grande	1948−1998	13	81	22
17	San Antonio-Nueces Coastal	1948−1998	9	53	9
18	Lavaca-Guadalupe Coastal Basin	1940−1996	2	68	0
19	Colorado-Lavaca Coastal Basin	1940−1996	1	111	8
20	Trinity-San Jacinto Coastal Basin	1940−1996	2	94	13
21	Neches-Trinity Coastal Basin	1940−1996	4	245	31

The data contained in the WAM System input datasets can be divided into the following three categories.

- Hydrology data consisting of sequences of monthly naturalized stream flow volumes and net reservoir evaporation-precipitation depths covering the hydrologic period-of-analysis at relevant control points are typically stored in files with filename extensions FLO and EVA, which are called the FLO and EVA files.

- Control point selections and watershed parameters used in computing naturalized flows at ungaged (unknown-flow) control points, called secondary control points, based on naturalized flows at gaged (known-flow) control points called primary control points. These flow distribution data are stored in a file with filename extension DIS.

- Water rights data describing water use requirements, reservoirs and other water-control infrastructure, water right permits and other institutional arrangements for allocating water among multiple users, and river/reservoir system operating rules and practices. These data are stored in a file with filename extension DAT.

Updating and Extending Hydrology

River basin hydrology is represented in the Texas Water Availability Modeling (WAM) System by sequences of monthly naturalized stream flows and net reservoir surface evaporation less precipitation depths covering a specified hydrologic simulation period. The period-of-analysis for the WAM System hydrology datasets all begin in either 1934, 1940, or 1948 and end in either 1989, 1996, 1997, 1998, or 2000. The datasets were compiled during 1997-2001 in conjunction with implementation of the WAM System pursuant to the 1997 Senate Bill 1. Several years of additional hydrologic observations have accumulated since compilation of the original hydrology data sequences incorporated in the WAM System datasets.

The WAM System hydrology dataset for the Brazos River Basin and San Jacinto-Brazos Coastal Basin has a period-of-analysis of 1940-1997. The sequences of naturalized flows and evaporation-precipitation depths are updated in the investigation reported here to cover 1940-2007.

Development of the original hydrology datasets during implementation of the WAM System required considerable time and effort. The methodology presented in this report is designed to significantly reduce the effort required to update the naturalized stream flows (FLO files) by utilizing the information now available in the WAM System water right datasets (DAT files). The information in the DAT file describes water resources development, allocation, management, and use. The flow extension procedure is based on creating a DAT file dataset representing actual water management/use during the extension period, which is 1998-2007 for the Brazos WAM, by modifying the current use scenario WAM System dataset. The results of *SIM* simulations with the actual use dataset are used to convert gaged 1998-2007 monthly stream flows to naturalized flows.

The period-of-analysis for the Brazos WAM was also extended backward to cover 1900-1939 in addition to the original 1940-1997 and the forward extension of 1998-2007. The total extended Brazos WAM hydrologic period-of-analysis covers January 1900 through December 2007. The naturalized stream flows for 1900-1939 are significantly less accurate than later flows due to the small number of stream gaging stations in operation during the earlier years. The process of converting gaged flows to naturalized flows is much simpler for 1900-1939 because water resources development and use were much less during this time period than later years. Rapid population and economic growth in Texas began in the 1950s. Most of the reservoir projects in Texas were constructed during the 1950s through 1970s. The 1900-1939 extension deals primarily with synthesizing flows at many ungaged sites based on limited available gaged flow data. WRAP simulations with the exceptionally long 108 years of hydrology provide interesting insights.

Condensing a WAM Dataset to Focus on a Particular River/Reservoir Water Management System

The larger TCEQ WAM System datasets listed in Table 1.1 contain hundreds of water rights, control points, and reservoirs. These large complex datasets are necessary for the regional and statewide planning and water right permitting applications for which the datasets were developed. However, simpler datasets are advantageous for certain other applications. A methodology is presented in this report for simplifying WAM System datasets to focus on management of a particular river/reservoir system. Selected water rights, control points, and reservoirs are removed with their effects retained in the adopted stream inflow input data for the condensed dataset. The objective is to develop a much simpler dataset for purposes of studying or providing decision support for the particular reservoir/river water management system. The condensed model allows alternative operating plans for the primary water management system to be simulated based on the premise of assuring complete protection of all other water rights.

The methodology for condensing a dataset is based on developing flows at selected control points that represent stream inflow amounts available to the selected system that reflect the impacts of all of the water rights and accompanying reservoirs removed from the original complete dataset. River flows are provided on *IN* records in a FLO input file for the condensed dataset. These are flows available to the selected system modeled in the condensed system-specific DAT input file considering the effects of all the other water rights in the river basin contained in the original complete DAT file that are not included in the condensed DAT file. The condensed model is designed for simulating alternative operating plans for the particular system of interest while considering the impacts of numerous other water users on stream flow availability. However, complexities associated with modeling the other water users and water management entities are greatly reduced. The model assures that all secondary water rights are fully protected.

Condensed authorized and current use datasets focused on operation of the Brazos River Authority (BRA) system are developed by condensing the TCEQ WAM System datasets for the Brazos River Basin and San Jacinto-Brazos Coastal Basin. The Brazos WAM authorized use dataset has 3,830 control points, 670 reservoirs, 1,634 water right *WR* records, 122 instream flow *IF* records, and 3,138 flow distribution *FD* records. The BRA condensed authorized use dataset contains 48 control points, 15 reservoirs, 135 *WR* and *IF* records, and no *FD* records. The impacts on stream flow available to the BRA system of the numerous water rights and reservoirs removed from the WAM dataset are reflected in the *IN* record inflows of the condensed dataset.

Scope and Organization of this Report

Proposed strategies for extending the hydrologic period-of-analysis and developing a condensed dataset are outlined in the new Chapter 6 of the *WRAP Reference Manual* added with the March 2008 Fourth Edition. These general methodologies are also described in the following Chapter 2 of this report. The remainder of the report then presents the application of the methodologies to the TCEQ WAM System dataset for the Brazos River Basin and San Jacinto-Brazos Coastal Basin, which is for brevity called the Brazos WAM dataset throughout the report. The existing Brazos WAM dataset is described in Chapter 3. Lengthening the Brazos WAM hydrologic period-of-Analysis from 1940-1997 to 1900-2007 is covered in Chapters 4, 5, 6, and 7. Developing a condensed dataset focused on the BRA system is covered in Chapters 8 and 9.

The general computational procedures for modifying WRAP input datasets are outlined in Chapter 2. The August 2008 version of the WRAP programs *SIM* and *HYD* contain new features added primarily to facilitate these procedures. Simple examples are presented in Chapter 2 to illustrate the *WRAP-SIM/HYD* computational methodologies, prior to dealing with the complicated Brazos WAM investigation throughout the remainder of this report.

Extending the Brazos WAM hydrologic simulation period forward by ten years from 1940-1997 to 1940-2007 is reported in Chapter 4. Further extending the period-of-analysis backward to also cover 1900-1939 is described in Chapter 5. Naturalized flows for the alternative periods are compared in Chapter 6. The impacts of the longer 1940-2007 and 1900-2007 periods-of-analysis on WRAP simulation results are investigated in Chapter 7.

The development of condensed BRAC3 (authorized use scenario) and BRAC8 (current use) datasets focusing on the Brazos River Authority (BRA) reservoir system is covered in Chapters 8 and 9. Chapter 8 documents the tasks involved in developing of the datasets, and Chapter 9 presents a comparative analysis of simulation results derived from the condensed versus original datasets.

WRAP-SIM simulation results are presented in Chapters 4, 7, and 9. Chapter 4 deals with *SIM* simulation results from the Bwam8A actual use dataset which has a hydrologic period-of-analysis of 1998-2007. Simulation results for the Bwam3 authorized use and Bwam8 current use scenario datasets with alternative hydrologic period-of-analysis of 1940-1997, 1940-2007, and 1900-2007 are covered in Chapter 7. Simulation results from a BRAC condensed dataset focusing on operation of the BRA system are compared with Bwam3 and Bwam8 results in Chapter 9.

The summary and conclusions of the investigation are presented in Chapter 10. The appendices present plots of 1900-2007 naturalized flows at 77 Bwam primary control points (Appendix A), observed 1998-2007 gaged flows and naturalized flows at 47 gaged control points (Appendix B), observed and simulated 1998-2007 storage volumes for 14 reservoirs (Appendix C), 1900-2007 Bwam3 and Bwam8 storage volumes for the 14 reservoirs (Appendix D), and adjusted inflows for the 48 control points of the BRAC3 and BRAC8 condensed datasets (Appendix E).

The investigation documented by this report produced several WRAP datasets. Chapter 2 includes two examples created by expanding an example from the *Reference Manual*. All of the chapters deal with modifications to TCEQ WAM System datasets for the Brazos River Basin and San Jacinto-Brazos Coastal Basin, which are referred to as the Brazos WAM. The sets of Brazos WAM input files are referenced by their filename roots in the following file inventory.

Bwam3 and Bwam8 − The Brazos WAM dataset consists of DAT, FLO, EVA, and DIS input files for WRAP-SIM. The 1940-1997 hydrologic period-of-analysis was lengthened to 1900-2007 in this investigation by expanding the FLO and EVA files common to the Brazos WAM authorized use (run 3) Bwam3 and current use (run 8) Bwam8 datasets.

Bwam8A − A 1998-2007 actual use Bwam8A dataset was created in the flow extension procedure by modifying the Bwam8 current use dataset as described in Chapter 4.

BRAC3 and BRAC8 − Condensed authorized use BRAC3 and current use BRAC8 datasets (DAT, FLO, EVA, RUF files) focusing on the Brazos River Authority (BRA) reservoir system were developed from the Bwam3 and Bwam8 datasets as described in Chapter 8.

CHAPTER 2
GENERAL METHODOLOGIES

This chapter is organized in four parts.

1. The chapter begins with a review of basic concepts regarding the generalized Water Rights Analysis Package (WRAP) modeling system and the WRAP input datasets contained in the TCEQ Water Availability Modeling (WAM) System that are particularly pertinent to subsequent descriptions of the following three methodologies.
2. The second part of the chapter outlines the procedure for extending the hydrologic period-of-analysis forward in time.
3. The third part discusses extending a hydrologic period-of-analysis backward in time.
4. The fourth part of the chapter outlines the procedure for developing a condensed dataset focusing on a particular river/reservoir water management system.

The methodologies as described in this chapter are generally applicable to any of the WAM System datasets. The techniques are applied to the Brazos WAM in subsequent chapters.

WRAP Programs *SIM* and *HYD*

The programs *SIM* and *HYD* are applied in combination in the procedures for extending the hydrologic period-of-analysis and condensing a dataset. New features added to *SIM* and *HYD* to support these procedures for modifying *WRAP* input datasets are documented in the August 2008 Fifth Edition of the *Reference* and *Users Manuals* (Wurbs 2008). New capabilities added to *HYD* were initially reported in the March 2008 Fourth Edition of the *Reference* and *Users Manuals*. Additional refinements to *HYD* during May-July are covered in the August 2008 Fifth Edition. The new *SIM* features described below were developed during June-July 2008 and incorporated into the August 2008 Fifth Edition of the *Manuals*.

The *SIM* simulation model will now operate reservoirs for sequences of monthly storage levels specified as input. The observed storage *OS* record was added to allow *SIM* to reproduce actual observed storage volumes entered in the DAT input file. The storage capacity set by water right storage *WS*, monthly storage *MS*, and observed storage *OS* records each month is now written to the *SIM* output OUT file. A new flow distribution option 10 is activated by the parameter *INMETHOD(cp)* entered on the *CP* records in the DAT file with parameters entered on *FD* and *WP* records in the DIS file. *UR* records stored in the FAD file were also added for condensed models.

The program *WRAP-HYD* is designed to assist in developing the hydrology files of stream flows and net evaporation-precipitation depths for the *SIM* simulation model input dataset. Program *HYD* capabilities are outlined in Chapter 3 of the *Reference Manual* and Chapter 5 of the *Users Manual*. *HYD* is a set of routines designed to assist in developing hydrology input datasets for *SIM*. The original *HYD* was developed during 1998-2000. However, most of the hydrology datasets for the WAM System were completed prior to completion of the program *HYD*. Microsoft Excel was used during the 1997-2001 WAM hydrology dataset compilation work for most of the computing tasks that have since been incorporated into *HYD*. The original *WRAP-HYD* has been significantly expanded during 2007-2008 to facilitate the types of computations addressed by this report.

Several new features of *HYD* are applied in the *SIM* input dataset modification procedures outlined here. *HYD* now reads simulation results from a *SIM* output OUT file. The quantities read from the OUT file can be applied within *HYD* in various ways. The new *OI* record allows *HYD* to create *SIM* input records from *SIM* simulation results. *SIM* simulation results can also be used to develop flow adjustments defined by parameters entered on the *HYD* job control *JC* and adjustment specification *AS* records. The new *AN* record feature in *HYD* is used to develop the frequency-based initial naturalized flows for the flow extension procedure discussed later in this chapter.

The WRAP programs *SIM* and *HYD* are applied in combination in the procedures outlined in this chapter for extending *SIM* hydrology datasets and condensing an overall *SIM* input dataset to focus on a particular river/reservoir water management system. Simulations are performed with *SIM*. *HYD* is used to develop *SIM* hydrology input. *HYD* reads and manipulates *SIM* simulation results in the process of developing *SIM* input datasets. The program *TABLES* is also applied in analyzing *SIM* simulation results.

The methodologies outlined here consist of manipulating the data stored in the *WRAP-SIM* DAT, FLO, and EVA input files contained in an existing WAM System dataset. Optionally, the hydrology data can also be stored in binary Data Storage System (DSS) files rather than FLO and EVA text files. The flow distribution DIS file is also relevant to this report. These *SIM* input files are covered in detail in the *WRAP Users Manual* (Wurbs 2008) and briefly described below.

- The DAT file contains water rights data and other related data. The DAT file provides information describing water use requirements, reservoir projects and other water-control infrastructure, water right permits and other institutional arrangements for allocating water among multiple users, and river/reservoir system operating rules and practices. Both the authorized use (run 3) and current use (run 8) versions of the TCEQ WAM System DAT files are adopted for the studies documented by this report.

- The FLO file contains the river system inflows stored on *IN* records. The FLO file contains naturalized flows in the TCEQ WAM System datasets. However, as discussed below, the meaning of inflows contained on *IN* records in a FLO file are redefined in the methodologies applied in this report.

- The EVA file contains the *EV* records with sequences of monthly reservoir surface net evaporation less precipitation depths.

- The DIS file contains information defining relevant control points and providing watershed parameters for distributing naturalized stream flows from primary (gaged or known-flow) control points to secondary (ungaged or unknown-flow) control points.

WRAP Stream Flow Definitions

A WRAP-SIM simulation consists essentially of modifying hydrologic period-of-analysis sequences of monthly naturalized (or otherwise defined) flows read from the FLO file for the effects of the water rights described in the DAT flow to obtain the resulting sequences of regulated flows and unappropriated flows recorded in the *SIM* output file. The methodologies presented in this report also consist of modifying sequences of monthly stream flows. The stream flow terms used with the WRAP modeling system are defined as follows.

naturalized (unregulated) flows − In the TCEQ WAM System, the flows in FLO files are naturalized or unregulated stream flows representing natural conditions without the effects of the human activities modeled by the information contained in the *SIM* input DAT file. Primary control points are locations, typically gaging stations, at which naturalized flows are provided as *IN* records in a FLO file or alternatively as a Data Storage System (DSS) file. Naturalized flows at secondary control points are computed within the *SIM* simulation model based on naturalized flows at primary control points and watershed parameters from a flow distribution DIS file. Naturalized flows at primary control points were determined during implementation of the WAM System as gaged flows adjusted to remove the effects of water resources development, management, and use. However, the flows on *IN* records in a DAT file are redefined to fit the purposes of methodologies outlined in this chapter. The *IN* record stream flows represent specified conditions of river basin management that are defined by the methodologies.

regulated flows − Regulated flows are computed by *SIM* by adjusting naturalized flows for the effects of the human activities modeled by the information contained in a *SIM* input DAT file. In general, regulated flows are the actual flows at a site which would be measured by a stream flow gage if the information in the *SIM* input file perfectly modeled actual water resources development, management, and use during each month of the simulation. However, the meaning of computed regulated flows can vary depending on definitions of naturalized flows adopted for the methodologies outlined in this report.

unappropriated flows − Unappropriated flows represent the stream flow volumes still available for appropriation after considering all water right requirements. In a particular month, the unappropriated flow at a control point may be less than the regulated flow because a portion or all of the flow may have been committed to meet instream flow requirements at that control point or for water supply diversions or storage further downstream. The unappropriated flow is the portion of the regulated flow that is not needed to meet the water right requirements included in the simulation.

The difference between the *IN* record flows representing natural or other specified conditions of development provided as input to a *SIM* simulation and the regulated flows computed by the *SIM* simulation is the summation of stream flow depletions, return flows, reservoir releases, inflows or outflows from constant inflow *CI* records or flow adjustment *FA* records which are each appropriately cascaded to downstream control points while accounting for channel losses. The *SIM* variables that cause or are represented by the differences between regulated and unregulated (naturalized) flows are defined as follows.

stream flow depletion − volume appropriated by a water right to meet diversion requirements and/or refill reservoir storage while also accounting for evaporation

return flow − portion of stream flow depletion that is returned to the stream

reservoir releases − those releases from reservoir storage made specifically for a water right to meet a diversion, instream flow, or refilling target at a control point located further downstream or releases for hydroelectric energy generation

other inflows − inflows representing water supply return flows, interbasin transport, or other considerations that are input on *CI* and/or *FA* records

The difference between regulated and naturalized flows at a particular control point consists of the accumulation of stream flow depletions, return flows, reservoir releases, and constant *CI* and flow adjustment *FA* record flows occurring at that control point and all upstream control points properly cascaded downstream with adjustments for channel losses.

Forward Extension of the Hydrologic Period-of-Analysis

River basin hydrology is represented in the WAM System datasets by both sequences of monthly naturalized stream flows and net reservoir surface evaporation less precipitation depths. However, the methodology outlined here for updating the hydrologic period-of-analysis focuses primarily on naturalized flows. Compiling monthly evaporation-precipitation depths is a step in the procedure for developing naturalized flows. The procedure for compiling evaporation-precipitation depths is still basically the same now as during the original development of the WAM System datasets. The procedure outlined here for developing naturalized flows is new. Developing naturalized flows represents a significantly greater portion of the total effort than compiling the evaporation-precipitation data though both are important.

The naturalized stream flow datasets for the WAM System were originally developed by adjusting observed flows at gaging stations to remove the effects of historical reservoir storage and operations, water supply diversions, return flows from diversions from surface and ground water sources, and other factors. This same general approach is adopted for extending the period-of-analysis covered by the naturalized flows. However, much time and effort is required to compile and manipulate the voluminous data describing actual water management and use that is required for the flow adjustments. The objective of the procedure outlined below is to greatly reduce the required effort by using the existing current use scenario (run 8) datasets (DAT files) from the TCEQ WAM System. These water rights datasets (DAT files) did not exist when the original naturalized flow datasets (FLO files) were developed but of course are now readily available. A current use dataset is modified to model actual use during the period of the extension.

The methodology outlined here is based on using a current use *SIM* input dataset from the WAM System modified represent actual use to convert gaged stream flows to naturalized flows. The WAM System current use scenario is defined in Chapter 1. An actual use scenario dataset is a developed by modifying the current use DAT file to better represent actual water resources development, allocation, management, and use during the flow extension period. Flow adjustments are determined from the results of a *SIM* simulation with the actual use input dataset. Capabilities are incorporated in *HYD* for performing the flow adjustment computations necessary to implement this strategy. Iterative repetitions of the procedure are necessary since naturalized flows are required as input to the *SIM* simulation incorporated in development of naturalized flows.

Regulated flows are computed from a set of naturalized flows, but regulated flows are required for the flow adjustments (naturalized − regulated flows) used to determine the naturalized flows. Thus, an iterative procedure is required. An initial set of adjustments is developed based on an initial approximation of naturalized flows. These initial flow adjustments are used to convert gaged flows to naturalized flows, which are then used to develop a better estimate of flow adjustments. Estimates of naturalized flows are upgraded with each iterative repetition of the *SIM/HYD* computational procedure. Program *HYD* is used to perform the flow adjustment computations based on the results from a *SIM* simulation.

Overview of the Flow Extension Methodology

The general methodologies described in this chapter are applicable to all of the WAM datasets. The period-of-analysis shown in Table 1.1 varies between the different WAM System datasets. However, the Brazos WAM period-of-analysis of 1940-1997 is adopted in this chapter to refer to any period-of-analysis. The task addressed here is expressed as developing naturalized flows at the primary control points for the period January 1998 through December 2007.

The proposed procedure for extending a naturalized flow dataset to cover the period 1998-2007 at pertinent primary control points consists of combining two datasets.

- 1998-2007 sequences of monthly flows at pertinent gaging stations compiled from available USGS gage records of observed daily flows
- *SIM* input DAT file representing 1998-2007 actual water management and use developed based on modifying the TCEQ WAM System current use input dataset

The procedure consists of iteratively adjusting gaged flows at USGS gaging stations with the differences between naturalized (unregulated) flows and regulated flows from a *SIM* simulation with a modified current use dataset. An iterative procedure is required because naturalized flows are computed as a function of flow adjustments but the flow adjustments are computed as a function of naturalized flows. The repetitive procedure begins with a statistically based set of 1998-2007 naturalized flows determined from the 1940-1997 naturalized flows that serves the sole purpose of determining an initial estimate of flow adjustments which are later updated.

The *SIM* simulation with the modified current use DAT input file serves the sole purpose of computing regulated flows allowing the differences between naturalized and regulated flows to be computed for use as adjustments in converting gaged flows to naturalized flows. The accuracy of the procedure depends upon the accuracy of the flow differences rather the accuracy of the naturalized and regulated flows themselves.

Flow Adjustments

The procedure for extending a naturalized flow dataset to cover the period 1998-2007 at pertinent primary control points consists of converting monthly gaged flows to naturalized flows based on a set of adjustments. Program *HYD* computes naturalized flows by developing flow adjustments from the results of a *SIM* simulation and adding the adjustments to gaged flows as follows.

$$\text{naturalized flow} = \text{gaged flow} + \text{flow adjustment} \tag{2.1}$$

$$\begin{aligned}\text{flow adjustment} = {} & \text{naturalized flow} - \text{regulated flow} \\ & + \text{storage shortage} + \text{diversion shortage}\end{aligned} \tag{2.2}$$

Program *HYD* reads gaged flows from its FLO input file and writes naturalized flows to its FLO output file. The flow adjustment and naturalized flow in Equation 2.1 are computed by *HYD* by activating options defined by the *JC* and *AS* records in the *HYD* input HIN file. The naturalized flows, regulated flows, storage shortages, and diversion shortages in Equation 2.2 are read by *HYD* from a *SIM* simulation results OUT output file. The *SIM* simulation with an actual use DAT file models actual water resources development, allocation, management, and use during a 1998-2007 period-of-analysis. The naturalized flows in Equation 2.2 are read by *SIM* from its FLO input file.

The naturalized flow and regulated flow components of the Equation 2.2 flow adjustment are mandatory representing the basic adjustment that is always applied. The storage shortage and diversion shortage components of Equation 2.2 are optional. These adjustments for shortages may or may not be applied depending on the particular application. Flows may alternatively be adjusted based on Equation 2.3 which reflects a rearrangement of Equations 2.1 and 2.2 with the storage and diversion shortage components omitted.

$$\text{naturalized flow} = \text{naturalized flow} + \text{gaged flow} - \text{regulated flow} \tag{2.3}$$

The diversion shortages in Equation 2.2 represent failures to meet targets specified on *SIM* water *WR* and target series *TS* records and associated input records defining diversion right targets. The storage shortage component of the flow adjustment is the difference between the capacities defined by the *SIM* water right storage *WS* and observed storage *OS* records and the storage volumes computed by *SIM*. Actual observed end-of-month reservoir storage volumes occurring each month during the 1998-2007 period-of-analysis may be entered as *SIM* input on observed storage *OS* records. The *OS* record storage levels are capacities to which storage is refilled constrained by the availability of stream flow. If the initial estimates of naturalized flow entered in the original FLO input file are too small, the storage levels on the *OS* records will not be reached in the *SIM* simulation. This part of the storage draw-down is expressed as a shortage in Eq. 2.2.

Outline of Steps in the Flow Extension Procedure

The procedure includes the following tasks. The details of performing each task may vary with different situations reflected in the datasets for the different river basins. A general strategy is outlined that may be modified in various ways for particular river basins.

1. A set of 1998-2007 monthly net evaporation-precipitation depths are compiled for all pertinent control points that have reservoirs.

2. Available gaged daily flow data for 1998-2007 at gaging stations are compiled and aggregated to monthly flows. HEC-DSSVue may be used to assist with this task.

3. An actual use *SIM* input dataset is developed that has a 1998-2007 simulation period. The original current use water rights input dataset already approximates 1998-2007 conditions of water management and use but is modified to further improve the representation of actual 1998-2007 water management/use. Although the current use DAT file may be used with minimal or no modifications, the following adjustments will improve accuracy in better representing actual 1998-2007 water management and use.

   - The upstream-to-downstream natural priority option may be adopted to replace the permit priorities. This is a simple option switch in *SIM.*

   - Beginning of 1998-2007 simulation reservoir storage volumes are compiled as follows. A *SIM* execution of the modified dataset with the 1940-1997 hydrology results in end-of-simulation December 1997 storage volumes for all of the typically numerous reservoirs.

These amounts are used to set the beginning of January 1998 reservoir storage using the *SIM* beginning-ending reservoir storage (BES) option. For the larger reservoirs, available observations from gage records are used to replace the *SIM* simulated beginning of January 1998 storage volumes. These are the beginning-of-simulation reservoir storage volumes for the 1998-2007 *SIM* simulation DAT file.

- For larger reservoirs with readily available gaged sequences of 1998-2007 end-of-month storage volume observations, the actual storages for all 120 months of the 1998-2007 period-of-analysis can be incorporated into the *SIM* DAT file with observed storage *OS* records. Thus, the *SIM* simulation reproduces actual observed storage contents.

- Diversion targets and return flows in the DAT file are not changed for many of the water rights due to lack of data, the effort required to update, and minimal impact on final results. However, considering data availability, any number of the larger diversion targets and return flow specifications may be revised with actual 1998-2007 observations. Time series of diversions may be entered on *TS* records or, alternatively, representative water use practices may be modeled with *WR* and *UC* records and other supporting records.

- Other modifications may also be made to the DAT file dataset to more closely model actual 1998-2007 water management and use.

4. A FLO or DSS file with 1998-2007 naturalized flows is required for the *SIM* input dataset. However, 1998-2007 naturalized flows are the unknowns that the overall procedure is designed to compute. An initial set of 1998-2007 naturalized flows is developed as follows solely for use in developing the initial estimate of flow adjustments. Mean flows, median flows, or flows associated with a specified exceedance frequency could be adopted for each of the 12 months of the year. For example, the 75 percent exceedance frequency flows are reasonably likely flows on the conservatively low side of mean and median flows. Using the 1940-1997 naturalized flows at a particular control point, the flow volume that is equaled or exceeded in 75% of the 58 years is determined for each of the 12 months January through December. The resulting set of 12 naturalized flow volumes for January, February, through December are repeated for each of the ten years during 1998−2007.

5. The *SIM* simulation model is executed with the 1998-2007 period-of-analysis input dataset consisting of the DAT file developed in the preceding Task 3, EVA file from Task 2, and FLO file from Task 4. The objective is to simulate regulated flows that can be used to develop an initial estimate of flow adjustments consisting of naturalized (unregulated) flows minus regulated flows at the pertinent control points. Storage and diversion shortages determined by *HYD* from the *SIM* simulation results can also be included in the adjustments.

6. *HYD* reads the *SIM* output OUT file developed as Task 5 and the gaged flows from Task 2. 1998-2007 sequences of monthly naturalized flows are computed as follows.

    - Flow adjustments are computed by *HYD* based on Equation 2.2 using data from the results of the *SIM* simulation.

    - Naturalized flows are computed based on Equation 2.1 by adding the Equation 2.2 adjustments to the gaged flows read by *HYD* from another *HYD* input file.

7. The naturalized flows developed in Task 6 are approximate for the initial application of the procedure since the flow adjustments were determined from *SIM* simulation results based on an initial estimate of 1998-2007 naturalized flows developed as Task 4. Thus, the tasks 5 and 6 computations are repeated. The naturalized flows developed in Task 6 above are stored as a FLO or DSS file which replaces the *SIM* input FLO or DSS file used in Task 5. *SIM* is executed again. The procedure is repeated until the changes in the 1998-2007 naturalized flows resulting from subsequent iterations are negligible which also means that the simulated regulated flows reproduce the gaged observed flows.

The procedure results in either a FLO or DSS file containing the final set of 1998-2007 naturalized flows at the pertinent primary control points. Flow distribution methods using data from a DIS file may be applied within *SIM* and/or *HYD* to determine naturalized flows at numerous ungaged secondary control points based on the naturalized flows at the primary control points.

Example Illustrating Key *SIM* and *HYD* Features

Application of the flow extension procedure to the Brazos WAM is presented in subsequent chapters of this report. However, pertinent features of *SIM* and *HYD* are explored here with a simple hypothetical example prior to dealing with the complexities of the very large and complicated Brazos WAM. Examples 15 and 16 in Appendix C of the *WRAP Reference Manual* consist of computing naturalized flows given regulated flows from Example 2 of the *Reference Manual*. The same exercise is performed here using Example 4 from the *Reference Manual*.

The *WRAP-SIM* simulation model is designed to compute regulated stream flows for given naturalized flows input in a FLO file and information describing water resources development, allocation, management, and use provided in a DAT input file. The reverse problem of computing naturalized flows for given regulated flows is addressed here. Regulated flows represent actual flows if and only if the DAT file information represents actual water resources development, allocation, management, and use during each month of the simulation.

Example 16 was added to the August 2008 Fifth Edition of the *Reference Manual* to illustrate new features in *SIM* and *HYD* designed to support the flow extension methodology. Example 16 consists of computing the naturalized flows given the regulated flows of Example 2. The Example 16 dataset is very simple with two control points, one reservoir, two diversions, and one instream flow requirement. For this simple dataset, the iterative computational procedure converges to the correct computed naturalized flows in just two iterations regardless of the initially assumed values for the naturalized flows. If the naturalized flows are all initially assumed to be zero, the procedure yields the correct final naturalized flows in just one additional repetition after the initial simulation. Any other initial estimate of the naturalized flows yields the same results.

The following Example 2.1 consists of computing naturalized flows given the regulated flows from the simulation results and DAT input file information of Example 4 found on pages 244-250 of Appendix B of the *WRAP Reference Manual*. In Example 4, regulated flows are computed in the conventional manner, with naturalized flows provided in the input dataset. In the adaptation of Example 4 presented here, naturalized flows are computed given the regulated flows and water rights data from Example 4. The naturalized flows computed in this hypothetical example can be checked since the computed flows should be identical to the given naturalized flows in Example 4.

Example 2.1 presented below does not illustrate the flow extension procedure in its entirety and actually does not extend the period-of-analysis covered by the naturalized flows. Rather the objective of the example is to illustrate key computational capabilities of *SIM* and *HYD* that are the main central component of the flow extension procedure. The computational methodology illustrated here consists of computing naturalized flows that when combined with a particular DAT file dataset will result in known regulated flows representing actual flows during the period covered by the regulated flows and DAT file information.

Programs *HYD* and *SIM* are applied iteratively to compute naturalized flows, with *HYD* developing flow adjustments from the results of a *SIM* simulation and adding the adjustments to regulated flows. For this example, gaged flows are replaced with regulated flows converting Equation 2.1 to the revised Equation 2.1R as follows.

$$\text{naturalized flow} = \text{regulated flow} + \text{flow adjustment} \tag{2.1R}$$

$$\begin{aligned}\text{flow adjustment} = {} & \text{naturalized flow} - \text{regulated flow} \\ & + \text{storage shortage} + \text{diversion shortage}\end{aligned} \tag{2.2}$$

Flow adjustments and naturalized flows are computed with *HYD* by using options specified by the *JC* and *AS* records in the *HYD* input HIN file which are described in the *WRAP Users Manual*. The naturalized flows, regulated flows, storage shortages, and diversion shortages in Equation 2.2 are read by *HYD* from a *SIM* simulation results OUT output file.

Reference Manual Example 4 and this Example 2.1 adaptation thereof contains three primary control points, two secondary control points, two reservoirs, and seven water rights which are described on pages 244-247 of the *Reference Manual*. The system schematic is reproduced below as Figure 2.1. The period-of-analysis is 1996-1998. The problem addressed consists of computing naturalized flows at the three primary control points for each of the 36 months of the 1996-1998 period-of-analysis. Naturalized flows at the two secondary control points are computed based on flows at the primary control points using the flow distribution methods adopted in the original Example 4. The *WRAP-SIM* DAT, EVA, and DIS input files and *WRAP-HYD* HIN and FLO input files are reproduced on the following pages.

The DAT file for this example, which is reproduced as Table 2.1, consists of the *Reference Manual* Example 4 DAT file with the addition of target series *TS* and observed storage *OS* records. The purpose of the target series *TS* and observed storage *OS* records is to force the *SIM* simulation to maintain the original diversions and reservoir storage levels even though the initial and adjusted naturalized flows vary in each repetition of the procedure. The storages computed in Example 4 for the two reservoirs are entered on *OS* records. Since diversion shortages occur in Example 4 for water rights WR-1 and WR-3, target series *TS* records are used to reproduce the actual diversions. Diversions for water rights WR-4 and WR-5 are modeled in this example without *TS* records since no shortages occur in either Example 4 or Example 2.1.

The initial naturalized flows are arbitrarily set at zero. All flows are zeros in the initial *SIM* input FLO file used in the iterative procedure. The FLO file is revised for each repetition of the computations. The final flow file after 12 iterations is reproduced as Table 2.2 The *SIM* input DIS file (Table 2.3) and EVA file (Table 2.4) are adopted from Example 4 without modification. The DIS and EVA files do not change during the iterative computational procedure.

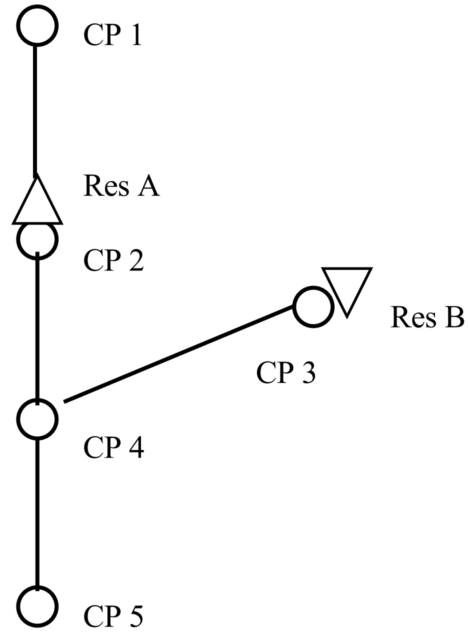

Figure 2.1 System Schematic for Examples 2.1 and 2.2

Program *HYD* is executed with HIN, FLO, and OUT input files. The *HYD* input HIN and FLO input files are reproduced as Tables 2.5 and 2.6. *HYD* computes naturalized flows by adjusting regulated flows from the FLO file based on data read from the OUT file. The adjustments are controlled by the *JC* and *AS* records from the HIN file as explained in Chapter 5 of the *WRAP Users Manual*. The *HYD* input FLO file contains the regulated flows from *Reference Manual* Example 4 that are being adjusted. The OUT file is generated with program *SIM* with filename Example.OUT and read by program *HYD* as an input file with the filename ExampleHYD.OUT. The HIN and FLO files are fixed as shown in Tables 2.5 and 2.6, and the OUT file changes with each iterative execution of *SIM*.

HYD creates an output file with the filename ExampleHYDOUT.FLO that contains the computed naturalized flows. The *HYD* output FLO file is converted to a *SIM* input FLO file by simply removing the header and changing the filename. A new FLO file is generated with each repetition of the procedure. The FLO output file created by the program *HYD* is switched to a FLO input file to be read by the Program *SIM* as the naturalized flows are adjusted in each repetition of the iterative *SIM/HYD* computational procedure.

Naturalized flows are computed for given regulated flows with water resources development, management, allocation, and use represented by the information provided by the DAT file. Since both naturalized and regulated flows are provided by *Reference Manual* Example 4, the results can be compared with the correct known naturalized flows. The iterative computational procedure consists of the following steps.

Step 1: The procedure begins with an assumed set of naturalized flows. Essentially any set of assumed naturalized flows will work for this example. However, zero was arbitrarily adopted as an initial estimate for the naturalized flows for all 36 months at the three primary control points. The naturalized flows are input to *SIM* as a FLO file.

Step 2: *SIM* is executed with input files Example.DAT, Example.FLO, Example.EVA, and Example.DIS which are shown in Tables 2.1, 2.2, 2.3, and 2.4.

Step 3: Naturalized flow, regulated flow, reservoir storage volume, and reservoir storage capacity (*OS* records) are read by *HYD* from the OUT file produced by *SIM*. *HYD* computes the flow adjustments for each of the 36 months at each of the three control points.

$$\text{flow adjustment} = \text{naturalized flow} - \text{regulated flow} \\ + \text{storage shortage} + \text{diversion shortage}$$

Step 4: Updated naturalized flows are computed by *HYD* by adding the flow adjustments defined by HIN file *AS* records (Table 2.5) to the Example 4 regulated flows provided in the file ExampleHYD.FLO (Table 2.6). *HYD* computes naturalized flows recorded in a file with filename ExampleHYDOUT.FLO. The naturalized flows in the *HYD* output FLO file are converted to a *SIM* input FLO file by removing the header and changing the filename.

Step 5: Steps 2, 3, and 4 are repeated with the updated estimate of naturalized flows. The procedure is repeated until the computed regulated flows exactly reproduce the known Example 4 regulated flows. Naturalized flows no longer change between iterations.

A set of naturalized flows at three primary control points covering a 36-month simulation period is developed in this example by applying programs *HYD* and *SIM* in combination. The procedure computes naturalized flows, but naturalized flows are required as input for the *SIM* simulation required by the procedure. Thus, an initial estimate of naturalized flows is developed somewhat arbitrarily to start the computational algorithm. These initially estimated flows are iteratively improved by the modeling algorithm.

The 36-month sequences of naturalized flows at the three primary control points resulting from seven repetitions of the procedure are tabulated in Tables 2.7, 2.8, and 2.9 along with the initial estimate and correct naturalized flows from Example 4. Seven consecutive updates of the computed naturalized flows are tabulated. Each iteration begins with the naturalized flows from the preceding iteration. If the procedure is initiated with the actual correct naturalized flows, the computed flows are these same correct naturalized flows. The naturalized flows were initially set at zero in the FLO file reproduced as Table 2.3. As shown in Tables 2.7, 2.8, and 2.9, the computed naturalized flows resulting from the first simulation with zero inflows are significantly different than the correct values. The procedure converges to the correct solution with subsequent iterations.

The correct values for naturalized flows from *Reference Manual* Example 4 are tabulated in the last column of Tables 2.7, 2.8, and 2.9. The correct computed naturalized flows are underlined in the tables in the column of the iteration in which the computed flow rounded to the nearest acre-foot was within one acre-foot of the precisely correct value shown in the last column. The computation procedure results in the values shown in Table 2.2 in 12 iterations which match the correct values. CP2, CP3, and CP5 included in the tables are the primary control points for which *IN* records are provided in the FLO file. The flows at the two secondary control points CP1 and CP4 are computed within *SIM* based on the flows at the primary control points CP2, CP3, and CP5.

Table 2.1

SIM Input DAT File for Example 2.1

```
T1  WRAP-SIM Input File Example1.DAT
T2  Flow Extension Example 2.1 Adapted from Example 4 of WRAP Reference Manual Appendix B
**
JD    3    1996       1      -1      -1
RO   -1
**
UC   mun    0.06    0.06    0.06    0.06    0.06    0.10    0.12    0.12    0.11    0.10    0.09    0.06
UC   irr    0.00    0.00    0.00    0.00    0.20    0.30    0.30    0.20    0.00    0.00    0.00    0.00
**
CP  CP-1    CP-2                      4            NONE
CP  CP-2    CP-4        0.083333      0                             0.10
CP  CP-3    CP-4                      0            CP-2             0.12
CP  CP-4    CP-5                      6            NONE             0.15
CP  CP-5     OUT                      0            NONE
**
WR  CP-1    1200     irr    1965             0.2                             WR-1
TS          1996    0.00    0.00    0.00    0.00  240.00    0.00    0.00  240.00    0.00    0.00    0.00
TS          1997    0.00    0.00    0.00    0.00  240.00  169.93    0.00    0.00    0.00    0.00    0.00
TS          1998    0.00    0.00    0.00    0.00   240.00   0.00  339.87    0.00    0.00    0.00    0.00
**
WR  CP-2                    9999                                    WR-2
WS Res A   80000
**
WR  CP-3             irr    1975             0.1                    WR-3
TS          1996     0.0     0.0     0.0     0.0  8400.0 12600.0 12600.0  8400.0     0.0     0.0     0.0
TS          1997     0.0     0.0     0.0     0.0  8400.0 12600.0 11831.2   884.5     0.0     0.0     0.0
TS          1998     0.0     0.0     0.0     0.0  8400.0 12600.0  6505.5   769.9     0.0     0.0     0.0
WS Res B   30000
**
WR  CP-3                    8888                                    WR-4
WS Res B   40000
**
WR  CP-4   26000     mun    1984   2        0.35                2  WR-5
WS Res A   80000
**
WR  CP-5   18000     mun    1952   2                            2  WR-6
WS Res A   80000
**
IF  CP-5   12000               0               1   WR-7
**
SV Res A       0     825    2980    8640   22100   42700   73700   89600
SA             0     112     327     920    1760    2480    3750    4930
SV Res B       0     740    2680    7780   19800   38400   52900
SA             0     100     298     832    1580    2230    2690
**
DI    1       -1
IS    5        0   60000  108000  108001  120000
IP            50     100     100     120     120
**
DI    2        1   Res A
IS    4        0   20000   20001  800000
IP            80      80     100     100
**
OS Res A  80000.  80000.  80000.  80000.  80000.  78101.  73855.  73253.  80000.  78030.  76572.  80000.
OS  1997  80000.  80000.  80000.  80000.  80000.  78640.  74234.  68113.  63473.  62010.  66667.  71635.
OS  1998  78377.  80000.  80000.  80000.  80000.  78814.  75835.  72838.  80000.  80000.  80000.  80000.
OS Res B  40000.  40000.  40000.  40000.  36736.  24576.  12551.   6022.  10520.  11272.  11980.  15181.
OS  1997  17080.  21184.  25641.  28128.  23802.  11990.    898.    291.   1286.   3480.   8303.  11286.
OS  1998  14825.  18125.  20507.  23203.  18439.   6514.    764.    846.   4759.   8865.  12237.  14918.
ED
```

Table 2.2
Final *SIM* Input FLO File After 12 Iterations

```
**  Final Example1.FLO file created by program HYD as output file Example1HYD.FLO after 12th iteration.
**  Naturalized flows in acre-feet/month
**
IN  CP-2    1996 10800.0 12500.0  8100.0  7620.0  9610.0  1199.4   850.5  2539.3  9520.6  1849.2  1760.2  7200.6
IN  CP-3    1996  5200.0  6280.0  3750.0  3970.0  4449.6   750.2  1090.2  2159.7  4669.9   914.5   850.8  3489.3
IN  CP-5    1996 19400.0 24600.0 14200.0 15200.0 18399.6  2639.7  2290.6  6239.3 21800.4  3779.0  3720.8 13900.0
IN  CP-2    1997  6250.1  8140.0  4190.0  7280.0  6930.0  1389.2   725.3   544.7   943.1  1890.5  4910.0  5740.1
IN  CP-3    1997  2180.6  4319.3  3760.3  2349.9  3759.8   870.1   915.7   295.6  1020.2  2250.0  4869.7  3190.4
IN  CP-5    1997 11200.5 17799.5 10620.2 14500.0 15399.9  2929.5  1910.8  1290.1  2301.6  5190.8 12800.4 13700.4
IN  CP-2    1998  7680.0  6590.8  5570.0  5230.0  6180.0  1279.9  1669.9  1050.0  7890.2  8670.0  6210.0  5360.0
IN  CP-3    1998  3819.4  3540.3  2189.5  2310.6  3290.0   656.7   845.7   839.5  3970.4  4229.8  3539.4  2869.9
IN  CP-5    1998 15399.5 13900.8 18299.6  9780.5 12600.0  2559.7  3420.4  2649.6 15400.5 17399.8 12699.5 11799.9
```

Table 2.3
SIM Input DIS File for Example 2.1

```
**  SIM Input File Example.DIS
**  Flow Distribution Information
FD  CP-4    CP-5       2    CP-2    CP-3
FD  CP-1    CP-2
WP  CP-1     225      74      31
WP  CP-2     398      69      31
WP  CP-3     194
WP  CP-4     650
WP  CP-5     715
ED
```

Table 2.4
SIM Input EVA File for Example 2.1

```
**   SIM Input File Example1.EVA
**   Net Evaporation-Precipitation (inches/month)
EV  CP-2    1996     3.2     2.8     3.1    -1.6    -3.7     1.9     4.3     3.9     2.5     1.9     1.6     2.9
EV  CP-2    1997     2.5     1.7    -4.9    -0.9    -2.1     0.7     3.5     2.8     3.1     2.5     0.9     2.6
EV  CP-2    1998     2.9     2.1    -1.5    -2.8    -2.6    -0.2     2.7    -1.4     2.2     2.1     2.0     1.9
```

Table 2.5
HYD Input FLO File with Regulated Flows for Example 2.1

```
**  HYD Input File ExampleHYD.FLO
**  Example 2.1 Regulated Flows (acre-feet) from Reference Manual Example 4
**
IN  CP-2    1996  9675.3 11515.9  7010.5  8182.3 10718.4  2441.8  3692.2  1731.7  1945.6  3163.0  2682.6  2784.1
IN  CP-3    1996  4591.8  5747.8  3160.8  4274.1     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
IN  CP-4    1996  1270.6  1270.6  1270.6  1270.6  2110.6  3294.1  3717.7  3032.9  2329.4  2117.7  1905.9  1270.6
IN  CP-5    1996 16224.7 21589.1 11065.8 13997.7 14773.3  1000.0  1000.0  1000.0  9102.4  1000.0  1000.0  6051.3
IN  CP-2    1997  5371.4  7542.5  5912.2  7596.3  7476.1  2370.1  3978.3  5812.8  4697.5  2665.2     0.0     0.0
IN  CP-3    1997     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
IN  CP-4    1997  1270.6  1016.5  1016.5  1016.5  1694.1  2032.9   94.96     0.0     0.0     0.0     0.0     0.0
IN  CP-5    1997  7037.2 12251.6  7265.0 11124.2 11859.3  1000.0  1000.0  1453.7  1000.0  1000.0  2611.1  5062.8
IN  CP-2    1998     0.0  4240.3  6097.2  6214.1  6901.8  2535.5  3472.7  4491.7     1.1  7931.9  5507.1  4692.2
IN  CP-3    1998     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
IN  CP-4    1998     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
IN  CP-5    1998  4807.4  7594.5 15205.2  6945.0  9545.3  1000.0  1000.0  1000.0  2985.4 10571.3  6724.3  7282.4
```

Table 2.6
HYD Input HIN File for Example 2.1

```
**  WRAP-HYD Input File ExampleHYD.HIN
**
**       1         2         3         4         5         6         7
**3456789012345678901234567890123456789012345678901234567890123456789012
**     !       !       !       !       !       !       !       !       !
JC  1996   3   1   1   0   1   0   0   1   0   1
**
CP  CP-2    CP-4        0.083333       0                               0.10
CP  CP-3    CP-4                       0            CP-2               0.12
CP  CP-4    CP-5                   1   0            NONE               0.15
CP  CP-5     OUT                       0            NONE
**     !       !       !       !       !       !       !       !       !
AS  CP-2                       5   1   0   1   0     1.0
AS  CP-2                       5   2   0   1   0    -1.0
AS  CP-2                       5  14   0   0   0     1.0         Res A
AS  CP-2                       5   8   0   0   0     1.0
AS  CP-3                       5   1   0   1   0     1.0
AS  CP-3                       5   2   0   1   0    -1.0
AS  CP-3                       5  14   0   0   0     1.0         Res B
AS  CP-3                       5   8   0   0   0     1.0
AS  CP-5                       5   1   0   1   0     1.0
AS  CP-5                       5   2   0   1   0    -1.0
AS  CP-5                       5  14   0   0   0     1.0         Res A
AS  CP-5                       5   8   0   0   0     1.0
ED
```

The first iteration starting with zero flows resulted in the flows listed in the column headed by the numeral one in Tables 2.7, 2.8, and 2.9. None of the flows are correct after this first simulation. The second iteration began with the naturalized flows listed in the column with the heading 1 and resulted in the naturalized flows listed in the column with the heading 2. The flows at control point CP3 are correct for all 36 months in the second iteration and all subsequent iterations. At control points CP2 and CP5, the naturalized flows computed in the second iteration are correct for 24 of the 36 months. The flows at control points CP2 and CP5 are correct for most but not all months by the seventh iteration which is the last iteration included in the tables. After twelve iterations, all computed flows for all months at all control points match the correct naturalized flows shown in the last column of Tables 2.7, 2.8, and 2.9. The final adopted flows are in Table 2.2.

In an actual application of the computational procedure illustrated by this example, the objective would normally be to estimate naturalized flows corresponding to observed gaged flows. The objective is to find a set of naturalized stream flows that closely reproduce actual observed flows at gaging stations when combined with an actual use DAT file in a *SIM* simulation. The iterations are continued until simulated regulated flows closely match gaged observed flows, in which case the naturalized flows will no longer been changing with additional iterations.

In the Brazos WAM investigation covered by subsequent chapters of this report, the 1940-1997 period-of-of analysis is extended through 1998-2007. Thus, the actual use *SIM* input DAT file represents actual 1998-2007 water resources development, allocation, management, and use.

Table 2.7
Naturalized Flows at Control Point CP2 in Example 2.1

		Naturalized Flows at CP2 (acre-feet/month)								
Year	M	Initial	1	2	3	4	5	6	7	Correct
1996	1	0	10,758	10,800	10,800	10,800	10,800	10,800	10,800	10,800
1996	2	0	16,627	12,500	12,500	12,500	12,500	12,500	12,500	12,500
1996	3	0	16,194	8,100	8,100	8,100	8,100	8,100	8,100	8,100
1996	4	0	20,051	7,620	7,620	7,620	7,620	7,620	7,620	7,620
1996	5	0	24,699	9,610	9,610	9,610	9,610	9,610	9,610	9,610
1996	6	0	18,174	2,442	1,199	1,198	1,199	1,198	1,199	1,200
1996	7	0	21,376	3,692	2,265	1,626	1,264	1,107	851	850
1996	8	0	25,866	2,539	2,539	2,539	2,539	2,539	2,539	2,540
1996	9	0	39,612	9,521	9,521	9,521	9,521	9,521	9,521	9,520
1996	10	0	44,969	3,163	1,974	1,849	1,849	1,849	1,849	1,850
1996	11	0	48,537	2,683	1,760	1,760	1,760	1,760	1,760	1,760
1996	12	0	57,227	7,201	7,201	7,201	7,201	7,201	7,201	7,200
1997	1	0	63,306	6,250	6,250	6,250	6,250	6,250	6,250	6,250
1997	2	0	68,832	8,140	8,140	8,140	8,140	8,140	8,140	8,140
1997	3	0	69,175	4,190	4,190	4,190	4,190	4,190	4,190	4,190
1997	4	0	73,285	7,280	7,280	7,280	7,280	7,280	7,280	7,280
1997	5	0	75,498	6,930	6,930	6,930	6,930	6,930	6,930	6,930
1997	6	0	71,593	2,506	1,389	1,389	1,388	1,388	1,387	1,390
1997	7	0	73,073	3,978	2,551	1,826	1,294	762	725	725
1997	8	0	73,820	5,813	4,979	4,144	3,310	2,476	1,930	545
1997	9	0	68,171	4,698	3,389	2,081	1,520	1,209	943	942
1997	10	0	64,675	2,665	1,890	1,890	1,890	1,890	1,890	1,890
1997	11	0	66,667	4,910	4,910	4,910	4,910	4,910	4,910	4,910
1997	12	0	71,635	5,740	5,740	5,740	5,740	5,740	5,740	5,740
1998	1	0	78,377	7,680	7,680	7,680	7,680	7,680	7,680	7,680
1998	2	0	84,240	6,591	6,591	6,591	6,591	6,591	6,591	6,590
1998	3	0	86,097	5,570	5,570	5,570	5,570	5,570	5,570	5,570
1998	4	0	86,214	5,230	5,230	5,230	5,230	5,230	5,230	5,230
1998	5	0	86,902	6,180	6,180	6,180	6,180	6,180	6,180	6,180
1998	6	0	81,350	2,536	1,346	1,280	1,280	1,280	1,280	1,280
1998	7	0	79,308	3,745	2,317	1,670	1,670	1,670	1,670	1,670
1998	8	0	77,330	4,492	3,064	1,637	1,050	1,050	1,050	1,050
1998	9	0	80,001	7,890	7,890	7,890	7,890	7,890	7,890	7,890
1998	10	0	87,932	8,670	8,670	8,670	8,670	8,670	8,670	8,670
1998	11	0	85,507	6,210	6,210	6,210	6,210	6,210	6,210	6,210
1998	12	0	84,692	5,360	5,360	5,360	5,360	5,360	5,360	5,360

In the Brazos WAM study presented in this report, larger reservoirs are modeled with observed storage *OS* records, but observed storage levels are not available for numerous smaller reservoirs. Since actual diversions are mainly unknown, *TS* records can not be used to force the *SIM* simulation to closely reproduce actual water use as in this example. However, *HYD* flow adjustments are included for both storage shortage and diversion shortages at the larger reservoirs. Starting the procedure with reasonable initial estimates of naturalized flows is more important for the Brazos WAM than for the simple hypothetical example presented in this section which simply began with zero flows for all months at all control points.

Table 2.8
Naturalized Flows at Control Point CP3 in Example 2.1

		Naturalized Flows at CP3 (acre-feet/month)								
Year	M	Initial	1	2	3	4	5	6	7	Correct
1996	1	0	5,197	5,200	5,200	5,200	5,200	5,200	5,200	5,200
1996	2	0	6,879	6,280	6,280	6,280	6,280	6,280	6,280	6,280
1996	3	0	4,870	3,750	3,750	3,750	3,750	3,750	3,750	3,750
1996	4	0	5,686	3,970	3,970	3,970	3,970	3,970	3,970	3,970
1996	5	0	5,900	4,450	4,450	4,450	4,450	4,450	4,450	4,450
1996	6	0	6,611	750	750	750	750	750	750	750
1996	7	0	7,546	1,090	1,090	1,090	1,090	1,090	1,090	1,090
1996	8	0	9,505	2,160	2,160	2,160	2,160	2,160	2,160	2,160
1996	9	0	10,520	4,670	4,670	4,670	4,670	4,670	4,670	4,670
1996	10	0	11,272	914	915	914	915	915	915	915
1996	11	0	11,980	851	851	851	851	851	851	850
1996	12	0	15,181	3,489	3,490	3,489	3,489	3,489	3,489	3,490
1997	1	0	17,080	2,181	2,181	2,181	2,181	2,181	2,181	2,180
1997	2	0	21,184	4,319	4,320	4,319	4,319	4,319	4,319	4,320
1997	3	0	25,641	3,760	3,761	3,760	3,760	3,760	3,760	3,760
1997	4	0	28,128	2,350	2,350	2,350	2,350	2,350	2,350	2,350
1997	5	0	32,202	3,760	3,760	3,760	3,760	3,760	3,760	3,760
1997	6	0	24,590	870	870	870	870	870	870	870
1997	7	0	12,729	916	916	916	916	916	916	915
1997	8	0	1,176	296	296	296	296	296	296	296
1997	9	0	1,286	1,020	1,020	1,020	1,020	1,020	1,020	1,020
1997	10	0	3,480	2,250	2,250	2,250	2,250	2,250	2,250	2,250
1997	11	0	8,303	4,870	4,870	4,870	4,870	4,870	4,870	4,870
1997	12	0	11,286	3,190	3,191	3,190	3,190	3,190	3,190	3,190
1998	1	0	14,825	3,819	3,820	3,819	3,819	3,819	3,819	3,820
1998	2	0	18,125	3,540	3,541	3,540	3,540	3,540	3,540	3,540
1998	3	0	20,507	2,190	2,190	2,190	2,190	2,190	2,190	2,190
1998	4	0	23,203	2,311	2,311	2,311	2,311	2,311	2,311	2,310
1998	5	0	26,839	3,290	3,290	3,290	3,290	3,290	3,290	3,290
1998	6	0	19,114	657	657	657	657	657	657	657
1998	7	0	7,270	846	846	846	846	846	846	845
1998	8	0	1,616	840	840	840	840	840	840	840
1998	9	0	4,759	3,970	3,971	3,970	3,970	3,970	3,970	3,970
1998	10	0	8,865	4,230	4,230	4,230	4,230	4,230	4,230	4,230
1998	11	0	12,237	3,539	3,540	3,539	3,539	3,539	3,539	3,540
1998	12	0	14,918	2,870	2,870	2,870	2,870	2,870	2,870	2,870

Table 2.9
Naturalized Flows at Control Point CP5 in Example 2.1

			Naturalized Flows at CP5 (acre-feet/month)							
Year	M	Initial	1	2	3	4	5	6	7	Correct
1996	1	0	23,594	19,400	19,400	19,400	19,400	19,400	19,400	19,400
1996	2	0	36,462	24,600	24,600	24,600	24,600	24,600	24,600	24,600
1996	3	0	33,557	14,200	14,200	14,200	14,200	14,200	14,200	14,200
1996	4	0	41,006	15,200	15,200	15,200	15,200	15,200	15,200	15,200
1996	5	0	48,153	18,400	18,400	18,400	18,400	18,400	18,400	18,400
1996	6	0	40,890	3,590	2,640	2,898	2,640	2,899	2,640	2,640
1996	7	0	46,702	4,465	3,373	2,884	2,607	2,487	2,291	2,290
1996	8	0	60,299	6,239	6,239	6,239	6,239	6,239	6,239	6,240
1996	9	0	92,629	21,800	21,801	21,800	21,800	21,800	21,800	21,800
1996	10	0	91,560	4,784	3,874	3,779	3,779	3,779	3,779	3,780
1996	11	0	98,401	4,426	3,721	3,721	3,721	3,721	3,721	3,720
1996	12	0	118,503	13,900	13,900	13,900	13,900	13,900	13,900	13,900
1997	1	0	127,073	11,201	11,201	11,201	11,201	11,200	11,201	11,200
1997	2	0	140,277	17,800	17,800	17,800	17,800	17,800	17,800	17,800
1997	3	0	142,107	10,620	10,620	10,620	10,620	10,620	10,620	10,620
1997	4	0	152,109	14,500	14,500	14,500	14,500	14,500	14,500	14,500
1997	5	0	160,010	15,400	15,400	15,400	15,400	15,400	15,400	15,400
1997	6	0	148,246	3,784	2,930	2,929	2,929	2,928	2,928	2,930
1997	7	0	140,482	4,399	3,307	2,753	2,346	1,939	1,911	1,910
1997	8	0	124,200	5,320	4,682	4,043	3,405	2,767	2,349	1,290
1997	9	0	115,576	5,173	4,172	3,171	2,742	2,504	2,301	2,300
1997	10	0	114,491	5,783	5,190	5,190	5,190	5,190	5,190	5,190
1997	11	0	127,785	12,799	12,800	12,799	12,799	12,799	12,799	12,800
1997	12	0	140,805	13,700	13,701	13,700	13,700	13,700	13,700	13,700
1998	1	0	155,096	15,400	15,400	15,400	15,400	15,400	15,400	15,400
1998	2	0	163,216	13,901	13,901	13,901	13,901	13,901	13,901	13,900
1998	3	0	172,608	18,300	18,300	18,300	18,300	18,300	18,300	18,300
1998	4	0	166,365	9,781	9,781	9,781	9,781	9,781	9,781	9,780
1998	5	0	171,685	12,600	12,600	12,600	12,600	12,600	12,600	12,600
1998	6	0	155,844	3,520	2,610	2,560	2,560	2,560	2,560	2,560
1998	7	0	142,014	5,008	3,916	3,421	3,420	3,421	3,420	3,420
1998	8	0	132,496	5,283	4,191	3,099	2,650	2,650	2,650	2,650
1998	9	0	149,329	15,401	15,401	15,401	15,401	15,401	15,401	15,400
1998	10	0	159,842	17,400	17,400	17,400	17,400	17,400	17,400	17,400
1998	11	0	158,374	12,700	12,700	12,700	12,700	12,700	12,700	12,700
1998	12	0	160,505	11,800	11,800	11,800	11,800	11,800	11,800	11,800

Unlike this example, known 1998-2007 naturalized flows are not available for the Brazos River Basin for comparison with the naturalized flows computed by the flow extension procedure. However, the procedure develops a set of naturalized flows that closely reproduce the gaged flows when combined within the *SIM* simulation with the actual use DAT file information. The match between simulated regulated flows and observed gage flows provide the criterion for stopping the iterations. With an exact match between simulated regulated flows and observed gaged flows, naturalized flows no longer change with further repetitions in the iterative naturalized flow adjustment procedure.

Summary of the Methodology for Updating the Period-of-Analysis

The purpose of the flow extension procedures addressed by this report is to lengthen the following two *SIM* hydrology input files by extending the period-of-analysis covered by the data.

- EVA file containing sequences of monthly reservoir surface evaporation less precipitation depths
- FLO file containing sequences of monthly naturalized stream flows

Updating of the EVA file consists of compiling evaporation and precipitation rates and subtracting precipitation rates from evaporation rates. Updating of the FLO file consists of compiling observed monthly stream flow volumes derived from measurements at stream gaging stations and adjusting these data to remove the effects of human water resources development, management, and use. The conversion of gaged flows to naturalized flows requires significant information and effort. The updated EVA file is a part of the information used in developing the updated FLO file.

EVA files in the WAM System datasets can be extended in essentially the same manner as the files were originally developed. However, the proposed new methodology for updating FLO files is based on the concept of reducing amount of work required by using the information already now available in the WAM System. An actual use DAT file is developed by modifying the current use (run 8) scenario water rights DAT file to develop flow adjustments for converting gaged flows to naturalized flows.

A current use DAT file can be modified in various ways to better represent actual water resources development, allocation, management, and use during each month of the period-of-analysis extension (such as 1998-2007). The objective is to convert a current use scenario dataset to an actual use dataset applicable to the extended portion (for example 1998-2007) of the period-of-analysis. The effort required to update the WAM datasets depends largely upon the detail to which the current use DAT file is refined and improved.

The actual use *SIM* simulation input dataset with a 1998-2007 simulation period requires 1998-2007 sequences of monthly naturalized flows. However, the 1998-2007 naturalized flows are not known. Computation of these unknown naturalized flows is the sole reason for the flow extension procedure. Therefore, an initial estimate of the 1998-2007 naturalized flows must be developed and then iteratively replaced as the computational methodology proceeds. Various approaches could be adopted for determining an initially estimated set of 1998-2007 naturalized flows. The strategy adopted for the Brazos WAM investigation was to develop the initial estimate of 1998-2007 naturalized flows based on frequency statistics of the 1940-1997 naturalized flows. For each of the 12 months of the year, the flow volume that is equaled or exceeded during 75 percent of the 58 years of the 1940-1997 hydrologic period-of-analysis was adopted as being reasonable though essentially arbitrary. The final results were found to not be very sensitive to the initially estimated values for the naturalized flows.

The sole purpose of the *SIM* simulation with an actual use input dataset with the 1998-2007 simulation period is to develop sequences of regulated flows, storage draw-downs, and diversion shortages for use by *HYD* in developing flow adjustments. The flow adjustments are computed as the difference between regulated flows and naturalized flows. Storage draw-down shortages and diversion shortages, appropriately cascaded downstream while accounting for channel losses, may also be included in the adjustments. These computed flow adjustments are then added to the observed flows to determine naturalized flows. The initial estimate of naturalized flows in the FLO file is replaced with the improved estimate of naturalized flows, and the *SIM* simulation is repeated. The next cycle of flow adjustments results in a revised set of naturalized flows.

The concept is to iteratively search for a set of naturalized stream flows that, when input to a *SIM* simulation along with an actual use DAT file, result in computed regulated flows that closely reproduce actual observed gaged flows. The iterative procedure is repeated until regulated flows computed by *SIM* closely match observed flows, in which case further changes in naturalized flows with additional repetitions of the computational procedure are negligible.

Backward Extension of the Hydrologic Period-of-Analysis

The Brazos WAM hydrologic period-of-analysis has also been extended backward to cover 1900-1939 as described in Chapter 5. The extended *SIM* input dataset includes naturalized monthly river flows extending from January 1900 through December 2007 at 77 primary control points which are distributed to the numerous secondary control points within the simulation model. Mean 1940-1997 reservoir surface net evaporation less precipitation rates for each of the 12 months of the year are adopted for the years from 1900 through 1939. Sequences of 1940-1939 naturalized stream flows were developed by transferring the flows at 20 gaging stations compiled in the previous study referenced below to the other Brazos WAM primary control points.

Wurbs, Bergman, Carriere, and Walls (1988) document a water availability modeling study for the Brazos River Basin which included developing 1900-1984 sequences of naturalized monthly flows at 20 U.S. Geological Survey (USGS) stream gaging stations based on data recorded at 24 stations. Ten of the gages have records extending back to 1924 or before. The USGS gage on the Brazos River near the City of Waco has a continuously record dating back to October 1898. Gages on the Brazos River at Richmond and Bryan have records beginning in 1899 and 1903, respectively, but also have periods of missing data. The gage on the Little River at Cameron has continuous recorded monthly flows dating back to November 1916. The observed monthly flows at 24 selected gaging stations were converted to unregulated flows in the 1988 investigation by adjusting for the storage and evaporation effects of 21 major reservoirs and diversions associated with two canal systems. The reservoir with the earliest storage record dates back to January 1936. Regression analyses with the Monthly Streamflow Synthesis (MOSS-IV) computer model were applied to fill in missing data as necessary to develop complete 1900-1984 sequences of unregulated flows at 20 gaging stations. The 1900-1939 portions of these sequences were adopted for the present study.

From a basin-wide perspective with hundreds of scattered model control points of concern, the naturalized stream flows for the earlier years of the 1900-1939 period-of-extension are significantly less accurate than 1940-2007 flows due to the small number of stream gaging stations in operation during the earlier years. However, the process of converting gaged flows to naturalized flows is much simpler and more accurate for 1900-1939 because the impacts on stream flows of water resources development and use were much less during this time period than later years. Essentially all of the major reservoir projects in Texas were constructed after 1939. Most population growth with its associated impacts on water resources development and use has occurred after 1939. Natural flows are essentially the same as regulated flows during 1900-1939. The primary task in extending the Brazos WAM hydrologic period-of-analysis to include 1900-1939 is developing flows at ungaged sites.

Development of a Condensed Dataset Modeling Management of a Particular Reservoir System

The WAM System datasets for the larger river basins of the state contain numerous water rights, reservoirs, and control points. These voluminous datasets are necessary to support administration of the water rights permit system by the TCEQ and the planning studies conducted by the TWDB and regional planning groups. The datasets are necessarily large to serve the original purposes for which the WAM System was developed. However, the modeling system is being applied for a growing range of different types of applications. Condensed datasets are advantageous for certain types of applications. A condensed model may be formulated that focuses on operation of a particular water management system to supply certain water users while protecting the priority-based rights of numerous other water users.

Overview of the Dataset Simplification Methodology

A methodology is presented here for reducing the number of control points, water rights, and reservoirs in a WAM dataset and thus simplifying the modeling system for certain applications. Selected water rights, control points, and reservoirs are removed with their effects incorporated in the stream inflow input data for the condensed dataset. A *SIM* water rights DAT file for the particular river/reservoir water management and use system of interest, called the primary system, is developed along with a FLO file containing river system inflows that have been adjusted to reflect all other water rights in the original full dataset which are referred to as secondary water rights.

The Brazos WAM authorized use dataset described in Chapter 3 contains 1,634 water right *WR* records, 122 instream flow *IF* records, 670 reservoirs, and 3,830 control points. The Brazos WAM current use dataset is slightly larger. Naturalized flows are input on inflow *IN* records in a FLO file for 77 primary control points and distributed within *SIM* to the other ungaged secondary control points as specified by 3,138 flow distribution *FD* records in a DIS file. The size of the datasets are dramatically reduced in developing the condensed authorized and current use datasets described in Chapters 8 and 9. The condensed datasets designed to focus on operation of the Brazos River Authority (BRA) reservoir system include the 15 largest reservoirs in the river basin and associated water rights. The 15 reservoirs include one proposed and 12 existing BRA reservoirs and 2 other reservoirs. The condensed dataset has 48 control points as compared to 3,380 control points in the complete WAM dataset. The condensed dataset has no DIS file. The impacts of the over 650 reservoirs and numerous water rights removed from the Brazos WAM dataset are reflected in the *IN* record river flows developed for the condensed *SIM* input dataset.

The objective is to develop a *SIM* input dataset for studying or providing decision support for a particular system, which in this case is the Brazos River Authority system. The reason for developing the greatly condensed dataset for the BRA system is simply that input datasets and corresponding simulation results with dramatically fewer control points, water rights, and reservoirs are much more manageable to use in modeling studies. The authorized and current use versions of the condensed dataset described in Chapters 8 and 9 each consists of the following *SIM* input files.

- DAT file with water rights and related information for 15 reservoirs (authorized use scenario) or 14 reservoirs (current use scenario) and associated water supply diversions.

- FLO or DSS files with 1940-2007 and alternative 1900-2007 sets of monthly flows at 48 control points representing conditions of river system development that includes all of the water rights and associated reservoirs in the original complete DAT file except the 15 reservoirs and associated diversions contained in the condensed DAT file.

- EVA files with 1940-2007 and alternative 1900-2007 sets of monthly net evaporation-precipitation depths for the 15 control points at which the 15 reservoirs are located.

The condensed dataset should adopt the same net evaporation-precipitation depths for the 15 reservoirs as used in the original complete dataset *SIM* simulation. *SIM* includes an option for adjusting net evaporation-precipitation depths for the precipitation runoff from the portion of the watershed covered by the reservoir. In this case, net evaporation-precipitation depths should be obtained from the OUT file for the complete simulation rather than using the original evaporation-precipitation depth input dataset.

The accuracy achieved in the development of a condensed dataset is checked by comparing simulation results with the original complete dataset. The monthly diversion amounts and reliabilities computed for the diversions included in the condensed dataset should be the same as in the simulation with the original complete dataset. Likewise, the sequences of monthly storage volumes at the common reservoirs and unappropriated stream flows at the common control points will be the same. Near perfect correspondence between simulation results with the condensed versus complete datasets should be expected.

The *SIM* input data vary as follows between the original Brazos WAM and condensed BRA system datasets. Numbers for the authorized use scenario original and condensed datasets are noted below, but are similar though a little different for the current use versions of the two datasets.

- In the original complete input dataset, the stream flows at the 77 primary control points provided on inflow *IN* records in a FLO file are naturalized flows representing river basin hydrology under natural conditions with no reservoirs and no diversions. The DAT input file contains 3,830 control points, 1,634 *WR* record water rights, 122 *IF* record instream flow rights, and 670 reservoirs. The DIS file contains 3,138 flow distribution *FD* records and associated watershed parameter *WP* records used to distribute flows to the 3,753 secondary control points.

- In the condensed input dataset, the stream flows at the 48 primary control points provided on the FLO file *IN* records represent conditions with the 655 reservoirs and numerous water rights that were removed from the DAT file being in operation but without the others that remain in the DAT file. The DAT input file contains 48 control points, 15 reservoirs, and associated water rights. Channel loss factors are aggregated for the fewer but longer reaches between control points. There is no DIS file.

The methodology for developing a condensed dataset is based on developing flows at the selected control points that represent stream inflow amounts available to the selected system that reflect the impacts of all of the water rights and accompanying reservoirs removed from the original complete dataset. River flows are either provided on *IN* records in a FLO input file or as DSS records in a hydrology input DSS file for the condensed dataset. These stream flows represent flows available to the selected system modeled in the water right DAT input file considering the effects of all the other water rights in the river basin contained in the original complete DAT file that are not included in the condensed DAT file.

The river system inflows input on *IN* records in a FLO file or DSS records in a DSS file for the condensed dataset include stream flow depletions made for the selected water rights less return flows plus unappropriated flows. Hydropower releases and reservoir releases made specifically to meet instream flow requirements are also appropriately incorporated in the flows. Summation and cascading operations are applied in developing the stream flow input data.

Outline of Methodology for Developing Hydrology Files for Condensed Dataset

The methodology for developing the sequences of monthly stream flow volumes and net evaporation-precipitation depths (FLO and EVA files or DSS file) for the condensed dataset is outlined as follows.

1. *SIM* is executed with the original complete dataset.

2. *HYD* is used to retrieve the adjusted net evaporation-precipitation depths from the *SIM* output OUT file and store them in a EVA or DSS input file for the condensed dataset.

3. *HYD* is applied to read pertinent stream flow depletions, return flows, unappropriated flows, and any other pertinent variables from the *SIM* output OUT file and combine these variables as required to develop the stream flow FLO or DSS input file for the condensed dataset. Combining the time sequences of flow volumes includes summations and cascading operations that may include channel losses. *HYD* reads the necessary control point information from an input file. Options are also provided in *HYD* for dealing with the issue of computed flows being negative numbers.

Referring again to the Brazos River Authority (BRA) system dataset, river flows developed for the 48 control points consist of the following 1940-2007 or 1900-2007 sequences of monthly volumes of the following variables obtained from the OUT file created by *SIM* with the original complete input dataset. The computations can be performed with *HYD*.

- Stream flow depletions made by each of the water rights associated with the 15 reservoirs are included in the flows being developed. These flow volumes are placed at the control point of the stream flow depletion and at all downstream control points. Channel losses are considered in cascading the stream flow depletions downstream.

- Return flows from the diversion component of the stream flow depletions are subtracted from the flows. These flow volumes are placed at the control point at which the return flow is returned to the stream and at all downstream control points. Channel losses are considered in cascading the return flows downstream.

- Unappropriated flows at each of the control points are added to the flows. Since unappropriated flows are cumulative total flows, these flows are not cascaded downstream

- Any releases from the 15 selected reservoirs made specifically for instream flow rights are subtracted at the control point of the reservoir and cascaded downstream in the normal manner which includes consideration of channel losses.

- Though not included in the Brazos WAM, any hydroelectric power releases from the selected reservoirs are likewise subtracted at the control point of the reservoir and cascaded downstream in the normal manner which includes consideration of channel losses.

As previously discussed, the accuracy of the procedure is confirmed by reproducing the sequences of monthly diversions, storage contents, unappropriated flows, and other pertinent variables contained in the *SIM* simulation results associated with the 15 reservoirs and associated diversions, and 48 control points. These *SIM* simulation results should be same with the condensed dataset versus the original complete dataset. The system of 15 reservoirs and associated diversions must be operated the same in both the condensed and complete datasets for the comparison simulations. After completing the comparison to confirm that the dataset is correct, the condensed dataset can be used to simulate alternative river/reservoir system operating rules and water management and use scenarios for the system of 15 reservoirs and associated diversions at the 48 control points.

Example of Developing a Condensed Dataset

Development of a model focused on operations of the Brazos River Authority System based on condensing the Brazos WAM dataset is presented in Chapters 8 and 9. Pertinent features of *WRAP-SIM* and *WRAP-HYD* are illustrated as follows with a simple hypothetical example prior to dealing with the complexities of the very large and complicated Brazos WAM in the later chapters.

Example 4 found on pages 244-250 of Appendix B of the *WRAP Reference Manual* was adopted earlier in this chapter to illustrate key aspects of the flow extension methodology. Example 4 is used again in this section to develop an example to illustrate the methodology for developing a condensed dataset. A system schematic for Example 4 in the *Reference Manual* and Examples 2.1 and 2.2 presented in this chapter is provided earlier in this chapter as Figure 2.1. In Example 2.2, the original river/reservoir water management and use system of Example 4 is subdivided into a primary system and secondary system as shown in Table 2.10.

Example 2.2 consists of developing a condensed *WRAP-SIM* input dataset that focuses on reservoir Res A and water rights WR-2, WR-5, and WR-6 located at control points CP-2, CP-4, and CP-5, which will be called the primary system. The DAT file of the condensed dataset describes the primary system which contains only reservoir Res A, water rights WR-2, WR-5, and WR-6, and control points CP-2, CP-4, and CP-5. The effects of the other reservoir (Res B), three other *WR* record water rights (WR-1, WR-3, WR-4), and instream flow *IF* record right (WR-7) are reflected in the naturalized flows at control points CP-2, CP-4, and CP-5. Water rights WR-1, WR-3, WR-4, and WR-7, reservoir Res B, and control points CP-1 and CP-3 are removed from the dataset.

The 5 control points, two reservoirs, and seven water rights in *Reference Manual* Example 4 are either included or not included in the *SIM* input DAT file created in Example 2.2 as shown in Table 2.10. The components included in the condensed DAT file are referred to as the primary system. The other components comprise the secondary system reflected in the stream inflows.

Table 2.10
System Components of Example 2.2

System Components	Primary System included in Condensed DAT File	Secondary System not included in Condensed DAT File
control points	CP-2, CP-4, CP-5	CP-1, CP-3
reservoirs	Res A	Res B
water rights	WR-2, WR-5, WR-6	WR-1, WR-3, WR-4, WR-7

Original Dataset

Example 2.2 consists of developing a condensed dataset based on modifying an original dataset. The original dataset consists of the DAT, FLO, EVA, and DIS files reproduced as Tables 2.11, 2.12, 2.13, and 2.14. The filename root Exam2O (O for original) is adopted.

The dataset from Example 4 of the Reference Manual is adopted as the original Example 2.2 dataset with one modification. The return flow options for the three water rights with return flow specifications are changed from the default option 1 consisting of applying a constant factor to the diversion in the same month to option 2 which is called the next-month return flow option. Thus, the integer 2 is entered for the parameter *RFMETH* if field 7 of the *WR* record for three water rights. These *WR* record fields are blank in the original Example 4 DAT file.

The *Reference Manual* addresses in detail the next-month return flow option and the water rights priority sequence issue that the next-month return flow option is designed to address. The issue is that, with the same-month return flow option (default option 1) activated, senior water rights do not have access to return flows associated with junior water rights. For example, in Example 2.2, water right WR-7 is an *IF* record instream flow requirement that is senior to all other rights. With the same-month return flow option activated, WR-6 may have to curtain its diversion and storage refilling to protect the WR-7 instream flow requirement, even though return flows generated by the more junior water rights WR-1, WR-3, and WR-5 provide more than enough flows for the WR-7 instream flow requirement. The next-month return flow option solves this problem. The next-month return flow option (*IF* record *RFMETH* option 2) is adopted rather than the default same-month option in most cases in the WAM datasets because of this issue.

Same-month return flows complicate the procedure for condensing datasets in the same way that they complicate conventional *SIM* simulation applications as discussed in the *Reference Manual*. This issue relates to condensing datasets in regard to effects of the partitioning on which primary or secondary water rights have access to the return flows. The next-month return flow option adds return flows to stream flows at the beginning of the water rights priority sequence and thus water rights have access to return flows along with access to stream flows in general.

The return flow option issue does affect the results of the Example 2.2 simulation though the effects are relatively small. With return flow option 2, results from the original and condensed datasets match perfectly. With return flow option 1, the match is a little off in several months.

The original dataset consists of the FLO, EVA, DIS, and DAT input files for the *SIM* simulation model reproduced as follows as Tables 2.11, 2.12, 2.13, and 2.14. A *TABLES* input TIN file for organizing the *SIM* simulation results is shown as Table 2.15. The simulation results are summarized in the *TABLES* output TOU file presented as Table 2.16.

A *SIM* simulation was performed with the original dataset consisting of the FLO, EVA, DIS and DAT files reproduced as Tables 2.11, 2.12, 2.13, and 2.14. *TABLES* was executed with the TIN input file reproduced as Table 2.15 to organize the *SIM* simulation results as a set of tables created in the *TABLES* output file which is reproduced as Table 2.16.

Table 2.11
Original *SIM* Input FLO File for Example 2.2

```
**   Naturalized Monthly Streamflows in acre-feet
IN  CP-2    1996  10800  12500   8100   7620   9610   1200    850   2540   9520   1850   1760   7200
IN  CP-3    1996   5200   6280   3750   3970   4450    750   1090   2160   4670    915    850   3490
IN  CP-5    1996  19400  24600  14200  15200  18400   2640   2290   6240  21800   3780   3720  13900
IN  CP-2    1997   6250   8140   4190   7280   6930   1390    725    545    942   1890   4910   5740
IN  CP-3    1997   2180   4320   3760   2350   3760    870    915    296   1020   2250   4870   3190
IN  CP-5    1997  11200  17800  10620  14500  15400   2930   1910   1290   2300   5190  12800  13700
IN  CP-2    1998   7680   6590   5570   5230   6180   1280   1670   1050   7890   8670   6210   5360
IN  CP-3    1998   3820   3540   2190   2310   3290    657    845    840   3970   4230   3540   2870
IN  CP-5    1998  15400  13900  18300   9780  12600   2560   3420   2650  15400  17400  12700  11800
```

Table 2.12
Original *SIM* Input EVA File for Example 2.2

```
**   Net Evaporation-Precipitation Rates in Inches
EV  CP-2    1996    3.2    2.8    3.1   -1.6   -3.7    1.9    4.3    3.9    2.5    1.9    1.6    2.9
EV  CP-2    1997    2.5    1.7   -4.9   -0.9   -2.1    0.7    3.5    2.8    3.1    2.5    0.9    2.6
EV  CP-2    1998    2.9    2.1   -1.5   -2.8   -2.6   -0.2    2.7   -1.4    2.2    2.1    2.0    1.9
```

Table 2.13
Original *SIM* Input DIS File for Example 2.2

```
**  Flow Distribution Information
FD  CP-4    CP-5       2    CP-2    CP-3
FD  CP-1    CP-2
WP  CP-1     225      74      31
WP  CP-2     398      69      31
WP  CP-3     194
WP  CP-4     650
WP  CP-5     715
ED
```

Table 2.14
Original *SIM* Input DAT File for Example 2.2

```
T1  WRAP-SIM Input File Exam2O.DAT
T2  Example 2.2 Original DAT File
T2  Example 2.2 is based on Example 4 from Reference Manual Appendix B.
**
JD     3    1996       1      -1      -1
**
UC   mun    0.06    0.06    0.06    0.06    0.06    0.10
UC          0.12    0.12    0.11    0.10    0.09    0.06
UC   irr    0.00    0.00    0.00    0.00    0.20    0.30
UC          0.30    0.20    0.00    0.00    0.00    0.00
**
CP  CP-1    CP-2                       4            NONE
CP  CP-2    CP-4        0.083333       0                                0.10
CP  CP-3    CP-4                       0            CP-2                0.12
CP  CP-4    CP-5                       6            NONE                0.15
CP  CP-5     OUT                       0            NONE
**
WR  CP-1    1200     irr    1965       2     0.2                 WR-1
**
WR  CP-2                    9999                                 WR-2
WS Res A   80000
**
WR  CP-3   42000     irr    1975       2     0.1                 WR-3
WS Res B   30000
WR  CP-3                    8888                                 WR-4
WS Res B   40000
**
WR  CP-4   26000     mun    1984   2   2    0.35               2  WR-5
WS Res A   80000
**
WR  CP-5   18000     mun    1952   2                           2  WR-6
WS Res A   80000
**
IF  CP-5   12000               0               1    WR-7
**
SV Res A       0     825    2980    8640   22100   42700   73700   89600
SA             0     112     327     920    1760    2480    3750    4930
**
SV Res B       0     740    2680    7780   19800   38400   52900
SA             0     100     298     832    1580    2230    2690
**
DI     1      -1
IS     5       0   60000  108000  108001  120000
IP            50     100     100     120     120
**
DI     2       1   Res A
IS     4       0   20000   20001  800000
IP            80      80     100     100
**
ED
```

Table 2.15

TABLES Input TIN File for Example 2.2

```
**  TABLES Input File Exam2.TIN for Example 2.2
**       1         2         3
**  567890123456789012345678901234
**     !   !   !   !   !   !   !
2NAT   1               3
IDEN    CP-2    CP-4    CP-5
2UNA   1              -3
2REG   1              -3
2DEP   1              -3
2DIV   1               2
IDEN    CP-4    CP-5
2RFL   1   0   0   0   1
IDEN            WR-5
2STO   1   0   0   0   1
IDEN    CP-2
ENDF
```

Table 2.16

TABLES Output TOU File with Simulation Results for Original Dataset

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	10800.	12500.	8100.	7620.	9610.	1200.	850.	2540.	9520.	1850.	1760.	7200.	73550.
1997	6250.	8140.	4190.	7280.	6930.	1390.	725.	545.	942.	1890.	4910.	5740.	48932.
1998	7680.	6590.	5570.	5230.	6180.	1280.	1670.	1050.	7890.	8670.	6210.	5360.	63380.
MEAN	8243.	9077.	5953.	6710.	7573.	1290.	1082.	1378.	6117.	4137.	4293.	6100.	61954.

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	17974.	22023.	13228.	13600.	16482.	2329.	2143.	5547.	18272.	3323.	3214.	12485.	130620.
1997	9973.	15360.	9415.	12260.	13243.	2634.	1798.	1082.	2160.	4727.	11445.	11486.	95583.
1998	13657.	12198.	13233.	8796.	11203.	2283.	3013.	2302.	13839.	15384.	11394.	10167.	117469.
MEAN	13868.	16527.	11959.	11552.	13643.	2415.	2318.	2977.	11424.	7811.	8684.	11379.	114557.

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	19400.	24600.	14200.	15200.	18400.	2640.	2290.	6240.	21800.	3780.	3720.	13900.	146170.
1997	11200.	17800.	10620.	14500.	15400.	2930.	1910.	1290.	2300.	5190.	12800.	13700.	109640.
1998	15400.	13900.	18300.	9780.	12600.	2560.	3420.	2650.	15400.	17400.	12700.	11800.	135910.
MEAN	15333.	18767.	14373.	13160.	15467.	2710.	2540.	3393.	13167.	8790.	9740.	13133.	130573.

Table 2.16 Continued

UNAPPROPRIATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	9675.	11516.	7010.	8182.	10670.	0.	0.	0.	517.	0.	0.	3017.	50589.
1997	5371.	7543.	5912.	7596.	7428.	0.	0.	0.	0.	0.	0.	0.	33850.
1998	0.	5382.	6097.	6214.	6854.	0.	0.	0.	0.	7652.	5507.	4692.	42397.
MEAN	5016.	8147.	6340.	7331.	8317.	0.	0.	0.	172.	2551.	1836.	2570.	42279.

UNAPPROPRIATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14867.	19109.	10169.	12813.	11961.	0.	0.	0.	4039.	0.	0.	4089.	77048.
1997	5704.	9461.	6096.	8917.	8822.	0.	0.	0.	0.	0.	401.	1953.	41354.
1998	1823.	6435.	10220.	6088.	7354.	0.	0.	0.	469.	8145.	5307.	5481.	51322.
MEAN	7465.	11668.	8828.	9273.	9379.	0.	0.	0.	1503.	2715.	1902.	3841.	56574.

UNAPPROPRIATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14479.	20389.	9866.	12798.	12823.	0.	0.	0.	7815.	0.	0.	5503.	83671.
1997	6037.	11252.	6265.	10124.	9909.	0.	0.	0.	0.	0.	1702.	4336.	49624.
1998	3807.	7468.	14205.	5945.	7795.	0.	0.	0.	2147.	9448.	5815.	6555.	63185.
MEAN	8108.	13036.	10112.	9622.	10175.	0.	0.	0.	3321.	3149.	2506.	5465.	65494.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	9675.	11516.	7010.	8182.	10670.	3646.	3930.	1265.	517.	3044.	2564.	3017.	65038.
1997	5371.	7543.	5912.	7596.	7428.	3313.	3904.	3844.	4168.	2546.	0.	0.	51624.
1998	0.	5382.	6097.	6214.	6854.	3478.	3033.	3839.	0.	7652.	5507.	4692.	52748.
MEAN	5016.	8147.	6340.	7331.	8317.	3479.	3622.	2983.	1562.	4414.	2690.	2570.	56470.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14867.	19109.	10169.	12813.	11961.	2110.	2095.	639.	4039.	992.	849.	4089.	83734.
1997	5704.	9461.	6096.	8917.	8822.	1838.	2198.	1997.	1675.	737.	401.	1953.	49800.
1998	1823.	6435.	10220.	6088.	7354.	1923.	1637.	1618.	469.	8145.	5307.	5481.	56499.
MEAN	7465.	11668.	8828.	9273.	9379.	1957.	1977.	1418.	2061.	3291.	2185.	3841.	63344.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	15679.	21589.	11066.	13998.	14023.	1200.	1000.	1000.	8815.	1000.	1000.	6503.	96871.
1997	7037.	12252.	7265.	11124.	11109.	1000.	1000.	1000.	1000.	1000.	2702.	5336.	61824.
1998	4807.	8468.	15205.	6945.	8795.	1000.	1000.	1000.	3147.	10448.	6815.	7555.	75185.
MEAN	9174.	14103.	11179.	10689.	11309.	1067.	1000.	1000.	4321.	4149.	3506.	6465.	77960.

Table 2.16 Continued

STREAMFLOW DEPLETIONS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1124.7	984.1	1089.5	-562.3	-1300.4	0.0	0.0	1106.9	9050.8	0.0	0.0	4182.6	15675.8
1997	878.7	597.5	-1722.2	-316.3	-738.1	0.0	0.0	0.0	0.0	0.0	4910.0	5740.0	9349.6
1998	7680.0	1208.4	-527.2	-984.1	-913.8	0.0	0.0	0.0	7938.0	1018.5	702.9	667.8	16790.5
MEAN	3227.8	930.0	-386.6	-620.9	-984.1	0.0	0.0	369.0	5662.9	339.5	1871.0	3530.1	13938.7

STREAMFLOW DEPLETIONS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1560.0	1560.0	1560.0	1560.0	1560.0	118.0	88.7	3120.0	2860.0	1525.4	1616.7	1560.0	18688.8
1997	1560.0	1560.0	1560.0	1560.0	1560.0	588.9	0.0	0.0	0.0	2009.4	2340.0	1560.0	14298.3
1998	1560.0	1560.0	1560.0	1560.0	1560.0	341.0	1633.7	458.7	2860.0	2600.0	2340.0	1560.0	19593.4
MEAN	1560.0	1560.0	1560.0	1560.0	1560.0	349.3	574.1	1192.9	1906.7	2044.9	2098.9	1560.0	17526.8

STREAMFLOW DEPLETIONS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0
1997	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0
1998	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0
MEAN	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0

DIVERSIONS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00
1997	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00
1998	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00
MEAN	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00

DIVERSIONS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00
1997	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00
1998	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00
MEAN	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00

RETURN FLOW (AC-FT) FOR WATER RIGHT WR-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0
1997	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0
1998	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0
MEAN	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0

Table 2.16 Continued

EOP RESERVOIR STORAGE (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1996	80000.0	80000.0	80000.0	80000.0	80000.0	76594.5	71857.6	71770.9	80000.0	78149.1	76808.0	80000.0	77931.7
1997	80000.0	80000.0	80000.0	80000.0	80000.0	77524.8	72927.6	68613.9	64542.8	63189.2	67843.1	72800.6	73953.5
1998	79526.6	80000.0	80000.0	80000.0	80000.0	77558.8	75020.4	72503.7	79717.8	80000.0	80000.0	80000.0	78693.9
MEAN	79842.2	80000.0	80000.0	80000.0	80000.0	77226.0	73268.5	70962.8	74753.5	73779.4	74883.7	77600.2	76859.7

Condensed Dataset

The original dataset consisting of the FLO, EVA, DIS and DAT files reproduced as Tables 2.11, 2.12, 2.13, and 2.14 is condensed to a smaller dataset consisting of the DAT, FLO, and EVA files reproduced as Tables 2.18, 2.19, and 2.20. The filename roots Exam2O (O for original) and Exam2C (C for condensed) are adopted for the original and condensed datasets.

The primary and secondary systems are defined in Table 2.10. The primary system is modeled by the DAT file of the condensed dataset. The effects of the secondary system are incorporated into the stream inflows recorded in the FLO file of the condensed dataset. The FLO file for the condensed dataset is created such that a *SIM* simulation with the condensed *SIM* input dataset results in exactly the same diversion and reservoir storage volumes as the original *SIM* input dataset. The unappropriated flows are also reproduced exactly by the condensed dataset model.

Table 2.17
WRAP-HYD Input HIN File for Example 2.2

```
T1  WRAP-HYD Input File Exam2C.HIN
**
**       1         2         3         4         5         6         7         8
**345678901234567890123456789012345678901234567890123456789012345678901234567890123
**     !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !
JC  1996   3   1   0   0   1   0   0   1   0   1
**
CP  CP-2    CP-4                    0                           0.10
CP  CP-4    CP-5                    0            NONE           0.15
CP  CP-5     OUT                    0            NONE
**
**  Unappropriated Flows
AS  CP-2                   5   3   0   1   0
AS  CP-4                   5   3   0   1   0
AS  CP-5                   5   3   0   1   0
**
**  Streamflow Depletions
AS  CP-2                   5   9   0   0   0                                    WR-2
AS  CP-4                   5   9   0   0   0                                    WR-5
AS  CP-5                   5   9   0   0   0                                    WR-6
**
**  Return Flows
AS  CP-5                   5 -10   0   0   0      -1                            WR-5
**     !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !
ED
```

The computational procedure begins by executing *SIM* with the original dataset. Program *HYD* reads the *SIM* output OUT file along with the *HYD* input HIN file reproduced as Table 2.17 and creates the FLO file shown below as Table 2.18 for the condensed dataset. The condensed DAT file shown as Table 2.19 is created by manually removing the secondary system components. For this example, the EVA file is the same for the condensed and original datasets. The condensed dataset has no DIS file.

Table 2.18
FLO File for Example 2.2 Condensed Dataset

```
*** WRAP-HYD Output File Exam2cOUT.FLO
*** The filename was changed to Exam2C.FLO for use as SIM input FLO file.  The inflows are in acre-feet/month.
IN  CP-2    1996 10800.0 12500.0  8100.0  7620.0  9370.0     0.0     0.0  1106.9  9568.0     0.0     0.0  7200.0
IN  CP-4    1996 17438.9 21555.0 12709.4 13867.4 12350.3   118.0    88.7  4116.2 15045.2  1525.4  1616.7  9413.7
IN  CP-5    1996 17745.1 23001.9 12559.3 14227.5 13687.8  1354.3  1325.4  4566.8 18057.6  2095.6  2084.2 10289.5
IN  CP-2    1997  6250.0  8140.0  4190.0  7280.0  6690.0     0.0     0.0     0.0     0.0     0.0  4910.0  5740.0
IN  CP-4    1997  8054.7 11558.8  6106.3 10191.9  9718.2   588.9     0.0     0.0     0.0  2009.4  7159.7  8678.9
IN  CP-5    1997  8569.4 13568.6  6807.5 11742.2 11203.9  1754.6  1250.0  1068.0   888.0  2507.0  8157.2 10313.9
IN  CP-2    1998  7680.0  6590.0  5570.0  5230.0  5940.0     0.0     0.0     0.0  7938.0  8670.0  6210.0  5360.0
IN  CP-4    1998 10295.3  9082.6 11305.6  6762.7  8091.9   341.0  1633.7   458.7 10473.0 11661.2  8279.1  7641.7
IN  CP-5    1998 11542.6 10252.1 15661.9  7052.1  8955.5  1543.9  2638.6  1457.9 11538.6 13236.0  9052.1  8653.2
```

Table 2.19
DAT File for Example 2.2 Condensed Dataset

```
T1  WRAP-SIM Input File Exam2C.DAT
T2  Example 2.2 Condensed DAT File

**       1         2         3         4         5         6         7         8
**345678901234567890123456789012345678901234567890123456789012345678901234567890123456789
** !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !
JD     3    1996       1      -1      -1
**JO                                                                               2   1
**
UC   mun    0.06    0.06    0.06    0.06    0.06    0.10
UC          0.12    0.12    0.11    0.10    0.09    0.06
UC   irr    0.00    0.00    0.00    0.00    0.20    0.30
UC          0.30    0.20    0.00    0.00    0.00    0.00
**
CP  CP-2    CP-4        0.083333       0                            0.10
CP  CP-4    CP-5                       0            NONE            0.15
CP  CP-5     OUT                       0            NONE
**
WR  CP-2                    9999                                WR-2
WS Res A   80000
**
WR  CP-4   26000     mun    1984   2   2    0.35              1  WR-5
WS Res A   80000
**
WR  CP-5   18000     mun    1952   2                          1  WR-6
WS Res A   80000
**
SV Res A       0     825    2980    8640   22100   42700   73700   89600
SA             0     112     327     920    1760    2480    3750    4930
**
DI     1       1   Res A
IS     4       0   20000   20001  800000
IP            80      80     100     100
ED
```

The *SIM* simulation results for the condensed dataset are summarized by the set of tables created with *TABLES* and reproduced as Table 2.20. The *TABLES* input TIN file shown as Table 2.15 was used to organize the simulation results for both the original dataset shown in Table 2.16 and the condensed dataset shown in Table 2.20.

Table 2.20
Simulation Results for Example 2.2 Condensed Dataset

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	10800.	12500.	8100.	7620.	9370.	0.	0.	1107.	9568.	0.	0.	7200.	66265.
1997	6250.	8140.	4190.	7280.	6690.	0.	0.	0.	0.	0.	4910.	5740.	43200.
1998	7680.	6590.	5570.	5230.	5940.	0.	0.	0.	7938.	8670.	6210.	5360.	59188.
MEAN	8243.	9077.	5953.	6710.	7333.	0.	0.	369.	5835.	2890.	3707.	6100.	56218.

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	17439.	21555.	12709.	13867.	12350.	118.	89.	4116.	15045.	1525.	1617.	9414.	109845.
1997	8055.	11559.	6106.	10192.	9718.	589.	0.	0.	0.	2009.	7160.	8679.	64067.
1998	10295.	9083.	11306.	6763.	8092.	341.	1634.	459.	10473.	11661.	8279.	7642.	86026.
MEAN	11930.	14065.	10040.	10274.	10053.	349.	574.	1525.	8506.	5065.	5685.	8578.	86646.

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	17745.	23002.	12559.	14228.	13688.	1354.	1325.	4567.	18058.	2096.	2084.	10290.	120995.
1997	8569.	13569.	6808.	11742.	11204.	1755.	1250.	1068.	888.	2507.	8157.	10314.	77830.
1998	11543.	10252.	15662.	7052.	8956.	1544.	2639.	1458.	11539.	13236.	9052.	8653.	101585.
MEAN	12619.	15608.	11676.	11007.	11282.	1551.	1738.	2364.	10161.	5946.	6431.	9752.	100137.

UNAPPROPRIATED FLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	9675.	11516.	7010.	8182.	10670.	0.	0.	0.	517.	0.	0.	3017.	50589.
1997	5371.	7543.	5912.	7596.	7428.	0.	0.	0.	0.	0.	0.	0.	33850.
1998	0.	5382.	6097.	6214.	6854.	0.	0.	0.	0.	7651.	5507.	4692.	42397.
MEAN	5016.	8147.	6340.	7331.	8317.	0.	0.	0.	172.	2550.	1836.	2570.	42279.

UNAPPROPRIATED FLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14867.	19109.	10169.	12814.	11961.	0.	0.	0.	4039.	0.	0.	4089.	77048.
1997	5704.	9461.	6096.	8917.	8822.	0.	0.	0.	0.	0.	401.	1953.	41354.
1998	1823.	6435.	10220.	6088.	7354.	0.	0.	0.	469.	8145.	5306.	5481.	51322.
MEAN	7465.	11668.	8828.	9273.	9379.	0.	0.	0.	1503.	2715.	1902.	3841.	56574.

Table 2.20 Continued

UNAPPROPRIATED FLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14479.	20389.	9866.	12798.	12823.	0.	0.	0.	7815.	0.	0.	5503.	83671.
1997	6037.	11252.	6265.	10124.	9909.	0.	0.	0.	0.	0.	1702.	4336.	49624.
1998	3807.	7468.	14205.	5945.	7795.	0.	0.	0.	2147.	9448.	5815.	6555.	63185.
MEAN	8108.	13036.	10112.	9622.	10175.	0.	0.	0.	3321.	3149.	2506.	5465.	65494.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	9675.	11516.	7010.	8182.	10670.	2758.	3368.	0.	517.	1194.	804.	3017.	58713.
1997	5371.	7543.	5912.	7596.	7428.	2235.	3467.	3467.	3178.	656.	0.	0.	46852.
1998	0.	5382.	6097.	6214.	6854.	2510.	1652.	2957.	0.	7651.	5507.	4692.	49516.
MEAN	5016.	8147.	6340.	7331.	8317.	2501.	2829.	2141.	1232.	3167.	2104.	2570.	51694.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14867.	19109.	10169.	12814.	11961.	0.	0.	0.	4039.	0.	0.	4089.	77048.
1997	5704.	9461.	6096.	8917.	8822.	0.	0.	0.	0.	0.	401.	1953.	41354.
1998	1823.	6435.	10220.	6088.	7354.	0.	0.	0.	469.	8145.	5306.	5481.	51322.
MEAN	7465.	11668.	8828.	9273.	9379.	0.	0.	0.	1503.	2715.	1902.	3841.	56574.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14479.	20389.	9866.	12798.	12823.	0.	0.	0.	7815.	0.	0.	5503.	83671.
1997	6037.	11252.	6265.	10124.	9909.	0.	0.	0.	0.	0.	1702.	4336.	49624.
1998	3807.	7468.	14205.	5945.	7795.	0.	0.	0.	2147.	9448.	5815.	6555.	63185.
MEAN	8108.	13036.	10112.	9622.	10175.	0.	0.	0.	3321.	3149.	2506.	5465.	65494.

STREAMFLOW DEPLETIONS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1124.7	984.1	1089.5	-562.3	-1300.4	0.0	0.0	1106.9	9050.8	0.0	0.0	4182.6	15675.8
1997	878.7	597.5	-1722.2	-316.3	-738.1	0.0	0.0	0.0	0.0	0.0	4910.0	5740.0	9349.6
1998	7680.0	1208.4	-527.2	-984.1	-913.8	0.0	0.0	0.0	7938.0	1018.5	702.9	667.8	16790.6
MEAN	3227.8	930.0	-386.6	-620.9	-984.1	0.0	0.0	369.0	5662.9	339.5	1871.0	3530.1	13938.7

STREAMFLOW DEPLETIONS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1560.0	1560.0	1560.0	1560.0	1560.0	118.0	88.7	3120.0	2860.0	1525.4	1616.7	1560.0	18688.8
1997	1560.0	1560.0	1560.0	1560.0	1560.0	588.9	0.0	0.0	0.0	2009.4	2340.0	1560.0	14298.3
1998	1560.0	1560.0	1560.0	1560.0	1560.0	341.0	1633.7	458.7	2860.0	2600.0	2340.0	1560.0	19593.4
MEAN	1560.0	1560.0	1560.0	1560.0	1560.0	349.3	574.1	1192.9	1906.7	2044.9	2098.9	1560.0	17526.8

Table 2.20 Continued

STREAMFLOW DEPLETIONS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0
1997	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0
1998	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0
MEAN	1080.0	1080.0	1080.0	1080.0	1080.0	1800.0	2160.0	2160.0	1980.0	1800.0	1620.0	1080.0	18000.0

DIVERSIONS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00
1997	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00
1998	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00
MEAN	1560.00	1560.00	1560.00	1560.00	1560.00	2600.00	3120.00	3120.00	2860.00	2600.00	2340.00	1560.00	26000.00

DIVERSIONS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00
1997	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00
1998	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00
MEAN	1080.00	1080.00	1080.00	1080.00	1080.00	1800.00	2160.00	2160.00	1980.00	1800.00	1620.00	1080.00	18000.00

RETURN FLOW (AC-FT) FOR WATER RIGHT WR-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0
1997	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0
1998	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0
MEAN	546.0	546.0	546.0	546.0	546.0	910.0	1092.0	1092.0	1001.0	910.0	819.0	546.0	9100.0

EOP RESERVOIR STORAGE (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1996	80000.0	80000.0	80000.0	80000.0	80000.0	76594.5	71857.6	71770.9	80000.0	78149.1	76808.0	80000.0	77931.7
1997	80000.0	80000.0	80000.0	80000.0	80000.0	77524.8	72927.6	68613.9	64542.8	63189.2	67843.1	72800.6	73953.5
1998	79526.6	80000.0	80000.0	80000.0	80000.0	77558.8	75020.3	72503.6	79717.7	80000.0	80000.0	80000.0	78693.9
MEAN	79842.2	80000.0	80000.0	80000.0	80000.0	77226.0	73268.5	70962.8	74753.5	73779.4	74883.7	77600.2	76859.7

The 3-year annual mean volumes for the simulation results for the original and condensed datasets presented in Tables 5.16 and 5.20 are compared in Table 5.21. The accuracy of the computational procedure can be checked by comparing the quantities that should be the same in the simulation results for both the condensed and original datasets. These quantities are found to be identically the same for all 36 months of the simulation. The annual means for the variables that match as required by the procedure are underlined in Table 2.21.

Table 2.21
Mean Annual Volumes in Simulation Results
for Original and Condensed Datasets

Dataset Mean Annual Volumes	Original (ac-ft)	Condensed (ac-ft)
naturalized flows or inflows at CP-2	61,954	56,218
naturalized flows or inflows at CP-4	114,557	86,646
naturalized flows or inflows at CP-5	130,573	100,137
unappropriated flows at CP-2	42,279	42,279
unappropriated flows at CP-4	56,574	56,574
unappropriated flows at CP-5	65,494	65,494
regulated flows at CP-2	56,470	51,694
regulated flows at CP-4	63,344	56,574
regulated flows at CP-5	77,960	65,494
streamflow depletions at CP-2	13,939	13,939
streamflow depletions at CP-4	17,527	17,527
streamflow depletions at CP-5	18,000	18,000
diversions at CP-4	26,000	26,000
diversions at CP-5	18,000	18,000
return flow for WR-5	9,100	9,100
reservoir storage at CP-2	76,860	76,860

Options for Adjusting Regulated Flows in a Condensed Model

A new feature was added to *WRAP-SIM* specifically for incorporating conventionally-defined regulated flows in condensed datasets utilizing a new type of input file with filename extension RUF. The regulated-unappropriated flow RUF file contains the differences between the regulated flows less unappropriated flows from the simulation results of the original complete dataset. These data are used to perform flow adjustments that allow conventionally-defined regulated flows to be included in the *SIM* simulation results for the condensed dataset.

The optional RUF file feature may not be needed in many applications for which inclusion of conventionally-defined regulated flows in the simulation results is not a concern. The RUF file options must be applied with caution because the combined effects on river flows of the primary water rights in the condensed DAT file and the secondary water rights reflected in the FLO file may not be modeled correctly in some situations. Unappropriated flows are adjusted to represent regulated flows. The effects of certain water rights in accounting for the differences between regulated and unappropriated flows may be omitted or double-counted.

Regulated flows computed by *WRAP-SIM* represent the physical flows of the river at a control point location. Unappropriated flows are the quantities still available after all water rights have appropriated their allocated quantities of water in the simulation. Unappropriated flow at a particular control point in a particular month can not exceed regulated flow in the *SIM* simulation results. However, the unappropriated flow may be less than the regulated flow. The difference between regulated and unappropriated flows at control point CP-X represents:

1. instream flow requirements at CP-X
2. releases associated with water right types 2 and 3 from upstream reservoirs located at or above CP-X for water rights at control points located downstream of CP-X
3. the portion of flows appropriated by diversion and/or storage rights and/or instream flow requirements at control points located downstream of CP-X that is provided by the flows flowing through control point CP-X

The FLO file for a condensed dataset will normally contain flows computed by *HYD* from *SIM* simulation results as the summation of stream flow depletions for the primary system water rights plus unappropriated flows. Without the RUF file feature described next, differences between regulated and unappropriated flows in the simulation results of the condensed model are caused only by the primary water rights included in the condensed DAT file. The effects of the secondary water rights are neglected. Thus, the regulated flows may be smaller in the condensed model than in the original model. If no instream flow rights are included in the condensed DAT file, this issue with regulated flows has no effect on simulation results other than the regulated flows themselves. Regulated flows in the simulation results of a condensed model are defined differently but affect no other aspects of the simulation except instream flow rights.

Incorporation of regulated flows, as normally defined in *WRAP-SIM* simulations, into a condensed model using the RUF file feature is complicated by the differences between regulated and unappropriated flows being caused by both secondary (FLO file) and primary system (DAT file) water rights. The RUF file feature is necessarily approximate in certain situations due to the combined effects of secondary and primary water rights on river flows.

RUF File Feature for Incorporating Regulated Flows for a Condensed Model

A new set of options added to *SIM* specifically for modeling regulated flows in condensed datasets is activated by the parameters RUFIN and RUF on the *JO* record and is based on *RU* records stored in a regulated-unappropriated flow RUF file. The RUF file is developed with *WRAP-HYD* from the results of a *SIM* simulation with the original complete dataset. The *RU* records in a RUF file contain the differences between monthly regulated flow volume (R) less unappropriated flow volume (U). These quantities are treated as flow adjustments ΔF in the *SIM* simulation with a condensed dataset that includes the RUF file as a *SIM* input file.

$$\Delta F = R - U \tag{2.4}$$

The new *RU* records have the same format as *IN* records. Each *RU* record contains ΔF values for each of the 12 months of a year. *RU* records are included in the RUF file for all control points with one or more months of non-zero differences between regulated and unappropriated flows. *SIM* assumes the differences are zero for any control points not included in the RUF file. *RU* records may be provided for each and all years, or a single *RU* record can be repeated for any number of years having the same 12 monthly amounts in the same manner as *IN* records. *SIM* contains several variations of options for using the ΔF read from a RUF file.

The application by *SIM* of the RUF file data is activated by the parameters RUFIN and RUF entered in columns 84 and 88 of the *JO* record. The *JO* record switch RUFIN controls options for adding the flow adjustments (ΔF) within *SIM* to the variable array INFLOW(cp). The *JO* record switch RUF controls options for adding the ΔF to the array REGFLOW(cp).

RUFIN entered in column 84 of the *JO* record in the condensed DAT file activates *SIM* routines for adding the ΔF from the RUF file to the inflows in the INFLOW(cp) array. *SIM* reads the inflows stored in the INFLOW(cp) array from *IN* records stored in the FLO file and also records the inflows in the *SIM* simulation results output OUT file. The inflows in the FLO file for a condensed dataset are the summation of unappropriated (U) flows plus flow depletions less return flows for the primary system water rights. The RUFIN feature applies Equation 2.5 to convert these inflows to regulated (R) flows plus primary system depletions less return flows.

$$R = U + \Delta F \tag{2.5}$$

The options activated by the RUFIN switch on the *JO* record are described as follows.

Option 1 (RUFIN = 1) The ΔF are added to the INFLOW(cp) array immediately after reading the FLO file. The adjusted inflows, with unappropriated flows replaced with regulated flows, are used in the *SIM* simulation computations. Option 1 has the same effect as incorporating regulated flows rather than unappropriated flows in the FLO file. RUF options described below can not be used in combination with RUFIN option 1.

Option 2 (RUFIN = 2) The ΔF are added to the inflows from the INFLOW(cp) array just before they are recorded in the *SIM* output file but have no effect on the simulation computations. RUFIN option 2 can be combined with any of the RUF options.

The parameter RUF entered in column 88 of the *JO* record in the condensed DAT file controls *SIM* routines for incorporating the ΔF from the RUF file in the determination of regulated flows recorded in the REGFLOW(cp) array at the completion of the water rights computational sequence. REGFLOW(cp) are the regulated flows at each control point (cp) in a particular month which are recorded in the *SIM* simulation results output file. The options activated by the RUF switch on the *JO* record are described as follows.

Option 1 (RUF = 1)

If ΔF from the RUF file is zero, the regulated flow is computed in the conventional manner as if there was no RUF file.

If ΔF from the RUF file is not zero, the regulated flow (R) is set as the greater of the following two alternative values of R.

$R = U + \Delta F$

R computed in the conventional manner

Option 2 (RUF = 2) $R = U + \Delta F$

Option 3 (RUF = 3) $R = U + \Delta F$ + reservoir releases

If the primary water management system is operated identically in both the original and condensed datasets, as reflected in the water rights data in the DAT file, RUF options 1 and 2 should always result in regulated flows computed with the condensed dataset that are the same as the regulated flows from a simulation with the original dataset. The regulated flows may be different if the primary water rights are not the same in the condensed and original datasets. Water management/use changes will typically result in changes in regulated flows. Often, but not always, monthly regulated flow volumes will change by the same amount as the corresponding unappropriated flows with changes in water rights (water management and use).

The RUF options may not always provide the correct changes in regulated flows with changes in water rights (water management and use). With RUF option 1, the following situations could occur in a particular month at a particular control point.

- In common situations in which regulated flows should change in the same amount as unappropriated flows, the condensed dataset provides a perfectly correct regulated flow computed as $R = U + \Delta F$.
- If ΔF is zero, the condensed dataset should provide a perfectly correct regulated flow.
- If regulated flows change differently than unappropriated flows, the condensed dataset will provide a perfectly correct regulated flow only if the R computed in the conventional manner is both correct and greater than $R = U + \Delta F$.

The first two situations noted above also result in correct regulated flows with RUF option 2. RUF option 3 is designed only for a situation in which the condensed dataset contains type 2 or 3 water rights but the original dataset does not. Option 1 is designed to be the standard recommended option. Options 2 and 3 may be useful in sensitivity analyses.

The options activated by the RUF switch affect only computation of the regulated flows stored in the REGFLOW(cp) array. The REGFLOW(cp) quantities are computed at the completion of the water rights simulation sequence. Thus, REGFLOW(cp) has no effect on any simulation results other than the regulated flows recorded in the *SIM* output file, unless the optional second-pass instream flow option is activated. The second pass instream flow options are controlled by the parameters IFMETH(wr) and the *IF* record and PASS2 on the *JO* record. Regulated flows are set at REGFLOW(cp) for the second pass through the water rights loop for purposes of determining whether instream flow targets specified by *IF* records are met.

The RUF switch feature is designed for setting the regulated flows stored in the *SIM* output file but affect no other simulation results unless the condensed DAT file contains at least one *IF* record with IFMETH option 2 or 4 or PASS2 option 2 is selected on the *JO* record. With an optional second pass through the water rights computational sequence, the REGFLOW(cp) are the regulated flows used in determining whether instream flow targets are met and thus can affect water availability for various water rights and corresponding simulation results.

<u>Expanded Example 2.2</u>

In Example 2.2, the regulated flows for the condensed model tabulated in Table 2.20 are smaller than the correct values tabulated in Table 2.16 in some or all months at all three control points as summarized in Table 2.21. The regulated flows are the same as the unappropriated flows at control points CP-4 and CP-5 in Table 2.19 but are different at CP-2. Regulated flows are included in the Example 2.2 computed simulation results but do not affect any other simulation results from the condensed model. The regulated flows computed by the condensed model tabulated in Table 2.20 reflect the effects of only the primary water rights included in the DAT file. Application of the RUF file feature to adjust the naturalized flows to reflect the effects of all water rights, both primary and secondary, is outlined as follows.

The WRAP flow adjustment capabilities described on the preceding pages are activated by the parameters RUFIN and RUF on the *JO* record and use *RU* records stored in a regulated-unappropriated flow RUF file. The *RU* records contain the differences between regulated flows less unappropriated flows in the simulation results of the original dataset. Program *HYD* creates and stores the *RU* records in the *HYD* output HOT file. The *HYD* input HIN file and resulting HOT file for Example 2.2 are shown as Tables 2.22 and 2.23. The filename of the *HYD* output file is changed from Exam2C.HOT to Exam2C.RUF to serve as a *SIM* input file.

Table 2.22
WRAP-HYD Input HIN File for Example 2.2

```
T1  WRAP-HYD Input File Exam2C.HIN for Creating RUF File for Example 2.2.
**
**       1         2         3         4         5         6         7
**3456789012345678901234567890123456789012345678901234567890123456789012
**     !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !   !
JC  1996   3   1   0   0   1   0   0   1   0   7
**
CP  CP-2    CP-4                       0                            0.10
CP  CP-4    CP-5                       0            NONE            0.15
CP  CP-5     OUT                       0            NONE
**
**  Regulated Flow
AS  CP-2                   5   2   0   1   0
AS  CP-4                   5   2   0   1   0
AS  CP-5                   5   2   0   1   0
**  Unappropriated Flow
AS  CP-2                   5   3   0   1   0      -1
AS  CP-4                   5   3   0   1   0      -1
AS  CP-5                   5   3   0   1   0      -1
ED
```

Table 2.23
HYD Output HOT File Used as *SIM* Input RUF File for Example 2.2

```
*** WRAP-HYD Output File Exam2COUT.HOT
***
RU  CP-2    1996    0.0    0.0    0.0    0.0    0.0 3645.8 3930.2 1265.1    0.0 3044.0 2563.7    0.0
RU  CP-2    1997    0.0    0.0    0.0    0.0    0.0 3312.6 3903.7 3843.7 4167.8 2546.2    0.0    0.0
RU  CP-2    1998    0.0    0.0    0.0    0.0    0.0 3478.0 3033.5 3839.0    0.0    0.0    0.0    0.0
RU  CP-4    1996    0.0    0.0    0.0    0.0    0.0 2110.3 2095.5  639.1    0.0  992.3  849.1    0.0
RU  CP-4    1997    0.0    0.0    0.0    0.0    0.0 1838.3 2198.2 1996.9 1675.0  737.5    0.0    0.0
RU  CP-4    1998    0.0    0.0    0.0    0.0    0.0 1922.9 1636.6 1617.8    0.0    0.0    0.0    0.0
RU  CP-5    1996 1200.0 1200.0 1200.0 1200.0 1200.0 1200.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0
RU  CP-5    1997 1000.0 1000.0 1000.0 1000.0 1200.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0
RU  CP-5    1998 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0 1000.0
```

WRAP-SIM is executed with the condensed dataset with the optional RUF input file added. The only change to the DAT file is the activation of the *JO* record that is commented out with ** in Table 2.19. The parameters RUFIN and RUF entered in columns 84 and 88 of the *JO* record activates *SIM* routines for incorporating the data from the RUF file in the reporting of inflows and regulated flows, respectively. *SIM* can be executed using the RUF options with or without RUF option 1, but the RUF options can not be combined with RUFIN option 2.

The *SIM* simulation results summarized by the tables created by program *TABLES* and reproduced as Table 2.20 are the same with or without the RUF file feature with the exception of the naturalized flows (inflows) and regulated flows shown in Table 2.24. The Table 2.21 summary of means is revised as Table 2.25 to reflect effects of activated the RUF file options.

Table 2.24
TABLES Output TOU File with Inflows and Regulated Flows from
SIM Simulation with Condensed Dataset with RUF File

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	10800.	12500.	8100.	7620.	9370.	3646.	3930.	2372.	9568.	3044.	2564.	7200.	80714.
1997	6250.	8140.	4190.	7280.	6690.	3313.	3904.	3844.	4168.	2546.	4910.	5740.	60974.
1998	7680.	6590.	5570.	5230.	5940.	3478.	3034.	3839.	7938.	8670.	6210.	5360.	69538.
MEAN	8243.	9077.	5953.	6710.	7333.	3479.	3622.	3352.	7225.	4753.	4561.	6100.	70409.

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	17439.	21555.	12709.	13867.	12350.	2228.	2184.	4755.	15045.	2518.	2466.	9414.	116531.
1997	8055.	11559.	6106.	10192.	9718.	2427.	2198.	1997.	1675.	2747.	7160.	8679.	72513.
1998	10295.	9083.	11306.	6763.	8092.	2264.	3270.	2076.	10473.	11661.	8279.	7642.	91204.
MEAN	11930.	14065.	10040.	10274.	10053.	2306.	2551.	2943.	9064.	5642.	5968.	8578.	93416.

NATURALIZED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	18945.	24202.	13759.	15428.	14888.	2554.	2325.	5567.	19058.	3096.	3084.	11290.	134195.
1997	9569.	14569.	7808.	12742.	12404.	2755.	2250.	2068.	1888.	3507.	9157.	11314.	90030.
1998	12543.	11252.	16662.	8052.	9956.	2544.	3639.	2458.	12539.	14236.	10052.	9653.	113585.
MEAN	13686.	16674.	12743.	12074.	12416.	2618.	2738.	3364.	11161.	6946.	7431.	10752.	112603.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-2

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	9675.	11516.	7010.	8182.	10670.	3646.	3930.	1265.	517.	3044.	2564.	3017.	65038.
1997	5371.	7543.	5912.	7596.	7428.	3313.	3904.	3844.	4168.	2546.	0.	0.	51624.
1998	0.	5382.	6097.	6214.	6854.	3478.	3034.	3839.	0.	7651.	5507.	4692.	52748.
MEAN	5016.	8147.	6340.	7331.	8317.	3479.	3622.	2983.	1562.	4414.	2690.	2570.	56470.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-4

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	14867.	19109.	10169.	12814.	11961.	2110.	2096.	639.	4039.	992.	849.	4089.	83734.
1997	5704.	9461.	6096.	8917.	8822.	1838.	2198.	1997.	1675.	738.	401.	1953.	49800.
1998	1823.	6435.	10220.	6088.	7354.	1923.	1637.	1618.	469.	8145.	5306.	5481.	56499.
MEAN	7465.	11668.	8828.	9273.	9379.	1957.	1977.	1418.	2061.	3291.	2185.	3841.	63344.

REGULATED STREAMFLOWS (AC-FT) AT CONTROL POINT CP-5

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1996	15679.	21589.	11066.	13998.	14023.	1200.	1000.	1000.	8815.	1000.	1000.	6503.	96871.
1997	7037.	12252.	7265.	11124.	11109.	1000.	1000.	1000.	1000.	1000.	2702.	5336.	61824.
1998	4807.	8468.	15205.	6945.	8795.	1000.	1000.	1000.	3147.	10448.	6815.	7555.	75185.
MEAN	9174.	14103.	11179.	10689.	11309.	1067.	1000.	1000.	4321.	4149.	3506.	6465.	77960.

Table 2.25
Mean Annual Volumes in Simulation Results
for Original and Condensed (with RUF File) Datasets

Dataset	Original	Condensed (ac-ft)	
Mean Annual Volumes	(ac-ft)	w/o RUF	with RUF
naturalized flows or inflows at CP-2	61,954	56,218	70,409
naturalized flows or inflows at CP-4	114,557	86,646	93,416
naturalized flows or inflows at CP-5	130,573	100,137	112,603
unappropriated flows at CP-2	42,279	42,279	42,279
unappropriated flows at CP-4	56,574	56,574	56,574
unappropriated flows at CP-5	65,494	65,494	65,494
regulated flows at CP-2	56,470	51,694	56,470
regulated flows at CP-4	63,344	56,574	63,344
regulated flows at CP-5	77,960	65,494	77,960
streamflow depletions at CP-2	13,939	13,939	13,939
streamflow depletions at CP-4	17,527	17,527	17,527
streamflow depletions at CP-5	18,000	18,000	18,000
diversions at CP-4	26,000	26,000	26,000
diversions at CP-5	18,000	18,000	18,000
return flow for WR-5	9,100	9,100	9,100
reservoir storage at CP-2	76,860	76,860	76,860

The regulated flows from the condensed model tabulated in Tables 2.24 and 2.25 are identical to those from the simulation results of the original dataset shown in Tables 2.16 and 2.21. The naturalized flows (more appropriately called inflows) differ from the *IN* record inflows of both the original and condensed FLO files as to be expected. The inflows at control point CP-2 reported as specified by RUFIN option 2 are higher than the original model due to the water right type 2 releases from reservoir Res A for water rights WR-5 and WR-6.

Summary and Discussion of the Methodology for Developing a Condensed Dataset

The purpose of the *WRAP-SIM/HYD*-based methodology is to develop a simpler dataset focusing on a primary river/reservoir water management/use system by reducing the number of control points, water rights, and reservoirs in a WAM dataset. Secondary water rights, control points, and reservoirs are removed with their effects incorporated in the stream inflow input data for the condensed dataset. A *SIM* water rights DAT file for the particular river/reservoir water management and use system of interest, called the primary system, is developed along with a FLO file containing stream flow inflows that reflect all other water rights (called secondary rights) in the original dataset that are not included in the primary system.

If the primary system is operated in the same manner in both the condensed and original datasets, the water supply diversions and shortages, streamflow depletions, and reservoir storage volumes computed by the *SIM* simulation model will be the same. The condensed dataset will reproduce the simulation results for the primary system that are obtained with the original dataset. Unappropriated flows are also reproduced. Thus, a comparison of simulation results provides a check on the accuracy and validity of the condensed dataset. With a validated operational condensed dataset, studies can be performed in which various alternative operating plans, management strategies, and water use scenarios are simulated for the primary system. The river inflows for the condensed dataset do not include flows appropriated by the secondary water rights and thus represent only flows that are actually available to the primary system.

Data Files Comprising the Original and Condensed Datasets

The original dataset for Example 2.2 consists of *SIM* input DAT, FLO, EVA, and DIS files. Likewise, the original Bwam3 and Bwam8 datasets for the Brazos WAM application of the methodology presented in Chapters 8 and 9 consist of DAT, FLO, EVA, and DIS files. The condensed datasets in both cases consist of DAT, FLO, and EVA files. A RUF file may also be included in a condensed dataset to properly incorporate regulated flows. The RUF file is not required if regulated flows are not of interest. The other types of optional *SIM* input files (DSS, FAD, BES) can be accommodated in developing condensed datasets as well.

The DAT file in the original Example 2.2 dataset includes five control points, two reservoirs, and seven water rights. The condensed DAT file contains three of the five control points, one of the two reservoirs, and four of the seven water rights. The original Brazos WAM Bwam3 DAT file has 3,830 control points, 670 reservoirs, and 1,756 water rights. The condensed version presented in Chapters 8 and 9 has 48 control points, 15 reservoirs, and just those water rights associated with the 15 reservoirs. The objective is to develop a condensed dataset designed for more conveniently studying a particular primary river/reservoir water management system. The simplification is achieved largely by reducing the size of the DAT file.

The DAT file for a condensed dataset is developed by excerpting pertinent water rights and associated data records from the original DAT file, excerpting pertinent records providing reservoir data, and modifying the control point *CP* records to reflect removal of some of the control points. Channel loss factors on the *CP* records of the DAT file may require computations. With removal of control points, channel loss factors for the stream reaches removed are aggregated for the combined longer reaches between the remaining control points.

The spatial configuration of the river system in Example 2.2 is such that combining of reaches and associated channel loss factors is not required. However, channel loss factor combining computations are required with the removal of numerous control points in the Brazos WAM. Channel loss factors C_L for N reaches that are combined into one single reach with the removal of intermediate control points are aggregated as follows.

$$(1.0 - C_L)_{total} = (1.0 - C_L)_1 + (1.0 - C_L)_2 + ... + (1.0 - C_L)_N \qquad (2.6)$$

The EVA file in Example 2.2 happens to be the same in the original and condensed datasets. However, the EVA file is different in the original and condensed versions of the Brazos WAM dataset. The Brazos WAM activates a *SIM* option that adjusts net evaporation-precipitation depths for reservoir site runoff included in the naturalized flows. The condensed EVA file contains net evaporation-precipitation depths read by program *HYD* from the *SIM* output OUT file from the original dataset that reflects these adjustments. The condensed dataset EVA file provides 15 sets of evaporation-precipitation depths for 15 reservoirs. The Brazos WAM has 67 sets of net evaporation-precipitation depths that are shared by 670 reservoirs.

The original datasets for both Example 2.2 and the Brazos WAM include DIS files providing specifications for distributing naturalized flows from gaged (known-flow) to ungaged (unknown-flow) locations. The Example 2.2 DIS file has two flow distribution *FD* records and five watershed parameter *WP* records. The Brazos WAM dataset contains over 3,000 *FD* records and over 3,000 *WP* records. There is no DIS file in the condensed datasets of either Example 2.2 or the Brazos WAM. The stream inflows in a condensed dataset are not naturalized flows, and flow distribution methods should generally not be applied. Thus, DIS files will normally not be included in condensed datasets.

The FLO file for the Example 2.2 original dataset contains flows at control points CP-2, CP-3, and CP-5. Flows are synthesized within the *SIM* simulation for control points CP-1 and CP-4. The FLO file for the Example 2.2 condensed dataset contains flows at control points CP-2, CP-4, and CP-5, which are the only control points considered. The DAT file flows at CP-4 in the condensed dataset are synthesized in the *SIM* simulation with the original dataset. The FLO file in the Brazos WAM dataset contains flows at 77 control points. The FLO file in the condensed dataset contains flows at 48 of the original 77 control points.

The hydrologic period-of-analysis sequences of stream inflows provided on *IN* records in a FLO file in a *WRAP-SIM* input dataset represent the inflows to the river system. In the original WAM datasets, these are naturalized flows representing natural conditions without the water resources development, management, and use described by the information in the DAT file. For the condensed datasets, the *IN* record inflows in a FLO file are the stream flows available to the water rights of the primary system described by the condensed DAT file. The flows appropriated by the secondary water rights are not available to the primary water rights and thus are not included in the *IN* record inflows in the FLO file.

<u>Simulation Results from the Original and Condensed Datasets</u>

Example 2.2 simulation results for the original and condensed datasets are presented in Tables 2.16 and 2.20, respectively, and are compared in Table 2.21. The comparisons in Table

2.21 illustrates which simulation results variables should always be the same between original and condensed datasets. Addition of a RUF file results in regulated flows also being the same as shown in Table 2.25. RUF file features are outlined in the preceding section of this chapter.

The term *naturalized flows* is a misnomer in the standard *TABLES* headings reproduced in Table 5.19 for the condensed dataset. The more accurate term is *stream flow inflows for specified conditions*, which for the original dataset are naturalized flows but for the condensed dataset are flows available to the primary system considering the effects of the secondary system. The difference between the naturalized flows for the original dataset in Table 2.16 and the *"naturalized flows"* for the condensed dataset in Table 2.20 represent all of the secondary water rights that are not included in the DAT file of the condensed dataset.

The quantities connected directly to the water rights and reservoirs included in the condensed DAT file are exactly the same in the simulation results for the condensed and original datasets. Diversions and diversion shortages, return flows, streamflow depletions, and reservoir evaporation and storage volumes are reproduced by a condensed dataset. A major defining objective of the computational methodology is to properly reproduce these quantities.

Unappropriated flows are also an exact match since unappropriated flows are included along with streamflow depletions less return flows in the FLO file inflows of the condensed *SIM* input dataset. Regulated flows do not and should not match in Table 2.21. Regulated stream flows also match as shown in Table 2.25 if a RUF file is added to the condensed dataset.

The *WRAP-HYD* input HIN file for Example 2.2 is reproduced as Table 2.17. The *SIM* FLO file for the condensed dataset is created by this HIN file as streamflow depletions less return flows plus unappropriated flows. Alternatively, with the *AS* records for adding unappropriated flows removed from the HIN file, the resulting FLO file would contain streamflow depletions less return flows. The simulation results for the condensed dataset would still reproduce the diversion and storage volumes shown in Table 2.20. However, both unappropriated and regulated flows would be zero in the simulation results.

Unappropriated flows are included in the HIN file and resulting FLO file based on the premise that the primary system should have access to unappropriated flows in addition to its own streamflow depletions less return flows from the original dataset simulation. Alternative water use strategies and reservoir operating plans for the primary system, as simulated by the condensed dataset, will result in appropriation of the unappropriated flow portion of the inflows.

<u>Components of Condensed Dataset Stream Inflows</u>

The streamflow inflows entered on *IN* records in the FLO file (or DSS records in a DSS file) of a *SIM* input dataset represent the inflows to the river system. These flows may be naturalized flows representing natural conditions or may reflect other defined conditions of water resources development, allocation, management, and use. There may also be other inflows to the river system. Return flows contribute to the flow amounts available for appropriation. *WRAP-SIM* also has optional constant inflow (*CI* record) and flow adjustment (*FA* record) features that allow additional inflows to the river system. Thus, inflows include the summation of flows from *IN*, *CI*, and *FA* records plus return flows from water right diversions.

The basic concept of the methodology for developing a condensed dataset is that the stream inflows in the original dataset can be partitioned based on the *SIM* simulation results between the following destination quantities.

1. flows that are appropriated by the secondary water rights that are omitted from the condensed dataset DAT file
2. flows that are appropriated by the primary system water rights that are included in the condensed dataset DAT file
3. unappropriated flows

The inflows entered on *IN* records in the *FLO* file of the condensed dataset consist of flows that are appropriated by the primary system water rights plus unappropriated flows at primary system control points. Flows that are appropriated by secondary water rights are not included.

The methodology for developing a condensed dataset is based on computing streamflow inflows that represent the flows allocated to and/or accessible to the primary system. These flows are recorded in the FLO or DSS file of the condensed dataset. Program *HYD* reads the components of these flows from the *SIM* simulation results output file and creates the FLO or DSS input file for the condensed dataset. The *HYD* input file controlling these operations for Example 2.2 is reproduced as Table 2.17. The inflows for the condensed dataset consist of streamflow depletions less return flows associated with the water rights in the primary system, properly cascaded downstream, plus unappropriated flows at each of the control points included in the condensed dataset. Channel losses are considered in cascading streamflow depletions and return flows to downstream control points.

<u>Return Flows and Reservoir Releases</u>

As discussed earlier in this chapter, same-month return flows can be a problem in developing a condensed dataset just like they are in performing conventional *SIM* simulations. The next-month return flow option is applied instead of the same-month option in most cases in the TCEQ WAM System datasets. Return flow options are controlled by the parameter *RFMETH* on the water right *WR* record.

The *WRAP Reference Manual* addresses in detail the return flow options and the water rights priority sequence complexity that the next-month return flow option is designed to address. The problem is that, with the same-month return flow option activated, senior water rights do not have access to return flows associated with junior water rights. The next month return flow option solves this problem by adding the return flows to the *IN* record inflows (naturalized or otherwise defined inflows) at the beginning of the water rights priority sequence in the next month.

The same-month return flow option complicates the procedure for condensing datasets in the same way that it complicates conventional routine *SIM* simulation applications. The order in which various primary or secondary water rights have access to returns flows can affect whether the condensed dataset can correctly reproduce simulation results. The return flow option issue does affect the results of the Example 2.2 simulation though the effects are relatively small. With the next-month return flow option activated, results from the original and condensed datasets match perfectly. With the same-month return flow option, the match is a little off in several months.

Reservoir releases for hydroelectric energy generation involve essentially the same issue. Hydropower releases are analogous to diversions with 100 percent return flows. The problem is likewise solved by the next-month hydropower option provided in *SIM*.

A similar problem occurs with releases from reservoir storage to meet instream flow requirements at downstream control points. This problem is not applicable to the one instream flow right (WR-7) in Example 2.2 and most of the numerous instream flow *IF* record rights in the Brazos WAM dataset because releases are nor required from reservoir storage. The reservoirs must pass inflows to meet the instream flow requirements but not release from storage. Instream flow options are selected by parameter *IFMETH* on the *IF* record. The problem discussed here is relevant for *IFMETH* options 3 and 4 but not for options 1 and 2.

The problem is that an *IFMETH* option 3 or 4 instream flow *IF* record right may be assigned a priority that places it between the various primary and secondary rights in the priority sequence. Splitting the water rights between primary and secondary rights may not perfectly preserve the effects of the instream flow *IF* record right. This is not a problem if the *IF* record right is the most senior water right in the dataset, but in general can be a problem. The impact on simulation results may be so small as to not be a concern. However, if warranted, a possible strategy for dealing with the problem involves reproducing reservoir releases from storage made to meet a instream flow requirement during the original simulation on target series *TS* records in the DAT file of the condensed dataset.

<u>Regulated Flows</u>

The basic condensed dataset methodology focuses on unappropriated river flows rather than regulated flows. However, a RUF file may be created that contains deviations between regulated and unappropriated flows from the simulation results for the original dataset that are used within a *SIM* simulation with a condensed dataset to estimate regulated flows based on adjusting unappropriated flows. The RUF file and accompanying flow adjustment options are not needed in various applications in which regulated flows are not of concern. However, the estimates of regulated flows provided by the RUF options may be required in applications that involve environmental instream flow requirements, flood control operations, or salinity simulation, or may be useful simply to provide general information regarding river flows.

<u>Negative Flows</u>

The *WRAP-HYD* based computations of inflows for the *SIM* input FLO file of a condensed dataset may result in negative flows which will be treated as zeros in *SIM*. Inflows are the summation of unappropriated flows plus streamflow depletions less return flows. Return flows from diversions from reservoir storage can occur in months with no streamflow depletions. Streamflow depletions may be negative due to negative net evaporation-precipitation, indicating precipitation exceeds evaporation as illustrated by Example 2.2. Though components of the computed inflows are sometimes negative in Example 2.2, the summation of unappropriated flows plus streamflow depletions minus return flows is never a negative number. The parameter *AS(7)* on the *HYD* adjustment specifications *AS* record provides options for dealing with negative flows if necessary. Negative values may be set to zero optionally with or without a corresponding adjustment in the next month.

CHAPTER 3
BRAZOS WAM DATASET

The TCEQ WAM System dataset for the Brazos River Basin and San Jacinto-Brazos Coastal Basin is adopted as a case study to investigate, test, evaluate, and further develop the methodology outlined in the preceding Chapter 2. This case study dataset is called the Brazos WAM throughout this report. Development of the original Brazos WAM model is described by the following reports prepared by HDR Engineering, Inc. under contract with the TCEQ.

Water Availability in the Brazos River Basin and the San Jacinto-Brazos Coastal Basin, HDR Engineering, Inc., TNRCC Contract No. 582-0-820108, December 2001.

Naturalized Flow Estimates for the Brazos River Basin and the San Jacinto-Brazos Coastal Basin, HDR Engineering, TNRCC Contract No. 582-0-820108, October 2001.

The Brazos River Basin has a total area of 44,620 square miles. The climate, hydrology, and geography of the basin varies greatly as it extends across Texas from New Mexico to the Gulf of Mexico. Mean annual precipitation varies from 19 inches in the upper basin which lies in the High Plains to 45 inches in the lower basin in the Gulf Coast region. The extreme upper end of the basin in and near New Mexico is an arid flat area that rarely contributes to stream flow.

The San Jacinto-Brazos Coastal Basin lies south of the City of Houston between the lower Brazos River Basin and Galveston Bay. This adjoining coastal basin has a watershed drainage area of 1,145 square miles and mean annual precipitation of 46.3 inches. The small streams that drain into Galveston Bay and the Gulf of Mexico include Clear Creek, Oyster Creek, and Dickinson, Mustang, Chocolate, and Bastrop Bayous.

Figure 3.1 Brazos River Basin and San Jacinto-Brazos Coastal Basin

The Brazos WAM model has 77 primary control points and a 696-month hydrologic period-of-analysis extending from January 1940 to December 1997. The authorized use and current use scenarios adopted for the WAM System are described in Chapter 1. The Brazos WAM files for the authorized use scenario (run 3) and current use scenario (run 8) have the filename roots Bwam3 and Bwam8, respectively. The Bwam3 and Bwam8 datasets used in this study were last updated by the TCEQ in August 2007. The simulation model *WRAP-SIM* prints a listing to its message file of the number of various system components. The data in Table 3.1 are taken from this listing for the authorized use and current use scenario models.

Table 3.1
Number of System Components in Brazos WAM Dataset

Water Use Scenario	Authorized	Current
Filename	Bwam3	Bwam8
Last simulation input data DAT file update	August 2007	August 2007
total number of control points	3,830	3,834
number of primary control points	77	77
control points with evaporation-precipitation rates	67	67
number of reservoirs	670	711
number of WR record water rights	1,634	1,725
number of instream flow IF record water rights	122	144
number of FD records in flow distribution DIS file	3,138	3,141

Control Points

Primary control points are locations at which naturalized flows are provided in a WAM input dataset. Naturalized flows at all other control points (called *secondary* control points) are computed within the *WRAP-SIM* simulation based on the naturalized flows provided at the primary control points and watershed parameters provided in a flow distribution DIS file.

The 77 primary control points for which naturalized stream flows are provided as *IN* records in the Bwam3.FLO and Bwam8.FLO files are listed in Table 3.2 with the six-character identifiers used in the data files. Their locations are shown in the map of Figure 3.2 and schematic of Figure 3.3. The first 73 control points listed in Table 3.2 are located in the Brazos River Basin, and the last four are in the San Jacinto-Brazos Coastal Basin.

All but three of the 77 primary control points are U.S. Geological Survey (USGS) gaging stations located on the Brazos River and its tributaries. Control point BRGM73 represents the site at which the Brazos River flows into the Gulf of Mexico. Control points SJGBC3 and SJCMC4 represent locations at which coastal basin streams flow into Galveston Bay and the Gulf of Mexico. The other 74 control points are USGS gaging stations. The USGS gage numbers and periods-of-record are included in Table 3.2 for these 74 control points. *IN* record naturalized flows at the gaged control points were computed by adjusting observed flows. In cases of periods of missing data during 1940-1997, gaps in the naturalized flows at gaged sites were filled in using regression.

The Bwam3.EVA and Bwam8.EVA files contain *EV* records with January 1940 through December 1997 sequences of monthly net reservoir surface evaporation less precipitation depths at 67 control points. The control points with *EV* record evaporation-precipitation depths are listed in Table 3.3. None of the *EV* record control points in Table 3.3 are primary control points listed in Table 3.2. The state of Texas is divided into quadrangles for purposes of compiling evaporation and precipitation data. The location of control points are indicated in Table 3.3 either by quadrangle number or by a major reservoir with its control point identifier assigned to the net evaporation data. The net evaporation-precipitation depths entered as *EV* records in the EVA file for these 67 control points are applied to reservoirs located at these control points and other nearby control points.

Table 3.2
Primary Control Points in the Brazos WAM Dataset

WAM CP ID	Stream	Nearest City	USGS Gage No.	Watershed Area (sq miles)	1940-1997 Mean Nat Flow (ac-ft/year)
RWPL01	Running Water Draw	Plainview	08080700	295	2,469
WRSP02	White River Reservoir	Spur	08080910	689	16,730
DUGI03	Duck Creek	Girard	08080950	300	10,078
SFPE04	Salt Fork Brazos River	Peacock	08081000	2,007	53,686
CRJA05	Croton Creek	Jayton	08081200	293	12,399
SFAS06	Salt Fork Brazos River	Aspermont	08082000	2,504	77,052
BSLU07	Buffalo Spring Lake	Lubbock	08079550	245	16,918
DMJU08	Double Mountain Fork	Justiceburg	08079600	265	22,230
DMAS09	Double Mountain Fork	Aspermont	08080500	1,891	108,367
NCKN10	North Croton Creek	Knox City	08082180	250	12,941
BRSE11	Brazos River	Seymour	08082500	5,996	250,096
MSMN12	Millers Creek	Munday	08082700	106	5,806
CFRO13	Clear Fork Brazos	Roby	08083100	266	7,221
CFHA14	Clear Fork Brazos	Hawley	08083240	1,456	45,162
MUHA15	Mulberry Creek	Hawley	08083245	208	7,780
CFNU16	Clear Fork Brazos	Nugent	08084000	2,236	95,668
CAST17	California Creek	Stamford	08084800	476	27,572
CFFG18	Clear Fork Brazos	Fort Griffin	08085500	4,031	174,974
HCAL19	Hubbard Creek	Albany	08086212	612	57,538
BSBR20	Big Sandy Creek	Breckenridge	08086290	289	23,348
HCBR21	Hubbard Creek	Breckenridge	08086500	1,092	97,181
CFEL22	Clear Fork Brazos	Eliasville	08087300	5,738	308,856
BRSB23	Brazos River	South Bend	08088000	13,171	656,260
GHGH24	Lake Graham	Graham	08088400	224	35,827
CCIV25	Big Cedar Creek	Ivan	08088450	97	13,452
SHGR26	Brazos River	Graford	08088600	14,093	793,483
BRPP27	Brazos River	Palo Pinto	08089000	14,309	810,380
PPSA28	Palo Pinto Creek	Santo	08090500	574	64,126
BRDE29	Brazos River	Dennis	08090800	15,733	1,003,749
BRGR30	Brazos River	Glen Rose	08091000	16,320	1,118,978
PAGR31	Paluxy River	Glen Rose	08091500	411	58,474
NRBL32	Nolan River	Blum	08092000	282	67,304
BRAQ33	Brazos River	Aquilla	08093100	17,746	1,379,053

Table 3.2 Continued
Primary Control Points in the Brazos WAM Dataset

WAM CP ID	Stream	Nearest City	USGS Gage No.	Watershed Area (sq miles)	1940-1997 Mean Nat Flow (ac-ft/year)
AQAQ34	Aquilla Creek	Aquilla	08093500	307	89,186
NBHI35	North Bosque River	Hico	08094800	360	44,879
NBCL36	North Bosque River	Clifton	08095000	977	162,919
NBVM37	North Bosque River	Valley Mills	08095200	1,158	202,937
MBMG38	Middle Bosque River	McGregor	08095300	77	55,164
HGCR39	Hog Creek	Crawford	08095400	181	25,735
BOWA40	Bosque River	Waco	08095600	1,660	356,832
BRWA41	Brazos River	Waco	08096500	20,065	1,942,324
BRHB42	Brazos River	Highbank	08098290	20,900	2,331,139
LEDL43	Leon River	De Leon	08099100	267	56,375
SADL44	Sabana River	De Leon	08099300	476	35,079
LEHS45	Leon River	Hasse	08099500	1,283	141,273
LEHM46	Leon River	Hamilton	08100000	1,928	166,469
LEGT47	Leon River	Gatesville	08100500	2,379	257,793
COPI48	Cowhouse Creek	Pidcoke	08101000	455	77,373
LEBE49	Leon River	Belton	08102500	3,579	505,257
LAKE50	Lampasas River	Kempner	08103800	817	119,776
LAYO51	Lampasas River	Youngsport	08104000	1,240	208,870
LABE52	Lampasas River	Belton	08104100	1,321	233,258
LRLR53	Little River	Little River	08104500	5,266	846,554
NGGE54	North Fork San Gabriel	Georgetown	08104700	248	57,922
SGGE55	South Fork San Gabriel	Georgetown	08104900	132	36,173
GAGE56	San Gabriel River	Georgetown	08105000	404	104,317
GALA57	San Gabriel River	Laneport	08105700	737	189,268
LRCA58	Little River	Cameron	08106500	7,100	1,318,302
BRBR59	Brazos River	Bryan	08109000	30,016	4,027,961
MYDB60	Middle Yegua Creek	Dime Box	08109700	235	39,362
EYDB61	East Yegua Creek	Dime Box	08109800	239	43,189
YCSO62	Yegua Creek	Somerville	08110000	1,011	223,399
DCLY63	Davidson Creek	Lyons	08110100	195	47,485
NAGR64	Navasota River	Groesbeck	08110325	240	83,472
BGFR65	Big Creek	Freestone	08110430	97	32,237
NAEA66	Navasota River	Easterly	08110500	936	322,578
NABR67	Navasota River	Bryan	08111000	1,427	421,304
BRHE68	Brazos River	Hempstead	08111500	34,374	5,358,943
MCBL69	Mill Creek	Bellville	08111700	377	149,586
BRRI70	Brazos River	Richmond	08114000	35,454	5,850,224
BGNE71	Big Creek	Needville	08115000	46	25,631
BRRO72	Brazos River	Rosharon	08116650	35,775	6,112,278
BRGM73	Brazos River	Gulf of Mexico	–	36,027	6,105,239
CLPEC1	Clear Creek	Pearland	08077000	38.8	28,734
CBALC2	Chocolate Bayou	Alvin	08078000	87.7	76,372
SJGBC3	Coastal Basin	Galveston Bay	–	415	345,148
SJGMC4	Coastal Basin	Gulf of Mexico	–	1,004	834,204

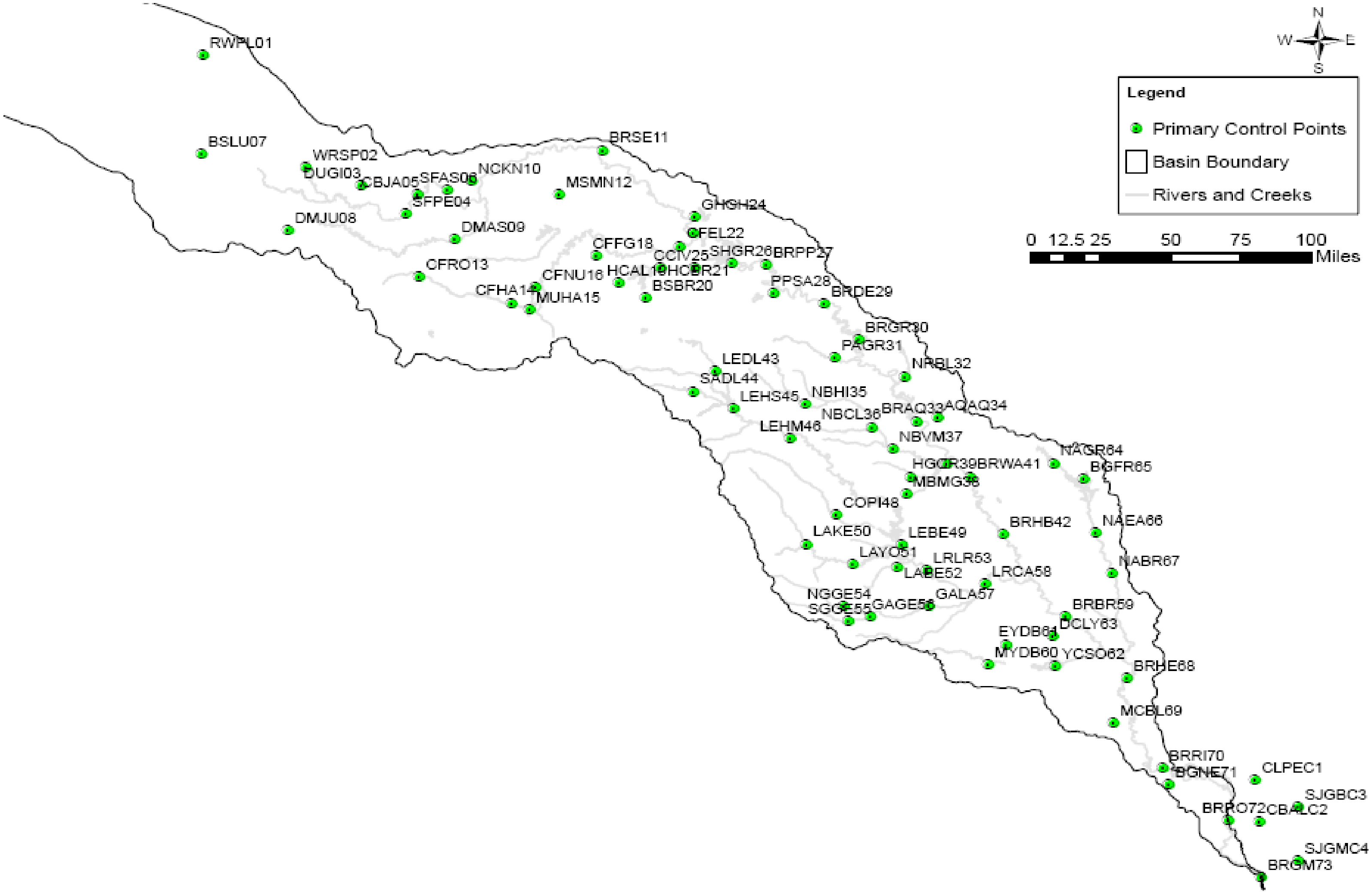

Figure 3.2 Primary Control Points

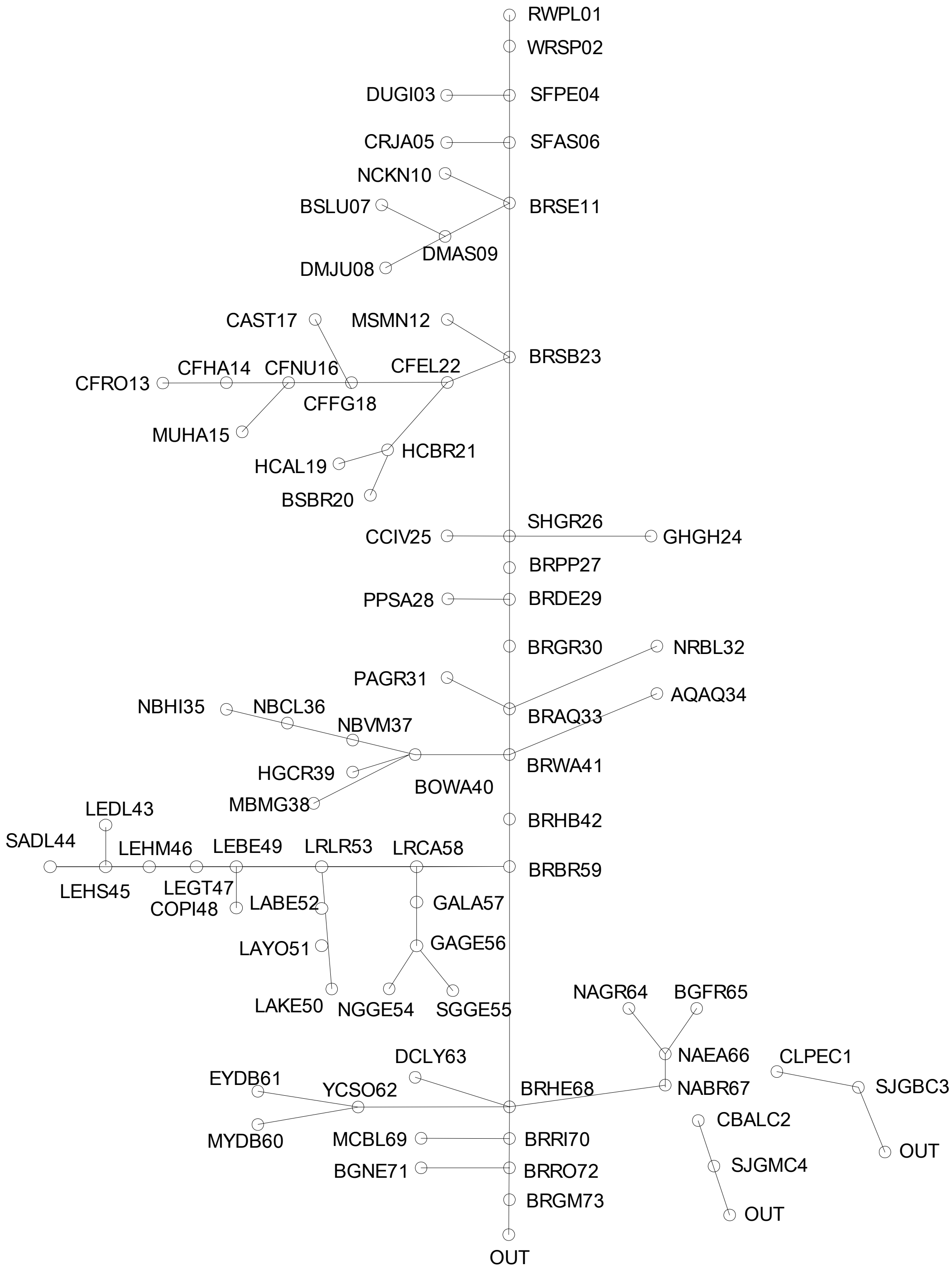

Figure 3.3 Schematic of Primary Control Points (Not to Scale)

Table 3.3
Control Points Assigned to Reservoir Net Evaporation-Precipitation Depth Input

Control Point	Quadrangle or Major Reservoir	Mean Rate feet/month	Control Point	Quadrangle or Major Reservoir	Mean Rate feet/month
366631	305	0.3216	416131	Fort Phantom Hill	0.2866
368131	306	0.3120	516231	Georgetown	0.1243
370431	405	0.3216	531131	Gibbons Creek	0.0673
368931	406	0.3053	345831	Graham	0.2473
341131	407	0.3184	515631	Granbury	0.1808
341331	408	0.2815	516331	Granger	0.1432
344801	409	0.2262	421331	Hubbard Creek	0.2557
371431	506	0.3411	415031	Kirby	0.2924
372031	507	0.3022	434531	Lake Creek	0.1611
413331	508	0.2785	347031	Leon	0.2235
220131	509	0.2364	516531	Limestone	0.1109
227031	510	0.1912	435533	Marlin City	0.1455
225331	609	0.0308	528731	Mexia	0.1480
228731	610	0.1818	344431	Millers Creek	0.2709
406331	611	0.1422	403931	Mineral Wells	0.2047
299231	710	0.1519	403131	Lake Palo Pinto	0.2183
375931	711	0.0888	410631	Pat Cleburne	0.1751
531531	712	0.0131	515531	Possum Kingdom	0.2324
401041	812	-0.0047	371131	Post	0.4469
516841	813	-0.0144	515931	Proctor	0.1734
414231	Abilene	0.2985	554032	Sandow Surface Mine	0.1354
4146P1	Alan Henry	0.3109	532531	Smithers	0.0043
527231	Alcoa	0.1354	516431	Somerville	0.0787
292531	Allen Creek	0.0392	409731	Squaw Creek	0.1768
515831	Aquilla	0.1658	417931	Stamford	0.2911
293631	Belton	0.1437	516131	Stillhouse Hollow	0.1382
532842	Brazoria	0.0512	413031	Sweetwater	0.3014
526831	Bryan Utilities	0.1011	434231	Tradinghouse Creek	0.1611
370631	Buffalo Springs	0.3104	529831	Twin oaks	0.1274
530131	Camp Creek	0.0848	231531	Waco	0.1709
421131	Cisco	0.1945	369331	White River	0.3106
421431	Daniel	0.2521	515731	Whitney	0.1709
344031	Davis	0.2913	532841	William Harris	0.0294
549231	Eagle Nest	0.0320			

The 670 reservoirs in the Bwam3 dataset and 711 reservoirs in the Bwam8 dataset are each assigned 1940-1997 sequences of monthly net evaporation-precipitation depths in feet/month read from EV records in the EVA file that are connected to one of the control points listed in Table 3.3. The first 20 control points listed in Table 3.3 serve as location identifiers for the one degree quadrangles that cover the Brazos River, which are shown on the Figure 4.1 map in Chapter 4. The other control points in Table 3.3 are locations of reservoirs. The 1940-1997 means of the net monthly net evaporation-precipitation depths are shown in the table.

Reservoirs

The authorized use dataset contains 665 reservoirs with conservation storage capacities totaling 4,694,851 acre-feet (excluding flood control storage capacity). The current use dataset contains 706 reservoirs with conservation storage capacities totaling 4,023,350 acre-feet. The range in conservation storage capacity is shown in Table 3.4. The Bwam3 and Bwam8 datasets have 246 and 266 reservoirs, respectively, that have less than 50 acre-feet of storage capacity and 12 and 11 reservoirs, respectively, that each contain over 100,000 acre-feet of conservation storage capacity. Although there are numerous smaller reservoirs, most of the total reservoir storage capacity in the Brazos River Basin is contained in a relatively few large reservoirs.

The authorized reservoir storage capacities in the Bwam3 dataset are the storage capacities stated in the water right permits. For most of the reservoirs, this is the capacity at the time of construction, prior to occurrence of reservoir sedimentation. The data for some permits are updated by sediment surveys. Reservoir storage capacity is diminished over time due to accumulation of sediment. The storage capacities in the current use Bwam8 dataset includes adjustments reflecting estimated year 2000 conditions of reservoir sedimentation.

Table 3.4
Reservoirs in the Brazos WAM

Range of Conservation Storage Capacity (acre-feet)	Authorized Use (Bwam3) Number of Reservoirs	Authorized Use (Bwam3) Total Capacity (acre-feet)	Current Use (Bwam8) Number of Reservoirs	Current Use (Bwam8) Total Capacity (acre-feet)
less than 50	246	4,440	266	4,904
50 to 99	82	5,838	89	6,325
100 to 499	195	44,558	208	47,431
500 to 999	49	35,503	51	36,841
1,000 to 4,999	44	93,738	49	108,146
5,000 to 9,999	12	94,479	10	76,849
10,000 to 49,999	18	463,298	19	511,698
50,000 to 99,999	7	421,066	3	174,621
100,000 to 499,999	10	2,171,092	9	1,943,444
greater than 500,000	2	1,360,839	2	1,113,087
Total	665	4,694,851	706	4,023,350

Table 3.1 shows the total *WRAP-SIM* counts of 670 and 711 reservoirs in the Bwam3 and Bwam8 data files. Table 3.4 shows that the numbers of actual Bwam3 and Bwam8 reservoirs are 665 and 706. The difference of five reservoirs in these counts is due to subdividing Whitney and Waco Reservoirs into component reservoirs in the model to reflect multiple owners, as shown in Table 3.5. In the 670 and 711 reservoir count of Table 3.1, Whitney Reservoir is counted as three model reservoirs, and Waco Reservoir is counted as the four reservoirs shown in Table 3.5.

Table 3.5
Whitney and Waco Component Reservoirs

Reservoir ID	Storage Capacity (acre-feet) Bwam3	Bwam8
	Whitney Reservoir	
WHITNY	387,024	311,998
BRA	50,000	50,000
CORWHT	199,076	199,076
Total	636,100	561,074
	Waco Reservoir	
LKWACO	39,100	39,100
WACO2	65,000	65,000
WACO4	88,062	88,062
WACO5	14,400	14,400
Total	206,562	206,562

Sixteen Largest Reservoirs in the Brazos River Basin

The 16 reservoirs listed in Table 3.6 are the only reservoirs in the Brazos River Basin that have a combined conservation and controlled (gated) flood control storage capacity of greater than 75,000 acre-feet. There are no reservoirs of this size in the San Jacinto-Brazos Coastal Basin. These 16 reservoirs contain about 80 percent of the conservation storage capacity and 100 percent of the flood control storage capacity in the basin. Figure 3.4 is a map showing their location. Several key USGS stream gaging stations are also shown on the map.

A system of nine federal multiple-purpose reservoirs is operated by the Corps of Engineers Fort Worth District. The Brazos River Authority (BRA) has contracted for the conservation storage in the nine federal reservoirs and owns three other reservoirs. The BRA also holds a water right permit jointly with the City of Houston and TWDB for Allens Creek Reservoir which has not yet been constructed. Two other municipal water supply reservoirs and a thermal-electric power plant cooling reservoir are included in Table 3.6.

The Brazos WAM dataset contains only conservation storage capacity, not flood control. Conservation capacity is used to store water for municipal, industrial, and agricultural water supply, hydroelectric power generation, and other beneficial uses. Flood control storage capacity is maintained empty except during and immediately following flood events. Flood control pools may be controlled by gated outlet structures operated by people or may consist of surcharge storage behind ungated structures. All of the controlled (gated) flood control storage capacity in the Brazos River Basin is contained in nine reservoirs operated by the Fort Worth District of the U.S. Army Corps of Engineers. These federal reservoirs contain flood control pools that are regulated by gated outlet structures and operating rules. There are numerous other smaller flood control dams constructed by the Natural Resource Conservation Service and other entities that have ungated outlet structures. These dams are not included in the storage capacity data presented here.

The storage capacity of the flood control pools of the nine Corps of Engineers reservoirs are tabulated in Table 3.6. The bottom of flood control pool is the top of the conservation pool. Flood control operations occur whenever lake levels rise above the top of conservation pool elevation. The flood control storage capacity shown in Table 3.6 is not included in the WAM dataset.

Possum Kingdom Lake has the largest conservation storage capacity in the Brazos River Basin, and Lake Whitney has the second largest conservation storage capacity. Considering the combined total of both flood control and conservation storage capacity, Lake Whitney is the largest reservoir in the Brazos River Basin and the seventh largest reservoir in Texas. Lakes Whitney, Granbury, and Possum Kingdom are the only major storage reservoirs on the main stream of the Brazos River. All other major reservoirs in the Brazos River Basin are on tributaries.

Table 3.6
Largest Reservoirs in the Brazos River Basin

Reservoir	WAM Identifier	Stream	Initial Impound-ment	Conservation Capacity Bwam3 (acre-feet)	Conservation Capacity Bwam8 (acre-feet)	Flood Control (acre-feet)
Brazos River Authority and U.S. Army Corps of Engineers						
Possum Kingdom	POSDOM	Brazos River	1941	724,739	552,013	–
Granbury	GRNBRY	Brazos River	1969	155,000	132,821	–
Whitney	Table 3.5	Brazos River	1951	636,100	561,074	1,372,400
Aquilla	AQUILA	Aquilla Creek	1983	52,400	41,700	86,700
Waco	Table 3.5	Bosque River	1965	206,562	206,562	553,300
Proctor	PRCTOR	Leon River	1963	59,400	54,702	310,100
Belton	BELTON	Leon River	1954	457,600	432,978	640,000
Stillhouse Hollow	STLHSE	Lampases R.	1968	235,700	224,279	390,660
Georgetown	GRGTWN	San Gabriel	1980	37,100	36,980	87,600
Granger	GRNGER	San Gabriel	1980	65,500	50,540	162,200
Limestone	LMSTNE	Navasota R.	1978	225,400	208,017	–
Somerville	SMRVLE	Yequa Creek	1967	160,110	154,254	337,700
Allens Creek	ALLENS	Allens Creek	–	145,533	–	–
City of Lubbock						
Alan Henry	ALANHN	Double Mountain	1993	115,937	115,773	–
West Central Texas Municipal Water District						
Hubbard Creek	HUBBRD	Hubbard Cr.	1962	317,750	317,750	–
Texas Utilities Services (cooling water for an electric power plant)						
Squaw Creek	SQWCRK	Squaw Creek	1977	151,500	151,015	–
Storage Capacity Totals						
Total for the 16 reservoirs listed above				3,746,331	3,240,458	3,940,660
Total of 16 reservoirs as a percentage of basin total				79.8%	80.5%	100.0%
Total for the entire river basin (665 and 706 reservoirs)				4,694,851	4,023,350	3,940,660

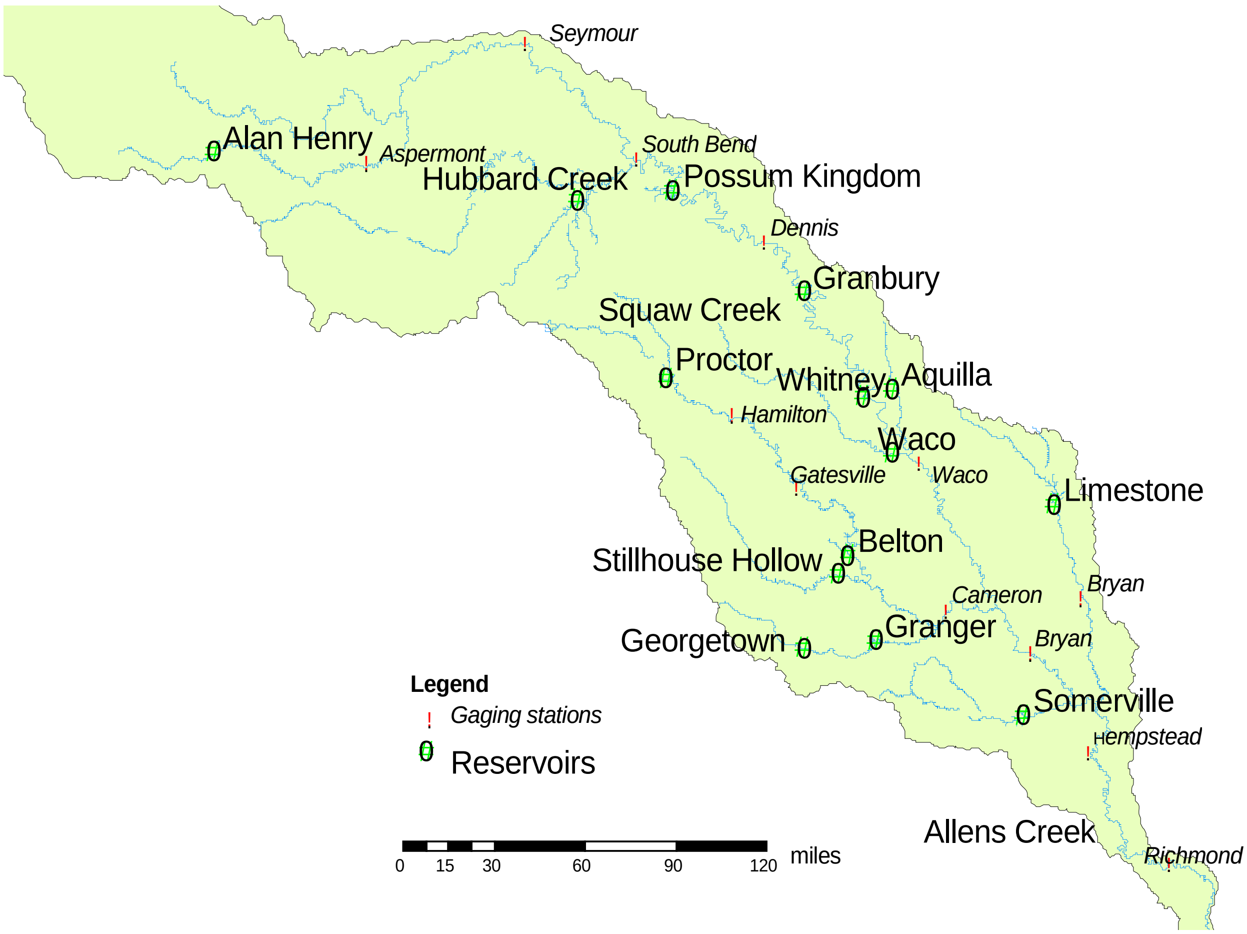

Figure 3.4 Largest Reservoirs and Selected Gaging Stations

The Fort Worth District of the U.S. Army Corps of Engineers operates a system of nine reservoirs in the Brazos River Basin that contain a little over 40 percent of the conservation storage capacity and all of the flood control storage capacity in the basin. The federal Whitney, Aquilla, Waco, Proctor, Belton, Stillhouse Hollow, Georgetown, Granger, and Somerville Reservoirs are the only reservoirs in Table 3.6 with flood control pools. The Corps of Engineers constructed, owns, and maintains the federal multiple-purpose reservoir system and is responsible for flood control operations. However, flood control operations are not modeled in the WAM datasets.

The Brazos River Authority (BRA) has contracted for most of the conservation storage capacity in the nine federal reservoirs, and owns three other reservoir projects: Lakes Possum Kingdom (Morris Sheppard Dam), Granbury (Decordova Bend Dam), and Limestone (Sterling C. Robertson Dam). The conservation storage in Lakes Waco and Proctor are dedicated to meeting local water supply needs in the vicinity of each individual reservoir. The City of Waco holds water right permits for use of water from Lake Waco. The BRA holds permits for use of most of the water supplied by the other reservoirs. The BRA operates the reservoirs as a system to meet water supply needs in the lower Brazos River Basin and adjoining coastal basins as well as in the vicinity of the reservoirs. However, the reservoirs are modeled essentially as individual projects in the August 2007 versions of the Bwam3 and Bwam 8 datasets, without detailed consideration of multiple-reservoir system operations. The water supply reservoirs are popular for recreation use.

Hydroelectric power is generated at Whitney and Possum Kingdom Reservoirs. The Southwest Power Administration is responsible for marketing hydroelectric power generated at Lake Whitney, which it sells to the Brazos Electric Power Cooperative. The BRA sells the power generated at Possum Kingdom also to the Brazos Electric Power Cooperative. Hydropower is generated by excess flows (spills) and releases for downstream water supply diversions. The inactive pool at Lake Whitney provides dead storage for hydropower. No water rights exist specifically for hydropower at the two Brazos River reservoir/hydropower projects.

In addition to releases for water supply diversions from the lower Brazos River, Possum Kingdom and Granbury Reservoirs supply water as needed to maintain constant operating levels in Lakes Squaw Creek, Tradinghouse Creek and Lake Creek which are owned and operated by utility companies for steam-electric power plant cooling. The BRA operates a desalting water treatment plant that allows use of water from Lake Granbury to supplement the water supply for the City of Granbury and other water users in Johnson and Hood Counties. The BRA holds a water right permit to impound 50,000 acre-feet of storage in Lake Whitney between elevations 520 feet (387,024 acre-feet) and 533 feet (642,179 acre-feet) to supply a diversion of 18,336 acre-feet/year for municipal use. The BRA has a water supply contract with the Corps of Engineers for the 50,000 acre-feet of storage capacity in Lake Whitney.

Allens Creek Reservoir is a proposed BRA storage project that has not yet been constructed. The BRA, City of Houston, and Texas Water Development Board jointly hold a water right permit for the proposed project. A water right permit was initially issued to Houston Lighting and Power (Reliant Energy) to construct a cooling lake for a nuclear power plant. The electric power plant was abandoned during the 1980s, and the City of Houston and BRA acquired the site for a municipal water supply storage project. The reservoir site is on Allens Creek, a tributary of the lower Brazos River, in Austin County near the towns of Wallis and Simonton. Allens Creek Reservoir is included in the Bwam3 dataset but is not included in Bwam8.

Lake Alan Henry in the upper basin is the most recently constructed of the 16 largest reservoirs listed in Table 3.6. The Brazos River Authority was responsible for the initial planning for the Alan Henry Reservoir project and held the original water right permit. Lake Alan Henry is now owned and operated by the City of Lubbock for municipal water supply. The West Central Texas Municipal Water District operates Hubbard Creek Reservoir to supply the cities of Abilene, Albany, Anson, and Breckenridge and other water users.

Squaw Creek Reservoir owned by Texas Utilities Services Company provides cooling water for the Comanche Peak Nuclear Power Plant. The reservoir is located between the cities of Glen Rose and Granbury on Squaw Creek which flows into the Brazos River between Lakes Granbury and Whitney. The BRA supplies water from Lakes Possum Kingdom and Granbury as needed to maintain a constant water level in Squaw Creek Reservoir to meet the demands of the power plant.

<u>Reservoirs with Authorized Storage Capacities Greater than 10,000 acre-feet</u>

Table 3.7 and Figure 3.5 show the 37 reservoirs in the Brazos River Basin with water right permits that authorize storage capacities exceeding 10,000 acre-feet. The proposed Allens Creek Reservoir is included along with 36 actual existing reservoirs. These 37 reservoirs contain about 93.4 percent of the authorized storage capacity in the basin reflected in all of the water right permits.

With the notable exception of Lake Whitney, the authorized storage capacities tabulated in Table 3.7 are the capacities included in the Bwam3 dataset. However, of the total Lake Whitney conservation storage capacity of 636,100 acre-feet shown in Table 3.5, only 50,000 acre-feet is authorized in a water right permit and thus tabulated in Table 3.7.

Table 3.7
Reservoirs with Authorized Storage Capacities Exceeding 10,000 acre-feet

Reservoir	Stream	County	Storage	Diversion	Owner
			(acre-feet)	(ac-ft/yr)	
Abilene	Elm Creek	Taylor	11,868	1,675	City of Abilene
Alan Henry	SF Double Mountain	Garza	115,937	35,000	City of Lubbock
Alcoa Lake	Sandy Creek	Milan	15,650	14,000	ALCOA Company
Allens Creek	Allens Creek	Austin	145,533	99,650	Brazos River Authority
Aquilla	Aquilla Creek	Hill	52,400	13,896	Corps of Engineers
Belton	Leon River	Bell	457,600	100,257	Corps of Engineers
Brazoria	Off-Channel	Brazoria	21,700	75,656	Dow Chemical
Bryan Utilities	Unnamed Tributary	Brazos	15,227	850	City of Bryan
Cisco	Sandy Creek	Eastland	45,000	2,027	City of Cisco
Cleburne	Nolan Creek	Johnson	25,600	6,000	City of Cleburne
Daniel	Gonzales Creek	Stephens	11,400	2,100	City of Breckenridge
Eagles Nest	Vamers Creek	Brazoria	11,315	1,800	T.L Smith Trust
Fort Phantom Hill	Elm Creek	Jones	73,960	33,190	City of Abilene
Georgetown	NF San Gabriel River	Williamson	37,100	13,610	Corps of Engineers
Gibbons Creek	Gibbons Creek	Grimes	32,084	9,740	Tex Mun Power Agency
Graham/Eddlerman	Flint Creek	Young	52,386	20,000	City of Graham
Granbury	Brazos River	Hood	155,000	64,712	Brazos River Authority
Granger	San Gabriel River	Williamson	65,500	19,840	Corps of Engineers
Harris	Off-Channel	Brazoria	10,200	230,000	Dow Chemical
Hubbard Creek	Hubbard Creek	Stephens	317,750	56,000	West Central Tex MWD
Leon	Leon River	Eastland	28,000	6,301	Eastland Co. WSD
Limestone	Navasota River	Robertson	225,400	65,074	Brazos River Authority
Millers Creek	Millers Creek	Baylor	30,696	5,000	North Central Tex MWD
Palo Pinto	Palo Pinto Creek	Palo Pinto	44,100	13,480	Palo Pinto MWD
Possum Kingdom	Brazos River	Palo Pinto	724,739	230,750	Brazos River Authority
Post	NF Double Mountain	Garza	57,420	10,600	White River MWD
Proctor	Leon River	Comanche	59,400	19,658	Corps of Engineers
Smithers	Smithers Creek	Fort Bend	18,750	34,300	Houston L&P Company
Somerville	Yegua Creek	Washington	160,110	48,000	Corps of Engineers
Squaw Creek	Squaw Creek	Somervell	151,500	23,180	Texas Utilities Electric
Stamford	Paint Creek	Haskell	60,000	10,000	City of Stamford
Stillhouse Hollow	Lampasas River	Bell	235,700	67,768	Corps of Engineers
Tradinghouse	Tradinghouse Creek	McLennan	37,800	15,000	Texas Utilities Electric
Twin Oaks	Duck Creek	Robertson	30,319	13,200	Texas Utilities Electric
Waco	Bosque River	McLennan	206,562	79,870	Corps of Engineers
White River	White River	Crosby	44,897	6,000	White River MWD
Whitney	Brazos River	Hill	50,000	18,336	Corps of Engineers
			----------	----------	
Total			3,838,603	1,466,520	

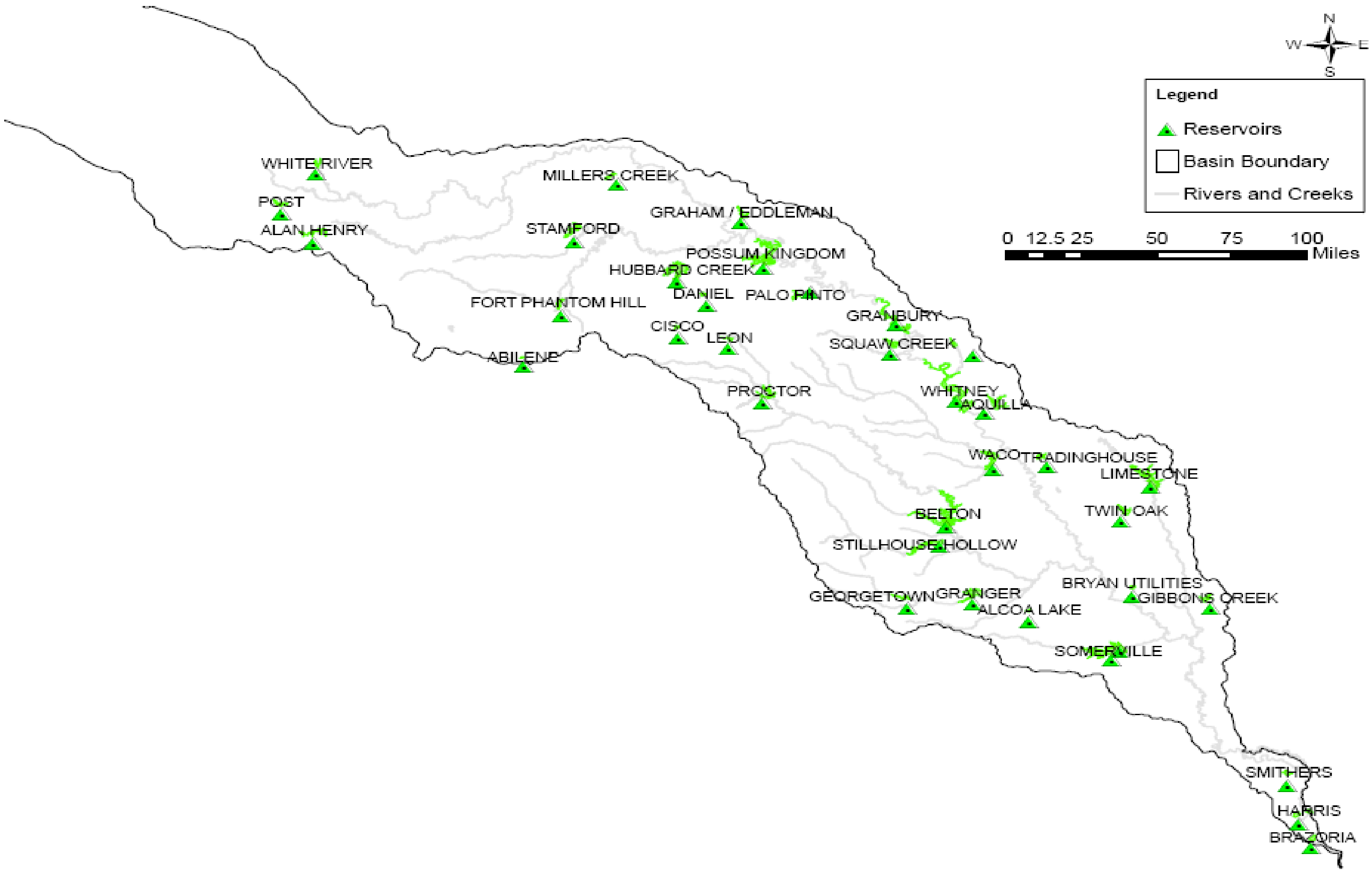

Figure 3.5 Reservoirs with Authorized Storage Capacities Exceeding 10,000 acre-feet

Water Rights

The Bwam3 authorized use scenario input data file with filename extension DAT contains 1,634 water right *WR* records and 122 instream flow *IF* records. The Bwam8 current use scenario DAT file contains 1,725 *WR* records and 144 *IF* records. In many cases, a single *WR* record represents a single actual water right permit. However, in some cases, multiple *WR* and *IF* records are used to model a particular water right permit. For example, separate *WR* records are included for municipal, industrial, and agricultural water use authorized by the same water right permit.

The Bwam3 and Bwam8 datasets model the authorized use and current use scenarios described in Chapter 1. The differences between the Bwam3 authorized use scenario and Bwam8 current use scenario models are as follows.

- The Bwam3 water supply diversion targets are based on the authorized amounts specified in the water right permits. The Bwam8 dataset models the current use scenario. Diversion targets were adopted based on the maximum annual water use associated with each individual water right permit during any year during 1988 through 1997. The Bwam8 diversion targets are generally significantly smaller than the Bwam3 diversion targets.
- The Bwam3 authorized use dataset has no return flows associated with the authorized diversions. Bwam8 includes estimated return flows. The Bwam8 return flows significantly increase water availability.
- The Bwam3 reservoir storage capacities are authorized volumes from the water right permits which typically reflect conditions at the time of initial impoundment prior to accumulation of sediment deposits. The Bwam8 storage capacities are adjusted to reflect estimated year 2000 conditions of reservoir sedimentation. The total storage capacity in the Bwam8 dataset is smaller than the storage capacity in Bwam3.
- Bwam8 includes term permits which are issued for fixed relatively short-term periods of time as well as regular water right permits. Bwam3 does not. Thus, Bwam8 has more water rights. However, the term permits generally involve relatively small storage and diversion volumes.

Overview of All Water Rights in the Dataset

The authorized diversions associated with the 37 reservoirs with conservation storage capacities greater than 10,000 acre-feet are tabulated in Table 3.7. The storage volumes and annual diversion volumes in Table 3.7 are the amounts specified in the water right permits which are modeled by Bwam3. The authorized diversion amounts associated with these 37 reservoirs represent about 60.2 percent of the total of the authorized diversion targets in the Bwam3 dataset.

The diversion targets for the water rights in the Bwam3 and Bwam8 input data DAT files sum to 2,437,338 and 1,496,432 acre-feet/year, respectively. Diversion targets from the water right *WR* records of the Bwam3 and Bwam8 DAT files are summarized in Tables 3.8 and 3.9, respectively. The water use type identifier connecting the *WR* records to monthly water use distribution factor *UC* records are shown in the first column of Tables 3.8 and 3.9. The following four regions of the river basin cited in the first column are considered in specifying *UC* record sets of 12 monthly water use distribution factors as well as the type of use.

- Region 1 is the upper basin upstream of Possum Kingdom reservoir. Alan Henry and Hubbard Creek Reservoirs are located in Region 1.
- Region 2 is the upper middle basin between Regions 1 and 3. Possum Kingdom, Granbury, Aquilla, Waco, Proctor, and Belton Reservoirs are in Region 2.
- Region 3 is the lower middle basin below Whitney Dam that includes the Little River and Navasota River subbasins. Stillhouse Hollow, Georgetown, Granger, Limestone, Somerville Reservoirs are located in Region 3.
- Region 4 in the lower basin below the confluence of the Navasota River with the Brazos River. The proposed Allens Creek Reservoir will be located in Region 4.

Several water supply diversion rights held by the Brazos River Authority and other permit holders are authorized for multiple types of use but included in the WAM dataset as municipal use. Since reservoirs supply multiple types of use, the storage capacities in Tables 3.8 and 3.9 reflect counting the same reservoirs more than once.

Table 3.8
Water Rights Summary for Bwam3 Authorized Use Scenario

Water Use Type Identifier on *UC* and *WR* Records (Type of Use and Region)	Number of WR Records	Total of Diversion Targets	Total Storage Capacity	Priorities Range from	to
		(ac-ft/yr)	(acre-feet)		
MUN1 municipal, region 1	39	165,493	2,339,399	Jun 1914	Oct 1981
MUN2 municipal, region 2	85	329,774	15,974,008	Oct 1914	88888888
MUN3 municipal, region 3	31	159,377	1,850,580	Mar 1914	Feb 2000
MUN4 municipal, region 4	33	672,752	355,332	0	Jun 2001
IRR1 irrigation, region 1	156	25,875	490,764	Dec 1914	Jun 1996
IRR2 irrigation, region 2	570	81,869	3,373,950	Dec 1889	Apr 2002
IRR3 irrigation, region 3	225	53,248	883,133	Dec 1883	Apr 2002
IRR4 irrigation, region 4	71	101,554	39,884	Jun 1914	Jun 2000
IND1 industrial, region 1	20	19,691	707,547	Mar 1925	Oct 1981
IND2 industrial, region 2	24	251,692	4,176,287	Oct 1915	Mar 1986
IND3 industrial, region 3	43	148,368	1,647,647	Jun 1914	Nov 1993
IND4 industrial, region 4	21	269,902	74,232	Jun 1914	Jan 1997
MIN1 mining, region 1	24	23,133	523,695	Jul 1926	Jul 2000
MIN2 mining, region 2	13	21,040	2,900,952	Dec 1919	Oct 2000
MIN3 mining, region 3	17	547	717,644	Dec 1963	Oct 1976
MIN4 mining, region 4	3	54,300	0	Feb 1939	Jul 2000
HYD2 PK hydropower	1	3,600	724,739	Apr 1934	Apr 1934
WHIT1, Whitney municipal	3	18,336	299,076	Aug 1982	99999999
UNIFO uniform distribution	180	543	1,126,539	Jun 1914	99999999
other individual water rights	75	36,243	1,685,440	Jun 1914	99999999
Total	1,634	2,437,337			

Table 3.9
Water Rights Summary for Bwam8 Current Use Scenario

Water Use Type Identifier on *UC* and *WR* Records (Type of Use and Region)	Number of WR Records	Total of Diversion Targets	Total Storage Capacity	Priorities Range from	to
		(ac-ft/yr)	(acre-feet)		
MUN1 municipal, region 1	39	50,502	2,284,300	Jun 1914	Oct 1981
MUN2 municipal, region 2	89	167,868	14,217,771	Oct 1914	88888888
MUN3 municipal, region 3	31	101,701	1,742,405	Mar 1914	Feb 2000
MUN4 municipal, region 4	32	484,515	64,301	0	Jun 2001
IRR1 irrigation, region 1	158	14,385	495,565	Dec 1914	Jun 1996
IRR2 irrigation, region 2	626	71,586	2,811,547	Dec 1889	Apr 2002
IRR3 irrigation, region 3	244	37,316	835,443	Dec 1883	Apr 2002
IRR4 irrigation, region 4	72	83,674	39,884	Jun 1914	Jun 2000
IND1 industrial, region 1	20	5,354	621,846	Mar 1925	Oct 1981
IND2 industrial, region 2	27	94,951	3,419,223	Oct 1915	Mar 1986
IND3 industrial, region 3	44	82,572	1,557,606	Jun 1914	Nov 1993
IND4 industrial, region 4	21	250,480	73,257	Jun 1914	Jan 1997
MIN1 mining, region 1	23	3,199	432,243	Jul 1926	Jul 2000
MIN2 mining, region 2	13	13,336	2,320,575	Dec 1919	Oct 2000
MIN3 mining, region 3	19	338	675,950	Dec 1963	Oct 1976
MIN4 mining, region 4	3	3,957	0	Feb 1939	Jul 2000
HYD2 PK hydropower	1	3,600	522,013	Apr 1934	Apr 1934
WHIT1 Whitney municipal		18,336	50,000	Aug 1982	99999999
UNIFO uniform distribution	184	426	184	Jun 1914	99999999
other individual water rights	79	26,470	1,769,002	Jun 1914	99999999
Total	1,725	1,496,230			

The Bwam3 DAT file contain 122 *IF* records specifying instream flow requirements. The Bwam8 dataset has 144 *IF* records. All instream flow rights require junior rights to pass inflows through reservoirs if necessary to meet the minimum instream flow targets. However, most of the *IF* record rights do not require release of additional water from reservoir storage to meet the instream flow targets. The exceptions are the following three relatively small instream flow rights that do require releases from reservoir storage if necessary to satisfy instream flow targets.

- *IF* record right IFC4097_1 sets a target of 1,086 acre-feet/year distributed uniformly over the 12 months of the year at control point 409702. Releases are made as necessary from Squaw Creek Reservoir.
- *IF* record right IFC5158_1 sets a target of 362 acre-feet/year distributed uniformly over the 12 months of the year at control point 515831. Releases are made as necessary from Aquilla Reservoir.
- *IF* record right IFC4355_1 sets a target of 72 acre-feet/year distributed uniformly over the 12 months of the year at control point 435533. Releases are made as necessary from Brushy Creek Reservoir.

Water Rights Associated with the 16 Largest Reservoirs

The annual diversion targets for the Bwam3 authorized use scenario and Bwam8 current use scenario are tabulated in Table 3.10 for water rights associated with the 16 large reservoirs previously listed in Table 3.6. The totals for the entire dataset are shown at the bottom of Table 3.10. The diversion targets associated with these 16 reservoirs account for about 39.7 percent and 31.7 percent of the total authorized diversion amounts for the Bwam3 and Bwam8 datasets.

For most of the 1,634 water right *WR* records in the Bwam3 DAT file or 1,725 *WR* records in the Bwam8 DAT file, each individual *WR* record represents a particular water right permit. In most cases, a water right permit is modeled with a single *WR* record and associated reservoir storage WS record. However, the water right permits governing the water supplied by the larger reservoirs are more complex. Several *WR* records may be used to model a single water right permit.

Information from the 133 *WR* records in the Bwam3 DAT file connected to the 16 largest reservoirs is tabulated in Table 3.11. Each of the 133 model water rights listed in Table 3.11 corresponds to a *WR* record in the Bwam3 DAT file. The water right identifier and corresponding control point identifier for the right are tabulated in the first two columns of Table 3.11. The annual diversion target in acre-feet/year for the water right is shown in the third column. The use type in the fourth column connects the annual diversion target to a set of 12 monthly water use distribution factors entered on water use coefficient *UC* records.

Bwam3 has zero return flows for all water rights. However, the Bwam3 and Bwam8 data files are designed to contain essentially the same records with entries in certain fields being different as appropriate for the authorized and current use scenarios. Thus, the files are designed so that return flows are conveniently activated in Bwam8 and set at zero in Bwam3. Return flows may be specified on the *WR* record as a constant fraction of monthly diversion volumes, or alternatively, a set of 12 monthly varying fractions may be specified. Both of these alternative options are incorporated in the water rights listed in Table 3.11. The identifier of the control point at which Bwam8 diversion return flows return to the river system is tabulated in the sixth column of Table 3.11. The default is for return flows to enter the river at the control point located immediately downstream of the diversion. The sixth column is blank for the majority of the water rights in Table 3.11 indicating adoption of the default next downstream control point option.

There are no water right permits for hydroelectric power generation at Lakes Whitney and Possum Kingdom. Most of the water that flows through the hydroelectric power turbines at these reservoirs consists of spills from full conservation pools or releases for downstream water supply diversions. Water right C5155_21 at Possum Kingdom Reservoir has an annual diversion target of 3,600 acre-feet/year and return flow factor of 100 percent. Water right C5155_21 represents the contribution of hydropower releases in meeting an instream flow requirement set by the Federal Energy Regulatory Commission.

The conservation pool of Lake Whitney serves largely to provide recreation and head for hydropower. Lake Whitney is an abnormality in the reservoir storage capacity inventory in that most of its conservation storage capacity, though included in both the Bwam3 and Bwam8 datasets, is not specified in any water right permit. The total conservation storage capacity of Lake Whitney is 636,100 and 561,074 acre-feet in the Bwam3 and Bwam8 datasets as shown in Table 3.5. The

Lake Whitney storage capacity authorized by a water right permit is 50,000 acre-feet between elevation 520 feet above mean sea level (387,024 acre-feet storage level) and 523 feet (642,179 acre-feet).

Table 3.10
Brazos WAM Water Rights

Reservoir	Reservoir Identifier	Control Point	Storage (acre-feet) Bwam3	Storage (acre-feet) Bwam8	Diversion (ac-ft/year) Bwam3	Diversion (ac-ft/year) Bwam8
Brazos River Authority System						
Possum Kingdom	POSDOM	515531	724,739	552,013	230,750	59,482
Granbury	GRNBRY	515631	155,000	132,821	64,712	36,025
Whitney	WHITNY	515731	387,024	311,998	0	0
	BRA	515731	50,000	50,000	18,336	18,336
	CORWHT	515731	199,076	199,076	0	0
Aquilla	AQUILA	515831	52,400	41,700	13,896	2,394
Waco	LKWACO	509431	39,100	39,100	39,100	37,448
	WACO2	509431	65,000	65,000	20,000	900
	WACO4	509431	88,062	88,062	20,777	0
	WACO5	509431	14,400	14,400	0	0
Proctor	PRCTOR	515931	59,400	54,702	19,658	14,068
Belton	BELTON	516031	457,600	432,978	112,257	107,738
Stillhouse Hollow	STLHSE	516131	235,700	224,279	67,768	67,768
Georgetown	GRGTWN	516231	37,100	36,980	13,610	11,943
Granger	GRNGER	516331	65,500	50,540	19,840	2,569
Limestone	LMSTNE	516531	225,400	208,017	65,074	39,337
Somerville	SMRVLE	516431	160,110	154,254	48,000	48,000
Allens Creek	ALLENS	292531	145,533	–	99,650	–
City of Lubbock						
Alan Henry	ALANHN	4146P1	115,937	115,773	35,000	288
West Central Texas Municipal Water District						
Hubbard Creek	HUBBRD	421331	317,750	317,750	56,000	9,924
Texas Utilities Services (cooling water for an electric power plant)						
Squaw Creek	SQWCRK	409702	151,500	151,015	23,180	17,536
Water Right Totals						
Total for the 16 reservoirs listed above			3,746,331	3,240,458	967,608	473,756
Percentage of basin total			(79.8%)	(80.5%)	(39.7%)	(31.7%)
All other water rights			948,520	782,892	1,469,730	1,022,675
Total for the entire river basin			4,694,851	4,023,350	2,437,338	1,496,431

Table 3.11
Bwam3 and Bwam8 Water Right *WR* Records Connected to the 16 Largest Reservoirs

Water Right	Control Point	Bwam3 Diversion	Bwam8 Diversion	Use Type	Priority	Return Flow CP	Water Right Permit Holder
		(ac-ft/yr)	(ac-ft/yr)				
Possum Kingdom Reservoir (POSDOM) with Storage Capacity of 724,739 and 552,013 acre-feet							
C5155_1	515531	1,000	1,000	MUN2	19380406	27891	Brazos River Authority
C5155_2	515531	237	237	MUN2	19380406		Brazos River Authority
C5155_3	515531	1,200	1,200	MUN2	19380406	101102	Brazos River Authority
C5155_4	515531	315	315	MUN2	19380406	106271	Brazos River Authority
C5155_5	515531	473	473	MUN2	19380406	104101	Brazos River Authority
C5155_6	515531	2,051	2,051	MUN2	19380406	105685	Brazos River Authority
C5155_7	515531	3,549	3,549	MUN2	19380406	103751	Brazos River Authority
C5155_8	515531	1,499	1,499	MUN2	19380406	101731	Brazos River Authority
C5155_9	515531	40,753	1,999&50	MUN2	19380406		Brazos River Authority
C5155_10	515531	5240	264	MUN2	19380406		Brazos River Authority
C5155_11	515531	168	13.9	IND2	19380406		Brazos River Authority
C5155_12	515531	107,447	8,864.4	IND2	19380406		Brazos River Authority
C5155_13	515531	371	30.6	IND2	19380406		Brazos River Authority
C5155_14	515531	31,538	2,601.9	IND2	19380406		Brazos River Authority
C5155_15	515531	1273	1,918.3	IRR2	19380406		Brazos River Authority
C5155_16	515531	840	1,275.8	IRR2	19380406		Brazos River Authority
C5155_17	515531	10,099	15,218.2	IRR2	19380406		Brazos River Authority
C5155_18	515531	18,924	13,201.4	MIN2	19380406		Brazos River Authority
C5155_19	515531	158	110.2	MIN2	19380406		Brazos River Authority
C5155_20	515531	15	10.5	MIN2	19380406		Brazos River Authority
C5155_21	515531	3,600	3,600	HYD2	19380406	515551	Brazos River Authority
Granbury Reservoir (GRNBRY) Storage Capacity of 155,000 (Bwam3) and 132,821 (Bwam8) ac-ft							
C5156_1	515631	1,557	397	MUN2	19640213		Brazos River Authority
C5156_2	515631	2,600	624	MUN2	19640213		Brazos River Authority
C5156_3	515631	6,705	1,652.8	MUN2	19640213	101782	Brazos River Authority
C5156_4	515631	1,475	363.6	MUN2	19640213		Brazos River Authority
C5156_5	515631	1,073	264.5	MUN2	19640213		Brazos River Authority
C5156_6	515631	2	1.3	IND2	19640213		Brazos River Authority
C5156_7	515631	3,748	2,472.2	IND2	19640213		Brazos River Authority
C5156_8	515631	40,000	26,384	IND2	19640213		Brazos River Authority
C5156_9	515631	4,544	2,326.1	IRR2	19640213		Brazos River Authority
C5156_10	515631	2,806	1,436.4	IRR2	19640213		Brazos River Authority
C5156_11	515631	200	102.4	IRR2	19640213		Brazos River Authority
C5156_12	515631	2	1.0	MIN2	19640213		Brazos River Authority
Whitney Reservoir (WHITNY) Storage Capacity of 387,024 (Bwam3) and 311,998 (Bwam8) ac-ft							
USACE_WHIT	515731	0	0		88888888		Corps of Engineers
EVAP1	515731	0	0		99999999		Corps of Engineers
Whitney Reservoir (BRA) Storage Capacity of 50,000 acre-feet (both Bwam3 and Bwam8)							
C5157_2	515731	18,336	18,336	WHIT1	19820830		Brazos River Authority
C5157_3	515731	0	0	WHIT1	40000101		Brazos River Authority
EVAP2	515731	0	0		99999999		
Whitney Reservoir (CORWHT) Storage Capacity of 199,076 acre-feet (both Bwam3 and Bwam8)							
FILLWHT	515731	0	0	WHIT1	99999999		Brazos River Authority
EVAP3	515731	0	0		99999999		Brazos River Authority
Aquilla Reservoir (AQUILLA) Storage Capacity of 52,400 (Bwam3) and 41,700 (Bwam8) acre-feet							
C5158_1	515831	12,246	2,110	MUN2	19761025		Brazos River Authority
C5158_2	515831	1,650	284.3	MUN2	19761025	106301	Brazos River Authority

C5158_3	515831	0	0	IND2	19761025		Brazos River Authority
C5158_4	515831	0	0	MIN2	19761025		Brazos River Authority
C5158_5	515831	0	0	UNIFO	19761025		Brazos River Authority

Waco Reservoir with Total Storage Capacity of 155,000 (Bwam3) and 132,821 (Bwam8) acre-feet

Waco Reservoir (LKWACO) Storage Capacity of 39,100 acre-feet (both Bwam3 and Bwam8)

C2315_1	509431	39,100	37,448	MUN2	19290110	110711	City of Waco
C2315_4	509431	0	0		99999999		City of Waco

Waco Reservoir (WACO2) Storage Capacity of 65,000 acre-feet (both Bwam3 and Bwam8)

C2315_2	509431	19,100	0	MUN2	19580416	110711	City of Waco
C2315_3	509431	900	900	IRR21	19790221		City of Waco

Waco Reservoir (WACO2) Storage Capacity of 39,100 acre-feet (both Bwam3 and Bwam8)

C2315_5	509431	0	0		99999999		

Waco Reservoir (WACO4) Storage Capacity of 88,062 acre-feet (both Bwam3 and Bwam8)

P5094_1	509431	20,089	0	MUN2	19860912	110711	City of Waco
P5094_2	509431	688	0	MUN2	19880121	110711	City of Waco
P5094_4	509431	0	0		99999999		

Waco Reservoir (WACO5) Storage Capacity of 14,400 acre-feet (both Bwam3 and Bwam8)

P5094_3	509431	0	0		88888888		City of Waco
P5094_3	509431	0	0		99999999		City of Waco

Proctor Reservoir (PRCTOR) Storage Capacity of 59,400 (Bwam3) and 54,702 (Bwam8) acre-feet

C5159_1	515931	2,685	1,343	MUN2	19631216		Brazos River Authority
C5159_2	515931	735	367.6	MUN2	19631216		Brazos River Authority
C5159_3	515931	1,147	573.7	MUN2	19631216		Brazos River Authority
C5159_4	515931	1,772	886.4	MUN2	19631216		Brazos River Authority
C5159_5	515931	1,671	835.8	MUN2	19631216		Brazos River Authority
C5159_6	515931	0	0.0	IND2	19631216		Brazos River Authority
C5159_7	515931	5,948	5137.9	IRR2	19631216		Brazos River Authority
C5159_8	515931	5,700	4,923.7	IRR2	19631216		Brazos River Authority
C5159_9	515931	0	0.0	MIN2	19631216		Brazos River Authority
C5159_10	515931	0	0.0	INIFO	19631216		Brazos River Authority

Belton Reservoir (BELTON) Storage Capacity of 10,000 acre-feet (both Bwam3 and Bwam8)

C2936_1	516031	10,000	7,483	MUN2	19530824		US Department of Army

Belton Reservoir (BELTON) Storage Capacity of 12,000 acre-feet (both Bwam3 and Bwam8)

C2936_2	516031	2,000	0	MUN2	19540823		US Department of Army

Belton Reservoir (BELTON) Storage Capacity of 457,600 (Bwam3) and 387,024 (Bwam8) acre-feet

C5160_1	516031	7,056	4,944.1	MUN2	19631216	102191	Brazos River Authority
C5160_2	516031	1,245	872.4	MUN2	19631216		Brazos River Authority
C5160_3	516031	3,432	2,404.8	MUN2	19631216	101761	Brazos River Authority
C5160_4	516031	2,016	1,412.6	MUN2	19631216	101741	Brazos River Authority
C5160_5	516031	27,735	19,433.9	MUN2	19631216	103513	Brazos River Authority
C5160_6	516031	7,745	5,426.9	MUN2	19631216	103512	Brazos River Authority
C5160_7	516031	540	378.4	MUN2	19631216		Brazos River Authority
C5160_8	516031	1,758	1,231.8	MUN2	19631216	100451	Brazos River Authority
C5160_9	516031	4,549	3,187.5	MUN2	19631216	100455	Brazos River Authority
C5160_10	516031	1,758	1,231.8	MUN2	19631216	100451	Brazos River Authority
C5160_11	516031	5,424	3,801.0	MUN2	19631216	101551	Brazos River Authority
C5160_12	516031	17,484	12,251.0	MUN2	19631216	113181	Brazos River Authority
C5160_13	516031	10,469	7,335.6	MUN2	19631216	104702	Brazos River Authority
C5160_14	516031	5,411	3,791.5	MUN2	19631216		Brazos River Authority
C5160_15	516031	200	140.1	MUN2	19631216		Brazos River Authority
C5160_16	516031	2,365	16,843.0	IND2	19631216		Brazos River Authority
C5160_17	516031	1,070	15,568.0	IRR2	19631216		Brazos River Authority

Stillhouse Hollow (STLHSE) Storage Capacity of 235,700 (Bwam3) and 224,279 (Bwam8) acre-feet

C5161_1	516131	6,973	6,973	MUN3	19631216	102051	Brazos River Authority
C5161_2	516131	2,092	2,092	MUN3	19631216		Brazos River Authority

C5161_3	516131	4,880	4,880	MUN3	19631216		Brazos River Authority
C5161_4	516131	53,823	53,823	MUN3	19631216		Brazos River Authority
Georgetown Reservoir (GRGTWN) Storage Capacity of 37,100 (Bwam3) and 36,980 (Bwam8) ac-ft							
C5162_1	516231	4,764	4,130.9	MUN3	19680212	104893	Brazos River Authority
C5162_2	516231	2,041	1,769.8	MUN3	19680212	104892	Brazos River Authority
C5162_3	516231	3,198	2,773.0	MUN3	19680212	102641	Brazos River Authority
C5162_4	516231	3,607	3,127.6	MUN3	19680212	102642	Brazos River Authority
C5162_5	516231	0	0.3	IND3	19680212		Brazos River Authority
C5162_6	516231	0	141.8	MIN3	19680212		Brazos River Authority
C5162_7	516231	0	0.0	IRR3	19680212		Brazos River Authority
Granger Reservoir (GRNGER) Storage Capacity of 65,500 (Bwam3) and (Bwam8) acre-feet							
C5163_1	516331	6,566	1,175.9	MUN3	19680212		Brazos River Authority
C5163_2	516331	6,721	1,203.1	MUN3	19680212	102991	Brazos River Authority
C5163_3	516331	5,659	0	IND3	19680212		Brazos River Authority
C5163_4	516331	0	0	IND3	19680212		Brazos River Authority
C5163_5	516331	20	0	MIN3	19680212		Brazos River Authority
C5163_6	516331	874	190	IRR3	19680212		Brazos River Authority
Limestone Reservoir (LMSTNE) Storage Capacity of 217,494 (Bwam3) and 208,017 (Bwam8) ac-ft							
C5165_1	516531	28,415	54	MUN3	19740506		Brazos River Authority
C5165_2	516531	200	1	MUN3	19740506		Brazos River Authority
C5165_3	516531	21,602	23,271.8	IND3	19740506		Brazos River Authority
C5165_4	516531	11,255	12,125	IND3	19740506		Brazos River Authority
C5165_5	516531	3,600	3,878.3	IND3	19740506		Brazos River Authority
C5165_6	516531	0	0	IRR3	19740506		Brazos River Authority
C5165_7	516531	2	7.0	MIN3	19740506		Brazos River Authority
C5165_8	516531	0	0	UNIFO	19790904		Brazos River Authority
Somerville Reservoir (SMRVLE) Storage Capacity of 160,110 (Bwam3) and (Bwam8) ac-ft							
C5164_1	516431	4,619	4,619	MUN3	19631216	103881	Brazos River Authority
C5164_2	516431	6,658	6,658	IND3	19631216		Brazos River Authority
C5164_3	516431	23,763	23,763	IND3	19631216		Brazos River Authority
C5164_4	516431	0	0	IRR3	19631216		Brazos River Authority
C5164_5	516431	12,928	12,928	IRR3	19631216		Brazos River Authority
C5164_6	516431	32	32	MIN3	19631216		Brazos River Authority
C5164_7	516431	0	0	UNIFO	19631216		Brazos River Authority
Proposed Allens Creek Reservoir (ALLENS) with Storage Capacity of 145,533 acre-feet (Bwam3)							
ALLENS_1	292531	99,650	–	MUN4	19990901		Brazos River Authority
Alan Henry Reservoir (ALANHN) Storage Capacity of 115,937 (Bwam3) and 115,773 (Bwam8) ac-ft							
P4146_1	4146P1	35,000	88	MUN1	19811005		City of Lubbock
P4146_2	4146P1	0	–	IRR1	19811005		City of Lubbock
P4146_3	4146P1	0	200.4	IND1	19811005		City of Lubbock
Hubbard Creek Reservoir (HUBBRD) Storage Capacity of 317,750 ac-ft (both Bwam3 and Bwam8)							
C4213_1	421331	21,008	3,349	MUN1	19570528		West Central Texas MWD
C4213_2	421331	17,362	2,768	MUN1	19570528	103341	West Central Texas MWD
C4213_3	421331	1,882	300	MUN1	19570528		West Central Texas MWD
C4213_4	421331	2,061	329	MUN1	19570528		West Central Texas MWD
C4213_5	421331	2,487	396	MUN1	19570528	100401	West Central Texas MWD
C4213_6	421331	2,000	1,026.3	D&L1	19720814		West Central Texas MWD
C4213_7	421331	1,200	0	IND1	19570528		West Central Texas MWD
C4213_8	421331	6,000	1,013.2	MIN1	19570528		West Central Texas MWD
C4213_9	421331	2,000	742	IRR1	19720814		West Central Texas MWD
Squaw Creek Reservoir (SQWCRK) Capacity of 151,500 (Bwam3) and 151,015 (Bwam8) acre-feet							
C4097_1	409732	23,180	17,536	IND2	19730425		Texas Utilities Electric Co

CHAPTER 4
UPDATING OF THE BRAZOS WAM HYDROLOGIC SIMULATION PERIOD TO INCLUDE 1998-2007

The procedure outlined in Chapter 2 is applied to the Brazos WAM dataset described in Chapter 3 to extend the period-of-analysis by ten years as described in the present Chapter 4. The January 1940 to December 1997 simulation period is extended through December 2007. Sequences of monthly naturalized flows at 77 primary control points are developed for 1998-2007. Reservoir surface evaporation less precipitation depths for 1998-2007 are compiled for 67 control points.

Actual observed flows were compiled at 48 of the 77 primary control points. Naturalized monthly flows for 1998-2007 were developed at these 48 control points by adjusting gaged flows. 1998-2007 naturalized flows were developed at the 29 other primary control points by applying flow distribution methods to the naturalized flows developed for the 48 control points.

Procedure for Extending the Hydrologic Period-of-Analysis

This chapter describes data compilation and computational methods for developing 1998-2007 sets of evaporation-precipitation depths at 67 control points and naturalized stream flows at 77 control points. Updating of the Brazos WAM hydrology dataset consisted of the following tasks.

1. Compilation of evaporation-precipitation depths for the 120 months of 1998-2007 for the 67 control points included in the EVA file.

2. Compilation and manipulation of available stream flow data at 48 USGS gaging stations (including reservoir releases representing flows at one site) to develop complete 1998-2007 sequences of actual observed monthly flows.

3. Development of a methodology and parameters for distributing naturalized flows to the original 29 primary control points that have no gaged flow data for 1998-2007.

4. Creation of an actual use Bwam8A DAT file by modifying the current use Bwam8 DAT file to better approximate actual water management and use during 1998-2007.

   - The upstream-to-downstream natural priority option was activated. With this option, flows are diverted for water supply and reservoir storage is refilled without regard to seniority specified in the water right permits.

   - Negative incremental flow option 4 was activated rather than option 5.

   - Beginning of January 1998 storage volumes were assigned based on observed storage contents for the 22 largest reservoirs and simulated volumes for the numerous other smaller reservoirs.

   - End-of-month actual storage volumes for the 120 months of the 1998-2007 period-of-analysis were compiled for the largest 22 reservoirs. Water rights data and related data in the DAT file were modified to reproduce the observed storage volumes in the *SIM* simulation.

   - Brazos River Authority water supply diversions were adjusted to reflect system operations. Actual diversions at Proctor Reservoir were adopted.

5. Computation of an initial set of 1998-2007 naturalized flows for 48 primary control points based on an adopted 75 percent exceedance frequency using program *HYD*.

6. Iterative development of improved sets of 1998-2007 naturalized flows. Storage and diversion shortages were included in the flow adjustments (Equations 2.1 and 2.2) in early iterations and omitted in later iterations (Eq. 2.3). Improved sets of naturalized flows at 3,834 control points were repeatedly computed based on the preceding estimate of naturalized flows at 48 control points being recorded in the *SIM* FLO file. The procedure was iteratively repeated until computed regulated flows matched gaged flows.

   - *SIM* was executed with the 1998-2007 input dataset consisting of the EVA file from Task 1, FLO file from Task 4, DAT file developed in Task 3, and DIS file with parameters for distributing flows to ungaged control points.
   - Naturalized flows are distributed within *SIM* to control points that have no gaged data for 1998-2007 based on known flows at 48 control points.
   - Flow adjustments were computed with program *HYD* as naturalized flows minus regulated flows combined with shortages in reaching observed reservoir storage levels and meeting diversion targets at the 22 largest reservoirs. Iterations were also performed without adjusting for shortages.
   - Naturalized flows at 48 control points were computed with *HYD* by adjusting observed flows. The resulting flows replaced the previously estimated naturalized flows in the *SIM* input FLO file.

Net Evaporation-Precipitation Depths

The Brazos WAM dataset includes sequences of monthly net evaporation less precipitation depths in feet/month recorded on *EV* records stored in a file with filename extension EVA for January 1940 through December 1997 at the 67 control points listed in Table 4.1. The net evaporation-precipitation rates represent reservoir water surface evaporation losses minus precipitation falling directly on the reservoir water surface. The task addressed in this section is to update the *WRAP-SIM* EVA input data file by extending the sequences by ten years to cover the period from January 1940 through December 2007.

Net evaporation-precipitation depths are provided in the EVA file for the 67 control points listed in Table 4.1. The first twenty control point identifiers listed in Table 4.1 represent the quadrangles delineated in Figure 4.1. Multiple smaller reservoirs are assigned the evaporation-precipitation rates recorded in the EVA file with these twenty control point identifiers. The 47 other control points listed in Table 4.1 represent individual major reservoirs.

Reservoirs are assigned a set of net evaporation-precipitation depths in one of two ways. All reservoirs are assigned a control point location. For the 47 reservoirs listed in Table 4.1, the control points assigned to identify the evaporation-precipitation rate sequences are the control points of the reservoirs. For the numerous other reservoirs in the dataset located at other control points, the *CP* record for each of their control points references one of the 67 control points listed in Table 4.1 as the source for their evaporation-precipitation depths.

The Texas Water Development Board (TWDB) maintains a database of monthly reservoir surface gross evaporation depths and a database of precipitation depths for the entire state by quadrangles of one-degree latitude and longitude. Figure 4.1 is a map showing the quadrangles that cover the Brazos River Basin. The TWDB data are currently available only through December 2004. Monthly evaporation and precipitation rates were obtained from the TWDB databases for the period from January 1998 through December 2004. Net evaporation less precipitation rates were computed by subtracting precipitation from evaporation. 1940-2004 mean net evaporation less precipitation depths for each of the 12 months of the year were adopted for 2005, 2006, and 2007.

A weighted average for adjoining quadrangles was applied for reservoir sites extending into more than one quadrangle. The equations shown in Table 4.2 are used for 39 of the reservoirs that have water surfaces located in two or four adjacent quadrangles. These equations assign net evaporation-precipitation depths to these 39 reservoirs as a weighted-average of net evaporation-precipitation depths for the quadrangles. The other eight reservoirs listed in Table 4.1 are each assigned only one quadrangle for 1998-2007 net evaporation-precipitation depths as follows: Allen Creek (811), Brazoria (812), Bryan Utilities (711), Eagle Nest (812), Marlin (611), Post (406), Sandow (710), and William Harris (812).

The Brazos WAM dataset was developed during 1997-2001 by HDR Engineering, Inc. under contract with the TCEQ. The equations in Table 4.2 are from the original HDR report. The original Brazos WAM 1940-1997 dataset is based largely upon the TWDB evaporation and precipitation databases that were used again for the 1998-2007 extension. The 1940-1997 dataset also contains some evaporation-precipitation data from weather stations located near several of the larger reservoirs obtained from the National Climatic Data Center (NCDC). The NCDC database was investigated but not actually used for the 1998-2007 extension.

Comparison of Mean Evaporation-Precipitation Depths

Net reservoir surface evaporation less precipitation rates were compiled for the 120 months of January 1998 through December 2007 for the 67 control point locations listed in Table 4.1. Monthly evaporation depths and precipitation depths were obtained from the Texas Water Development Board databases for 1998-2003. However, the TWDB has not yet updated the databases with data extending past 2003. Thus, 1940-2004 mean net evaporation less precipitation depths for each of the 12 months of the year were adopted for 2005, 2006, and 2007.

The 1998-2007 means are compared with the 1940-1997 means of the evaporation-precipitation rates from the original Brazos WAM dataset in Table 4.1. In most cases, the mean net depths are positive with mean evaporation exceeding mean precipitation. Quadrangles 812 and 813 covering the lower reach of the Brazos River Basin and the adjoining Brazos-San Jacinto Coastal Basin have negative net evaporation-precipitation depths indicating that mean precipitation exceeds mean reservoir surface evaporation.

The 1998-2007 means are expressed as a percentage of 1940-1997 means in the last column of Table 4.1. Differences between 1998-2007 and 1940-1997 mean depths vary significantly between individual quadrangles or reservoirs. Precipitation varies more than evaporation. The mean net evaporation-precipitation depths for each of the 20 quadrangles covering the Brazos River Basin and Brazos-San Jacinto Coastal Basin (Figure 4.1) are tabulated in the first twenty lines of

Table 5.1. The arithmetic average of the means for the 20 quadrangles is 29.0 inches/year for 1940-1997 and 30.2 inches/year for 1998-2007. Thus, the net evaporation-precipitation depths adopted for 1998-2007 are on average about 4.1 percent higher than the 1940-1997 means.

Table 4.1
Means of Net Evaporation-Precipitation Depths

Control Point	Quadrangle or Major Reservoir	Mean Rate in feet/month 1940-1997	1998-2007	1998-2007 as Percent of 40-97
366631	305	0.3216	0.3513	109.3
368131	306	0.3120	0.3625	116.2
370431	405	0.3216	0.3620	112.6
368931	406	0.3053	0.3797	124.4
341131	407	0.3184	0.3626	113.9
341331	408	0.2815	0.2800	99.5
344801	409	0.2262	0.2329	103.0
371431	506	0.3411	0.3703	108.6
372031	507	0.3022	0.3054	101.1
413331	508	0.2785	0.2629	94.4
220131	509	0.2364	0.2167	91.7
227031	510	0.1912	0.1573	82.3
225331	609	0.0308	0.1430	463.8
228731	610	0.1818	0.1346	74.0
406331	611	0.1422	0.1165	82.0
299231	710	0.1519	0.1133	74.6
375931	711	0.0888	0.0804	90.5
531531	712	0.0131	0.0225	171.4
401041	812	−0.0047	−0.0210	444.1
516841	813	−0.0144	−0.0429	297.9
414231	Abilene	0.2985	0.2892	96.9
4146P1	Alan Henry	0.3109	0.3302	106.2
527231	Alcoa	0.1354	0.1068	78.8
292531	Allen Creek	0.0392	0.0233	59.4
515831	Aquilla	0.1658	0.1317	79.4
293631	Belton	0.1437	0.1348	93.8
532842	Brazoria	0.0512	−0.0060	−11.8
526831	Bryan Utilities	0.1011	0.0837	82.8
370631	Buffalo Springs	0.3104	0.3720	119.8
530131	Camp Creek	0.0848	0.0764	90.1
421131	Cisco	0.1945	0.2148	110.4
421431	Daniel	0.2521	0.2402	95.3
344031	Davis	0.2913	0.3020	103.7
549231	Eagle Nest	0.0320	−0.0111	−34.8

Table 4.1 (continued)
Means of Net Evaporation-Precipitation Depths

Control Point	Quadrangle or Major Reservoir	Mean Rate in feet/month 1940-1997	1998-2007	1998-2007 as Percent of 40-97
416131	Fort Phantom Hill	0.2866	0.2822	98.5
516231	Georgetown	0.1243	0.1258	101.2
531131	Gibbons Creek	0.0673	0.0637	94.6
345831	Graham	0.2473	0.2427	98.1
515631	Granbury	0.1808	0.1644	90.9
516331	Granger	0.1432	0.1110	77.5
421331	Hubbard Creek	0.2557	0.2460	96.2
415031	Kirby	0.2924	0.2810	96.1
434531	Lake Creek	0.1611	0.1252	77.7
347031	Leon	0.2235	0.2267	101.4
516531	Limestone	0.1109	0.0948	85.5
435533	Marlin City	0.1455	0.1174	80.7
528731	Mexia	0.1480	0.1202	81.2
344431	Millers Creek	0.2709	0.2677	98.8
403931	Mineral Wells	0.2047	0.1920	93.8
403131	Lake Palo Pinto	0.2183	0.2030	93.0
410631	Pat Cleburne	0.1751	0.1419	81.0
515531	Possum Kingdom	0.2324	0.2230	95.9
371131	Post	0.4469	0.4177	93.4
515931	Proctor	0.1734	0.1907	110.0
554032	Sandow Surface Mine	0.1354	0.1089	80.4
532531	Smithers	0.0043	−0.0139	−321.2
516431	Somerville	0.0787	0.0731	92.9
409731	Squaw Creek	0.1768	0.1645	93.0
417931	Stamford	0.2911	0.2949	101.3
516131	Stillhouse Hollow	0.1382	0.1332	96.4
413031	Sweetwater	0.3014	0.2985	99.0
432431	Tradinghouse Creek	0.1611	0.1252	77.7
529831	Twin Oaks	0.1274	0.1066	83.6
231531	Waco	0.1709	0.1315	76.9
369331	White River	0.3106	0.3726	120.0
515731	Whitney	0.1709	0.1344	78.6
532841	William Harris	0.0294	0.0207	70.2

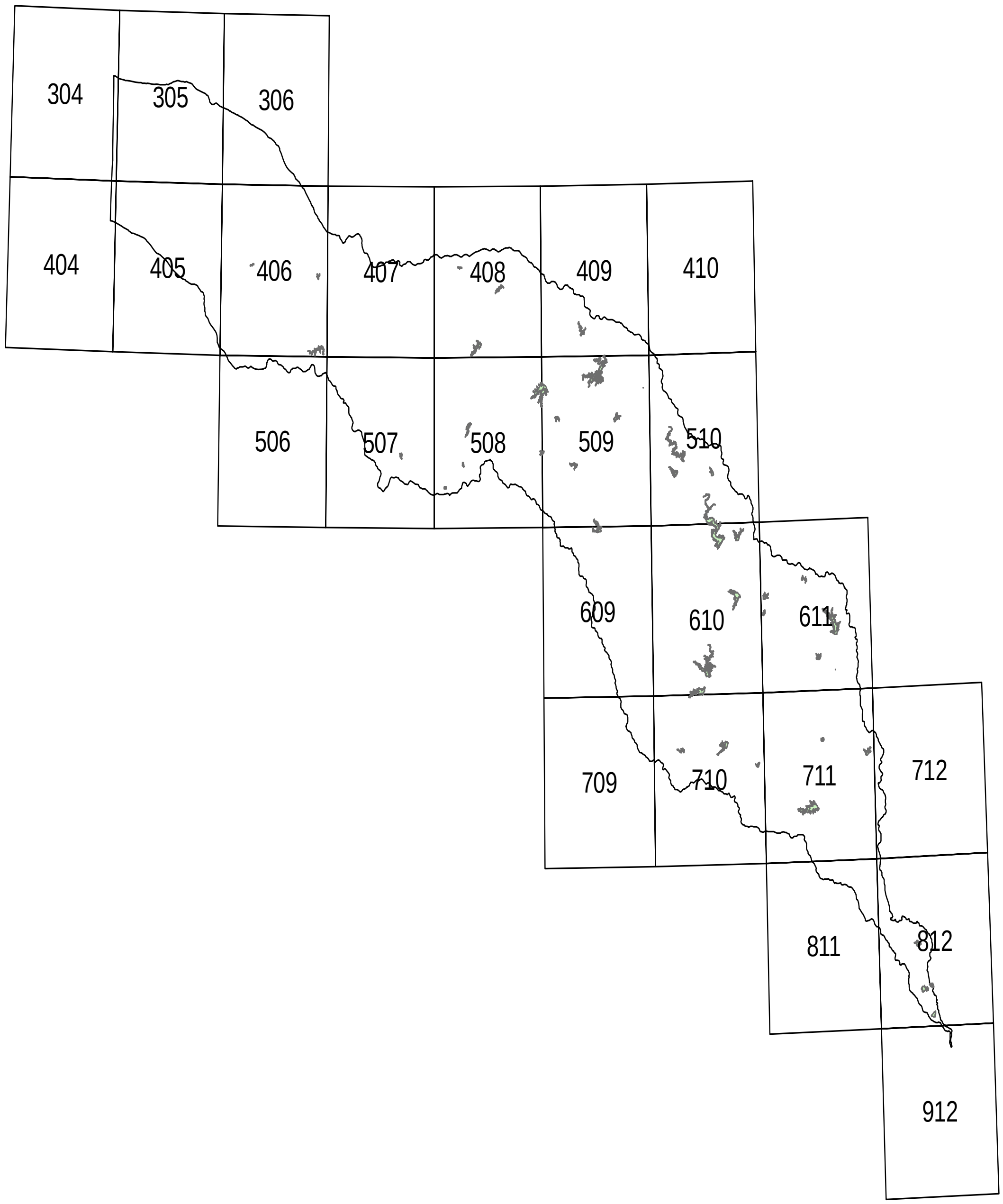

Figure 4.1 Quadrangles for TWDB Evaporation and Precipitation Data

Table 4.2
Equations Developed by HDR for Averaging Net Evaporation-Precipitation Depths for Major Reservoirs Lying in Multiple Quadrangles

	Reservoir	Quadrangle Interpolation Equation
1	White River	0.589*(406)+0.411*(407)
2	Buffalo Springs	0.097*(305)+0.115*(306)+0.170*(405)+0.618*(406)
3	Alan Henry	0.097*(406)+0.115*(407)+0.170*(506)+0.618*(507)
4	Davis	0.267*(407)+0.733*(408)
5	Sweetwater	0.633*(507)+0.158*(508)+0.114*(607)+0.094*(608)
6	Abilene	0.277*(507)+0.364*(508)+0.175*(607)+0.184*(608)
7	Kirby	0.193*(507)+0.550*(508)+0.116*(607)+0.141*(608)
8	Fort Phantom Hill	0.103*(407)+0.126*(408)+0.168*(507)+0.602*(508)
9	Stamford	0.188*(407)+0.339*(408)+0.176*(507)+0.297*(508)
10	Cisco	0.188*(407)+0.339*(408)+0.176*(507)+0.297*(508)
11	Hubbard	0.194*(408)+0.194*(409)+0.299*(508)+0.313*(509)
12	Daniel	0.142*(408)+0.158*(409)+0.255*(508)+0.446*(509)
13	Millers Creek	0.707*(408)+0.118*(409)+0.098*(508)+0.076*(509)
14	Graham	0.193*(408)+0.410*(409)+0.159*(508)+0.237*(509)
15	Possum Kingdom	0.386*(409)+0.614*(509)
16	Palo Pinto	0.137*(409)+0.108*(410)+0.586*(509)+0.170*(510)
17	Mineral Wells	0.206*(409)+0.195*(410)+0.312*(509)+0.287*(510)
18	Squaw Creek	0.218*(509)+0.468*(510)+0.142*(609)+0.173*(610)
19	Granbury	0.199*(509)+0.556*(510)+0.112*(609)+0.132*(610)
20	Pat Cleburne	0.577*(510)+0.154*(511)+0.157*(610)+0.112*(611)
21	Whitney	0.296*(510)+0.169*(511)+0.355*(610)+0.180*(611)
22	Aquilla	0.262*(510)+0.196*(511)+0.321*(610)+0.221*(611)
23	Waco	0.138*(510)+0.119*(511)+0.528*(610)+0.215*(611)
24	Tradinghouse	0.480*(610)+0.520*(611)
25	Lake Creek	0.480*(610)+0.520*(611)
26	Leon	0.266*(508)+0.42*(509)+0.15*(608)+0.165*(609)
27	Proctor	0.511*(509)+0.489*(609)
28	Belton	0.171*(609)+0.421*(610)+0.151*(709)+0.257*(710)
29	Stillhouse Hollow	0.175*(609)+0.329*(610)+0.168*(709)+0.329*(710)
30	Georgetown	0.128*(609)+0.158*(610)+0.200*(709)+0.514*(710)
31	Granger	0.157*(610)+0.117*(611)+0.557*(710)+0.169*(711)
32	Alcoa	0.153*(610)+0.146*(611)+0.391*(710)+0.309*(711)
33	Somerville	0.150*(710)+0.592*(711)+0.108*(811)+0.150*(811)
34	Mexia	0.064*(510)+0.086*(511)+0.094*(610)+0.755*(611)
35	Limestone	0.655*(611)+0.143*(612)+0.113*(711)+0.089*(712)
36	Twin Oaks	0.724*(611)+0.276*(711)
37	Camp Creek	0.338*(611)+0.197*(612)+0.284*(711)+0.182*(712)
38	Gibbons Creek	0.168*(611)+0.162*(612)+0.359*(711)+0.310*(712)
39	Smithers	0.144*(811)+0.856*(812)

Stream Flows at 77 Primary Control Points

The Brazos WAM dataset includes sequences of naturalized monthly stream flow volumes recorded on *IN* records stored in a file with filename extension FLO for January 1940 through December 1997 at 77 control points. The task addressed here is to extend these flow sequences ten years to cover the period from January 1940 through December 2007. The 77 primary control points are listed in Tables 3.2 and 4.2 and shown in the map of Figure 3.2 and schematic of Figure 4.2. The extended 1998-2007 sequences of naturalized flows were developed for each of the 77 control points in one of the following ways.

- Naturalized flows were computed by adjusting 1998-2007 observed gaged flows as outlined in the next section of this chapter if measured flow data are available. This approach was applied to the 48 control points shown in bold face type in Figure 4.2. The last column of Table 4.2 indicates that observed flows are adopted directly from the USGS database for 41 sites and certain adjustments are required for six other sites.

- Naturalized flows for 1998-2007 for each of the remaining 30 control points listed in Table 4.2 for which gaged flows are not available are computed based on the naturalized flows at one or more of the 48 control points for which gaged flows are available. The distribution of flows to these 30 control points is based on ratios of 1940-1997 mean naturalized flows at pertinent control points.

Primary control points are the sites for which naturalized flows are included in a *SIM* simulation input file. The 77 primary control points listed in Table 4.2 were selected during development of the original Brazos WAM model by HDR Engineering, Inc. during 1997-2001 under contract with the TCEQ. Four of the primary control points are in the Jan Jacinto-Brazos Coastal Basin, and the other 73 control points are in the Brazos River Basin. The WRAP control point identifier in the first column of Table 4.2 consists of four letters referring to the stream and nearest town followed by the integers 1-73 for the Brazos Basin and 1-4 for the coastal basin.

All but the following five primary control points are at USGS stream gaging stations that were in operation during all or portions of 1940-1997.

- Control point BRGM73 represents the outlet of the Brazos River at the Gulf of Mexico.
- Control points SJGBC3 and SJGMC4 represent outlets of the Jan Jacinto-Brazos Coastal Basin into Galveston Bay and the Gulf of Mexico.
- Control points BSLU07 and GHGH24 are located at Buffalo Spring Lake and Lake Graham, respectively. The 1940-1997 flow data at these two sites are releases from the reservoirs. The release data were provided to HDR by the reservoir operators.

The other 72 primary control points are USGS gaging stations. However, a number of these gaging stations are no longer in operation. Only 20 of the 77 primary control points listed in Table 4.2 are stream gaging stations with periods-of-record that span the entire WAM 1940-1997 period-of-analysis. Flows for the months during 1940-1997 with missing observed data were synthesized by HDR based on regression with flows at other gaging stations. The period-of-record for 17 of the stream gaging stations end before 1997. Others with periods-of-record extending past 1997 could not be used in the present hydrology update investigation because of missing data in most of the months during 1998-2007.

Compilation of 1998-2007 Actual Flows at 48 Gaged Control Points

The U.S. Geological Survey (USGS) routinely measures stream stage in feet and converts the stage to flows in ft^3/s. Mean daily stage and flow are recorded in the USGS National Water Information System (NWIS) which is accessible through the internet. Monthly flow volumes computed by aggregating daily flows are also sometimes provided in the NWIS. Some USGS gaging stations have complete data records with few if any periods of missing data. Some stations have been discontinued with an official ending date for the period-of-record. Other stations are still listed as operational but have multiple-year periods with no data including most or all of 1998-2007.

Table 4.3
Availability of 1998-2007 Gaged Flows

Control Point	River or Stream	Nearest City	USGS Gage No.	USGS Period of Record	1998-2007 Availability
RWPL01	Running Water Draw	Plainview	08080700	1939–present	adjusted (1)
WRSP02	White River Reservoir	Spur	08080910	1964-1976	missing
DUGI03	Duck Creek	Girard	08080950	1964-1989	missing
SFPE04	Salt Fork Brazos River	Peacock	08081000	1950–1986	missing
CRJA05	Croton Creek	Jayton	08081200	1959–1986	missing
SFAS06	Salt Fork Brazos River	Aspermont	08082000	1924–present	observed (1)
BSLU07	Buffalo Spring Lake	Lubbock	reservoir releases		not a gage
DMJU08	Double Mountain Fork	Justiceburg	08079600	1961–present	observed (2)
DMAS09	Double Mountain Fork	Aspermont	08080500	1923–present	observed (3)
NCKN10	North Croton Creek	Knox City	08082180	1965–1986	missing
BRSE11	Brazos River	Seymour	08082500	1923–present	observed (4)
MSMN12	Millers Creek	Munday	08082700	1963–present	observed (5)
CFRO13	Clear Fork Brazos	Roby	08083100	1962–present	observed (6)
CFHA14	Clear Fork Brazos	Hawley	08083240	1967–1989	missing
MUHA15	Mulberry Creek	Hawley	08083245	1967–1989	missing
CFNU16	Clear Fork Brazos	Nugent	08084000	1924–present	observed (7)
CAST17	California Creek	Stamford	08084800	1962–present	observed (8)
CFFG18	Clear Fork Brazos	Fort Griffin	08085500	1924–present	observed (9)
HCAL19	Hubbard Creek	Albany	08086212	1966–present	observed (10)
BSBR20	Big Sandy Creek	Breckenridge	08086290	1962–present	observed (11)
HCBR21	Hubbard Creek	Breckenridge	08086500	1955–1986	missing
CFEL22	Clear Fork Brazos	Eliasville	08087300	1915–1982	missing
BRSB23	Brazos River	South Bend	08088000	1938–present	observed (12)
GHGH24	Lake Graham	Graham	reservoir releases		not a gage
CCIV25	Big Cedar Creek	Ivan	08088450	1964–1989	missing
SHGR26	Brazos River	Graford	08088600	1976–1994	missing
BRPP27	Brazos River	Palo Pinto	08089000	1924–present	observed (13)
PPSA28	Palo Pinto Creek	Santo	08090500	1924–1976	missing
BRDE29	Brazos River	Dennis	08090800	1968–present	observed (14)
BRGR30	Brazos River	Glen Rose	08091000	1923–present	observed (15)
PAGR31	Paluxy River	Glen Rose	08091500	1924–present	observed (16)
NRBL32	Nolan River	Blum	08092000	1947–present	missing
BRAQ33	Brazos River	Aquilla	08093100	1938–present	observed (17)

Table 4.3 Continued
Availability of 1998-2007 Gaged Flows

Control Point	River or Stream	Nearest City	USGS Gage No.	Period-of Record	1998-2007 Availability
AQAQ34	Aquilla Creek	Aquilla	08093500	1939–2001	adjusted (2)
NBHI35	North Bosque River	Hico	08094800	1994–2003	missing
NBCL36	North Bosque River	Clifton	08095000	1923–2008	observed (18)
NBVM37	North Bosque River	Valley Mills	08095200	1959–present	observed (19)
MBMG38	Middle Bosque River	McGregor	08095300	1959–present	missing
HGCR39	Hog Creek	Crawford	08095400	1959–present	missing
BOWA40	Bosque River	Waco	08095600	1959–1982	missing
BRWA41	Brazos River	Waco	08096500	1898–present	observed (20)
BRHB42	Brazos River	Highbank	08098290	1965–present	observed (21)
LEDL43	Leon River	De Leon	08099100	1960–present	missing
SADL44	Sabana River	De Leon	08099300	1960–present	adjusted (3)
LEHS45	Leon River	Hasse	08099500	1939–present	reservoir releases
LEHM46	Leon River	Hamilton	08100000	1925–present	missing
LEGT47	Leon River	Gatesville	08100500	1950–present	observed (22)
COPI48	Cowhouse Creek	Pidcoke	08101000	1950–present	observed (23)
LEBE49	Leon River	Belton	08102500	1923–present	observed (24)
LAKE50	Lampasas River	Kempner	08103800	1962–present	observed (25)
LAYO51	Lampasas River	Youngsport	08104000	1924–1980	missing
LABE52	Lampasas River	Belton	08104100	1963–present	adjusted (4)
LRLR53	Little River	Little River	08104500	1923–present	observed (26)
NGGE54	North Fork San Gabriel	Georgetown	08104700	1968–present	observed (27)
SGGE55	South Fork San Gabriel	Georgetown	08104900	1967–present	observed (28)
GAGE56	San Gabriel River	Georgetown	08105000	1924–1987	missing
GALA57	San Gabriel River	Laneport	08105700	1965–present	observed (29)
LRCA58	Little River	Cameron	08106500	1916–present	observed (30)
BRBR59	Brazos River	Bryan	08109000	1899–1993	adjusted (5)
MYDB60	Middle Yegua Creek	Dime Box	08109700	1962–present	observed (31)
EYDB61	East Yegua Creek	Dime Box	08109800	1962–present	observed (32)
YCSO62	Yegua Creek	Somerville	08110000	1924–1991	missing
DCLY63	Davidson Creek	Lyons	08110100	1962–present	observed (33)
NAGR64	Navasota River	Groesbeck	08110325	1978–present	observed (34)
BGFR65	Big Creek	Freestone	08110430	1978–present	observed (35)
NAEA66	Navasota River	Easterly	08110500	1924–present	observed (36)
NABR67	Navasota River	Bryan	08111000	1951–1997	adjusted (6)
BRHE68	Brazos River	Hempstead	08111500	1938–present	observed (37)
MCBL69	Mill Creek	Bellville	08111700	1963–1993	missing
BRRI70	Brazos River	Richmond	08114000	1903–present	observed (38)
BGNE71	Big Creek	Needville	08115000	1947–present	observed (39)
BRRO72	Brazos River	Rosharon	08116650	1967–present	observed (40)
BRGM73	Brazos River	Gulf of Mexico	outlet cp	–	not a gage
CLPEC1	Clear Creek	Pearland	08077000	1944–1994	missing
CBALC2	Chocolate Bayou	Alvin	08078000	1959–present	observed (41)
SJGBC3	Coastal Basin	Galveston Bay	outlet cp	–	not a gage
SJGMC4	Coastal Basin	Gulf of Mexico	outlet cp	–	not a gage

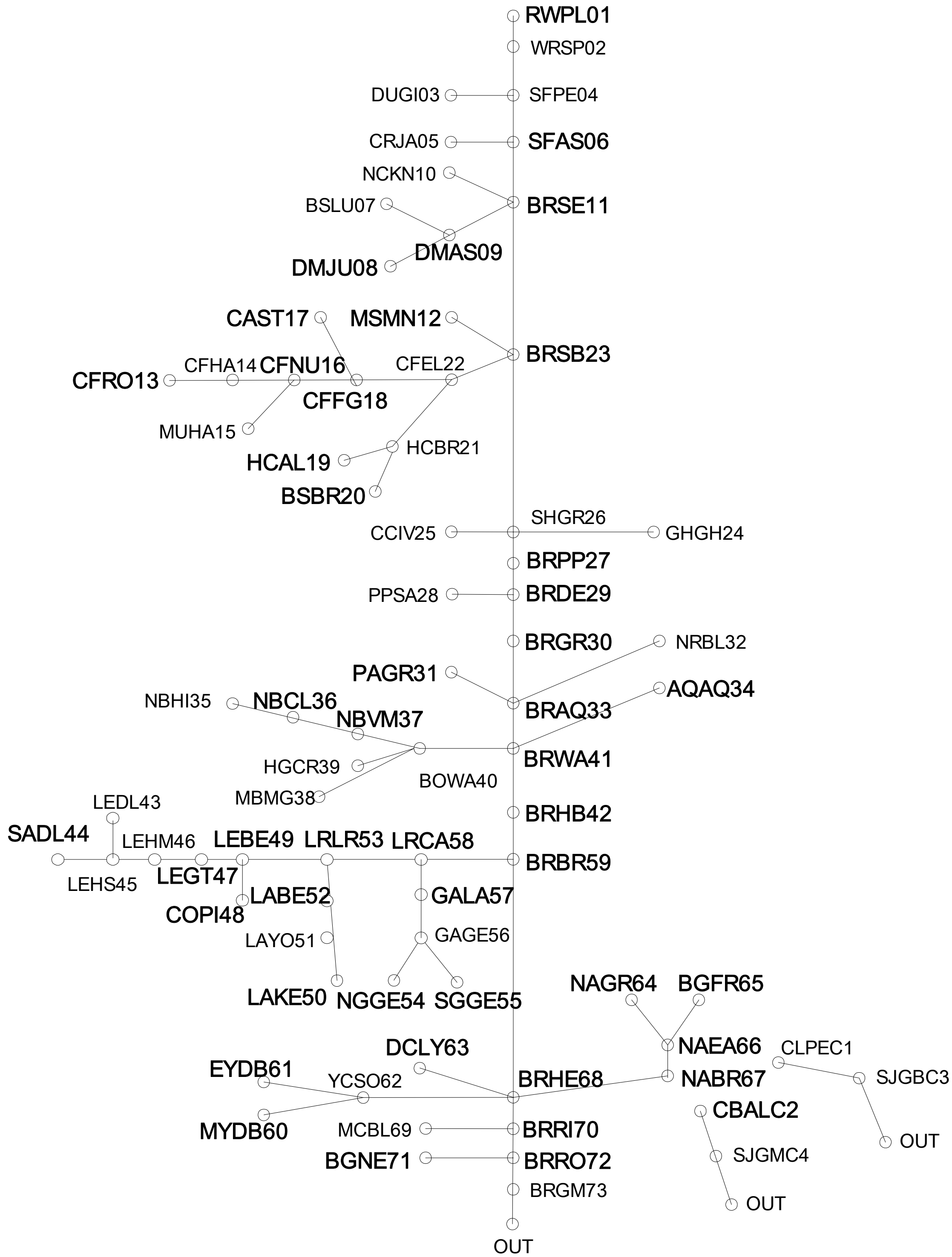

Figure 4.2 Schematic of 77 Primary Control Points (The 47 USGS gaging stations that were active during 1998-2007 are shown in bold.)

The availability of actual observed flow data is indicated in the last column of Table 4.3. Seventy-two of the 77 control points are sites of USGS gaging stations, of which some are still operational today and others have been discontinued. The terms *observed*, *adjusted*, or *missing* is entered in the last column of Table 4.3 to categorize the availability of observed data from USGS gage measurements at each control point as follows.

observed − Mean daily measured flows in units of ft^3/s are available from the USGS NWIS for the 41 gaging stations categorized as *observed* in Table 4.3. The HEC-DSSVue computer program available from the USACE Hydrologic Engineering Center was used to retrieve these daily flows from the USGS database and aggregate them to monthly flow volumes in acre-feet/month for the period January 1998 through December 2007.

adjusted − The six control points listed as *adjusted* also have observed flow data covering all or most of 1998-2007. However, data adjustments were required to compile complete 1998-2007 sequences of monthly flow volumes. Methods adopted to compile flow data for each of these six control points are outlined below.

missing − Flow data are missing for all or most of 1998-2007 at 25 of the USGS gaging stations. Seventeen of the gaging stations have been terminated with their periods-of-record ending several years before 1997. The other eight gaging stations are still listed in the NWIS as operational but no data were collected during all or most of 1998-2007.

A set of actual 1998-2007 monthly flows were developed for 48 control points which include the 41 control points labeled *observed* in the last column of Table 4.3, six control points labeled as being *adjusted*, and control point LEHS45 for which flows were determined as releases from Proctor Reservoir. Complete sets of 1998-2007 monthly flows were developed by summing daily flows downloaded with HEC-DSSVue from the USGS National Water Information System (NWIS) for the 41 control points labeled *observed*. Proctor Reservoir releases and adjustments of observed flows performed at the six other control points labeled *adjusted* are described below. Computation of naturalized flows at the 29 remaining control points labeled *missing* based on naturalized flows at one or more of the other control points is covered later in this chapter.

<u>Releases from Proctor Reservoir</u>

Control point LEHS45 located immediately downstream of Proctor Dam is the site of the former USGS stream flow gaging station on the Leon River near Hasse. Measured releases from Proctor Reservoir during 1998-2007 compiled by the Brazos River Authority were adopted as the gaged flows at control point LEHS45.

Control points LEDL43, LEHS45 and LEHM46 are sites of discontinued USGS gaging stations on the Leon River above, immediately below, and further below Proctor Reservoir. These three former gaging stations have no measurements recorded during 1998-2007. Flows at LEHS45 were initially estimated based on flows at LEGT47 using the technique outlined later in this chapter. LEHS47 is an active USGS gage on the Leon River near Gatesville. As indicated in Table 3.2, the drainage areas of LEHS45 and LEGT47 are 1,283 and 2,379 square miles, respectively, reflecting a drainage area ratio of 0.539. *WRAP-SIM* simulated storage volumes for Proctor Reservoir for 1998-2007 were found to vary greatly from observed storage volumes. Consequently, 1998-2007 release data for Proctor Reservoir were adopted as the gaged flows at LEHS45.

Observed Flow Data Adjustments at Six Control Points

Complete 1998-2007 records of observed daily flows are directly available without any adjustment other than aggregating daily mean flows to monthly volumes at 41 of the USGS stream gaging stations, as noted above. USGS gage measurements are also available for compiling flows at the following six other control points. However, extra manipulations were required in compiling the observed flows for these control points.

RWPL01	Running Water Draw near Plainview
SADL44	Sabana River near De Leon
AQAQ34	Aquilla Creek near Aquilla
LABE52	Lampasas River near Belton
BRBR59	Brazos River near Bryan
NABR67	Navasota River near Bryan

Control point RWPL01 on Running Water Draw near Plainview is at the extreme upper end of the Brazos River Basin. The watershed area is 1,291 square miles of which the USGS classifies only 382 square miles to be contributing drainage area. The region is flat and dry. Monthly flows at control point RWPL01 are typically small and are zero in many months. The USGS NWIS provides daily and aggregated monthly flows for most months from July 1939 through September 1978 and from October 2002 to the present. Observed gaged flows available for October 2002 through December 2007 were adopted for extending the Brazos WAM dataset. Period-of-record means for each of the 12 months of the year were adopted for January 1998 through September 2002. Adopting 12 monthly means for 1998-2002 for this particular control point is considered more accurate than transferring gaged or naturalized flows from other gaging stations.

Control point SADL44 on the Sabana River near De Leon has a drainage area of 264 square miles. The USGS NWIS provides daily and aggregated monthly flows for all months from September 1960 through September 1986 and from October 1999 to the present. Observed gaged flows available for October 1999 through December 2007 are adopted for the Brazos WAM dataset. January 1998 through September 1999 flows were synthesized based on flows at control point BSBR20 on Big Sandy Creek near Breckenridge which represents a nearby watershed with similar characteristics. The methodology for estimating 1998-1999 SADL44 actual flows consisted of multiplying BSBR20 gaged flows by 12 monthly ratios of 1940-1997 mean naturalized flows.

Control point AQAQ34 on Aquilla Creek near the town of Aquilla has a period-of-record of 1939 through May 2001. The January 1998 through May 2001 measured flows are adopted for extending the Brazos WAM dataset. Flows for June 2001 through December 2007 are synthesized as follows based on flows at the other two gaging stations listed below.

AQAQ34 on Aquilla Creek near Aquilla	08093500	DA = 308 square miles
Aquilla Creek just below Aquilla Dam	08093360	DA = 255 square miles
NAGR64 on Navasota River near Groesbeck	08110325	DA = 239 square miles

USGS gaging station 08093360 on Aquilla Creek is located just below Aquilla Reservoir and is not included in the 77 primary control points. Its period-of-record extends from 1982 to the present, but there are many months between 1982 and 2001 with missing data. The record is complete for June 2001 through December 2007. The June 2001 through December 2007 monthly actual flows at control point AQAQ34 were synthesized as the flows at gaging station 08093360 below Aquilla Dam plus the incremental flows from the 53 square mile (308 less 255 square miles) watershed between the dam and AQAQ34. The incremental flows were estimated based on applying the ratio of 1940-1997 naturalized flows to the June 2001 through December 2007 monthly actual gaged flows at control point NAGR64 on the Navasota River near Groesbeck.

Control point LABE52 on the Lampasas River near Belton has daily and monthly flows recorded in the USGS National Water Information System for October 1966 through September 1989 and May 1999 to the present. Observed gaged flows available for May 1999 through December 2007 are adopted for the Brazos WAM dataset. Actual observed flows for January 1998 through April 1999 were estimated as the difference in gaged flows at LRLR53 and LEBE49 less incremental flows determined by applying a drainage area ratio to gaged flows at LAKE50. The drainage area ratio is 0.448 computed by dividing 366 square miles by 817 square miles.

$$\text{LABE52} = \text{LRLR53} - \text{LEBE49} - (0.448)(\text{LAKE50})$$

LABE52	Lampasas River near Belton	DA = 1,321 square miles
LEBE49	Leon River at Belton	DA = 3,579 square miles
LRLR53	Little River at Little River	DA = 5,266 square miles
LAKE50	Lampasas River at Kempner	DA = 817 square miles

Control point BRBR59 is at USGS gaging station 08109000 on the Brazos River near Bryan which has a continuous record from October 1940 through September 1993 and a drainage area of 29,949 square miles. USGS gaging station 08108700 on the Brazos River at State Highway 21 near Bryan has a continuous record from August 1993 to the present and a drainage area of 29,483 square miles. The flows are identical at the two gaging stations for the two months of overlapping records (August and September 1993). The January 1997 through December 2007 flows at gaging station 08108700 were adopted for control point BRBR59.

Control point NABR67 is at USGS gaging station 08111000 on the Navasota River near Bryan which has a continuous record from October 1978 through March 1997 and a drainage area of 1,454 square miles. USGS gaging station 08110800 on the Navasota River at Old San Antonio Road near Bryan has a continuous record from April 1997 to the present and a drainage area of 1,287 square miles. Lake Limestone with a drainage area of 675 square miles is located upstream of these two gaging stations. The 1998-2007 monthly flows adopted for control point NABR67 consist of the flows at gaging station 08110800 multiplied by a drainage area ratio of 0.8851.

New Reservoir Storage Features Added to WRAP-SIM

A procedure for extending naturalized flow sequences is outlined generically in Chapter 2 and described again in the present Chapter 4 from the perspective of application to the Brazos WAM. Conversion of gaged flows to naturalized flows by iterative execution of the simulation program *SIM* is a central thrust of the methodology. The two new features described below were added to *SIM* during June-July 2008 specifically to support this procedure. The basic idea is to reproduce actual observed reservoir storage levels in the *SIM* simulation.

1. Storage capacity limits varying in each month of the period-of-analysis can now be input on a set of observed storage *OS* records.

2. Storage capacities as governed by *W*S, *MS* and *OS* record limits are included in the *SIM* output file, allowing program *HYD* to tabulate shortages in reaching the storage limits.

OS records provide storage volumes for each individual month of the hydrologic period-of-analysis for a particular reservoir. In each month of the simulation, as each water right is considered in the priority sequence, the storage capacity of the reservoir is the lesser of the storage capacity specified for the water right on its *WS* record and the volume specified for the reservoir on its *OS* record. The reservoir is filled to the capacity defined by the *WR/WS* and *OS* records subject to being constrained to the amount of stream flow available for filling. The end-of-month storage volume contained in the reservoir is limited to not exceed its capacity. Excess storage is released as a spill which is cascaded downstream just as any other reservoir release. The *OS* record feature is explained in the last section of Chapter 4 of the August 2008 *WRAP Reference Manual*.

Another related feature added to *SIM* consists of recording the storage capacity set by *WS*, *OS*, and *MS* records in the simulation results output file. The simulated storage volume has always been included in the *SIM* output file. Programs *HYD* and *TABLES* can now tabulate the shortage in reaching the storage capacity as the difference between the capacity and simulated storage volumes.

As discussed later in this chapter, in applying the methodology to the Brazos WAM, observed end-of-month storage contents for each of the 120 months of the 1998-2007 simulation are provided as *SIM* input on *OS* records in the DAT file for 22 large reservoirs. The objective is to reproduce observed storage contents in the *SIM* simulation. The *SIM* model attempts to reproduce the specified observed storage levels to the extent that available stream flow allows. Shortages in reaching the specified storage levels are incorporated in the *HYD* naturalized flow adjustments.

Creation of Actual Use Bwam8A Dataset from Current Use Bwam8 Dataset

The information contained in a *WRAP-SIM* water rights input file with filename extension DAT describes water resources development, allocation, management, and use. The filename root Bwam8A is adopted here for the Brazos dataset that models the actual water management and use that occurred during January 1998 through December 2007. This section outlines the development of a file with the filename Bwam8A.DAT by modifying the Brazos WAM current use scenario Bwam8.DAT file. The Bwam8A actual use DAT file is designed for application with FLO and EVA files with a hydrologic period-of-analysis of 1998-2007. This dataset is used as described later in this chapter to convert gaged flows to naturalized flows.

The Bwam8 current use scenario dataset already approximates recent conditions. Annual diversion targets for each individual water right are based on the greatest annual use reported for the right in any year during 1988-1997. Reservoir storage capacity is based upon estimated year 2000 sedimentation conditions. The modifications discussed here are designed to more closely represent actual water management and use during January 1998 through December 2007. Conversion of the Bwam8 current use DAT file to a Bwam8A actual use DAT file involved the following tasks.

- The beginning-of-simulation storage volume at the beginning of January 1998 was set for each of the 706 reservoirs. Observed storage contents were adopted for the 22 larger reservoirs containing 87.5 percent of the total storage capacity for which the data are available. Simulated storages were used for the 684 smaller reservoirs containing the remaining 12.5 percent of the total storage capacity for which measured storage data is not readily available.

- A dataset of observed end-of-month storage volumes for each of the 120 months of 1998-2007 were compiled for the 22 largest reservoirs for which recorded measurements are available. These data are input on the new reservoir storage *OS* record described in the preceding section.
- The observed actual storage volumes provided in the *SIM* input for the 22 larger reservoirs were greater than conservation storage capacities in some months reflecting encroachments into surcharge storage or flood control pools. Reservoir storage capacities on *WS* and *SV/SA* records were extended as necessary to assure that the observed storages never exceeded storage capacities in the model.
- Brazos River Authority (BRA) water supply diversions were adjusted to reflect system operations. In the Bwam8 dataset, the BRA diversions are all located at the reservoirs. In the Bwam8A dataset, a portion of the BRA diversions is located at the Richmond gage.
- Actual measured BRA diversions from Proctor Reservoir replaced Bwam8 diversions.
- The natural priority option switch in *JO* record field 9 was activated to replace the priority system. Storage refilling and water use targets are met in an upstream-to-downstream order, which was considered to better represent actual water management and use.
- Negative incremental inflow option 4 was activated on the *JD* record, replacing option 5.

<u>Beginning of Simulation Storage Contents</u>

A beginning reservoir storage (BES) file was created for the Bwam8A dataset. The beginning of January 1998 storage contents was assigned for each reservoir based on either simulated or observed storage volumes. The original Bwam8 dataset with the 1940-1997 hydrologic period-of-analysis was executed with the only modification being activation of the natural priority option. The simulation results provided end-of-simulation storage volumes for the 706 reservoirs. These end-of-month December 1997 (beginning of January 1998) storage volumes for the 22 reservoirs listed in Table 4.3 were replaced with actual observed storage volumes from the USGS National Water Information System supplemented by data from the TWDB website.

The observed end-of-month December 1997 (beginning of January 1998) storage contents obtained from the USGS NWIS and/or TWDB website for the 22 reservoirs are tabulated in Table 4.4 along with their Bwam8 storage capacities and end-of-month December 1997 simulated storage volume from the 1940-1997 Bwam8 simulation. The storage capacities for these 22 reservoirs represent 87.5 percent of the total storage capacity of the 706 reservoirs in the Bwam8 dataset.

<u>Sequences of 1998-2007 Storage Contents for 22 Reservoirs</u>

Sequences of actual end-of-month storage contents for each of the 120 months from January 1998 through December 2007 were compiled from the USGS NWIS for the 22 reservoirs listed in Tables 4.4 and 4.5. Reservoir water surface elevation is actually measured, and the observed stage is converted to storage volume using an elevation versus volume table for the reservoir, which may be occasionally updated to reflect sedimentation. The USGS NWIS records daily reservoir surface elevations and storage volumes in acre-feet which represent storage amounts at midnight in some cases or the mean storage during the day in other cases. The volumes or elevations for the last day of each of the 120 months were compiled for 22 of the reservoirs.

Table 4.4
December 1997 End-of-Month Storage for 22 Largest Reservoirs

Reservoir	WAM Reservoir Identifier	Storage Capacity (acre-feet)	End of December 1997 Simulated (acre-feet)	End of December 1997 Observed (acre-feet)
Alan Henry	ALANHN	115,773	112,592	38,910
Aquilla	AQUILA	41,700	41,700	57,800
Belton	BELTON	432,978	432,978	483,000
Fort Phantom Hill	FPHNHR	69,379	52,273	60,290
Georgetown	GRGTWN	36,980	36,980	43,760
Graham	EDLGRM	44,883	44,545	45,120
Granbury	GRNBRY	132,821	132,821	132,600
Granger	GRNGER	50,540	50,540	67,140
Hubbard Creek	HUBBRD	317,750	298,231	293,200
Limestone	LMSTNE	208,017	208,017	212,100
Millers Creek	MLRCRK	26,631	24,651	11,640
Lake Palo Pinto	PLPNTO	26,405	25,637	34,900
Pat Cleburne	CLEBRN	25,600	24,045	24,200
Possum Kingdom	POSDOM	552,013	537,716	454,800
Proctor	PRCTOR	54,702	54,702	48,800
Squaw Creek	SQWCRK	151,015	46,817	152,001
Somerville	SMRVLE	154,254	151,685	159,300
Stamford	STMFRD	47,557	41,901	29,200
Stillhouse Hollow	STLHSE	224,279	224,279	253,400
Waco	LKWACO	206,562	206,562	125,800
White River	WHTRVR	28,774	10,491	12,870
Whitney	WHITNY	561,074	561,074	531,300
Total		3,509,687	3,320,237	3,272,131

The availability of 1998-2007 reservoir storage data in the USGS NWIS for the 22 reservoirs is outlined in Table 4.5. The midnight storage volume for the last day of each month was used if available. The second column of Table 4.5 shows the periods for which midnight storage volumes are recorded in the USGS NWIS. The mean storage volume for the last day of each month was used for the periods shown in the third column. For the periods listed in the fourth and fifth columns, water surface elevations are recorded in the USGS NWIS but storage volumes are not. Storage volumes were computed by linear interpolation and extrapolation of elevation-area tables available at the TWDB website. The last column of Table 4.5 shows periods for which no USGS data are available. Storage volumes were obtained from monthly TWDB Water Conditions Reports.

The 120 end-of-month storage volumes at each of 22 reservoirs were recorded on *OS* records for inclusion in the Bwam8A *SIM* input DAT file. The objective is to reproduce in the *SIM* simulation with the Bwam8A dataset the actual observed storage volumes of these 22 large reservoirs which account for 87.5 percent of the total Bwam8 storage capacity of the 706 reservoirs in the Bwam8 and Bwam8A datasets. Storage volumes are computed by *SIM* in the normal manner for the 684 other reservoirs. Compiling actual observed storage sequences for these 684 smaller reservoirs accounting for 12.5 percent of the total storage capacity is not feasible.

Table 4.5
Availability of Storage Content Data in USGS NWIS

	Storage Volume (acre-feet)		Water Surface Elevation (feet)		
Reservoir	Midnight	Mean Daily	Midnight	Mean Daily	Missing
Alan Henry	Jan 98 – Mar 03 May 2003 Jul 03 – Oct03	Apr 03, Jun 03	–	Nov 03 – Dec 07	–
Aquilla	Jan 98 – Oct 2000	–	–	Nov 02 – Dec 07	–
Belton	Jan 1998 – Jan 04	–	–	Feb 04 – Dec 07	–
Fort Phantom Hill	Apr 99 – Oct 00	Nov 00 – Oct 02	–	Nov 02 – Dec 07	Jan 98 – Mar 99
Georgetown	Jan 98 – Jan 04		–	Feb 04 – Dec 07	–
Graham	Jan 98 – Oct 00	Nov 00 – Oct 06	–	Nov 06 – Dec 07	–
Granbury	Jan 98 – Jul 01	Aug 01 – Dec 07	–		–
Granger	Jan 98 – Aug 03 Oct 03 – Jan 04	–	–	Feb 04 – Dec 07	Sep 2003
Hubbard Creek	Jan 98 – Oct 03	–	–	Nov 04 – Dec 07	–
Limestone	Jan 98 – Jan 01	Feb 01 – Oct 01	Nov 01 – Nov 04	Dec 04 – Dec 07	–
Millers Creek	Nov 98 – Feb 02	Mar 02 – Oct 07	–	Nov 07 – Dec 07	Jan 98 – Oct 98
Palo Pinto	Mar 99 – Oct 00	Nov 00 – Oct 02	–	Nov 02 – Dec 07	Jan 98 – Feb 99
Pat Cleburne	Jul 98 – Oct 00	Nov 00 – Oct 02	–	Nov 02 – Dec 07	Jan 98 – Jun 98
Possum Kingdom	Jan 98 – Oct 00	Nov 00 – Oct 07	–	Nov 07 – Dec 07	–
Proctor	Jan 98 – Oct 00	Nov 00 – Oct 02	–	Nov 04 – Dec 07	–
Somerville	Jan 98 – Jan 04	–	–	Feb 04 – Dec 07	–
Squaw Creek	–	–	–	Oct 00 – Dec 07	Jan 98 – Sep 00
Stamford	Mar 99 – Oct 00	Nov 00 – Oct 02	–	Nov 02 – Dec 07	Jan 98 – Feb 99 January 2005
Stillhouse Hollow	Jan 98 – Oct 02	Nov 02 – Oct 04	–	Nov 04 – Dec 07	–
White River	Feb 99 – Oct 00	Nov 00 – Oct 02	–	Nov 02 – Dec 07	Jan 1998 – Jan 99
Whitney	Jan 98 – Oct 00	Nov 00 – Oct 02	–	Nov 02 – Dec 07	–
Waco	Jan 98 – Jan 04	–	Feb 04 – May 04	Jun 04 – Dec 07	–

The program *SIM* input DAT file in the WAM System datasets include reservoir storage capacities on *WS* records. Volume-area tables are provided on *SV* and *SA* records. These data have been adjusted in Bwam8A to facilitate the storage at the 22 reservoirs rising above the top of conservation pool into surcharge or flood control pools. Although elevation-volume relationships are sensitive to sediment survey updates, volume-area relationships remain relative constant. The Bwam8 reservoir surface area versus storage volume relationships are considered to still be valid with the actual observed volumes.

The observed storage contents entered on *OS* records for the 22 reservoirs are treated in *SIM* as storage capacities. In *SIM*, in each month, the storage capacity for a particular reservoir is the lesser of the storage volume read from an *OS* record and the largest *WS* record storage capacity associated with one or multiple water rights connected to the reservoir. In the Bwam8A DAT file, the *WS* record capacities at the 22 reservoirs are revised as necessary to not constrain the *OS* record capacities. Spills in *SIM* assure that the *OS* record capacities are never exceeded. *SIM* fills the reservoirs to the capacities specified by the *OS* records subject to stream flow availability. An option is activated within *HYD* that increases naturalized flows by the amount of the shortage in reaching the *OS* record storage level. Likewise, a similar flow adjustment option in *HYD* increases naturalized flows in the amount of water supply diversion shortages for diversions from the 22 reservoirs, with the exception of the Brazos River Authority system diversion at the Richmond gage control point discussed in the next section.

Brazos River Authority Reservoir System Operations

The 12 Brazos River Authority (BRA) reservoirs listed in Table 4.6 represent 66.0 percent of the total permitted conservation storage capacity of the 706 reservoirs in the Bwam8 and Bwam8A datasets. The diversion targets associated with these 12 reservoirs account for 29.8 percent of the total of all diversion targets in the Bwam8 and Bwam8A datasets. Reliabilities computed in the Bwam8 model for these diversions are 100 percent or close to 100 percent.

Table 4.6
Brazos River Authority System Diversions

Reservoir	Control Point	Storage Capacity (acre-feet)	Bwam8 Diversion (ac-ft/year)	Bwam8A Diversion (ac-ft/year)
Possum Kingdom	515531	552,013	59,482	43,464
Granbury	515631	132,821	36,025	26,324
Whitney	515731	561,074	18,336	13,398
Aquilla	515831	41,700	2,394	1,749
Waco	509431	206,562	38,348	no change
Proctor	515931	54,702	14,068	no change
Belton	516031	432,978	107,738	78,725
Stillhouse Hollow	516131	224,279	67,768	49,518
Georgetown	516231	36,980	11,943	8,727
Granger	516331	50,540	2,569	1,877
Limestone	516531	208,017	39,337	28,744
Somerville	516431	154,254	48,000	35,074
System Diversion at the Richmond Gage			none	105,992
Total		2,655,920	446,008	446,008
Total as Percent of Basin Total		66.0%	29.8%	29.8%

The U.S. Army Corps of Engineers Fort Worth owns and operates nine of the 12 reservoirs listed in Table 4.6. The BRA owns and operates the other three reservoirs. The BRA has contracted for the conservation storage capacity of the nine federal reservoirs. The Corps of

Engineers is responsible for flood control operations. The large flood control pools contained in these nine reservoirs represent all of the flood control storage capacity controlled by gated outlet structures in the Brazos River Basin. Flood control storage capacity and operations are not included in the Bwam3 and Bwam8 models but are reflected in Bwam8A to the extent noted below.

Hydropower operations at Whitney and Possum Kingdom Reservoirs actually rely primarily on excess flows and water supply releases for downstream diversions. There are no water rights for hydropower generation. Hydropower operations are not included in the Bwam3 and Bwam8 models but are reflected in Bwam8A as discussed in the next paragraph.

Multiple-reservoir, multiple-purpose operations of the 12-reservoir BRA/USACE system are modeled in the Bwam8A dataset with observed storage *OS* records as described in the preceding section. Flood control, hydroelectric power generation, and multiple-reservoir system operations are not modeled in the Bwam3 and Bwam8 datasets. However, the *OS* record observed storages in Bwam8A reflect all aspects of actual reservoir operations. *WS* record storage capacities and *SV/SA* record storage-area tables were modified to allow encroachment into flood control pools or into surcharge storage in reservoirs that have no flood control pool.

BRA multiple-purpose, multiple-reservoir system operations include diversions from the lower Brazos River supplied by releases from multiple reservoirs as well as lakeside diversions and diversions at various distances below the dams on tributaries of the Brazos River. The City of Waco holds the water rights for diversions from Waco Reservoir. The BRA operates Proctor Reservoir to meet water supply needs in the vicinity of the reservoir. The other ten reservoirs are operated for downstream as well as lakeside diversions. About 26 percent of the BRA water right commitments occur in the lower Brazos River and can be supplied from releases from multiple reservoirs and/or unregulated stream flow under an excess flows permit.

In the Bwam8 dataset, all diversions associated with the BRA reservoirs occur at the individual reservoirs. The Bwam8A dataset includes modifications to more realistically approximate system operations. As discussed in the preceding section, observed end-of-month storage contents are reproduced in the Bwam8A model for these 12 BRA reservoirs and ten other reservoirs. The observed storage volumes input on *OS* records reflect actual system operations. The Bwam8 diversion targets are also adopted for the Bwam8A model with the following modification designed to better approximate system diversions from the lower Brazos River.

A diversion target of 105,992 acre-feet/year representing 26 percent of the total diversion amount associated with all the BRA water rights is assigned to the Richmond gage control point in the Bwam8A dataset. The BRA diversion rights are associated with the 11 reservoirs listed in Table 4.6 excluding Waco Reservoir. Proctor Reservoir is modeled in Bwam8A as well as Bwam8 as a local use reservoir. The diversion targets at the ten other BRA reservoirs are reduced by 26.93 percent for a total reduction of 105,992 acre-feet/year. The diversion targets in Bwam8 and Bwam8A are compared in the last two columns of Table 4.6.

The system diversion target 105,992 acre-feet/year is entered in the Bwam8A DAT file as a run-of-river diversion not connected to reservoirs. However, 22 reservoirs are operated with observed storage *OS* records in Bwam8A including the ten reservoirs assumed to be included in the system that makes releases for the 105,992 acre-feet/year diversion at the Richmond gage.

Reservoir spills mandated by *OS* records contribute to regulated flows at the Richmond gage and thus contribute to stream flows available to the system diversion. The *HYD* option to adjust naturalized flows for diversion shortages was not activated for this diversion.

Waco and Whitney Reservoirs are modeled in Bwam8 as multiple-owner reservoirs. The reservoirs are divided into component reservoirs and net evaporation is allocated using *EA* records. The dual simulation option is activated. These features in the Bwam8 dataset are designed for allocating storage between multiple water rights. Waco and Whitney Reservoirs are each modeled as individual reservoirs in the Bwam8A dataset. The component reservoirs are combined; the dual simulation feature is deactivated; and the evaporation allocation *EA* record feature is not used.

Actual BRA diversions from Proctor Reservoir are included in the Bwam8A DAT file replacing the Bwam8 diversions. The actual Bwam8A diversions at Proctor Reservoir average a little less than the Bwam8 diversions. This is the only case of adopting actual measured diversions.

Water Supply Diversions and Return Flows

The Bwam8 diversion targets and return flow specifications are adopted for Bwam8A. As noted in Chapter 1, the current use diversion targets were estimated during development of the original WAM dataset for each individual water right as the maximum annual diversion in any year of the ten year period from 1988 through 1997. As noted in Chapter 5, diversion shortages occasionally occur in the Bwam8A simulation. Thus, the diversion targets impose maximum limits on diversions, but the computed diversions are sometimes less than the targets.

The diversions associated with the 22 large reservoirs are handled differently in the *HYD* flow adjustments. The naturalized flows are increased in the *HYD* adjustment routines by the amount of the diversion shortages and storage shortages associated with the 22 reservoirs read by *HYD* from the *SIM* simulation results output file. These *HYD* flow adjustment options are applied to reproduce the actual observed reservoir storage levels and Bwam8 diversions. Storages and diversions are successfully reproduced for reservoirs located at primary control points for which naturalized flows are being computed by adjusting gaged flows. However, the 22 reservoirs are located at ungaged secondary control points for which naturalized flows are computed based on naturalized flows at primary gaged control points using flow distribution methods. Thus, the storage and diversion volumes are not always perfectly reproduced.

Reservoir storage volumes and diversions at the 684 other reservoirs and run-of-river diversions are computed in the conventional manner. Diversion shortages can and do occur in the Bwam8A as well as Bwam8 simulations.

Initial Estimate of 1998-2007 Naturalized Flows

A FLO file with 1998-2007 naturalized flows is required for the actual use Bwam8A *SIM* input dataset applied in the procedure described in the next section. However, 1998-2007 naturalized flows are the unknown data that the procedure is designed to compute. An initial set of 1998-2007 naturalized flows is developed for the 48 control points as follows solely for use in developing the initial estimate of flow adjustments. The new *AN* record feature of program *HYD* was used to develop this initial set of naturalized flows.

Although mean flows, median flows, or any other exceedance frequency flows could be adopted, the 75 percent exceedance frequency flows was adopted as being reasonably likely flows on the conservatively low side of median flows. Using the 1940-1997 naturalized flows at a particular control point, the flow volume that is equaled or exceeded in 75 percent of the 58 years was determined for each of the 12 months January through December. For example, at each control point, the January naturalized flow volume that is equaled or exceeded during 75 percent of the 58 years in the 1940 to 1997 naturalized flow dataset was determined. The resulting set of twelve 75% exceedance frequency naturalized flow volumes for January through December are repeated for each of the ten years during 1998-2007.

Computation of 1998-2007 Naturalized Flows for 48 Control Points

The *SIM* simulation model was executed repeatedly as described in Chapter 5 with the Bwam8A dataset with a period-of-analysis of January 1998 through December 2007. The Bwam8A (modified Bwam8) DAT file is designed to represent actual water resources development, management, and use during 1998-2007. The EVA file contains the previously discussed 1998-2007 net evaporation-precipitation depths. Since naturalized flows are not known, the statistical (75% frequency) flows described in the preceding section were used as the initial-estimate FLO file. The methodology is based on iteratively replacing the FLO file 1998-2007 naturalized flows.

Naturalized flows for 1998-2007 at the 48 control points were computed using programs *SIM* and *HYD* by generating flow adjustments and adding the flow adjustments to actual 1998-2007 observed flows. Naturalized flows at the 29 other control points were determined by flow distribution computations based on flows at one or more of the 48 control points as discussed in the next section. Since the naturalized flows were originally computed based on an initial estimate of naturalized flows, the *SIM* simulation was repeated with the latest naturalized flows as the FLO file input data. The process was repeated until the resulting naturalized flows stabilized, essentially no longer changing with further iterations.

The naturalized flow volumes for each of the 120 months at each of the 48 control points were computed as follows.

naturalized flow volume = actual observed flow volume + flow adjustment

The 75 percent frequency naturalized flows served only to obtain an initial set of flow adjustments. With the iterative procedure, the improved-estimate set of naturalized flows are input to *SIM* to obtain an improved-estimate set of flow adjustments which are added to observed flows to obtain an improved-estimate set of naturalized flows.

SIM simulations were performed with the Bwam8A dataset for the sole purpose of generating sequences of regulated and naturalized flows at the 48 control points and storage shortages and diversion shortages at the 22 large reservoirs that were used only for computing flow adjustments. The flow adjustments at 48 control points involved *SIM* simulation results at 70 control points including the control points of the 22 reservoirs. Program *HYD* was used to read the *SIM* simulation results and compute the flow adjustments.

The flow adjustments for each of the 120 months at each of the 48 control points were computed by subtracting regulated flows from naturalized flows and adding storage shortages and diversion shortages associated with 22 large reservoirs. Additional iterations omitted the shortages. Storage shortages occur when the storage volumes computed by *SIM* fail to reach the observed storage levels input of *OS* records due to insufficient available stream flow for refilling.

flow adjustment = naturalized flow − regulated flow + cascaded storage shortage
+ cascaded diversion shortage

storage shortage = storage target from *OS* record − simulated storage volume

The naturalized flow less regulated flow adjustment pertains to 48 individual control points and does not require cascading to downstream control points. However, the storage and diversion shortages apply to the control point at which the reservoir is located and all downstream control points. Cascading computations are performed within *HYD* to adjust flows at each of the 48 control points which happen to be located downstream of the reservoir.

Channel loss factors are required in the cascading computations that translate the storage and diversion shortage adjustments to downstream control points. The channel loss factors on the *CP* records in the Bwam8 DAT file are for reaches defined by the over three thousand control points. Any number of secondary control points with channel loss factors may be located between primary control points. Channel loss factors C_L were determined for the reaches defined by the 77 primary control points and 22 major reservoir control points based on aggregating the delivery ratios ($1.0-C_L$) of the sub-reaches. Channel loss factors C_L for N sub-reaches defined by secondary control points located between two primary control points are aggregated to a single reach based on the following relationship.

$$(1.0 - C_L)_{total} = (1.0 - C_L)_1 + (1.0 - C_L)_2 + ... + (1.0 - C_L)_N$$

Channel loss factors computed for the reaches between the primary control points are tabulated in Table 4.7.

Distribution of Naturalized Flows to the 29 Other Control Points

The 77 Brazos WAM primary control points are divided into two groups.

- Observed gaged flows from are available during 1998-2007 for 48 of the control points. Naturalized flows were determined at these 48 control points based on the methodology outlined in the preceding sections.
- Observed flow data are not available for the other 29 control points. Naturalized flows were determined at these 29 control points based on the methodology outlined in this section.

Naturalized monthly flows for 1998-2007 at each of the 29 control points are computed based on the naturalized flows at one or more of the 48 control points within the program *SIM*. The resulting flows at 77 control points comprise the 1998-2007 extension to the FLO input file.

Programs *HYD* and *SIM* both contain the same set of optional methods for distributing naturalized flows from gaged to ungaged control points. The option for generating naturalized flows is selected by parameter *INMETHOD(cp)* on the control point *CP* record. Information required to implement the flow distribution methods is provided in the DIS file. The August 2008 Fifth Edition of the *Reference* and *Users Manuals* describe the new *INMETHOD(cp)* option 10 which was added to support the flow extension applications. Application of this recently added flow distribution option is described as follows.

Table 4.7
Channel Loss Factors for Reaches Between Primary Control Points

	Control Points Upstream	Control Points Downstream	Loss Factor		Control Points Upstream	Control Points Downstream	Loss Factor
1	RWPL01	WRSP02	0.9501	40	BOWA40	BRWA41	0.0139
2	WRSP02	SFPE04	0.3814	41	BRWA41	BRHB42	0.0100
3	DUGI03	SFPE04	0.1983	42	BRHB42	BRBR59	0.0139
4	SFPE04	SFAS06	0.1520	43	SADL44	LEHS45	0.1747
5	CRJA05	SFAS06	0.1173	44	LEDL43	LEHS45	0.1987
6	SFAS06	BRSE11	0.4687	45	LEHS45	LEHM46	0.3624
7	NCKN10	BRSE11	0.3729	46	LEHM46	LEGT47	0.0119
8	BSLU07	DMAS09	0.6335	47	LEGT47	LEBE49	0.0267
9	DMJU08	DMAS09	0.4874	48	COPI48	LEBE49	0.0070
10	DMAS09	BRSE11	0.4918	49	LEBE49	LRLR53	0.0060
11	BRSE11	BRSB23	0.4205	50	LAKE50	LAYO51	0.0070
12	MSMN12	BRSB23	0.4616	51	LAYO51	LABE52	0.0080
13	CFRO13	CFHA14	0.3366	52	LABE52	LRLR53	0.0040
14	CFHA14	CFNU16	0.1217	53	LRLR53	LRCA58	0.0208
15	MUHA15	CFNU16	0.1043	54	NGGE54	GAGE56	0.0010
16	CFNU16	CFFG18	0.4346	55	SGGE55	GAGE56	0.0000
17	CAST17	CFFG18	0.3271	56	GAGE56	GALA57	0.0080
18	CFFG18	CFEL22	0.3139	57	GALA57	LRCA58	0.0139
19	HCAL19	HCBR21	0.1357	58	LRCA58	BRBR59	0.0364
20	BSBR20	HCBR21	0.0966	59	BRBR59	BRHE68	0.0247
21	HCBR21	CFEL22	0.1554	60	MYDB60	YCSO62	0.0228
22	CFEL22	BRSB23	0.0872	61	EYDB61	YCSO62	0.0198
23	BRSB23	SHGR26	0.0179	62	YCSO62	BRHE68	0.0228
24	GHGH24	SHGR26	0.0169	63	DCLY63	BRHE68	0.0257
25	CCIV25	SHGR26	0.0080	64	NAGR64	NAEA66	0.0139
26	SHGR26	BRPP27	0.0050	65	BGFR65	NAEA66	0.0070
27	BRPP27	BRDE29	0.0198	66	NAEA66	NABR67	0.0100
28	PPSA28	BRDE29	0.0384	67	NABR67	BRHE68	0.0383
29	BRDE29	BRGR30	0.0179	68	BRHE68	BRRI70	0.0236
30	BRGR30	BRAQ33	0.0208	69	MCBL69	BRRI70	0.0189
31	PAGR31	BRAQ33	0.0218	70	BRRI70	BRRO72	0.0100
32	NRBL32	BRAQ33	0.0119	71	BGNE71	BRRO72	0.0100
33	BRAQ33	BRWA41	0.0090	72	BRRO72	BRGM72	0.0169
34	AQAQ34	BRWA41	0.0080	73	BRGM73	OUT	0.0000
35	NBHI35	NBCL36	0.2156	74	CBALC2	SJGMC4	0.0000
36	NBCL36	NBVM37	0.0637	75	SJGMC4	OUT	0.0000
37	NBVM37	BOWA40	0.1105	76	CLPEC1	SJGBC3	0.0000
38	HGCR39	BOWA40	0.0534	77	SJGBC3	OUT	0.0000
39	MBMG38	BOWA40	0.0541				

Sequences of monthly naturalized flow volumes for January 1998 through December 2007 were computed at each of the 29 unknown-flow control points based on naturalized flows at one or more of the 48 known-flow control points and ratios between the means of 1940-1997 naturalized flows at the respective control points.

$$F_U = F_K \left(\frac{M_U}{M_K} \right)$$

F_U – naturalized flow at unknown flow control point

F_K – naturalized flow at a known flow control point or the summation of flows or difference in flows at multiple control points

M_U – 1940-1997 mean of naturalized flow at an unknown flow control point or the summation or difference in means at multiple control points

M_K – 1940-1997 mean of naturalized flow at a known flow control point or the summation or difference in means at multiple control points

The ratios of 1940-1997 mean naturalized flows were applied in a manner similar to the manner in which conventional drainage area ratios are applied routinely in many other studies. The mean flow ratios replace drainage area ratios.

Means of 1940-1997 naturalized flows at the 77 control points are tabulated in Table 3.2. The 29 unknown-flow control points are listed in Table 4.8 along with the relationships with known-flow control points from which their 1998-2007 naturalized flows were derived.

The naturalized flows at each of the 29 unknown-flow (1998-2007) control points were related by ratios of 1940-1997 means to naturalized flows at one or more selected known-flow control points as shown in Table 4.7. In most cases, the unknown-flow and known-flow control points are located on the same stream. In some cases, known-flow control points in adjacent watersheds were selected for synthesizing flows at a particular unknown-flow control point. For 21 of the unknown-flow control points, flows are transferred from a single known-flow control point. In four cases, incremental flows between known-flow control points are used to estimate flows at an unknown-flow control point. Flow at two or three upstream known-flow control points are used for synthesizing 1998-2007 monthly naturalized flows at four of the unknown-flow control points.

As an alternative to the approach outlined above, the flow distribution method based on combining the Natural Resource Conservation Service (NRCS) curve number (CN) equation with channel losses was also investigated. This is a technique described in the *Reference Manual* that is activated as flow distribution option 8 on *CP* records in either programs *HYD* or *SIM*. The watershed drainage area, curve number, and mean precipitation for each control point required for the NRCS CN method are available on the watershed parameter *WP* records in the flow distribution DIS file which is used by both *HYD* and *SIM*. The required channel loss factors are tabulated in Table 4.6. The NRCS CN method with channel losses was applied but not adopted for the final data set. The methodology outlined above based on ratios of 1940-1997 mean naturalized flows was concluded to yield more consistent and reasonable results.

As noted earlier in this chapter, measured releases from Proctor Reservoir were adopted as the gaged flows at control point LEHS45 located immediately downstream of Proctor Dam. However, control point LEHS45 was initially included with the control points listed in Table 4.8 for which naturalized flows were synthesized.

Control point LEHS45 is the site of the discontinued USGS stream gaging station on the Leon River near Hasse for which gage measurements were not made during 1998-2007. The 1998-2007 monthly naturalized flows at control point LEHS45 were initially computed as follows.

LEHS45 = 0.5480 (LEGT47)

The 1940-1997 mean naturalized flows at LEHS45 and LEGT47 from Table 3.2 are 141,270 and 257,790 acre-feet/year, with their ratio being 0.5480. The drainage areas of LEHS45 and LEGT47 are 1,283 and 2,379 square miles, and thus the drainage area ratio is 0.539 which is close to the mean flow ratio of 0.5480. However, the 1998-2007 storage volumes for Proctor Reservoir from a Bwam8A *SIM* simulation with these synthesized naturalized flows deviated significantly from observed storage volumes. Consequently, reservoir releases were compiled to provide gaged flows at LEHS45. With gaged flows at LEHS45 converted to naturalized flows as outlined earlier in this chapter, 1998-2007 *SIM* simulated Proctor Reservoir storages closely match observed storages.

Table 4.8
Relationships for Computing 1998-2007 Naturalized Flows for 29 Control Points

Control Point	River or Stream	Nearest City	Flow Synthesis Relationship with Source Control Points
WRSP02	White River Reservoir	Spur	6.7760 (RWPL01)
DUGI03	Duck Creek	Girard	0.4534 (DMJU08)
SFPE04	Salt Fork Brazos River	Peacock	0.6968 (SFAS06)
CRJA05	Croton Creek	Jayton	0.5578 (DMJU08)
BSLU07	Buffalo Spring Lake	Lubbock	6.8522 (RWPL01)
NCKN10	North Croton Creek	Knox City	0.5821 (DMJU08)
CFHA14	Clear Fork Brazos	Hawley	0.4721 (CFNU16)
MUHA15	Mulberry Creek	Hawley	0.0813 (CFNU16)
HCBR21	Hubbard Creek	Breckenridge	1.2015 (HCAL19 + BSBR20)
CFEL22	Clear Fork Brazos	Eliasville	1.2071 (CFFG18 + HCAL19 + BSBR20)
GHGH24	Lake Graham	Graham	0.2325 (BRPP27 − BRSB23)
CCIV25	Big Cedar Creek	Ivan	0.5762 (BSBR20)
SHGR26	Brazos River	Graford	0.9791 (BRPP27)
PPSA28	Palo Pinto Creek	Santo	0.3316 (BRDE29 − BRPP27)
NRBL32	Nolan River	Blum	0.3338 (BRAQ33 − BRGR30 − PAGR31)
NBHI35	North Bosque River	Hico	0.2755 (NBCL36)
MBMG38	Middle Bosque River	McGregor	0.2718 (NBVM37)
HGCR39	Hog Creek	Crawford	0.1268 (NBVM37)
BOWA40	Bosque River	Waco	1.7583 (NBVM37)
LEDL43	Leon River	De Leon	1.6071 (SADL44)
LEHM46	Leon River	Hamilton	0.6457 (LEGT47)
LAYO51	Lampasas River	Youngsport	1.7438 (LAKE50)
GAGE56	San Gabriel River	Georgetown	1.1086 (NGGE54 + SGGE55)
YCSO62	Yegua Creek	Somerville	2.7062 (MYDB60 + EYDB61)
MCBL69	Mill Creek	Bellville	0.3045 (BRRI70 − BRHE68)
BRGM73	Brazos River	Gulf of Mexico	0.9988 (BRRO72)
CLPEC1	Clear Creek	Pearland	0.3762 (CBALC2)
SJGBC3	Coastal Basin	Galveston Bay	4.5193 (CBALC2)
SJGMC4	Coastal Basin	Gulf of Mexico	10.9229 (CBALC2)

Iterative Algorithm for Computing Naturalized Flows

The computational task addressed in this section is defined as follows.

> A repetitive search procedure using *SIM* and *HYD* is applied to find 1998-2007 sequences of naturalized flows at 48 gaged control points that satisfy the following requirement. When the naturalized flows are input to *SIM* as a FLO file along with the Bwam8A DAT file, the *SIM* simulation produces 1998-2007 sequences of regulated flows at the 48 gaged control points that closely match the actual observed gaged flows at these sites.

The objective is to find a set of values for naturalized flows that will result in Bwam8A computed regulated flows that very closely reproduce the actual observed flows at the 48 gaged control points.

An iterative methodology is outlined in the preceding Chapter 2 and beginning of the present Chapter 4 for computing 1998-2007 monthly naturalized stream flows at 48 gaged control points based on observed gaged flows and the actual use scenario Bwam8A DAT file. *SIM* and *HYD* are applied in a repetitive search for a set of naturalized flows that will result in a set of regulated flows that closely reproduce gaged flows. *HYD* is used to adjust gaged flows based on *SIM* Bwam8A simulation results. Naturalized flows are distributed within *SIM* to 3,786 other control points based on the known flows at the 48 control points. This section focuses on the behavior of the simulation results as the iterations progress from the initial estimate of naturalized flows to the final adopted naturalized flows.

The adjustments to the naturalized flows performed in the repetitive *SIM/HYD* based computations are expressed in Equations 2.1, 2.2, and 2.3 introduced in Chapter 2.

$$\text{naturalized flow} = \text{gaged flow} + \text{flow adjustment} \tag{2.1}$$

$$\begin{gathered}\text{flow adjustment} = \text{naturalized flow} - \text{regulated flow} \\ + \text{storage shortage} + \text{diversion shortage}\end{gathered} \tag{2.2}$$

$$\text{naturalized flow} = \text{naturalized flow} + \text{gaged flow} - \text{regulated flow} \tag{2.3}$$

The results of two sets of iterations are presented in Tables 5.2 through 5.14. Iterations 1 through 12 are based on Equations 2.1 and 2.2. Iterations 13 through 20 are based on Equation 2.3. Storage shortages and diversion shortages associated with 22 reservoirs are included in the adjustments during the first twelve iterations but are omitted in the last eight iterations for reasons discussed in the next paragraph.

The storage shortage and diversion shortage adjustments in Equation 2.2 are associated with the 22 major reservoirs listed in Tables 4.2, 4.3, 4.9, and 4.10. Locations of the reservoirs are shown in the Figure 3.6 map. The storage and diversion shortage adjustments in Equation 2.2 work perfectly for the large reservoirs located at or near one of the 48 gaged control points at which flow adjustments are being applied. The procedure assures that observed storage contents are reproduced with the final computed set of naturalized flows. However, the majority of the 22 reservoirs are smaller reservoir projects located at ungaged control points significant distances from the nearest of the 48 gaged control points. Naturalized flows at ungaged control points are computed within *SIM* by flow distribution techniques. The Equation 2.2 flow adjustments reduce storage shortages and diversion shortages at these ungaged control point reservoirs, but some shortages may still occur. At some point in the iterations, no further reductions in storage and diversion shortages at the 22 reservoirs is possible and shifting from Equations 2.2 and 2.3 to Equation 2.3 is worthwhile.

The mean 1998-2007 end-of-month storage shortages (drawdowns) occurring in each the 22 reservoirs in each of 20 *SIM* simulations are tabulated in Table 4.9. The maximum shortage (drawdown) to occur in any of the 120 months of the 1998-2007 simulations are shown in Table 4.10. The shortage or drawdown volumes are the storage capacities recorded on observed storage *OS* records less the end-of-month storage volumes computed by *SIM*. The shortages are expressed in Tables 4.9 and 4.10 as a percentage of the volumes entered on the observed storage *OS* records.

Possum Kingdom, Granbury, Whitney, Proctor, Belton, Stillhouse Hollow, Georgetown, Granger, and Somerville Reservoirs have no storage shortages, meaning their observed storage levels during 1998-2007 are reproduced in the *SIM* simulation. Of the 22 reservoirs listed in Table 4.9, Millers Creek, Fort Phantom Hill, Stamford, Graham, Palo Pinto, and Waco are the only reservoirs with mean storage shortages greater than 1.0 percent of the *OS* record actual observed storage volumes. These reservoirs are located at ungaged control points that are significant distances from the nearest gaged control points.

Twenty iterations of the procedure outlined in Chapters 2 and 4 are summarized in Tables 4.9 through 4.21. Each iteration represents an execution of the *SIM* simulation model with the Bwam8A DAT file and 1998-2007 hydrologic period-of-analysis. The DAT, EVA, and DIS input files are the same for all 20 iterations. The naturalized flows in the FLO file change with each iteration. Program *HYD* uses data read from the *SIM* simulation results OUT file to adjust the naturalized flows based on Equations 2.1 and 2.2 for iterations 1 through 12 and Equation 2.3 for iterations 13 through 20. The revised naturalized flows recorded in the *HYD* output FLO file are adopted as the *SIM* input FLO file for the next iteration. The iterations continue until the regulated flows at the 48 gaged control points very closely match the actual observed flows at these locations.

The interconnected executions of the WRAP programs *SIM* and *HYD* are very efficient. With the *SIM* and *HYD* input files complete and proficiency in understanding and applying the procedure established, each additional iteration requires only a few minutes. *SIM* and *HYD* execute quickly, and the manual interchange of data files is also quick.

Table 4.9
Mean Reservoir Storage Shortage as Percentage of Observed Storage Volume

Reservoir Name	1998-2007 Mean Storage Shortage at Each Iteration as a Percentage of Observed Storage 1	2	3	4	5	6	7	8	9	10	11	12
Alan Henry	62.3%	0.1%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
White River	78.6%	7.7%	3.4%	1.6%	0.9%	0.8%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
Millers Creek	20.2%	0.4%	2.1%	2.2%	2.0%	2.2%	2.0%	2.1%	2.0%	2.1%	2.1%	2.1%
Fort Phantom	47.5%	0.2%	2.4%	0.8%	1.0%	1.0%	0.9%	1.0%	0.9%	1.0%	0.9%	1.0%
Stamford	64.1%	0.6%	5.7%	1.7%	2.9%	1.9%	2.2%	2.0%	2.2%	2.0%	2.2%	2.0%
Hubbard	31.1%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Graham	16.7%	0.5%	2.1%	1.6%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
Possum Kingd	4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Palo Pinto	13.2%	3.1%	1.9%	2.1%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Proctor	71.2%	0.3%	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Granbury	1.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Squaw Creek	7.5%	0.1%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%	0.7%
Pat Cleburne	6.9%	0.2%	0.6%	0.5%	0.6%	0.6%	0.5%	0.6%	0.5%	0.6%	0.5%	0.6%
Whitney	9.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aquilla	15.6%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Waco	10.6%	1.6%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Belton	5.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stillhouse	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Georgetown	19.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Granger	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Somerville	12.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Limestone	7.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Reservoir Name	Reservoir WAM ID	Mean Storage Shortage at Each Iteration as a Percentage of Observed Storage 13	14	15	16	17	18	19	20
Alan Henry	ALANHN	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
White River	WHTRVR	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Millers Creek	MLRCRK	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
Fort Phantom	FPHNHR	4.2%	7.3%	9.4%	10.7%	11.3%	11.6%	11.8%	11.9%
Stamford	STMFRD	7.1%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%	7.4%
Hubbard	HUBBRD	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%	0.5%
Graham	EDLGRM	2.6%	2.7%	2.7%	2.8%	2.8%	2.8%	2.8%	2.8%
Possum Kingd	POSDOM	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Palo Pinto	PLPNTO	3.4%	3.7%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
Proctor	PRCTOR	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Granbury	GRNBRY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Squaw Creek	SQWCRK	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Pat Cleburne	CLEBRN	0.8%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%	0.9%
Whitney	WHITNY	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aquilla	AQUILA	0.1%	0.2%	0.2%	0.3%	0.3%	0.3%	0.3%	0.4%
Waco	LKWACO	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
Belton	BELTON	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stillhouse	STLHSE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Georgetown	GRGTWN	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Granger	GRNGER	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Somerville	SMRVLE	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Limestone	LMSTNE	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table 4.10
Maximum Reservoir Shortage as Percentage of Observed Storage Volume

Reservoir Name	Maximum Storage Shortage during 1998-2007 as a Percentage of Observed Storage Volume											
	1	2	3	4	5	6	7	8	9	10	11	12
Alan Henry	82.3%	5.0%	6.6%	6.5%	6.7%	6.7%	6.7%	6.8%	6.8%	6.8%	6.8%	6.8%
White River	97.9%	38.7%	28.6%	27.6%	26.7%	25.9%	25.1%	24.4%	23.8%	23.2%	22.7%	22.5%
Millers Creek	47.5%	13.1%	29.2%	27.7%	26.9%	27.6%	27.0%	27.6%	27.1%	27.5%	27.1%	27.5%
Fort Phantom	83.6%	11.8%	27.1%	17.7%	17.9%	17.8%	17.9%	17.8%	17.9%	17.8%	17.9%	17.8%
Stamford	96.2%	18.3%	36.4%	29.2%	31.6%	30.9%	31.4%	30.9%	31.4%	30.9%	31.4%	30.9%
Hubbard	86.3%	6.2%	5.7%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
Graham	43.3%	32.3%	35.8%	32.8%	33.0%	33.0%	33.0%	33.0%	33.0%	33.0%	33.0%	33.0%
Possum Kingd	19.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Palo Pinto	65.4%	24.2%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%	24.3%
Proctor	100.0%	26.0%	6.2%	1.6%	0.6%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Granbury	9.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Squaw Creek	12.0%	2.6%	4.4%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%	4.1%
Pat Cleburne	36.2%	12.9%	15.7%	14.7%	14.7%	14.7%	14.6%	14.7%	14.6%	14.7%	14.6%	14.7%
Whitney	56.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aquilla	71.1%	4.4%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%	3.8%
Waco	63.5%	51.5%	50.9%	50.1%	49.9%	49.9%	49.9%	49.9%	49.9%	49.9%	49.9%	49.9%
Belton	60.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stillhouse	60.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Georgetown	78.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Granger	69.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Somerville	65.3%	13.0%	12.9%	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%
Limestone	22.6%	0.5%	0.6%	0.6%	0.6%	0.6%	0.6%	0.5%	0.5%	0.5%	0.5%	0.5%

Reservoir WAM ID	Maximum Storage Shortage as a Percentage of Observed Storage Volume							
	13	14	15	16	17	18	19	20
Alan Henry	8.1%	8.2%	8.2%	8.2%	8.2%	8.2%	8.2%	8.2%
White River	22.6%	22.7%	22.9%	23.1%	23.3%	23.5%	23.7%	23.9%
Millers Creek	34.6%	34.9%	34.8%	34.8%	34.8%	34.8%	34.7%	34.7%
Fort Phantom	32.5%	41.0%	45.3%	47.6%	48.8%	49.4%	49.7%	49.8%
Stamford	44.7%	46.6%	46.8%	46.8%	46.8%	46.8%	46.8%	46.8%
Hubbard	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
Graham	41.7%	42.9%	43.0%	43.1%	43.1%	43.1%	43.1%	43.1%
Possum Kingd	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Palo Pinto	26.8%	28.2%	28.6%	28.7%	28.7%	28.7%	28.7%	28.7%
Proctor	0.3%	0.4%	0.6%	0.7%	0.8%	0.9%	1.1%	1.2%
Granbury	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Squaw Creek	5.4%	5.5%	5.6%	5.6%	5.6%	5.6%	5.6%	5.6%
Pat Cleburne	18.7%	19.3%	19.5%	19.5%	19.5%	19.5%	19.5%	19.5%
Whitney	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Aquilla	7.3%	10.2%	12.6%	14.5%	16.2%	17.5%	18.6%	19.5%
Waco	49.9%	49.9%	49.9%	49.9%	49.9%	49.9%	49.9%	49.9%
Belton	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Stillhouse	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Georgetown	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Granger	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Somerville	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%	12.8%
Limestone	1.5%	2.2%	2.5%	2.7%	2.8%	2.9%	2.9%	2.9%

Basin summaries developed with the WRAP program *TABLES* with a 2SBA record from the results of the 20 *SIM* simulations are tabulated in Table 4.11. The table consists of means of 1998-2007 annual volumes in acre-feet/year. For naturalized and unappropriated stream flows, the quantities shown represent the maximum flow at any control point in any given month, based on comparing all control points. All other quantities in Table 4.11 basin summary are the sum of the values for all control points.

Table 4.11
Summary Table of 1998-2007 Mean Annual Volumes for the Twenty Iterative Simulations

	Naturalized Flow (ac-ft/yr)	Return Flow (ac-ft/yr)	Flow Depletion (ac-ft/yr)	Unappropriated Flow (ac-ft/yr)	Storage (acre-feet)	Net Evap-Pre (ac-ft/yr)	Diversion Target (ac-ft/yr)	Actual Diversion (ac-ft/yr)	Shortage (ac-ft/yr)
1	2,040,574	223,516	1,376,162	905,145	2,844,063	281,611	1,613,065	1,007,602	605,463
2	26,241,132	294,661	2,727,068	9,130,894	3,404,096	550,253	1,526,470	1,425,663	100,807
3	13,471,006	285,897	2,635,423	6,531,769	3,389,539	462,655	1,564,328	1,387,270	177,059
4	13,476,056	289,859	2,641,184	6,512,200	3,395,097	461,795	1,539,065	1,392,586	146,479
5	13,438,992	286,804	2,635,597	6,492,053	3,393,569	460,493	1,559,088	1,388,325	170,764
6	13,444,754	289,226	2,639,080	6,497,911	3,394,479	460,902	1,541,795	1,391,255	150,541
7	13,441,368	287,324	2,636,491	6,492,452	3,394,257	460,584	1,555,943	1,389,032	166,911
8	13,443,494	288,846	2,638,424	6,495,959	3,394,296	460,815	1,543,366	1,390,669	152,697
9	13,441,648	287,609	2,637,001	6,492,650	3,394,446	460,623	1,554,081	1,389,467	164,615
10	13,443,283	288,648	2,638,474	6,495,319	3,394,211	460,791	1,544,370	1,390,766	153,604
11	13,441,894	287,810	2,637,460	6,492,958	3,394,563	460,648	1,552,748	1,389,893	162,855
12	13,443,096	288,511	2,638,435	6,495,045	3,394,134	460,768	1,544,914	1,390,795	154,119
13	13,053,365	283,070	2,616,205	6,379,536	3,385,230	457,185	1,572,119	1,375,407	196,712
14	13,042,354	281,602	2,607,133	6,370,500	3,380,228	456,226	1,574,600	1,369,061	205,539
15	13,041,504	281,034	2,603,246	6,367,670	3,377,655	455,790	1,574,843	1,366,359	208,485
16	13,041,218	280,910	2,601,347	6,367,029	3,376,403	455,555	1,574,935	1,365,293	209,643
17	13,041,117	280,874	2,600,273	6,366,750	3,375,785	455,430	1,574,964	1,364,683	210,280
18	13,041,059	280,852	2,599,579	6,366,614	3,375,491	455,360	1,574,979	1,364,244	210,736
19	13,041,053	280,831	2,599,095	6,366,526	3,375,348	455,318	1,575,040	1,363,901	211,139
20	13,041,063	280,820	2,598,888	6,366,312	3,375,284	455,293	1,575,069	1,363,788	211,281

Each line of Table 4.11 summarizes one of the twenty *SIM* simulations. Most changes in flow volumes and other variables occur during the first three iterations, but gradual changes continue with further iterations. The results are stable by 20 iterations.

The first column of Table 4.11 numbers the 20 consecutive iterative repetitions of the *SIM* simulation with naturalized flows being adjusted in each iteration. The mean of the basin total naturalized flows as defined by the *TABLES* 2SBA record are tabulated in the second column. The naturalized flows for the first iteration were arbitrarily set as 75 percent exceedance flows for each of the 12 months of the year which were repeated of each of the ten years of the 1998-2007 hydrologic simulation period. The naturalized flows for each of the 12 months January through December are the amounts equaled or exceeded during 75 percent of the 58 years of the original 1940-1997 hydrologic period-of-analysis.

The initial mean basin total naturalized flow shown in Table 4.11 is 2,040,574 acre-feet/year. With the *HYD* adjustments reflected in Equations 2.1 and 2.2, the mean basin total naturalized flows shown in Table 4.11 increased to 26,241,132 acre-feet/year for the second iteration and then decreased to 13,471,006 acre-feet/year for the third iteration. Between iterations 3 and 20, the mean naturalized flows gradually changed from 13,471,006 acre-feet/year to 13,041,063 acre-feet/year. The mean naturalized flows stayed essentially constant, varying between 13,041,053 and 13,041,218 acre-feet/year, during the last five iterations. The mean naturalized flow is essentially a constant 13,041,100 acre-feet/year for iterations 17, 18, 19, and 20.

To the extent that the Bwam8A DAT file and all other aspects of the *SIM* simulation represents actual water resources development, allocation, management, and use during each month of the 1998-2007 period-of-analysis, the regulated flows computed by *SIM* at the 48 gaged control points represent actual physical monthly flow volumes at these locations. Thus, the iterations are continued until the computed regulated flows closely reproduce actual observed flows at the 48 gaged sites.

Frequency tables are presented as Tables 4.12 through 4.21 as measures of how closely regulated flows match gaged flows in each of the consecutive 20 iterations of the *SIM/HYD* computational procedure. Frequency tables were created from the *SIM* simulation results using the *TABLES* 2FRE record feature. Observed gaged flows are shown in Tables 4.12 through 4.21 in units of acre-feet/month. *SIM* computed monthly regulated flow volumes at the 48 gaged control points are expressed in the tables as a percentage of the corresponding actual observed flow volumes. The objective is to iterate to a set of naturalized flows resulting in regulated flows that are 100.0 percent of the corresponding gaged flows.

Frequency statistics for gaged observed flows and *SIM* computed regulated flows at the Richmond, Waco, and Cameron gages (control points BRRI70, BRWA41, LRCA58) for each of the 20 iterations are presented as Tables 4.12, 4.13, and 4.14. Regulated flows are expressed as a percentage of gaged flows. The locations of the control points are shown in Figure 3.5 as well as in several other figures in Chapters 3 and 4. The Richmond gage on the Brazos River about 60 miles above its confluence at the Gulf of Mexico represents the outlet for most of the Brazos River Basin.

The objective is for regulated flows to be the same as gaged flows which is expressed in the tables as 100.0 percent of gaged flow statistics. The regulated flow statistics for the Richmond gage shown in Table 4.12 range from 100.0 percent to 100.2 percent of the corresponding gaged flow volume by iteration 20 and in most cases is 100.0 percent. The regulated flow statistics for the Waco gage on the Brazos River and Cameron gage on the Little River similarly reach 100.0 percent or very close to 100.0 percent of the corresponding gaged flow volumes as the iterations proceed.

Means and flow-frequency relationships for all 48 gaged control points are presented as Tables 4.15 through 4.21. The 1998-1997 mean gaged flow in acre-feet/month at the 48 gaged locations and corresponding mean regulated flows as a percentage of gaged flows are tabulated in Table 4.15 for each of the 20 repeats of the *SIM* Bwam8A simulation. By the 20th iteration, the mean regulated flow is 100.0% of the mean gaged flow at 47 of the 48 control points and 100.3% at the remaining control point. Thus, mean gaged flows at the 48 gaged control points are very closely reproduced. Flows equaled or exceeded during 98%, 90%, 75%, 50%, 25%, and 10% of the 120 months of the 1998-2007 simulations are tabulated in Tables 4.16-4.21. Though not perfect, the flow-frequency relationships are reproduced very closely.

Table 4.12
Frequency Statistics for Observed and Regulated Flow
Richmond Gage on the Brazos River (Control Point BRRI70)

	Gaged Flow	Iterations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	(acre-feet/month)	Regulated Flow at Each Iteration as a Percentage of Gaged Flow																			
Mean	515,766	18.7	145.3	102.7	102.3	102.0	102.1	102.0	102.0	102.0	102.0	102.0	102.0	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
Std Dev	609,133	9.0	125.9	100.8	100.4	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Minimum	25,763	126.9	249.5	152.7	142.7	142.8	141.5	143.4	141.0	143.7	140.7	143.9	140.4	103.8	101.0	100.4	100.2	100.1	100.0	100.1	100.0
99.50%	28,715	113.9	224.5	141.3	137.0	137.2	135.8	137.6	135.4	137.8	135.1	138.0	135.0	103.6	101.0	100.4	100.2	100.1	100.0	100.0	100.0
99%	30,941	106.0	211.5	136.0	132.8	133.0	131.6	133.4	131.3	133.6	131.0	133.7	130.9	103.5	101.0	100.4	100.2	100.1	100.0	99.9	100.0
98%	32,170	103.4	214.7	144.2	131.5	131.7	130.5	132.0	130.1	132.1	129.9	132.2	129.8	102.8	100.9	100.4	100.2	100.1	100.1	100.1	100.0
95%	39,537	87.0	229.1	136.1	131.5	131.5	131.5	131.5	130.9	125.4	125.5	125.4	125.5	104.1	101.9	101.0	100.5	100.3	100.2	100.1	100.1
90%	50,666	109.9	328.8	136.7	121.1	120.8	120.6	121.0	120.4	121.1	120.3	121.2	120.3	103.3	101.1	101.1	101.1	101.1	101.1	100.9	100.2
85%	69,911	79.6	302.6	117.7	120.5	118.4	118.1	118.3	117.5	118.3	117.4	118.4	117.3	103.2	102.2	100.4	100.3	100.2	100.2	100.2	100.2
80%	79,503	73.8	308.1	114.8	111.1	108.3	108.9	108.4	108.9	108.4	108.9	108.4	108.9	100.7	100.2	100.1	100.1	100.0	100.0	100.0	100.0
75%	89,465	69.6	309.0	114.4	116.8	116.3	116.0	116.3	116.0	116.3	116.0	116.3	116.0	101.6	100.6	100.3	100.2	100.2	100.2	100.2	100.2
70%	117,687	55.0	244.6	104.5	106.4	104.9	105.1	104.9	104.7	105.0	104.6	105.1	104.6	100.7	100.3	100.1	100.1	100.0	100.0	100.0	100.0
60%	184,770	36.5	195.0	105.8	102.3	101.3	101.5	101.3	101.4	101.3	101.4	101.3	101.4	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
50%	259,662	27.2	184.6	102.5	102.4	102.4	102.3	102.4	102.3	102.4	102.3	102.4	102.3	100.3	100.1	100.1	100.1	100.1	100.0	100.0	100.0
40%	382,268	26.4	162.7	102.8	101.7	101.5	101.6	101.5	101.6	101.5	101.6	101.5	101.6	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
30%	595,999	17.9	144.4	101.2	101.4	101.4	101.4	101.4	101.3	101.4	101.3	101.4	101.3	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0
25%	741,909	15.0	141.8	101.6	101.5	100.7	100.8	100.7	100.8	100.7	100.8	100.7	100.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20%	1,021,248	11.1	123.4	101.5	101.2	101.2	101.2	101.2	101.2	101.2	101.2	101.2	101.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
15%	1,220,529	15.1	114.2	100.4	101.2	100.5	100.6	100.6	100.5	100.6	100.5	100.6	100.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10%	1,357,154	15.0	128.9	102.9	103.7	102.7	102.9	102.8	102.9	102.9	102.9	102.9	102.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
5%	1,632,496	13.2	138.7	100.3	100.5	100.3	100.4	100.3	100.4	100.3	100.4	100.3	100.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2%	2,365,662	10.1	142.6	101.7	100.4	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1%	3,530,287	7.3	138.1	101.8	100.4	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Max	3,751,359	7.0	137.2	101.7	100.4	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.13
Frequency Statistics for Observed and Regulated Flow
Waco Gage on the Brazos River (Control Point BRWA41)

	Gaged Flow	Iterations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	(acre-feet/month)	Regulated Flow at Each Iteration as a Percentage of Gaged Flow																			
Mean	116,466	9.4	246.3	108.7	109.8	108.3	108.9	108.4	108.7	108.5	108.7	108.5	108.7	100.5	100.1	100.1	100.0	100.0	100.0	100.0	100.0
Std Dev	217,543	6.8	143.4	100.8	100.5	100.3	100.3	100.4	100.4	100.4	100.4	100.4	100.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Minimum	2,029	0.0	1,446.8	572.9	678.2	683.4	660.1	689.2	655.1	692.6	651.0	695.0	648.8	134.1	108.1	108.1	103.7	101.8	102.1	100.9	100.8
99.50%	2,140	0.0	1,434.8	552.8	657.6	655.8	640.0	659.9	634.5	661.5	630.3	662.4	627.6	139.3	104.4	104.4	102.0	101.1	101.3	100.9	100.8
99%	2,250	0.0	1,408.3	537.2	635.5	629.2	618.6	633.3	612.7	634.5	608.6	634.9	605.9	142.8	102.5	102.5	101.2	100.7	100.8	100.8	100.7
98%	2,496	0.0	1,316.8	507.9	577.5	570.9	565.2	578.6	560.6	582.2	557.7	584.5	556.1	144.2	104.4	104.4	102.0	100.9	100.0	100.1	100.1
95%	7,256	0.0	939.1	228.7	236.9	212.7	226.1	213.9	225.7	214.2	225.7	214.2	225.7	119.3	105.4	105.4	102.4	101.0	99.9	99.9	99.8
90%	10,699	9.0	779.8	174.3	199.4	190.0	193.5	190.0	193.3	190.2	193.1	190.4	193.0	110.1	101.1	101.1	100.5	100.2	100.1	100.1	100.0
85%	15,310	8.6	645.5	153.5	155.2	145.5	151.8	145.9	151.8	145.9	151.8	145.9	151.8	102.4	100.7	100.7	100.3	100.2	100.1	100.0	100.0
80%	19,615	10.8	617.8	145.3	154.2	151.6	154.2	151.4	154.3	151.3	154.4	151.2	154.5	106.0	100.7	100.7	100.4	100.2	100.1	100.1	100.0
75%	25,456	10.2	523.8	132.9	134.8	132.1	134.5	132.4	132.5	132.0	132.0	132.0	131.7	101.3	100.1	100.1	100.0	100.0	100.0	100.0	100.0
70%	27,301	13.1	517.6	129.6	133.4	128.2	132.5	128.1	132.3	128.1	132.1	128.1	132.0	101.8	100.9	100.9	100.5	100.2	100.1	100.1	100.0
60%	35,970	10.7	472.7	127.1	127.3	125.6	127.1	125.6	127.2	125.6	127.2	125.6	127.2	103.4	103.0	103.0	102.5	102.0	101.6	101.3	101.1
50%	53,248	11.7	381.6	116.4	122.7	116.5	121.9	117.7	119.2	118.4	118.7	118.8	118.3	104.0	100.9	100.9	100.4	100.2	100.1	100.0	100.0
40%	70,157	10.2	318.2	110.2	111.5	108.7	111.0	108.9	109.6	109.1	109.3	109.2	109.1	100.7	100.6	100.6	100.5	100.5	100.4	100.3	100.2
30%	96,781	8.3	289.0	97.6	105.1	101.6	103.1	101.6	102.5	101.5	102.5	101.5	102.5	100.0	99.9	99.9	100.0	100.0	100.0	100.0	100.0
25%	113,875	14.3	266.8	104.0	102.1	102.2	102.0	102.3	102.0	102.3	102.0	102.3	102.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20%	135,027	12.1	283.5	108.0	107.9	105.3	106.3	105.4	105.8	105.6	105.8	105.6	105.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
15%	176,838	14.1	258.7	109.5	104.8	104.2	104.5	104.1	104.5	104.1	104.6	104.1	104.6	99.7	99.7	99.7	99.7	99.7	99.8	99.8	99.9
10%	262,860	11.7	225.2	105.7	106.1	104.2	104.5	104.2	104.5	104.2	104.4	104.2	104.4	99.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0
5%	451,872	9.0	180.0	113.0	112.3	111.7	111.8	111.6	111.8	111.6	111.7	111.7	111.7	100.4	100.1	100.1	100.0	100.0	100.0	100.0	100.0
2%	1,076,980	5.9	152.0	101.5	100.5	100.4	100.4	100.4	100.4	100.4	100.4	100.4	100.4	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1%	1,541,777	5.3	141.0	100.4	100.3	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Max	1,629,606	5.3	138.2	100.1	100.3	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.14
Frequency Statistics for Observed and Regulated Flow
Cameron Gage on the Little River (Control Point LRCA58)

	Gaged Flow	Iteration 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	(acre-feet/month)	Regulated Flow at Each Iteration as a Percentage of Gaged Flow																			
Mean	133,094	9.7	143.4	101.1	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Std Dev	167,904	6.0	159.8	102.2	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Minimum	3,382	125.9	190.0	128.9	114.1	112.6	112.0	111.6	111.1	111.0	110.9	110.9	110.9	109.9	108.9	108.0	107.2	106.4	105.8	105.2	104.7
99.50%	3,751	113.6	203.1	139.6	114.6	108.1	106.4	105.5	104.2	104.0	104.0	104.0	104.0	103.6	103.2	102.9	102.6	102.4	102.1	101.9	101.7
99%	4,366	97.7	193.0	133.6	110.9	104.0	102.4	101.5	100.3	100.1	100.1	100.1	100.0	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
98%	5,891	72.9	149.8	100.9	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
95%	6,887	63.2	145.0	106.8	101.0	100.9	100.8	100.6	100.3	100.2	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
90%	8,547	54.4	200.1	103.3	102.0	101.6	101.3	100.8	100.5	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
85%	9,715	50.7	257.8	108.6	101.8	100.6	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
80%	12,789	42.3	252.1	102.1	102.1	102.0	102.0	102.0	101.9	101.9	101.9	101.9	101.9	101.9	101.7	101.5	101.4	101.2	101.1	101.0	100.9
75%	15,310	38.0	240.0	102.5	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
70%	21,029	29.3	207.4	104.9	101.5	101.2	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
60%	33,818	23.2	190.3	101.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
50%	54,417	15.6	185.2	101.7	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
40%	92,416	12.4	147.3	100.3	100.0	100.0	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
30%	181,450	7.5	121.5	100.8	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
25%	218,834	8.4	117.1	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
20%	240,663	8.8	117.5	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
15%	293,911	8.1	115.0	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10%	377,472	7.0	116.5	100.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
5%	504,690	7.3	122.0	100.4	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2%	709,567	6.2	199.2	103.7	100.6	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1%	779,294	5.8	209.3	108.1	101.3	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Max	795,096	5.7	208.0	108.6	101.4	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.15
Mean Regulated Flow at the 48 Control Points as a Percentage of Mean Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	Regulated Flow as Percentage of Gaged Flow : Mean 1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	100.0	0.3	30.7	64.9	81.8	92.2	97.0	98.5	99.2	99.6	99.8	99.9	99.9
SFAS06	2653.9	20.5	220.4	114.5	107.1	104.6	103.5	103.2	103.1	103.1	103.0	103.0	103.0
DMJU08	2242.3	4.5	98.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	5379.9	15.0	626.8	102.5	105.0	105.0	105.1	105.1	105.2	105.2	105.2	105.2	105.2
BRSE11	13484.6	21.8	218.5	102.0	101.8	101.5	101.4	101.4	101.4	101.4	101.4	101.4	101.4
MSMN12	537.3	0.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	220.1	27.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFNU16	1725.4	2.9	1372.3	185.2	321.1	224.5	270.8	233.6	263.8	237.9	259.9	241.3	257.0
CAST17	2037.6	5.7	96.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	7366.8	4.3	494.6	111.0	151.2	120.2	134.5	122.9	130.7	124.1	129.7	124.8	129.1
HCAL19	2301.4	4.8	93.6	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	1409.8	3.0	90.2	99.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	30399.9	22.5	336.8	106.9	112.8	108.0	110.1	108.3	109.5	108.5	109.3	108.6	109.3
BRPP27	31076.1	5.2	406.0	109.3	115.4	110.2	112.2	110.6	111.7	110.7	111.5	110.8	111.4
BRDE29	38118.2	11.2	352.6	110.2	114.7	110.5	112.2	110.8	111.7	111.0	111.6	111.0	111.5
BRGR30	43592.7	8.6	319.4	108.9	112.6	109.0	110.4	109.3	110.1	109.4	110.0	109.5	109.9
PAGR31	4576.3	17.1	97.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	66702.3	3.9	322.3	109.2	111.3	108.8	109.7	109.0	109.5	109.1	109.4	109.1	109.4
AQAQ34	11988.9	1.3	149.6	100.6	100.3	100.3	100.3	100.3	100.3	100.3	100.3	100.3	100.3
NBCL36	15189.3	6.7	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	27723.7	5.5	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	116466.2	9.4	246.3	108.7	109.8	108.3	108.9	108.4	108.7	108.5	108.7	108.5	108.7
BRHB42	155638.4	12.7	209.0	106.4	107.2	106.2	106.6	106.3	106.5	106.3	106.4	106.3	106.4
SADL44	1975.0	8.0	97.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	5700.6	0.5	636.0	109.6	101.9	100.5	100.2	100.1	100.0	100.0	100.0	100.0	100.0
LEGT47	21397.2	7.6	189.6	101.3	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	7595.6	5.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	39383.9	1.1	206.4	101.7	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	13135.1	11.7	100.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	25229.4	0.4	128.6	103.1	100.6	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	78574.7	5.5	162.6	101.8	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	4397.3	1.0	261.8	100.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	3433.9	11.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	18227.7	6.0	153.6	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	133094.0	9.7	143.4	101.1	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	334336.8	14.3	166.8	103.4	103.4	102.9	103.0	102.9	103.0	102.9	103.0	102.9	102.9
MYDB60	5381.8	4.8	98.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	5326.7	8.0	98.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	5333.2	5.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	8073.7	5.5	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	3841.2	5.7	99.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	30221.5	3.0	141.6	101.5	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8
NABR67	33730.7	6.7	136.4	101.3	100.7	100.7	100.7	100.7	100.7	100.7	100.7	100.7	100.7
BRHE68	486485.3	17.6	150.5	102.5	102.5	102.1	102.2	102.1	102.2	102.1	102.2	102.2	102.2
BRRI70	515766.2	18.7	145.3	102.7	102.3	102.0	102.1	102.0	102.0	102.0	102.0	102.0	102.0
BGNE71	2477.5	8.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	525369.6	14.4	143.7	102.6	102.2	101.9	102.0	101.9	102.0	101.9	102.0	101.9	102.0
CBALC2	7168.9	16.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.15 (Continued)
Mean Regulated Flow at the 48 Control Points as a Percentage of Mean Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	Regulated Flow as Percentage of Gaged Flow : Mean 13	14	15	16	17	18	19	20
RWPL01	100.0	99.9	99.9	99.9	99.9	100.0	100.0	100.0	100.0
SFAS06	2653.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	2242.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	5379.9	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSE11	13484.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MSMN12	537.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	220.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFNU16	1725.4	156.1	125.1	111.7	105.5	102.6	101.2	100.6	100.3
CAST17	2037.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	7366.8	105.6	103.1	101.5	100.7	100.3	100.2	100.1	100.0
HCAL19	2301.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	1409.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	30399.9	100.9	100.5	100.2	100.1	100.1	100.0	100.0	100.0
BRPP27	31076.1	101.0	100.5	100.2	100.1	100.0	100.0	100.0	100.0
BRDE29	38118.2	101.1	100.4	100.2	100.1	100.0	100.0	100.0	100.0
BRGR30	43592.7	100.9	100.4	100.2	100.1	100.0	100.0	100.0	100.0
PAGR31	4576.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	66702.3	100.8	100.2	100.1	100.0	100.0	100.0	100.0	100.0
AQAQ34	11988.9	100.1	100.1	100.1	100.1	100.1	100.0	100.0	100.0
NBCL36	15189.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	27723.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	116466.2	100.5	100.2	100.1	100.0	100.0	100.0	100.0	100.0
BRHB42	155638.4	100.3	100.1	100.1	100.0	100.0	100.0	100.0	100.0
SADL44	1975.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	5700.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEGT47	21397.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	7595.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	39383.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	13135.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	25229.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	78574.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	4397.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	3433.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	18227.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	133094.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	334336.8	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
MYDB60	5381.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	5326.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	5333.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	8073.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	3841.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	30221.5	100.4	100.2	100.1	100.1	100.0	100.0	100.0	100.0
NABR67	33730.7	100.3	100.2	100.1	100.1	100.0	100.0	100.0	100.0
BRHE68	486485.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRI70	515766.2	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
BGNE71	2477.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	525369.6	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
CBALC2	7168.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.16
98% Regulated Flow at the 48 Control Points as a Percentage of 98% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	98% Regulated Flow as Percentage of 98% Gaged Flow at Each Iteration 1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	0.0	-	-	-	-	-	-	-	-	-	-	-	-
SFAS06	0.6	38083.3	84388.3	4455.0	1.7	0.0	0.0	0.0	0.0	3.3	38.3	100.0	100.0
DMJU08	0.0	-	-	-	-	-	-	-	-	-	-	-	-
DMAS09	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BRSE11	87.3	1387.7	1455.6	244.3	241.5	244.9	245.3	245.5	245.5	245.6	245.6	245.5	245.5
MSMN12	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CFRO13	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CFNU16	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CAST17	1.8	1236.1	442.2	159.4	108.9	102.8	102.8	102.8	102.8	102.8	102.8	102.8	102.8
CFFG18	0.0	-	-	-	-	-	-	-	-	-	-	-	-
HCAL19	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BSBR20	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BRSB23	18.4	13554.5	54513.8	8952.6	9036.3	8608.8	8245.0	8724.8	7041.3	9049.2	6413.1	9322.6	6056.5
BRPP27	2468.1	12.0	596.1	147.5	166.9	165.9	161.4	168.2	157.8	169.7	155.1	170.5	152.8
BRDE29	1881.5	22.0	786.4	193.1	201.2	218.8	195.3	225.1	192.0	228.9	189.3	231.4	187.3
BRGR30	1033.0	0.0	1276.0	297.8	307.3	290.9	286.8	299.5	275.1	307.5	265.8	313.9	260.6
PAGR31	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BRAQ33	1598.7	4.2	1581.3	387.9	588.4	479.5	541.8	483.7	539.9	483.5	539.9	482.9	540.2
AQAQ34	2.4	0.0	2597.1	2360.0	2385.0	2385.0	2385.0	2385.0	2385.0	2385.0	2385.0	2385.0	2385.0
NBCL36	24.6	5.1	7.9	10.0	92.5	87.4	86.3	99.1	115.7	118.5	119.0	119.0	118.7
NBVM37	209.1	127.9	34.5	35.8	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	2496.4	0.0	1316.8	507.9	577.5	570.9	565.2	578.6	560.6	582.2	557.7	584.5	556.1
BRHB42	7476.9	57.2	516.3	246.3	261.2	251.8	255.7	252.8	254.4	253.0	253.8	253.0	253.2
SADL44	0.0	-	-	-	-	-	-	-	-	-	-	-	-
LEHS45	0.0	-	-	-	-	-	-	-	-	-	-	-	-
LEGT47	146.3	197.1	1034.0	265.3	130.7	115.0	111.5	103.7	101.8	100.8	100.4	100.2	100.2
COPI48	0.0	-	-	-	-	-	-	-	-	-	-	-	-
LEBE49	498.1	0.0	387.1	166.9	117.4	111.0	105.1	102.6	101.1	100.5	100.3	100.1	100.0
LAKE50	708.4	122.7	105.7	102.9	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	136.7	0.0	200.9	258.1	246.6	246.5	246.5	246.5	246.5	246.5	246.5	246.5	246.5
LRLR53	3358.5	37.8	199.4	114.0	108.0	105.8	105.4	105.2	105.0	105.0	105.0	105.0	105.0
NGGE54	26.3	2.2	124.4	124.3	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	9.5	863.6	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7
GALA57	291.5	2.8	129.1	100.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	5890.5	72.9	149.8	100.9	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	15581.7	88.5	360.6	164.7	172.4	171.6	169.5	172.1	168.8	172.5	168.4	172.7	168.1
MYDB60	181.6	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	626.3	20.9	92.9	99.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	0.0	-	-	-	-	-	-	-	-	-	-	-	-
NAGR64	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BGFR65	0.0	-	-	-	-	-	-	-	-	-	-	-	-
NAEA66	660.9	3.2	149.8	130.0	130.0	130.0	130.0	130.0	130.0	129.9	129.9	129.9	129.9
NABR67	793.3	11.0	231.2	174.5	158.5	157.5	157.4	157.4	157.4	157.4	157.4	157.4	157.4
BRHE68	27694.0	90.1	240.7	129.6	138.9	137.7	137.3	138.0	137.0	138.2	136.9	138.3	136.8
BRRI70	32170.4	103.4	214.7	144.2	131.5	131.7	130.5	132.0	130.1	132.1	129.9	132.2	129.8
BGNE71	72.5	151.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	25234.5	39.5	247.0	150.5	144.5	144.2	143.2	144.6	142.8	144.9	142.6	145.1	142.4
CBALC2	89.5	259.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.16 (Continued)
98% Regulated Flow at the 48 Control Points as a Percentage of 98% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	98% Regulated Flow as Percentage of 98% Gaged Flow at Each Iteration 13	14	15	16	17	18	19	20
RWPL01	0.0	-	-	-	-	-	-	-	-
SFAS06	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DMJU08	0.0	-	-	-	-	-	-	-	-
DMAS09	0.0	-	-	-	-	-	-	-	-
BRSE11	87.3	124.2	102.6	100.2	100.0	100.0	100.0	100.0	100.0
MSMN12	0.0	-	-	-	-	-	-	-	-
CFRO13	0.0	-	-	-	-	-	-	-	-
CFNU16	0.0	-	-	-	-	-	-	-	-
CAST17	1.8	102.8	102.8	102.8	102.8	102.8	102.8	102.8	102.8
CFFG18	0.0	-	-	-	-	-	-	-	-
HCAL19	0.0	-	-	-	-	-	-	-	-
BSBR20	0.0	-	-	-	-	-	-	-	-
BRSB23	18.4	2441.3	1636.3	1049.3	598.8	354.6	386.8	267.9	225.2
BRPP27	2468.1	111.3	104.7	102.1	101.2	100.7	100.2	99.8	99.7
BRDE29	1881.5	113.3	104.2	100.8	100.3	100.4	100.5	100.4	100.5
BRGR30	1033.0	144.2	123.2	109.8	104.8	102.5	103.0	101.8	101.2
PAGR31	0.0	-	-	-	-	-	-	-	-
BRAQ33	1598.7	147.6	111.6	104.0	101.7	101.3	101.1	101.2	101.0
AQAQ34	2.4	2014.6	1707.9	1455.4	1135.0	632.1	279.2	250.0	250.0
NBCL36	24.6	118.8	118.7	118.6	118.3	118.2	123.8	113.2	96.6
NBVM37	209.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	2496.4	144.2	112.2	104.4	102.0	100.9	100.0	100.1	100.1
BRHB42	7476.9	114.6	104.6	101.8	100.8	100.4	100.4	100.2	100.2
SADL44	0.0	-	-	-	-	-	-	-	-
LEHS45	0.0	-	-	-	-	-	-	-	-
LEGT47	146.3	100.1	100.1	100.1	100.2	100.1	100.1	100.1	100.1
COPI48	0.0	-	-	-	-	-	-	-	-
LEBE49	498.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	708.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	136.7	246.6	242.0	235.4	229.5	219.4	209.9	196.9	186.8
LRLR53	3358.5	104.5	104.1	103.8	103.4	103.1	102.9	102.6	102.4
NGGE54	26.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	9.5	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7
GALA57	291.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	5890.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	15581.7	106.8	102.2	100.9	100.4	100.2	100.2	100.1	100.0
MYDB60	181.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	626.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	0.0	-	-	-	-	-	-	-	-
NAGR64	0.0	-	-	-	-	-	-	-	-
BGFR65	0.0	-	-	-	-	-	-	-	-
NAEA66	660.9	122.4	117.0	110.0	104.7	103.9	103.4	102.2	101.3
NABR67	793.3	140.5	125.2	120.1	114.9	108.8	105.0	102.8	101.6
BRHE68	27694.0	103.3	101.0	100.5	100.3	100.2	100.1	100.1	100.1
BRRI70	32170.4	102.8	100.9	100.4	100.2	100.1	100.1	100.1	100.0
BGNE71	72.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	25234.5	108.4	104.8	104.4	104.3	104.2	104.1	104.0	100.1
CBALC2	89.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.17
90% Regulated Flow at the 48 Control Points as a Percentage of 90% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	90% Regulated Flow as Percentage of 90% Gaged Flow at Each Iteration											
		1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	0.0	-	-	-	-	-	-	-	-	-	-	-	-
SFAS06	13.5	1710.8	11167.6	1254.7	424.9	500.1	432.7	417.5	417.8	418.5	418.9	418.7	419.3
DMJU08	0.0	-	-	-	-	-	-	-	-	-	-	-	-
DMAS09	61.5	153.3	1959.3	394.0	559.7	599.8	599.8	599.8	599.8	599.8	599.8	599.8	599.8
BRSE11	252.1	491.2	2320.6	246.4	246.8	238.2	220.0	218.0	215.8	214.4	213.3	212.1	211.0
MSMN12	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CFRO13	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CFNU16	12.3	57.9	20065.7	4735.1	14186.7	5298.2	10603.3	5058.5	7749.4	5086.2	5760.7	4799.7	4382.4
CAST17	8.0	482.8	193.1	119.6	110.3	100.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8
CFFG18	36.9	0.0	9399.5	1968.2	4631.2	2646.4	3690.1	2722.4	2353.2	2860.0	1901.9	2836.4	1581.5
HCAL19	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BSBR20	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BRSB23	362.8	742.5	4826.7	708.5	1027.8	631.2	670.6	651.5	627.3	663.6	598.8	675.5	582.2
BRPP27	3873.7	7.8	578.9	150.2	157.0	148.2	152.4	149.4	150.0	151.1	148.3	152.3	148.4
BRDE29	4673.1	26.7	497.6	140.7	145.0	133.1	139.4	134.6	139.1	136.3	139.0	137.5	139.0
BRGR30	1783.1	0.0	1268.5	224.1	219.0	203.9	209.4	206.4	207.1	209.9	204.4	212.3	202.2
PAGR31	110.7	212.5	117.5	99.8	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	6210.0	1.6	949.7	171.8	185.9	187.6	182.2	188.8	181.0	189.5	180.1	189.9	179.5
AQAQ34	59.5	0.0	278.2	125.5	134.2	134.2	134.2	134.2	134.2	134.2	134.2	134.2	134.2
NBCL36	116.8	2.1	142.8	125.1	91.7	102.6	100.6	100.1	100.0	100.0	100.0	100.0	100.0
NBVM37	553.4	51.0	99.7	103.5	101.4	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	10698.8	9.0	779.8	174.3	199.4	190.0	193.5	190.0	193.3	190.2	193.1	190.4	193.0
BRHB42	18692.2	32.3	521.5	131.4	139.1	138.6	138.4	139.3	138.0	139.7	137.8	140.0	137.7
SADL44	0.0	-	-	-	-	-	-	-	-	-	-	-	-
LEHS45	0.0	-	-	-	-	-	-	-	-	-	-	-	-
LEGT47	504.2	84.8	441.7	150.1	113.0	109.9	104.0	100.8	100.1	100.0	100.0	100.0	100.0
COPI48	6.1	655.6	141.5	103.1	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2
LEBE49	1186.7	0.0	292.6	130.3	105.4	101.4	100.4	100.2	100.1	100.0	100.0	100.0	100.0
LAKE50	1174.4	81.8	100.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	449.3	0.0	96.2	107.8	104.1	104.3	104.1	104.3	104.2	104.2	104.2	104.2	104.2
LRLR53	5792.1	28.2	189.6	109.2	103.6	100.4	100.1	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	89.2	0.7	100.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	43.0	224.6	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
GALA57	387.4	6.3	128.3	102.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	8546.8	54.4	200.1	103.3	102.0	101.6	101.3	100.8	100.5	100.2	100.1	100.0	100.0
BRBR59	38054.7	55.2	370.8	118.5	123.2	121.9	122.2	122.2	122.0	122.4	121.8	122.5	121.8
MYDB60	440.9	1.4	98.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	935.2	14.5	96.2	100.2	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	8.0	462.5	101.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BGFR65	0.0	-	-	-	-	-	-	-	-	-	-	-	-
NAEA66	905.7	2.8	214.9	158.0	146.3	146.3	146.3	146.3	146.5	146.6	146.6	146.3	146.3
NABR67	1465.2	8.8	202.1	135.6	132.5	132.4	132.4	132.4	132.4	132.4	132.4	132.4	132.4
BRHE68	50235.4	93.9	362.3	127.4	125.6	122.6	125.2	122.6	125.1	122.6	125.1	122.7	125.0
BRRI70	50665.8	109.9	328.8	136.7	121.1	120.8	120.6	121.0	120.4	121.1	120.3	121.2	120.3
BGNE71	97.8	134.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	50419.8	66.8	306.6	126.1	124.5	123.8	123.5	123.7	123.2	123.5	123.1	123.6	123.0
CBALC2	386.1	88.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.17 (Continued)
90% Regulated Flow at the 48 Control Points as a Percentage of 90% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	90% Regulated Flow as Percentage of 90% Gaged Flow at Each Iteration 13	14	15	16	17	18	19	20
RWPL01	0.0	-	-	-	-	-	-	-	-
SFAS06	13.5	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6
DMJU08	0.0	-	-	-	-	-	-	-	-
DMAS09	61.5	127.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSE11	252.1	103.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MSMN12	0.0	-	-	-	-	-	-	-	-
CFRO13	0.0	-	-	-	-	-	-	-	-
CFNU16	12.3	3754.6	2083.4	1910.7	1340.0	809.2	517.6	321.1	211.1
CAST17	8.0	99.8	99.8	99.8	99.8	99.8	99.8	99.8	99.8
CFFG18	36.9	1782.0	1142.6	648.5	340.2	238.5	186.6	138.0	121.5
HCAL19	0.0	-	-	-	-	-	-	-	-
BSBR20	0.0	-	-	-	-	-	-	-	-
BRSB23	362.8	250.2	142.3	112.7	104.0	106.3	107.0	106.1	106.8
BRPP27	3873.7	108.0	106.3	100.8	100.3	100.2	100.0	100.0	100.0
BRDE29	4673.1	106.5	99.0	99.9	99.8	99.8	99.9	100.0	100.0
BRGR30	1783.1	118.5	107.8	102.6	101.1	100.3	100.1	100.0	100.0
PAGR31	110.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	6210.0	122.1	104.6	100.0	99.9	99.9	99.9	100.0	100.0
AQAQ34	59.5	126.5	124.0	124.0	108.5	108.3	108.1	108.0	107.9
NBCL36	116.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	553.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	10698.8	110.1	103.2	101.1	100.5	100.2	100.1	100.1	100.0
BRHB42	18692.2	104.2	100.8	100.2	100.1	100.0	100.0	100.0	100.0
SADL44	0.0	-	-	-	-	-	-	-	-
LEHS45	0.0	-	-	-	-	-	-	-	-
LEGT47	504.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	6.1	100.2	100.2	100.2	100.2	100.2	100.2	100.2	100.2
LEBE49	1186.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	1174.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	449.3	104.2	104.2	104.2	104.2	104.2	103.7	102.2	100.7
LRLR53	5792.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	89.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	43.0	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
GALA57	387.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	8546.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	38054.7	101.4	100.3	100.1	100.0	100.1	100.1	100.0	100.1
MYDB60	440.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	935.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	8.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	0.0	-	-	-	-	-	-	-	-
BGFR65	0.0	-	-	-	-	-	-	-	-
NAEA66	905.7	145.8	120.3	110.6	102.7	102.7	102.7	102.7	102.7
NABR67	1465.2	102.8	101.8	101.8	101.8	100.3	100.2	100.1	100.1
BRHE68	50235.4	103.6	101.8	100.9	100.6	100.4	100.3	100.3	100.2
BRRI70	50665.8	103.3	101.1	101.1	101.1	101.1	101.1	100.9	100.2
BGNE71	97.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	50419.8	104.1	103.0	100.8	100.4	100.2	100.1	100.1	100.1
CBALC2	386.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.18
75% Regulated Flow at the 48 Control Points as a Percentage of 75% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	75% Regulated Flow as Percentage of 75% Gaged Flow at Each Iteration 1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	2.5	0.0	11.6	18.8	26.8	34.0	38.4	43.2	47.6	51.6	55.2	58.8	62.0
SFAS06	159.9	178.2	1863.6	277.3	246.4	197.1	162.1	160.4	155.0	151.9	152.0	157.6	160.4
DMJU08	5.5	36.9	143.5	99.3	86.2	92.7	96.0	97.6	98.4	99.3	99.3	99.3	99.3
DMAS09	547.2	28.2	4752.2	111.6	119.5	121.6	121.8	122.0	122.4	122.7	121.4	121.4	121.5
BRSE11	2016.8	65.9	829.5	107.2	106.8	106.7	106.7	106.7	106.7	106.7	106.7	106.7	106.7
MSMN12	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CFRO13	0.0	-	-	-	-	-	-	-	-	-	-	-	-
CFNU16	104.5	10.3	7809.7	1056.6	2133.7	1147.1	1859.3	1090.3	1712.7	1087.1	1553.7	1087.4	1410.5
CAST17	48.6	101.0	107.3	100.7	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	633.3	0.0	1849.2	176.4	416.7	226.4	367.6	247.3	326.4	276.2	315.7	293.1	312.9
HCAL19	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BSBR20	0.0	-	-	-	-	-	-	-	-	-	-	-	-
BRSB23	3750.7	89.6	769.9	141.0	190.2	149.5	171.5	153.8	165.5	154.3	162.1	155.8	159.8
BRPP27	6739.0	5.7	734.7	137.9	153.6	139.7	146.5	141.8	145.5	143.1	144.3	143.9	143.4
BRDE29	7378.5	29.4	733.4	143.0	160.3	144.1	152.6	147.7	152.7	147.8	152.5	147.9	152.1
BRGR30	3258.8	9.1	1610.0	181.6	206.5	178.8	193.8	182.5	191.3	184.9	189.9	186.7	189.7
PAGR31	498.0	81.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	13957.7	1.6	580.5	138.2	140.3	134.1	134.2	134.9	133.7	135.5	133.5	135.9	133.3
AQAQ34	141.4	0.0	1230.4	139.2	139.2	139.2	139.2	139.2	139.2	139.2	139.2	139.2	139.2
NBCL36	547.2	57.9	96.1	97.9	99.5	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	1106.8	49.9	104.0	101.0	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	25456.0	10.2	523.8	132.9	134.8	132.1	134.5	132.4	132.5	132.0	132.0	132.0	131.7
BRHB42	35847.0	24.0	434.0	115.2	120.7	117.5	120.2	117.3	119.9	117.2	119.7	117.1	119.6
SADL44	22.1	176.2	142.9	102.0	100.4	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
LEHS45	0.0	-	-	-	-	-	-	-	-	-	-	-	-
LEGT47	1617.1	33.2	938.7	122.6	104.0	101.6	100.7	100.3	100.2	100.1	100.1	100.0	100.0
COPI48	221.4	43.4	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	1764.7	0.4	1089.1	120.8	105.2	102.6	100.7	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	1666.3	60.9	99.9	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	806.5	0.0	105.7	100.5	100.5	100.5	100.1	99.9	100.1	99.9	100.1	99.9	100.1
LRLR53	8208.6	31.0	346.4	100.7	100.2	100.1	99.9	99.8	100.0	100.0	100.0	100.0	100.0
NGGE54	156.8	0.8	161.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	172.8	90.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	1076.0	3.9	148.4	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	15310.4	38.0	240.0	102.5	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	61862.7	41.0	352.9	118.2	121.6	117.6	119.7	118.8	118.9	119.1	118.8	119.2	118.6
MYDB60	661.0	2.9	98.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	1268.5	20.6	93.5	98.6	101.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	140.2	28.8	104.8	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	0.6	8053.3	8025.0	8020.0	7333.3	6166.7	4250.0	2050.0	2050.0	1233.3	200.0	200.0	200.0
BGFR65	91.0	20.0	88.0	98.2	99.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	1719.8	2.8	334.4	115.0	112.2	112.2	112.2	112.2	112.2	112.2	112.2	112.2	112.2
NABR67	2763.3	13.3	323.0	110.0	108.3	108.4	108.4	108.4	108.4	108.4	108.4	108.4	108.4
BRHE68	92662.0	53.7	287.7	112.0	117.0	115.5	116.5	115.5	116.5	115.5	116.5	115.5	116.4
BRRI70	89464.5	69.6	309.0	114.4	116.8	116.3	116.0	116.3	116.0	116.3	116.0	116.3	116.0
BGNE71	175.2	93.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	95429.0	46.1	275.9	116.9	113.8	112.1	113.1	112.2	113.1	112.1	113.0	112.1	113.1
CBALC2	1090.8	60.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.18 (Continued)
75% Regulated Flow at the 48 Control Points as a Percentage of 75% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	75% Regulated Flow as Percentage of 75% Gaged Flow at Each Iteration 13	14	15	16	17	18	19	20
RWPL01	2.5	64.8	67.6	70.4	72.4	74.4	76.8	85.2	92.0
SFAS06	159.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	5.5	99.3	99.3	99.3	99.3	99.3	99.3	99.3	99.3
DMAS09	547.2	92.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSE11	2016.8	100.4	100.1	100.0	100.0	100.0	100.0	100.0	100.0
MSMN12	0.0	-	-	-	-	-	-	-	-
CFRO13	0.0	-	-	-	-	-	-	-	-
CFNU16	104.5	722.4	531.8	296.4	216.3	149.4	118.8	107.4	109.6
CAST17	48.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	633.3	142.8	122.7	124.1	110.1	103.4	100.2	100.0	100.0
HCAL19	0.0	-	-	-	-	-	-	-	-
BSBR20	0.0	-	-	-	-	-	-	-	-
BRSB23	3750.7	92.5	95.9	98.5	99.5	99.8	99.9	100.0	100.0
BRPP27	6739.0	107.2	103.5	101.7	100.8	100.4	100.2	100.3	100.2
BRDE29	7378.5	110.3	105.7	102.4	101.0	100.4	100.2	100.1	100.0
BRGR30	3258.8	121.2	112.2	102.9	102.7	101.4	101.5	100.9	100.5
PAGR31	498.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	13957.7	106.0	101.4	100.8	100.4	100.2	100.1	100.1	100.0
AQAQ34	141.4	126.9	126.9	126.9	126.9	126.9	122.7	113.1	113.1
NBCL36	547.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	1106.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	25456.0	101.3	100.3	100.1	100.0	100.0	100.0	100.0	100.0
BRHB42	35847.0	100.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SADL44	22.1	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
LEHS45	0.0	-	-	-	-	-	-	-	-
LEGT47	1617.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	221.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	1764.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	1666.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	806.5	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	8208.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	156.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	172.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	1076.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	15310.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	61862.7	101.3	100.7	100.2	100.1	100.0	100.0	100.0	100.0
MYDB60	661.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	1268.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	140.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	0.6	200.0	200.0	200.0	200.0	200.0	200.0	200.0	200.0
BGFR65	91.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	1719.8	109.0	104.5	103.5	101.1	100.5	100.5	100.5	100.4
NABR67	2763.3	105.9	105.9	105.9	105.5	102.9	101.4	100.6	100.1
BRHE68	92662.0	100.2	100.0	100.1	100.1	100.1	100.0	100.0	100.0
BRRI70	89464.5	101.6	100.6	100.3	100.2	100.2	100.2	100.2	100.2
BGNE71	175.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	95429.0	100.7	100.6	100.3	100.2	100.1	100.1	100.0	100.0
CBALC2	1090.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.19
50% Regulated Flow at the 48 Control Points as a Percentage of 50% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	50% Regulated Flow as Percentage of 50% Gaged Flow at Each Iteration 1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	19.7	0.0	8.6	15.4	22.3	29.4	52.2	59.9	67.3	78.2	83.0	87.8	96.8
SFAS06	720.0	43.6	639.0	159.0	123.8	114.9	114.9	114.9	114.9	114.9	114.9	114.9	114.9
DMJU08	443.9	2.1	96.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	1746.2	18.4	1931.5	109.1	124.1	124.9	125.2	125.3	125.3	125.4	125.4	125.4	125.4
BRSE11	5220.3	36.3	474.7	105.0	102.0	101.0	101.0	101.0	101.0	101.0	101.0	101.0	101.0
MSMN12	0.6	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	0.6	6743.3	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
CFNU16	325.9	8.6	6790.5	553.3	950.1	592.4	888.9	655.9	880.5	695.3	884.6	742.6	894.1
CAST17	154.3	39.4	105.6	98.1	99.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	1561.8	0.7	2327.9	136.1	323.1	161.9	249.4	174.9	222.1	174.3	219.5	175.1	215.5
HCAL19	61.5	73.4	117.1	102.5	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	17.9	0.0	67.9	90.8	96.3	98.9	99.6	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	10176.2	37.1	752.1	110.8	121.7	110.4	118.8	110.3	117.0	112.3	116.4	113.7	115.9
BRPP27	12494.3	3.6	729.8	118.8	134.5	118.5	127.9	118.5	123.6	120.1	123.9	120.3	123.8
BRDE29	13281.3	22.4	723.3	129.9	136.0	126.6	135.5	127.3	135.0	127.8	134.9	128.0	134.2
BRGR30	8731.2	12.4	1130.1	142.4	148.9	140.1	139.6	140.4	138.3	140.9	137.5	141.1	137.4
PAGR31	1192.9	49.9	95.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	25763.3	2.1	615.7	118.8	126.2	120.2	125.8	120.5	124.4	120.6	124.6	120.7	124.6
AQAQ34	1549.5	1.4	570.8	104.6	104.6	104.6	104.6	104.6	104.6	104.6	104.6	104.6	104.6
NBCL36	2822.3	24.6	98.4	99.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	4119.7	29.4	93.2	99.8	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	53248.3	11.7	381.6	116.4	122.7	116.5	121.9	117.7	119.2	118.4	118.7	118.8	118.3
BRHB42	67083.0	16.5	327.3	114.9	115.4	113.4	114.7	113.6	114.6	113.6	114.5	113.6	114.5
SADL44	283.5	26.8	95.8	99.8	100.0	100.0	99.5	99.6	100.0	100.0	100.0	100.0	100.0
LEHS45	60.0	1.4	58447.1	1253.8	301.4	157.1	111.5	101.9	101.7	101.6	101.7	101.7	101.7
LEGT47	5398.6	16.1	531.0	110.2	102.6	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	1801.6	9.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	5029.7	0.4	794.4	106.1	101.0	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	4765.3	26.6	104.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	9244.7	0.2	96.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	30153.5	10.5	205.9	103.2	100.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	357.2	0.8	1951.2	105.2	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	1247.6	17.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	6849.7	9.3	260.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	54416.5	15.6	185.2	101.7	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	139263.3	20.8	254.2	105.5	106.0	104.0	104.4	103.9	104.4	103.9	104.4	103.9	104.4
MYDB60	1307.8	21.0	98.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	2021.1	18.2	93.8	99.2	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	941.4	24.6	100.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	386.1	14.8	134.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	726.2	18.3	95.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	3804.2	13.2	613.9	114.3	112.4	112.4	112.4	112.4	112.4	112.4	112.4	112.4	112.1
NABR67	7010.2	20.0	350.3	106.2	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRHE68	235313.0	24.7	196.3	104.1	104.8	104.3	104.6	104.3	104.6	104.2	104.6	104.2	104.7
BRRI70	259662.0	27.2	184.6	102.5	102.4	102.4	102.3	102.4	102.3	102.4	102.3	102.4	102.3
BGNE71	768.0	22.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	295325.0	19.8	167.2	102.1	102.6	101.8	102.1	101.8	102.0	101.8	102.0	101.8	102.0
CBALC2	3054.7	41.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.19 (Continued)
50% Regulated Flow at the 48 Control Points as a Percentage of 50% Gaged Flow

Control Point	Gaged Flow	50% Regulated Flow as Percentage of 50% Gaged Flow at Each Iteration 13	14	15	16	17	18	19	20
	(ac-ft/month)								
RWPL01	19.7	97.1	99.7	99.9	99.9	99.9	99.9	99.9	99.9
SFAS06	720.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	443.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	1746.2	101.6	100.3	100.1	100.1	100.1	100.1	100.1	100.0
BRSE11	5220.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MSMN12	0.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	0.6	105.0	105.0	105.0	105.0	105.0	105.0	105.0	105.0
CFNU16	325.9	397.0	257.9	171.1	128.4	114.0	105.8	101.8	99.9
CAST17	154.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	1561.8	126.1	113.2	104.3	99.8	99.9	100.0	100.0	100.0
HCAL19	61.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	17.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	10176.2	99.9	99.8	99.9	100.0	100.0	100.0	100.0	100.0
BRPP27	12494.3	100.9	100.7	100.4	100.4	100.2	100.1	100.0	100.0
BRDE29	13281.3	103.4	99.0	99.4	99.8	100.0	100.0	100.0	100.0
BRGR30	8731.2	110.0	103.9	101.7	100.8	100.3	100.2	100.1	100.0
PAGR31	1192.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	25763.3	101.6	101.2	100.3	99.9	100.0	100.0	100.0	100.0
AQAQ34	1549.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBCL36	2822.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	4119.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	53248.3	104.0	102.0	100.9	100.4	100.2	100.1	100.0	100.0
BRHB42	67083.0	101.1	100.4	100.2	100.1	100.0	100.0	100.0	100.0
SADL44	283.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	60.0	101.6	101.7	101.6	101.7	101.7	101.7	101.6	101.6
LEGT47	5398.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	1801.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	5029.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	4765.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	9244.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	30153.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	357.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	1247.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	6849.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	54416.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	139263.3	100.2	100.2	100.1	100.0	100.0	100.0	100.0	100.0
MYDB60	1307.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	2021.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	941.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	386.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	726.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	3804.2	102.7	100.4	100.0	100.0	100.0	100.0	100.0	100.0
NABR67	7010.2	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0
BRHE68	235313.0	101.5	100.4	100.1	100.1	100.0	100.0	100.0	100.0
BRRI70	259662.0	100.3	100.1	100.1	100.1	100.1	100.0	100.0	100.0
BGNE71	768.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	295325.0	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CBALC2	3054.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.20
25% Regulated Flow at the 48 Control Points as a Percentage of 25% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	25% Regulated Flow as Percentage of 25% Gaged Flow at Each Iteration 1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	62.7	0.5	9.1	20.8	40.8	64.8	93.5	97.2	98.8	105.5	110.0	112.0	111.9
SFAS06	3077.5	15.7	216.8	101.5	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	2211.7	7.3	96.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	5620.0	14.2	780.2	99.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSE11	14302.0	20.4	232.5	101.2	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8	100.8
MSMN12	71.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	15.4	371.6	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7
CFNU16	1383.5	3.4	2321.2	195.2	407.8	213.3	305.8	233.8	273.3	250.2	271.9	272.1	272.2
CAST17	962.9	10.5	86.0	99.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	5693.8	1.3	871.4	110.3	202.0	125.4	161.0	134.8	161.5	136.9	161.9	136.7	162.3
HCAL19	657.9	20.8	92.8	99.4	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	297.5	4.7	91.7	99.2	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	23912.5	23.5	605.1	115.6	132.9	113.3	119.2	113.4	119.1	116.7	119.0	116.8	118.9
BRPP27	25566.5	4.5	710.3	111.1	115.5	112.2	113.9	112.1	114.1	112.1	114.2	112.1	114.2
BRDE29	28899.2	15.6	634.2	119.9	123.6	111.7	117.5	111.5	116.2	111.4	116.2	111.5	116.3
BRGR30	36954.1	9.3	490.2	122.3	124.5	121.2	124.3	121.2	124.1	121.3	124.0	121.3	124.0
PAGR31	4494.7	28.9	93.1	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	54785.5	2.6	472.9	105.1	110.3	105.5	107.0	105.5	107.1	105.5	107.1	105.6	107.0
AQAQ34	12758.1	1.2	170.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBCL36	11787.2	13.7	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	16540.2	12.8	99.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	113875.0	14.3	266.8	104.0	102.1	102.2	102.0	102.3	102.0	102.3	102.0	102.3	102.0
BRHB42	157592.7	17.5	246.8	102.4	104.0	102.7	103.7	102.8	103.4	102.8	103.4	102.8	103.4
SADL44	863.0	27.2	93.4	98.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	246.0	1.4	20416.0	722.4	364.0	216.6	103.3	101.2	100.4	100.2	100.1	100.0	100.0
LEGT47	24877.9	8.7	180.6	100.9	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	7563.0	9.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	55769.3	0.1	164.2	102.4	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	10791.1	15.5	102.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	27979.3	0.3	109.4	101.0	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	98909.0	5.3	142.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	4024.4	0.2	387.6	101.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	4558.1	12.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	28868.4	5.8	127.5	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	218834.4	8.4	117.1	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	480796.2	15.4	134.6	101.2	101.6	101.1	101.3	101.1	101.1	101.1	101.1	101.1	101.0
MYDB60	4734.5	9.9	98.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	5409.1	10.9	103.8	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	6210.2	7.3	100.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	9759.9	8.8	99.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	3546.6	12.9	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	35192.4	4.8	126.3	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NABR67	53123.4	7.2	111.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRHE68	719097.5	13.9	149.5	100.6	100.7	100.5	100.7	100.5	100.6	100.6	100.6	100.6	100.6
BRRI70	741909.0	15.0	141.8	101.6	101.5	100.7	100.8	100.7	100.8	100.7	100.8	100.7	100.8
BGNE71	2824.7	9.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	775973.6	11.6	138.9	100.4	100.6	100.5	100.6	100.5	100.6	100.5	100.6	100.5	100.5
CBALC2	9430.4	17.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.20 (Continued)
25% Regulated Flow at the 48 Control Points as a Percentage of 25% Gaged Flow

Control Point	Gaged Flow	25% Regulated Flow as Percentage of 25% Gaged Flow at Each Iteration 13	14	15	16	17	18	19	20
	(ac-ft/month)								
RWPL01	62.7	111.8	111.8	110.9	109.9	108.8	107.9	107.0	103.0
SFAS06	3077.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	2211.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	5620.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSE11	14302.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MSMN12	71.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	15.4	99.7	99.7	99.7	99.7	99.7	99.7	99.7	99.7
CFNU16	1383.5	151.0	126.2	110.7	104.5	103.3	100.8	100.4	100.2
CAST17	962.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	5693.8	107.2	108.7	107.2	101.8	99.7	99.8	99.9	99.9
HCAL19	657.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	297.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	23912.5	101.7	101.7	101.0	100.3	100.0	100.0	100.0	100.0
BRPP27	25566.5	98.3	100.9	100.6	100.2	100.1	100.0	100.0	100.0
BRDE29	28899.2	100.9	100.2	100.2	100.1	100.0	100.0	100.0	100.0
BRGR30	36954.1	101.4	101.0	100.2	100.1	100.0	100.0	100.0	100.0
PAGR31	4494.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	54785.5	100.6	100.3	100.2	100.1	100.0	100.0	100.0	100.0
AQAQ34	12758.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBCL36	11787.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	16540.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	113875.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRHB42	157592.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SADL44	863.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	246.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEGT47	24877.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	7563.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	55769.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	10791.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	27979.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	98909.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	4024.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	4558.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	28868.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	218834.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	480796.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MYDB60	4734.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	5409.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	6210.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	9759.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	3546.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	35192.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NABR67	53123.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRHE68	719097.5	99.8	100.1	100.0	100.0	100.0	100.0	100.0	100.0
BRRI70	741909.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGNE71	2824.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	775973.6	99.9	100.1	100.0	100.0	100.0	100.0	100.0	100.0
CBALC2	9430.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.21
10% Regulated Flow at the 48 Control Points as a Percentage of 10% Gaged Flow

Control Point	Gaged Flow (ac-ft/month)	10% Regulated Flow as Percentage of 10% Gaged Flow at Each Iteration 1	2	3	4	5	6	7	8	9	10	11	12
RWPL01	216.4	0.6	10.6	84.2	94.5	97.6	98.9	99.5	99.8	99.9	100.0	100.0	100.0
SFAS06	7223.6	17.9	154.8	106.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	6376.9	5.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	11381.4	25.0	455.1	106.2	109.0	108.3	108.3	108.4	108.5	108.5	108.6	108.6	108.6
BRSE11	38128.5	17.0	153.0	100.6	100.6	100.5	100.5	100.6	100.6	100.6	100.6	100.6	100.6
MSMN12	1215.0	1.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	144.5	112.1	99.9	100.0	100.0	99.9	99.9	99.9	100.0	100.0	100.0	100.0	100.0
CFNU16	3713.9	2.3	1351.0	210.5	312.3	261.8	238.5	262.3	238.2	264.3	237.8	265.8	237.5
CAST17	4668.8	6.7	95.5	102.2	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	14246.7	11.5	507.2	110.6	124.3	105.8	118.0	107.9	118.1	107.9	118.1	107.9	118.2
HCAL19	3787.6	10.7	91.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	3379.8	4.1	90.4	99.1	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	81440.3	23.3	249.6	101.8	107.8	103.2	105.8	103.2	105.1	103.4	105.1	103.4	105.1
BRPP27	61014.1	4.2	424.9	106.5	107.0	106.5	107.0	106.4	107.0	106.4	107.0	106.4	107.0
BRDE29	58413.2	13.6	456.4	116.3	121.2	120.0	119.1	119.9	119.2	119.8	119.2	119.8	119.2
BRGR30	103914.0	15.0	270.0	107.7	104.9	104.1	104.7	104.0	104.8	104.0	104.8	103.9	104.8
PAGR31	9887.2	15.7	99.0	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	141728.9	3.2	296.4	105.9	108.1	104.5	104.0	104.6	104.0	104.6	104.0	104.6	104.0
AQAQ34	38380.6	1.3	117.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBCL36	42500.2	5.9	98.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	57859.8	6.4	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	262859.5	11.7	225.2	105.7	106.1	104.2	104.5	104.2	104.5	104.2	104.4	104.2	104.4
BRHB42	348142.8	14.6	194.1	101.5	104.6	100.5	101.5	101.0	101.3	101.1	101.1	101.4	101.0
SADL44	5289.5	8.9	94.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	14400.0	0.1	422.6	101.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEGT47	55345.0	6.6	148.1	100.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	20690.6	6.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	138439.3	0.8	131.1	100.3	100.1	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	26427.4	10.3	100.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	79380.5	0.2	94.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	244702.2	3.9	109.0	100.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	14232.5	0.2	207.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	8077.0	9.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	55252.8	5.1	120.3	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	377472.4	7.0	116.5	100.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	919609.0	11.9	135.3	102.8	102.5	102.4	102.4	102.4	102.4	102.4	102.4	102.4	102.4
MYDB60	17148.3	3.1	98.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	13852.5	4.9	100.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	17829.6	3.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	31772.5	4.8	101.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	14404.1	3.6	100.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	119579.2	1.9	116.4	100.0	99.9	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NABR67	133049.3	4.4	107.5	100.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRHE68	1286075.0	14.3	125.3	100.3	100.6	100.1	100.2	100.2	100.2	100.2	100.2	100.2	100.2
BRRI70	1357154.0	15.0	128.9	102.9	103.7	102.7	102.9	102.8	102.9	102.9	102.9	102.9	102.8
BGNE71	8511.7	3.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	1464450.0	12.0	118.7	100.7	101.0	100.8	100.9	100.8	100.9	100.8	100.9	100.8	100.9
CBALC2	19910.3	9.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table 4.21 (Continued)
10% Regulated Flow at the 48 Control Points as a Percentage of 10% Gaged Flow

Control Point	Gaged Flow	10% Regulated Flow as Percentage of 10% Gaged Flow at Each Iteration 13	14	15	16	17	18	19	20
	(ac-ft/month)								
RWPL01	216.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SFAS06	7223.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMJU08	6376.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DMAS09	11381.4	100.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSE11	38128.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
MSMN12	1215.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFRO13	144.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFNU16	3713.9	178.6	137.9	113.6	104.9	100.4	98.7	98.3	98.2
CAST17	4668.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CFFG18	14246.7	103.8	103.1	100.7	99.5	99.7	99.8	99.9	100.0
HCAL19	3787.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BSBR20	3379.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRSB23	81440.3	100.2	100.4	100.1	100.0	100.0	100.0	100.0	100.0
BRPP27	61014.1	100.9	100.7	100.5	100.2	100.1	100.0	100.0	100.0
BRDE29	58413.2	103.8	101.1	100.4	100.3	100.1	100.1	100.0	100.0
BRGR30	103914.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
PAGR31	9887.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRAQ33	141728.9	99.8	99.5	99.8	100.0	100.0	100.0	100.0	100.0
AQAQ34	38380.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBCL36	42500.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NBVM37	57859.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRWA41	262859.5	99.3	99.8	100.0	100.0	100.0	100.0	100.0	100.0
BRHB42	348142.8	99.5	99.8	100.0	100.0	100.0	100.0	100.0	100.0
SADL44	5289.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEHS45	14400.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEGT47	55345.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
COPI48	20690.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LEBE49	138439.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LAKE50	26427.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LABE52	79380.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRLR53	244702.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NGGE54	14232.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
SGGE55	8077.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
GALA57	55252.8	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LRCA58	377472.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRBR59	919609.0	100.1	100.1	100.0	100.0	100.0	100.0	100.0	100.0
MYDB60	17148.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
EYDB61	13852.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
DCLY63	17829.6	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAGR64	31772.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGFR65	14404.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NAEA66	119579.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NABR67	133049.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRHE68	1286075.0	99.6	99.8	99.9	99.9	100.0	100.0	100.0	100.0
BRRI70	1357154.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BGNE71	8511.7	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
BRRO72	1464450.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CBALC2	19910.3	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

<u>Bwam8A Simulation Results</u>

The basin summary table presented below as Table 4.22 was developed with the WRAP program *TABLES* with a 2SBA record for the *SIM* simulation with the Bwam8A DAT, EVA, and DIS files and the FLO file with the adopted naturalized flows. The mean annual volumes in the last line of Table 4.22 correspond to the final iteration 20 in Table 4.11.

Table 4.22
Annual Summary for Bwam8A Simulation with Final Adopted Naturalized Flows

	Naturalized Flow (ac-ft/yr)	Return Flow (ac-ft/yr)	Flow Depletion (ac-ft/yr)	Unappropriated Flow (ac-ft/yr)	Storage (acre-feet)	Net Evap-Prec (ac-ft/yr)	Diversion Target (ac-ft/yr)	Actual Diversion (ac-ft/yr)	Shortage (ac-ft/yr)
					3,131,705				
1998	15,290,265	270,721	2,551,686	9,411,566	3,602,484	578,638	1,568,510	1,382,592	185,918
1999	3,393,795	278,642	1,812,217	2,134,353	3,009,098	541,245	1,589,966	1,310,630	279,336
2000	8,601,709	267,119	2,367,799	1,854,199	3,344,236	431,163	1,597,250	1,252,477	344,774
2001	13,684,570	278,694	2,300,169	7,608,931	3,340,252	366,373	1,567,788	1,412,753	155,035
2002	10,751,553	289,615	2,286,167	5,221,468	3,472,843	327,932	1,570,752	1,401,516	169,236
2003	6,853,309	284,468	1,950,031	4,368,417	3,089,225	451,190	1,576,217	1,355,158	221,059
2004	24,123,398	292,161	3,757,403	10,982,540	3,835,481	201,307	1,579,557	1,445,808	133,750
2005	9,545,607	286,733	2,018,485	4,929,907	3,300,310	454,348	1,569,217	1,360,846	208,371
2006	5,234,924	271,105	1,823,148	1,789,598	3,088,017	386,470	1,578,015	1,256,945	321,070
2007	32,931,514	288,946	5,121,776	15,362,143	3,670,893	814,263	1,553,413	1,459,153	94,260
Mean	13,041,063	280,820	2,598,888	6,366,312	3,375,284	455,293	1,575,069	1,363,788	211,281

The Bwam8 diversion targets in Bwam8A were developed for the original Brazos WAM current use scenario with the annual target for each individual water right set at the maximum annual water use in any year during the ten-year period 1988-1997. The total mean diversion target, diversion, and shortage shown in Table 4.22 are 1,575,069 acre-feet/year, 1,363,788 acre-feet/year, and 211,281 acre-feet/year, resulting in a volume reliability of 86.6 percent. Thus, the mean diversion volume is significantly less than the mean of diversion targets in the Bwam8A model. Diversion shortages vary greatly between water rights and between months and years.

The volume budgets in Table 4.23 were developed with program *TABLES* with a 2BUD input record. The variables included in the 2SBA and 2BUD tables and associated computations are explained in the *WRAP Reference* and *Users Manuals*. Means of naturalized flows are different in the two different types of program *TABLES* tables represented by Tables 4.22 and 4.23.

The means of naturalized flows and unappropriated flows in the 2SBA basin summary reproduced as Table 4.22 represent the maximum flow at any control point in any given month, based on program *TABLES* comparing all control points. All other quantities in the Table 4.22 basin summary are the sum of the values for all control points.

As explained in the *WRAP Reference Manual*, program *TABLES* volume budgets created with the 2BUD record are based on summations of quantities computed individually for all control points. Naturalized flows are presented twice in the *TABLES* 2BUD volume budget of Table 4.23.

The first values are the means of the naturalized flows at the one or more basin outlet control points as read by *SIM* from the *IN* records in the *SIM* input FLO file and recorded in the *SIM* output file read by *TABLES*. The second value for naturalized flows shown in Table 4.23 is the summation of incremental naturalized flow volumes at all control points. These two alternative values for naturalized flows would ideally be identical if the computer provided absolutely perfect precision. However, the numbers are slightly different due to a small loss of precision as *TABLES* computes incremental flows for each control point and then later sums the incrementals to obtain basin totals.

Table 4.23
Volume Budgets for Bwam8A Simulation

Entire dataset or sub-basins above the Richmond and Waco gages on Brazos	Entire Dataset	Richmond Gage	Waco Gage
	(ac-ft/year)	(ac-ft/year)	(ac-ft/year)
Naturalized flows at outlet	9,424,868	7,637,495	2,129,842
Naturalized flows (sum incrementals)	9,422,430	7,635,889	2,129,727
Return flows	280,821	93,225	14,991
CI record constant inflows	63,845	34,560	5,047
Channel loss credits	317,680	266,796	111,689
Channel losses	18,031	14,649	5,355
Regulated flows at outlet	7,470,119	6,189,332	1,397,664
Diversions	1,363,713	601,899	192,549
Other flows at control points	783,613	782,836	380,802
Net evaporation	455,289	446,855	276,957
Inflows − Outflows	−5,989	−5,101	8,127
Beginning reservoir storage	370,821	363,148	212,900
Ending reservoir storage	367,089	359,524	221,106
Change in storage	−3,732	−3,624	8,206
Water balance difference	−2,257	−1,476	−79

Three volume budgets are presented in Table 4.23. The first is for the entire Bwam8A dataset. The second is for the Brazos River Basin above control point BRRI70 which is the USGS gaging station on the Brazos River at Richmond. The third *TABLES* 2BUD record volume budget in Table 4.23 is for the Brazos River Basin above control point BRWA41 which is the USGS gaging station on the Brazos River at Waco. The quantities are 1998-2007 means of annual volumes. The water balance differences in the last line of Table 4.23 would ideally be zero, but are non-zero due to lack of perfect preciseness in the *SIM* and *TABLES* computations.

The Bwam8A dataset was applied with *SIM* and *HYD* to compute monthly naturalized flows given the corresponding observed flows as outlined in this chapter. Actual observed (gaged) flows, Bwam8A-simulated regulated flows, and the resulting naturalized flows at the Richmond and Waco gaging stations on the Brazos River are compared in Table 4.24. The regulated and naturalized flows tabulated in Table 4.24 are reproduced from Table 4.23. The gaged and Bwam8A regulated flows conceptually should be the same and are the same to four significant digits.

Table 4.24
1998-2007 Mean Flows at the Richmond and Waco Gages on the Brazos River

Control Point Location	BRRI70 Richmond Gage	BRWA41 Waco Gage
Gaged Flow (acre-feet/year)	6,189,195	1,397,595
Regulated Flow (ac-ft/year)	6,189,332	1,397,664
Naturalized Flow (ac-ft/year)	7,637,495	2,129,842

The components of the water budgets presented in Table 4.23 are defined in the last section of Chapter 6 of the *WRAP Reference Manual*. The water budget components are related as follows.

change in reservoir storage =
naturalized flows + return flows + CI record constant inflows + channel loss credits
− channel losses − regulated flows − diversions − other flows − net evaporation

This volume budget equation can be rearranged as follows to relate naturalized flows to gaged flows (regulated flows).

naturalized flow = regulated flows + change in reservoir storage
+ diversions + other flows + net evaporation + channel losses
− channel loss credits − return flows − CI record constant inflows

The 1998-2007 mean annual volumes tabulated in Tables 4.23 and 4.24 can be substituted into these equations to represent a volume budget in terms of the *SIM* simulation results as organized by the *TABLES* water budget analysis feature. The volume budget provides insights into the causes of the differences between the quantities of observed versus naturalized stream flows.

The January 1998 through December 2007 sequences of monthly naturalized flows at the completion (20th iteration) of the iterative procedure outlined in this chapter were adopted for the 77 primary control points. The 77 primary control points in the original Brazos WAM dataset include the 48 control points in the Bwam8A dataset for which gaged flow data were compiled for 1998-2007 and the 29 other control points for which gaged flow data are not available for 1998-2007. Naturalized flows at the 29 other control points were computed within *SIM* as a function of flows at the 48 control points using the methodology and parameters described earlier in this chapter.

The 1998-2007 naturalized flows developed in this investigation are combined with the 1940-1997 naturalized flows from the original Brazos WAM dataset to obtain a FLO file with 1940-2007 naturalized flows at 77 control points. The period-of-analysis is further lengthened in the following Chapter 5 to also include 1900-1939. The 1900-2007 monthly naturalized flow sequences at the 77 control points are plotted in Appendix A. The 1998-2007 sequences of gaged and naturalized monthly flows at 48 control points are plotted for comparison in Appendix B. Naturalized flows for the sub-periods 1900-1939, 1940-1997, and 1998-2007 are compared in Chapter 6. Observed flows versus naturalized flows are also compared in Chapter 6. *WRAP-SIM* simulation results for the alternative hydrologic periods-of-analysis are compared in Chapter 7.

Programs *SIM* and *HYD* Data Files

This chapter is summarized below with an inventory of the *SIM* and *HYD* input files created and/or used. The Brazos WAM dataset consists of the following program *SIM* input files for the authorized use scenario (run3) and current use scenario (run 8).

Bwam3.DAT	Bwam8.DAT
Bwam3.FLO	Bwam8.FLO
Bwam3.EVA	Bwam8.EVA
Bwam3.DIS	Bwam8.DIS

The FLO and EVA files are the same for run 3 and run 8. The FLO file contains 1940-1997 monthly naturalized flows in acre-feet/month for 77 control points. The EVA file contains 67 sequences of 1940-1997 monthly net evaporation-precipitation depths in units of feet.

The WAM System datasets are periodically updated by the TCEQ to reflect new or modified water right permits or other changes. The Brazos WAM (Bwam) dataset used in this study was last updated by the TCEQ in August 2007.

The purpose of the methodology outlined in this chapter is to update the FLO and EVA files by ten years to cover the entire period from January 1940 through December 2007. The hydrologic period-of-analysis is further lengthened in Chapter 5 to cover January 1900 through December 2007. The final product of the hydrology dataset update consists of the following four new files. Bwam3 and Bwam8 simulation results with the 1940-1997, 1940-2007, and 1900-2007 hydrology are presented in Chapter 7.

Bwam1940-2007.FLO − 1940-2007 naturalized flows at 77 control points.
Bwam1940-2007.EVA − 1940-2007 evaporation-precipitation rates at 67 control points.
Bwam1900-2007.FLO − 1900-2007 naturalized flows at 77 control points.
Bwam1900-2007.EVA − 1900-2007 evaporation-precipitation rates at 67 control points.

The following *SIM* actual use dataset with filename root Bwam8A (*A for actual*) was created by modifying the Bwam8 input dataset as described in Chapters 4 and 5 to model actual water resources development, allocation, management, and use occurring during January 1940 through December 2007.

Bwam8A.DAT − The Bwam8.DAT file was modified to develop the Bwam8A.DAT file.

Bwam8A.BES − January 1998 beginning reservoir storage contents are assigned.

Bwam8A.EVA − 1998-2007 evaporation-precipitation rates at 67 control points.

Bwam8A.DIS − The flow distribution parameters for 3,141 control points are identical in the Bwam8.DIS and Bwam8A.DIS files. Flow distribution parameters for an additional 29 control points are included in the Bwam8A.DIS file. Naturalized flows for these 29 control points for 1940-1997 are included in the original Bwam8.FLO, which includes 77 primary control points. However, 1998-2007 flows are not included in Bwam8A.FLO for these 29 control points.

Bwam8A75%.FLO − Naturalized flows for 1998-2007 at 48 control points. An initial FLO file contains 75% exceedance frequency naturalized flows. The FLO file is replaced with each repetition of the iterative computational procedure.

Bwam8A.FLO − The final 1998-2007 naturalized flows computed in the iterative procedure that are adopted for the Bwam8A dataset.

The following *WRAP-HYD* input files were created in the process of converting 1998-2007 gaged flows to naturalized flows at the 48 gaged control points and associated flows computed within the *SIM* simulation for the other 29 original primary control points for which gaged flows are not available for 1998-2007.

Bwam8AH.HIN − This *HYD* input HIN file controls the reading of *SIM* simulation results from the Bwam8A.OUT file, performing flows adjustments, and writing the resulting naturalized flows to the BwamH.FLO file.

Bwam8AH.FLO − This *HYD* input file contains 1998-2007 gaged flows at 48 control points. The *HYD* FLO input file is applied at each repetition but does not itself change during the iterative computational procedure.

Bwam8AHOUT.FLO − This *HYD* output file contains 1998-2007 naturalized flows at 48 control points. This output file changes with each iteration of the computational procedure. This *HYD* output file is converted to the *SIM* input file with filename Bwam8A.FLO simply by removing the header and changing the filename.

CHAPTER 5
LENGTHENING OF THE BRAZOS WAM HYDROLOGIC SIMULATION PERIOD TO INCLUDE 1900-1939

The Brazos WAM hydrologic period-of-analysis has also been extended backward to cover the period from January 1900 through December 1939. Thus, the period-of-analysis now spans 1900-2007. The naturalized flows at most (but not all) control points are significantly less accurate for the 1900-1940 period than for later years due to the limited number of stream gaging stations in operation prior to 1940, particularly prior to 1924. Since water resources development and use were relatively minimal during these early years, naturalized flows at gaging stations in operation during 1900-1940 are essentially the same as the actual observed gaged flows. This exceptionally long 108-year 1900-2007 hydrologic period-of-analysis provides unique opportunities for investigating long-term river flow characteristics and water supply capabilities for this major Texas river basin.

Monthly flows during 1900-1939 at 20 control points located at sites that were gaged during at least portions of 1900-1939 were taken from an investigation conducted at Texas A&M University during 1986-1988 (Wurbs, Bergman, Carriere, and Walls 1988). Periods of missing flow data during 1900-1939 were synthesized in this previous 1986-1988 study. Naturalized flows at the other 57 Brazos WAM primary control points were computed in the current study based on distributing the 1900-1939 sequences of flows at one or more of the 20 control points in proportion to 1940-1997 means of the 77 control points. Thus, 1900-1939 monthly naturalized flow sequences are developed for the 77 primary control points in the Brazos WAM dataset.

The extended *SIM* input dataset includes naturalized monthly stream flows extending from January 1900 through December 2007 at 77 primary control points which are distributed to the numerous other secondary control points within the *SIM* simulation model. The 1900-2007 naturalized flows at the 77 primary control points are plotted in Appendix A.

The Brazos WAM dataset contains reservoir surface net evaporation less precipitation rates for 67 control points. Evaporation-precipitation depths at each of the 67 control points for each of the 12 months of the year for the 40 years from 1900 through 1939 were assigned as the 1940-1997 means. The same set of twelve 1940-1997 mean evaporation-precipitation depths for the 12 months of the year were repeated for each year from 1900 through 1939.

Historical Water Resources Development

Converting gaged flows to naturalized flows was the key central concern in the 1998-1997 flow extension computations described in the preceding Chapter 4. However, gaged flows are essentially natural flows during 1900-1939. Water resources development during 1900-1939 was minimal as compared to 1940-2007. Statewide population growth in Texas is shown in Table 5.1.

Wurbs et al (1988) compiled the information in Table 5.2 regarding reservoirs in the Brazos River Basin as an index of water resources development during 1900-1986. Table 5.2 reflects data for the 1,178 reservoirs located in the Brazos River Basin included in the dam inventory maintained by the Texas Water Commission as of 1986. Reservoirs are categorized as small or major depending on whether total controlled storage capacity is greater than 5,000 acre-feet. The 40 major reservoirs account for most of the total storage of the 1,178 reservoirs. Few dams were constructed in the Brazos River Basin prior to 1940 compared to subsequent decades. Of the 3,908,000 acre-feet of conservation storage capacity in 40 major reservoirs as of the end of 1986, only 3.0 percent (117,000 acre-feet) of the total was contained in reservoirs with initial impoundment before 1940.

As indicated by Table 3.4, the Bwam3 and Bwam8 datasets include 665 and 706 reservoirs, respectively, with total conservation storage capacities of 4,694,851 and 4,023,350 acre-feet. The counts in Table 5.2 include many small flood control dams and very small water supply reservoirs that are not included in the Brazos WAM dataset, but Table 5.2 excludes several large reservoirs with construction completed after 1986. As indicated by Table 3.6, Possum Kingdom with impoundment beginning in 1941 is the oldest of the 16 largest reservoirs in the Brazos River Basin.

Table 5.1
Texas Population Growth

Year	Population	Year	Population
1930	5,820,000	1970	11,200,000
1940	6,410,000	1980	14,230,000
1950	7,710,000	1990	16,990,000
1960	9,580,000	2000	20,850,000

Table 5.2
Growth in Reservoir Storage Capacity in the Brazos River Basin

Initial Impoundment Date	Number of Reservoirs		Controlled Storage Capacity of Major Reservoirs in acre-feet	
	Small	Major	Conservation	Flood Control
Before 1910	11	0	0	0
1910-1919	12	0	0	0
1920-1929	50	4	31,000	0
1930-1939	20	2	86,000	0
1940-1949	34	4	600,000	0
1950-1959	161	10	1,271,000	2,012,000
1960-1969	524	11	1,261,000	1,592,000
1970-1979	285	4	417,000	0
1980-1986	41	5	242,000	337,000
Total	1,138	40	3,908,000	3,941,000

Adjusting 1900-1939 gaged flows to remove the effects of water resources development, management, and use is a relatively minor concern compared to developing naturalized flows for 1940-1997 and 1998-2007. The primary concern in extending the hydrologic period-of-analysis to include 1900-1939 is the stream flow synthesis necessitated by the small number of gaging stations in operation before 1940, particularly the very small number of gages before 1924.

Naturalized Flows at 20 Control Points from Past Studies

Wurbs, Bergman, Carriere, and Walls (1988) document a water availability modeling study for the Brazos River Basin which included developing 1900-1984 sequences of naturalized monthly flows at 20 U.S. Geological Survey (USGS) stream gaging stations. Flows at the 24 gaging stations listed in Table 5.3 were compiled. Only one of the 24 gages had a continuous record during 1900-1984 with no gaps. The flows at the 24 gaging stations were used to develop complete 1900-1984 sequences of flows, with all missing flows synthesized, at the first 20 stations listed in Table 5.3 which were adopted for the study described by the 1988 report.

Table 5.3
USGS Gaging Stations for which 1900-1940 Flows Were Compiled

	River or Stream	Nearest City	USGS Gage	Record Began	Drainage Area (square miles)	Control Point ID
1	Hubbard Creek	Breckenridge	08086500	May 1955	1,089	HCBR21
2	Brazos River	South Bend	08088000	Oct 1938	22,670	BRSB23
3	Brazos River	Palo Pinto	08089000	Jan 1924	23,810	BRPP27
4	Brazos River	Glen Rose	08091000	Oct 1923	25,820	BRGR30
5	Brazos River	Aquilla	08093100	Oct 1938	27,240	BRAQ33
6	Aquilla Creek	Aquilla	08093500	Jan 1939	308	AQAQ34
7	Bosque River	Waco	08095600	Sep 1959	1,656	BOWA40
8	Brazos River	Waco	08096500	Oct 1898	29,570	BRWA41
9	Leon River	Hasse	08099500	Jan 1939	1,260	LEHS45
10	Leon River	Belton	08102500	Oct 1923	3,540	LEBE49
11	Lampasas River	Belton	08104100	Oct 1923	1,320	LABE52
12	Little River	Little River	08104500	Oct 1923	5,270	LRLR53
13	N. Fork San Gabriel	Georgetown	08104700	Jul 1968	248	NGGE54
14	San Gabriel River	Laneport	08105700	Aug 1965	738	GALA57
15	Little River	Cameron	08106500	Nov 1916	7,065	LRCA58
16	Brazos River	Bryan	08109000	Aug 1899	39,515	BRBR59
17	Yegua Creek	Somerville	08110000	Jun 1924	1,010	YCSO62
18	Navasota River	Easterly	08110500	Apr 1924	968	NAEA66
19	Brazos River	Hempstead	08111500	Oct 1938	43,880	BRHE68
20	Brazos River	Richmond	08114000	Jan 1903	45,010	BRRI70
		Additional Gaging Stations Not Included in 20				
	Brazos River	Dennis	08090800	May 1968	25,240	BRDE29
	North Bosque River	Clifton	08095000	Oct 1923	968	NBCL36
	Lampasas River	Youngsport	08104000	Nov 1924	1,240	LAYO51
	Navasota River	Bryan	08111000	Jan 1951	1,450	NABR67

The observed monthly flows at the 24 gaging stations were converted to unregulated (naturalized) flows in the 1986-1988 investigation by adjusting for the storage and evaporation effects of 21 major reservoirs and diversions associated with two canal systems. Sweetwater Reservoir on Bitlers Creek had the earliest storage record which dates back to January 1936. Sweetwater is the only one of the 21 reservoirs with initial impoundment before 1940. Naturalized flows equal gaged flows for 1900 through 1935.

Records of flow measurements at each of the 24 stream gages began at the dates shown in Table 5.3. Twelve of the 24 gages have records dating back to 1924 or before. The USGS gaging station on the Brazos River at Waco has a continuously record from October 1898 to the present. The gage on the Little River at Cameron has continuous recorded monthly flows dating back to November 1916. Gages on the Brazos River at Richmond and Bryan have records beginning in 1899 and 1903, respectively, but also have periods of missing data. Flow measurements are missing during January 1903 through February 1918 at gage 08109000 on the Brazos River near Bryan and during July 1906 through September 1922 at gage 08114000 on the Brazos River near Richmond.

Flow data at the four gaging stations listed at the bottom of Table 5.3 were used by Wurbs et al (1988) to synthesize flows for gaps in the 1900-1984 period-of-analysis at the other 20 gaging stations. All 24 gages were included in developing 1900-1984 naturalized flows and synthezing flows as necessary to develop complete sequences of naturalized flows at 20 gaging stations.

Wurbs, et al. (1988) synthesized monthly flows for the periods of missing records. Flows were reconstituted at all of the gages to cover January 1900 through December 1984 using the following computer models.

HEC-4 Monthly Streamflow Synthesis developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers (1971).

MOSS-IV Monthly Streamflow Synthesis developing by the Texas Water Development Board by modifying HEC-4 (Beard 1973).

Both HEC-4 and MOSS-IV were applied for comparison. Flows synthesized with MOSS-IV were adopted. MOSS-IV is an improved version of HEC-4 (USACE, HEC 1971), modified for the Texas Water Development Board (Beard 1973).

MOSS-IV fills in gaps in monthly streamflow data based on measured streamflow at multiple nearby gaging stations. The program uses a multiple linear regression algorithm based on the transformed incremental logarithm of the monthly flow volumes. A random component is included in order to reproduce the distribution of random departures from the regression model observed in the basic data. The missing dependent value to be estimated is related to values for the same month at all of the stations where such values exist or values for the preceding month if the current-month values do not exist.

The gaging stations were grouped into the following four passes for the regression analysis to fill in missing flows. Selected stations were included in more than one pass.

1. Brazos River at Breckenridge, South Bend, Palo Pinto, Dennis, Glen Rose, Aquilla, and Waco; Little River at Cameron; and North Bosque River at Clifton.
2. Brazos River at Waco; Bosque River at Waco; Leon River at Hasse and Belton;Lampasas River at Belton and Youngsport; North Fork of San Gabriel River at Georgetown; San Gabriel River at Laneport; Little River at Cameron; and North Bosque River at Clifton.
3. Brazos River at Waco, Bryan, Hempstead, and Richmond; Little River at Cameron; Yequa Creek at Somerville; and Navasota River at Easterly.
4. Aquilla Creek at Aquilla; and Brazos River at Glen Rose, Aquilla, and Waco.

Wurbs, et al. (1988) adopted the resulting unregulated flows at the first 20 gaging stations listed in Table 5.3. The 1900-1939 flows at these 20 control points are adopted for the present extended Brazos WAM dataset. The 77 Brazos WAM primary control points in the Brazos WAM are shown in Figure 5.1 with these 20 control points highlighted in bold print.

Transfer of Naturalized Flows to the Other Primary Control Points

Mean flow relationships used to distribute 1900-1939 flows from 20 to 48 control points are presented in Table 5.4. The 1940-1997 mean flows from which these relationships are derived are tabulated in Table 3.2. The same flow distribution methodology is applied in both Chapters 4 and 5 but to different subsets of control points and for different time periods.

Distribution of 1998-2007 naturalized flows from 48 control points with gaged flows during 1998-2007 to the other 29 Brazos WAM primary control points is described in Chapter 4. The mean flow relationships used to distribute 1998-2007 flows from 48 to 29 other control points are presented in Table 4.8 based on the mean flow volumes of Table 3.2. Similar mean flow relationships used to distribute 1900-1939 flows from 20 to 31 other control points are presented in Table 5.4. Sequences of monthly naturalized flow volumes for unknown-flow control points are computed based on naturalized flows at one or more known-flow control points and ratios between the means of 1940-1997 naturalized flows at the respective control points. The ratios of 1940-1997 mean naturalized flows were applied in a manner similar to the conventional application of drainage area ratios, with mean flow ratios replacing drainage area ratios.

$$F_U = F_K \left(\frac{M_U}{M_K} \right)$$

F_U − naturalized flow at unknown flow control point

F_K − naturalized flow at a known flow control point or the summation of flows or difference in flows at multiple control points

M_U − 1940-1997 mean of naturalized flow at an unknown flow control point or the summation or difference in means at multiple control points

M_K − 1940-1997 mean of naturalized flow at a known flow control point or the summation or difference in means at multiple control points

The 1900-1939 monthly flows at the 20 control points listed in Table 5.3 are combined with the relationships shown in Table 5.4 to compute flows at the 31 other control points listed in Table 5.4. The 1900-1939 monthly flows at these 51 control points are combined with the relationships shown in Table 4.8 of Chapter 4 to obtain flows at the remainder of the 77 original Brazos WAM primary control points. The flow distribution computations are performed with *WRAP-HYD*. The results of these computations are January 1900 through December 1939 sequences of naturalized flows at the 77 Brazos WAM primary control points.

The 20 control points for which 1900-1939 flows are adopted from the previous investigation are listed in Table 5.3. Seventeen of these 20 control points are included in the 48 control points discussed in Chapter 4 for which 1998-2007 gaged flows are available. The other three (HCBR21, BOWA40, YCSO62) of the 20 control points are not included in the 48 control points with 1998-2007 gaged flows. Flow distribution computations based on relationships in Table 4.8 are applied to compute flows at control points HCBR21, BOWA40, and YCSO62, but since these three control points are included in the 20 with known 1900-1939 flows, relationships for computing flows at these sites are not included in Table 5.4. Relationships for distributing 1900-1939 flows from the 20 control points to the 31 other (48-17=31) control points are presented in Table 5.4.

Table 5.4
Relationships for Computing 1900-1939 Naturalized Flow for 31 Control Points

Control Point	River or Stream	Nearest City	Flow Synthesis Relationship with Source Control Points
RWPL01	Running Water Draw	Plainview	0.0038 (BRSB23)
SFAS06	Salt Fork Brazos River	Aspermont	0.1174 (BRSB23)
DMJU08	Double Mountain Fork	Justiceburg	0.0339 (BRSB23)
DMAS09	Double Mountain Fork	Aspermont	0.1651 (BRSB23)
BRSE11	Brazos River	Seymour	0.3811 (BRSB23)
MSMN12	Millers Creek	Munday	0.0088 (BRSB23)
CFRO13	Clear Fork Brazos	Roby	0.0743 (HCBR21)
CFNU16	Clear Fork Brazos	Nugent	0.9844 (HCBR21)
CAST17	California Creek	Stamford	0.2838 (HCBR21)
CFFG18	Clear Fork Brazos	Fort Griffin	1.8005 (HCBR21)
HCAL19	Hubbard Creek	Albany	0.5912 (HCBR21)
BSBR20	Big Sandy Creek	Breckenridge	0.2403 (HCBR21)
BRDE29	Brazos River	Dennis	BRPP27 + 0.6266 (BRGR30 − BRPP27)
PAGR31	Paluxy River	Glen Rose	0.0523 (BRGR30)
NBCL36	North Bosque River	Clifton	0.4566 (BOWA40)
NBVM37	North Bosque River	Valley Mills	0.5687 (BOWA40)
BRHB42	Brazos River	Highbank	BRWA41 + 0.1864 (BRBR59 − BRWA41)
SADL44	Sabana River	De Leon	0.2483 (LEHS45)
LEGT47	Leon River	Gatesville	LEHS45 + 0.3201 (LEBE49 − LEHS45)
COPI48	Cowhouse Creek	Pidcoke	0.2126 (LEBE49 − LEHS45)
LAKE50	Lampasas River	Kempner	0.5135 (LABE52)
SGGE55	South Fork San Gabriel	Georgetown	0.2754 (GALA57 − NGGE54)
MYDB60	Middle Yegua Creek	Dime Box	0.1762 (YCSO62)
EYDB61	East Yegua Creek	Dime Box	0.1933 (YCSO62)
DCLY63	Davidson Creek	Lyons	0.2126 (YCSO62)
NAGR64	Navasota River	Groesbeck	0.2588 (NAEA66)
BGFR65	Big Creek	Freestone	0.0999 (NAEA66)
NABR67	Navasota River	Bryan	1.3060 (NAEA66)
BGNE71	Big Creek	Needville	0.0044 (BRRI70)
BRRO72	Brazos River	Rosharon	1.0448 (BRRI70)
CBALC2	Chocolate Bayou	Alvin	0.0131 (BRRI70)

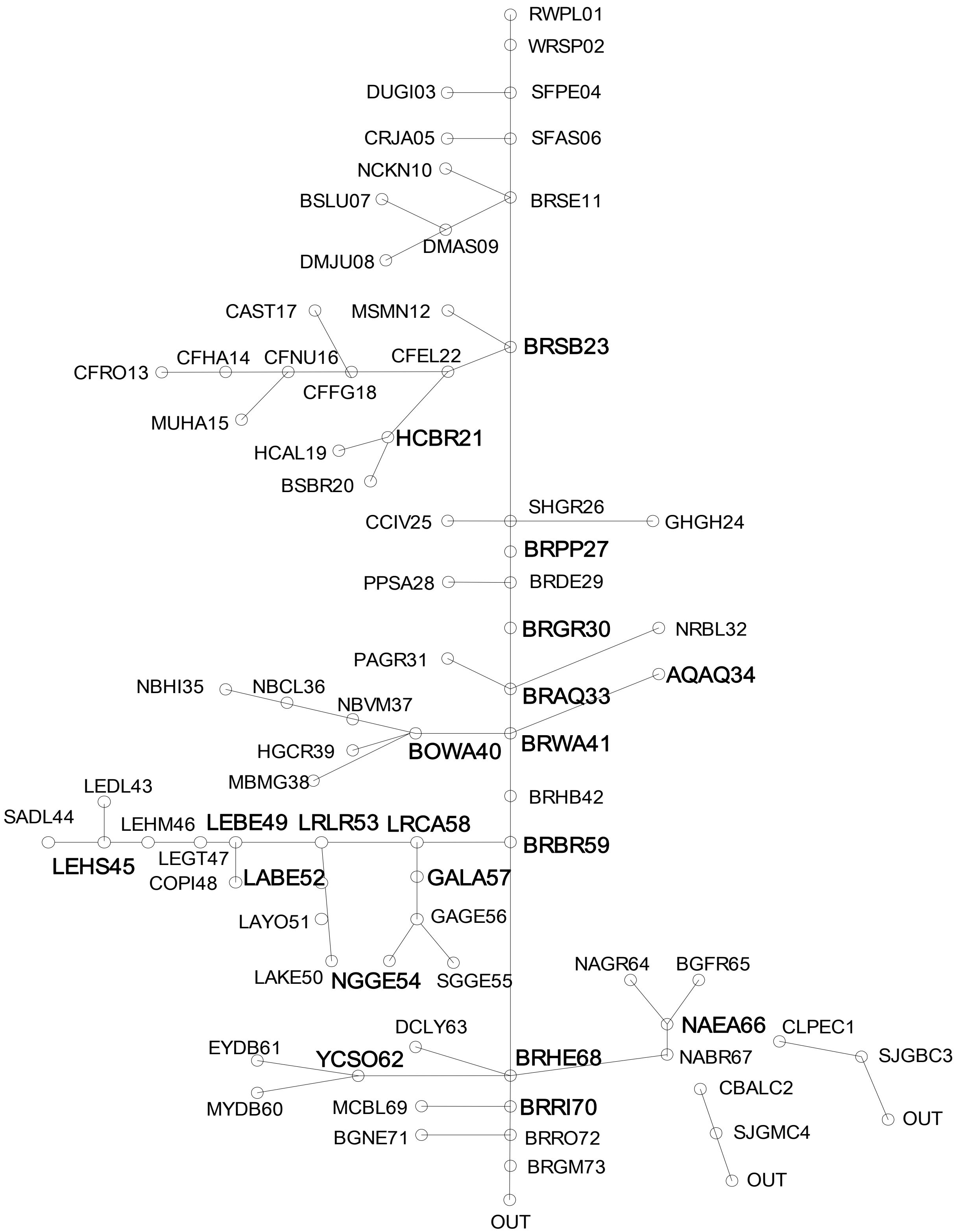

Figure 5.1 Schematic of 77 Primary Control Points with 20 Control Points in Bold
(Not to Scale)

The distribution of flows from 20 to 77 control points involves major uncertainties and approximations in addition to the inaccuracies reflected in the flows at the 20 control points. The level of accuracy of the 1900-1939 naturalized flows that may logically be expected varies greatly between the different control points depending largely upon their distance from USGS gaging stations with periods-of-record covering major portions of 1900-1939.

The accuracy of the 1900-1939 monthly naturalized flows varies temporally as well as spatially. Several of the 20 gaging stations have records beginning in 1923 or 1924. Inaccuraries and uncertainties prior to 1924 are greater than 1924-1939 due to the number of gaging stations.

Flows are most subject to uncertainties in the upper basin above Possum Kingdom Reservoir. As indicated in Figure 5.1, control point BRSB23 at the South Bend gage on the Brazos River is the most upstream control point on the main-stem Brazos River included in the 20 control points for which flows were obtained from the study by Wurbs et al (1988). Records at the South Bend gage date back to October 1938. Distribution of flows from control point BRSB23 to the other control points located further upstream in the upper basin involves large distances between gaged and ungaged control points and is necessarily highly approximate.

Control point BRWA41 is at the Waco Gage on the Brazos River which has a continuous record from October 1898 to the present. This is the only gage with a continuous record covering the complete 1900-1939 period. As indicated in Table 5.3, the gaging stations on the Brazos River at Bryan and Richmond and the Little River at Cameron have the next longest records. The record at the Bryan gage extends from August 1899 through December 1902, from March 1918 through December 1925, and from July 1926 through the remainder of the 1900-1939 period-of-analysis. The record at the Richmond gage extends from January 1903 through June 1905 and from October 1922 to the present The gage on the Little River at Cameron has a continuous record of monthly flows dating back to November 1916. The 1900-1939 flows should be most accurate at these sites.

Resulting Naturalized Flows

The 1900-1939 naturalized flows are combined with the 1940-2007 naturalized flows to obtain the 1900-2007 sequences of naturalized flows at 77 primary control points which comprise the WRAP-SIM input FLO file. The January 1900 through December 2007 naturalized flows at 77 control points are plotted in Appendix A. The naturalized flows at three selected control points (Richmond, Waco, and Cameron gages) are tabulated in Tables 6.1, 6.2, and 6.3. The naturalized flows for the period 1900-1939 are essentially the same as gaged flows. Naturalized flows for the sub-periods 1900-1939, 1940-1997, and 1998-2007 are compared in Chapter 6.

Comparison with Mean Annual Precipitation

Observed precipitation provides another means to identify and compare periods of droughts and floods and more normal hydrologic conditions. Precipitation data can be used as an additional check of whether the naturalized flow sequences are reasonable. Annual precipitation depths at 41 precipitation stations located in the Brazos River Basin with records beginning between 1899 and 1933 were compiled during the 1986-1988 study. Twenty-five of the precipitation gages have records dating back to 1912 or before with eight gages dating back to 1899. The mean annual precipitation depths for the watersheds above the stream gaging stations on the Brazos River near the Cities of Richmond, Bryan, and Waco and on the Little River near Cameron were estimated for each year of 1900-1984 as the arithmetic average of the data available at the gages located in each watershed. These annual precipitation depths are tabulated in Table 5.5.

Table 5.5
Annual Precipitation for Watersheds of Selected Stream Gaging Stations

	Mean Precipitation (inches) above Gage			
Year	Waco	Cameron	Bryan	Richmond
1900	37.42	35.47	38.88	41.83
1901	17.83	15.80	17.76	18.23
1902	33.53	27.97	34.16	35.83
1903	27.54	31.55	30.38	31.59
1904	28.20	32.44	29.44	30.74
1905	44.03	37.13	44.10	44.74
1906	34.90	28.62	33.47	33.58
1907	30.22	32.42	33.16	35.01
1908	35.79	32.61	36.05	36.41
1909	21.89	21.18	22.84	23.31
1910	18.38	21.72	20.69	21.02
1911	27.99	25.38	27.57	28.75
1912	22.32	22.65	23.03	23.54
1913	32.75	39.76	35.10	36.25
1914	36.42	35.04	36.70	37.69
1915	31.67	27.00	31.51	31.92
1916	23.09	25.38	23.94	24.36
1917	14.86	15.03	15.35	15.51
1918	23.46	23.21	24.29	24.76
1919	39.70	44.58	41.81	44.02
1920	32.91	35.70	34.00	35.01
1921	21.06	25.36	23.81	25.53
1922	24.79	32.25	28.33	29.80
1923	31.98	35.11	33.46	35.39
1924	18.83	20.83	20.16	21.08
1925	21.23	22.33	21.59	22.49
1926	32.91	32.68	33.89	34.99
1927	22.24	28.91	25.08	25.89
1928	22.79	26.15	24.04	24.69
1929	22.44	26.88	24.47	26.04
1930	25.00	29.41	26.85	27.44
1931	23.74	31.49	25.67	26.20
1932	33.96	37.80	35.31	35.43
1933	21.07	25.00	22.32	23.01
1934	16.47	23.75	19.47	20.94
1935	31.15	36.33	33.49	34.58
1936	25.67	35.89	28.73	29.34
1937	22.56	28.99	25.03	25.34
1938	24.55	30.67	26.42	26.94
1939	20.34	26.09	22.15	22.30
1940	25.87	41.81	30.81	31.87
1941	43.53	37.80	42.33	43.41
1942	28.89	39.62	31.75	32.03
1943	17.10	21.53	18.85	19.81
1944	29.08	38.15	32.89	33.64
1945	25.16	37.61	29.53	30.95
1946	26.32	35.86	29.39	30.89
1947	21.82	20.66	22.58	23.58
1948	16.70	21.99	18.47	18.72
1949	29.10	32.57	30.06	31.57
1950	24.12	25.17	24.37	24.68
1951	18.50	22.91	19.67	20.41
1952	18.25	24.60	20.73	21.72
1953	21.03	30.75	24.33	25.32
1954	15.97	16.19	16.24	16.45
1955	22.90	28.08	24.76	25.11
1956	12.35	17.70	13.99	14.44
1957	36.65	46.15	39.88	40.40
1958	25.00	32.22	27.28	27.87
1959	28.09	34.09	30.72	31.66
1960	26.25	33.81	28.88	30.18
1961	30.54	36.08	32.47	33.53
1962	26.35	27.11	26.77	27.13
1963	20.78	20.33	20.65	20.79
1964	22.31	31.91	25.16	25.74
1965	25.75	35.32	29.48	30.45
1966	24.29	28.76	26.31	26.73
1967	22.83	28.10	24.75	24.97
1968	29.41	39.97	32.93	34.24
1969	31.49	29.49	31.30	31.56
1970	19.14	28.66	21.98	22.89
1971	27.61	31.27	29.04	29.28
1972	25.70	24.86	25.88	26.38
1973	28.72	33.78	31.56	32.19
1974	28.47	34.18	30.68	31.09
1975	24.49	28.67	26.18	26.59
1976	26.09	33.43	28.90	28.61
1977	20.51	22.80	21.86	22.15
1978	23.16	25.89	24.29	24.77
1979	26.68	35.06	29.83	30.87
1980	23.40	27.50	24.42	24.84
1981	27.98	30.56	29.81	30.61
1982	27.63	28.61	28.26	28.64
1983	22.52	23.81	23.93	24.51
1984	24.52	27.21	26.11	26.45
Mean	25.89	29.64	27.58	28.37

Bomar (1995) provides a historical review of Texas weather. From a statewide perspective, the most hydrologically severe drought on record occurred during the period 1950-1957. However, the driest year statewide during the period 1880-1993 was 1917 which had a statewide mean annual precipitation of 14.30 inches. The wettest year was 1941 with a statewide annual precipitation of 42.62 inches.

The three driest years during 1900-1984 for the watersheds above the four stream gaging stations of Table 5.5 are listed in Table 5.6. Minimum extremes of annual precipitation occurred during the years 1917, 1954, and 1956 in the Brazos River Basin which is consistent with statewide means.

Table 5.6
Annual Precipitation for the Three Driest Years of 1900-1984
for the Watersheds of Selected Stream Gaging Stations

Gage	Three Smallest Annual Precipitation Depths during 1900-1984		
Little River at Cameron	1917 (15.0 inches)	1901 (15.8 inches)	1954 (16.2 inches)
Brazos River at Waco	1956 (12.35 inches)	1917 (14.9 inches)	1954 (16.0 inches)
Brazos River at Bryan	1956 (14.0 inches)	1917 (15.35 inches)	1954 (16.2 inches)
Brazos River at Richmond	1956 (14.4 inches)	1917 (15.5 inches)	1954 (16.45 inches)

The three smallest annual naturalized flow volumes during 1900-2007 at the three gaging stations with flows tabulated in Tables 6.1, 6.2, and 6.3 of Chapter 6 are compared in Table 5.7 below. The drought year 1917 and various years during the 1950-1957 drought represent the three driest years defined in terms of naturalized river flows at these three locations. Comparisons of naturalized flows and simulation results for alternative sub-periods of the 1900-2007 hydrologic period-of-analysis are presented in Chapters 6, 7, and 10.

Table 5.7
Annual Naturalized Flow Volumes for the
Three Years of 1900-2007 for which Flows are the Smallest

Gage	Three Smallest Annual Naturalized Flows during 1900-2007		
Little River at Cameron	1954 (95,390 ac-ft)	1917 (117,040 ac-ft)	1951 (132,150 ac-ft)
Brazos River at Waco	1917 (303,920 ac-ft)	1956 (465,630 ac-ft)	1952 (474,630 ac-ft)
Brazos River at Richmond	1956 (883,330 ac-ft)	1951 (986,470 ac-ft)	1917 (997,270 ac-ft)

CHAPTER 6
NATURALIZED FLOW COMPARISON

The hydrologic period-of-analysis for the original Brazos WAM dataset is 1940-1997. The procedures outlined in Chapters 4 and 5 resulted in lengthening the hydrologic period-of-analysis to 1900-2007. Chapter 4 documents the hydrology update to cover 1998-2007. Chapter 5 describes the extension of the hydrologic period-of-analysis backward in time to include 1900-1939. Monthly net evaporation-precipitation depths for 1900-2007 have been compiled for 67 control point locations. Naturalized monthly flow volumes for 1900-2007 have been developed for the 77 Brazos WAM primary control points. This chapter provides a comparison of the naturalized flows spanning the 1900-1939, 1940-1997, and 1998-2007 sub-periods of the overall 1900-2007 hydrologic period-of-analysis. Naturalized flows are also compared with observed gaged flows.

Naturalized Flows

The 1900-2007 sequences of monthly naturalized stream flows at the 77 Brazos WAM primary control points are plotted in Appendix A. The 1998-2007 observed gaged flows and computed naturalized flows at the 48 control points for which 1998-2007 gaged flows are available are plotted in Appendix B. The 1900-2007 naturalized flows at the Richmond, Waco, and Cameron gaging stations (control points BRRI70, BRWA41, LRCA58) are tabulated in Tables 6.1, 6.2, and 6.3. As noted at several places in this report, at most control points, the flows for 1900-1939 reflect a lesser level of accuracy than the flows for 1940-2007 due to the limited number of gaging stations in operation prior to 1940, particularly the very small number of gaging stations before 1924.

Table 6.1
Naturalized Flows at the Richmond Gage on the Brazos River (Control Point BRRI70)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1900	563104.	293242.	526759.	2493000.	4250000.	850751.	278379.	260077.	997696.	645893.	301272.	222493.	11682666.
1901	154940.	86087.	105469.	194555.	365099.	537395.	38577.	72725.	124230.	28031.	46201.	38639.	1791948.
1902	40535.	34444.	182346.	116407.	826999.	278613.	1193000.	848246.	169242.	148713.	673457.	403116.	4915118.
1903	451521.	994702.	2194000.	415000.	268400.	228099.	296088.	718200.	77834.	397536.	82711.	88540.	6212631.
1904	62537.	110100.	62967.	142800.	924804.	300901.	249083.	162600.	112492.	118792.	144201.	69790.	2461067.
1905	159506.	374400.	822759.	1052000.	3424000.	1016000.	148994.	325302.	188584.	163898.	148600.	274502.	8098545.
1906	231989.	229000.	120010.	134000.	296000.	649000.	181816.	182094.	409334.	107436.	211167.	876227.	3628073.
1907	302595.	179971.	263659.	89980.	534924.	391254.	437457.	274646.	73375.	854220.	437173.	559635.	4398889.
1908	486531.	381635.	595986.	3594000.	2892000.	1101000.	183103.	95862.	195678.	374831.	116457.	192072.	10209155.
1909	45137.	19370.	43491.	60789.	177845.	267037.	108448.	63829.	19417.	86768.	71697.	189641.	1153469.
1910	84308.	163813.	14403.	278443.	418457.	68823.	16737.	0.	51321.	66550.	26993.	54768.	1244616.
1911	42804.	281703.	139067.	257339.	194704.	212449.	214758.	232263.	168502.	39552.	61212.	118436.	1962789.
1912	167914.	303873.	349263.	586694.	178999.	272091.	61777.	124169.	44958.	306012.	40550.	33177.	2469477.
1913	23929.	102122.	151891.	191575.	924321.	514784.	259640.	49996.	344048.	582821.	983894.	2508000.	6637021.
1914	239598.	299825.	303234.	820334.	5291000.	2842000.	474478.	196136.	254455.	311151.	433732.	556373.	12022316.
1915	364565.	329877.	455656.	2066000.	3335000.	1836000.	1274000.	297568.	152664.	730442.	186635.	263874.	11292281.
1916	529132.	911642.	512171.	969370.	1161000.	577509.	156082.	53198.	140818.	300651.	116155.	59780.	5487508.
1917	59362.	20139.	77768.	64042.	223268.	232751.	60513.	25332.	156860.	24872.	25513.	26845.	997265.
1918	44852.	60047.	24130.	638718.	309505.	293781.	54150.	65234.	171070.	425882.	869449.	1066000.	4022818.
1919	842635.	960761.	739365.	630317.	1469000.	970336.	1016000.	339230.	745913.	1417000.	1294000.	1190000.	11614557.
1920	1498000.	804309.	381188.	134134.	1925000.	525964.	265914.	755479.	704325.	332805.	340019.	373431.	8040568.
1921	277810.	277343.	540520.	843805.	351962.	1103000.	378890.	44363.	861015.	174876.	117951.	103592.	5075127.
1922	82959.	146592.	387834.	2573000.	7354000.	903061.	190258.	236121.	45977.	54601.	113999.	63500.	12151902.
1923	79608.	221001.	435079.	1400000.	615998.	405999.	99099.	45500.	189999.	296002.	631988.	1870000.	6290273.
1924	727024.	893998.	1380000.	765000.	632002.	909001.	88794.	46100.	108012.	83798.	41000.	45101.	5719830.
1925	44094.	34400.	30894.	27000.	514001.	52700.	31903.	42400.	289993.	990923.	1120000.	95801.	3274109.
1926	539003.	186000.	955161.	2190000.	1240000.	462001.	372041.	272000.	340027.	382974.	203006.	701009.	7843222.--

Table 6.1 Continued
Naturalized Flows at the Richmond Gage on the Brazos River (Control Point BRRI70)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1927	292003.	544001.	678773.	961001.	421001.	838002.	378040.	103999.	58589.	598964.	81499.	82400.	5038272.
1928	85505.	318000.	298026.	214000.	295000.	814999.	160988.	264000.	104978.	37601.	40800.	230997.	2864894.
1929	327997.	96100.	296001.	708001.	1130000.	2360000.	321963.	57500.	393010.	86100.	555002.	97799.	6429473.
1930	213977.	408000.	238020.	134000.	2600000.	582001.	128003.	58000.	117980.	916048.	212005.	935027.	6543061.
1931	713016.	782995.	867016.	378000.	416000.	218000.	96495.	59500.	44995.	175453.	152001.	179998.	4083469.
1932	1750000.	1470000.	971892.	165000.	938027.	447200.	575062.	139451.	1153000.	162996.	68400.	106001.	7947029.
1933	282002.	270000.	434088.	220000.	390680.	346541.	51695.	165610.	115752.	57197.	48400.	34100.	2416065.
1934	329998.	513998.	787098.	1330000.	189400.	47500.	26130.	19650.	33220.	37481.	155002.	229900.	3699377.
1935	207578.	443501.	197279.	210250.	3310000.	1420000.	425448.	163750.	563707.	328996.	285100.	1213000.	8768609.
1936	201487.	144447.	118424.	81216.	1199000.	839344.	1091000.	96394.	458420.	1443000.	466254.	784662.	6923648.
1937	850138.	380693.	583095.	237926.	118970.	278637.	131333.	65289.	125478.	169899.	177502.	430605.	3549565.
1938	1140000.	1047000.	510080.	1191000.	1170000.	327504.	368193.	374854.	79643.	47868.	38356.	39772.	6334270.
1939	165143.	155105.	169399.	83678.	561454.	471581.	216692.	56261.	51533.	32584.	34721.	57839.	2055990.
1940	51388.	148983.	43537.	200367.	319712.	660079.	1324621.	257456.	110260.	66621.	1408897.	3249758.	7841679.
1941	1186703.	1355739.	1619576.	1228816.	2796541.	2107990.	1152361.	363549.	316620.	749627.	640748.	166534.	13684804.
1942	138492.	106630.	97484.	2145751.	1970552.	1313171.	352634.	114527.	855136.	722141.	409735.	243467.	8469720.
1943	330501.	121939.	226983.	312769.	226930.	269631.	141323.	87180.	63623.	88173.	53706.	88418.	2011176.
1944	673564.	954469.	1167999.	361916.	2857198.	1081847.	174038.	72569.	269624.	114747.	327291.	779695.	8834957.
1945	1313527.	914826.	1348256.	2559710.	772069.	585796.	546199.	439755.	358432.	546772.	129401.	476876.	9991619.
1946	659965.	871210.	1314320.	510391.	1622996.	881706.	220852.	88111.	297845.	275544.	1036818.	587140.	8366898.
1947	985931.	305067.	811934.	434430.	1001274.	355036.	100176.	349617.	129603.	71565.	88360.	230713.	4863706.
1948	101687.	239222.	358634.	158442.	315392.	228985.	275325.	16912.	60546.	44631.	32526.	27629.	1859931.
1949	70753.	237853.	495181.	785062.	1050636.	505228.	216969.	36345.	102591.	278979.	199337.	264136.	4243070.
1950	281304.	758165.	173482.	529261.	559937.	665039.	249891.	198312.	294134.	126095.	39744.	32791.	3908155.
1951	21961.	49281.	60103.	78886.	175612.	365392.	37512.	31878.	77250.	32557.	23596.	32442.	986470.
1952	23048.	49734.	77722.	393347.	458387.	219557.	49304.	0.	30205.	12334.	69618.	245522.	1628778.
1953	285191.	123707.	263753.	103518.	1789798.	113055.	295391.	123985.	125570.	455456.	222666.	554906.	4456996.
1954	135090.	51876.	29086.	139559.	520301.	159243.	32153.	51969.	18444.	42704.	75284.	25854.	1281563.
1955	33292.	256191.	79452.	314765.	536879.	409303.	134963.	84539.	195279.	619289.	60262.	30954.	2755168.
1956	37242.	100771.	45222.	50820.	397044.	46514.	0.	16588.	16252.	24467.	54953.	93459.	883332.
1957	10859.	237971.	231074.	1942597.	6135975.	1996450.	592803.	173087.	101543.	1821357.	1058405.	470562.	14772683.
1958	558038.	878211.	796695.	429495.	1567963.	311145.	425625.	106642.	337797.	227234.	106401.	82633.	5827879.
1959	61453.	308892.	120249.	859606.	554019.	506546.	302171.	150344.	60474.	1670909.	468363.	658380.	5721406.
1960	1038957.	680343.	381929.	246053.	482261.	437937.	438919.	109016.	45380.	598185.	1009330.	1573005.	7041315.
1961	2303834.	2005113.	740332.	316685.	205556.	1079309.	1019755.	260041.	779815.	360904.	381450.	402200.	9854994.
1962	230109.	198120.	137389.	128911.	193000.	521943.	321370.	159856.	551424.	290725.	146460.	356112.	3235419.
1963	186279.	201692.	100332.	276899.	188308.	208895.	84369.	24140.	25483.	45655.	105709.	57074.	1504835.
1964	61676.	169841.	243113.	158607.	164225.	188102.	51832.	52385.	300767.	133024.	376164.	132869.	2032605.
1965	483970.	1100068.	375742.	476667.	3407290.	1005051.	190041.	157946.	146923.	175317.	399229.	461106.	8379350.
1966	204840.	431456.	373576.	1110474.	2137793.	329514.	111204.	300301.	734309.	283178.	73750.	57851.	6148246.
1967	70194.	51993.	60312.	174512.	216780.	282543.	176855.	52566.	134629.	72938.	255020.	153534.	1701876.
1968	1613700.	650655.	1064033.	961360.	2356464.	1771630.	990169.	162978.	251281.	131813.	184610.	518700.	10657393.
1969	148988.	579729.	937405.	1434337.	1602429.	310836.	116066.	112391.	196326.	133566.	167169.	364118.	6103360.
1970	305739.	374811.	1586500.	706040.	722011.	348857.	89227.	50523.	197715.	394058.	103774.	57086.	4936341.
1971	54009.	54651.	55796.	80177.	165643.	109424.	216477.	395894.	194581.	416132.	288958.	847479.	2879221.
1972	432453.	250254.	151766.	102229.	560749.	174587.	83430.	174023.	155917.	138681.	384867.	177852.	2786808.
1973	533364.	567714.	967397.	1350747.	926850.	1452406.	378639.	158595.	143848.	1525018.	529799.	434796.	8969173.
1974	795479.	412888.	205491.	161599.	335152.	112288.	50942.	178104.	1556466.	843957.	1927514.	783072.	7362952.
1975	532022.	1397763.	485095.	664043.	1688357.	1133992.	507798.	263565.	150391.	92367.	82947.	79829.	7078169.
1976	79560.	107955.	141022.	832353.	1235948.	666978.	760842.	164571.	193444.	459136.	372684.	1128780.	6143273.
1977	385193.	1175612.	712742.	2149729.	1009744.	418418.	131074.	55371.	80472.	43943.	56841.	60984.	6280123.
1978	172365.	265842.	213854.	117514.	74868.	139911.	37159.	569701.	180054.	46298.	155827.	114162.	2087555.
1979	698592.	610046.	1112940.	1284999.	1847737.	2016433.	495658.	385166.	263819.	109016.	71500.	165658.	9061564.
1980	432251.	399092.	209581.	352833.	1229898.	243274.	72100.	40254.	153485.	281250.	53543.	85060.	3552621.
1981	63727.	84221.	216103.	188504.	289363.	2212760.	487298.	115057.	235019.	1231960.	787775.	141870.	6053657.
1982	89066.	111154.	180470.	330038.	1441734.	1034392.	628582.	103807.	38477.	49146.	122058.	219248.	4348172.
1983	212028.	692948.	765652.	267739.	995484.	381440.	100965.	211080.	141862.	137134.	72030.	105798.	4084160.
1984	93118.	86000.	242070.	63732.	78709.	90098.	49113.	45515.	48442.	933287.	542259.	718204.	2990547.
1985	669142.	598639.	911297.	431825.	427598.	321044.	123610.	34850.	49922.	408075.	685346.	1097312.	5758660.
1986	184892.	842190.	214890.	140701.	746806.	1561399.	240245.	133284.	426843.	653272.	545550.	1448194.	7138266.
1987	674205.	669590.	1144266.	426531.	630088.	2902239.	574449.	183584.	123470.	67634.	133995.	284149.	7814200.
1988	204364.	138628.	243400.	119426.	90898.	298063.	96079.	54638.	89383.	38633.	23008.	45531.	1442051.
1989	158767.	297694.	345090.	321160.	1477226.	1371807.	330253.	295879.	151037.	51433.	43967.	29443.	4873756.
1990	116543.	209420.	738166.	1568748.	2172498.	768327.	165875.	137277.	162177.	81839.	144283.	69116.	6334269.

Table 6.1 Continued
Naturalized Flows at the Richmond Gage on the Brazos River (Control Point BRRI70)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1991	1562352.	674023.	281932.	929813.	899822.	813250.	191063.	259368.	256313.	456600.	453629.	3720403.	10498568.
1992	2762782.	4262364.	2664145.	1023822.	1448282.	1853371.	494803.	319127.	203840.	96118.	174870.	545893.	15849417.
1993	676615.	782522.	1240002.	887208.	1233566.	1195841.	348693.	89976.	72353.	308445.	129081.	111803.	7076105.
1994	130941.	348443.	341431.	124822.	1056260.	414950.	131433.	74420.	104454.	1548149.	354312.	976023.	5605638.
1995	930250.	279159.	872961.	923507.	1026562.	839996.	212904.	795660.	211615.	134974.	81305.	172269.	6481162.
1996	83511.	80888.	56073.	87732.	49025.	85888.	61968.	220382.	733862.	223749.	238751.	481193.	2403022.
1997	439578.	1891675.	2091461.	1729174.	1181179.	1171316.	501353.	189406.	99863.	180181.	128755.	770252.	10374193.
1998	1469098.	1016491.	1529825.	639172.	218243.	157399.	129977.	121069.	352396.	1595284.	1734205.	1102944.	10066103.
1999	465115.	664092.	376974.	325022.	317089.	362128.	202135.	142568.	73997.	46995.	48119.	47009.	3071244.
2000	74119.	59977.	175838.	169925.	265988.	626692.	112392.	93596.	68982.	87287.	1060275.	493394.	3288465.
2001	1010808.	975173.	2069228.	795490.	563765.	447449.	216074.	173938.	650265.	302116.	427974.	1182250.	8814530.
2002	420684.	447173.	392179.	576554.	185454.	180436.	515954.	328222.	165769.	518703.	1307471.	1226126.	6264725.
2003	703323.	1274101.	1090049.	337063.	159249.	294325.	138181.	87102.	179183.	502910.	218680.	106059.	5090225.
2004	309749.	812972.	551498.	594698.	1503495.	1835514.	1653200.	486815.	352399.	304563.	2570650.	1770746.	12746299.
2005	813520.	1351426.	1451227.	447278.	233864.	212577.	162699.	757707.	235865.	123597.	105682.	108314.	6003756.
2006	97819.	117884.	218253.	184736.	345027.	118218.	122772.	90604.	73371.	461057.	114096.	90890.	2034728.
2007	1408345.	212897.	1549853.	1464017.	2832356.	3587742.	4193992.	1553476.	1097273.	576441.	282861.	235618.	18994870.
MEAN	446786.	500114.	551071.	651547.	1121183.	719132.	344771.	195760.	250873.	363214.	345540.	464071.	5954065.

Table 6.2
Naturalized Flows at the Waco Gage on the Brazos River (Control Point BRWA41)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1900	143003.	49197.	67006.	653964.	449023.	296997.	185900.	131997.	908007.	268708.	115496.	38968.	3308266.
1901	21631.	22680.	15721.	37560.	184001.	161295.	7798.	30130.	44740.	15808.	15400.	6770.	563534.
1902	2970.	2590.	62238.	61329.	266188.	127998.	946036.	144503.	98840.	74633.	275196.	100803.	2163324.
1903	66625.	343584.	406427.	67850.	43561.	96368.	86374.	45810.	33160.	231610.	26811.	9150.	1457330.
1904	6880.	14920.	22699.	28770.	132397.	202902.	108458.	104999.	65470.	115400.	27460.	12010.	842365.
1905	21480.	30280.	98805.	435384.	1122000.	229597.	351156.	137599.	110499.	95898.	42697.	57200.	2732595.
1906	33700.	40700.	21600.	32500.	244000.	511994.	189934.	246993.	180001.	86103.	38099.	78104.	1703728.
1907	50796.	32200.	34198.	20900.	195997.	220001.	208963.	52799.	22400.	156991.	153992.	212014.	1361251.
1908	74995.	86300.	80586.	1140000.	1350000.	186000.	65196.	47800.	55100.	27303.	13000.	22601.	3148881.
1909	1970.	1220.	1960.	1600.	21799.	274004.	22104.	86701.	6720.	14100.	26000.	169010.	627188.
1910	7010.	10699.	2559.	89198.	201999.	36899.	10507.	1140.	36700.	16600.	4680.	3450.	421441.
1911	756.	62195.	14800.	26400.	11500.	1982.	190955.	106000.	303999.	10901.	4710.	141996.	876194.
1912	16200.	21101.	55299.	43600.	47201.	58901.	16101.	215997.	25700.	61798.	8170.	2480.	572548.
1913	655.	5020.	14300.	31900.	245004.	79900.	64694.	21600.	159999.	316994.	333960.	1520000.	2794026.
1914	53398.	18199.	43797.	433982.	1190000.	441996.	88026.	669990.	204999.	69428.	72609.	115100.	3401524.
1915	77964.	51342.	84360.	838398.	485325.	679604.	184763.	141697.	129499.	198007.	30300.	25499.	2926758.
1916	91597.	86300.	29297.	821014.	397982.	148000.	32199.	10600.	22800.	101001.	16701.	8360.	1765851.
1917	7190.	4770.	5860.	15900.	51999.	70203.	29501.	23999.	77999.	10799.	2480.	3220.	303920.
1918	2720.	1470.	1290.	198000.	167998.	179003.	13997.	167.	159000.	282009.	672047.	382987.	2060688.
1919	358974.	221998.	215036.	261008.	580989.	564000.	324014.	271999.	319002.	762006.	701984.	181004.	4762014.
1920	380028.	152008.	124999.	59500.	909977.	329998.	87304.	480013.	607003.	144012.	170008.	89805.	3534655.
1921	139990.	128008.	124018.	88101.	32599.	361999.	49693.	9530.	36100.	10698.	3990.	5560.	990286.
1922	4860.	4850.	17901.	1130000.	1460000.	229996.	47705.	7250.	8520.	6981.	13499.	8490.	2940052.
1923	9000.	42900.	11300.	413998.	182997.	342000.	14800.	1040.	52600.	267013.	245986.	348024.	1931658.
1924	61004.	51497.	352013.	170992.	219999.	129998.	5608.	4590.	115000.	18599.	10400.	9070.	1148770.
1925	8980.	3500.	2080.	79303.	499000.	18499.	4658.	43200.	359998.	165996.	74203.	9390.	1268807.
1926	94807.	19600.	110986.	407004.	184001.	345996.	219888.	166001.	286005.	332008.	38699.	102015.	2307010.
1927	34102.	68405.	112008.	270997.	126001.	427999.	105025.	39100.	19700.	128999.	7910.	12700.	1352946.
1928	11200.	57498.	25001.	101998.	303989.	317997.	143993.	209004.	61300.	5139.	9940.	46097.	1293156.
1929	45697.	24700.	52208.	131002.	316997.	174006.	41601.	10100.	319002.	50504.	24500.	16001.	1206318.
1930	7620.	28800.	16500.	26400.	922016.	358995.	41095.	14400.	63100.	632994.	70199.	277991.	2460110.
1931	118002.	253989.	158978.	105999.	114002.	83301.	29198.	12400.	8930.	275012.	90393.	84900.	1335104.
1932	340986.	471991.	215993.	53300.	415991.	255007.	503895.	42500.	619007.	56400.	21200.	101000.	3097270.
1933	94703.	22501.	131980.	55401.	429007.	91004.	65196.	82400.	101001.	25502.	18500.	23900.	1141095.
1934	70103.	35000.	175017.	286001.	39901.	6660.	1022.	959.	14000.	7292.	87193.	24160.	747308.
1935	49949.	74744.	40018.	113195.	1359000.	662015.	268092.	61789.	314598.	108503.	90393.	99223.	3241519.

Table 6.2 Continued
Naturalized Flows at the Waco Gage on the Brazos River (Control Point BRWA41)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1936	31766.	16197.	9570.	11696.	287938.	104422.	64360.	5454.	1166000.	434273.	104448.	218681.	2454805.
1937	132584.	79783.	141667.	42189.	31661.	149986.	24747.	77988.	50037.	75580.	12374.	167004.	985600.
1938	413360.	453019.	272830.	358737.	306932.	284614.	230301.	87513.	14142.	4229.	4116.	4762.	2434555.
1939	54745.	45072.	21859.	28198.	274819.	355948.	58396.	34402.	11002.	1633.	15061.	4979.	906114.
1940	13511.	8751.	6311.	101058.	122519.	451522.	168538.	255025.	72277.	13015.	416155.	405857.	2034539.
1941	133251.	492000.	318981.	508670.	1597861.	889095.	311899.	289184.	115304.	696350.	238298.	56767.	5647660.
1942	70132.	31336.	29147.	1401100.	670494.	579811.	51907.	55723.	358139.	527354.	105937.	71104.	3952184.
1943	44340.	31851.	73147.	110754.	89262.	95298.	17695.	5540.	32245.	15965.	5048.	9192.	530337.
1944	35857.	124744.	159193.	105126.	799391.	129965.	53302.	18829.	68051.	63554.	29701.	55540.	1643253.
1945	169336.	293601.	623968.	921067.	164507.	169682.	385705.	37233.	19884.	190258.	34980.	44715.	3054936.
1946	94816.	181795.	211690.	91267.	250528.	150689.	24717.	58841.	251697.	149131.	199340.	226418.	1890929.
1947	121070.	71206.	154912.	148784.	533060.	102259.	22351.	11410.	20402.	43651.	18216.	102513.	1349834.
1948	36297.	110596.	88161.	24339.	133683.	160620.	169895.	10027.	30427.	20527.	12101.	7324.	803997.
1949	16811.	69629.	103325.	116907.	711815.	321502.	61082.	9058.	101714.	105862.	33496.	11945.	1663146.
1950	27468.	124134.	24277.	135709.	248739.	79302.	264857.	129938.	237233.	54828.	9336.	7937.	1343758.
1951	2807.	16680.	11695.	10058.	145072.	290951.	26291.	31130.	44937.	6144.	8128.	10348.	604241.
1952	2679.	7888.	4138.	114264.	181202.	4674.	8307.	7541.	11621.	2868.	63290.	66153.	474625.
1953	22309.	8344.	65384.	49725.	346687.	658.	257207.	98607.	15421.	271823.	29943.	11873.	1177981.
1954	4012.	4515.	6528.	117990.	435691.	108754.	19080.	25155.	4504.	30170.	29672.	339.	786410.
1955	1612.	19071.	26282.	29644.	418528.	251878.	69588.	34920.	318764.	530893.	20788.	10526.	1732494.
1956	11472.	11813.	8006.	20571.	260403.	24749.	1858.	6619.	9965.	26692.	31205.	52363.	465716.
1957	3483.	245003.	56524.	1270684.	3376485.	820741.	128189.	23015.	31869.	257701.	308852.	91125.	6613671.
1958	95673.	112397.	183794.	207233.	766687.	72614.	252763.	47863.	87224.	12453.	10802.	12434.	1861937.
1959	9281.	31288.	15685.	32092.	80840.	272887.	149083.	35498.	16332.	940385.	57196.	144050.	1784617.
1960	330275.	154751.	83972.	97134.	99926.	39077.	205696.	22776.	4688.	264411.	68642.	192364.	1563712.
1961	569683.	424506.	156875.	54263.	56062.	485169.	403672.	67637.	82401.	165966.	139137.	108420.	2713791.
1962	45581.	29229.	33000.	48551.	33921.	410648.	239547.	115982.	554450.	165200.	59877.	66017.	1802003.
1963	24652.	17881.	23959.	140145.	133079.	213550.	23618.	0.	6964.	19390.	59273.	5920.	668431.
1964	19843.	72007.	66433.	92482.	35696.	99403.	6707.	31985.	142709.	15875.	224565.	25200.	832905.
1965	66295.	246828.	81367.	81729.	1220316.	118840.	20771.	43436.	59297.	73862.	63809.	30069.	2106619.
1966	10374.	44689.	46120.	569538.	680919.	113837.	35109.	100582.	619618.	98012.	34137.	17952.	2370887.
1967	15551.	13758.	20187.	94040.	55008.	194189.	166585.	37344.	66041.	66191.	35471.	41289.	805654.
1968	578887.	189354.	574446.	306677.	919100.	249612.	227613.	51312.	23272.	20152.	19894.	35462.	3195781.
1969	23923.	43026.	212274.	293027.	1148063.	131668.	44874.	41169.	155342.	87233.	64356.	124874.	2369829.
1970	93143.	129342.	553969.	222928.	202014.	60775.	6199.	9244.	41546.	53912.	13753.	12781.	1399606.
1971	13573.	18053.	13645.	41723.	77352.	86968.	94432.	288674.	146109.	404187.	78671.	362366.	1625753.
1972	147430.	61154.	31200.	46158.	122561.	38502.	34945.	130904.	138500.	86679.	162195.	44090.	1044318.
1973	126836.	129346.	198391.	499647.	187195.	433977.	125866.	59295.	35877.	221935.	47265.	27661.	2093291.
1974	52972.	26028.	27132.	55440.	38405.	42590.	8813.	70810.	374528.	423863.	559597.	100490.	1780668.
1975	108418.	433919.	108148.	308048.	325572.	286249.	70107.	57066.	52545.	9001.	14406.	4134.	1777613.
1976	11436.	21516.	18152.	142907.	219231.	132632.	285252.	37920.	101104.	166410.	96377.	111548.	1344485.
1977	86797.	205150.	450576.	645516.	333823.	97432.	24617.	8897.	17760.	9325.	8368.	6258.	1894519.
1978	7479.	22674.	33817.	66443.	42195.	26714.	3940.	601580.	24760.	28105.	17598.	8752.	884057.
1979	50578.	55002.	277256.	182194.	641949.	293719.	64127.	40800.	13017.	21506.	0.	29431.	1669579.
1980	59915.	56220.	25129.	82858.	312875.	52285.	7002.	1770.	116130.	270537.	17054.	52978.	1054753.
1981	19262.	16236.	100688.	92179.	55974.	572020.	53624.	29058.	5815.	1084073.	189644.	38806.	2257379.
1982	26170.	48280.	91801.	47773.	798827.	909409.	399441.	38612.	4688.	4578.	20062.	21144.	2410785.
1983	16155.	98914.	79337.	31696.	153482.	59490.	16447.	6653.	2272.	90284.	25296.	3834.	583860.
1984	36045.	18372.	57088.	13022.	12071.	17494.	5094.	11300.	10639.	215466.	92306.	235050.	723947.
1985	187713.	107914.	229495.	192150.	211973.	156915.	38047.	19983.	27913.	205158.	46862.	116251.	1540374.
1986	27195.	148119.	37447.	39350.	146315.	554207.	103128.	28863.	268976.	374276.	136909.	180199.	2044984.
1987	137076.	222062.	342034.	106827.	302223.	692822.	89092.	19057.	28631.	0.	20793.	79937.	2040554.
1988	48540.	38539.	34550.	20310.	16721.	146444.	35656.	733.	65076.	12339.	8221.	18254.	445383.
1989	27278.	134660.	196265.	124012.	959549.	819937.	55020.	75519.	116305.	15328.	8189.	6770.	2538832.
1990	44449.	86468.	370518.	1256164.	1413028.	422384.	26589.	60116.	98748.	35689.	33843.	15117.	3863113.
1991	101793.	65719.	45123.	138624.	265234.	518743.	70969.	187815.	118244.	427178.	267234.	2149397.	4356073.
1992	688885.	1374527.	782802.	207501.	312731.	684912.	135066.	57084.	45690.	11869.	45727.	108209.	4455003.
1993	72204.	303711.	305636.	147662.	106685.	108164.	25035.	11003.	15278.	183578.	19803.	30512.	1329271.
1994	40182.	92230.	91292.	58439.	628787.	113259.	35650.	0.	53915.	163384.	220838.	248794.	1746770.
1995	179571.	75637.	309638.	423311.	643423.	386179.	107773.	486342.	129703.	40271.	15609.	13884.	2811341.
1996	4694.	19703.	12795.	39749.	16030.	39054.	13167.	155998.	418270.	96992.	177896.	224000.	1218348.
1997	132951.	1084526.	813019.	550390.	440237.	391916.	137380.	37188.	12231.	21032.	16987.	236379.	3874236.
1998	329561.	211018.	803309.	135989.	79770.	85511.	84879.	65653.	59014.	55619.	115809.	211004.	2237137.
1999	103183.	69612.	116010.	76958.	70659.	167547.	53724.	65051.	16828.	10364.	9308.	11131.	770376.

Table 6.2 Continued
Naturalized Flows at the Waco Gage on the Brazos River (Control Point BRWA41)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
2000	25347.	16611.	66145.	40510.	48797.	451755.	57731.	61916.	45216.	25932.	182889.	88065.	1110914.
2001	184746.	609255.	934692.	205313.	161915.	48424.	97682.	99268.	39955.	47393.	109447.	214503.	2752591.
2002	84638.	155596.	234480.	242510.	127583.	74243.	132423.	101800.	52451.	73933.	92095.	160980.	1532733.
2003	96153.	108941.	138800.	46845.	53621.	140267.	56130.	37367.	46860.	81876.	51940.	23728.	882526.
2004	72684.	147982.	193678.	277369.	241315.	369350.	387913.	196804.	129164.	113070.	814024.	467737.	3411090.
2005	211622.	294658.	287626.	102597.	48551.	76198.	61118.	354197.	90998.	56834.	40873.	47204.	1672477.
2006	36256.	34641.	97757.	28873.	125527.	44537.	59032.	51358.	28786.	83137.	38497.	23374.	651774.
2007	60041.	25405.	371886.	518934.	1044112.	1723996.	1700392.	329562.	342558.	84288.	37704.	37918.	6276796.
MEAN	87947.	121678.	145795.	221545.	393608.	258877.	126993.	87785.	130468.	147341.	92412.	116326.	1930776.

Table 6.3
Naturalized Flows at the Cameron Gage on the Little River (Control Point LRCA58)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1900	44761.	26135.	84947.	371334.	1009000.	179298.	129199.	97148.	88021.	489064.	115882.	115410.	2750199.
1901	6709.	64009.	35808.	26156.	236076.	35519.	5907.	11261.	13573.	237.	12601.	6192.	454048.
1902	8454.	3043.	69009.	14688.	932527.	59363.	165111.	29239.	30718.	24453.	41866.	36887.	1415358.
1903	176223.	375920.	503529.	134286.	39650.	45523.	35566.	17305.	3737.	99146.	105157.	20946.	1556988.
1904	23638.	22515.	34025.	53361.	100788.	135863.	84615.	33562.	28210.	26035.	36013.	40579.	619204.
1905	26010.	40418.	47742.	566403.	1443000.	120869.	77125.	29769.	10989.	16097.	78591.	165265.	2622278.
1906	64457.	73669.	53693.	13628.	313500.	109630.	11896.	6422.	195471.	6471.	58136.	189730.	1096703.
1907	42043.	43783.	69712.	13484.	108559.	117398.	74813.	59139.	14785.	337198.	39846.	54632.	975392.
1908	44934.	77181.	132848.	873944.	706608.	71629.	43705.	9139.	64062.	74642.	49117.	33471.	2181280.
1909	2816.	2158.	11903.	8158.	35211.	45988.	20195.	14525.	487.	15371.	19971.	56171.	232954.
1910	9729.	29382.	726.	77509.	28906.	29839.	0.	0.	6524.	21775.	5234.	2935.	212559.
1911	6324.	15831.	23359.	35508.	35527.	20545.	9675.	17265.	26296.	2549.	20732.	19471.	233082.
1912	10280.	32560.	41671.	92270.	58030.	0.	3488.	7534.	1905.	57588.	6777.	574.	312677.
1913	2730.	12135.	18496.	47566.	345200.	178851.	29981.	3583.	71090.	196963.	167468.	770067.	1844130.
1914	13059.	36121.	58046.	369294.	1672000.	372485.	105880.	37674.	27216.	129989.	105057.	94696.	3021517.
1915	89886.	37523.	120116.	862941.	728985.	589506.	302793.	43755.	8035.	288804.	62907.	82345.	3217596.
1916	147447.	219405.	104663.	163718.	123994.	110451.	64746.	15416.	28591.	64641.	7200.	5790.	1056062.
1917	5850.	5030.	5110.	13787.	26600.	13200.	4830.	867.	35196.	1210.	3480.	1880.	117040.
1918	2340.	4651.	2290.	163972.	29000.	47999.	2550.	512.	5140.	46199.	178000.	186018.	668671.
1919	219997.	189028.	141002.	124064.	257005.	317005.	246996.	101996.	134996.	433997.	335992.	234023.	2736101.
1920	499994.	203963.	122001.	75023.	228003.	120001.	68899.	194989.	167981.	60200.	101999.	84192.	1927245.
1921	69500.	53499.	87300.	183993.	105998.	146001.	79902.	10699.	1565000.	36099.	20200.	23299.	2381490.
1922	20200.	29802.	108000.	825975.	1000000.	126001.	31201.	10600.	9520.	7780.	12100.	9200.	2190379.
1923	7760.	19998.	39901.	244971.	98595.	53001.	17800.	2670.	62795.	29601.	72801.	316994.	966887.
1924	98398.	178992.	217002.	179879.	172004.	130999.	22301.	10899.	27500.	8460.	6310.	7790.	1060534.
1925	8350.	6280.	5330.	3656.	53702.	4870.	1810.	2510.	20100.	141994.	182997.	16701.	448300.
1926	123000.	38297.	218999.	571392.	273999.	96103.	105000.	21500.	13100.	30300.	15400.	28301.	1535391.
1927	33700.	173027.	164000.	182956.	91298.	222003.	39398.	10899.	5860.	180004.	26600.	21799.	1151544.
1928	18200.	85719.	41100.	27611.	42099.	98203.	12900.	21500.	8390.	3060.	2430.	11901.	373113.
1929	17600.	12099.	33799.	141901.	535006.	140003.	26300.	8241.	53897.	8480.	29300.	7810.	1014436.
1930	15500.	25401.	25601.	10087.	559013.	37400.	11600.	10899.	17000.	207004.	30300.	134988.	1084793.
1931	152000.	222006.	198998.	97660.	121003.	73801.	35701.	9590.	10199.	23600.	6370.	13301.	964229.
1932	140001.	197958.	161997.	61290.	303003.	134005.	35198.	28999.	179021.	13200.	8330.	14401.	1277403.
1933	67601.	34304.	68202.	49681.	114002.	48401.	14700.	27199.	12099.	4480.	6250.	3820.	450739.
1934	71300.	78288.	121000.	293237.	39701.	10500.	3060.	1490.	6840.	968.	68330.	9601.	704315.
1935	11380.	73862.	15420.	27978.	656502.	470104.	63002.	21340.	290722.	100402.	65989.	246790.	2043491.
1936	64560.	37261.	36400.	46184.	682917.	203488.	184110.	19630.	352692.	359407.	176906.	352868.	2516423.
1937	292102.	157507.	216699.	85543.	37601.	114000.	86805.	12740.	17999.	29480.	47500.	186309.	1284285.
1938	459591.	323908.	144702.	334890.	268699.	134505.	278700.	106003.	22439.	12400.	10030.	11250.	2107117.
1939	28010.	19930.	27171.	25106.	118105.	63620.	18640.	14449.	3720.	11990.	3020.	4100.	337861.
1940	4226.	21590.	5258.	106875.	118827.	246700.	402103.	19420.	8136.	4495.	506043.	610025.	2053698.
1941	315015.	455249.	479749.	373647.	726451.	362613.	284318.	63419.	64427.	91154.	32427.	31703.	3280172.
1942	23611.	21123.	19061.	425969.	430471.	399415.	50025.	37408.	363203.	194891.	104993.	79515.	2149685.
1943	57420.	35888.	63316.	80835.	60426.	21544.	13364.	5496.	17900.	14417.	7410.	11746.	389762.
1944	135108.	250462.	293583.	104171.	1068994.	348162.	61100.	25487.	56027.	22390.	51862.	167741.	2585087.

Table 6.3 Continued
Naturalized Flows at the Cameron Gage on the Little River (Control Point LRCA58)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1945	297407.	273083.	363821.	727424.	202570.	198540.	78128.	36705.	27622.	108972.	38913.	91310.	2444495.
1946	139675.	206939.	285995.	149245.	296669.	130473.	28745.	14295.	68529.	31980.	195864.	142339.	1690748.
1947	291011.	104021.	194624.	143003.	153937.	50414.	16068.	10291.	7176.	4705.	8829.	15755.	999834.
1948	10867.	30930.	28825.	35462.	76134.	22574.	34972.	6921.	9553.	2397.	1731.	2768.	263134.
1949	14724.	24366.	78939.	328272.	128540.	79661.	19280.	6422.	3333.	8832.	8073.	13895.	714337.
1950	6727.	56793.	10489.	63097.	67404.	53390.	32616.	3481.	61698.	3378.	1664.	2178.	362915.
1951	2612.	5157.	17554.	5356.	33662.	53473.	1469.	357.	9342.	1084.	813.	1269.	132148.
1952	1434.	2197.	4451.	66336.	147443.	40467.	6170.	631.	194.	42.	9515.	48595.	327475.
1953	36748.	21496.	31670.	43639.	308665.	18478.	11832.	6446.	22462.	180731.	30011.	139039.	851217.
1954	12248.	7277.	5001.	8669.	33502.	885.	383.	499.	1261.	3035.	21181.	1445.	95386.
1955	3872.	36918.	15379.	51025.	164383.	99776.	17921.	23814.	27151.	10262.	1651.	2016.	454168.
1956	2934.	9845.	1134.	2816.	152079.	5674.	0.	2835.	0.	965.	16402.	16922.	211606.
1957	2608.	4490.	50463.	929072.	918874.	438716.	73019.	39289.	18151.	557391.	216694.	111667.	3360434.
1958	88002.	453666.	271342.	134038.	378932.	120411.	39544.	14005.	68454.	24501.	19316.	15032.	1627243.
1959	13153.	29231.	17095.	52065.	40144.	73992.	51048.	28166.	24919.	753704.	155207.	238967.	1477691.
1960	340219.	231706.	122548.	79105.	51140.	26225.	19517.	11294.	8639.	322054.	127079.	421910.	1761436.
1961	553706.	604542.	232899.	98858.	60088.	224407.	218538.	49457.	115461.	115421.	56456.	73767.	2403600.
1962	40457.	37607.	29942.	60340.	37024.	88833.	30018.	11344.	74927.	59877.	53625.	60050.	584044.
1963	19814.	44799.	20596.	23763.	51968.	25929.	13560.	1460.	4582.	13295.	18464.	4744.	242974.
1964	11307.	31646.	48923.	65542.	44837.	117572.	15580.	24676.	143601.	48880.	109312.	41258.	703134.
1965	233735.	370929.	143957.	116742.	1318816.	199502.	82164.	51249.	57907.	57116.	177225.	129637.	2938979.
1966	70898.	124114.	97968.	371795.	286922.	87782.	31012.	76562.	150089.	37779.	20018.	17768.	1372707.
1967	15648.	12770.	13966.	27670.	85515.	28518.	19777.	3479.	27728.	29354.	83485.	47114.	395024.
1968	691195.	205119.	393816.	247919.	463806.	225958.	192749.	27593.	29522.	13098.	26881.	56212.	2573868.
1969	24533.	75747.	120277.	327202.	268971.	55233.	15243.	30381.	18782.	39111.	28597.	93104.	1097181.
1970	85925.	160015.	504530.	182973.	237648.	129579.	26751.	13200.	70584.	43533.	12277.	12767.	1479782.
1971	11879.	11593.	12004.	17895.	40452.	7665.	146759.	51247.	12873.	80498.	54209.	149841.	596915.
1972	74681.	45317.	27688.	18960.	82310.	44853.	14989.	7141.	4276.	61086.	44521.	30031.	455853.
1973	104438.	98034.	143990.	181291.	161860.	98294.	62933.	14159.	29256.	278181.	110709.	46228.	1329373.
1974	76926.	43133.	33649.	22309.	113400.	22808.	9571.	106606.	272382.	227246.	380376.	131691.	1440097.
1975	131636.	408286.	126988.	145374.	573701.	255471.	123061.	60054.	27287.	21599.	14049.	16227.	1903733.
1976	14865.	13265.	22672.	260733.	235938.	92373.	247140.	39966.	34043.	69352.	64923.	171137.	1266407.
1977	82730.	251201.	161950.	656109.	234136.	87293.	29728.	13090.	7981.	4645.	6539.	6462.	1541864.
1978	7337.	19546.	21682.	18293.	9536.	13266.	4802.	8269.	3698.	1519.	14720.	7501.	130169.
1979	83145.	129735.	272084.	212412.	422369.	316696.	233681.	61632.	15847.	10211.	9322.	19413.	1786547.
1980	25594.	40885.	50864.	46476.	328986.	38696.	10670.	6084.	10707.	5963.	6568.	12796.	584289.
1981	8964.	16086.	59378.	39855.	57057.	799417.	90423.	19309.	85928.	117109.	48980.	23149.	1365655.
1982	20992.	19687.	35745.	69523.	232452.	100366.	38295.	8665.	2009.	5190.	7951.	8709.	549584.
1983	15134.	83314.	145185.	46042.	192718.	86093.	16414.	26040.	6341.	5588.	4951.	5089.	632909.
1984	9168.	6405.	25218.	6843.	207.	21514.	3465.	1259.	2302.	170360.	29158.	89979.	365878.
1985	108080.	145987.	186568.	87601.	86664.	81531.	14701.	3966.	3075.	109496.	96981.	197214.	1121864.
1986	49014.	265813.	52271.	27167.	131271.	382704.	40139.	23807.	116569.	165242.	119916.	418349.	1792262.
1987	187741.	172902.	236611.	100795.	229780.	769125.	148625.	46189.	31538.	15023.	31699.	39841.	2009869.
1988	31269.	24431.	25216.	18001.	9350.	122843.	15192.	13400.	4700.	2730.	3617.	4298.	275047.
1989	17931.	36193.	52408.	34837.	247694.	161443.	37365.	19098.	7286.	6161.	2531.	2071.	625018.
1990	9514.	10753.	76108.	344155.	423858.	98865.	61149.	30140.	19711.	15035.	22719.	8341.	1120348.
1991	195638.	91220.	50450.	130030.	186205.	112987.	28856.	28875.	37788.	68174.	87033.	1320477.	2337733.
1992	574007.	1403136.	690408.	224458.	568694.	401559.	163609.	107953.	67406.	24855.	32663.	86273.	4345021.
1993	100136.	233876.	299945.	186726.	290048.	208711.	62120.	13708.	16249.	42243.	28287.	18564.	1500613.
1994	16754.	48847.	49040.	19774.	233470.	96358.	34327.	8664.	13725.	100557.	52099.	144553.	818168.
1995	100503.	51057.	211495.	295836.	240525.	193678.	49472.	118107.	36377.	33867.	8819.	11828.	1351564.
1996	10371.	12165.	7739.	14624.	11049.	41477.	11180.	53649.	153452.	42102.	58669.	150299.	566776.
1997	134515.	655338.	461944.	665585.	536956.	616065.	177556.	56231.	17994.	17905.	25341.	258527.	3623957.
1998	404778.	316788.	508227.	328709.	63995.	32372.	33118.	31556.	51896.	363179.	259483.	222483.	2616584.
1999	84776.	61829.	117677.	88917.	111943.	69454.	55242.	26293.	20095.	16930.	13800.	14595.	681550.
2000	19227.	23442.	23654.	57840.	55872.	67222.	18713.	23001.	18890.	38366.	353907.	145561.	845694.
2001	250225.	219472.	435180.	210506.	199866.	78397.	65166.	87554.	136475.	43480.	239740.	308160.	2274222.
2002	91171.	142922.	80137.	102204.	39180.	36073.	274705.	39926.	31670.	87010.	119431.	204303.	1248730.
2003	122179.	282888.	250718.	68159.	38404.	68468.	27474.	22126.	21959.	131932.	18998.	15454.	1068758.
2004	57538.	93562.	118248.	249382.	287443.	457735.	184017.	169261.	99981.	104762.	963429.	608921.	3394280.
2005	308180.	363804.	487790.	142798.	89677.	64314.	33797.	303132.	49245.	19082.	16500.	16301.	1894619.
2006	18021.	21437.	44862.	53776.	111888.	34220.	24978.	19187.	21352.	43537.	13935.	33418.	440610.
2007	255211.	36645.	505173.	374096.	997550.	1165964.	1104341.	719464.	632774.	368717.	44534.	38616.	6243085.
MEAN	97292.	121605.	126763.	171260.	277989.	151382.	75379.	38128.	67856.	86288.	73114.	104736.	1391791.

Comparison of 1900-1939, 1940-1997 and 1998-2007 Naturalized Flows

The 1900-2007 sequences of naturalized stream flows at the 77 control points are plotted in Appendix A, allowing a visual comparison of the 1900-1939, 1940-1997 and 1998-2007 segments. Statistics for eight selected control points are compared in Tables 6.4 and 6.5. Table 6.4 compares 1900-1939, 1940-1997, and 1998-2007 mean naturalized flow volumes and also includes 1998-2007 mean observed flows. Table 6.5 compares naturalized flow frequency relationships for the eight selected control points. The eight control points selected for inclusion in Tables 6.4 and 6.5 are gaging stations with records covering the complete 1940-2007 period. The Waco gage on the Brazos River (control BRWA41) has gaged flow records covering the complete 1900-2007 period. Control points LEBE49, LRCA58, and BRRI70 have gaged flows covering much of 1900-1939 as well as all of 1940-2007. Tables 6.6, 6.7, 6.8, and 6.9 provide statistics for all the 77 control points.

Table 6.4
Comparison of Mean Flows at Selected Gaging Stations

Control Point ID	Stream	Nearest Town	Drainage Area (sq. miles)	Mean Naturalized Flow 1900-1939 (ac-ft/year)	1940-1997 (ac-ft/year)	1998-2007 (ac-ft/year)	Gaged Flow 1998-2007 (ac-ft/year)
BRSE11	Brazos River	Seymour	6,000	285,440	250,096	172,359	161,815
BRSB23	Brazos River	South Bend	13,170	748,990	656,260	440,512	364,799
BRAQ33	Brazos River	Aquilla	17,750	1,625,743	1,379,050	1,392,972	800,427
BRWA41	Brazos River	Waco	20,070	1,854,264	1,942,324	2,129,842	1,397,595
LEBE49	Leon River	Belton	3,580	465,934	505,257	755,088	472,607
LRCA58	Little River	Cameron	7,100	1,328,595	1,318,302	2,070,813	1,597,128
BRHE68	Brazos River	Hempstead	34,370	5,279,984	5,358,943	7,208,408	5,837,823
BRRI70	Brazos River	Richmond	35,450	5,683,774	5,850,224	7,637,494	6,189,194

Mean 1900-1939, 1940-1997 and 1998-2007 naturalized flows are compared in Table 6.4. Control points locations are shown in the maps of Figures 3.2 and 3.4 and schematic of Figure 3.3. The relative comparison of mean flows varies spatially. The Seymour and South Bend gaging stations are upstream of Possum Kingdom Reservoir and are the most upstream of the six gages on the Brazos River. The period 1900-1939 has the highest mean flows, and 1998-2007 has the lowest mean flows at the Seymour and South Bend gaging stations. Conversely, the smallest mean flow occurs during 1900-1939 and the largest during 1998-2007 at the Belton gage on the Leon River and the Waco, Cameron, and Richmond gages on the Brazos River. The period 1940-1997 has the smallest mean flow at the Aquilla gage on the Brazos River and Cameron gage on the Little River.

The 1998-2007 means in Table 6.4 range from 67.1% (South Bend gage) to 157.1% (Cameron gage) of the 1940-1997 means. For the Belton and Cameron gages in the Little River subbasin, the 1998-2007 mean naturalized flows are 149.4 and 157.1 percent, respectively, of the corresponding 1940-1997 means. For the Hempstead and Richmond gages on the lower Brazos River below the other six gages, the mean of the 1998-2007 naturalized flows are 134.5 and 130.6 percent, respectively, of the corresponding means of the 1940-1997 naturalized flows.

Naturalized flow exceedance frequency relationships at the eight control points included in Table 6.4 are tabulated in Table 6.5. Monthly naturalized flow volumes that occur during specified percentages of the 480 months of 1900-1939, the 696 months of 1940-1997 or the 120 months of 1998-2007 are shown in Table 6.5.

Table 6.5
Comparison of Exceedance Frequency Relationships for Naturalized Flows

	Percentage of Months in which Flows (acre-feet/month) Equaled or Exceeded Values							
	100%	95%	90%	75%	50%	25%	10%	maximum
	Monthly Naturalized Flow Volume (acre-feet/month)							
	Seymour Gage on Brazos River (BRSE11)							
1900-1939	0	0	305	1,424	5,789	24,483	70,839	453,509
1940-1998	0	266	621	1,711	5,042	18,500	57,693	414,811
1998-2007	134	312	488	2,215	5,454	15,080	40,328	149,614
	South Bend Gage on Brazos River (BRSB23)							
1900-1939	0	0	801	3,737	15,190	64,242	185,879	1,190,000
1940-1998	0	785	2,083	4,889	13,817	52,133	145,077	1,395,822
1998-2007	200	439	1,150	5,171	11,793	33,713	104,323	464,133
	Aquilla Gage on Brazos River (BRAQ33)							
1900-1939	0	3,891	6,688	18,670	62,971	169,895	351,497	1,770,000
1940-1998	0	3,425	6,929	16,626	46,163	131,747	280,970	2,981,239
1998-2007	6,756	18,517	23,526	35,410	55,651	109,472	286,403	1,260,169
	Waco Gage on Brazos River (BRWA41)							
1900-1939	167	3,500	7,010	21,600	70,103	198,000	382,987	1,520,000
1940-1998	0	6,300	10,364	24,749	68,642	183,578	422,755	3,376,485
1998-2007	9,308	23,728	34,641	51,358	85,511	193,678	371,886	1,723,996
	Belton Gage on Leon River (LEBE49)							
1900-1939	0	365	956	3,398	13,916	40,493	106,409	718,653
1940-1998	0	0	479	3,360	12,757	47,585	113,249	629,618
1998-2007	5,116	6,594	7,913	11,125	22,819	69,258	178,412	470,319
	Cameron Gage on Little River (LRCA58)							
1900-1939	0	2,816	5,850	13,787	41,100	124,064	273,999	1,672,000
1940-1998	0	2,706	5,440	15,032	44,799	130,473	290,433	1,403,136
1998-2007	13,800	16,930	19,187	33,797	84,776	250,225	435,180	1,165,964
	Hempstead Gage on Brazos River (BRHE68)							
1900-1939	0	27,522	36,415	86,285	223,744	521,818	1,032,000	6,113,000
1940-1998	1,634	30,122	44,643	89,698	229,331	581,968	1,153,505	5,723,482
1998-2007	39,826	72,281	88,276	156,830	319,808	961,557	1,442,134	4,013,333
	Richmond Gage on Brazos River (BRRI70)							
1900-1939	0	34,444	45,977	104,978	263,874	563,707	1,066,000	7,354,000
1940-1998	0	39,522	53,888	111,204	257,456	653,272	1,230,723	6,135,975
1998-2007	46,995	73,997	93,596	165,769	352,399	975,173	1,549,853	4,193,992

Means of the naturalized flows for 1900-1939, 1940-1997 and 1998-2007 at the 77 primary control points are compared in Table 6.6. Frequency tables developed with *TABLES* are presented as Tables 6.7, 6.8, and 6.9 for naturalized flows at the 77 control points for 1900-1939, 1940-1997, and 1998-2007.

Table 6.6
Means of Flows at the Primary Control Points

WAM CP ID	Stream	Nearest City	1900-1939 Naturalized (ac-ft/year)	1940-1997 Naturalized (ac-ft/year)	1998-2007 Naturalized (ac-ft/year)
RWPL01	Running Water Draw	Plainview	2,846	2,469	2,882
WRSP02	White River Reservoir	Spur	19,285	16,730	19,527
DUGI03	Duck Creek	Girard	11,512	10,078	12,396
SFPE04	Salt Fork Brazos River	Peacock	61,271	53,686	25,031
CRJA05	Croton Creek	Jayton	14,163	12,399	15,250
SFAS06	Salt Fork Brazos River	Aspermont	87,931	77,052	35,922
BSLU07	Buffalo Spring Lake	Lubbock	19,502	16,918	19,747
DMJU08	Double Mountain Fork	Justicebury	25,391	22,230	27,340
DMAS09	Double Mountain Fork	Aspermont	123,658	108,367	76,392
NCKN10	North Croton Creek	Knox City	14,780	12,941	15,914
BRSE11	Brazos River	Seymour	285,440	250,096	172,359
MSMN12	Millers Creek	Munday	6,591	5,806	6,447
CFRO13	Clear Fork Brazos	Roby	6,689	7,221	2,658
CFHA14	Clear Fork Brazos	Hawley	41,838	45,162	25,506
MUHA15	Mulberry Creek	Hawley	7,205	7,780	4,392
CFNU16	Clear Fork Brazos	Nugent	88,621	95,668	54,028
CAST17	California Creek	Stamford	25,549	27,572	25,671
CFFG18	Clear Fork Brazos	Fort Griffin	162,090	174,974	122,120
HCAL19	Hubbard Creek	Albany	53,223	57,538	29,753
BSBR20	Big Sandy Creek	Breckenridge	21,633	23,348	18,959
HCBR21	Hubbard Creek	Breckenridge	90,025	97,181	58,527
CFEL22	Clear Fork Brazos	Eliasville	286,018	308,856	206,210
BRSB23	Brazos River	South Bend	748,990	656,260	440,512
GHGH24	Lake Graham	Graham	50,535	35,827	44,817
CCIV25	Big Cedar Creek	Ivan	12,465	13,452	10,924
SHGR26	Brazos River	Graford	881,580	793,483	600,404
BRPP27	Brazos River	Palo Pinto	900,399	810,380	613,221
PPSA28	Palo Pinto Creek	Santo	63,122	64,126	39,624
BRDE29	Brazos River	Dennis	1,059,323	1,003,749	707,975
BRGR30	Brazos River	Glen Rose	1,154,028	1,118,978	823,607
PAGR31	Paluxy River	Glen Rose	60,356	58,474	56,897
NRBL32	Nolan River	Blum	157,661	67,304	172,267
BRAQ33	Brazos River	Aquilla	1,625,743	1,379,053	1,392,972
AQAQ34	Aquilla Creek	Aquilla	96,925	89,186	170,893
NBHI35	North Bosque River	Hico	42,291	44,879	51,710
NBCL36	North Bosque River	Clifton	153,506	162,919	187,695
NBVM37	North Bosque River	Valley Mills	191,193	202,937	337,745

Table 6.6 Continued
Means of Flows at the Primary Control Points

WAM CP ID	Stream	Nearest City	1900-1939 Naturalized (ac-ft/year)	1940-1997 Naturalized (ac-ft/year)	1998-2007 Naturalized (ac-ft/year)
MBMG38	Middle Bosque River	McGregor	51,966	55,164	91,799
HGCR39	Hog Creek	Crawford	24,243	25,735	42,826
BOWA40	Bosque River	Waco	336,193	356,832	593,857
BRWA41	Brazos River	Waco	1,864,264	1,942,324	2,129,842
BRHB42	Brazos River	Highbank	2,248,474	2,331,139	2,591,359
LEDL43	Leon River	De Leon	51,444	56,375	39,434
SADL44	Sabana River	De Leon	32,011	35,079	24,537
LEHS45	Leon River	Hasse	128,920	141,273	132,198
LEHM46	Leon River	Hamilton	152,900	166,469	195,042
LEGT47	Leon River	Gatesville	236,798	257,793	302,062
COPI48	Cowhouse Creek	Pidcoke	73,130	77,373	91,262
LEBE49	Leon River	Belton	465,934	505,257	755,088
LAKE50	Lampasas River	Kempner	108,367	119,776	155,574
LAYO51	Lampasas River	Youngsport	188,970	208,870	271,290
LABE52	Lampasas River	Belton	211,036	233,258	437,327
LRLR53	Little River	Little River	983,126	846,554	1,351,407
NGGE54	North Fork San Gabriel	Georgetown	66,056	57,922	83,750
SGGE55	South Fork San Gabriel	Georgetown	32,543	36,173	41,209
GAGE56	San Gabriel River	Georgetown	109,306	104,317	138,530
GALA57	San Gabriel River	Laneport	184,221	189,268	295,650
LRCA58	Little River	Cameron	1,328,595	1,318,302	2,070,813
BRBR59	Brazos River	Bryan	3,925,480	4,027,961	5,192,002
MYDB60	Middle Yegua Creek	Dime Box	44,755	39,362	65,487
EYDB61	East Yegua Creek	Dime Box	49,098	43,189	65,453
YCSO62	Yegua Creek	Somerville	253,999	223,399	354,350
DCLY63	Davidson Creek	Lyons	54,000	47,485	63,814
NAGR64	Navasota River	Groesbeck	86,637	83,472	99,685
BGFR65	Big Creek	Freestone	33,443	32,237	46,733
NAEA66	Navasota River	Easterly	334,764	322,578	430,544
NABR67	Navasota River	Bryan	437,201	421,304	476,575
BRHE68	Brazos River	Hempstead	5,279,984	5,358,943	7,208,408
MCBL69	Mill Creek	Bellville	179,813	149,586	144,158
BRRI70	Brazos River	Richmond	5,683,774	5,850,225	7,637,494
BGNE71	Big Creek	Needville	25,009	25,631	28,652
BRRO72	Brazos River	Rosharon	5,938,407	6,112,278	8,089,455
BRGM73	Brazos River	Gulf of Mexico	5,931,281	6,105,238	8,079,747
CLPEC1	Clear Creek	Pearland	28,011	28,734	32,770
CBALC2	Chocolate Bayou	Alvin	74,457	76,372	87,106
SJGBC3	Coastal Basin	Galveston Bay	336,495	345,148	393,660
SJGMC4	Coastal Basin	Gulf of Mexico	813,298	834,204	951,464

Table 6.7
Frequency Analysis of 1900-1939 Naturalized Flows

CONTROL POINT	MEAN	STANDARD DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
			PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
RWPL01	237.2	448.	0.0	0.0	0.0	0.0	3.0	14.2	35.	58.	104.	244.	706.	4522.
WRSP02	1607.1	3036.	0.0	0.0	0.0	0.0	20.3	96.2	239.	391.	706.	1654.	4786.	30641.
DUGI03	959.3	1812.	0.0	0.0	0.0	0.0	12.3	57.4	143.	234.	421.	987.	2857.	18291.
SFPE04	5105.9	9646.	0.0	0.0	0.0	0.0	65.5	305.7	759.	1243.	2243.	5255.	15206.	97347.
CRJA05	1180.2	2230.	0.0	0.0	0.0	0.0	15.2	70.7	175.	287.	518.	1215.	3515.	22502.
SFAS06	7327.6	13843.	0.0	0.0	0.0	0.0	94.0	438.7	1089.	1783.	3219.	7542.	21822.	139706.
BSLU07	1625.2	3070.	0.0	0.0	0.0	0.0	20.6	97.3	242.	395.	714.	1673.	4840.	30986.
DMJU08	2115.9	3997.	0.0	0.0	0.0	0.0	27.2	126.7	315.	515.	929.	2178.	6301.	40341.
DMAS09	10304.8	19468.	0.0	0.0	0.0	0.0	132.2	617.0	1532.	2508.	4526.	10606.	30689.	196469.
NCKN10	1231.7	2327.	0.0	0.0	0.0	0.0	15.8	73.8	183.	300.	541.	1268.	3668.	23482.
BRSE11	23786.7	44937.	0.0	0.0	0.0	0.0	305.3	1424.2	3537.	5789.	10449.	24483.	70838.	453509.
MSMN12	549.3	1038.	0.0	0.0	0.0	0.0	7.0	32.9	82.	134.	241.	565.	1636.	10472.
CFRO13	557.4	1348.	0.0	0.0	0.0	0.0	0.0	0.0	36.	92.	183.	480.	1610.	14114.
CFHA14	3486.5	8433.	0.0	0.0	0.0	0.0	0.0	0.0	224.	579.	1144.	3002.	10069.	88282.
MUHA15	600.4	1452.	0.0	0.0	0.0	0.0	0.0	0.0	39.	100.	197.	517.	1734.	15203.
CFNU16	7385.1	17863.	0.0	0.0	0.0	0.0	0.0	0.0	474.	1226.	2424.	6358.	21329.	186999.
CAST17	2129.1	5150.	0.0	0.0	0.0	0.0	0.0	0.0	137.	353.	699.	1833.	6149.	53911.
CFFG18	13507.5	32671.	0.0	0.0	0.0	0.0	0.0	0.0	868.	2242.	4433.	11629.	39011.	342027.
HCAL19	4435.2	10728.	0.0	0.0	0.0	0.0	0.0	0.0	285.	736.	1456.	3819.	12810.	112306.
BSBR20	1802.8	4360.	0.0	0.0	0.0	0.0	0.0	0.0	116.	299.	592.	1552.	5207.	45648.
HCBR21	7502.1	18146.	0.0	0.0	0.0	0.0	0.0	0.0	482.	1245.	2462.	6459.	21667.	189962.
CFEL22	23834.8	57650.	0.0	0.0	0.0	0.0	0.0	0.0	1531.	3955.	7822.	20521.	68838.	603526.
BRSB23	62415.8	117915.	0.0	0.0	0.0	0.0	801.0	3737.0	9280.	15190.	27417.	64242.	185879.	1190000.
GHGH24	4211.2	8699.	0.0	0.0	0.0	0.0	0.0	0.0	113.	437.	1100.	4285.	14100.	81349.
CCIV25	1038.7	2512.	0.0	0.0	0.0	0.0	0.0	0.0	67.	172.	341.	894.	3000.	26302.
SHGR26	73465.0	132466.	0.0	0.0	0.0	0.0	681.5	4358.0	12204.	19484.	34232.	79581.	214424.	1412841.
BRPP27	75033.2	135293.	0.0	0.0	0.0	0.0	696.0	4451.0	12465.	19900.	34963.	81280.	219001.	1443000.
PPSA28	5260.2	9072.	0.0	0.0	0.0	0.0	0.0	264.5	947.	1739.	2783.	5977.	14778.	70392.
BRDE29	88276.9	143124.	0.0	0.0	232.4	879.5	1935.0	7668.6	19681.	29962.	47378.	117488.	233589.	1340238.
BRGR30	96169.0	150707.	0.0	0.0	352.0	1110.0	2340.0	8649.0	22030.	34209.	58698.	129249.	248469.	1279000.
PAGR31	5029.6	7882.	0.0	0.0	18.4	58.1	122.4	452.3	1152.	1789.	3070.	6760.	12995.	66892.
NRBL32	13138.4	25132.	0.0	0.0	0.0	0.0	0.0	962.6	2733.	4688.	7286.	13117.	39916.	305041.
BRAQ33	135478.5	201772.	0.0	1976.0	2549.8	3891.0	6688.0	18670.0	39822.	62971.	88519.	169895.	351497.	1770000.
AQAQ34	8077.1	20204.	0.0	0.0	0.0	0.0	0.0	168.0	741.	1280.	2514.	5682.	21490.	182916.
NBHI35	3524.2	6984.	15.5	75.8	106.8	147.1	190.0	360.1	704.	1018.	1564.	3453.	10508.	74027.
NBCL36	12792.2	25349.	56.2	275.0	387.6	533.8	689.5	1307.2	2557.	3694.	5676.	12535.	38141.	268701.
NBWM37	15932.8	31572.	70.0	342.5	482.7	664.8	858.7	1628.2	3185.	4601.	7070.	15612.	47505.	334670.
MBMG38	4330.5	8581.	19.0	93.1	131.2	180.7	233.4	442.5	866.	1251.	1922.	4244.	12912.	90963.
HGCR39	2020.3	4003.	8.9	43.4	61.2	84.3	108.9	206.5	404.	584.	896.	1980.	6024.	42436.
BOWA40	28016.1	55517.	123.0	602.2	848.8	1169.0	1510.0	2863.0	5600.	8091.	12431.	27453.	83532.	588483.
BRWA41	155355.3	229021.	167.0	1036.4	1548.0	3500.0	7010.0	21600.0	45697.	70103.	101998.	198000.	382987.	1520000.
BRHB42	187372.9	269152.	927.5	2431.1	2976.4	6897.3	11191.2	28476.4	59456.	92560.	127558.	235646.	465093.	1862624.
LEDL43	4287.0	11649.	0.0	0.0	0.0	0.0	29.1	231.1	608.	1037.	1597.	3382.	9352.	141974.
SADL44	2667.6	7248.	0.0	0.0	0.0	0.0	18.1	143.8	378.	645.	994.	2105.	5819.	88342.
LEHS45	10743.3	29191.	0.0	0.0	0.0	0.0	73.0	579.0	1524.	2598.	4002.	8476.	23437.	355787.
LEHM46	12741.7	25929.	0.0	0.0	47.2	129.5	336.5	1196.1	2745.	4331.	6514.	12503.	32227.	244046.
LEGT47	19733.2	40157.	0.0	0.0	73.1	200.6	521.2	1852.4	4251.	6707.	10088.	19363.	49910.	377956.
COPI48	6094.2	11218.	0.0	0.0	0.0	0.0	0.0	383.7	1201.	1954.	3215.	6722.	19024.	109557.
LEBE49	38827.8	71801.	0.0	0.0	0.0	365.0	956.0	3398.0	9014.	13916.	20189.	40493.	106409.	718653.
LAKE50	9030.6	15392.	0.0	0.0	39.6	211.0	415.4	1228.3	2281.	3567.	5512.	10433.	21862.	149890.
LAYO51	15747.5	26841.	0.0	0.0	69.1	367.9	724.4	2141.9	3978.	6220.	9612.	18193.	38122.	261378.
LABE52	17586.3	29975.	0.0	0.0	77.2	411.0	809.0	2392.0	4442.	6946.	10734.	20317.	42574.	291899.
LRLR53	81927.1	142488.	0.0	374.4	823.4	2083.0	4328.0	10202.0	21460.	30414.	50024.	91807.	202759.	1237000.
NGGE54	5504.6	8773.	0.0	0.0	0.0	0.0	119.0	584.0	1469.	2168.	3432.	6662.	15036.	69958.
SGGE55	2711.9	4528.	0.0	0.0	0.0	0.0	57.0	246.5	649.	981.	1607.	3048.	7399.	37940.

Table 6.7 Continued
Frequency Analysis of 1900-1939 Naturalized Flows

CONTROL		STANDARD	PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
POINT	MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
GAGE56	9108.9	14713.	0.0	0.0	0.0	0.0	207.3	920.4	2385.	3462.	5674.	10688.	25246.	119616.
GALA57	15351.8	25158.	0.0	0.0	0.0	0.0	321.0	1474.0	3867.	5458.	9305.	17682.	42241.	207723.
LRCA58	110716.3	192576.	0.0	507.0	1113.2	2816.0	5850.0	13787.0	29000.	41100.	67601.	124064.	273999.	1672000.
BRBR59	327123.3	491282.	0.0	6487.6	9474.6	14510.0	23549.0	57000.0	117370.	157614.	234001.	402283.	765525.	4463000.
MYDB60	3729.6	7914.	0.0	0.0	0.0	0.0	0.0	44.2	339.	693.	1250.	3157.	11383.	63606.
EYDB61	4091.5	8682.	0.0	0.0	0.0	0.0	0.0	48.5	372.	760.	1372.	3464.	12487.	69778.
YCSO62	21166.6	44912.	0.0	0.0	0.0	0.0	0.0	251.0	1927.	3934.	7097.	17918.	64601.	360985.
DCLY63	4500.0	9548.	0.0	0.0	0.0	0.0	0.0	53.4	410.	836.	1509.	3809.	13734.	76745.
NAGR64	7219.7	14262.	0.0	0.0	0.0	4.9	35.2	200.6	887.	1584.	3204.	7453.	18862.	107072.
BGFR65	2786.9	5505.	0.0	0.0	0.0	1.9	13.6	77.4	343.	612.	1237.	2877.	7281.	41331.
NAEA66	27897.0	55109.	0.0	0.0	0.0	19.0	136.0	775.0	3429.	6121.	12379.	28800.	72882.	413723.
NABR67	36433.5	71972.	0.0	0.0	0.0	24.8	177.6	1012.2	4478.	7994.	16167.	37613.	95184.	540322.
BRHE68	439998.7	642280.	0.0	14333.8	17724.4	27522.0	36415.0	86285.0	171425.	223744.	308642.	521818.	1032000.	6113000.
MCBL69	14984.4	40314.	0.0	0.0	0.0	0.0	0.0	0.0	3133.	4899.	7002.	14078.	39552.	680253.
BRRI70	473647.8	689697.	0.0	19603.4	25148.0	34444.0	45977.0	104978.0	183103.	263874.	332805.	563707.	1066000.	7354000.
BGNE71	2084.1	3035.	0.0	86.3	110.7	151.6	202.3	461.9	806.	1161.	1464.	2480.	4690.	32358.
BRRO72	494867.3	720595.	0.0	20481.4	26274.7	35987.0	48037.0	109681.0	191306.	275696.	347715.	588961.	1113757.	7683460.
BRGM73	494273.4	719731.	0.0	20456.5	26243.1	35944.0	47979.0	109549.4	191076.	275365.	347298.	588254.	1112420.	7674240.
CLPEC1	2334.2	3399.	0.0	96.6	123.9	169.7	226.6	517.4	902.	1300.	1640.	2778.	5254.	36242.
CBALC2	6204.8	9035.	0.0	256.8	329.4	451.2	602.3	1375.2	2399.	3457.	4360.	7385.	13965.	96337.
SJGBC3	28041.3	40832.	0.0	1160.6	1488.7	2039.1	2722.0	6214.9	10840.	15622.	19703.	33373.	63110.	435378.
SJGMC4	67774.9	98690.	0.0	2805.0	3598.1	4928.5	6579.0	15021.3	26200.	37758.	47621.	80662.	152535.	1052293.

Table 6.8
Frequency Analysis of 1940-1997 Naturalized Flows (acre-feet/month)

CONTROL		STANDARD	PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
POINT	MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
RWPL01	205.7	993.	0.0	0.0	0.0	0.0	0.0	0.0	4.	12.	26.	71.	304.	21017.
WRSP02	1394.1	3644.	0.0	0.0	0.0	0.0	0.0	17.0	109.	214.	357.	897.	3286.	38538.
DUGI03	839.8	2247.	0.0	1.0	1.0	3.0	9.0	57.0	89.	127.	190.	415.	1952.	18749.
SFPE04	4473.9	10838.	0.0	3.0	6.0	15.8	36.6	224.0	448.	693.	1219.	3100.	10907.	95241.
CRJA05	1033.2	2527.	0.0	0.0	0.0	0.0	2.0	33.0	80.	141.	260.	700.	2640.	20787.
SFAS06	6421.0	15348.	0.0	4.0	8.9	24.8	67.2	362.0	723.	1111.	1886.	4700.	15583.	135865.
BSLU07	1409.8	3084.	0.0	0.0	0.0	0.0	0.0	17.0	161.	314.	574.	1189.	3428.	23740.
DMJU08	1852.5	4374.	0.0	0.0	0.0	0.0	0.6	12.0	82.	224.	466.	1363.	5331.	34415.
DMAS09	9030.6	20143.	0.0	0.0	0.0	8.0	81.2	344.0	938.	1636.	2762.	7870.	25049.	175553.
NCKN10	1078.4	3218.	0.0	0.0	1.0	3.0	7.0	48.0	89.	156.	253.	627.	2379.	50743.
BRSE11	20841.3	42817.	0.0	0.0	52.0	266.2	621.2	1711.0	3082.	5042.	8026.	18500.	57693.	414811.
MSMN12	483.8	1887.	0.0	0.0	0.0	0.0	0.0	0.0	0.	7.	29.	158.	983.	24988.
CFRO13	601.7	1569.	0.0	0.0	0.0	0.8	8.6	43.0	91.	130.	195.	398.	1355.	15773.
CFHA14	3763.5	8370.	0.0	0.0	0.0	18.6	184.6	484.0	922.	1262.	1791.	3546.	8977.	137859.
MUHA15	648.4	1475.	0.0	0.0	0.0	0.0	0.0	38.0	89.	162.	269.	610.	1671.	24066.
CFNU16	7972.3	17242.	0.0	0.0	0.0	0.0	255.0	892.0	1759.	2568.	3737.	7960.	19821.	297109.
CAST17	2297.7	6263.	0.0	0.0	0.0	0.0	9.6	76.0	180.	286.	511.	1592.	5914.	73502.
CFFG18	14581.1	37167.	0.0	0.0	0.0	0.0	0.0	492.0	1584.	2837.	4686.	11953.	35198.	471164.
HCAL19	4794.8	14739.	0.0	0.0	0.0	0.0	13.0	69.0	229.	473.	999.	2726.	11977.	206975.
BSBR20	1945.7	5352.	0.0	0.0	0.0	0.0	0.0	0.0	59.	167.	423.	1383.	5708.	77964.
HCBR21	8098.4	23079.	0.0	0.0	0.0	0.0	0.0	17.0	631.	1251.	2171.	5118.	22114.	265359.
CFEL22	25738.0	60025.	0.0	0.0	0.0	150.8	469.4	1770.0	3520.	5945.	9807.	23129.	65587.	759321.
BRSB23	54688.3	116203.	0.0	64.8	119.4	785.0	2082.8	4889.0	9258.	13817.	23707.	52133.	145077.	1395822.

Table 6.8 Continued
Frequency Analysis of 1940-1997 Naturalized Flows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
			PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
GHGH24	2985.6	13628.	0.0	0.0	0.0	0.0	0.0	0.0	99.	287.	597.	1514.	5474.	263724.
CCIV25	1121.0	3117.	0.0	0.0	0.0	0.0	0.0	2.0	66.	186.	378.	890.	2900.	47074.
SHGR26	66123.6	137151.	0.0	0.0	0.0	284.0	2186.8	6883.0	12816.	18404.	30992.	64391.	166331.	1794495.
BRPP27	67531.7	137771.	0.0	0.0	0.0	340.0	2097.6	6759.0	13251.	19022.	31092.	65601.	170549.	1810792.
PPSA28	5343.8	12081.	0.0	0.0	0.0	0.0	0.0	148.0	673.	1125.	2075.	4779.	14879.	159551.
BRDE29	83645.7	165799.	0.0	0.0	529.0	1992.8	3713.4	9442.0	17481.	27265.	44882.	87622.	211034.	2450046.
BRGR30	93248.2	182476.	0.0	0.0	527.5	1861.6	4597.8	10445.0	20145.	30585.	50324.	96926.	242476.	2710228.
PAGR31	4872.8	9601.	0.0	0.0	29.4	124.0	252.8	607.0	1047.	1520.	2138.	4522.	12192.	84978.
NRBL32	5608.7	11447.	0.0	0.0	0.0	0.0	0.0	136.0	633.	1348.	2170.	5793.	14986.	107634.
BRAQ33	114921.1	204744.	0.0	0.0	1717.0	3425.4	6929.0	16626.0	28719.	46163.	65837.	131747.	280970.	2981239.
AQAQ34	7432.2	14492.	0.0	0.0	0.0	0.0	0.0	45.0	570.	1194.	2438.	7957.	23510.	123995.
NBHI35	3739.9	8289.	0.0	0.0	0.0	0.0	9.6	145.0	333.	623.	1337.	3270.	10319.	78927.
NBCL36	13576.6	31085.	0.0	0.0	0.0	1.6	166.2	771.0	1619.	2594.	4889.	11722.	40586.	450470.
NBVM37	16911.4	37025.	0.0	0.0	0.0	60.4	270.6	1241.0	2366.	3710.	6320.	14679.	48135.	459004.
MBMG38	4597.0	8416.	0.0	0.0	0.0	0.0	13.0	224.0	718.	1257.	2187.	5339.	12819.	76944.
HGCR39	2144.6	4084.	0.0	0.0	0.0	1.0	12.0	111.0	309.	565.	1025.	2341.	6093.	38904.
BOWA40	29736.0	53194.	0.0	0.0	0.0	0.0	469.0	2712.0	5984.	9936.	15246.	34506.	80009.	526505.
BRWA41	161860.3	266253.	0.0	1576.8	3433.8	6300.4	10363.6	24749.0	45705.	68642.	102411.	183578.	422755.	3376485.
BRHB42	194261.6	300104.	1251.0	3561.2	6377.8	8762.8	14725.6	31658.0	60614.	89483.	125100.	232892.	488252.	3599269.
LEDL43	4697.9	11403.	0.0	0.0	0.0	0.0	4.2	159.0	454.	876.	1451.	3796.	12326.	135961.
SADL44	2923.3	7129.	0.0	0.0	0.0	4.0	15.0	84.0	222.	503.	856.	2322.	7600.	85534.
LEHS45	11772.8	27843.	0.0	0.0	0.0	0.0	55.0	483.0	1276.	2390.	3709.	10572.	32405.	319157.
LEHM46	13872.5	29227.	0.0	0.0	0.9	60.6	192.0	829.0	2198.	3408.	5291.	12774.	37199.	269330.
LEGT47	21482.8	41916.	0.0	0.0	0.0	31.6	383.0	1361.0	3722.	5793.	9792.	21255.	56294.	383340.
COPI48	6447.8	14071.	0.0	0.0	0.0	1.0	15.6	201.0	668.	1286.	2217.	5935.	18477.	130144.
LEBE49	42104.7	75480.	0.0	0.0	0.0	0.0	478.6	3360.0	7761.	12757.	22410.	47585.	113249.	629618.
LAKE50	9981.3	20700.	15.0	89.5	229.3	362.0	665.8	1229.0	2006.	2702.	3963.	9847.	25207.	202765.
LAYO51	17405.8	34980.	26.0	158.1	342.3	605.2	999.0	1878.0	3190.	4593.	6991.	17488.	45780.	334157.
LABE52	19438.1	34333.	0.0	0.0	116.9	435.6	695.6	2091.0	3927.	6061.	9827.	21523.	54148.	310885.
LRLR53	70546.2	120022.	30.0	297.1	562.4	1577.4	3418.4	8225.0	16213.	25741.	37521.	80406.	190524.	950933.
NGGE54	4826.8	8471.	0.0	0.0	0.0	19.8	85.8	346.0	885.	1425.	2348.	5545.	14575.	75382.
SGGE55	3014.4	5397.	0.0	4.0	10.8	26.0	60.0	241.0	571.	946.	1536.	3497.	8301.	50622.
GAGE56	8693.1	15106.	0.0	16.7	26.9	97.8	203.8	751.0	1691.	2754.	4354.	10232.	25510.	140494.
GALA57	15772.4	25225.	0.0	0.0	0.0	175.4	481.4	1805.0	3652.	5489.	8552.	19998.	45534.	212283.
LRCA58	109858.4	170466.	0.0	494.4	1249.0	2706.4	5440.0	15032.0	28988.	44799.	65294.	130473.	290433.	1403136.
BRBR59	335663.5	483897.	0.0	6558.6	11161.7	17707.0	28172.8	60717.0	107622.	158629.	232671.	402271.	810073.	4704312.
MYDB60	3280.1	6625.	0.0	0.0	0.0	0.0	0.0	59.0	295.	552.	1104.	3021.	10826.	62553.
EYDB61	3599.0	6547.	0.0	0.0	0.0	11.8	78.6	344.0	557.	814.	1320.	3411.	11912.	52708.
YCSO62	18616.6	33266.	0.0	0.0	0.0	0.0	3.6	766.0	2332.	3904.	7387.	18933.	60819.	251523.
DCLY63	3957.1	7512.	0.0	0.0	0.0	0.0	0.0	71.0	290.	649.	1311.	3709.	13339.	54457.
NAGR64	6956.0	13055.	0.0	0.0	0.0	0.0	32.6	184.0	483.	1066.	2598.	7384.	23055.	85878.
BGFR65	2686.4	4704.	0.0	0.0	0.0	1.0	13.0	73.0	223.	528.	1149.	2993.	8669.	37449.
NAEA66	26881.5	46900.	0.0	0.0	0.0	0.0	125.4	848.0	2577.	5743.	11060.	28826.	87562.	332958.
NABR67	35108.6	57655.	0.0	0.0	0.0	76.0	295.4	1759.0	4736.	8530.	16202.	40035.	109997.	384272.
BRHE68	446578.6	588542.	1634.0	13817.1	17422.0	30122.4	44643.0	89698.0	157333.	229331.	306815.	581968.	1153505.	5723482.
MCBL69	12465.5	21465.	0.0	0.0	0.0	47.0	175.8	681.0	1829.	3110.	5192.	12318.	40523.	128658.
BRRI70	487518.7	613002.	0.0	18382.7	25401.7	39521.8	53887.8	111204.0	184723.	257456.	358553.	653272.	1230723.	6135975.
BGNE71	2135.9	3490.	0.0	0.0	0.0	0.0	9.6	91.0	280.	591.	1024.	2602.	6679.	27782.
BRRO72	509356.5	639652.	0.0	19044.5	26315.8	40684.8	59060.2	118878.0	198276.	269256.	375960.	671495.	1274444.	6356870.
BRGM73	508769.8	634290.	4.0	18771.8	25991.5	42893.2	59767.2	121025.0	199329.	269220.	376386.	676536.	1272971.	6254466.
CLPEC1	2394.5	3196.	0.0	10.8	26.0	63.4	134.4	397.0	688.	1000.	1566.	3369.	6670.	29816.
CBALC2	6364.4	8768.	0.0	0.0	39.4	116.4	332.4	1100.0	2085.	2957.	4313.	8180.	17827.	99985.
SJGBC3	28762.3	38137.	0.0	149.0	296.4	866.6	1956.0	5169.0	10039.	13799.	19653.	38605.	78692.	385928.
SJGMC4	69517.0	92174.	0.0	360.6	716.4	2095.2	4728.0	12492.0	24264.	33350.	47498.	93306.	190193.	932768.

Table 6.9
Frequency Analysis of 1998-2007 Naturalized Flows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
			PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
RWPL01	240.2	425.	0.0	0.0	0.0	0.0	0.0	25.2	69.	101.	165.	208.	481.	2165.
WRSP02	1627.3	2882.	0.0	0.0	0.0	0.0	0.0	170.8	467.	686.	1115.	1411.	3261.	14669.
DUGI03	1033.0	2026.	0.1	0.1	0.1	0.1	0.1	5.5	73.	216.	505.	1037.	2905.	11355.
SFPE04	2085.9	3670.	4.3	24.3	53.1	80.9	97.1	201.6	450.	644.	1037.	2438.	5298.	23019.
CRJA05	1270.8	2492.	0.1	0.1	0.1	0.1	0.1	6.8	90.	266.	621.	1275.	3574.	13970.
SFAS06	2993.5	5267.	6.2	34.9	76.2	116.1	139.3	289.4	647.	924.	1489.	3499.	7603.	33036.
BSLU07	1645.6	2914.	0.0	0.0	0.0	0.0	0.0	172.7	473.	694.	1128.	1427.	3298.	14834.
DMJU08	2278.3	4468.	0.1	0.1	0.1	0.1	0.1	12.1	161.	476.	1113.	2286.	6408.	25045.
DMAS09	6366.0	12644.	48.6	78.7	94.5	123.2	174.2	649.0	1519.	2393.	3540.	6163.	14794.	95389.
NCKN10	1326.2	2601.	0.1	0.1	0.1	0.1	0.1	7.0	93.	277.	648.	1331.	3730.	14579.
BRSE11	14363.2	24435.	133.7	190.1	248.5	312.0	487.5	2215.0	3836.	5454.	8806.	15080.	40328.	149614.
MSMN12	537.3	2588.	0.0	0.0	0.0	0.0	0.0	0.0	0.	1.	11.	72.	1215.	26677.
CFRO13	221.5	1169.	0.0	0.4	0.5	0.6	0.9	1.4	2.	3.	4.	15.	146.	11083.
CFHA14	2125.5	5875.	32.0	42.7	52.1	71.0	102.2	438.4	1087.	1216.	1517.	1976.	4288.	63402.
MUHA15	366.0	1012.	5.5	7.4	9.0	12.2	17.6	75.5	187.	209.	261.	340.	738.	10918.
CFNU16	4502.3	12445.	67.7	90.4	110.3	150.4	216.4	928.6	2303.	2576.	3212.	4186.	9084.	134299.
CAST17	2139.2	6373.	1.4	1.6	2.2	3.7	9.5	57.9	122.	184.	325.	1127.	4775.	41886.
CFFG18	10176.6	24678.	83.1	122.2	124.9	188.0	211.9	1764.3	2660.	3087.	4248.	8224.	18572.	195161.
HCAL19	2479.4	8526.	0.0	0.0	0.0	0.0	0.0	0.0	21.	84.	192.	767.	4136.	66437.
BSBR20	1579.9	6214.	0.0	0.0	0.0	0.0	0.0	0.0	9.	26.	130.	390.	3811.	60518.
HOBR21	4877.3	17194.	0.0	0.0	0.0	0.0	0.0	0.0	60.	234.	542.	1505.	13039.	152537.
CFEL22	17184.2	40487.	100.3	147.4	150.8	226.9	255.8	2135.5	3338.	4570.	5992.	11620.	38843.	255859.
BRSB23	36709.4	72270.	199.8	261.4	336.8	439.0	1150.1	5171.3	9106.	11793.	18064.	33713.	104323.	464133.
GHGH24	3734.8	6003.	0.0	0.0	0.0	0.0	0.0	828.1	1700.	2339.	2885.	4667.	6400.	42315.
CCIV25	910.3	3580.	0.0	0.0	0.0	0.0	0.0	0.0	5.	15.	75.	225.	2196.	34871.
SHGR26	50033.7	81727.	5131.9	5406.3	6107.5	7777.6	8686.4	13930.9	19745.	23582.	31814.	46137.	105425.	602990.
BRPP27	51101.7	83472.	5241.4	5521.6	6237.9	7943.6	8871.8	14228.3	20167.	24086.	32493.	47122.	107675.	615861.
PPSA28	3302.0	9623.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	535.	1747.	9014.	62817.
BRDE29	58997.9	104759.	4891.1	5248.0	6168.4	8780.1	9729.2	14722.1	20769.	25229.	30935.	53206.	132181.	805297.
BRGR30	68633.9	123267.	5911.1	6436.3	7374.5	8575.5	9412.7	15235.9	19252.	26640.	37286.	65652.	158128.	923880.
PAGR31	4741.4	10479.	0.2	0.2	0.2	32.3	126.8	549.3	897.	1280.	2009.	4853.	10110.	84005.
NRBL32	14355.5	22135.	0.0	0.0	0.0	380.0	1727.9	4648.7	6504.	7800.	10057.	16468.	29985.	182355.
BRAQ33	116081.0	183990.	6755.5	7420.4	10461.3	18517.3	23526.0	35410.0	49455.	55651.	69683.	109472.	286402.	1260169.
AQAQ34	14241.1	29374.	0.0	0.0	0.0	120.5	228.9	342.2	789.	1987.	4492.	16629.	38484.	226284.
NBHI35	4309.2	9694.	23.2	30.0	50.0	58.0	83.5	238.2	454.	914.	1407.	3264.	11949.	69382.
NBCL36	15641.2	35189.	84.3	108.9	181.4	210.6	303.2	864.5	1649.	3317.	5107.	11846.	43372.	251841.
NBVM37	28145.4	103253.	207.1	311.1	362.3	499.6	758.2	1329.6	2394.	4452.	6304.	17127.	57972.	930907.
MBMG38	7649.9	28064.	56.3	84.6	98.5	135.8	206.1	361.4	651.	1210.	1713.	4655.	15757.	253021.
HGCR39	3568.8	13092.	26.3	39.5	46.0	63.3	96.1	168.6	304.	564.	799.	2172.	7351.	118039.
BOWA40	49488.1	181549.	364.1	547.0	637.1	878.5	1333.1	2337.8	4210.	7828.	11084.	30115.	101932.	1636814.
BRWA41	177486.8	270057.	9307.9	10517.7	13322.9	23727.5	34641.4	51357.8	70659.	85511.	109447.	193678.	371886.	1723996.
BRHB42	215946.6	311299.	13102.5	16339.4	19148.0	27117.4	38967.3	57194.9	87376.	110752.	148848.	233288.	504804.	1891643.
LEDL43	3286.2	10106.	0.6	2.9	3.1	4.5	7.1	56.9	254.	518.	719.	1485.	9028.	95570.
SADL44	2044.8	6288.	0.4	1.8	1.9	2.8	4.4	35.4	158.	322.	448.	924.	5617.	59467.
LEHS45	11016.5	30366.	0.9	6.6	8.7	15.1	50.8	187.5	406.	905.	2698.	7176.	26858.	223374.
LEHM46	16253.5	32914.	195.0	213.4	234.6	387.2	504.7	1369.6	3091.	4981.	7856.	17419.	40154.	210357.
LEGT47	25171.9	50975.	302.0	330.4	363.4	599.7	781.6	2121.1	4787.	7715.	12166.	26977.	62186.	325782.
COPI48	7605.1	15417.	0.5	0.6	0.9	4.7	19.5	231.5	1336.	1808.	4038.	7565.	20704.	114880.
LEBE49	62924.0	93203.	5115.7	5636.1	6040.5	6594.0	7913.0	11125.2	16758.	22818.	32867.	69258.	178412.	470319.
LAKE50	12964.5	28122.	385.6	514.9	552.9	723.6	973.4	1503.0	2853.	4594.	6351.	10584.	26261.	183688.
LAYO51	22607.5	49040.	672.4	897.9	964.1	1261.8	1697.4	2620.9	4975.	8011.	11074.	18457.	45794.	320314.
LABE52	36443.9	53434.	3354.4	3504.4	3609.6	3778.6	4358.5	6498.6	10859.	15575.	19899.	39434.	98398.	290823.
LRLR53	112617.2	157631.	11282.7	12016.8	12413.0	13115.3	16135.9	23264.9	34850.	51052.	69928.	136617.	276113.	856802.
NGGE54	6979.2	11854.	640.3	669.7	687.6	733.4	843.0	1032.2	1206.	1508.	2944.	8410.	19217.	72264.
SGGE55	3434.1	6553.	6.5	7.7	9.8	17.2	43.1	173.1	664.	1248.	1732.	4558.	8077.	52320.

Table 6.9 Continued
Frequency Analysis of 1998-2007 Naturalized Flows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
			PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
GAGE56	11544.1	19724.	748.6	805.5	844.4	948.4	1057.6	1401.5	2071.	3302.	5754.	12884.	31917.	138114.
GALA57	24637.5	34289.	670.4	736.6	854.1	1013.7	1507.0	2815.4	5556.	8172.	15820.	37626.	62285.	171880.
LRCA58	172567.8	223802.	13800.2	14067.2	14938.8	16929.6	19186.8	33796.9	57537.	84776.	117677.	250225.	435180.	1165964.
BRBR59	432666.8	556638.	25363.3	28615.9	35721.0	54829.7	67176.7	99897.7	161197.	206599.	328883.	569912.	1016283.	3260673.
MYDB60	5457.3	9502.	34.1	146.2	182.8	369.4	449.7	668.0	1076.	1334.	2268.	4823.	17484.	46561.
EYDB61	5454.4	8087.	497.8	550.3	668.8	791.5	904.4	1352.9	1822.	2157.	2917.	5185.	13789.	43891.
YCSO62	29529.1	46787.	1727.6	2075.4	2505.0	3220.1	3603.9	5906.0	7951.	9177.	13903.	30876.	89324.	244781.
DCLY63	5317.8	9581.	0.0	0.0	0.0	0.0	0.0	126.3	476.	934.	1859.	6177.	17784.	57069.
NAGR64	8307.1	14877.	0.0	0.0	0.0	0.0	0.0	0.0	218.	746.	2366.	10060.	31572.	59660.
BGFR65	3894.4	7093.	0.0	0.0	0.0	0.0	0.0	102.3	377.	775.	1152.	3614.	14410.	45865.
NAEA66	35878.6	54183.	1188.5	1387.8	1503.8	1633.6	2429.1	3953.1	6471.	8793.	14730.	43637.	137279.	260707.
NABR67	39714.6	53318.	1251.4	1548.0	1681.9	2269.0	3267.6	5661.8	8099.	13055.	20046.	60852.	140647.	258290.
BRHE68	600700.6	685783.	39826.3	40788.4	47439.5	72281.0	88276.0	156830.0	224432.	319808.	480254.	961557.	1442134.	4013333.
MCBL69	12013.2	16926.	0.0	0.0	0.0	0.0	0.0	559.7	2779.	5437.	9398.	16692.	36858.	79233.
BRRI70	636457.9	715803.	46995.4	47231.1	52862.4	73997.4	93596.0	165769.0	265988.	352399.	493394.	975173.	1549853.	4193992.
BGNE71	2387.7	3964.	0.0	0.0	0.0	0.0	13.4	87.7	352.	680.	1248.	2729.	8425.	21429.
BRRO72	674121.2	709461.	63968.4	66178.0	70851.3	91663.4	122857.0	206814.0	315967.	423120.	541748.	931660.	1651272.	4165656.
BRGM73	673312.3	708609.	63891.6	66098.5	70766.3	91553.4	122710.0	206566.0	315588.	422612.	541098.	930542.	1649290.	4160657.
CLPEC1	2730.8	3678.	20.2	24.1	36.8	96.9	154.0	457.4	746.	1234.	1998.	3551.	7493.	22706.
CBALC2	7258.9	9776.	53.6	63.9	98.0	257.5	409.4	1215.8	1984.	3280.	5312.	9438.	19917.	60357.
SJGBC3	32805.0	44182.	242.2	288.9	442.7	1163.7	1850.2	5494.6	8966.	14825.	24006.	42653.	90010.	272773.
SJGMC4	79288.6	106786.	585.5	698.2	1070.0	2812.7	4471.9	13280.2	21670.	35832.	58021.	103091.	217551.	659284.

Comparison of Observed Flows and Naturalized Flows

Differences between gaged and naturalized flows vary greatly between gaging stations. At some of the gages, the naturalized flows are the same or almost the same as the observed flows. At a number of the gages, the differences between gaged and naturalized flows are large. In most but not all cases, monthly naturalized flow volumes are equal to or greater than gaged flows. Differences are generally more pronounced for lower flows than for higher flows.

Mean naturalized versus gaged flows during 1900-1939, 1940-1997, and 1998-2007 for the Richmond and Waco gages on the Brazos River (control points BRRI70 and BRWA41) and Cameron gage on the Little River (control point LRCA58) are compared in Table 6.10. Annual observed versus naturalized flows at the Richmond and Waco gages for each year from 1940 through 2007 are compared in Table 6.11. Annual observed versus naturalized flows at the Cameron gage are compared in Table 6.12. The 1998-2007 observed and naturalized monthly flows at 48 gaging stations are plotted in Appendix B. The means of the 1998-2007 observed and naturalized monthly flows at the 48 gaging stations are compared in Table 6.13.

Mean flows for the Richmond and Waco gages on the Brazos River (control points BRRI70 and BRWA41) and Cameron gage on the Little River (control point LRCA58) are compared in Table 6.10. The locations of these gaging stations are shown in Figure 3.4. The 1900-1939, 1940-1997, and 1998-2007 means of the naturalized flows are tabulated in Table 6.10 along with the means of the observed gaged flows. The means of naturalized flows are expressed both in units of acre-feet/year and as a percentage of the corresponding means of the gaged flows.

As discussed in the preceding Chapter 5, the naturalized flows for 1900-1939 are essentially the same as the gaged flows at the three control points in Table 5.3. The gage on the Brazos River near the City of Waco has a complete record from before 1900 to the present. Thus the monthly gaged flows at the Waco gage for all months of 1900-2007 are based directly on actual daily or periodic measurements. However, the Richmond gage on the Brazos River has a gap of January 1906 through September 1922 in the gaged flow record. Flows have been measured at the Cameron gage from November 1916 to the present. Thus, the gaged/naturalized flows for 1906-1922 at the Richmond gage and 1900-1916 at the Cameron gage are synthesized based on regression analyses with flows at the Waco and Bryan gages on the Brazos River.

Table 6.10
Comparison of Mean Gaged and Naturalized Flows

Period	Gaged Flow (acre-feet/yr)	Naturalized (acre-feet/yr)	Naturalized (percent)
Richmond Gage on Brazos River (BRRI70)			
1900-1930	5,683,774	5,683,774	100.0%
1940-1997	5,501,256	5,850,225	106.3%
1998-2007	6,189,194	7,637,494	123.4%
Waco Gage on Brazos River (BRWA41)			
1900-1930	1,864,264	1,864,264	100.0%
1940-1997	1,683,861	1,942,324	115.3%
1998-2007	1,397,595	2,129,842	152.4%
Cameron Gage on Little River (LRCA58)			
1900-1930	1,328,595	1,328,595	100.0%
1940-1997	1,257,447	1,318,301	104.8%
1998-2007	1,597,128	2,070,813	129,7%

Naturalized flows in a particular month at a particular control month are generally related to gaged flows as follows.

naturalized flow = gaged flow + diversions − return flows
+ net reservoir evaporation + reservoir storage change

Water supply diversions at the particular control point and all upstream control points (adjusted for channel losses) are added to gaged flows to obtain naturalized flows. Return flows from diversions from surface and ground water sources are subtracted after adjustments for channel losses. Net reservoir evaporation less precipitation is added to gaged flows to obtain naturalized flows. Differences in the long term means of Table 6.10 are due to water supply diversions, return flows from diversions from surface and groundwater sources, and net reservoir surface evaporation-precipitation. Increases and decreases in reservoir storage contents can greatly affect the difference between gaged and naturalized flows at downstream sites in individual months or years. Reservoir operations tend to result in naturalized flows at downstream locations being greater than observed flows during periods of high flows and less than observed flows during low flow periods.

At the USGS gage on the Brazos River near Richmond (control point BRRI70), the mean of the 1940-1997 naturalized flows is 106.3 percent of the mean actual observed flow. The 1998-2007 mean naturalized flow is 123.4 percent of the mean observed flow. A volume budget that relates the 1998-2007 mean gaged and naturalized flows is presented in Tables 4.23 and 4.24 of Chapter 4.

Naturalized versus gaged annual flows for each year of 1940-2007 at the Richmond and Waco gages on the Brazos River are compared in Table 6.11 and at the Cameron gage on the Little River in Table 6.12. Annual naturalized flows are expressed as a percentage of the corresponding annual observed flow. Means for 1940-1997, 1998-2007, and 1940-2007 are also shown.

Table 6.11
Comparison of Annual Gaged and Naturalized Flows at the Richmond and Waco Gages

Year	Richmond Gage on Brazos River Gaged Flow (acre-feet)	Richmond Naturalized Flow (acre-feet)	Richmond Naturalized Flow (percent)	Waco Gage on Brazos River Gaged Flow (acre-feet)	Waco Naturalized Flow (acre-feet)	Waco Naturalized Flow (percent)
1940	7,785,910	7,841,679	100.7	2,003,570	2,034,539	101.5
1941	13,910,500	13,684,804	98.4	4,965,660	5,647,660	113.7
1942	8,296,710	8,469,720	102.1	3,831,550	3,952,184	103.1
1943	2,108,960	2,011,176	95.4	738,920	530,337	71.8
1944	8,600,480	8,834,957	102.7	1,472,020	1,643,253	111.6
1945	9,695,400	9,991,619	103.1	2,835,030	3,054,936	107.8
1946	8,227,090	8,366,898	101.7	1,808,160	1,890,929	104.6
1947	4,781,200	4,863,706	101.7	1,361,740	1,349,834	99.1
1948	1,697,900	1,859,931	109.5	737,470	803,997	109.0
1949	4,023,710	4,243,070	105.5	1,540,300	1,663,146	108.0
1950	3,670,770	3,908,155	106.5	197,430	1,343,758	680.6
1951	891,910	986,470	110.6	610,680	604,241	98.9
1952	1,466,990	1,628,778	111.0	412,650	474,625	115.0
1953	3,668,980	4,456,996	121.5	432,510	1,177,981	272.4
1954	1,127,660	1,281,563	113.6	761,420	786,410	103.3
1955	2,236,590	2,755,168	123.2	1,424,510	1,732,494	121.6
1956	960,020	883,332	92.0	649,280	465,716	71.7
1957	14,209,420	14,772,683	104.0	6,151,850	6,613,671	107.5
1958	5,756,700	5,827,879	101.2	1,864,540	1,861,937	99.9
1959	5,447,250	5,721,406	105.0	1,572,870	1,784,617	113.5
1960	6,857,140	7,041,315	102.7	1,459,370	1,563,712	107.1
1961	9,693,800	9,854,994	101.7	2,639,660	2,713,791	102.8
1962	2,941,700	3,235,419	110.0	1,627,110	1,802,003	110.7
1963	1,353,000	1,504,835	111.2	370,760	668,431	180.3
1964	1,659,280	2,032,605	122.5	582,220	832,905	143.1
1965	7,861,000	8,379,350	106.6	1,680,290	2,106,619	125.4
1966	5,822,080	6,148,246	105.6	2,139,400	2,370,887	110.8
1967	1,381,440	1,701,876	123.2	626,760	805,654	128.5
1968	10,009,900	10,657,393	106.5	3,006,640	3,195,781	106.3
1969	5,524,730	6,103,360	110.5	1,936,150	2,369,829	122.4
1970	4,711,890	4,936,341	104.8	1,311,110	1,399,606	106.7

Table 6.11 (Continued)
Comparison of Annual Gaged and Naturalized Flows at the Richmond and Waco Gages

	Richmond Gage on Brazos River			Waco Gage on Brazos River		
Year	Gaged Flow (acre-feet)	Naturalized Flow (acre-feet)	Naturalized Flow (percent)	Gaged Flow (acre-feet)	Naturalized Flow (acre-feet)	Naturalized Flow (percent)
1971	2,073,450	2,879,221	138.9	1,042,860	1,625,753	155.9
1972	2,370,460	2,786,808	117.6	802,910	1,044,318	130.1
1973	8,566,400	8,969,173	104.7	1,911,350	2,093,291	109.5
1974	6,601,540	7,362,952	111.5	1,339,000	1,780,668	133.0
1975	7,084,590	7,078,169	99.9	1,721,810	1,777,613	103.2
1976	5,707,000	6,143,273	107.6	1,057,090	1,344,485	127.2
1977	6,167,470	6,280,123	101.8	1,861,470	1,894,519	101.8
1978	1,519,940	2,087,555	137.3	340,850	884,057	259.4
1979	8,385,830	9,061,564	108.1	1,479,820	1,669,579	112.8
1980	2,911,890	3,552,621	122.0	563,450	1,054,753	187.2
1981	5,405,430	6,053,657	112.0	1,974,480	2,257,379	114.3
1982	4,135,140	4,348,172	105.2	1,269,840	2,410,785	189.8
1983	3,770,640	4,084,160	108.3	406,130	583,860	143.8
1984	2,412,720	2,990,547	123.9	303,070	723,947	238.9
1985	5,046,526	5,758,660	114.1	1,160,136	1,540,374	132.8
1986	6,484,186	7,138,266	110.1	1,677,766	2,044,984	121.9
1987	7,902,950	7,814,200	98.9	2,131,167	2,040,554	95.7
1988	1,273,984	1,442,051	113.2	343,750	445,383	129.6
1989	4,002,619	4,873,756	121.8	1,983,359	2,538,832	128.0
1990	5,704,184	6,334,269	111.0	3,502,795	3,863,113	110.3
1991	7,852,162	10,498,568	133.7	2,788,821	4,356,073	156.2
1992	17,622,924	15,849,417	89.9	5,553,514	4,455,003	80.2
1993	6,765,668	7,076,105	104.6	1,162,456	1,329,271	114.4
1994	4,767,698	5,605,638	117.6	1,259,074	1,746,770	138.7
1995	6,355,345	6,481,162	102.0	2,718,023	2,811,341	103.4
1996	1,834,257	2,403,022	131.0	780,173	1,218,348	156.2
1997	9,967,741	10,374,193	104.1	3,777,127	3,874,236	102.6
1998	8,640,175	10,066,103	116.5	1,672,586	2,237,137	133.8
1999	2,297,177	3,071,244	133.7	309,652	770,376	248.8
2000	2,003,451	3,284,465	163.9	405,080	1,110,914	274.2
2001	7,618,926	8,814,530	115.7	2,110,316	2,752,590	130.4
2002	5,104,455	6,264,725	122.7	888,127	1,532,733	172.6
2003	4,183,309	5,090,225	121.7	486,244	882,526	181.5
2004	10,309,136	12,746,299	123.6	2,139,338	3,411,089	159.4
2005	5,047,579	6,003,756	118.5	1,134,139	1,672,477	147.5
2006	1,239,406	2,024,728	163.4	228,488	651,774	285.3
2007	15,448,332	18,994,870	123.0	4,601,978	6,276,796	136.4
Means for						
1940-1997	5,501,256	5,850,225	106.3	1,683,861	1,942,324	115.3
1998-2007	6,189,195	7,636,095	123.4	1,397,595	2,129,841	152.4
1940-2007	5,602,424	6,113,058	109.1	1,641,763	1,969,900	120.0

Table 6.12
Comparison of Annual Gaged and Naturalized Flows
at the Cameron Gage on the Little River

Year	Gaged Flow (acre-feet)	Naturalized Flow (acre-feet)	Naturalized Flow (percent)	Year	Gaged Flow (acre-feet)	Naturalized Flow (acre-feet)	Naturalized Flow (percent)
1940	2,051,350	2,053,698	100.1	1976	1,195,070	1,266,407	106.0
1941	3,280,800	3,280,172	100.0	1977	1,507,640	1,541,864	102.3
1942	2,150,180	2,149,685	100.0	1978	192,960	130,169	67.5
1943	389,420	389,762	100.1	1979	1,594,690	1,786,547	112.0
1944	2,584,280	2,585,087	100.0	1980	505,490	584,289	115.6
1945	2,443,240	2,444,495	100.1	1981	1,171,790	1,365,655	116.5
1946	1,689,000	1,690,748	100.1	1982	506,720	549,584	108.5
1947	998,350	999,834	100.1	1983	579,470	632,909	109.2
1948	261,030	263,134	100.8	1984	309,450	365,878	118.2
1949	712,810	714,337	100.2	1985	870,767	1,121,864	128.8
1950	363,350	362,915	99.9	1986	1,656,118	1,792,262	108.2
1951	133,230	132,148	99.2	1987	2,056,822	2,009,869	97.7
1952	327,952	327,475	99.9	1988	302,066	275,047	91.1
1953	835,610	851,217	101.9	1989	434,169	625,018	144.0
1954	73,087	95,386	130.5	1990	987,650	1,120,348	113.4
1955	274,780	454,168	165.3	1991	1,438,878	2,337,733	162.5
1956	216,220	211,606	97.9	1992	5,099,168	4,345,021	85.2
1957	3,244,730	3,360,434	103.6	1993	1,458,836	1,500,613	102.9
1958	1,614,040	1,627,243	100.8	1994	711,682	818,168	115.0
1959	1,450,690	1,477,691	101.9	1995	1,298,057	1,351,564	104.1
1960	1,740,640	1,761,436	101.2	1996	460,564	566,776	123.1
1961	2,385,510	2,403,600	100.8	1997	3,440,561	3,623,957	105.3
1962	547,420	584,044	106.7	1998	2,208,635	2,616,584	118.5
1963	201,030	242,974	120.9	1999	508,626	681,550	134.0
1964	647,770	703,134	108.5	2000	491,470	845,694	172.1
1965	2,905,700	2,938,979	101.1	2001	1,970,555	2,274,222	115.4
1966	1,331,540	1,372,707	103.1	2002	1,001,818	1,248,730	124.6
1967	379,370	395,024	104.1	2003	838,629	1,068,758	127.4
1968	2,284,140	2,573,868	112.7	2004	2,490,186	3,394,280	136.3
1969	1,012,770	1,097,181	108.3	2005	1,630,344	1,894,619	116.2
1970	1,424,410	1,479,782	103.9	2006	253,144	440,610	174.1
1971	427,860	596,915	139.5	2007	4,577,874	6,243,085	136.4
1972	378,960	455,853	120.3				
1973	1,142,550	1,329,373	116.4	Means for			
1974	1,188,100	1,440,097	121.2	1940-1997	1,257,447	1,318,301	104.8
1975	2,061,360	1,903,733	92.4	1998-2007	1,597,128	2,070,813	129.7
				1940-2007	1,307,400	1,428,965	109.3

Table 6.13
Means of Observed and Naturalized Flows

WAM CP ID	Stream	Nearest City	1998-2007 Observed (ac-ft/year)	1998-2007 Naturalized (ac-ft/year)	1998-2007 Naturalized (percent)
RWPL01	Running Water Draw	Plainview	1,200	2,882	240.2
SFAS06	Salt Fork Brazos River	Aspermont	31,846	35,922	112.8
DMJU08	Double Mountain Fork	Justicebury	26,907	27,340	101.6
DMAS09	Double Mountain Fork	Aspermont	64,558	76,392	118.3
BRSE11	Brazos River	Seymour	161,815	172,359	106.5
MSMN12	Millers Creek	Munday	6,447	6,447	100.0
CFRO13	Clear Fork Brazos	Roby	2,642	2,658	100.6
CFNU16	Clear Fork Brazos	Nugent	20,705	54,028	260.9
CAST17	California Creek	Stamford	24,452	25,671	105.0
CFFG18	Clear Fork Brazos	Fort Griffin	88,401	122,120	138.1
HCAL19	Hubbard Creek	Albany	27,617	29,753	107.7
BSBR20	Big Sandy Creek	Breckenridge	16,917	18,959	112.1
BRSB23	Brazos River	South Bend	364,799	440,512	120.8
BRPP27	Brazos River	Palo Pinto	372,913	613,221	164.4
BRDE29	Brazos River	Dennis	457,419	707,975	154.8
BRGR30	Brazos River	Glen Rose	523,112	823,607	157.4
PAGR31	Paluxy River	Glen Rose	54,915	56,897	103.6
BRAQ33	Brazos River	Aquilla	800,427	1,392,972	174.0
AQAQ34	Aquilla Creek	Aquilla	143,867	170,893	118.8
NBCL36	North Bosque River	Clifton	182,272	187,695	103.0
NBVM37	North Bosque River	Valley Mills	332,685	337,745	101.5
BRWA41	Brazos River	Waco	1,397,595	2,129,841	152.4
BRHB42	Brazos River	Highbank	1,867,661	2,591,359	138.7
SADL44	Sabana River	De Leon	23,701	24,537	103.5
LEHS45	Leon River	Hasse	68,407	132,198	193.3
LEGT47	Leon River	Gatesville	256,766	302,062	117.6
COPI48	Cowhouse Creek	Pidcoke	91,147	91,262	100.1
LEBE49	Leon River	Belton	472,607	755,088	159.8
LAKE50	Lampasas River	Kempner	157,622	155,574	98.7
LABE52	Lampasas River	Belton	302,753	437,327	144.5
LRLR53	Little River	Little River	942,896	1,351,407	143.3
NGGE54	North Fork San Gabriel	Georgetown	52,767	83,751	158.7
SGGE55	South Fork San Gabriel	Georgetown	41,207	41,209	100.0
GALA57	San Gabriel River	Laneport	218,733	295,650	135.2
LRCA58	Little River	Cameron	1,597,128	2,070,813	129.7
BRBR59	Brazos River	Bryan	4,012,042	5,192,002	129.4
MYDB60	Middle Yegua Creek	Dime Box	64,581	65,487	101.4
EYDB61	East Yegua Creek	Dime Box	63,921	65,453	102.4
DCLY63	Davidson Creek	Lyons	63,998	63,814	99.7
NAGR64	Navasota River	Groesbeck	96,885	99,685	102.9
BGFR65	Big Creek	Freestone	46,094	46,732	101.4
NAEA66	Navasota River	Easterly	362,658	430,544	118.7
NABR67	Navasota River	Bryan	404,769	476,575	117.7

Table 6.13 Continued
Means of Observed and Naturalized Flows

WAM CP ID	Stream	Nearest City	1998-2007 Observed (ac-ft/year)	1998-2007 Naturalized (ac-ft/year)	1998-2007 Naturalized (percent)
BRHE68	Brazos River	Hempstead	5,837,824	7,208,408	123.5
BRRI70	Brazos River	Richmond	6,189,195	7,637,495	123.4
BGNE71	Big Creek	Needville	29,730	28,652	96.4
BRRO72	Brazos River	Rosharon	6,304,435	8,089,455	128.3
CBALC2	Chocolate Bayou	Alvin	86,027	87,107	101.3

The differences between naturalized and gaged flows are larger during 1998-2007 than during 1940-1997. The 1998-2007 means of the observed and naturalized flows at the 48 control points at which flow measurements are available are tabulated in Table 6.13. Mean 1998-2007 naturalized flows are expressed as a percentage of the corresponding mean gaged flow in the last column of Table 6.13. The January 1998 through December 2007 sequences of monthly naturalized and gaged flows at the 48 control points are plotted for comparison in Appendix B.

Naturalized Flows at Control Point LEHS45

As discussed in Chapter 4, control point LEHS45 located immediately downstream of Proctor Dam is the only control point for which reservoir releases were adopted for 1998-2007 observed flows. Control point LEHS45 is the site of the discontinued USGS stream gaging station on the Leon River near Hasse for which gage measurements were not made during 1998-2007. Two other USGS gaging stations (control points LEDL43 and LEHM46) on the Leon River upstream and downstream of Proctor Reservoir also had no gage measurements recorded during 1998-2007. The gaging station at Gatesville (control point LEGT47) is the most upstream gage on the Leon River with measurements recorded during 1998-2007.

The 1998-2007 monthly naturalized flows at control point LEHS45 were initially computed as follows.

$$\text{Flow at LEHS45} = 0.5480 \text{ (Flow at LEGT47)}$$

The 1940-1997 mean naturalized flows at control points LEHS45 and LEGT47 from Table 3.2 are 141,270 and 257,790 acre-feet/year, with their ratio being 0.5480. The drainage areas of LEHS45 and LEGT47 are 1,283 and 2,379 square miles. The drainage area ratio of 0.539 is close to the mean flow ratio of 0.5480. However, as discussed in Chapter 7, the 1998-2007 storage volumes for Proctor Reservoir from Bwam8 and Bwam8A *SIM* simulations with these synthesized naturalized flows deviated dramatically from observed storage volumes. Consequently, 1998-2007 reservoir release data for Lake Proctor compiled by the Brazos River Authority were adopted as the actual measured flows at control point LEHS45. With gaged flows at LEHS45 converted to naturalized flows as outlined in Chapter 4, 1998-2007 *SIM* simulated Proctor Reservoir storages match observed storages reasonably closely.

The measured flows at control point LEHS45 shown in Table 6.14 are gaged releases from Proctor Reservoir. Two sets of naturalized flows are compared in Table 6.14. The initial set, which was not adopted in the final results presented in this report, is based on computing the naturalized monthly flows at LEHS45 as 54.8 percent of the naturalized flows at control point LEGT47. The adopted flows summarized in the last column of Table 6.14 were computed based on including LEHS45 with the 48 control points with measured flows as outlined in Chapter 4, with the measured flows being releases and spills from Proctor Reservoir.

Table 6.14
Flows at Control Point LEHS45

Year	Measured Flow (ac-ft/year)	Naturalized Flow Initial (ac-ft/year)	Naturalized Flow Adopted (ac-ft/year)
1998	81,505	167,283	138,330
1999	1,222	27,057	22,544
2000	738	57,185	27,117
2001	16,562	139,993	74,637
2002	31,784	98,162	90,909
2003	3,003	69,777	24,166
2004	69,566	286,597	179,889
2005	72,673	206,268	96,092
2006	390	14,246	21,410
2007	406,631	631,628	646,886
Average	68,407	169,820	132,198

The ten-year 1998-2007 mean annual naturalized flow of 132,198 acre-feet/year is 77.9 percent of the corresponding mean of 169,820 acre-feet/year for the naturalized flows initially estimated based on the flow ratio technique. As discussed in Chapter 7, the most severe drawdown of Proctor Reservoir during 1998-2007 both in actual observed reality and in the *WRAP-SIM* simulation model occurred during 1999-2001. Proctor Reservoir has a Bwam8 conservation storage capacity of 54,700 acre-feet. The observed and Bwam8A simulated minimum storage contents during 1998-2007 are both 6,340 acre-feet at the end of October 2000. The adopted naturalized flow of 27,117 acre-feet for the year 2000 is 47.4 percent of the initially estimated flow of 57,185 acre-feet. This difference in naturalized flow estimates for at control point LEHS45 significantly affects *SIM* simulated storage levels in Proctor Reservoir.

CHAPTER 7
BRAZOS WAM SIMULATION RESULTS

This chapter explores the impacts of extending the hydrologic period-of-analysis on the Brazos WAM simulation results. *WRAP-SIM* simulation results for the authorized use scenario and current use scenario datasets with the 1940-1997 versus 1940-2007 and 1900-2007 simulation periods are compared. The authorized and current use scenarios are defined in Chapter 1, and the Brazos WAM dataset is described in Chapter 3. The Bwam3 and Bwam8 DAT file adopted for this study was last updated by the TCEQ in August 2007. The program *SIM* was executed with the four alternative input datasets listed in Table 7.1, and the program *TABLES* was applied to analyze the simulation results. A 1940-1997 simulation is embedded within the 1940-2007 and 1900-2007 simulations. The simulation results summarized in this chapter demonstrate the effects of lengthening the hydrologic period-of-analysis from 1940-1997 (58 years) to either 1940-2007 (68 years) or 1900-2007 (108 years).

Table 7.1
Brazos WAM Simulations Compared in Chapter 7

Simulation	Water Use Scenario	Filename	Hydrologic Period-of-Analysis
1	authorized use (run 3)	Bwam3	January 1940 through December 2007
2	authorized use (run 3)	Bwam3	January 1900 through December 2007
3	current use (run 8)	Bwam8	January 1940 through December 2007
4	current use (run 8)	Bwam8	January 1900 through December 2007

The four simulations presented in this chapter incorporate the premise that the beginning-of-simulation storage volume in each reservoir is equal to its storage capacity. The simulations begin with all reservoirs full to capacity. The Bwam3 and Bwam8 simulations with the 1940-2007 and 1900-2007 simulation periods begin with all storage volumes at the beginning of January 1940 or January 1900 set at capacity. The end-of-month December 1939 (beginning of January 1940) storage volumes computed in the 1900-2007 simulation is not necessarily equal to the storage capacity in each of the numerous reservoirs. Thus, simulation results for January 1940 and subsequent months vary between a 1940-2007 simulation and 1900-2007 simulation.

The tables in this chapter summarize results from the four *WRAP-SIM* simulations listed in Table 7.1. Results are presented by sub-periods of the hydrologic period-of-analysis. The 1940-1997 hydrologic simulation period is a sub-period incorporated in all four simulations. Likewise, the periods 1998-2007 and 1940-2007 are also included in all four of the simulations. The hydrologic simulation period 1900-1939 is included in only simulations 2 and 4 listed in Table 7.1.

River Basin Summaries

Summaries of annual means developed with program *TABLES* with a 2SBA record from the results of the *SIM* simulations are tabulated in Tables 7.2 through 7.7 for simulations that begin with full reservoirs at the beginning of January 1900 and January 1940. The period 1940-1997 is a sub-period of all four simulations. Complete Bwam3 and Bwam8 annual summaries for the 1940-2007 and 1900-2007 simulations are reproduced as Tables 7.4, 7.5, 7.6, and 7.7. These four annual summary tables are further summarized in Tables 7.2 and 7.3. The tables are basin summaries of *SIM* simulation results for the entire Brazos River Basin and San Jacinto-Brazos Coastal Basin with Bwam3 and Bwam8 input datasets. Flow volumes are in acre-feet/year and end-of-year reservoir storage volumes are in acre-feet. The last line of Tables 7.2 and 7.3 shows volume reliabilities with mean diversion volumes expressed as a percentage of the mean diversion targets.

Table 7.2
Brazos WAM Simulation Results Summaries
For Simulations 1 and 3 that Begin with January 1940

	Bwam3 Authorized Use			Bwam8 Current Use		
	1940-1997	1998-2007	1940-2007	1940-1997	1998-2007	1940-2007
	mean flow volumes in acre-feet/year and storage volumes in acre-feet					
naturalized flow	7,735,889	13,041,066	8,516,062	7,735,889	13,041,066	8,516,062
return flow	99,889	115,727	102,218	309,285	313,780	309,946
streamflow depletion	2,598,568	2,663,523	2,608,120	1,861,770	1,923,270	1,870,814
unappropriated flow	5,588,001	8,289,901	5,985,340	6,306,919	9,354,053	6,755,028
reservoir storage	3,439,055	3,446,550	3,440,158	3,419,647	3,531,101	3,436,037
evaporation-precip	396,684	399,441	397,089	432,426	455,454	435,813
diversion target	2,463,873	2,503,687	2,469,728	1,522,967	1,535,392	1,524,794
diversion amount	2,216,748	2,248,042	2,221,350	1,434,398	1,454,490	1,437,353
diversion shortage	247,125	255,645	248,378	88,569	80,901	87,442
volume reliability	89.97%	89.79%	89.94%	94.18%	94.73%	94.27%

Table 7.3
Brazos WAM Simulation Results Summaries
For Simulations 2 and 4 that Begin with January 1900

	Bwam3 Authorized Use			Bwam8 Current Use		
	1900-1939	1940-1997	1900-2007	1900-1939	1940-1997	1900-2007
	mean flow volumes in acre-feet/year and storage volumes in acre-feet					
naturalized flow	11,777,329	7,735,889	9,723,938	11,777,329	7,735,889	9,723,938
return flow	98,490	99,937	100,863	307,699	309,545	309,253
streamflow depletion	2,620,138	2,618,390	2,623,217	1,885,993	1,870,215	1,880,971
unappropriated flow	6,030,213	5,573,745	5,994,304	7,351,694	6,301,068	6,972,873
reservoir storage	3,584,999	3,411,349	3,478,922	3,634,382	3,409,515	3,504,055
evaporation-precip	430,194	391,817	406,736	464,856	430,900	445,750
diversion target	2,473,032	2,464,366	2,471,217	1,522,126	1,523,116	1,523,886
diversion amount	2,229,743	2,213,797	2,222,874	1,436,381	1,433,719	1,436,628
diversion shortage	243,290	250,568	248,343	85,744	89,397	87,258
volume reliability	90.16%	89.83%	89.95%	94.37%	94.13%	94.27%

Table 7.4
Annual Summary for Bwam3 Authorized Use Scenario for 1940-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1940	8370545.5	95084.2	2677444.5	6477945.0	4549303.0	575009.2	2444632.8	2247522.0	197110.7
1941	14544272.0	116848.9	2831736.5	12950069.0	4513898.0	458632.2	2454964.5	2408408.2	46556.3
1942	9232316.0	120574.6	2871871.0	7387587.0	4477174.0	560100.4	2464162.2	2348459.2	115702.9
1943	2388090.2	97975.4	1800948.9	1140338.9	3348253.8	678012.8	2460730.8	2251652.8	209078.1
1944	9223878.0	117277.5	2969924.2	6984807.5	3559961.5	470739.2	2459416.8	2287378.8	172037.9
1945	12917494.0	124383.7	3011946.5	11255917.0	3745396.5	484590.3	2466244.8	2342023.0	124221.8
1946	8863349.0	113838.2	2647603.8	7299583.5	3694094.2	419084.5	2464091.2	2279743.5	184347.9
1947	5245481.0	105734.3	2365084.2	3743309.5	3229799.2	574131.4	2454908.8	2254991.5	199917.3
1948	2514889.8	86779.4	1979463.6	709825.9	2622397.5	557916.6	2472266.5	2028617.2	443649.3
1949	5013065.5	106840.1	3218548.8	3449821.0	3268181.0	336811.2	2503255.5	2235647.0	267608.5
1950	4923034.5	98462.2	2553761.2	2490827.2	3030832.2	520479.0	2471446.5	2270422.8	201023.6
1951	2002667.8	54896.1	1360055.8	246898.0	2058979.9	509917.9	2453212.5	1821756.8	631455.8
1952	2495267.8	66434.3	1786501.9	718095.8	1653170.9	383170.3	2572577.0	1808989.0	763588.0
1953	4774741.5	95439.7	3617196.5	2604531.5	2822490.8	333037.5	2512636.2	2114797.5	397838.6
1954	1779414.1	60812.2	1587336.1	494609.2	2051048.5	515909.3	2473997.0	1842632.2	631364.8
1955	3203789.5	80096.0	2987390.5	1167288.5	2565614.8	345664.3	2496536.5	2126995.0	369541.6
1956	2125384.8	43835.5	1123748.8	139854.7	1623477.4	471628.7	2484974.2	1594030.9	890943.4
1957	21224914.0	101564.5	5218321.0	16532849.0	4287877.5	299945.8	2462667.5	2253883.2	208784.3
1958	6977795.5	102445.6	2259105.2	5624533.5	3880702.2	371695.8	2447012.8	2294201.5	152811.2
1959	7165160.5	107783.0	2821713.5	5035284.5	4100848.8	270473.5	2449744.5	2330959.5	118785.1
1960	9940976.0	106223.7	2571764.0	7015193.0	4013977.2	361408.2	2455848.5	2297056.8	158791.7
1961	12710218.0	115445.5	2767116.8	10491396.0	4100573.2	316605.7	2443621.0	2363902.8	79718.3
1962	3917897.5	101944.6	2601388.8	1779667.8	3968188.0	399451.8	2458239.5	2334263.8	123975.8
1963	1944356.6	85819.3	1624138.0	713807.4	2998040.8	514302.6	2455551.2	2079756.5	375794.8
1964	2961722.2	91084.4	2321345.5	572970.6	2875173.0	340947.6	2511213.5	2103077.0	408136.5
1965	9283932.0	110612.7	3372167.2	6250665.5	3597841.8	360715.6	2448756.0	2288693.0	160063.0
1966	7376064.0	113161.2	2762089.0	5628382.0	3635569.5	412953.9	2450223.0	2311206.5	139016.6
1967	2139661.2	82551.3	2164631.5	568053.0	3210132.8	432998.2	2439226.8	2156959.0	282267.6
1968	13836409.0	114274.0	2975111.5	11864195.0	3548911.5	273201.1	2452272.5	2363104.0	89168.6
1969	7232474.5	101339.5	2923010.2	4578038.0	3786250.8	379184.7	2466369.5	2306370.2	159999.3
1970	6979219.5	107416.2	2205797.2	4951430.5	3246448.2	460936.1	2468494.0	2284602.2	183891.7
1971	8958747.0	87429.6	2857330.5	4105093.0	3564710.2	381594.8	2443474.0	2157462.0	286012.1
1972	5750679.0	93805.1	2364943.0	3826187.0	3340851.5	398345.1	2455826.2	2190271.5	265554.7
1973	11014019.0	114585.7	2856249.5	9067088.0	3651367.5	224902.1	2448043.8	2320831.0	127212.7
1974	8317648.0	102552.9	2748269.8	5796975.0	3894460.8	336644.9	2446899.2	2168421.0	278478.3
1975	8856902.0	110919.4	2363186.2	7474202.0	3525611.0	392969.2	2453742.2	2338872.5	114869.7
1976	7339916.0	113405.1	2634927.0	4899571.0	3655089.0	247280.1	2445317.2	2258167.2	187150.0
1977	9376888.0	94823.4	1907480.0	8466600.0	2886946.0	488233.9	2450625.0	2187083.5	263541.6
1978	3394920.5	71490.9	2492097.0	1071550.4	2973570.0	348661.1	2463991.0	2056590.5	407400.4
1979	10518358.0	115978.6	3088890.0	8463230.0	3470829.5	272111.8	2460654.8	2319456.0	141198.7
1980	3992167.2	83255.3	2359793.0	2125313.2	3259858.8	473751.2	2505795.2	2096948.5	408846.7
1981	7976748.0	107177.9	3229496.0	5940489.5	3947997.0	250382.7	2464769.5	2290916.5	173852.9
1982	5818414.0	89873.1	2337060.8	3492629.0	3636172.2	407448.6	2443434.5	2241302.8	202131.9
1983	4470741.5	96163.7	2247009.8	3259094.2	3293543.5	346210.3	2471345.5	2243401.2	227944.2
1984	3368378.5	84607.2	2172223.5	1837923.9	3082849.0	355173.9	2498895.8	2027596.5	471299.3
1985	7730600.5	101256.8	3018351.8	4525745.5	3547084.8	349929.0	2452090.5	2204122.8	247967.7
1986	8187564.0	116877.5	2986001.8	5439041.0	3959067.0	256889.5	2469361.2	2317011.0	152350.3
1987	10085820.0	110722.1	2389537.0	8474686.0	3608620.2	384182.2	2452459.5	2355747.5	96711.9
1988	1950015.5	78401.9	1571423.2	419269.2	2653959.8	464866.5	2463017.5	2061089.5	401928.1
1989	9760159.0	103735.1	3053368.0	4703507.0	3103008.8	344617.1	2470549.8	2259482.8	211067.1
1990	12102569.0	111043.5	3039748.2	9779651.0	3551451.8	332015.1	2447252.5	2258796.8	188455.8
1991	15821836.0	115711.8	3193204.5	13315830.0	4099623.8	288565.0	2457198.0	2356336.0	100862.1
1992	20150672.0	126239.2	2882411.2	18141320.0	4162364.2	407648.9	2464328.5	2411541.5	52787.0
1993	9483550.0	115903.2	2340650.5	7535488.5	3665048.0	507638.3	2455581.5	2330155.8	125425.8
1994	9155517.0	109375.2	2862084.5	4589815.0	3837656.0	379007.4	2459312.0	2310444.0	148867.9
1995	17313834.0	112816.6	2509412.0	15476137.0	3648593.2	356351.2	2442512.0	2341885.0	100627.1
1996	3013868.2	82502.5	2344319.5	1134823.0	3557033.2	357230.3	2448287.0	2078138.2	370148.8
1997	11462574.0	115947.3	2889221.2	9875049.0	3823235.8	265343.3	2450579.0	2357191.2	93387.7
1998	15290264.0	115774.6	2660634.5	10643707.0	3635182.2	556532.5	2456620.8	2291981.2	164639.5
1999	3393794.8	106493.6	2131150.0	1917304.9	3062180.0	510482.2	2476242.5	2193659.0	282583.4
2000	8601712.0	101902.6	2701070.2	1390593.8	3277615.0	359911.9	2519633.8	2125687.8	393946.1
2001	13684570.0	117858.9	2713651.5	10028019.0	3416524.0	314464.9	2531450.5	2260175.0	271275.6

Table 7.4 Continued
Annual Summary for Bwam3 Authorized Use Scenario for 1940-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
2002	10751560.0	117992.3	2660354.0	6107816.5	3527275.5	280580.9	2519450.0	2268994.0	250456.1
2003	6853310.0	118995.9	2260947.0	3985050.2	3195426.2	378015.8	2536985.8	2214780.5	322205.2
2004	24123402.0	125065.9	3010511.2	19826378.0	3789226.2	145012.7	2520867.5	2271700.8	249166.8
2005	9545604.0	116963.3	2421168.8	5379465.0	3493837.0	416347.7	2508477.8	2300186.2	208291.5
2006	5234925.5	110335.2	2111170.0	1573682.6	3085066.2	333847.9	2500624.5	2186005.0	314619.6
2007	32931516.0	125884.1	3964571.2	22046994.0	3983172.0	699209.4	2466515.5	2367254.2	99261.3
MEAN	8516062.0	102218.3	2608120.2	5985339.5	3440158.0	397089.0	2469727.8	2221350.0	248378.2

Note: For naturalized streamflow and unappropriated flow, the quantities shown represent the maximum flow at any control point in a given month, based on comparing all control points. All other quantities shown are the sum of the values for all the control points.

Table 7.5
Annual Summary for Bwam8 Current Use Scenario 1940-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1940	8370545.5	289079.5	1896166.5	7070435.5	3964690.8	537329.2	1513487.5	1417116.9	96370.7
1941	14544272.0	315944.7	1879891.4	13451233.0	3934535.8	418679.9	1513887.0	1491180.4	22706.6
1942	9232316.0	320157.1	1972179.5	8044901.0	3914925.5	526515.9	1530211.6	1465196.2	65015.4
1943	2388090.2	311422.8	1414866.8	1455324.2	3237079.0	663008.8	1530742.4	1429477.8	101264.6
1944	9223878.0	318577.5	2340202.5	7569803.0	3620695.2	502647.7	1526708.4	1453797.0	72911.3
1945	12917494.0	323516.5	2084901.4	11973507.0	3688965.0	540838.8	1520453.0	1475792.2	44660.7
1946	8863349.0	316214.7	1976607.9	7803201.0	3679513.8	511686.7	1521539.5	1474276.0	47263.5
1947	5245481.0	317683.2	1713783.4	4312791.0	3303058.8	628657.4	1520541.8	1461361.1	59180.7
1948	2514889.8	301270.0	1590439.8	1175078.1	2845638.8	652681.8	1543669.1	1395045.9	148623.2
1949	5013065.5	317079.8	2349193.0	3828765.0	3348117.0	394983.5	1522744.2	1451126.6	71617.7
1950	4923034.5	314320.8	1833234.4	3023610.8	3135470.8	577601.9	1513844.4	1467974.0	45870.4
1951	2002667.8	280065.8	1286724.0	422549.8	2537673.8	617243.9	1516264.0	1267211.1	249052.9
1952	2495267.8	277821.7	1514243.0	950747.1	2247811.8	541949.1	1568837.6	1262034.1	306803.5
1953	4774741.5	302919.5	2695005.2	3201225.2	3053507.0	464911.0	1543400.0	1424394.9	119005.1
1954	1779414.1	289186.6	1285728.5	707343.4	2480901.2	608676.9	1522102.1	1249600.5	272501.6
1955	3203789.5	294843.2	2157512.5	1779528.6	2801263.8	426133.8	1544443.0	1410982.0	133461.0
1956	2125384.8	266583.5	1149695.9	283340.9	2213593.8	599135.6	1552637.9	1138187.9	414450.0
1957	21224914.0	304768.6	3266915.5	17532042.0	3778304.0	275989.2	1509228.2	1426195.6	83032.6
1958	6977795.5	317866.2	1596062.1	6049156.0	3567634.2	356907.3	1517039.1	1449485.5	67553.7
1959	7165160.0	315218.8	1942616.8	5605235.5	3758939.2	276779.9	1515995.6	1474435.9	41559.7
1960	9940976.0	313870.3	1741750.5	7434134.0	3670365.0	369542.3	1516786.0	1460657.1	56128.8
1961	12710218.0	318039.3	1889984.4	11447192.0	3771126.8	304251.8	1514346.4	1484969.0	29377.3
1962	3917897.5	304931.1	1824012.4	2818412.5	3737472.5	393777.2	1512500.1	1463503.2	48996.9
1963	1944356.6	298531.2	1301005.8	961456.5	3156777.2	527251.1	1523627.5	1354308.8	169318.7
1964	2961722.2	304388.2	1901498.6	995389.4	3273651.2	401753.5	1529950.5	1382829.8	147120.7
1965	9283932.0	309401.2	2159886.0	7977208.5	3584637.2	395111.7	1512466.6	1453654.6	58812.0
1966	7376064.0	314669.9	1921093.6	6190580.5	3597861.0	436120.8	1513442.9	1471638.5	41804.4
1967	2139661.2	296156.0	1611864.5	1160358.0	3327427.2	480599.8	1509084.2	1401669.5	107414.8
1968	13836409.0	321820.3	1986565.0	12632114.0	3543580.5	286425.7	1519750.2	1483965.6	35784.7
1969	7232474.5	309800.6	1998292.8	5384186.5	3675093.2	385998.8	1526755.5	1480668.2	46087.2
1970	6979219.5	316942.8	1638137.9	5617201.5	3370048.2	487543.3	1522973.4	1455630.4	67343.0
1971	8958747.0	301133.9	2045752.1	6870027.5	3552828.2	445733.0	1512148.8	1417193.4	94955.4
1972	5750679.0	304462.4	1669186.5	4310577.5	3318624.8	451552.5	1520945.6	1451474.9	69470.8
1973	11014019.0	320215.3	1972820.2	9597924.0	3550190.0	252482.6	1516020.5	1488774.0	27246.5
1974	8317648.0	309985.5	2042199.5	6416070.0	3760761.0	382299.9	1516043.6	1449241.8	66801.9
1975	8856902.0	321659.6	1669998.1	7996713.0	3533485.8	410734.5	1517152.4	1486163.9	30988.6
1976	7339916.0	316662.9	1884993.2	5436993.5	3667516.0	292104.6	1515566.5	1458773.0	56793.5
1977	9376888.0	309941.2	1445172.5	8650271.0	3106628.8	553231.1	1518352.1	1452586.5	65765.6
1978	3394920.5	299355.3	1775207.9	1390915.9	3050487.5	425882.1	1532496.2	1405424.6	127071.7

Table 7.5 Continued
Annual Summary for Bwam8 Current Use Scenario 1940-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1979	10518358.0	324905.6	2195236.2	8994097.0	3455277.0	295536.3	1529161.6	1494898.4	34263.2
1980	3992167.2	302588.2	1734431.8	2692309.0	3265747.8	525266.6	1517991.0	1398685.4	119305.6
1981	7976748.0	320380.9	2172406.5	6326888.5	3688221.2	286302.2	1531060.0	1463535.8	67524.3
1982	5818414.0	307172.0	1602496.5	3988762.5	3443673.8	399131.6	1516889.6	1447894.1	68995.5
1983	4470741.5	316404.7	1699678.9	3651692.8	3334037.5	367295.1	1542635.9	1442009.4	100626.5
1984	3368378.5	303010.8	1689251.8	2371658.0	3235523.8	426642.8	1547813.0	1361093.0	186720.0
1985	7730600.5	312865.9	2126743.2	5233767.0	3556567.2	377993.0	1523111.5	1427695.4	95416.1
1986	8187564.0	316405.3	1912869.1	7151695.5	3724177.2	282010.0	1515425.8	1463061.4	52364.4
1987	10085820.0	314418.7	1729391.8	8942787.0	3599754.0	377945.2	1519089.8	1475839.6	43250.2
1988	1950015.5	294500.6	1365328.1	713567.9	3057667.2	518671.7	1524772.2	1388720.2	136052.0
1989	9760159.0	314113.4	2050693.4	7908290.0	3255521.5	394349.1	1519058.0	1458373.5	60684.5
1990	12102569.0	319631.2	2070861.2	11002817.0	3525401.2	340104.5	1520338.9	1460534.2	59804.6
1991	15821836.0	317631.2	2090911.5	14762970.0	3816594.0	315550.8	1516162.8	1483982.1	32180.6
1992	20150672.0	323878.4	1890339.6	18807504.0	3817034.2	389421.7	1518301.0	1500102.6	18198.4
1993	9483550.0	318850.2	1735355.0	7930398.5	3566941.8	501572.3	1523918.2	1483759.2	40159.0
1994	9155517.0	313181.0	2000054.1	7142004.5	3686651.0	397257.3	1528953.6	1483086.8	45866.9
1995	17313834.0	318711.8	1821151.9	16873542.0	3639876.8	377556.1	1512576.0	1490177.4	22398.6
1996	3013868.2	291988.1	1766289.9	1622711.9	3587958.5	419958.2	1507921.6	1397779.0	110142.7
1997	11462574.0	321387.5	1903771.0	10156282.0	3721993.8	283403.9	1518735.6	1485862.6	32873.0
1998	15290264.0	316110.9	1962704.0	11256589.0	3622689.0	590812.3	1521943.5	1471093.2	50850.3
1999	3393794.8	308540.1	1596706.0	2358625.2	3247325.2	558277.4	1519051.2	1413651.5	105399.7
2000	8601712.0	308884.2	2065085.1	5012547.0	3456264.8	448924.4	1525065.9	1407221.8	117844.1
2001	13684570.0	314305.2	1859461.5	10602506.0	3469575.0	373956.5	1537114.2	1472108.1	65006.1
2002	10751560.0	316529.3	1954556.4	7647719.0	3605430.8	334001.3	1540526.1	1484696.2	55829.9
2003	6853310.0	312019.6	1724633.1	4477041.5	3408574.5	472932.6	1557258.5	1448560.5	108697.9
2004	24123402.0	317536.6	1978448.2	20485200.0	3700172.0	202363.0	1550721.2	1484293.8	66427.5
2005	9545604.0	315202.6	1759045.0	6786871.0	3549027.2	458342.8	1537011.6	1451841.4	85170.3
2006	5234925.5	306978.8	1661888.2	1868764.2	3397321.2	400501.4	1535679.8	1413005.9	122673.9
2007	32931516.0	321694.0	2670170.5	23044670.0	3854629.2	714432.1	1529544.4	1498431.0	31113.4
MEAN	8516062.0	309946.1	1870814.0	6755027.5	3436037.2	435812.8	1524794.2	1437353.0	87441.6

Table 7.6
Annual Summary for Bwam3 Authorized Use Scenario 1900-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1900	20518162.0	115782.7	2923646.0	14060025.0	4615140.0	595411.1	2457415.2	2407711.0	49704.3
1901	3379020.0	87259.8	1622517.1	1780524.1	3635787.0	446002.4	2476631.5	2155456.5	321175.1
1902	13035603.0	96789.2	3313589.0	5370549.5	4176011.5	457708.2	2457121.0	2315526.5	141594.4
1903	13264413.0	109472.8	2436378.5	4756698.5	3782193.0	472239.2	2456636.0	2357748.8	98887.3
1904	6586585.5	100893.4	2383809.8	865902.8	3497742.2	376182.2	2468929.5	2291746.5	177183.1
1905	15143339.0	104631.5	3189198.2	6504685.5	3868260.2	482404.1	2462581.0	2335933.5	126647.6
1906	7665399.0	107161.4	2792644.5	2220590.0	3873828.8	429533.8	2474755.0	2357128.8	117626.3
1907	9928151.0	103410.4	2982251.2	4111780.2	4067438.2	440596.3	2454626.2	2347622.5	107003.7
1908	25028760.0	112888.2	2666181.2	14252279.0	3817191.8	563940.9	2453035.8	2352232.2	100803.5
1909	6029185.5	70058.1	1474140.8	148171.7	2948069.8	343536.2	2471545.2	1999570.5	471974.7
1910	3157185.0	61546.4	1473233.8	361235.4	2339298.0	279014.1	2464146.0	1802441.2	661704.8
1911	6005543.0	98407.9	2043062.2	514648.0	2101582.5	226628.4	2583206.5	2053919.5	529287.0
1912	4342691.5	86167.8	1824352.8	1244339.8	1817620.4	210084.6	2595040.0	1897765.6	697274.4
1913	13644529.0	105227.3	4152382.5	9319216.0	3612665.5	270897.1	2567641.5	2085974.2	481667.2
1914	18150640.0	120367.1	3171906.0	10845221.0	3919364.0	492423.9	2472241.5	2372674.0	99567.5
1915	13140758.0	116017.5	3260127.2	10980914.0	4218068.0	554493.8	2449819.5	2406446.0	43373.6
1916	10330962.0	103398.8	2247043.0	8968288.0	3709767.8	465519.0	2454182.0	2289379.5	164802.6
1917	2552019.0	65560.0	1164692.1	173190.2	2629120.0	322208.7	2484025.5	1922891.5	561133.9
1918	11526029.0	85189.7	3098926.8	1842709.8	3311432.8	317671.2	2537568.2	2098447.0	439121.4
1919	26814616.0	119528.2	4031175.2	12127385.0	4361430.0	572949.3	2446937.2	2408190.0	38747.3

Table 7.6 Continued
Annual Summary for Bwam3 Authorized Use Scenario 1900-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1920	18201364.0	110131.6	2914818.2	12969379.0	4317948.0	551511.1	2451905.5	2406486.5	45418.9
1921	9428539.0	109704.9	2198931.2	5650838.0	3728287.0	463319.5	2469071.2	2325194.5	143876.7
1922	21163070.0	90872.0	2582788.2	18629510.0	3474184.5	550259.6	2452589.8	2286588.8	166001.0
1923	13257192.0	105724.8	3191331.2	7325662.0	3942681.0	444884.0	2477447.0	2277763.5	199683.6
1924	11488936.0	85600.6	1904882.8	4621720.5	3272280.0	439100.7	2449270.0	2136103.0	313167.1
1925	4674278.5	71563.2	2495387.8	1722100.6	3480027.5	340352.3	2484945.2	1946872.5	538072.8
1926	11351932.0	109212.2	3149039.5	7248236.0	3820294.5	442556.9	2457578.2	2365848.0	91730.2
1927	9763355.0	109460.4	2520155.0	7006577.0	3600245.2	424598.1	2459894.8	2315350.0	144544.8
1928	7173268.5	95888.5	2729793.8	1572152.2	3647016.2	399014.0	2461100.5	2283514.8	177585.8
1929	9462536.0	100423.2	2758375.5	4819936.0	3652752.5	447431.4	2459900.5	2304828.0	155072.6
1930	8656993.0	97561.1	3111631.2	5667074.5	4045936.0	446841.3	2466402.5	2271336.2	195066.2
1931	10104903.0	100512.7	2141321.8	4298818.5	3530742.5	436753.8	2470726.5	2219547.5	251179.0
1932	18228772.0	107868.4	3294584.8	12598689.0	3958635.8	499480.6	2452943.0	2366824.8	86118.4
1933	6533672.5	80931.1	1961755.0	1160001.8	3324870.5	409144.2	2466289.8	2186309.0	279980.8
1934	6331331.0	82572.4	2087623.9	3459317.8	3113163.2	373783.8	2464956.2	1925325.0	539631.2
1935	30036858.0	120158.5	3760486.2	7813480.0	3986083.5	516759.4	2455065.5	2370772.8	84292.6
1936	13102664.0	106217.2	2843277.0	8443198.0	4024331.2	469859.3	2448176.5	2335124.0	113052.6
1937	11812503.0	99581.7	2236143.8	4163335.5	3626550.0	408418.5	2464856.5	2225403.5	239452.9
1938	17192544.0	100964.6	2618011.5	10940952.0	3460000.8	474490.3	2460632.0	2309758.5	150873.6
1939	2884847.0	84901.4	2053927.5	649184.2	3091912.2	349742.3	2459458.2	2071946.1	387512.1
1940	8370545.5	98510.4	3380087.8	6033346.5	3876865.5	420696.7	2463782.5	2173929.8	289852.7
1941	14544272.0	116816.9	3246432.5	12616606.0	4286944.0	429608.0	2463421.5	2406554.0	56867.6
1942	9232316.0	120574.6	2902487.2	7352362.0	4307901.0	541929.1	2464328.2	2339417.8	124910.5
1943	2388090.2	97701.6	1801055.8	1127513.5	3218676.5	658556.1	2461321.8	2231654.2	229667.5
1944	9223878.0	117260.4	2970596.5	6984222.0	3456828.5	458527.6	2459425.8	2273755.5	185670.3
1945	12917494.0	124383.7	3012043.0	11255894.0	3656429.0	475213.9	2466244.8	2337229.2	129015.5
1946	8863349.0	113838.2	2647755.8	7299560.5	3620671.8	410162.4	2464100.2	2273187.2	190913.1
1947	5245481.0	105552.8	2365028.2	3743228.5	3180366.2	564439.1	2454933.8	2240769.8	214164.1
1948	2514889.8	86676.8	1979868.1	709620.4	2601294.5	551081.6	2472274.5	2007656.5	464618.0
1949	5013065.5	106759.5	3218747.5	3449900.5	3250054.8	335003.2	2503389.0	2234759.8	268629.2
1950	4923034.5	98462.2	2553815.8	2490823.2	3015891.5	517521.0	2471448.2	2270239.2	201209.0
1951	2002667.8	54896.1	1360055.8	246898.0	2047844.1	507279.1	2453212.5	1820590.2	632622.2
1952	2495267.8	66434.3	1786501.9	718095.8	1645943.9	381153.9	2572577.0	1807096.4	765480.6
1953	4774741.5	95439.7	3617198.5	2604529.2	2817549.0	331864.4	2512636.2	2113691.5	398944.8
1954	1779414.1	60812.2	1587336.1	494609.2	2047193.5	514822.8	2473997.0	1842632.2	631364.8
1955	3203789.5	80096.0	2987390.5	1167288.5	2562487.5	344943.5	2496537.0	2126990.8	369546.2
1956	2125384.8	43835.5	1123748.9	139854.7	1622214.5	470849.2	2484997.0	1592946.0	892050.9
1957	21224914.0	101564.5	5218345.5	16532829.0	4286808.5	299894.6	2462667.5	2253749.8	208917.6
1958	6977795.5	102445.6	2259106.2	5624532.0	3879764.0	371566.3	2447012.8	2294201.5	152811.2
1959	7165160.5	107783.0	2821714.0	5035284.0	4099991.8	270392.9	2449744.5	2330959.5	118785.1
1960	9940976.0	106223.7	2571764.8	7015192.5	4013196.2	361332.6	2455848.5	2297056.8	158791.7
1961	12710218.0	115445.5	2767117.2	10491396.0	4099895.0	316506.7	2443621.0	2363902.8	79718.3
1962	3917897.5	101944.6	2601389.0	1779667.5	3967617.0	399345.7	2458239.5	2334263.8	123975.8
1963	1944356.6	85819.3	1624138.0	713807.4	2997607.8	514164.3	2455551.2	2079756.5	375794.8
1964	2961722.2	91084.4	2321345.5	572970.6	2874809.8	340879.3	2511213.5	2103076.2	408137.3
1965	9283932.0	110612.7	3372167.5	6250665.5	3597512.2	360681.7	2448756.0	2288693.0	160063.0
1966	7376064.0	113161.2	2762089.2	5628381.5	3635287.2	412907.6	2450223.0	2311206.5	139016.6
1967	2139661.2	82551.3	2164631.5	568053.0	3209893.2	432955.5	2439226.8	2156959.0	282267.6
1968	13836409.0	114274.0	2975114.5	11864195.0	3548698.0	273178.3	2452272.5	2363104.0	89168.6
1969	7232474.5	101339.5	2923010.5	4578038.0	3786062.5	379159.3	2466369.5	2306370.2	159999.3
1970	6979219.5	107416.2	2205797.2	4951430.5	3246291.0	460910.1	2468494.0	2284602.2	183891.7
1971	8958747.0	87429.6	2857332.0	4105091.5	3564583.5	381565.7	2443474.0	2157462.0	286012.1
1972	5750679.0	93805.1	2364943.0	3826187.0	3340743.8	398326.1	2455826.2	2190271.5	265554.7
1973	11014019.0	114585.7	2856251.0	9067086.0	3651265.2	224894.2	2448043.8	2320831.0	127212.7
1974	8317648.0	102552.9	2748269.2	5796975.5	3894384.8	336631.6	2446899.2	2168407.0	278492.2
1975	8856902.0	110919.4	2363186.2	7474202.0	3525548.2	392958.8	2453742.2	2338872.5	114869.7
1976	7339916.0	113405.1	2634927.0	4899571.0	3655031.2	247276.7	2445317.2	2258167.2	187150.0
1977	9376888.0	94823.4	1907480.1	8466600.0	2886901.2	488220.7	2450625.0	2187083.5	263541.6
1978	3394920.5	71490.9	2492097.0	1071550.4	2973532.5	348654.1	2463991.0	2056590.5	407400.4
1979	10518358.0	115978.6	3088890.0	8463230.0	3470795.2	272108.4	2460654.8	2319456.0	141198.7
1980	3992167.2	83255.3	2359793.0	2125313.2	3259831.8	473743.8	2505795.2	2096948.5	408846.7
1981	7976748.0	107177.9	3229496.2	5940489.5	3947973.5	250379.8	2464769.5	2290916.5	173852.9

Table 7.6 Continued
Annual Summary for Bwam3 Current Use Scenario 1900-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1982	5818414.0	89873.1	2337060.8	3492629.0	3636152.2	407444.9	2443434.5	2241302.8	202131.9
1983	4470741.5	96163.7	2247009.8	3259094.2	3293525.5	346207.8	2471345.5	2243401.2	227944.2
1984	3368378.5	84607.2	2172236.5	1837951.5	3082791.5	355167.6	2498895.8	2027596.5	471299.3
1985	7730600.5	101256.8	3018352.8	4525820.5	3547033.0	349924.0	2452090.5	2204122.8	247967.7
1986	8187564.0	116877.5	2986003.0	5439040.0	3959019.8	256886.1	2469361.5	2317011.0	152350.6
1987	10085820.0	110722.1	2389571.8	8474685.0	3608610.2	384180.0	2452459.5	2355747.5	96711.9
1988	1950015.5	78401.9	1571423.2	419269.2	2653951.5	464864.2	2463017.5	2061089.5	401928.1
1989	9760159.0	103735.1	3053368.0	4703507.0	3103001.8	344615.9	2470549.8	2259482.8	211067.1
1990	12102569.0	111043.5	3039748.2	9779651.0	3551445.8	332014.4	2447252.5	2258796.8	188455.8
1991	15821836.0	115711.8	3193204.5	13315830.0	4099618.2	288564.6	2457198.0	2356336.0	100862.1
1992	20150672.0	126239.2	2882411.2	18141320.0	4162359.2	407648.3	2464328.5	2411541.5	52787.0
1993	9483550.0	115903.2	2340650.8	7535488.5	3665043.8	507637.6	2455581.5	2330155.8	125425.8
1994	9155517.0	109375.2	2862084.5	4589815.0	3837652.5	379006.7	2459312.0	2310444.0	148867.9
1995	17313834.0	112816.6	2509412.0	15476137.0	3648590.0	356350.9	2442512.0	2341885.0	100627.1
1996	3013868.2	82502.5	2344319.2	1134823.2	3557029.5	357229.9	2448287.0	2078138.2	370148.8
1997	11462574.0	115947.3	2889223.0	9875047.0	3823234.5	265343.2	2450579.0	2357191.2	93387.7
1998	15290264.0	115774.6	2660634.5	10643707.0	3635181.2	556532.2	2456620.8	2291981.2	164639.5
1999	3393794.8	106493.6	2131150.0	1917304.9	3062179.0	510482.0	2476242.5	2193659.0	282583.4
2000	8601712.0	101902.6	2701070.5	1390593.9	3277614.2	359911.8	2519634.0	2125688.0	393946.1
2001	13684570.0	117858.9	2713651.2	10028019.0	3416519.8	314464.7	2531450.5	2260175.0	271275.6
2002	10751560.0	117992.3	2660357.8	6107816.5	3527275.0	280580.8	2519450.0	2268994.0	250456.1
2003	6853310.0	118995.9	2260947.0	3985050.2	3195425.8	378015.7	2536985.8	2214780.5	322205.2
2004	24123402.0	125065.9	3010511.2	19826378.0	3789225.8	145012.7	2520867.5	2271700.8	249166.8
2005	9545604.0	116963.3	2421168.8	5379465.0	3493836.8	416347.6	2508477.8	2300186.2	208291.5
2006	5234925.5	110335.2	2111170.0	1573682.6	3085065.8	333847.8	2500624.5	2186005.0	314619.6
2007	32931516.0	125884.1	3964571.2	22046994.0	3983171.8	699209.4	2466515.5	2367254.2	99261.3
MEAN	9723938.0	100862.9	2623216.5	5994304.0	3478921.8	406736.2	2471216.8	2222873.8	248342.6

Table 7.7
Annual Summary for Bwam8 Current Use Scenario 1900-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1900	20518162.0	299317.0	2021455.5	14688779.0	3991231.5	554882.6	1511151.0	1498513.5	12637.5
1901	3379020.0	305447.8	1345656.4	2068188.8	3512315.2	430926.2	1523375.8	1393346.5	130029.3
1902	13035603.0	302530.3	2275128.0	6351650.0	3860924.5	463452.9	1516810.5	1462959.6	53850.9
1903	13264413.0	316865.1	1838441.0	9443452.0	3731151.2	477264.7	1522014.9	1490675.1	31339.8
1904	6586585.5	303991.6	1867044.6	1373201.2	3699696.2	426061.2	1521007.8	1472166.9	48840.9
1905	15143339.0	310045.0	2126663.0	7320221.5	3833294.0	513577.0	1518789.8	1479200.4	39589.3
1906	7665399.0	316112.5	1909229.0	5965567.5	3808905.2	450574.5	1520570.6	1482762.9	37807.8
1907	9928151.0	312719.8	2012860.4	5236187.5	3884803.8	459797.4	1513004.9	1476791.2	36213.6
1908	25028760.0	315982.1	1923898.5	14768228.0	3768090.2	558378.1	1515893.6	1482040.8	33852.8
1909	6029185.5	289258.5	1335675.6	381476.0	3385344.0	392904.0	1531897.5	1325404.1	206493.4
1910	3157185.0	271675.2	1268644.9	674177.2	3056730.5	377260.8	1527038.4	1219567.1	307471.3
1911	6005543.0	311937.0	1749927.6	862289.8	2992019.2	362538.8	1524315.9	1451971.1	72344.8
1912	4342691.5	302860.4	1543757.6	1784507.4	2788698.8	348571.1	1564724.1	1398346.5	166377.7
1913	13644529.0	302274.4	2645808.0	9937974.0	3613642.0	410017.9	1565786.0	1410474.2	155311.8
1914	18150640.0	320105.2	2158203.8	12060635.0	3737689.2	539891.3	1515608.8	1494177.8	21431.0
1915	13140758.0	318745.8	2118063.5	11688886.0	3826796.5	532112.1	1512455.1	1496472.5	15982.6
1916	10330962.0	314050.5	1680370.6	9379830.0	3596702.2	459100.7	1519616.1	1451065.6	68550.5
1917	2552019.0	284616.9	1132158.4	374069.7	3077710.5	372103.4	1520698.6	1278914.0	241784.6
1918	11526029.0	304840.0	2212698.0	5267410.0	3487823.0	412044.0	1522374.9	1390378.5	131996.4
1919	26814616.0	317735.5	2558746.5	16216007.0	3936469.2	611919.8	1513421.5	1498174.9	15246.7
1920	18201364.0	309479.8	1977209.1	13858836.0	3901297.2	525390.1	1507737.9	1486718.5	21019.4
1921	9428539.0	316122.8	1670416.1	7810154.0	3640381.0	463515.9	1533823.5	1467808.5	66015.0

Table 7.7 Continued
Annual Summary for Bwam8 Current Use Scenario 1900-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1922	21163070.0	313269.2	1834526.0	19189772.0	3475858.8	529788.8	1522648.2	1469254.0	53394.3
1923	13257192.0	311727.0	2244278.2	8068172.0	3815258.2	472205.2	1525873.5	1432569.0	93304.4
1924	11488936.0	306868.8	1523436.0	7044814.0	3454652.0	467937.1	1518289.1	1416099.1	102190.0
1925	4674278.5	291677.6	1885472.1	2288305.8	3657110.8	405327.1	1518938.9	1277313.6	241625.2
1926	11351932.0	316889.2	2099666.5	7930687.5	3791405.5	473818.8	1512737.6	1491191.1	21546.5
1927	9763355.0	316192.4	1869959.2	7544032.0	3731284.5	457046.5	1518804.4	1472839.4	45965.0
1928	7173268.5	304626.2	1827686.0	2497423.0	3661619.2	426991.5	1513662.5	1469898.1	43764.4
1929	9462536.0	314138.3	1958790.9	5510797.0	3696435.0	463472.6	1517276.1	1460204.0	57072.1
1930	8656993.0	310990.1	2093109.4	6926529.5	3876077.2	468072.6	1519733.6	1445174.8	74558.9
1931	10104903.0	310010.2	1694097.2	4725092.5	3663431.8	469065.7	1522840.4	1437488.4	85352.0
1932	18228772.0	309722.8	2191214.2	15934165.0	3843967.0	526045.2	1515444.1	1484303.1	31141.0
1933	6533672.5	301419.2	1500786.8	2184241.8	3484733.5	433527.8	1521237.0	1426480.2	94756.8
1934	6331331.0	300681.9	1602793.8	4400483.5	3392951.2	423684.3	1529026.0	1270780.4	258245.6
1935	30036858.0	322841.8	2581625.2	10750938.0	3915351.0	559883.4	1518743.2	1499251.5	19491.7
1936	13102664.0	309963.7	1965422.4	9250356.0	3913767.0	496010.8	1516760.1	1470993.0	45767.2
1937	11812503.0	309254.8	1796451.1	7565081.0	3814315.8	452331.7	1536430.0	1443494.8	92935.2
1938	17192544.0	304780.5	1825797.6	13561555.0	3649919.8	515769.6	1511171.4	1474172.2	36999.2
1939	2884847.0	306187.6	1572566.2	1183570.0	3405440.2	410991.7	1523298.4	1405819.0	117479.3
1940	8370545.5	305831.0	2345083.5	6748149.0	3854399.8	499442.8	1522028.2	1396312.5	125715.8
1941	14544272.0	314456.3	1909364.2	13440013.0	3863478.2	412335.5	1513894.2	1487766.0	26128.3
1942	9232316.0	320157.1	1979333.5	8039178.5	3857209.0	520643.5	1530211.6	1464881.5	65330.1
1943	2388090.2	311389.0	1414180.2	1455320.8	3185827.5	656845.4	1530807.6	1428489.1	102318.5
1944	9223878.0	318527.0	2340260.0	7569758.0	3573123.8	499183.8	1526708.6	1453639.2	73069.4
1945	12917494.0	323516.5	2085072.5	11973493.0	3645064.5	537338.9	1520453.0	1475792.2	44660.7
1946	8863349.0	316214.7	1978028.5	7803201.0	3639900.5	508820.0	1521539.5	1474276.0	47263.5
1947	5245481.0	317683.2	1715110.5	4312791.0	3267104.2	625014.8	1520541.8	1462672.2	57869.5
1948	2514889.8	301270.0	1590956.8	1175078.1	2813810.0	648572.8	1543669.1	1395546.2	148122.9
1949	5013065.5	317079.8	2349088.8	3828732.5	3318120.5	393192.8	1522744.2	1450981.1	71763.1
1950	4923034.5	314231.5	1834330.8	3023610.8	3115468.0	573678.6	1513844.4	1463089.1	50755.2
1951	2002667.8	280044.9	1287587.6	422549.8	2529873.8	614680.8	1516264.0	1258456.2	257807.8
1952	2495267.8	277821.7	1514003.0	950747.1	2241262.2	540698.5	1568837.6	1261794.2	307043.3
1953	4774741.5	302919.5	2694299.2	3201225.2	3048353.2	463998.8	1543400.0	1423205.5	120194.5
1954	1779414.1	289186.6	1285728.5	707343.4	2476827.2	607597.4	1522102.1	1249600.5	272501.6
1955	3203789.5	294843.2	2158063.2	1779528.6	2797771.8	425551.9	1544443.2	1411532.1	132911.2
1956	2125384.8	266583.5	1149695.9	283340.9	2211610.8	598491.4	1552660.8	1137323.2	415337.4
1957	21224914.0	304768.6	3266915.5	17532042.0	3776406.5	275903.7	1509228.2	1426195.6	83032.6
1958	6977795.5	317866.2	1596062.1	6049156.0	3565909.2	356735.0	1517039.1	1449485.5	67553.7
1959	7165160.0	315218.8	1942616.8	5605235.5	3757352.5	276641.5	1515995.6	1474435.9	41559.7
1960	9940976.0	313870.3	1741750.5	7434134.0	3668913.0	369407.4	1516786.0	1460657.1	56128.8
1961	12710218.0	318039.3	1889984.4	11447192.0	3769800.8	304126.2	1514346.4	1484969.0	29377.3
1962	3917897.5	304931.1	1824012.4	2818412.5	3736291.0	393632.6	1512500.1	1463503.2	48996.9
1963	1944356.6	298531.2	1301005.8	961456.5	3155779.2	527066.8	1523627.5	1354308.8	169318.7
1964	2961722.2	304388.2	1901498.6	995389.4	3272772.5	401634.7	1529950.5	1382829.8	147120.7
1965	9283932.0	309401.2	2159886.0	7977208.5	3583833.2	395036.8	1512466.6	1453654.6	58812.0
1966	7376064.0	314669.9	1921093.6	6190580.5	3597141.0	436037.0	1513442.9	1471638.5	41804.4
1967	2139661.2	296156.0	1611864.5	1160358.0	3326789.2	480517.5	1509084.2	1401669.5	107414.8
1968	13836409.0	321820.3	1986565.0	12632114.0	3542989.5	286378.4	1519750.2	1483965.6	35784.7
1969	7232474.5	309800.6	1998292.8	5384186.5	3674547.5	385954.2	1526755.5	1480668.2	46087.2
1970	6979219.5	316942.8	1638137.9	5617201.5	3369560.2	487485.5	1522973.4	1455630.4	67343.0
1971	8958747.0	301133.9	2045752.1	6870027.5	3552394.8	445678.4	1512148.8	1417193.4	94955.4
1972	5750679.0	304462.4	1669186.5	4310577.5	3318236.8	451506.8	1520945.6	1451474.9	69470.8
1973	11014019.0	320215.3	1972820.2	9597924.0	3549826.5	252458.4	1516020.5	1488774.0	27246.5
1974	8317648.0	309985.5	2042199.5	6416070.0	3760427.8	382269.4	1516043.6	1449241.8	66801.9
1975	8856902.0	321659.6	1669998.1	7996713.0	3533183.0	410703.9	1517152.4	1486163.9	30988.6
1976	7339916.0	316662.9	1884993.2	5436993.5	3667233.2	292084.8	1515566.5	1458773.0	56793.5
1977	9376888.0	309941.2	1445172.5	8650271.0	3106379.8	553197.0	1518352.1	1452586.5	65765.6
1978	3394920.5	299355.3	1775207.9	1390915.9	3050264.5	425856.4	1532496.2	1405424.6	127071.7
1979	10518358.0	324905.6	2195236.2	8994097.0	3455071.2	295519.2	1529161.6	1494898.4	34263.2
1980	3992167.2	302588.2	1734431.8	2692309.0	3265566.0	525242.3	1517991.0	1398685.4	119305.6
1981	7976748.0	320380.9	2172406.5	6326888.5	3688056.8	286284.9	1531060.0	1463535.8	67524.3
1982	5818414.0	307172.0	1602496.5	3988762.5	3443521.8	399119.1	1516889.6	1447894.1	68995.5
1983	4470741.5	316404.7	1699678.9	3651692.8	3333898.0	367282.6	1542635.9	1442009.4	100626.5

Table 7.7 Continued
Annual Summary for Bwam8 Current Use Scenario 1900-2007 Simulation

YEAR	NATURALIZED STREAMFLOW (AC-FT)	RETURN FLOW (AC-FT)	STREAMFLOW DEPLETION (AC-FT)	UNAPPROPRIATED FLOW (AC-FT)	EOP STORAGE (AC-FT)	EVAPORATION (AC-FT)	TARGET DIVERSION (AC-FT)	ACTUAL DIVERSION (AC-FT)	DIVERSION SHORTAGE (AC-FT)
1984	3368378.5	303010.8	1689251.8	2371658.0	3235398.2	426628.9	1547813.0	1361093.0	186720.0
1985	7730600.5	312865.9	2126743.2	5233767.0	3556452.5	377982.3	1523111.5	1427695.4	95416.1
1986	8187564.0	316405.3	1912869.1	7151695.5	3724069.0	282003.1	1515425.8	1463061.4	52364.4
1987	10085820.0	314418.7	1729391.8	8942787.0	3599653.2	377938.0	1519089.8	1475839.6	43250.2
1988	1950015.5	294500.6	1365328.1	713567.9	3057577.0	518661.1	1524772.2	1388720.2	136052.0
1989	9760159.0	314113.4	2050693.4	7908290.5	3255438.0	394342.2	1519058.0	1458373.5	60684.5
1990	12102569.0	319631.2	2070861.2	11002817.0	3525322.2	340100.2	1520338.9	1460534.2	59804.6
1991	15821836.0	317631.2	2090911.5	14762970.0	3816519.8	315546.1	1516162.8	1483982.1	32180.6
1992	20150672.0	323878.4	1890339.6	18807504.0	3816964.8	389416.9	1518301.0	1500102.6	18198.4
1993	9483550.0	318850.2	1735355.0	7930398.5	3566878.8	501566.2	1523918.2	1483759.2	40159.0
1994	9155517.0	313181.0	2000054.1	7142004.5	3686592.5	397252.5	1528953.6	1483086.8	45866.9
1995	17313834.0	318711.8	1821151.9	16873542.0	3639822.0	377552.4	1512576.0	1490177.4	22398.6
1996	3013868.2	291988.1	1766289.9	1622711.9	3587908.2	419953.8	1507921.6	1397779.0	110142.7
1997	11462574.0	321387.5	1903771.0	10156282.0	3721947.0	283400.5	1518735.6	1485862.6	32873.0
1998	15290264.0	316110.9	1962704.0	11256589.0	3622646.8	590807.7	1521943.5	1471093.2	50850.3
1999	3393794.8	308540.1	1596706.0	2358625.2	3247288.0	558272.5	1519051.2	1413651.5	105399.7
2000	8601712.0	308884.2	2065085.1	5012547.0	3456231.5	448920.2	1525065.9	1407221.8	117844.1
2001	13684570.0	314305.2	1859461.5	10602506.0	3469545.0	373953.4	1537114.2	1472108.1	65006.1
2002	10751560.0	316529.3	1954556.4	7647719.0	3605403.2	333998.8	1540526.1	1484696.2	55829.9
2003	6853310.0	312019.6	1724633.1	4477041.5	3408550.0	472929.7	1557258.5	1448560.5	108697.9
2004	24123402.0	317536.6	1978448.2	20485200.0	3700149.0	202361.6	1550721.2	1484293.8	66427.5
2005	9545604.0	315202.6	1759045.0	6786871.0	3549006.0	458340.8	1537011.6	1451841.4	85170.3
2006	5234925.5	306978.8	1661888.2	1868764.2	3397302.0	400499.5	1535679.8	1413005.9	122673.9
2007	32931516.0	321694.0	2670170.5	23044670.0	3854612.0	714429.9	1529544.4	1498431.0	31113.4
MEAN	9723938.0	309253.3	1880971.0	6972873.0	3504054.8	445749.6	1523886.2	1436628.2	87257.7

The naturalized and unappropriated flows shown in Tables 7.2 through 7.7 represent the maximum flow at any control point in a given month, based on *TABLES* comparing all control points. These means represent flows throughout the river basin rather than at the outlet and may be significantly greater than the mean of the naturalized or unappropriated flow at the river basin outlets. All other quantities shown are the sum of the amounts for all of the control points. The volume reliabilities in Tables 7.2 and 7.3 are the total volume diverted in the simulations expressed as a percentage of the summation of the diversion targets of all water rights in the dataset.

The 1998-2007 mean annual naturalized flow shown in Table 7.2 is 13,041,066 acre-feet/year compared with a 1940-1997 mean annual naturalized flow of 7,735,889 acre-feet/year. Thus, the 1998-2007 mean annual naturalized flow is 169 percent of the 1940-1997 mean annual naturalized flow. The minimum annual naturalized flow during 1940-1997 was 1,779,414 acre-feet occurring in 1954. The minimum annual naturalized flow during 1998-2007 was 3,393,795 ac-ft occurring in 1999. The naturalized flow of 21,224,914 acre-feet in 1957 is the largest annual naturalized flow of any of the 58 years between 1940 and 1997. The 1957 flow included the flood that ended the 1950's most hydrological severe drought on record. Annual naturalized flow volumes of 24,123,402 and 32,931,516 acre-feet in 2004 and 2007, respectively, are greater than the 1957 naturalized flow.

The 1900-1939 mean naturalized flow of 11,777,327 acre-feet is larger than the 1940-1997 mean and smaller than the 1998-2007 mean naturalized flow. The three smallest annual naturalized flows during 1900-1939 are 2,884,847 ac-ft, 2,552,019 ac-ft, and 3,157,185 ac-ft in 1939, 1917, and

1910, respectively. These flow volumes are all greater than the 1900-2007 minimum annual flow of 1,779,414 acre-feet occurring in 1954.

The 1998-2007 mean of the unappropriated flows for Bwam3 in Table 7.2 is 138.5 percent of the 1940-1997 mean unappropriated flow. The Bwam3 1940-2007 mean unappropriated flow is 107.1 percent of the 1940-1997 mean unappropriated flow. The 1900-1939 mean of the unappropriated flows for Bwam3 in Table 7.3 is 107.9 percent of the 1940-1997 mean unappropriated flow. The Bwam3 1900-2007 mean unappropriated flow is 100.15 percent of the 1940-1997 mean unappropriated flow. Frequency statistics for naturalized and regulated flows at selected gaging stations are compared later in this chapter.

The average volume of water stored in the 665 Bwam3 reservoirs at the end of December during 1998-2007 is 100.06 percent of the corresponding 1940-1997 mean storage volume. The Bwam3 1940-2007 mean end-of-year storage volume is 100.02 percent of the 1940-1997 mean storage. The simulation begins in January 1940 with all reservoirs filled to capacity, but the period 1998-1997 begins with end of December 1997 storage contents, which reflects significant draw-downs. Storage volumes are explored later in this chapter.

Water Supply Diversion Reliabilities

Diversion targets increase a little during 1998-2007 because some targets are computed within *SIM* as a function of stream flow. Lengthening the hydrologic period-of-analysis has only minimal impacts on volume reliabilities for the aggregate summation of all diversion targets in the dataset. Volume reliabilities for the summation of all diversions in the dataset are shown in the last line of the Tables 7.2 and 7.3 summaries. Total volume reliabilities are 89.97% and 89.94%, respectively, for 1940-1997 and 1940-2007 periods-of-analysis, for the Bwam3 dataset of Table 7.2. The volume reliabilities for the total of all diversions in the Bwam8 dataset are 94.18% and 94.27%, respectively, for 1940-1997 and 1940-2007 periods-of-analysis. Volume reliabilities are 90.16% and 89.95%, respectively, for 1900-1939 and 1900-2007 periods-of-analysis, for the Bwam3 dataset of Table 7.3. The volume reliabilities for the total of all diversions in the Bwam8 dataset are 94.37% and 94.27%, respectively, for 1900-1939 and 1900-2007 periods-of-analysis.

Reliabilities computed with the *TABLES* 2REL record feature for water supply diversions from 14 of the larger reservoirs are tabulated in Tables 7.8, 7.9, and 7.10 for Bwam3 and Tables 7.11, 7.12, and 7.13 for Bwam8. The locations of these 14 reservoirs are shown in Figure 3.4. Storage capacities, diversion targets, and other information are tabulated in Tables 3.6 and 3.10. The statistics shown in the reliability tables represent the aggregated totals of all diversions at the specified control points. The control points corresponding to each of the 14 reservoirs are listed below Tables 7.11 and 7.13.

Lengthening the hydrologic period-of-analysis has little impact on the reliabilities of the diversions from these 14 reservoirs. Bwam3 volume reliabilities for the total of all diversions from the 14 reservoirs are 96.76% and 96.53%, respectively, for 1940-1997 and 1940-2007 periods-of-analysis. The Bwam8 reliabilities are 100.0% for all 14 reservoirs except Somerville Reservoir which has 1940-1997 and 1940-2007 reliabilities of 99.80% and 99.83%. Bwam3 and Bwam8 volume reliabilities for the aggregate of all diversions associated with the 14 reservoirs for a 1900-1939 simulation are 97.76% and 100.00%, respectively.

Table 7.8
1900-1939 Reliabilities for Bwam3 Authorized Use Diversions

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS 100%	98%	95%	90%	75%	50%	1%
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515731	19084.6	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	95612.2	2518.90	92.50	97.37	92.5	92.5	92.7	92.7	99.6	100.0	100.0	87.5	87.5	90.0	92.5	95.0	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	13610.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	19840.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4146P1	35000.0	9507.24	68.96	72.84	69.0	69.6	70.0	70.6	71.7	74.2	75.4	32.5	35.0	37.5	40.0	67.5	75.0	97.5
421331	56000.0	7247.76	84.58	87.06	84.6	84.6	84.8	85.2	86.2	87.3	87.7	70.0	70.0	70.0	70.0	90.0	90.0	97.5
Total	861261.8	19273.93		97.76														

Table 7.9
1940-1997 Reliabilities for Bwam3 Authorized Use Diversions for Simulation Beginning in 1940

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS 100%	98%	95%	90%	75%	50%	1%
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515731	18907.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	91518.6	2280.27	94.68	97.51	94.7	94.7	94.8	95.1	99.6	99.7	100.0	89.7	89.7	93.1	94.8	96.6	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	367.19	98.85	99.46	98.9	99.0	99.0	99.3	99.4	99.6	99.6	94.8	94.8	96.6	96.6	100.0	100.0	100.0
516231	13610.0	229.43	98.13	98.31	98.1	98.1	98.1	98.1	98.3	98.4	98.6	93.1	94.8	94.8	94.8	98.3	98.3	100.0
516331	19840.0	53.35	99.57	99.73	99.6	99.6	99.6	99.6	99.6	99.7	99.9	96.6	96.6	98.3	98.3	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	189.42	99.14	99.61	99.1	99.1	99.1	99.1	99.3	99.4	99.6	96.6	96.6	96.6	98.3	100.0	100.0	100.0
4146P1	35000.0	15852.58	49.28	54.71	49.3	49.6	50.4	51.1	52.9	56.0	58.6	24.1	24.1	27.6	29.3	34.5	46.6	89.7
421331	56000.0	8804.43	82.76	84.28	82.8	83.0	83.0	83.5	84.2	84.5	85.1	69.0	69.0	70.7	70.7	77.6	84.5	98.3
Total	856990.9	27776.70		96.76														

Reservoir	Control Point	Reservoir	Control Point
Possum Kingdom	515531	Stillhouse Hollow	516131
Granbury	515631	Georgetown	516231
Whitney	515731	Granger	516331
Aquilla	515831	Limestone	516531
Waco	509431	Somerville	516431
Proctor	515931	Alan Henry	4146P1
Belton	516031	Hubbard Creek	421331

Table 7.10
1940-2007 Reliabilities for Bwam3 Authorized Use Diversions for Simulation Beginning in 1940

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515731	18894.9	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	90900.9	1944.94	95.47	97.86	95.5	95.5	95.6	95.8	99.6	99.8	100.0	91.2	91.2	94.1	95.6	97.1	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	313.19	99.02	99.54	99.0	99.1	99.1	99.4	99.5	99.6	99.6	95.6	95.6	97.1	97.1	100.0	100.0	100.0
516231	13610.0	195.69	98.41	98.56	98.4	98.4	98.4	98.4	98.5	98.7	98.8	94.1	95.6	95.6	95.6	98.5	98.5	100.0
516331	19840.0	45.51	99.63	99.77	99.6	99.6	99.6	99.6	99.6	99.8	99.9	97.1	97.1	98.5	98.5	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	161.56	99.26	99.66	99.3	99.3	99.3	99.3	99.4	99.5	99.6	97.1	97.1	97.1	98.5	100.0	100.0	100.0
4146P1	35000.0	16944.20	46.32	51.59	46.3	46.6	47.3	48.2	49.9	53.1	55.5	22.1	22.1	25.0	26.5	30.9	44.1	89.7
421331	56000.0	10124.41	80.15	81.92	80.1	80.4	80.4	80.9	82.0	82.4	83.0	63.2	63.2	64.7	66.2	73.5	82.4	98.5
Total	856360.8	29729.53		96.53														

Table 7.11
1900-1939 Reliabilities for Bwam8 Current Use Diversions

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS WITH DIVERSIONS EQUALING OR EXCEEDING PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515731	18773.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	43558.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.4	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
4146P1	288.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	461868.3	0.01		100.00														

Reservoir	Control Point
Possum Kingdom	515531
Granbury	515631
Whitney	515731
Aquilla	515831
Waco	509431
Proctor	515931
Belton	516031

Reservoir	Control Point
Stillhouse Hollow	516131
Georgetown	516231
Granger	516331
Limestone	516531
Somerville	516431
Alan Henry	4146P1
Hubbard Creek	421331

Table 7.12
1940-1997 Reliabilities for Bwam8 Current Use Diversions for Simulation Beginning in 1940

CONTROL POINT	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515731	18789.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	43244.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.5	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	95.78	99.43	99.80	99.4	99.6	99.6	99.6	99.6	99.7	99.9	96.6	96.6	98.3	100.0	100.0	100.0	100.0
4146P1	288.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	461570.0	95.79		99.98														

Table 7.13
1940-2007 Reliabilities for Bwam8 Current Use Diversions for Simulation Beginning in 1940

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515731	18762.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	42935.6	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.5	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	81.69	99.51	99.83	99.5	99.6	99.6	99.6	99.6	99.8	99.9	97.1	97.1	98.5	100.0	100.0	100.0	100.0
4146P1	288.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	461234.6	81.70		99.98														

Naturalized and Regulated Flow Frequency Statistics

Naturalized monthly flows for 1900-2007 at the 77 primary control points are plotted in Appendix A. Naturalized flows are the same for both the Bwam3 and Bwam8 input datasets. Regulated flows are computed in the *SIM* simulation. Frequency statistics for regulated and naturalized flows for the periods 1940-1997 and 1940-2007 at the Richmond and Waco gaging stations on the Brazos River and Cameron gaging station on the Little River are compared in Tables 7.14, 7.15, and 7.16. The locations of these gaging stations are shown in Figure 3.4.

The Richmond gaging station (control point BRRI70) on the lower Brazos River is near the outlet of the Brazos River Basin. The Bwam3 1940-2007 mean regulated flow at the Richmond gage is 105.2 percent of the 1940-1997 mean regulated flow. The Bwam8 1940-2007 mean regulated flow at the Richmond gage is 104.8 percent of the 1940-1997 mean regulated flow. The monthly regulated flows for all the exceedance frequencies listed in Table 7.9 are higher for the 1940-2007 hydrologic period-of-analysis than for the 1940-1997 period-of-analysis. The minimum and maximum monthly flow volumes occur during 1940-1997 and thus are the same for 1940-1997 and 1940-2007.

The differences between 1940-2007 and 1940-1997 regulated flows are smaller at the Waco gage and larger at the Cameron gage. The Bwam3 and Bwam8 1940-2007 mean regulated flows at the Waco gage are 100.88 and 101.07 percent of the 1940-1997 mean regulated flow. The Bwam3 and Bwam8 1940-2007 mean regulated flows at the Cameron gage are 110.6 and 109.7 percent of the 1940-1997 mean regulated flow.

Table 7.14
Stream Flow Frequency Statistics
Richmond Gage on Brazos River (Control Point BRRI70)

	Naturalized Flow		Bwam3 Regulated Flow		Bwam8 Regulated Flow	
	1940-1997	1940-2007	1940-1997	1940-2007	1940-1997	1940-2007
	Monthly Flow Volumes in acre-feet/month					
Mean	487,519	509,422	386,857	407,019	431,605	452,266
Std Dev	613,002	630,905	563,876	582,501	591,821	609,670
Minimum	0.0	0.0	307	307	8,291	8,291
99.50%	14,215	16,279	10,582	11,833	16,088	16,643
99%	18,383	22,129	13,297	14,657	19,519	20,403
98%	25,402	28,095	17,714	18,909	24,983	25,642
95%	39,522	44,498	27,684	27,919	32,928	33,228
90%	53,888	57,081	36,444	37,496	43,425	46,235
85%	72,717	79,495	43,725	46,337	56,039	57,557
80%	89,258	98,228	53,567	55,253	66,842	69,919
75%	111,204	117,514	64,431	66,244	82,597	84,368
70%	133,510	138,601	71,386	72,188	95,838	98,628
60%	184,723	193,899	95,550	101,294	133,416	141,432
50%	257,456	275,325	148,801	162,456	191,962	209,882
40%	358,553	375,995	236,229	254,218	283,122	306,974
30%	512,053	537,955	382,698	405,691	435,104	461,306
25%	653,272	665,039	474,586	527,407	571,341	595,695
20%	779,791	808,886	633,476	675,605	687,082	752,153
15%	981,968	1,025,466	823,337	853,112	904,138	937,893
10%	1,230,723	1,313,844	1,064,539	1,122,514	1,147,463	1,236,303
5%	1,674,399	1,730,180	1,484,334	1,527,559	1,559,551	1,586,916
2%	2,220,046	2,339,623	2,060,751	2,222,482	2,102,152	2,285,604
1%	2,859,000	2,895,033	2,667,753	2,738,197	2,776,821	2,818,921
0.50%	3,570,109	3,709,790	3,360,573	3,515,712	3,498,644	3,656,486
Maximum	6,135,975	6,135,975	5,489,781	5,489,781	5,994,799	5,994,799

Table 7.15
Stream Flow Frequency Statistics
Waco Gage on Brazos River (Control Point BRWA41)

	Naturalized Flow		Bwam3 Regulated Flow		Bwam8 Regulated Flow	
	1940-1997	1940-2007	1940-1997	1940-2007	1940-1997	1940-2007
	Monthly Flow Volumes in acre-feet/month					
Mean	161,860	164,158	116,077	117,104	134,062	135,498
Std Dev	266,253	266,706	239,206	238,274	257,189	256,204
Minimum	0.0	0.0	0.00	0.00	0.00	0.00
99.50%	163	365	0.00	1.43	4.78	5.23
99%	1,577	1,784	30.1	47.0	49.5	55.1
98%	3,434	3,963	342	693	446	960
95%	6,300	6,925	1,704	1,835	1,783	2,028
90%	10,364	11,561	3,166	3,542	3,430	3,824
85%	15,181	16,696	5,041	5,499	5,693	5,951
80%	19,453	21,508	6,327	7,071	6,365	7,459
75%	24,749	28,105	7,794	8,380	8,510	10,006
70%	31,006	35,469	9,398	10,988	12,160	14,943
60%	45,705	52,398	16,568	18,728	22,147	25,689
50%	68,642	72,277	27,046	29,727	39,225	42,490
40%	102,411	103,161	48,735	50,483	66,374	67,832
30%	146,341	146,641	84,108	85,280	109,302	110,672
25%	183,578	183,794	118,686	121,435	136,962	141,624
20%	233,939	229,119	152,683	154,544	188,975	190,705
15%	298,821	294,282	230,865	221,762	253,320	253,166
10%	422,755	418,373	343,890	326,824	383,896	364,820
5%	642,244	642,244	576,939	576,939	606,972	606,972
2%	941,918	953,417	817,529	828,847	884,561	897,974
1%	1,274,838	1,357,912	1,151,579	1,240,458	1,197,035	1,309,408
0.50%	1,509,141	1,692,190	1,393,884	1,485,719	1,466,739	1,554,218
Maximum	3,376,485	3,376,485	3,131,747	3,131,747	3,319,012	3,319,012

Table 7.16
Stream Flow Frequency Statistics
Cameron Gage on Little River (Control Point LRLC58)

	Naturalized Flow		Bwam3 Regulated Flow		Bwam8 Regulated Flow	
	1940-1997	1940-2007	1940-1997	1940-2007	1940-1997	1940-2007
	Monthly Flow Volumes in acre-feet/month					
Mean	109,858	119,080	83,223	92,032	91,173	100,049
Std Dev	170,466	180,519	157,642	168,636	161,881	172,663
Minimum	0.00	0.00	0.00	0.00	1,112	1,112
99.50%	200	219	2.37	4.99	1,230	1,230
99%	494	660	85.5	209	1,230	1,423
98%	1,249	1,322	579	875	2,576	2,607
95%	2,706	3,067	1,190	1,230	3,475	3,714
90%	5,440	6,508	1,261	1,774	5,045	5,385
85%	8,667	10,274	2,597	3,244	6,184	6,745
80%	11,904	13,974	3,809	4,969	7,725	8,226
75%	15,032	17,905	5,832	6,872	9,493	10,057
70%	19,041	21,484	7,550	8,472	11,601	12,209
60%	28,988	32,137	12,459	13,819	16,299	17,959
50%	44,799	49,457	18,935	21,426	23,839	27,067
40%	65,294	74,405	31,839	36,107	40,617	45,225
30%	104,549	113,804	63,957	73,404	74,615	82,334
25%	130,473	143,003	87,682	102,047	98,849	112,672
20%	165,070	187,538	122,211	140,475	135,248	159,670
15%	226,731	239,431	176,409	199,822	192,577	213,333
10%	290,433	315,687	235,472	264,861	248,450	278,106
5%	426,869	458,577	389,504	412,225	409,628	436,402
2%	667,571	710,418	592,517	638,865	605,900	649,114
1%	804,195	957,932	696,354	913,298	712,484	945,745
0.50%	1,198,902	1,161,034	1,173,751	1,120,576	1,185,201	1,131,497
Maximum	1,403,136	1,403,136	1,399,450	1,399,450	1,406,391	1,406,391

Reservoir Storage

The Bwam3 and Bwam8 datasets contain 665 and 706 reservoirs, respectively, with total conservation storage capacities of 4,694,850 acre-feet and 4,023,350 acre-feet. Frequency statistics for end-of-month storage volumes in these reservoirs are compared in Table 7.17 for the 1900-1939, 1940-1997, and 1940-2007 hydrologic periods-of-analysis. The 1900-1939 simulations begin with the reservoirs full to capacity at the beginning of January 1900. Likewise, the 1940-1997 and 1940-2007 simulations start with the reservoirs full at the beginning of January 1940. The mean end-of-month storage volume in the 665 Bwam3 reservoirs during the 1900-1939 (480 months) simulation is 103.9% of the corresponding mean storage of the 1940-1997 (696 months) simulation. The Bwam3 mean storage volume for the 1940-2007 simulation is 99.94% of the corresponding mean storage of the 1940-1997 simulation.

Table 7.17
Storage-Frequency for Alternative Simulation Periods

	Bwam3 Authorized Use			Bwam8 Current Use		
	1900-1939	1940-1997	1940-2007	1900-1939	1940-1997	1940-2007
	End-of-Month Storage Volume (acre-feet) of 665 Bwam3 or 706 Bwam8 Reservoirs					
mean	3,644,940	3,506,458	3,504,212	3,666,620	3,460,329	3,472,296
standard deviation	588,348	607,338	570,852	275,907	363,554	342,144
100%	1,733,141	1,518,825	1,518,825	2,740,942	2,093,678	2,093,678
99%	1,842,157	1,675,468	1,707,477	2,787,847	2,235,064	2,249,634
98%	2,047,281	1,811,885	1,888,234	2,937,744	2,358,366	2,441,818
95%	2,298,465	2,266,194	2,365,693	3,050,321	2,670,920	2,751,328
90%	2,780,294	2,691,605	2,763,078	3,216,304	2,980,643	3,052,299
75%	3,465,788	3,236,247	3,262,166	3,561,048	3,303,272	3,334,038
60%	3,653,495	3,497,950	3,486,026	3,687,980	3,477,918	3,483,882
50%	3,799,856	3,597,546	3,575,640	3,745,262	3,552,828	3,553,784
40%	3,878,855	3,724,485	3,675,425	3,811,594	3,612,524	3,605,531
25%	3,993,207	3,898,245	3,868,355	3,867,448	3,713,852	3,705,539
10%	4,250,634	4,172,872	4,103,305	3,923,675	3,795,034	3,792,939
maximum	4,688,516	4,647,887	4,647,887	4,019,208	3,996,971	3,996,971

Bwam3 and Bwam8 Simulated Storage Volumes in 14 Reservoirs

Bwam3 and Bwam8 end-of-month storage volumes for 14 reservoirs are plotted in Figures 7.1 through 7.28 for simulations 1 and 3 listed in Table 7.1. Figures 7.29 and 7.30 are plots of the summation of the total storage volume in all 14 reservoirs, representing general basin-wide conditions. The plots of Figures 7.1 through 7.30 span the 1940-2007 hydrologic period-of-analysis. The corresponding plots of the Bwam3 and Bwam8 1900-2007 monthly storage volumes from simulations 2 and 4 listed in Table 7.1 are provided as Appendix D.

The locations of Possum Kingdom, Granbury, Whitney, Aquilla, Waco, Proctor, Belton, Stillhouse Hollow, Georgetown, Granger, Limestone, Somerville, Alan Henry, and Hubbard Creek Reservoirs are shown in Figure 3.4. Storage capacities and other information regarding the reservoirs are tabulated in Tables 3.6 and 3.10. These 14 reservoirs contain 73.5 percent and 76.8 percent of the total conservation storage capacity of the 665 and 706 reservoirs, respectively, in the Bwam3 and Bwam8 datasets. Water supply reliabilities associated with these 14 reservoirs are presented in Tables 7.8 through 7.13.

Reservoir storage volumes or drawdowns provide an index of dry periods including critical drought periods. Severe storage drawdowns representing major drought periods can be readily identified. Individual reservoirs represent different regions of the Brazos River Basin. The plots of Figures 7.1−7.30 and D.1−D.30 show that, with a few exceptions, reservoir storage depletions during 1998-2007 are generally not nearly as large as the 1951-1957 drought and other drought periods during the original 1940-1997 hydrologic period-of-analysis. Severe reservoir storage depletions also occur during 1900-1939.

Bwam3 storage drawdowns are greater than Bwam8 drawdowns as expected since Bwam3 diversion targets are larger. The patterns and timing of major storage depletion periods, though generally similar, also vary between Bwam3 and Bwam8 at some of the reservoirs.

Alan Henry and Hubbard Creek Reservoirs are the extreme cases of dramatic differences between Bwam3 and Bwam8 simulated storage sequences. Bwam3 storage depletions in Lakes Alan Henry and Hubbard Creek are unusually severe, much different than the 12 other reservoirs. Lake Alan Henry (Figures 7.1 and 7.2) is empty much of the time in the Bwam3 simulation but never empties or even comes close to emptying in the Bwam8 simulation, which is very unusual. Lake Hubbard Creek (Figures 7.1 and 7.2) also empties a number of times in the Bwam3 simulation but never empties in the Bwam8 simulation.

The critical drought period for most of the Brazos River Basin began gradually during 1951 and ended abruptly with the flood of April-May 1957. The severity of the 1950's drought relative to the overall 1940-2007 period-of-analysis at the majority of the reservoirs is clearly illustrated by the reservoir storage plots of Figures 7.1-7.30. However, there are exceptions in which more severe or almost as severe drawdowns occur during the 1998-2007 hydrologic period-of-analysis extension.

Likewise, the severity of the 1950's drought relative to the overall 1900-2007 period-of-analysis at the majority of the reservoirs is illustrated by the reservoir storage plots of Figures D.1-D.30 of Appendix D. The Bwam3 reservoir storage plots indicate that severe droughts occurred during the periods from about January 1909 through August 1913 and from about December 1916 through August 1918 that are comparable to the 1950's drought at over half of the 14 reservoirs. The 1909-1913 and 1916-1918 droughts are significantly less severe relative to the 1950's drought in the Bwam8 simulation.

At most of the reservoirs, drawdowns during 1998-2007 are much less severe that the droughts of 1909-1913, 1916-1918, and 1950-1957. However, major draw-downs do occur at several reservoirs after 1997 in the Bwam3 and Bwam8 simulations. Although the 1950's represent a more severe drought period for Waco Reservoir, severe Bwam3 storage drawdowns also occur during the 1960's, 1970's, and early 2000's. Major drawdowns during 1999-2003 occur at Lake Granbury in the Bwam3, though even lower storage levels occur in the 1950's and 1980's. Severe Bwam3 and Bwam8 drawdowns occur at Alan Henry and Hubbard Creek Reservoirs periodically throughout the 1900-2007 hydrologic period-of-analysis including 1998-2007.

Proctor Reservoir is somewhat unique in that it has multiple periods of major Bwam3 and Bwam8 simulated draw-downs of fairly comparable magnitude. In addition to the droughts of 1909-1913, 1916-1918, and 1950-1957, severe Bwam3 and Bwam8 drawdowns for Lake Proctor extend from the late 1970's through early 1980's and during 1999-2001.

<u>Proctor Reservoir</u>

As discussed in Chapters 4 and 6, control point LEHS45 located immediately downstream of Proctor Dam is the only control point for which reservoir releases were adopted for 1998-2007 observed flows. Naturalized flows synthesized earlier using the standard flow distribution method resulted in 1998-2007 Bwam8 storage volumes at Proctor that did not match observed volumes. Consequently, naturalized flows were recomputed based on releases from Proctor Reservoir.

Observed flows measured at USGS stream gaging stations were adopted for 47 other control points. Control point LEHS45 is the site of one of three discontinued USGS gaging stations on the Leon River upstream and downstream of Proctor Reservoir for which gage measurements were not made during 1998-2007. Earlier in the study, naturalized flows at control point LEHS45 were synthesized by applying the 1940-1997 mean flow ratio of 0.548 to naturalized flows at control point LEGT47 which is the still active gaging station on the Leon River near Gatesville. For comparison, the drainage area ratio is 0.539, just slightly less than the 0.548 flow ratio.

Bwam8 storage volumes for 1998-2007 for Proctor Reservoir are very different than observed volumes with the initially estimated naturalized flows. The flows at the site were relatively high, and the reservoir drawdowns were relatively minimal. However, as shown in Figure C.8 in Appendix C, large drawdowns had actually occurred in Proctor Reservoir from 1999 to early 2001 with the storage contents reaching a minimum level of about 11.6 percent of capacity in October 2000. Consequently, the originally computed 1998-2007 naturalized flows at control point LEHS45 were replaced with naturalized flows developed based on adopting measured releases from Proctor Reservoir as gaged flows at LEHS45. The original and revised 1998-2007 naturalized are compared in Table 6.14. The revised LEHS45 naturalized flows resulted in Bwam8 storage volumes that closely reproduce the observed volumes as shown in Figure C.8.

Proctor Reservoir storage volumes are plotted in Figures 7.15, 7.16, D.15, D.16, and C.8. Severe drawdowns occur in 1999-2001 as well as 1909-1913, 1916-1918, 1950-1957, and 1978-1986. The relative severity of these different drought periods vary between Bwam3 and Bwam8.

Observed Versus Simulated 1998-2007 Simulated Storage Volumes

Appendix C provides plots comparing 1998-2007 observed and Bwam3, Bwam8, and Bwam8A simulated storage volumes of the 14 reservoirs. The observed storage volumes available from the U.S. Geological Survey (USGS) National Water Information System (NWIS) online database are determined by reservoir operators and/or USGS personnel based on combining measured water surface elevations with the latest updated relationships between reservoir water surface elevation and storage volume. Bwam3 reservoir storage capacities are based on the information recorded in the water right permits which typically cite pre-construction storage capacities without adjustments for sedimentation. Bwam8 reservoir storage capacities are based on designated top of conservation elevations and estimated year 2000 conditions of sedimentation.

Nine of the 14 reservoirs have flood control pools. The bottom of a flood control pool is the top of the conservation pool. All of the reservoirs allow uncontrolled surcharge storage above the top of conservation pool. The Bwam3 and Bwam8 datasets allow no storage above the designated top of conservation pool. This is evident in the Bwam3 and Bwam8 storage plots in which the storage volume never exceeds the conservation storage capacity. The actual use Bwam8A dataset discussed in earlier chapters does allow storage volumes to exceed conservation storage capacities. The Bwam8A dataset is designed to actually reproduce observed storage volumes.

Plots of 1940-1997 current use scenario simulated storage levels combined with 1998-2007 observed storage levels provide a convenient way to predict whether updating the period-of-analysis will likely change critical reservoir drawdown periods and associated results of firm yield analyses and related types of water availability analyses.

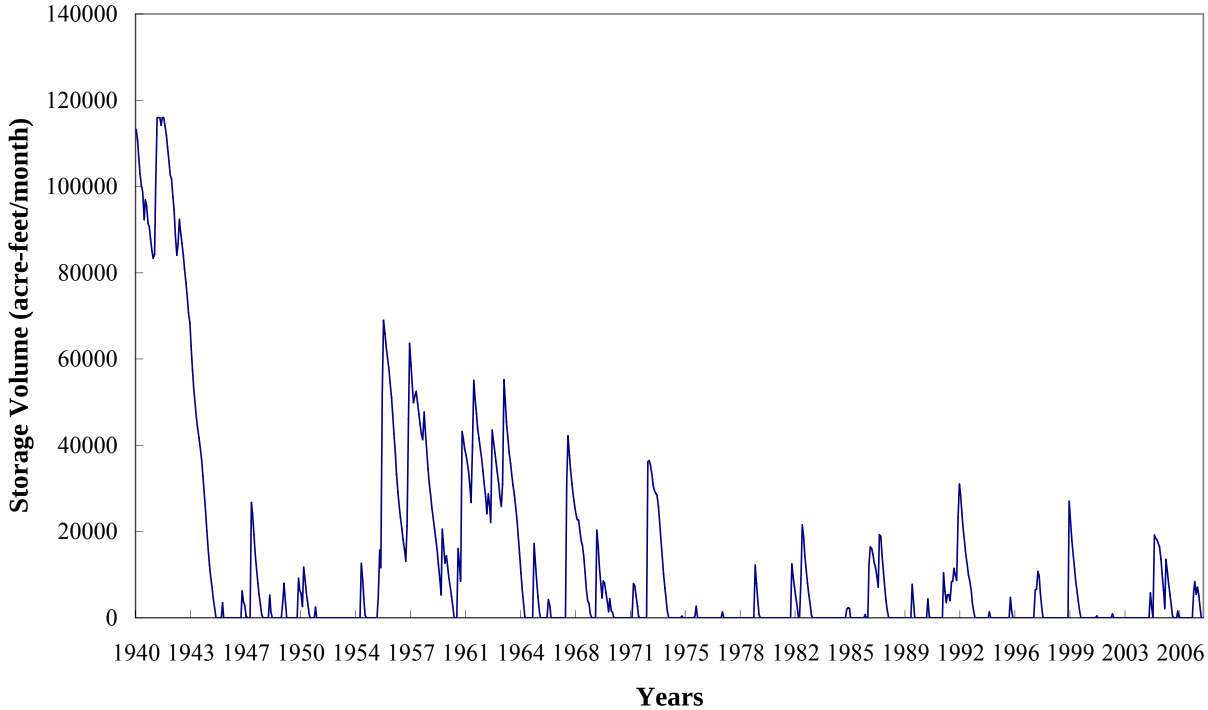

Figure 7.1 Bwam3 Storage Volume of Alan Henry Reservoir

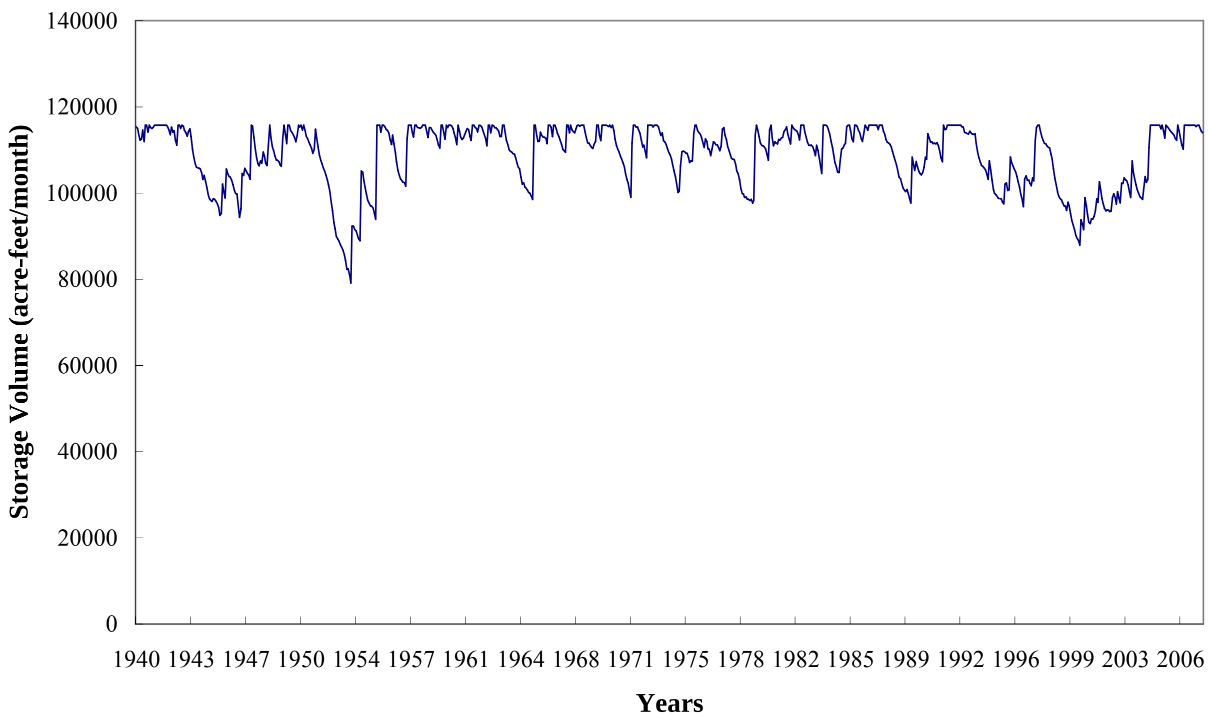

Figure 7.2 Bwam8 Storage Volume of Alan Henry Reservoir

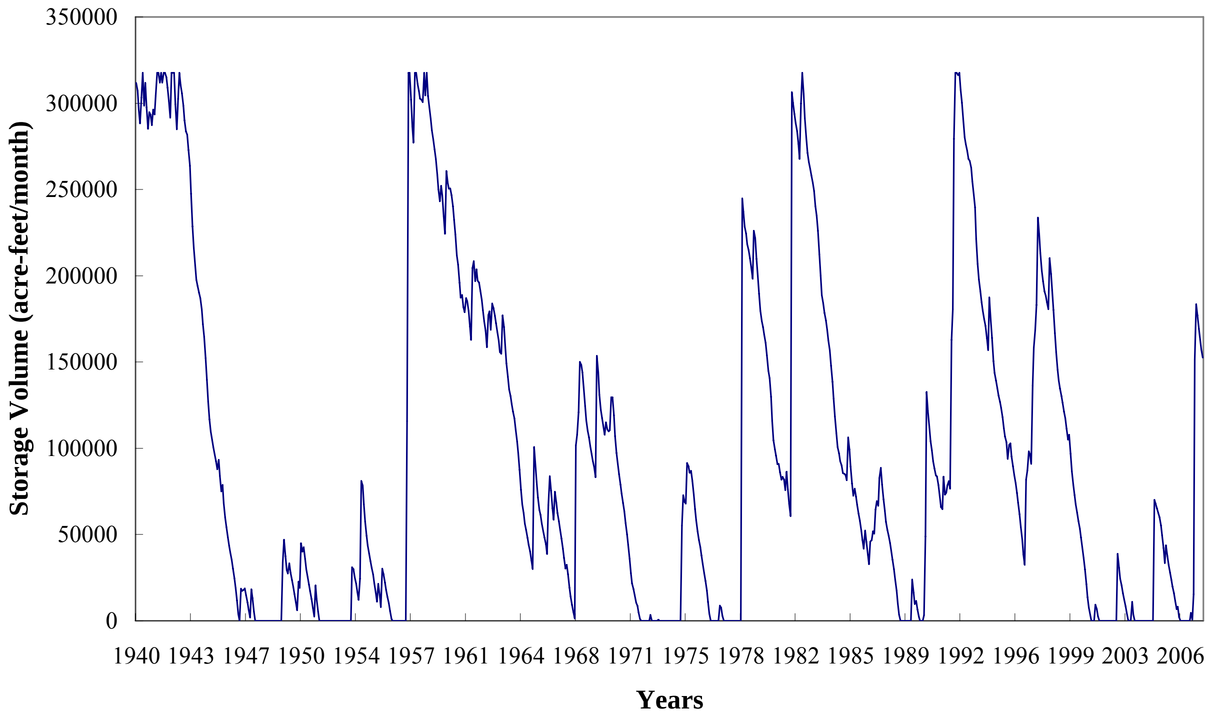

Figure 7.3 Bwam3 Storage Volume of Hubbard Creek Reservoir

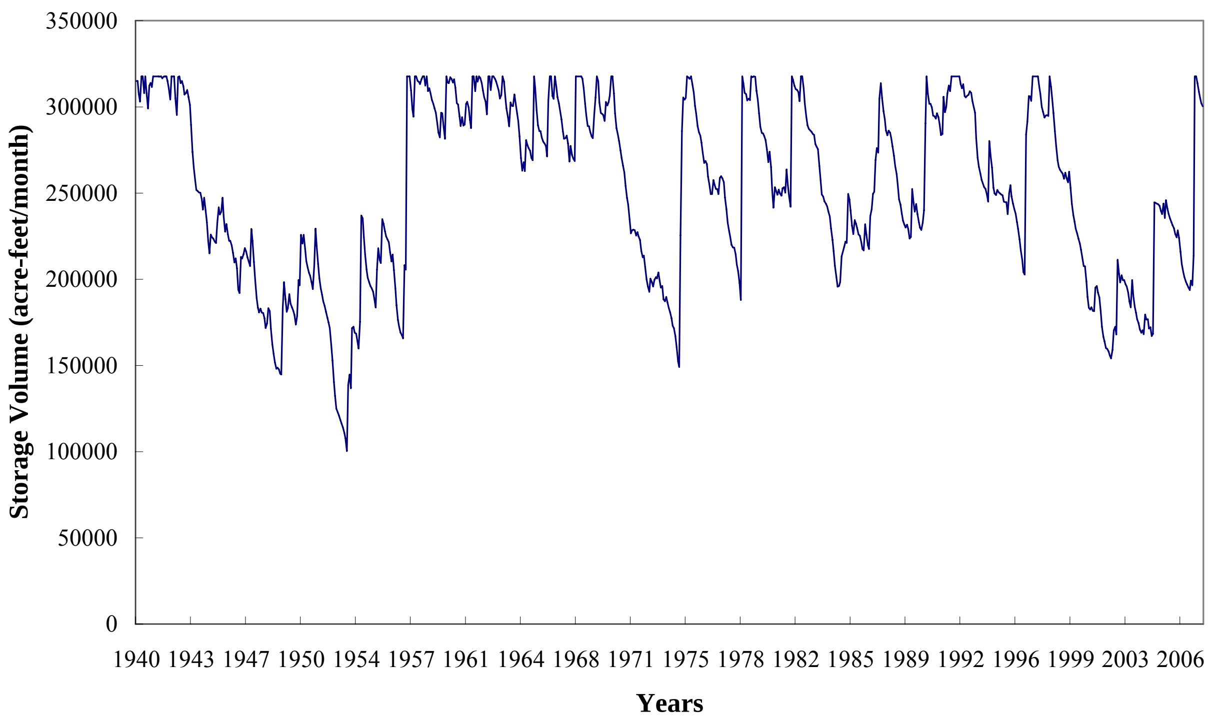

Figure 7.4 Bwam8 Storage Volume of Hubbard Creek Reservoir

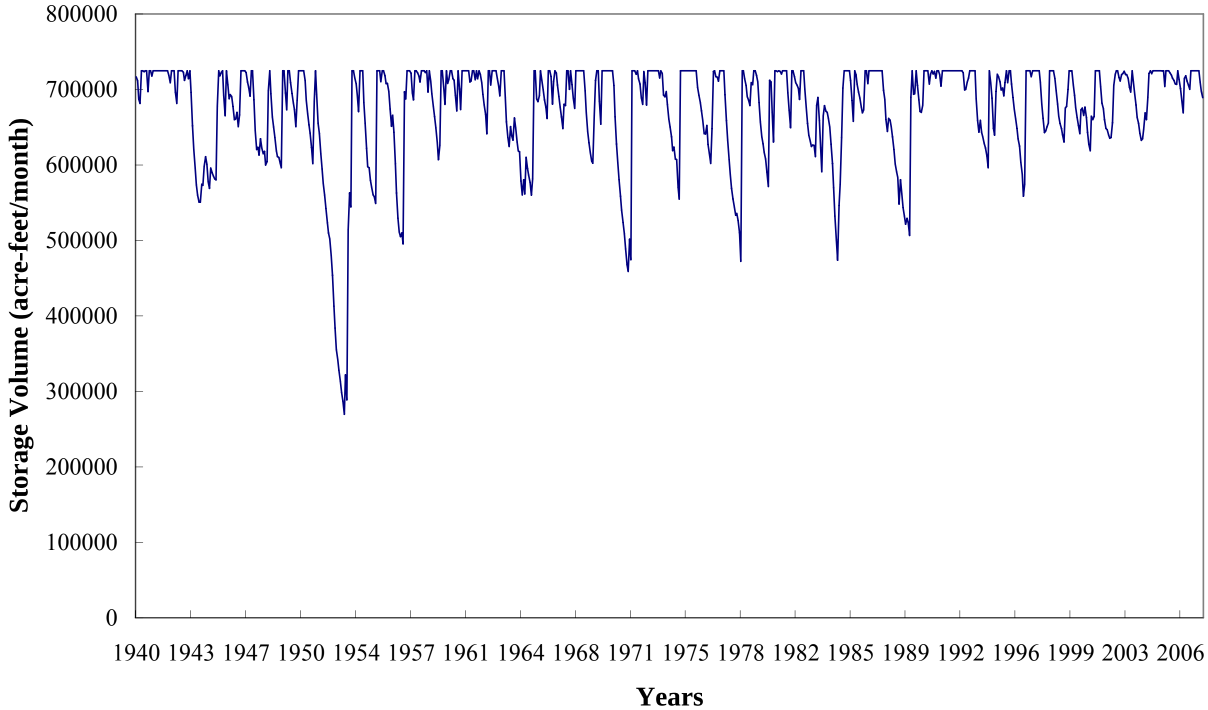

Figure 7.5 Bwam3 Storage Volume of Possum Kingdom Reservoir

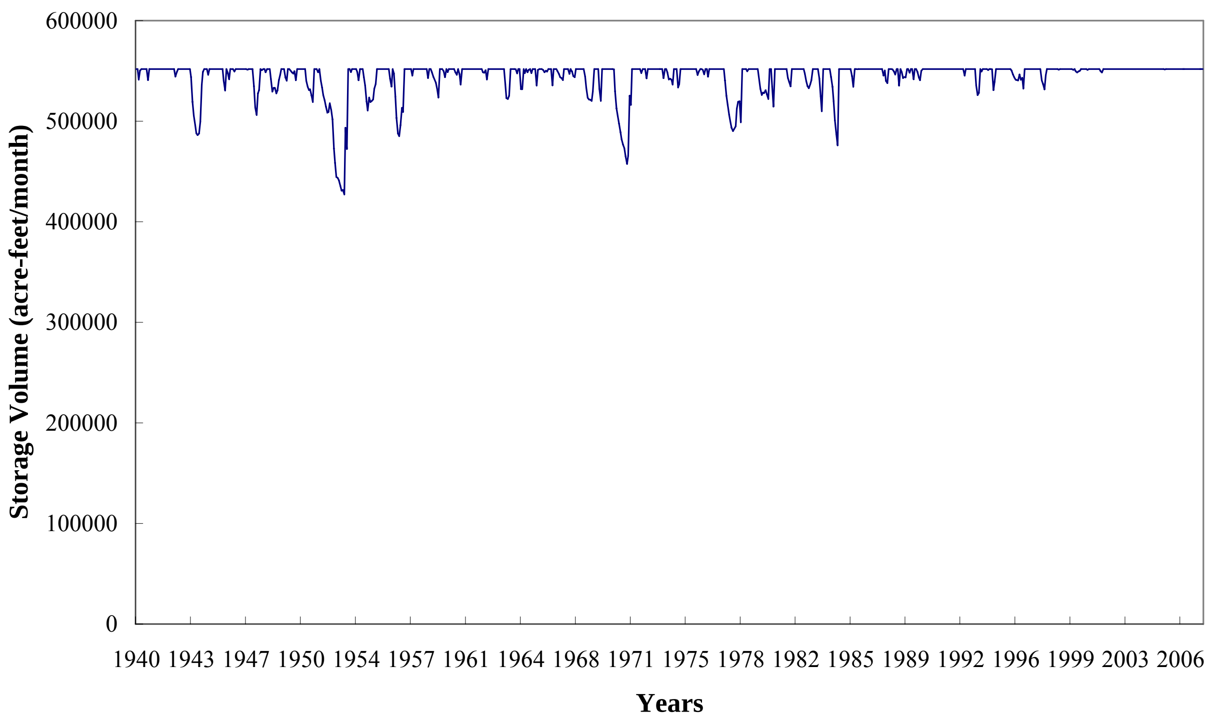

Figure 7.6 Bwam8 Storage Volume of Possum Kingdom Reservoir

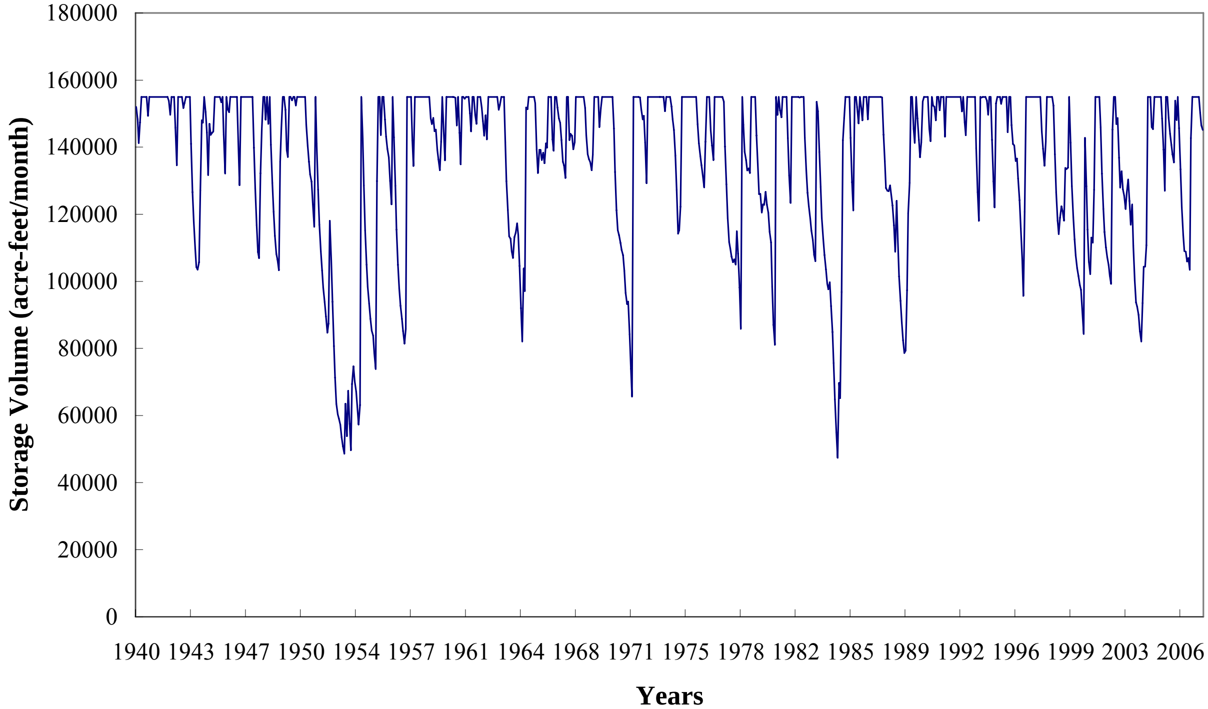

Figure 7.7 Bwam3 Storage Volume of Granbury Reservoir

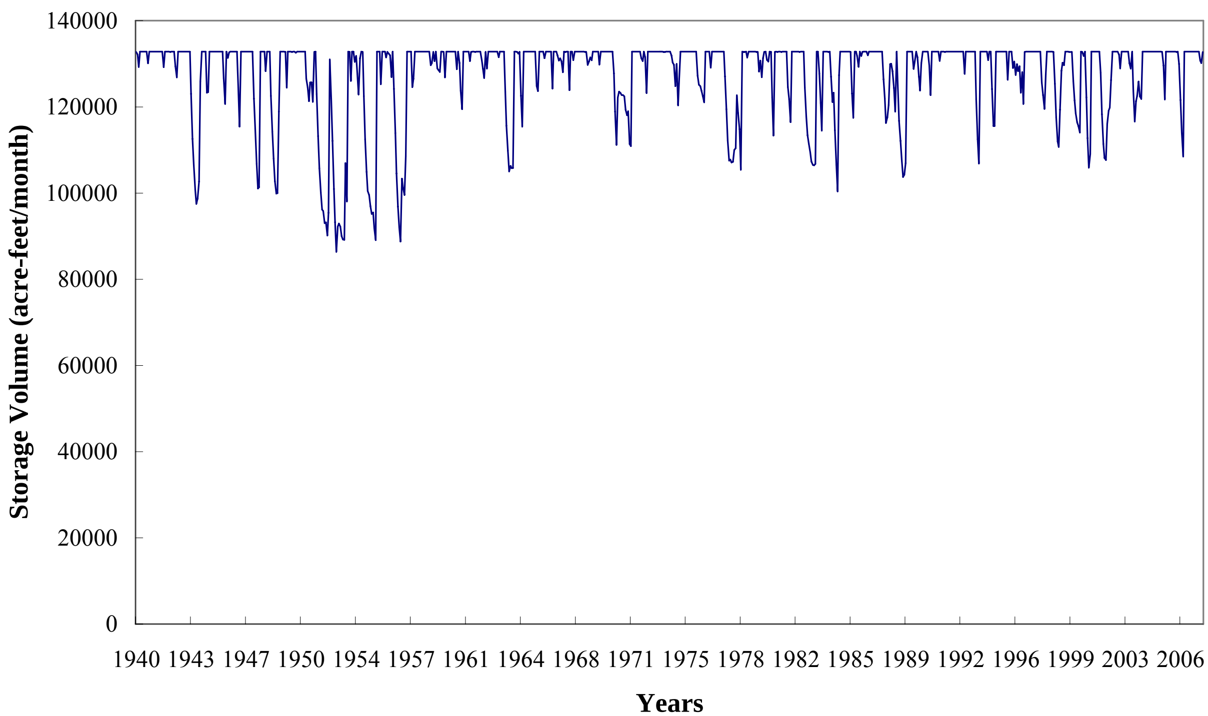

Figure 7.8 Bwam8 Storage Volume of Granbury Reservoir

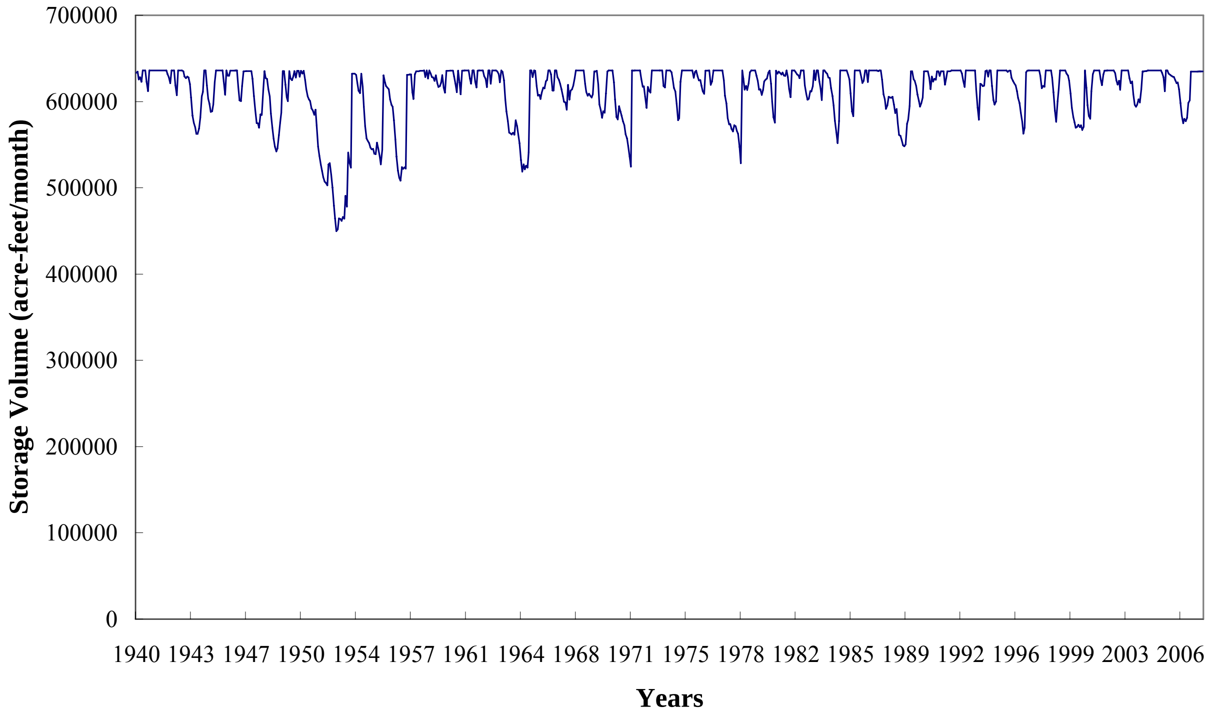

Figure 7.9 Bwam3 Storage Volume of Whitney Reservoir

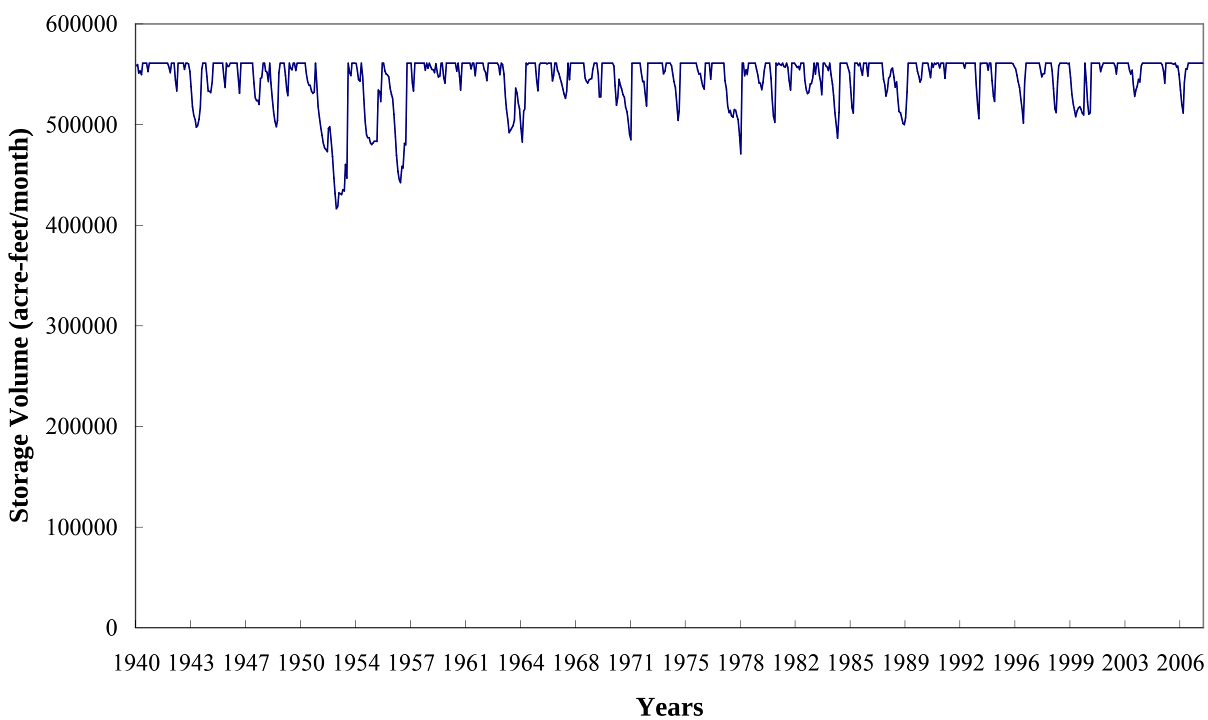

Figure 7.10 Bwam8 Storage Volume of Whitney Reservoir

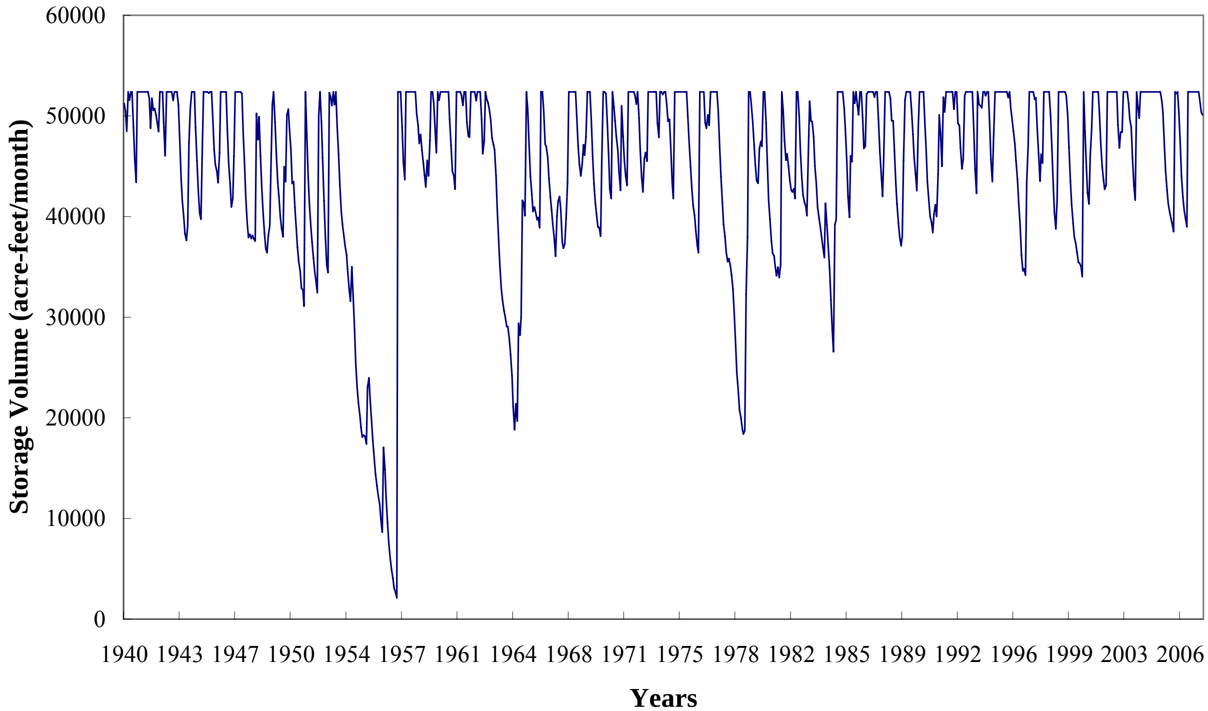

Figure 7.11 Bwam3 Storage Volume of Aquilla Reservoir

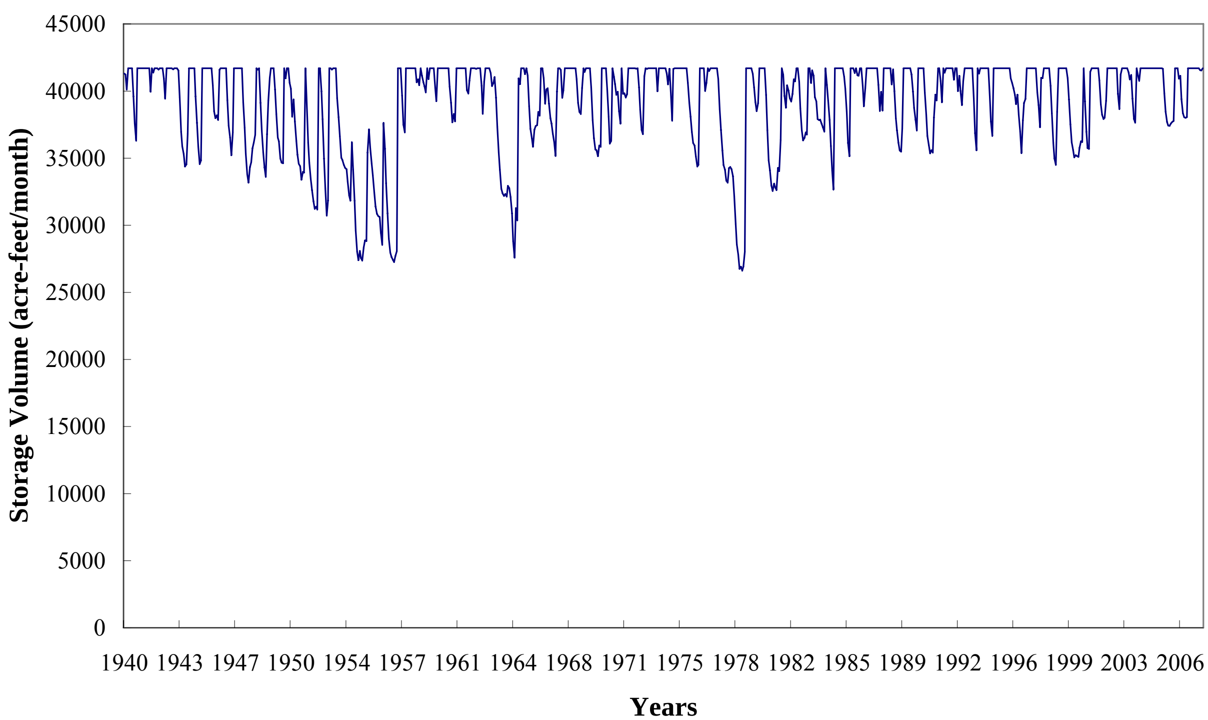

Figure 7.12 Bwam8 Storage Volume of Aquilla Reservoir

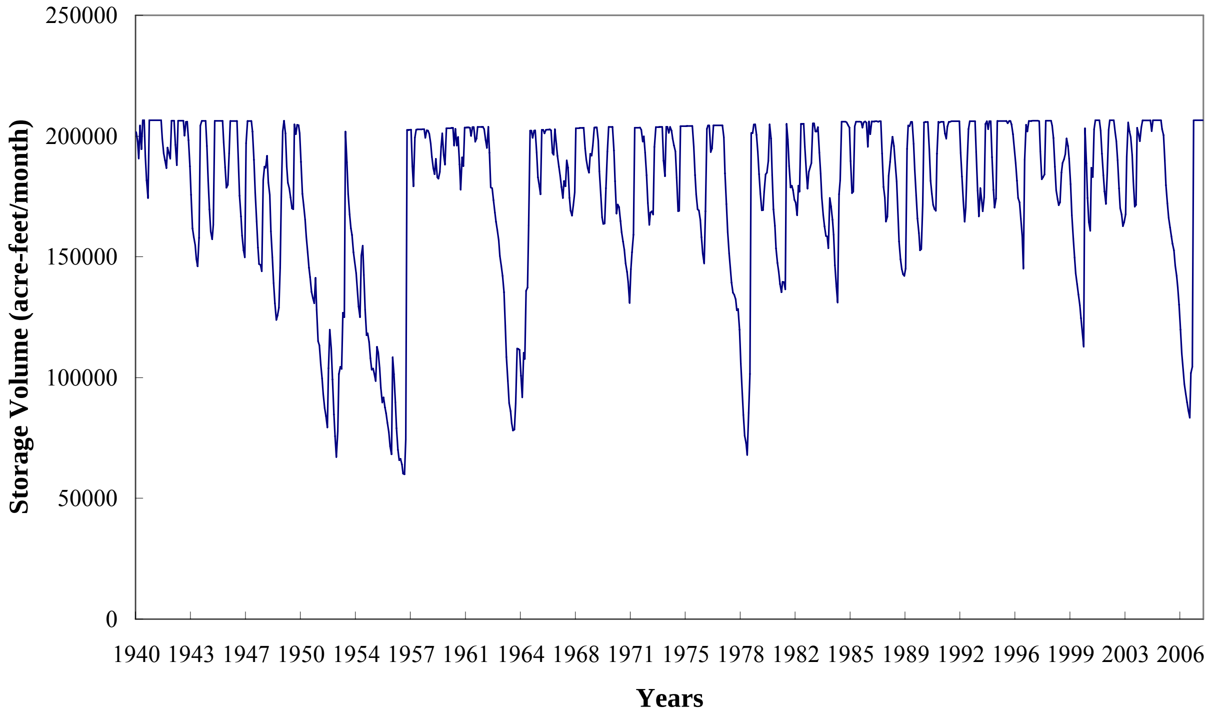

Figure 7.13 Bwam3 Storage Volume of Waco Reservoir

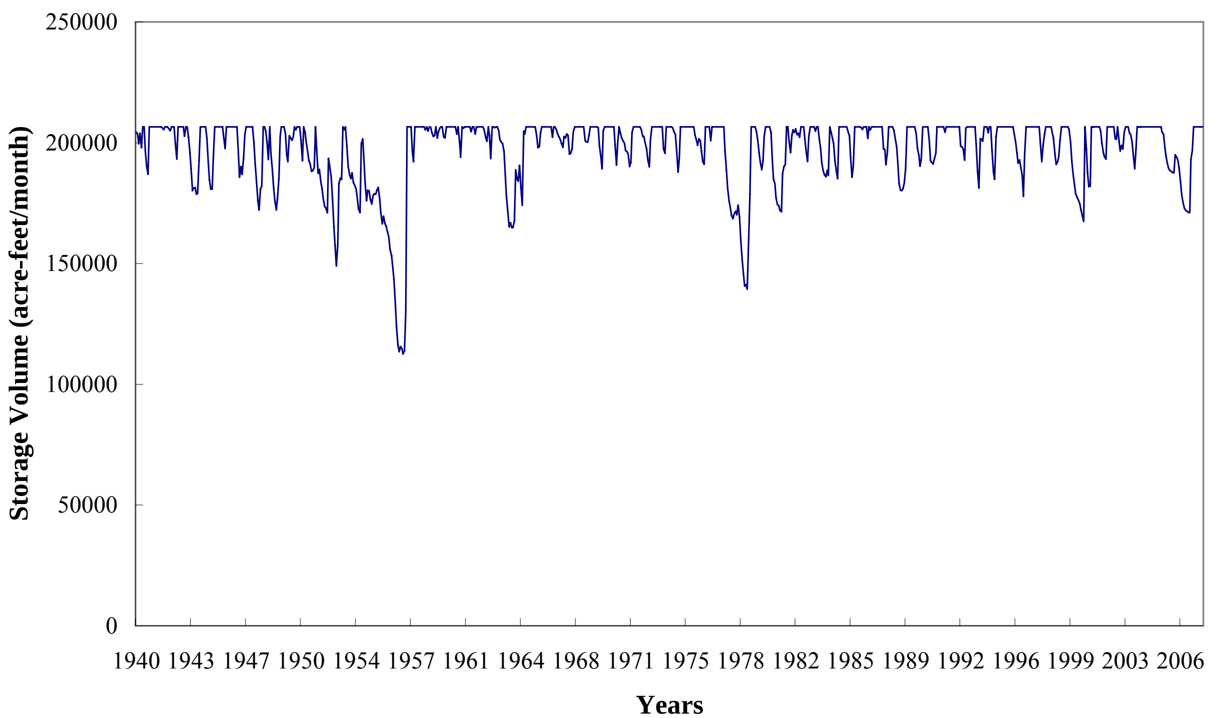

Figure 7.14 Bwam8 Storage Volume of Waco Reservoir

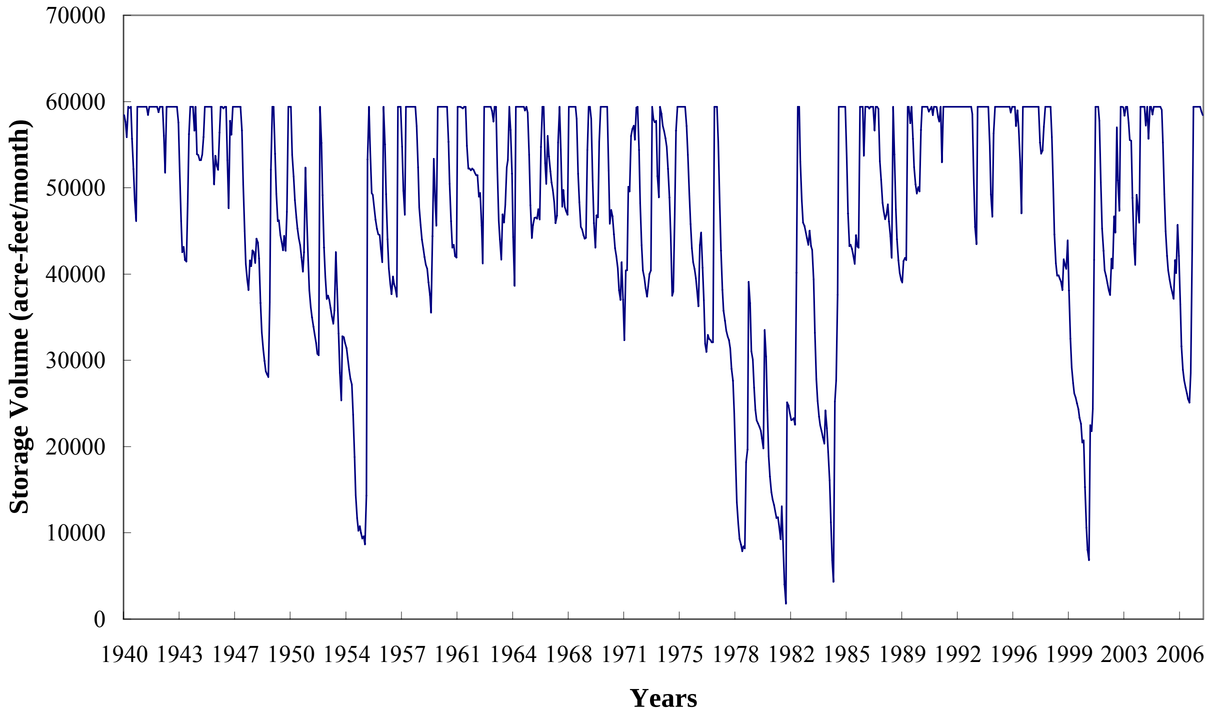

Figure 7.15 Bwam3 Storage Volume of Proctor Reservoir

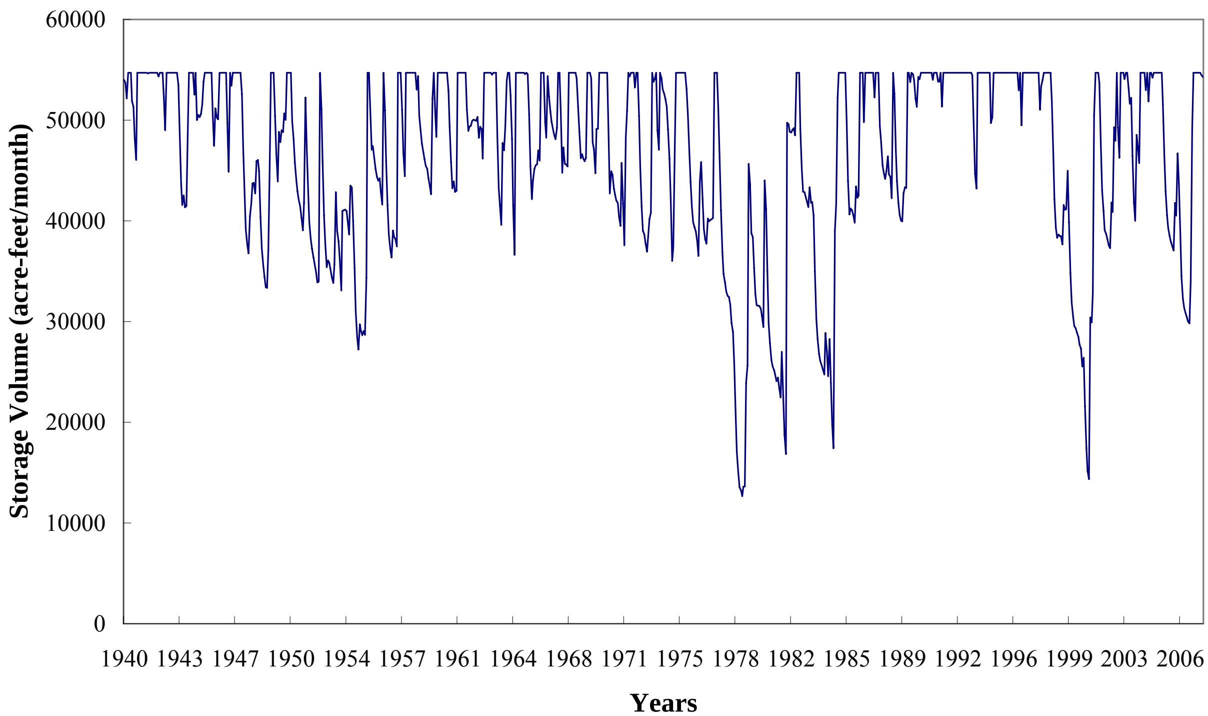

Figure 7.16 Bwam8 Storage Volume of Proctor Reservoir

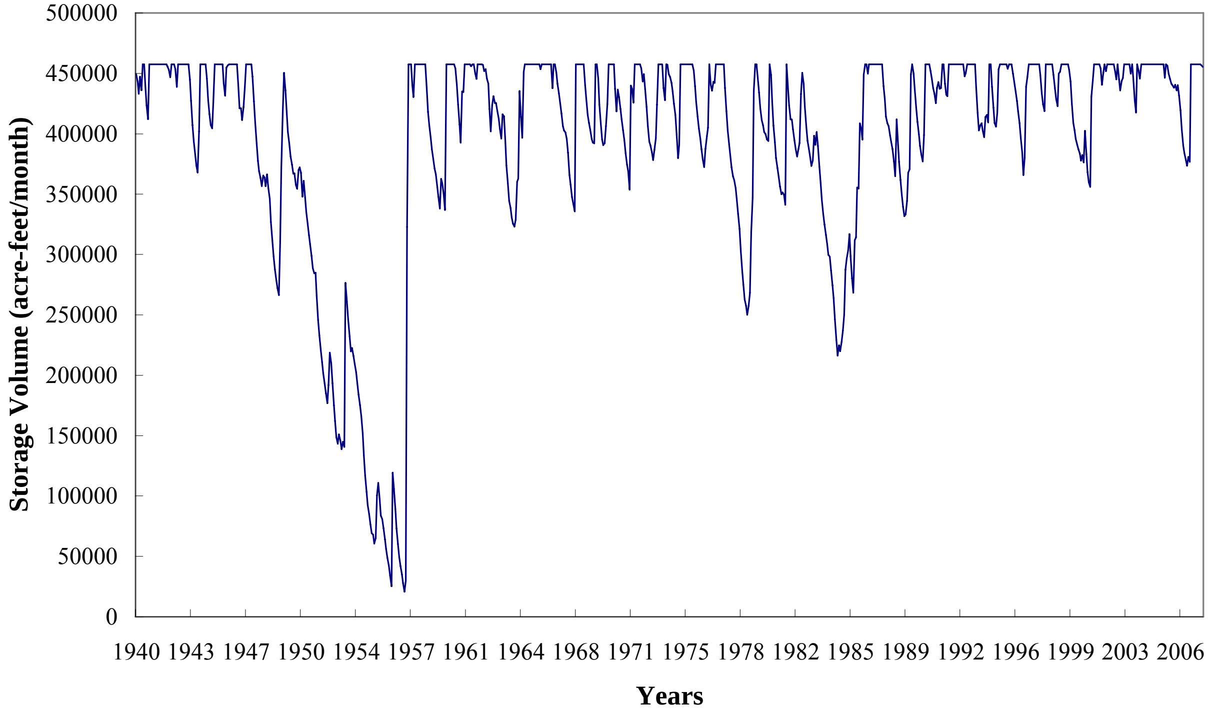

Figure 7.17 Bwam3 Storage Volume of Belton Reservoir

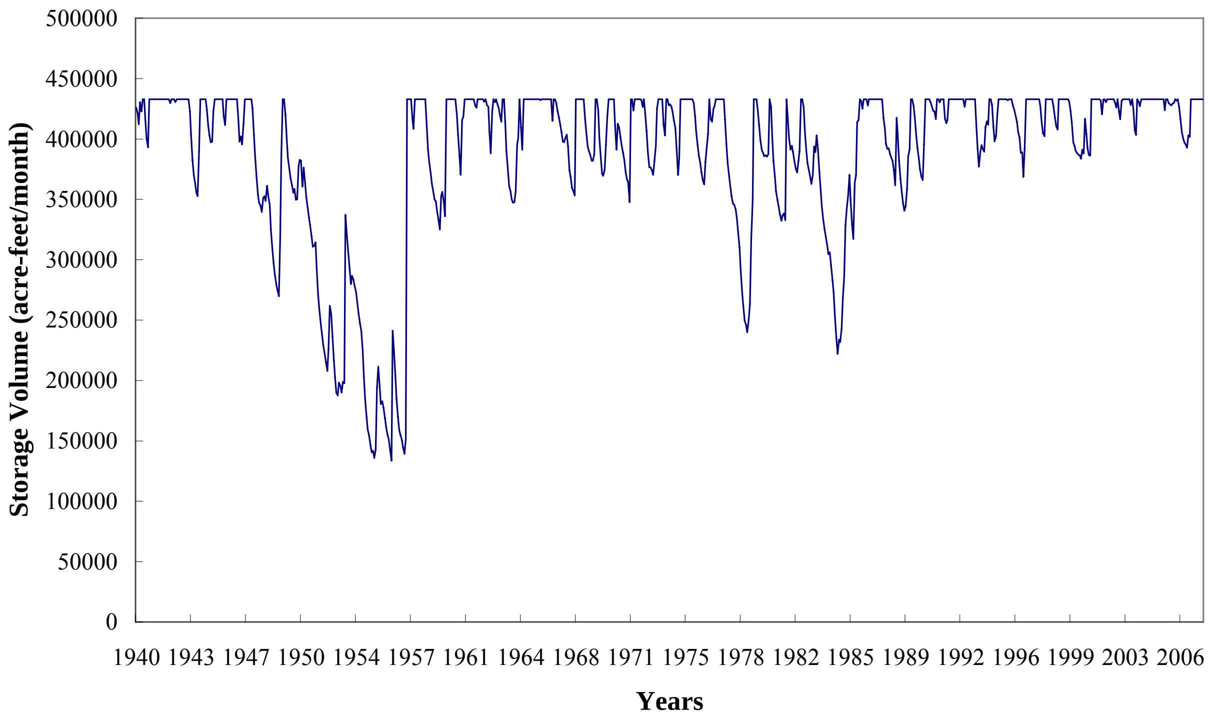

Figure 7.18 Bwam8 Storage Volume of Belton Reservoir

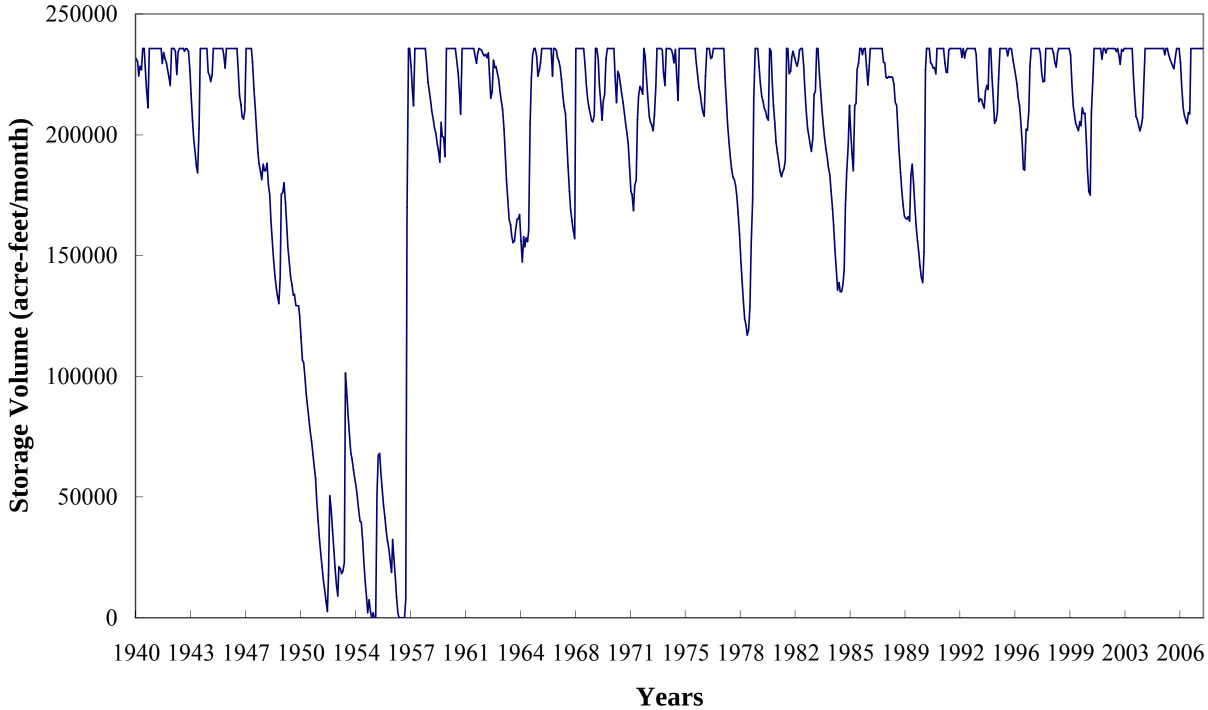

Figure 7.19 Bwam3 Storage Volume of Stillhouse Hollow Reservoir

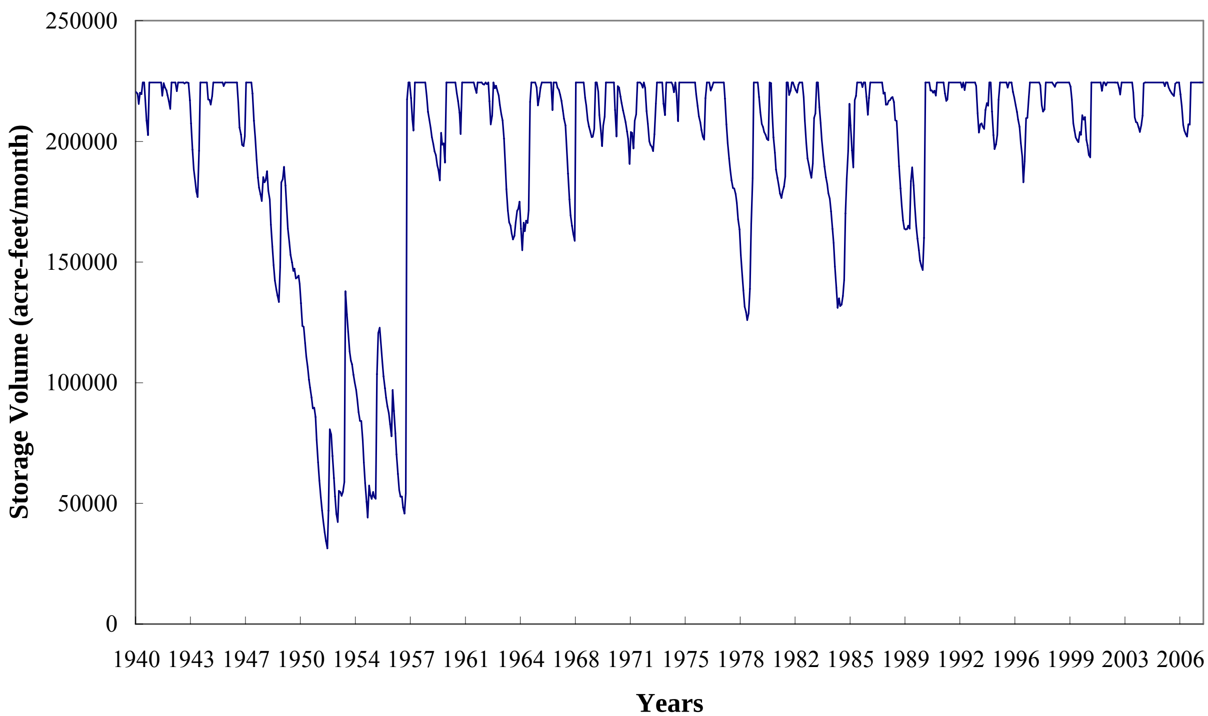

Figure 7.20 Bwam8 Storage Volume of Stillhouse Hollow Reservoir

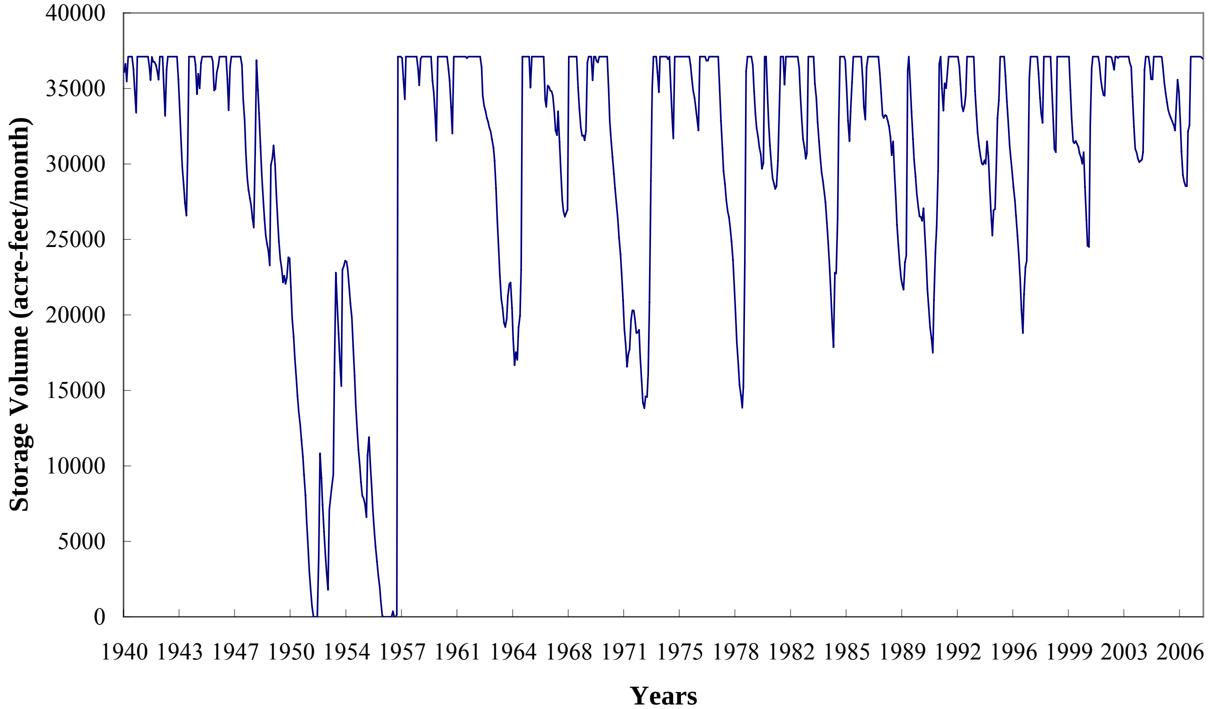

Figure 7.21 Bwam3 Storage Volume of Georgetown Reservoir

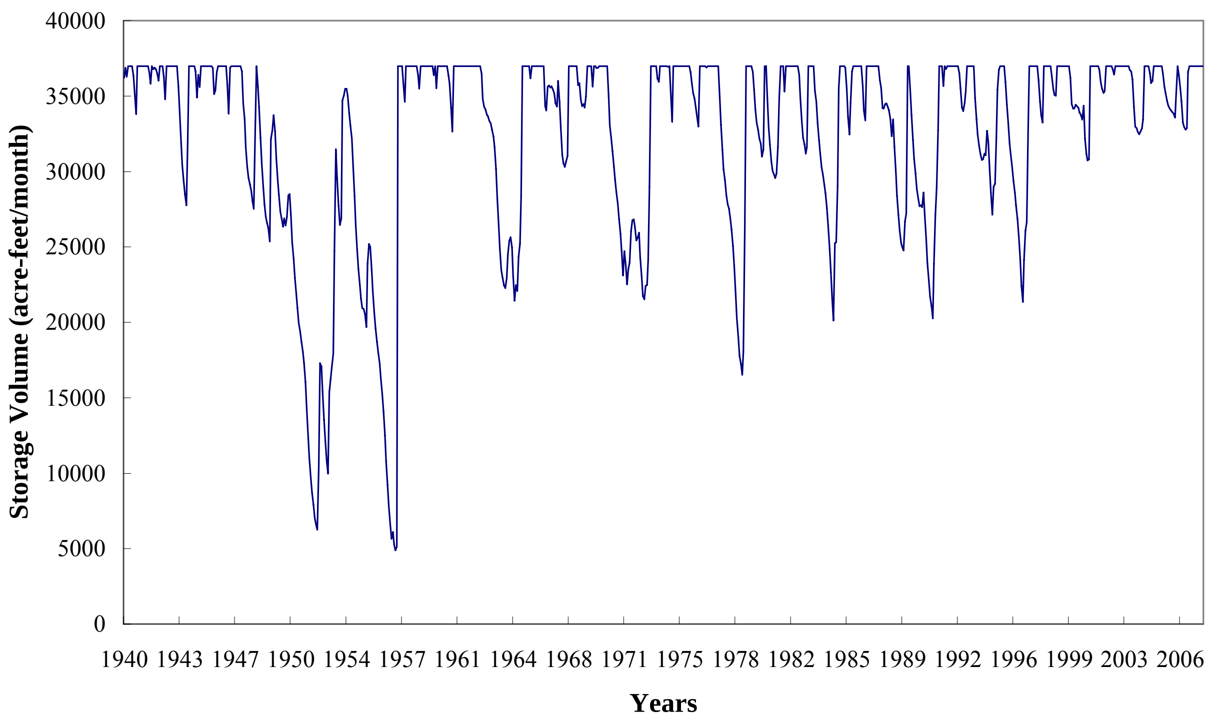

Figure 7.22 Bwam8 Storage Volume of Georgetown Reservoir

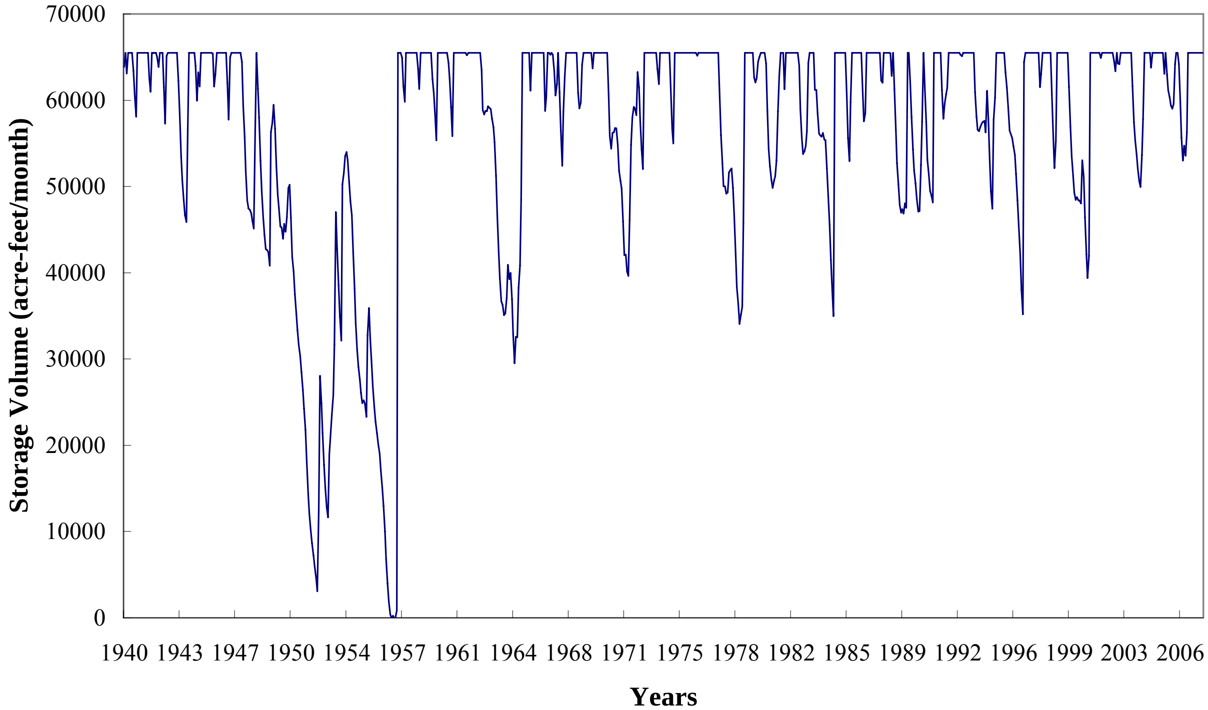

Figure 7.23 Bwam3 Storage Volume of Granger Reservoir

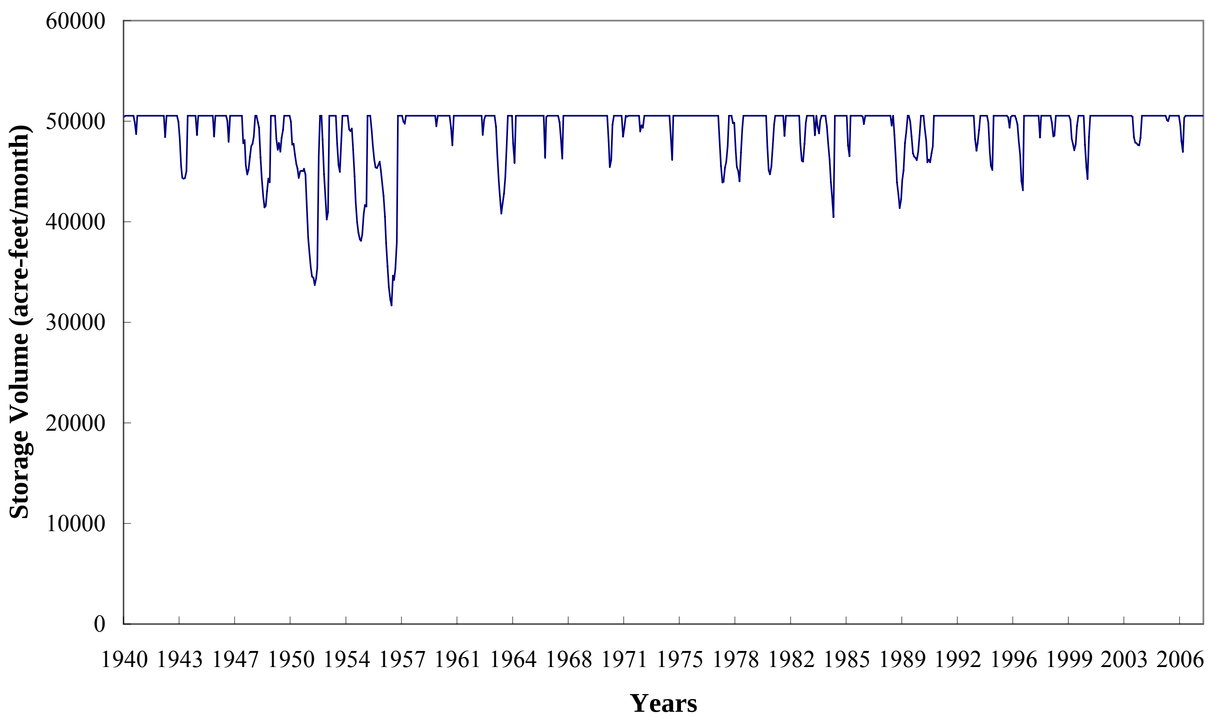

Figure 7.24 Bwam8 Storage Volume of Granger Reservoir

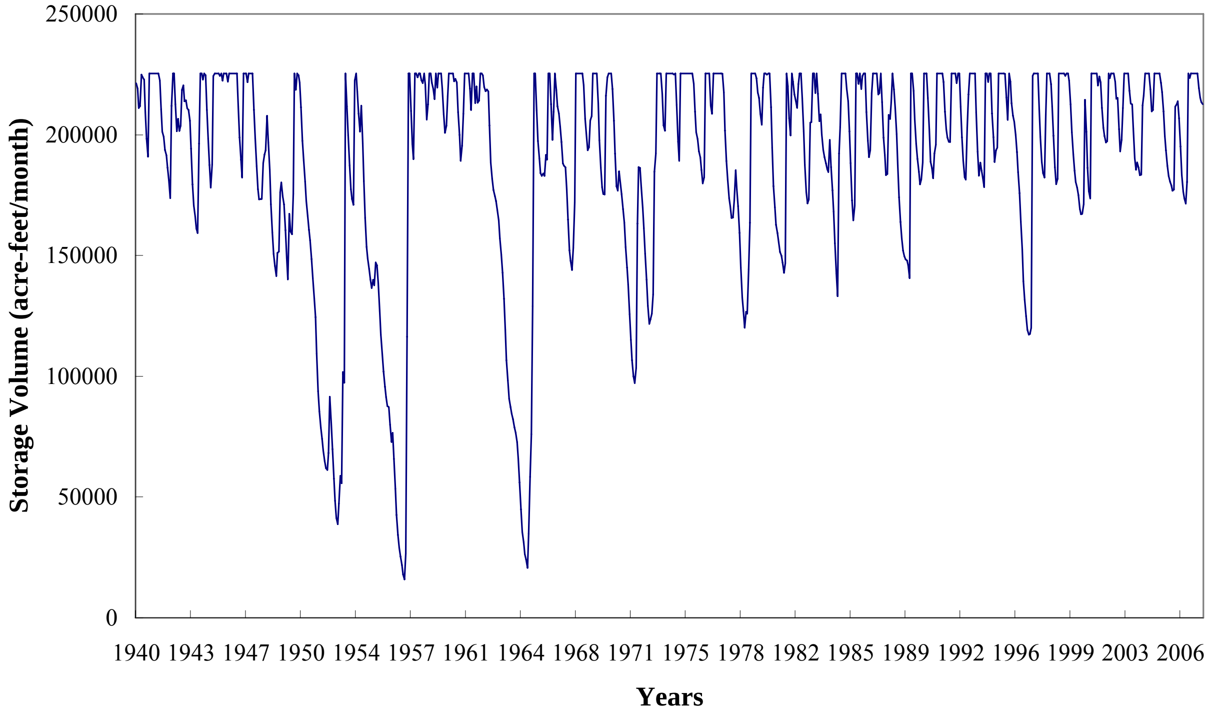

Figure 7.25 Bwam3 Storage Volume of Limestone Reservoir

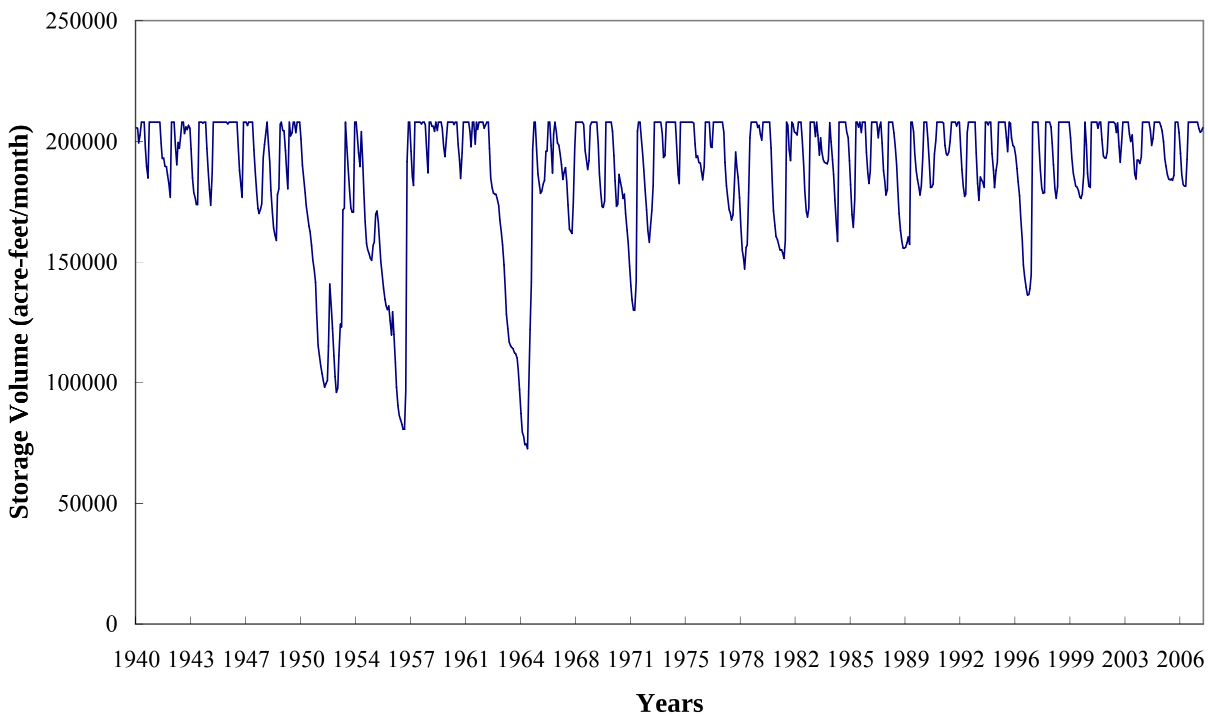

Figure 7.26 Bwam8 Storage Volume of Limestone Reservoir

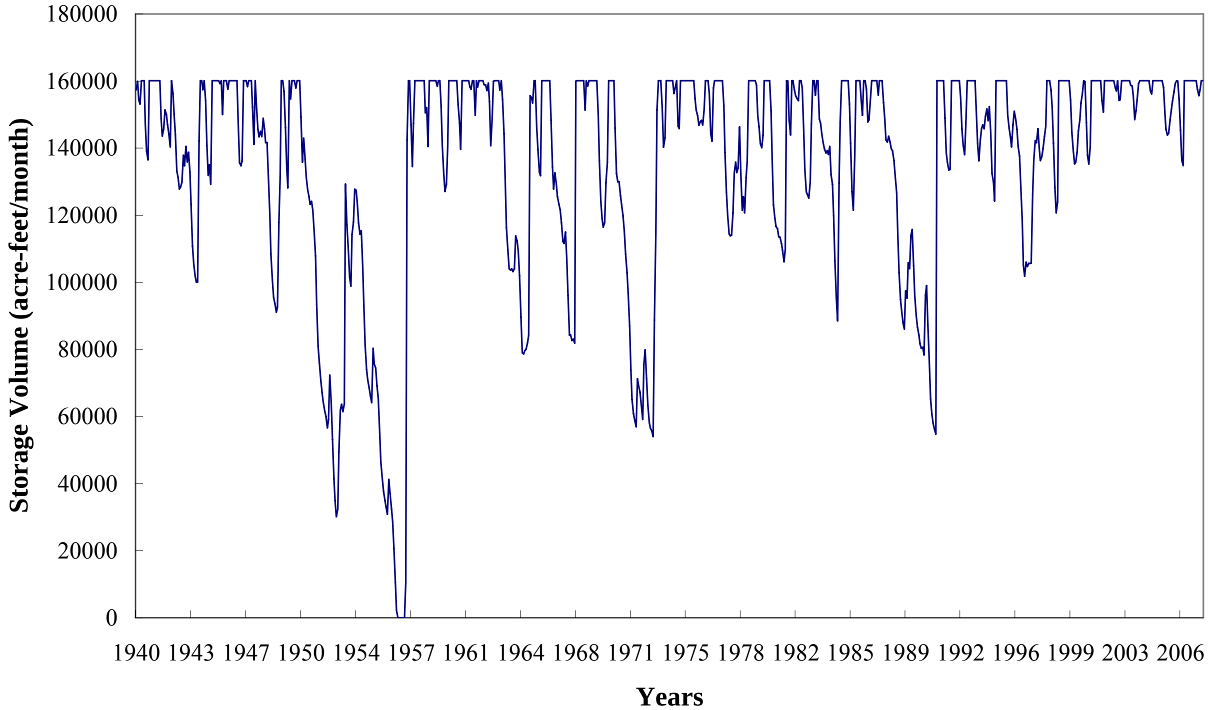

Figure 7.27 Bwam3 Storage Volume of Somerville Reservoir

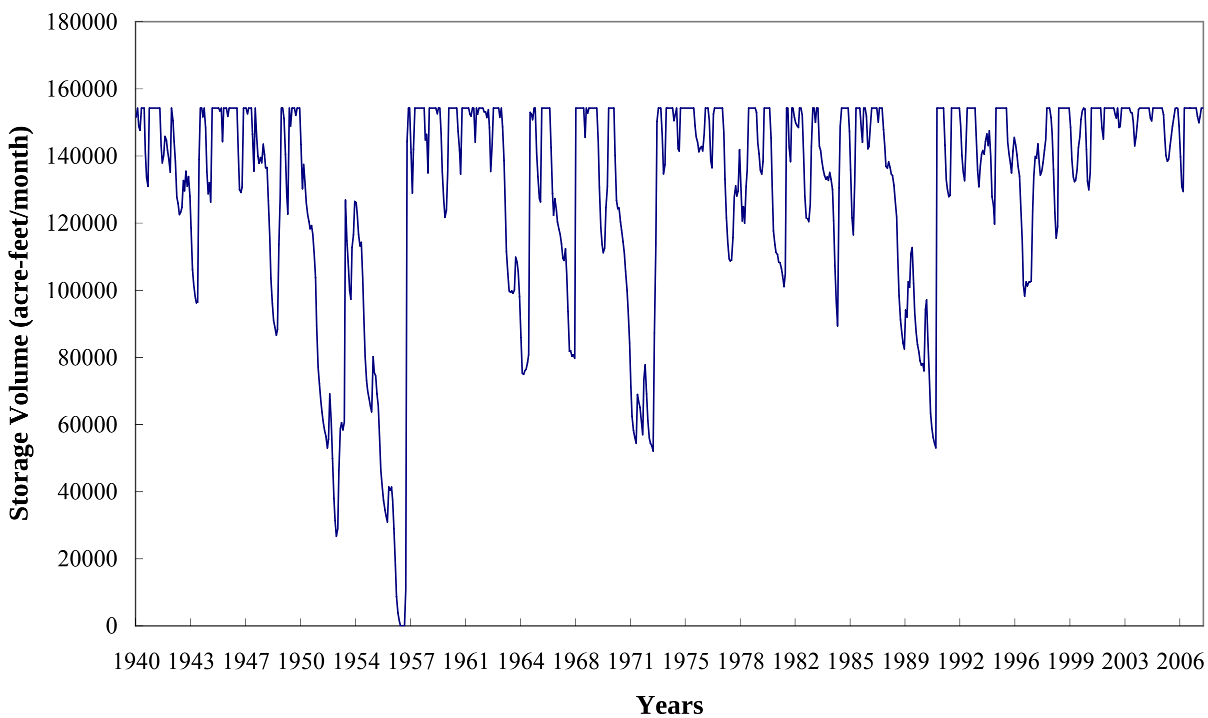

Figure 7.28 Bwam8 Storage Volume of Somerville Reservoir

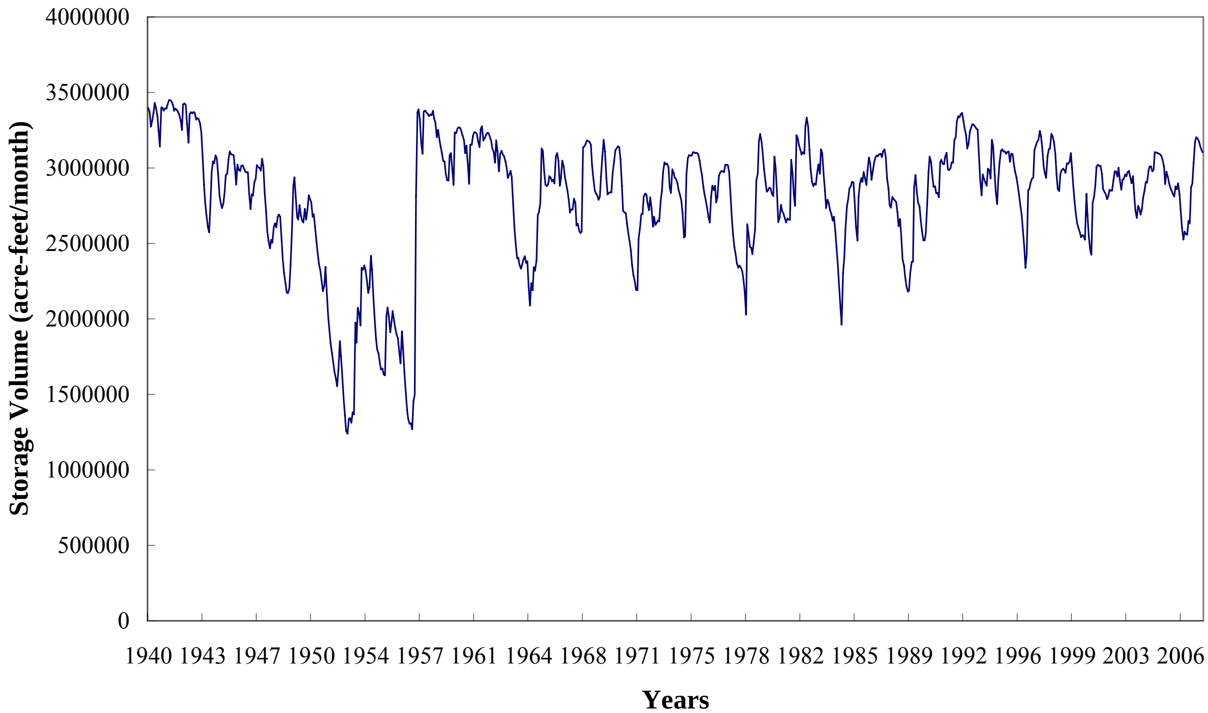

Figure 7.29 Bwam3 Total Storage Volume of 14 Reservoirs

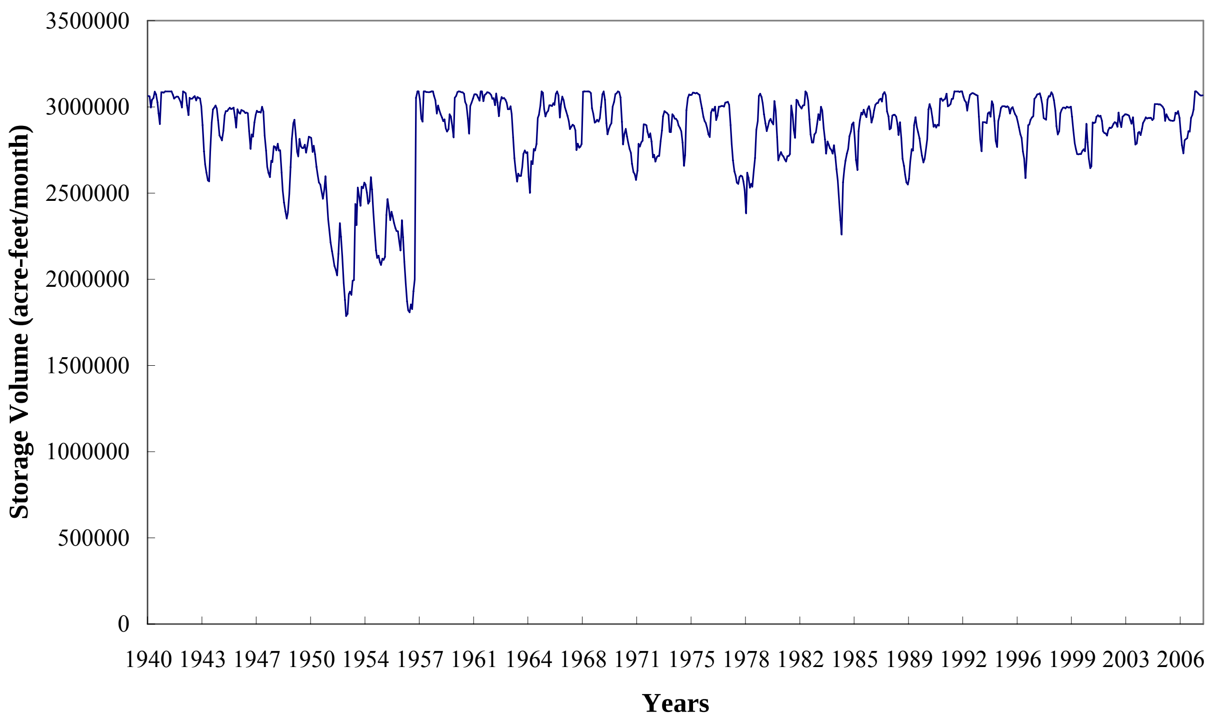

Figure 7.30 Bwam8 Total Storage Volume of 14 Reservoirs

CHAPTER 8
CONDENSING THE BRAZOS WAM DATASET TO FOCUS ON THE BRAZOS RIVER AUTHORITY SYSTEM

The procedure outlined in Chapter 2 for condensing WAM datasets is applied to the Brazos WAM described in Chapter 3 to develop a much simpler model designed for studies of operations of the Brazos River Authority (BRA) reservoir system. The development of condensed datasets from the TCEQ Water Availability Modeling (WAM) System authorized use scenario and current use scenario datasets for the Brazos River Basin and Brazos-San Jacinto Coastal Basin is described in the present Chapter 8. Simulation results with the Brazos River Authority Condensed (BRAC) datasets versus original complete Brazos WAM (Bwam) datasets are compared in Chapter 9.

Chapter 8 describes the authorized use scenario and current use scenario condensed datasets focused on the BRA system developed from the Brazos WAM datasets. These datasets are listed in Table 8.1. The filename root BRAC is adopted to refer to the condensed datasets. BRAC3 and BRAC8 refer to the authorized and current use condensed datasets corresponding to the Bwam3 and Bwam8 datasets described in Chapter 3. Versions of the condensed model are developed with hydrologic periods-of-analysis of 1940-2007 and 1900-2007, which includes the 1998-2007 and 1900-1939 extensions covered in Chapters 4 and 5. The 1940-1997 hydrologic period-of-analysis is readily adopted as a subset of the 1940-2007 BRAC3 and BRAC8 datasets.

Table 8.1
WRAP-SIM Input Datasets Discussed in Chapters 8 and 9

Filename	Water Use Scenario	Hydrologic Period-of-Analysis
	Original Brazos WAM Datasets	
Bwam3	authorized use (run 3)	January 1940 through December 2007
Bwam3	authorized use (run 3)	January 1900 through December 2007
Bwam8	current use (run 8)	January 1940 through December 2007
Bwam8	current use (run 8)	January 1900 through December 2007
	Brazos River Authority Condensed (BRAC) Datasets	
BRAC3	authorized use (run 3)	January 1940 through December 2007
BRAC3	authorized use (run 3)	January 1900 through December 2007
BRAC8	current use (run 8)	January 1940 through December 2007
BRAC8	current use (run 8)	January 1900 through December 2007

The BRAC3 and BRAC8 datasets designed for modeling BRA river/reservoir water management system operations consist of DAT, FLO, EVA, and RUF files. Alternative versions of the files with filename roots BRAC3 and BRAC8, corresponding to the original full Brazos WAM Bwam3 and Bwam8 files, model the authorized use (run 3) and current use (run 8) scenarios defined in Chapter 1. The FLO and EVA input files storing monthly stream flow volumes and net evaporation-precipitation depths can also be easily converted to DSS files with the data stored in the binary format of the Hydrologic Engineering Center (HEC) Data Storage System (DSS).

Components of the Brazos River Authority Condensed (BRAC) Datasets

The primary purpose for developing the BRAC datasets is to have a much simpler model that facilitates operational planning studies and other decision support activities for the Brazos River Authority reservoir system. An input dataset and corresponding simulation results with dramatically fewer control points, water rights, and reservoirs are much more manageable to use in modeling studies. The Brazos WAM authorized use dataset described in Chapter 3 contains 1,634 water right *WR* records, 122 instream flow *IF* records, 670 reservoirs, and 3,830 control points. The Brazos WAM current use dataset is slightly larger. Naturalized flows are input on inflow *IN* records in a FLO file for 77 primary control points and distributed within *SIM* to the other ungaged secondary control points as specified by 3,138 flow distribution *FD* records in a DIS file. The size of the Bwam dataset is dramatically reduced in developing the BRAC dataset.

The Brazos River Authority Condensed (BRAC) dataset (DAT, FLO, EVA, and RUF files) created by reducing the size of the Brazos WAM dataset has 48 control points. The BRAC3 authorized use and BRAC8 current use versions of the condensed dataset have 15 and 14 reservoirs, respectively. The permitted but not yet constructed Allens Creek Reservoir is included in the Bwam3 and BRAC3 datasets but is not included in the Bwam8 and BRAC8 datasets. Net evaporation-precipitation depths are provided in the EVA file for the reservoir control points. River flows are included in the BRAC3 and BRAC8 versions of the FLO file for all of the 48 control points. Thus, there is no flow distribution DIS file. Only water rights associated with the 15 or 14 reservoirs are included in the two versions of the BRAC DAT file. A RUF file facilitates modeling regulated flows. The impacts of the over 650 reservoirs and numerous water rights removed from the Brazos WAM are reflected in the *IN* record river flows developed for the condensed dataset.

As discussed in Chapter 2, the control points, reservoirs, and water rights included in the condensed DAT file are called the *primary* system. The control points, reservoirs, and water rights that are not included in the primary system comprise the secondary system. The effects of the secondary water rights on stream flows available to the primary water rights are reflected in the FLO file inflow *IN* record stream flows. The condensed model allows alternative operating plans to modeled based on the premise of allowing no impacts on the numerous secondary rights.

Reservoirs in the BRAC Dataset

Figure 8.1 is a map showing the locations of the 15 BRAC reservoirs and 11 of the 22 USGS stream gaging stations included in the BRAC control points. Information describing the reservoirs is provided in Tables 3.6 and 3.10 of Chapter 3 as well as Table 8.2. Nine of the 15 BRAC reservoirs are Corps of Engineers multiple-purpose projects for which the BRA has contracted for most of the conservation storage capacity. Lakes Possum Kingdom, Granbury, and Limestone are owned and operated by the BRA for water supply and other purposes. The BRA, City of Houston, and TWDB jointly hold a water right permit for the proposed Allens Creek Reservoir, which has not yet been constructed. Allens Creek Reservoir is included in the authorized use Bwam3 and BRAC3 but is not included in the current use Bwam8 and BRAC8 datasets.

Squaw Creek Reservoir owned by the Texas Utilities Services Company provides cooling water for the Comache Peak Nuclear Power Plant. Hubbard Creek Reservoir is owned and operated by the West Central Texas Municipal Water District to supply water to several cities.

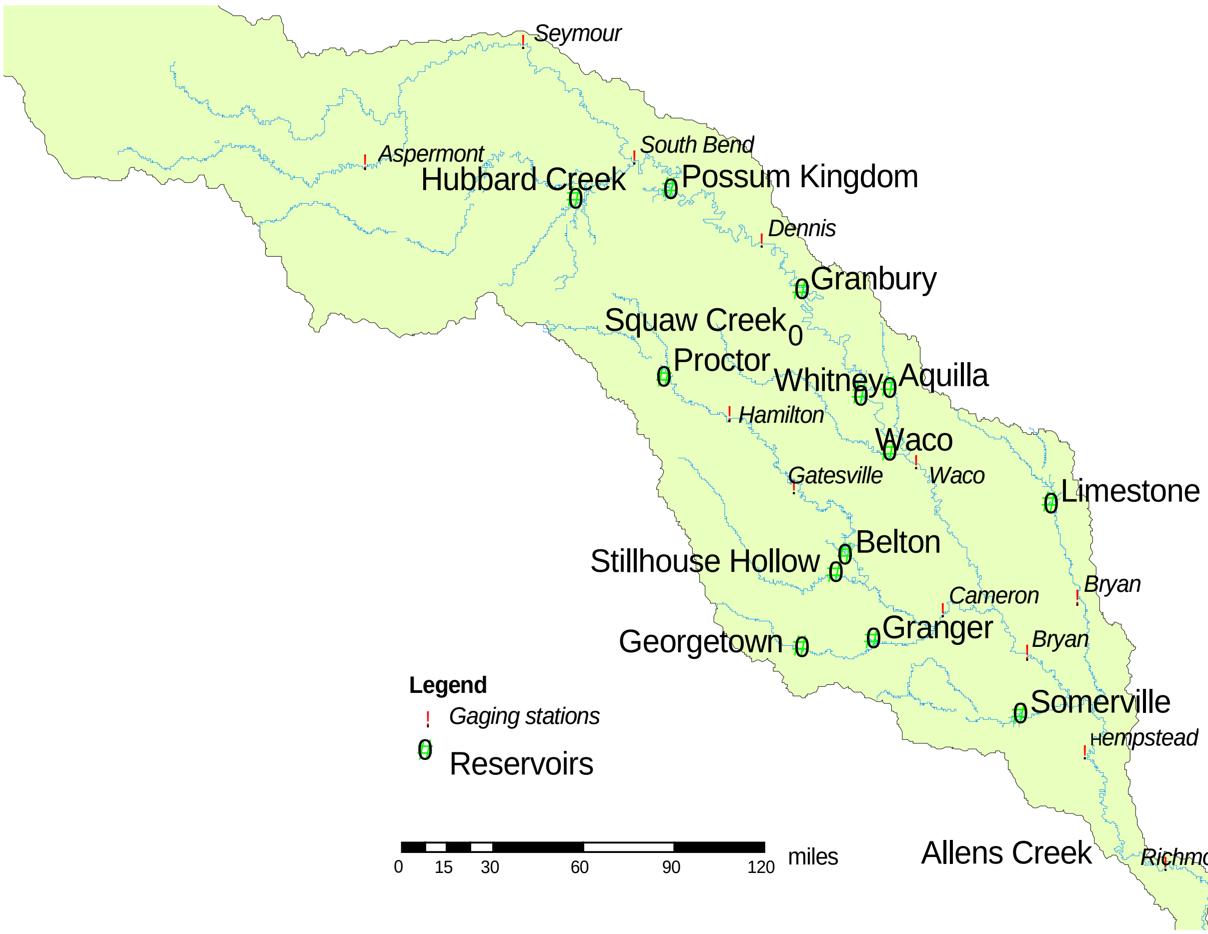

Figure 8.1 BRAC Reservoirs

The objective of the BRAC datasets is to model operations of the Brazos River Authority system composed of the nine federal reservoirs for which BRA partners with the Corps of Engineers and the three BRA owned reservoirs. The proposed Allens Creek Reservoir planned for construction in the future is also an integral consideration in BRA operational planning. Squaw Creek Reservoir at the Comanche Peak Nuclear Power Plant is owned by Texas Utilities Services which purchases water from the BRA to maintain constant levels in the large cooling reservoir. Hubbard Creek Reservoir is owned and operated by the West Central Texas Municipal Water District. The BRA is not directly involved in its operation. However, the conservation storage capacity of Hubbard Creek Reservoir is the fourth largest in the Brazos River Basin. Since it is a very large reservoir located upstream of the three BRA reservoirs on the main-stem Brazos River, inclusion of Hubbard Creek Reservoir in the BRAC model was judged to be worthwhile.

<u>Control Points in the BRAC Dataset</u>

Figure 8.2 is a BRAC control point map. Figure 8.3 is a schematic of the spatial configuration of the system as defined by the 48 control points. The 48 control points included in the BRAC dataset are listed in Tables 8.2, 8.3, and 8.4. The 15 control points in Table 8.2 are locations of reservoir projects. The 11 control points in Table 8.3 represent stream confluences and the basin outlet. The 22 control points in Table 8.4 are locations of stream gaging stations.

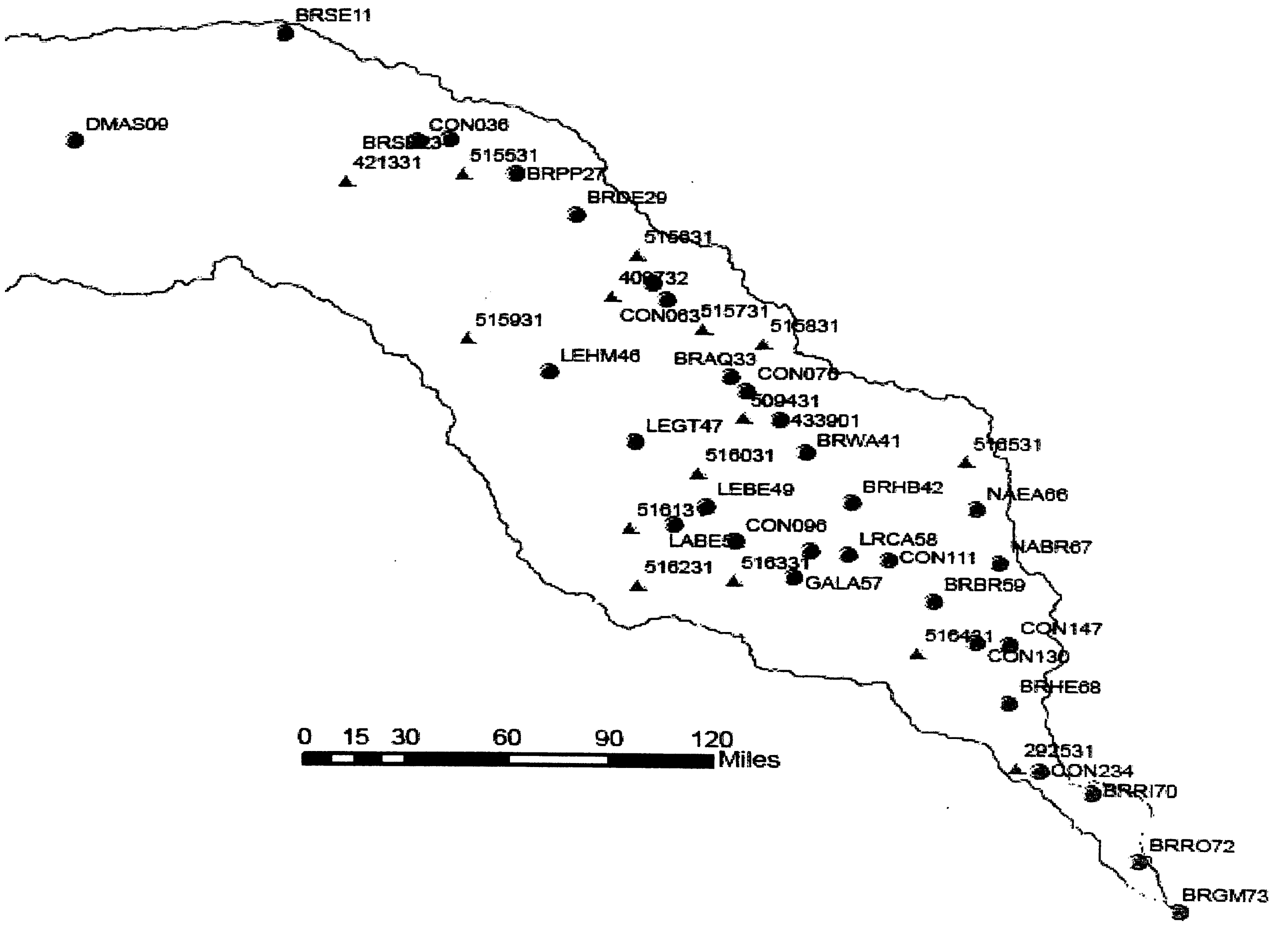

Figure 8.2 BRAC Control Points

The control points are referenced by the six-character identifiers originally assigned in the Brazos WAM data files and continued in the BRAC datasets. The six-character WAM reservoir identifiers are shown in parenthesis under the control point identifiers in the Figure 8.3 schematic.

The WRAP term *primary control point* refers to locations at which stream flows are provided as input on *IN* records stored in a FLO file. The Brazos WAM dataset has 77 primary control points which are listed in Table 3.2 of Chapter 3. The locations of the 77 Brazos WAM primary control points are shown on the map of Figure 3.2.

The 22 BRAC gaging station control points listed in Table 8.4 are included in the 77 primary control points in the Brazos WAM. All 48 control points listed in Tables 8.2, 8.3, and 8.4 are primary control points in the BRAC dataset even though only 22 are located at gaging stations. River flows for all 48 control points computed as outlined in this chapter are stored as *IN* records in the FLO files of the BRAC3 and BRAC8 datasets. The corresponding regulated less unappropriated flow adjustments are recorded in *UR* records in RUF files.

The BRAC3 and BRAC8 DAT files include *CP* records for each of the 48 control points. The EVA file contains evaporation-precipitation depths for the 15 reservoir control points.

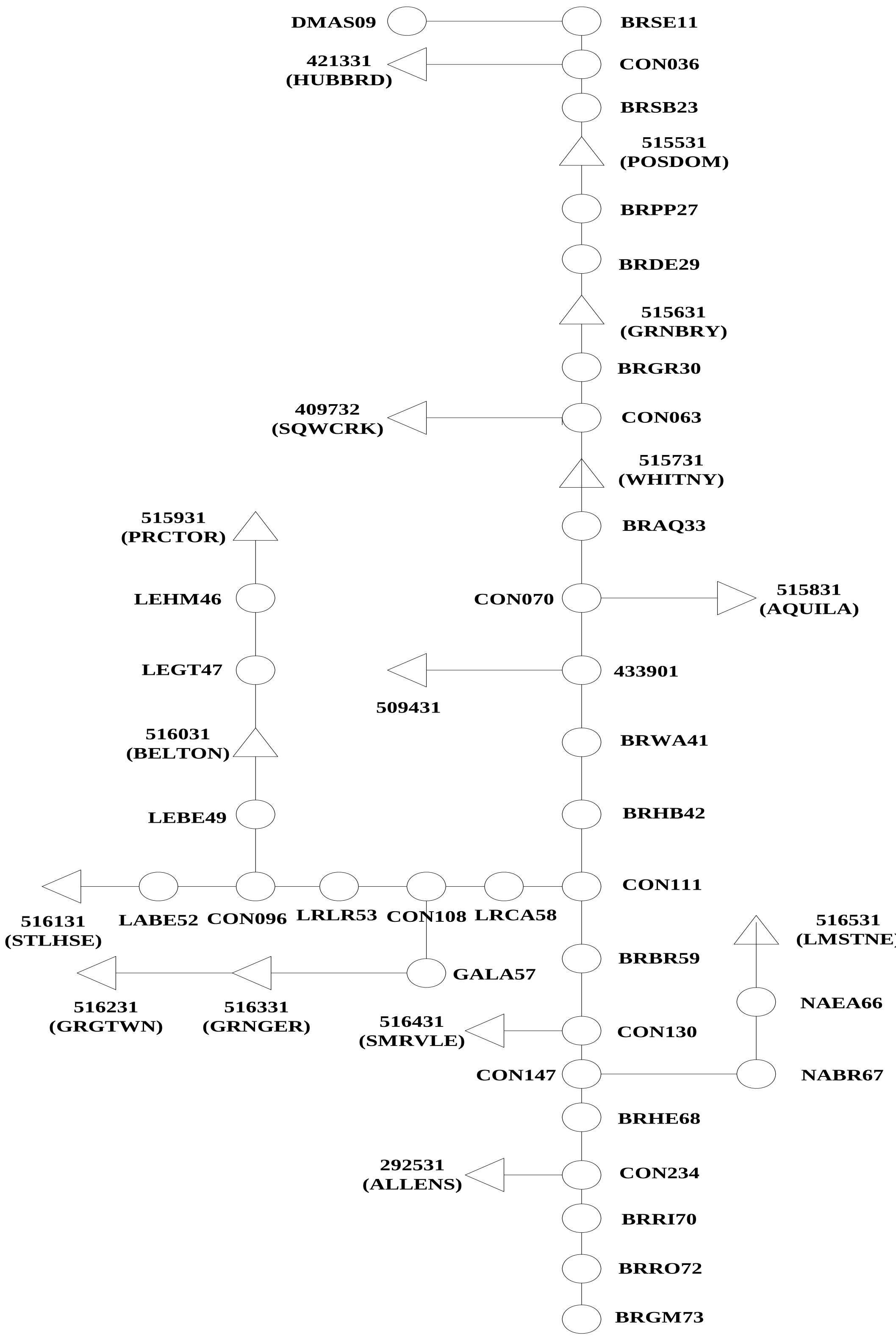

Figure 8.3 BRAC Control Point Schematic (Not to Scale)

Table 8.2
BRAC Control Points for Reservoirs

Control Point	Reservoir	Reservoir Identifier	Storage (acre-feet) BRAC3	Storage (acre-feet) BRAC8	Diversion (ac-ft/year) BRAC3	Diversion (ac-ft/year) BRAC8
			Brazos River Authority and Corps of Engineers			
515531	Possum Kingdom	POSDOM	724,739	552,013	230,750	59,482
515631	Granbury	GRNBRY	155,000	132,821	64,712	36,025
515731	Whitney	WHIT	636,100	561,074	18,336	18,336
515831	Aquilla	AQUILA	52,400	41,700	13,896	2,394
509431	Waco	WACO	206,562	206,562	79,877	38,348
515931	Proctor	PRCTOR	59,400	54,702	19,658	14,068
516031	Belton	BELTON	457,600	432,978	112,257	107,738
516131	Stillhouse Hollow	STLHSE	235,700	224,279	67,768	67,768
516231	Georgetown	GRGTWN	37,100	36,980	13,610	11,943
516331	Granger	GRNGER	65,500	50,540	19,840	2,569
516531	Limestone	LMSTNE	225,400	208,017	65,074	39,337
516431	Somerville	SMRVLE	160,110	154,254	48,000	48,000
			Proposed by BRA and City of Houston but Not Yet Constructed			
292531	Allens Creek	ALLENS	145,533	–	99,650	–
			West Central Texas Municipal Water District			
421331	Hubbard Creek	HUBBRD	317,750	317,750	56,000	9,924
			Comache Peak Nuclear Power Plant			
409732	Squaw Creek	SQWCRK	151,500	151,015	23,180	17,536

Table 8.3
BRAC Control Points for Stream Confluences and the Basin Outlet

Control Point	Location
CON036	Confluence of Hubbard Creek and Brazos River
CON063	Confluence of Squaw Creek and Brazos River
CON070	Confluence of Aquilla Creek and Brazos River
433901	Confluence of Bosque and Brazos River
CON096	Confluence of Lampasas and Little River
CON108	Confluence of Little River and San Gabriel
CON111	Confluence of Little River and Brazos River
CON130	Confluence of Yegua Creek and Brazos River
CON147	Confluence of Navasota River and Brazos River
CON234	Confluence of Allens Creek and Brazos River
BRGM73	Brazos River Outlet at the Gulf of Mexico

Table 8.4
BRAC Control Points for USGS Gaging Stations

WAM CP ID	River	Nearest City	USGS Gage No.	Period-of Record	Watershed Area (square miles)
DMAS09	Double Mountain Fork	Aspermont	08080500	1923–present	265
BRSE11	Brazos River	Seymour	08082500	1923–present	5,996
BRSB23	Brazos River	South Bend	08088000	1938–present	13,171
BRPP27	Brazos River	Palo Pinto	08089000	1924–present	14,309
BRDE29	Brazos River	Dennis	08090800	1968–present	15,733
BRGR30	Brazos River	Glen Rose	08091000	1923–present	16,320
BRAQ33	Brazos River	Aquilla	08093100	1938–present	17,746
BRWA41	Brazos River	Waco	08096500	1898–present	20,065
BRHB42	Brazos River	Highbank	08098290	1965–present	20,900
LEHM46	Leon River	Hamilton	08100000	1925–present	1,928
LEGT47	Leon River	Gatesville	08100500	1950–present	2,379
LEBE49	Leon River	Belton	08102500	1923–present	3,579
LABE52	Lampasas River	Belton	08104100	1963–present	1,321
LRLR53	Little River	Little River	08104500	1923–present	5,266
GALA57	San Gabriel River	Laneport	08105700	1965–present	737
LRCA58	Little River	Cameron	08106500	1916–present	7,100
BRBR59	Brazos River	Bryan	08109000	1899–1993	30,016
NAEA66	Navasota River	Easterly	08110500	1924–present	936
NABR67	Navasota River	Bryan	08111000	1951–1997	1,427
BRHE68	Brazos River	Hempstead	08111500	1938–present	34,374
BRRI70	Brazos River	Richmond	08114000	1903–present	35,454
BRRO72	Brazos River	Rosharon	08116650	1967–present	35,775

Water Rights in the Brazos River Authority Condensed (BRAC) Datasets

The BRAC3 and BRAC8 DAT files include only those water rights from the Brazos WAM dataset that are associated with the 15 and 14 reservoirs, respectively. Water rights associated with Allens Creek Reservoir are included in the authorized use scenario BRAC3 but are not included in the current use BRAC8 version. *WR* record water rights in the BRAC3 and BRAC8 DAT files refill storage in the 15 or 14 reservoirs and supply water supply diversion requirements with withdrawals and releases from the reservoirs. The BRAC water rights are listed in Table 8.5 with their storage capacities and annual diversion targets for the BRAC3 and BRAC8 versions of the condensed datasets. The main portion of the water right identifiers is tabulated in Table 8.5 A complete listing of water rights with their full identifiers is provided in Table 3.11 of Chapter 3.

Whitney and Waco Reservoirs are modeled in the Brazos WAM and BRAC datasets as sets of component reservoirs with the evaporation allocation *EA* record option activated. The storage capacity and diversion target of the water rights associated with each component reservoir are shown in parenthesis in Table 8.5.

BRAC dataset totals are compared with Brazos WAM dataset totals at the bottom of Table 8.5. The 15 reservoirs in the authorized use scenario BRAC3 dataset account for 77.3 percent of the total reservoir storage capacity in the 665 reservoirs in the Bwam3 dataset. The 14 reservoirs in the current use scenario BRAC8 dataset account for 77.7 percent of the total reservoir storage capacity in the 706 reservoirs in the Bwam8 dataset. The diversion targets for the water rights in the BRAC3 and BRAC8 datasets are 38.3 and 31.6 percent of the of the total diversion targets in the Bwam3 and Bwam8 datasets.

Table 8.5
BRAC Water Rights Summary

Reservoir	Reservoir Identifier	Control Point	Water Right	Storage (acre-feet) BRAC3	Storage (acre-feet) BRAC8	Diversion (ac-ft/year) BRAC3	Diversion (ac-ft/year) BRAC8
Brazos River Authority System							
Possum Kingdom	POSDOM	515531	C5155	724,739	552,013	230,750	59,482
Granbury	GRNBRY	515631	C5156	155,000	132,821	64,712	36,025
Whitney		515731		636,100	561,074	18,336	18,336
	WHITNY		USACE	(387,024)	(311,998)	0	0
	BRA		C5157	(50,000)	(50,000)	(18,336)	(18,336)
	CORWHT		EVAP3	(199,076)	(199,076)	0	0
Aquilla	AQUILA	515831	C5158	52,400	41,700	13,896	2,394
Waco		509431		206,562	206,562	79,877	38,388
	LKWACO		C2315	(39,100)	(39,100)	(39,100)	(37,448)
	WACO2		C2315	(65,000)	(65,000)	(20,000)	(900)
	WACO4		P5094	(88,062)	(88,062)	(20,777)	0
	WACO5		P5094	(14,400)	(14,400)	0	0
Proctor	PRCTOR	515931	C5159	59,400	54,702	19,658	14,068
Belton	BELTON	516031	C2936	457,600	432,978	112,257	107,738
Stillhouse Hollow	STLHSE	516131	C5161	235,700	224,279	67,768	67,768
Georgetown	GRGTWN	516231	C5162	37,100	36,980	13,610	11,943
Granger	GRNGER	516331	C5163	65,500	50,540	19,840	2,569
Limestone	LMSTNE	516531	C5165	225,400	208,017	65,074	39,337
Somerville	SMRVLE	516431	C5164	160,110	154,254	48,000	48,000
Allens Creek	ALLENS	292531	ALLENS	145,533	–	99,650	–
West Central Texas Municipal Water District							
Hubbard Creek	HUBBRD	421331	C4213	317,750	317,750	56,000	9,924
Texas Utilities Services							
Squaw Creek	SQWCRK	409732	C4097	151,500	151,015	23,180	17,536
Water Right Totals							
Total for the 15 reservoirs listed above				3,630,394	3,124,685	932,608	473,468
Percentage of basin total				(77.3%)	(77.7%)	(38.3%)	(31.6%)
All other water rights				1,064,457	898,665	1,504,730	1,022,963
Total for the entire river basin				4,694,851	4,023,350	2,437,338	1,496,431

Methodology for Developing the Condensed Datasets

The primary system focused on BRA reservoirs that is modeled in the DAT file of each version of the BRAC datasets is described in the preceding section. All other water rights (called secondary rights) and associated control points and reservoirs are removed from the DAT files with their effects incorporated in the river system inflow input data stored in the FLO file for each version of the BRAC datasets. The objectives guiding creation of the BRAC datasets are to:

- develop a much simpler dataset designed specifically for modeling the management and operation of the BRA reservoir system by reducing the number of control points, water rights, and reservoirs in the Brazos WAM dataset

- model the effects of the secondary water rights and their associated water control facilities such that the primary system is allowed access to only water quantities remaining after appropriate allocations to all secondary water rights

A *WRAP-SIM* water rights input DAT file for the BRA river/reservoir water management and use system and other closely associated reservoirs and water users, called the primary system, is developed along with a FLO file containing stream flow inflows that exclude the flows appropriated by all of the other water rights in the original Brazos WAM dataset that are not included in the primary system.

The procedure is repeated to develop a BRAC3 DAT file, BRAC8 DAT file, and a separate set of FLO, EVA, and RUF files for each of the following four alternative *SIM* input datasets. Each of these four BRAC datasets is comprised of a DAT file, FLO file, EVA file, and RUF file.

BRAC3	authorized use (run 3)	January 1940 through December 2007
BRAC3	authorized use (run 3)	January 1900 through December 2007
BRAC8	current use (run 8)	January 1940 through December 2007
BRAC8	current use (run 8)	January 1900 through December 2007

BRAC3 and BRAC8 datasets were developed for alternative hydrologic periods-of-analysis of 1940-2007 and 1900-2007. Datasets for the 1940-1997 period-of-analysis are automatically contained within the datasets with a 1940-2007 period-of-analysis. Likewise, models for 1900-1939 are automatically contained within the datasets with a 1900-2007 simulation period. The BRAC3 and BRAC8 DAT files can be applied with any hydrologic period-of-analysis.

The *WRAP-SIM/HYD*-based methodology is described in Chapter 2. Application of the programs *SIM* and *HYD* to develop the 1940-2007 BRAC3, 1900-2007 BRAC3, 1940-2007 BRAC8, and 1900-2007 BRAC8 datasets consists of applying the methodology described in Chapter 2 to create the two DAT files and four sets of FLO, EVA, and RUF files.

- The BRAC3 and BRAC8 DAT files contain water rights and related information for 15 and 14 reservoirs, respectively, and associated water supply diversions. This information is excerpted from the Bwam3 and Bwam8 DAT files. All but 48 of the original over 3,800 control point *CP* records are omitted. Thus, the next downstream control point identifiers and channel loss factors on the *CP* records are modified for the adopted 48 control points. Various organizational refinements that have no effect on simulation results are also made.

- FLO files with alternative 1940-2007 and 1900-2007 sets of monthly flows at 48 control points represent conditions of river system development that includes all of the water rights and associated reservoirs in the original complete Bwam3 and Bwam8 DAT files except the 15 reservoirs and associated diversions contained in the condensed DAT files.

- EVA files contain alternative 1940-2007 and 1900-2007 sets of monthly net evaporation-precipitation depths for the 15 control points at which the 15 reservoirs are located. Adjusted net evaporation-precipitation depths are obtained from the *SIM* output OUT file.

- RUF files contain alternative 1940-2007 and 1900-2007 sets of differences between the regulated flows less unappropriated flows from the *SIM* output file. The optional RUF files allow regulated flows to be included in the BRAC simulation results.

BRAC3 and BRAC8 DAT Files

The DAT file for a condensed dataset is developed by excerpting pertinent water rights and associated data records from the original DAT file, excerpting pertinent records providing reservoir data, and modifying remaining control point *CP* records to reflect removal of many of the control points. With removal of control points, channel loss factors for the stream reaches removed are aggregated for the combined longer reaches between the remaining control points.

Table 8.6
Channel Loss Factors for Reaches Between 48 Control Points

	Control Points		Loss		Control Points		Loss
	Upstream	Downstream	Factor		Upstream	Downstream	Factor
1	DMAS09	BRSE11	0.4918	25	LEBE49	CON096	0.0040
2	BRSE11	CON036	0.4146	26	516131	LABE52	0.0010
3	421331	CON036	0.2275	27	LABE52	CON096	0.0020
4	CON036	BRSB23	0.0100	28	CON096	LRLR53	0.0020
5	BRSB23	515531	0.0179	29	LRLR53	CON108	0.0208
6	515531	BRPP27	0.0050	30	516231	516331	0.0080
7	BRPP27	BRDE29	0.0198	31	516331	GALA57	0.0060
8	BRDE29	515631	0.0119	32	GALA57	CON108	0.0139
9	515631	BRGR30	0.0060	33	CON108	LRCA58	0.0020
10	BRGR30	CON063	0.0010	34	LRCA58	CON111	0.0267
11	409732	CON063	0.0000	35	CON111	BRBR59	0.0100
12	CON063	515731	0.0198	36	BRBR59	CON130	0.0119
13	515731	BRAQ33	0.0000	37	516431	CON130	0.0110
14	BRAQ33	CON070	0.0050	38	CON130	CON147	0.0040
15	515831	CON070	0.0050	39	516531	NAEA66	0.0050
16	CON070	433901	0.0020	40	NAEA66	NABR67	0.0100
17	509431	433901	0.0199	41	NABR67	CON147	0.0296
18	433901	BRWA41	0.0020	42	CON147	BRHE68	0.0090
19	BRWA41	BRHB42	0.0100	43	BRHE68	CON234	0.0177
20	BRHB42	CON111	0.0040	44	292531	CON234	0.0040
21	515931	LEHM46	0.3795	45	CON234	BRRI70	0.0060
22	LEHM46	LEGT47	0.0119	46	BRRI70	BRRO72	0.0100
23	LEGT47	516031	0.0252	47	BRRO72	BRGM73	0.0169
24	516031	LEBE49	0.0010	48	BRGM73	OUT	0.0000

Channel loss factors C_L for N reaches that are combined into one single reach with the removal of intermediate control points are aggregated as follows.

$$(1.0 - C_L)_{total} = (1.0 - C_L)_1 + (1.0 - C_L)_2 + ... + (1.0 - C_L)_N$$

Channel loss factors for the stream reaches between the 77 primary control points in the Brazos WAM are tabulated in Table 4.6 of Chapter 4. Channel loss factors for the stream reaches defined by the 48 control points in the BRAC dataset are tabulated in Table 8.6

Table 8.7
Return Flow Control Points

Bwam Return Flow CP	Water Rights	Reservoir ID	BRAC Return Flow CP	Control Point Description
103341	C4213_2	HUBBARD	CON036	confluence
100401	C4213_5	HUBBARD	CON036	confluence
027891	C5155_1	POSDOM	BRPP27	Palo Pinto gage
101102	C5155_3	POSDOM	BRHB42	Highbank gage
106271	C5155_4	POSDOM	OUT	Gulf of Mexico
104101	C5155_5	POSDOM	OUT	Gulf of Mexico
105685	C5155_6	POSDOM	OUT	Gulf of Mexico
103751	C5155_7	POSDOM	OUT	Gulf of Mexico
101731	C5155_8	POSDOM	OUT	Gulf of Mexico
BRA_AB	C5155_A	POSDOM	OUT	City of Abilene
SHGR26	C5155_20	POSDOM	BRPP27	Palo Pinto gage
515551	C5155_21	POSDOM	BRPP27	Palo Pinto gage
101782	C5156_3	GRNBRY	515631	Granbury Reservoir
106301	C5158_2	AQUILA	515831	Aquilla Reservoir
110711	C2315_1	LKWACO	BRHB42	Highbank gage
110711	C2315_3	LKWACO	BRHB42	Highbank gage
110711	P5094_1	LKWACO	BRHB42	Highbank gage
110711	P5094_2	LKWACO	BRHB42	Highbank gage
110711	P5094_3	LKWACO	BRHB42	Highbank gage
102191	C5160_1	BELTON	509431	Lake Waco
101761	C5160_3	BELTON	516031	Lake Belton
101741	C5160_4	BELTON	OUT	Gulf of Mexico
103513	C5160_5	BELTON	CON096	confluence
103512	C5160_6	BELTON	CON096	confluence
100451	C5160_8	BELTON	516131	Stillhouse Reservoir
100455	C5160_9	BELTON	516031	Belton Reservoir
100451	C5160_10	BELTON	516131	Stillhouse Reservoir
101551	C5160_11	BELTON	CON096	confluence
113181	C5160_12	BELTON	CON096	confluence
104702	C5160_13	BELTON	CON111	confluence
102051	C5161_1	STLHSE	516131	Stillhouse Reservoir
104893	C5162_1	STLHSE	516331	Granger Reservoir
104892	C5162_2	STLHSE	516331	Granger Reservoir
102641	C5162_3	STLHSE	CON108	confluence
102642	C5162_4	STLHSE	CON108	confluence
102991	C5163_2	GRNGER	CON108	confluence
103881	C5164_1	LMSTNE	BRHE68	Hempstead gage

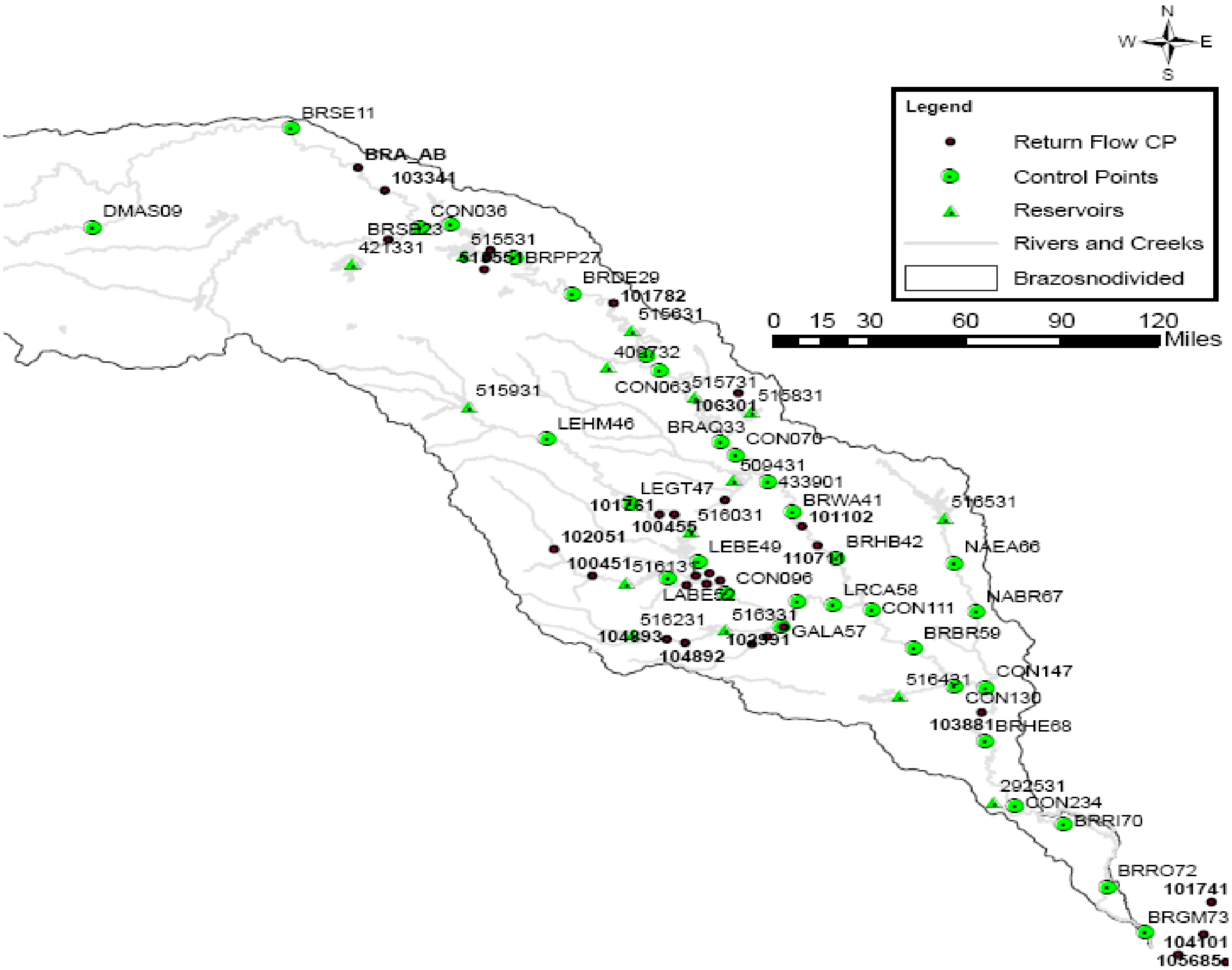

Figure 8.4 BRAC Control Points and the Bwam
Return Flow Control Points Removed

A number of the water rights included in the BRAC dataset have diversion return flows that are returned back to the river in the Brazos WAM dataset at control points that have been removed in the BRAC dataset. The return flows are returned in the BRAC dataset at the next downstream control point that was not removed. Return flow locations that were thus modified are listed in Table 8.7. Return flows returning to the river in Bwam at the control points listed in the first column of Table 8.7 are returned in BRAC at the control points listed in the 4th column. The Bwam return flow control points removed in the BRAC datasets are shown in Figure 8.4. Channel losses associated with the return flows may be affected. The decrease in channel loss could be offset by increasing the return flow factor. However, this ploy was not applied.

FLO, EVA, and RUF Files for the BRAC3 and BRAC8 Datasets

The methodology for developing the 1940-2007 and 1900-2007 sequences of flow volumes and net evaporation-precipitation depths stored in FLO, RUF, and EVA files of the BRAC3 and BRAC8 datasets is outlined as follows. The program *HYD* reads the required data from the output OUT files from *SIM* simulations with the Bwam3 and Bwam8 datasets.

1. *SIM* is executed with the original complete Brazos WAM dataset.
2. *HYD* is used to retrieve the adjusted net evaporation-precipitation depths from the *SIM* output OUT file and store them in a EVA input file for the condensed dataset.
3. *HYD* is used to retrieve the regulated and unappropriated flow volumes from the *SIM* output OUT file and compute and store the differences in a RUF file.
4. *HYD* reads stream flow depletions, return flows, unappropriated flows, and reservoir releases from storage to meet instream flow requirements from the *SIM* output OUT file and combines these variables as required to develop the stream flow FLO file for the condensed dataset. Combining the time sequences of flow volumes includes summations and cascading operations that may include channel losses. Program *HYD* reads the necessary control point information from a HIN input file.

The EVA file in the condensed dataset provides 15 sets of net evaporation-precipitation depths for 15 reservoirs. The simplified dataset adopts the same net evaporation-precipitation depths for the 15 reservoirs as used in the original complete dataset *SIM* simulation. The Brazos WAM activates a *SIM* option that adjusts net evaporation-precipitation depths for reservoir site runoff included in the naturalized flows. The condensed EVA file contains net evaporation-precipitation depths read by program *HYD* from the *SIM* output OUT file from the original dataset that reflects these adjustments.

Inclusion of a regulated-unappropriated flow RUF file in a *WRAP-SIM* input dataset allows unregulated flows to be included in a condensed model. The flow differences read from a RUF file are added to unappropriated flows within *SIM* to obtain regulated flows. Options in *SIM* control variations in the manner in which the flow adjustments are applied in a condensed model. The optional RUF file is not required if regulated flows are not of interest.

FLO Files for the BRAC3 and BRAC8 Datasets

The hydrologic period-of-analysis sequences of stream flows provided on *IN* records in a FLO file in a *WRAP-SIM* input dataset represent the inflows to the river system. In the original WAM datasets, these are naturalized flows representing natural conditions without the water resources development, management, and use described by the information in the DAT file. For the condensed datasets, the *IN* record inflows in a FLO file are the stream flows available to the water rights of the primary system described by the condensed DAT file. The flows appropriated by the secondary water rights are not available to the primary water rights and thus are not included in the *IN* record inflows in the FLO file.

River flows developed for the 48 control points and stored in a FLO file consist of 1940-2007 or 1900-2007 sequences of monthly volumes of the following variables obtained from the OUT file created by *SIM* with the original complete Brazos WAM input dataset. The computations are performed with *HYD*.

- Stream flow depletions made by each of the water rights associated with the 15 reservoirs are included in the flows being developed. These flow volumes are placed at the control point of the stream flow depletion and at all downstream control points. Channel losses are considered in cascading the stream flow depletions downstream.

- Return flows from the diversion component of the stream flow depletions are subtracted from the flows. These flow volumes are placed at the control point at which the return flow is returned to the stream and at all downstream control points. Channel losses are considered in cascading the return flows downstream.

- Water supplied from Waco and Whitney Reservoirs by backup rights are subtracted from the flows and cascaded downstream accounting for channel losses.

- Any releases from storage in Aquilla and Squaw Creek Reservoirs made specifically for instream flow rights are subtracted at the control point of the reservoir and cascaded downstream in the normal manner which includes consideration of channel losses.

- Unappropriated flows at each of the control points are added to the flows. Since unappropriated flows are cumulative totals, these flows are not cascaded downstream

Of the 15 BRAC reservoirs, Aquilla and Squaw Creek are the only reservoirs that release from storage to meet instream flow requirements in the Brazos WAM. The Bwam3 and Bwam8 DAT files contain 122 and 144 instream flow *IF* records, respectively. Reservoirs must pass inflows as necessary to meet senior instream flow requirements at downstream control points. However, though required to pass inflows, reservoirs are not required to release from storage to meet instream flow requirements unless specifically required in a water right permit as is the case with Aquilla and Squaw Creek Reservoirs. The BRAC DAT files contain no *IF* records.

Comparison of Bwam and BRAC Inflows

The 1900-2007 monthly inflows at 48 control points on the *IN* records in the BRAC3 and BRAC8 FLO files are plotted in Appendix E. Mean annual inflows for the 48 control points are tabulated in Table 8.8 for the BRAC3 and BRAC8 FLO files covering 1940-1997, 1940-2007, and 1900-2007 simulation periods along with the 1940-1997 means for the original Brazos WAM (Bwam) naturalized flows. The Bwam inflows are naturalized flows. The BRAC inflows are the portion of the naturalized flows still available to the primary system water rights after the secondary water rights have appropriated their appropriate quantities of the stream flow. Naturalized flows are the same in the Bwam3 and Bwam8 datasets. Inflows are different in the BRAC3 versus BRAC8 datasets. The 1940-1997 means from Table 8.8 are compared as follows for three control points.

USGS Gaging Station	CP ID	Bwam	BRAC3	BRAC8
Cameron gage on Little River	LRCA58	1,318,302	81.5%	83.9%
Waco gage on Brazos River	BRWA41	1,942,324	85.6%	87.5%
Richmond gage on Brazos River	BRRI70	5,850,224	77.8%	78.2%

The 1940-1997 means of the Bwam naturalized flows at the three control points are tabulated above in acre-feet/year. The corresponding 1940-1997 means of the BRAC3 and BRAC8 inflows are shown as a percentage of the Bwam naturalized flows. The BRAC8 inflows reflect smaller Bwam streamflow depletions but larger Bwam unappropriated flows than the BRAC3 inflows. At the Richmond gage, the mean BRAC3 and BRAC8 inflows are 77.8% and 78.2% of naturalized flows.

Table 8.8
Mean Annual Inflow Comparison

Control Point	Naturalized 1940-1997 (ac-ft/yr)	Mean BRAC3 Inflow (acre-feet/year) 1940-1997	1940-2007	1900-2007	Mean BRAC8 Inflow (acre-feet/year) 1940-1997	1940-2007	1900-2007
DMAS09	108,367	44,460	41,448	49,049	74,326	68,686	79,680
BRSE11	250,096	132,042	122,291	141,209	178,075	166,901	191,777
BRSB23	656,260	325,207	300,013	316,583	436,956	411,960	445,290
BRPP27	810,380	645,899	618,490	634,695	624,593	598,655	630,120
BRDE29	1,003,749	792,955	752,373	754,209	798,957	762,134	784,013
BRGR30	1,118,978	932,062	892,731	886,416	925,180	890,778	905,673
BRAQ33	1,379,053	1,218,568	1,190,268	1,166,997	1,243,201	1,221,944	1,220,284
BRWA41	1,942,324	1,663,149	1,686,947	1,611,069	1,699,166	1,718,093	1,636,573
BRHB42	2,331,139	1,918,534	1,954,664	1,870,094	1,986,461	2,016,233	1,925,858
LEHM46	166,469	113,636	121,634	116,585	122,293	129,868	123,882
LEGT47	257,793	184,085	195,392	181,646	189,827	200,320	186,520
LEBE49	505,257	446,925	482,795	444,228	470,944	507,651	469,555
LABE52	233,258	218,704	247,270	226,516	225,028	253,680	233,184
LRLR53	846,554	710,551	781,485	781,592	725,859	797,499	803,633
GALA57	189,268	175,267	191,160	180,741	177,635	193,089	182,689
LRCA58	1,318,302	1,074,595	1,180,248	1,113,263	1,105,941	1,212,400	1,149,826
BRBR59	4,027,961	3,145,590	3,314,460	3,167,977	3,287,679	3,453,651	3,300,320
NAEA66	322,578	287,078	303,274	299,981	297,182	312,739	307,926
NABR67	421,304	361,504	371,745	367,370	381,092	390,210	383,597
BRHE68	5,358,943	3,757,219	4,009,383	3,846,009	4,172,630	4,434,926	4,251,048
BRRI70	5,850,224	4,551,922	4,804,536	4,642,490	4,576,835	4,833,041	4,668,702
BRRO72	6,112,278	5,339,820	5,612,354	5,438,737	5,521,223	5,802,469	5,630,372
515531	793,475	637,768	611,703	629,482	614,423	589,726	622,464
515631	1,093,872	915,523	875,206	871,428	906,356	871,360	887,845
515731	1,366,866	1,209,580	1,181,021	1,159,217	1,233,376	1,211,836	1,212,006
515831	73,769	69,596	79,049	74,773	70,125	80,386	76,996
509431	357,464	353,635	387,189	353,050	352,265	386,751	357,087
515931	144,846	107,035	108,691	103,453	113,572	114,667	108,241
516031	502,986	447,362	483,252	444,651	471,037	507,624	469,570
516131	230,861	217,295	243,987	224,285	223,474	250,244	230,835
516231	57,558	54,078	57,940	58,489	55,307	59,222	60,091
516331	186,622	173,350	188,890	178,838	175,398	190,528	180,403
516531	232,793	214,648	226,470	224,267	221,471	232,922	229,746
516431	222,869	214,876	233,114	235,218	220,247	238,278	240,595
516031	502,986	447,362	483,252	444,651	471,037	507,624	469,570
421331	97,210	74,124	70,032	66,820	86,166	81,529	79,944
409732	14,098	13,221	15,210	18,821	13,533	15,694	19,485
CON036	662,147	328,374	302,938	319,657	441,183	415,942	449,570
CON063	1,199,051	991,691	954,815	946,991	988,825	957,236	973,188
CON070	1,561,064	1,368,216	1,356,724	1,316,082	1,404,556	1,393,169	1,360,303
433901	1,931,926	1,665,658	1,689,118	1,612,877	1,701,747	1,720,326	1,638,278
CON096	845,754	711,975	783,051	783,143	727,315	799,098	805,230
CON108	1,317,498	1,075,127	1,180,788	1,113,803	1,106,360	1,212,825	1,150,250
CON111	3,912,185	3,141,016	3,305,400	3,155,638	3,300,309	3,461,937	3,303,293
CON130	4,431,340	3,490,079	3,701,680	3,545,080	3,826,467	4,031,679	3,862,690
CON147	5,208,345	3,781,114	4,031,695	3,869,617	4,201,584	4,461,015	4,277,781
CON234	5,840,577	4,579,370	4,833,506	4,670,484	4,604,430	4,862,180	4,696,849
BRGM73	6,105,239	5,265,884	5,533,323	5,360,813	5,467,242	5,744,583	5,573,062

Tables of inflow frequency statistics created with the WRAP program *TABLES* from the *SIM* simulation results are reproduced as Tables 8.9 through 8.14 as follows.

	1940-2007	1900-2007
Bwam3/Bwam8	Table 8.9	Table 8.10
BRAC3	Table 8.11	Table 8.12
BRAC8	Table 8.13	Table 8.14

Table 8.9
Frequency Analysis of 1940-2007 Bwam3 and Bwam8 Naturalized Flows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE 100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
DMAS09	8638.7	19241.	0.0	0.0	0.0	15.4	98.0	408.0	1017.	1767.	2904.	7570.	23284.	175553.
BRSE11	19888.7	40692.	0.0	0.2	96.5	274.4	608.8	1760.0	3204.	5076.	8319.	17493.	50872.	414811.
421331	7627.1	22331.	0.0	0.0	0.0	0.0	0.8	18.8	432.	1008.	1846.	4738.	18768.	264176.
CON036	52532.7	112023.	0.0	87.7	155.2	712.3	1908.3	4934.5	9298.	13531.	22024.	47557.	137224.	1408762.
BRSB23	52044.4	110987.	0.0	86.9	152.7	705.0	1889.5	4889.0	9211.	13404.	21821.	47106.	135962.	1395822.
515531	63756.7	130569.	0.0	0.0	0.1	568.6	2755.3	7862.5	14038.	19434.	31477.	60972.	159486.	1794484.
BRPP27	65115.5	131291.	0.0	0.0	0.0	763.4	2807.6	8130.0	14381.	20365.	31391.	63786.	161781.	1810792.
BRDE29	80021.1	158495.	0.0	0.0	640.3	2692.2	4501.0	10357.0	17917.	26875.	41030.	81692.	208141.	2450046.
515631	87528.8	171460.	0.0	126.1	881.8	2754.5	5183.5	10883.1	19707.	29263.	45641.	92473.	229614.	2653863.
BRGR30	89628.4	175185.	0.0	0.0	729.0	2333.4	5335.4	11197.0	19899.	29923.	47105.	94546.	236741.	2710228.
409732	1359.8	2459.	0.0	0.0	0.0	0.0	0.0	146.7	385.	576.	863.	1486.	3176.	30604.
CON063	96637.8	183347.	86.7	777.5	1292.6	3294.6	6291.2	13088.8	23397.	34255.	53425.	103451.	252195.	2804884.
515731	113888.0	200287.	7.5	777.2	1970.7	3751.1	8094.7	19030.7	33162.	48393.	65813.	122066.	277133.	2962997.
BRAQ33	115091.6	201719.	0.0	0.0	1830.0	3799.4	8324.0	19278.0	33513.	49170.	67669.	123659.	280970.	2981239.
515831	6975.7	14584.	0.0	0.0	0.0	0.0	0.0	99.7	482.	1069.	2154.	6999.	21039.	187168.
CON070	129977.2	213882.	0.0	1815.5	2684.5	5117.0	9361.7	22584.8	40119.	60066.	83655.	143918.	346730.	3096309.
509431	32698.5	85476.	0.0	2.3	13.4	63.6	619.6	2662.4	5671.	9463.	14947.	33162.	80856.	1639712.
515931	11955.4	28919.	0.0	0.0	0.0	0.9	52.4	383.8	1163.	2226.	3694.	10569.	32460.	327284.
LEHM46	14222.6	29789.	0.0	0.0	7.3	74.4	224.6	865.0	2348.	3590.	5709.	13080.	37199.	269330.
LEGT47	22025.3	43352.	0.0	0.0	0.0	89.2	446.7	1451.0	3817.	5895.	10268.	21255.	56490.	383340.
516031	44943.3	78296.	0.0	0.0	0.2	7.3	802.1	4554.4	9117.	14907.	23731.	48793.	117463.	627569.
LEBE49	45166.4	78621.	0.0	0.0	0.0	0.0	800.2	4569.0	9169.	14959.	23869.	49052.	117978.	629618.
516131	21565.9	37850.	27.8	137.0	150.9	523.1	846.9	2504.7	4762.	7160.	10853.	24145.	60046.	309090.
LABE52	21939.0	38189.	0.0	0.0	140.0	510.0	823.8	2490.0	4833.	7533.	11070.	24775.	60886.	310885.
CON096	76664.2	126984.	30.0	301.9	604.8	1922.7	3701.2	10054.5	18744.	28467.	43054.	86716.	204999.	950215.
LRLR53	76733.1	127022.	30.0	301.8	604.5	1923.2	3749.8	10072.0	18766.	28506.	43231.	86704.	205310.	950933.
516231	5111.1	9015.	0.0	0.0	0.0	39.7	116.1	436.2	1016.	1418.	2392.	5901.	14849.	74909.
516331	16827.5	26548.	0.0	1.8	8.3	227.0	535.8	1921.2	3899.	5737.	8919.	21197.	48208.	210085.
GALA57	17076.1	26910.	0.0	0.0	1.3	231.0	541.2	1946.0	3966.	5845.	9069.	21498.	48945.	212283.
CON108	119008.5	180423.	0.1	659.7	1320.9	3072.9	6504.3	17904.1	32113.	49411.	74413.	142871.	315478.	1402268.
LRCA58	119080.4	180519.	0.0	660.1	1321.8	3067.0	6508.2	17905.0	32137.	49457.	74405.	143003.	315687.	1403136.
433901	163479.0	267106.	200.9	2268.1	3844.9	7262.7	11600.5	28518.7	52015.	71785.	102600.	182272.	416331.	3370212.
BRWA41	164158.3	266706.	0.0	1784.1	3963.0	6925.2	11561.4	28105.0	52398.	72277.	103161.	183794.	418373.	3376485.
BRHB42	197450.5	301679.	1251.0	3762.4	6853.4	9600.6	16185.2	36387.0	63924.	92690.	129238.	232892.	489825.	3599269.
CON111	339663.1	485237.	499.4	7419.8	11718.6	17898.6	29289.3	64077.9	112144.	160906.	238121.	433617.	838762.	4659786.
BRBR59	349928.7	496087.	0.0	7171.2	12242.7	19632.6	29968.6	67176.7	116114.	166979.	242256.	444505.	846307.	4704312.
516431	20173.4	35669.	0.0	0.0	0.0	1.7	82.6	1070.1	3240.	5460.	8300.	20488.	63443.	250982.
516531	20311.8	34957.	0.0	0.0	3.6	52.3	131.7	841.8	2306.	4296.	8295.	22329.	64525.	240424.
NAEA66	28204.6	48110.	0.0	0.0	0.0	0.0	154.2	1188.5	3502.	6471.	11678.	30642.	90733.	332958.
NABR67	35786.0	57030.	0.0	0.0	0.0	119.8	352.4	2178.0	5590.	9361.	17303.	42839.	116126.	384272.
CON130	386687.5	527842.	876.8	8981.0	13246.1	23708.8	35594.0	76544.7	133030.	188137.	266314.	480081.	991065.	4931350.
CON147	455240.0	595796.	1424.1	13458.1	17286.4	30280.3	44812.2	92772.8	159987.	232849.	311701.	579669.	1185598.	5562412.
BRHE68	469243.6	605833.	1634.0	14606.9	18902.8	33083.4	46601.8	97408.0	167049.	241867.	320295.	603980.	1247625.	5723482.
292531	3833.6	5328.	0.0	0.0	0.0	0.0	0.0	620.3	1361.	1987.	2890.	5158.	9723.	59403.
CON234	508765.2	631899.	185.0	21564.0	27555.7	43536.4	56287.6	115854.1	192580.	274735.	373212.	665466.	1314572.	6125002.

BRRI70	509421.5	630905.	0.0	22128.5	28095.2	44498.2	57081.2	117514.0	193899.	275325.	375995.	665039.	1313844.	6135975.
BRRO72	533586.6	652544.	0.0	22803.2	27751.5	46727.6	62696.0	130248.0	212511.	286867.	397569.	688980.	1360593.	6356870.
BRGM73	532967.2	647922.	4.0	22782.6	27291.8	46441.2	63546.0	132173.0	213375.	286855.	397043.	689498.	1344876.	6254466.

Table 8.10
Frequency Analysis of 1900-2007 Bwam3 and Bwam8 Naturalized Flows (acre-feet/month)

CONTROL		STANDARD	PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
POINT	MEAN	DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
DMAS09	9255.8	19335.	0.0	0.0	0.0	8.0	108.2	464.8	1162.	1970.	3473.	8511.	25930.	196469.
BRSE11	21332.4	42338.	0.0	0.0	0.0	180.7	474.1	1678.0	3238.	5383.	9029.	20152.	61576.	453509.
421331	7581.6	20874.	0.0	0.0	0.0	0.0	0.0	9.0	442.	1073.	2012.	5152.	20605.	264176.
CON036	56406.1	114722.	0.0	0.0	0.0	383.8	1371.0	4627.9	9298.	14233.	23908.	54846.	156395.	1408762.
BRSB23	55885.6	113667.	0.0	0.0	0.0	380.6	1359.0	4587.0	9211.	14092.	23692.	54349.	154951.	1395822.
515531	67352.2	131307.	0.0	0.0	0.1	198.6	1526.2	6662.0	13374.	19480.	32705.	67263.	190079.	1794484.
BRPP27	68788.7	132822.	0.0	0.0	0.0	191.0	1558.8	6714.0	13737.	20111.	33088.	69049.	196500.	1810792.
BRDE29	83078.8	152978.	0.0	0.0	416.0	1444.2	3142.2	9601.0	18241.	27314.	42907.	89330.	218696.	2450046.
515631	90104.7	163483.	0.0	39.5	621.8	1705.6	3653.1	10266.1	20267.	30441.	47942.	99877.	235096.	2653863.
BRGR30	92050.9	166509.	0.0	0.0	403.3	1677.6	3731.4	10484.0	20268.	31280.	49647.	101401.	239023.	2710228.
409732	1689.0	3243.	0.0	0.0	0.0	0.0	0.0	153.6	426.	663.	984.	1775.	4155.	50627.
CON063	99527.7	175573.	0.0	671.5	1124.8	2260.0	4810.6	12741.6	23758.	36707.	55877.	115126.	256948.	2804884.
515731	121222.7	199896.	0.0	1286.0	2151.2	3751.1	7522.7	18856.7	35013.	52745.	74263.	140961.	313472.	2962997.
BRAQ33	122642.4	201902.	0.0	1283.8	2097.8	3850.8	7703.2	19021.0	35664.	53399.	75411.	141059.	317574.	2981239.
515831	6866.5	15401.	0.0	0.0	0.0	0.0	0.0	113.3	516.	1059.	2120.	6249.	19701.	187168.
CON070	130795.6	206744.	0.0	761.0	1716.1	3929.5	7064.9	20598.3	39142.	59498.	84157.	150653.	329390.	3096309.
509431	30982.7	75810.	0.0	6.7	28.4	395.4	1138.6	2772.9	5631.	8788.	14018.	30824.	82506.	1639712.
515931	11607.1	29289.	0.0	0.0	0.0	0.1	57.4	456.1	1244.	2392.	3806.	9650.	28030.	364784.
LEHM46	13674.1	28419.	0.0	0.0	14.4	87.6	256.6	968.3	2495.	3768.	6082.	12696.	35299.	269330.
LEGT47	21176.3	42195.	0.0	0.0	0.0	125.3	466.3	1618.0	4046.	6174.	10154.	20732.	54451.	383340.
516031	42614.1	75881.	0.0	0.0	0.3	19.6	850.0	4126.8	9006.	14207.	22394.	47127.	115439.	715440.
LEBE49	42818.8	76200.	0.0	0.0	0.0	8.0	855.6	4149.0	9052.	14267.	22532.	47388.	116204.	718653.
516131	20025.1	35088.	0.0	83.0	141.8	504.7	803.1	2447.8	4645.	7005.	10696.	22442.	52410.	309090.
LABE52	20326.9	35420.	0.0	0.0	112.0	471.6	807.0	2463.0	4691.	7084.	10864.	22681.	53407.	310885.
CON096	78461.1	132488.	0.0	305.7	618.0	1989.2	3849.0	10098.5	19931.	28967.	45779.	88772.	203232.	1232362.
LRLR53	78656.8	132929.	0.0	305.8	617.7	2003.8	3877.8	10084.0	20095.	28926.	45788.	88886.	203518.	1237000.
516231	5244.0	8904.	0.0	0.0	0.0	14.7	117.9	479.0	1088.	1668.	2698.	6259.	14894.	74909.
516331	16209.3	25929.	0.0	0.0	0.0	133.5	489.8	1824.7	3820.	5600.	9016.	19728.	46321.	210085.
GALA57	16437.4	26278.	0.0	0.0	0.0	135.4	496.8	1858.0	3882.	5664.	9192.	19991.	47087.	212283.
CON108	115922.2	184952.	0.0	512.2	1259.3	2934.0	6265.3	16213.4	30324.	46165.	69471.	134457.	298298.	1670985.
LRCA58	115982.6	185046.	0.0	511.5	1260.8	2934.8	6268.0	16227.0	30332.	46184.	69514.	134505.	298422.	1672000.
433901	161154.5	253994.	200.9	1627.2	2475.8	5218.4	9653.9	25211.9	49999.	72162.	102600.	187963.	406610.	3370212.
BRWA41	160898.0	253348.	0.0	1136.0	2256.6	5042.4	9331.6	25200.0	49706.	71206.	102563.	187713.	406658.	3376485.
BRHB42	193718.1	289993.	927.5	2955.6	4493.7	8477.2	13990.4	33140.9	62898.	92565.	128826.	233093.	475728.	3599269.
CON111	331738.2	479817.	311.5	6191.5	9722.8	17063.5	25890.5	61444.5	111343.	156128.	232562.	407631.	802176.	4659786.
BRBR59	341482.3	494246.	0.0	6932.6	11161.7	17747.0	27683.4	64259.0	116195.	162593.	239988.	415787.	820463.	4704312.
516431	20522.6	39287.	0.0	0.0	0.0	0.0	2.0	777.2	2730.	4922.	8089.	20021.	63443.	360128.
516531	20245.3	36798.	0.0	0.0	0.0	28.7	111.6	723.8	2336.	4388.	8525.	21556.	62675.	298569.
NAEA66	28090.7	50794.	0.0	0.0	0.0	11.6	141.0	1024.0	3485.	6366.	11996.	29608.	87042.	413723.
NABR67	36025.8	62952.	0.0	0.0	0.0	55.5	244.1	1862.0	5058.	8907.	16543.	40035.	108614.	540322.
CON130	378020.6	531480.	0.0	8884.6	13123.1	21218.7	32759.0	73776.6	133030.	183411.	265307.	462088.	946012.	4969734.
CON147	445171.7	606750.	0.0	13386.8	16245.1	27044.2	41973.4	89460.8	158928.	225676.	306386.	558092.	1138511.	5900311.
BRHE68	458412.1	619496.	0.0	14555.2	17788.1	29512.4	43971.0	95023.0	167539.	235452.	313516.	577625.	1153505.	6113000.
292531	3762.5	6907.	0.0	0.0	0.0	0.0	0.0	499.3	1159.	1688.	2506.	4775.	9646.	148840.
CON234	495780.4	653584.	0.0	19853.9	24924.9	38273.7	52782.6	111618.6	189102.	265929.	359086.	627990.	1195949.	7237370.
BRRI70	496172.0	653262.	0.0	19640.7	25510.6	38637.8	52998.8	113055.0	189402.	267037.	362043.	630317.	1194136.	7354000.
BRRO72	519246.1	678527.	0.0	20520.3	26640.9	40611.6	57984.2	123258.0	204316.	280424.	383575.	658555.	1245282.	7683460.
BRGM73	518636.2	675392.	0.0	20495.3	26427.6	41180.6	58122.0	123118.0	203218.	280532.	383903.	657765.	1242238.	7674240.

Table 8.11
Frequency Analysis of 1940-2007 BRAC3 Inflows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
			100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
DMAS09	3454.0	13005.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	0.	7296.	158444.
BRSE11	10190.9	34306.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	248.	26596.	408040.
421331	5836.0	21353.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	1202.	16523.	254365.
CON036	25244.8	91412.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	3574.	67182.	1381721.
BRSB23	25001.1	90538.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	3538.	66540.	1369052.
515531	50975.2	109563.	0.0	0.0	0.0	220.4	2078.1	7071.4	13086.	18182.	26687.	46107.	124379.	1763180.
BRPP27	51540.8	110704.	0.0	0.0	0.0	0.0	1764.7	6767.2	12878.	17857.	26505.	48484.	130020.	1779641.
BRDE29	62697.7	141036.	0.0	0.0	0.0	0.0	1729.7	6802.6	13354.	20217.	29737.	57025.	177967.	2414256.
515631	72933.8	153525.	0.0	0.0	0.0	571.6	3216.0	9249.8	16285.	25873.	39238.	72099.	195115.	2617464.
BRGR30	74394.2	156648.	0.0	0.0	0.0	568.1	3226.2	9202.3	16363.	25951.	39888.	72569.	199819.	2673790.
409732	1267.5	2488.	0.0	0.0	0.0	0.0	0.0	0.0	179.	445.	750.	1370.	3176.	30604.
CON063	79568.0	164409.	0.0	0.0	0.0	655.1	3408.8	9848.2	17566.	27585.	41805.	78583.	212533.	2768396.
515731	98418.4	190217.	0.0	0.0	0.0	875.6	3768.5	12190.5	22728.	36935.	53105.	98094.	260895.	2921541.
BRAQ33	99189.0	191443.	0.0	0.0	0.0	875.6	3768.5	12190.5	22871.	37148.	53873.	98546.	261165.	2939689.
515831	6587.4	14410.	0.0	0.0	0.0	0.0	0.0	0.0	255.	810.	1840.	6570.	20388.	187126.
CON070	113060.3	208932.	0.0	0.0	0.0	840.8	4029.9	12658.2	25248.	42485.	63716.	118763.	307892.	3054515.
509431	32265.8	83703.	0.0	0.0	0.0	0.0	378.7	2113.6	4571.	6682.	11497.	30476.	87095.	1504543.
515931	9057.6	26530.	0.0	0.0	0.0	0.0	0.0	0.0	359.	1022.	2072.	5231.	20615.	278004.
LEHM46	10136.1	27601.	0.0	0.0	0.0	0.0	0.0	0.0	280.	824.	1907.	6338.	25666.	261235.
LEGT47	16282.7	41705.	0.0	0.0	0.0	0.0	0.0	0.0	289.	840.	2122.	11622.	48163.	374981.
516031	40271.0	77247.	0.0	0.0	0.0	0.0	0.0	1079.3	4938.	9309.	17748.	42809.	113051.	618545.
LEBE49	40232.9	77179.	0.0	0.0	0.0	0.0	0.0	1078.2	4933.	9300.	17730.	42766.	112938.	617926.
516131	20332.2	37679.	0.0	0.0	0.0	0.0	0.0	1208.6	3793.	6311.	9173.	20883.	59399.	308044.
LABE52	20605.8	38223.	0.0	0.0	0.0	0.0	0.0	1207.4	3789.	6305.	9164.	21926.	60102.	309463.
CON096	65254.2	122896.	0.0	0.0	0.0	0.0	0.0	2435.1	9909.	17592.	28541.	71328.	186266.	912758.
LRLR53	65123.7	122650.	0.0	0.0	0.0	0.0	0.0	2430.3	9889.	17557.	28484.	71185.	185894.	910932.
516231	4828.3	9025.	0.0	0.0	0.0	0.0	0.0	42.7	786.	1176.	1863.	5509.	14623.	74899.
516331	15740.8	26812.	0.0	0.0	0.0	0.0	0.0	405.3	2814.	4545.	7349.	19703.	48066.	209947.
GALA57	15930.0	27174.	0.0	0.0	0.0	0.0	0.0	402.9	2797.	4547.	7486.	19879.	48668.	212137.
CON108	98399.0	174345.	0.0	0.0	0.0	0.0	0.0	5141.1	15108.	26072.	45528.	117088.	288959.	1393346.
LRCA58	98354.0	174318.	0.0	0.0	0.0	0.0	0.0	5130.8	15085.	26020.	45452.	117051.	288813.	1393344.
433901	140759.8	256133.	0.0	0.0	166.9	2853.6	6421.7	16173.0	32999.	50937.	76137.	148478.	365172.	3310588.
BRWA41	140578.9	255980.	0.0	0.0	166.6	2847.9	6408.8	16140.0	32933.	50835.	75985.	148181.	364663.	3303970.
BRHB42	162888.7	286864.	0.0	0.0	164.9	2819.4	6577.8	16297.8	35864.	56516.	86806.	191437.	427072.	3503276.
CON111	275450.0	462153.	0.0	0.0	338.6	3194.0	8620.4	25341.7	56397.	94523.	139907.	318368.	742728.	4585996.
BRBR59	276205.0	464295.	0.0	0.0	335.2	3162.1	8534.2	25088.3	55833.	93577.	138510.	323908.	755014.	4572952.
516431	19426.1	35147.	0.0	0.0	0.0	0.0	0.9	854.0	3001.	5041.	7925.	19051.	62133.	248962.
516531	18872.5	33938.	0.0	0.0	0.0	0.0	0.0	379.9	1538.	3461.	6916.	20079.	62754.	239515.
NAEA66	25272.8	45250.	0.0	0.0	0.0	0.0	0.0	437.7	1847.	4199.	8445.	26057.	86955.	309336.
NABR67	30978.8	53138.	0.0	0.0	0.0	0.0	0.0	501.3	2415.	5581.	11231.	35233.	105096.	373377.
CON130	308473.3	500133.	0.0	0.0	535.4	4077.3	9357.3	31025.0	65841.	103266.	154552.	377729.	895887.	4854951.
CON147	335974.6	544131.	0.0	13.5	533.2	4276.4	9555.5	32692.0	68979.	106256.	170234.	411150.	965516.	5390970.
BRHE68	334115.3	541884.	0.0	13.4	528.4	4237.9	9469.8	32397.0	68358.	105300.	168703.	407450.	970358.	5342528.
292531	3664.6	5426.	0.0	0.0	0.0	0.0	0.0	0.0	959.	1915.	2874.	5158.	9723.	59403.
CON234	402792.2	592300.	0.0	13.1	674.0	4253.7	11048.9	42967.0	95337.	157132.	251514.	544564.	1144791.	5731446.
BRRI70	400378.0	588751.	0.0	13.1	669.8	4228.6	10982.2	42709.0	94765.	156190.	250005.	541300.	1137931.	5697100.
BRRO72	467696.1	644595.	0.0	12.9	663.2	4207.6	11733.6	63921.0	133043.	218196.	329273.	630852.	1278923.	6171675.
BRGM73	461110.3	635249.	0.0	12.8	654.2	4139.8	11537.9	62843.0	130796.	214513.	323733.	624086.	1257840.	6067532.

The mean and standard deviation of the monthly inflows in acre-feet/month at the 48 control points are tabulated in the second and third columns of the tables. The inflow volumes (acre-feet/month) that are equaled or exceeded in specified percentages of the 816 months of 1940-2007 (Tables 8.9 and 8.11) or 1,296 months of 1900-2007 (Tables 8.10 and 8.12) are also tabulated. For example, the inflow at control point BRRI70 (Richmond gage), is equal to or greater than 10,982 ac-ft during 90% of the months of 1940-2007.

Table 8.12
Frequency Analysis of 1900-2007 BRAC3 Inflows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
			PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
DMAS09	4087.4	13428.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	369.	10919.	159572.
BRSE11	11767.4	36233.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	2044.	37132.	431046.
421331	5568.3	19870.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	1249.	15532.	254365.
CON036	26638.1	88617.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	5635.	74696.	1381721.
BRSB23	26381.9	87772.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	0.	5578.	73964.	1369052.
515531	52456.9	105356.	0.0	0.0	0.0	139.3	1069.4	5989.2	12490.	18028.	27427.	52796.	132556.	1763180.
BRPP27	52891.2	106345.	0.0	0.0	0.0	0.0	778.1	5652.2	12310.	17784.	27103.	54082.	133395.	1779641.
BRDE29	62850.8	129577.	0.0	0.0	0.0	0.0	762.6	5765.7	13041.	20283.	31110.	64255.	171647.	2414256.
515631	72619.0	140363.	0.0	0.0	0.0	89.8	1915.1	8246.3	16110.	25960.	39783.	79322.	190388.	2617464.
BRGR30	73868.0	142961.	0.0	0.0	0.0	89.3	1903.7	8328.4	16151.	26412.	40433.	81484.	195346.	2673790.
409732	1568.4	3276.	0.0	0.0	0.0	0.0	0.0	0.0	143.	453.	828.	1692.	4093.	50627.
CON063	78915.9	150544.	0.0	0.0	0.0	142.9	2009.4	8904.4	17566.	28732.	42981.	89302.	204308.	2768396.
515731	96601.4	175472.	0.0	0.0	0.0	140.0	2184.9	11004.2	22864.	37044.	54437.	103094.	255068.	2921541.
BRAQ33	97249.7	176566.	0.0	0.0	0.0	140.0	2184.9	11004.2	23035.	37302.	54587.	104674.	255068.	2939689.
515831	6231.1	14882.	0.0	0.0	0.0	0.0	0.0	0.0	232.	738.	1617.	5354.	17910.	187126.
CON070	109673.5	196054.	0.0	0.0	0.0	129.6	2212.1	11634.6	25158.	41065.	62377.	119207.	286189.	3054515.
509431	29420.9	74388.	0.0	0.0	0.0	24.2	594.0	2023.8	3947.	6149.	9867.	28312.	79409.	1504543.
515931	8621.1	26713.	0.0	0.0	0.0	0.0	0.0	0.0	416.	1109.	2171.	5100.	18228.	356617.
LEHM46	9715.4	26568.	0.0	0.0	0.0	0.0	0.0	0.0	306.	860.	1912.	6914.	25617.	261235.
LEGT47	15137.2	40442.	0.0	0.0	0.0	0.0	0.0	0.0	305.	871.	2021.	10513.	44202.	374981.
516031	37054.3	72864.	0.0	0.0	0.0	0.0	0.0	993.4	4506.	9029.	16435.	37604.	106827.	624850.
LEBE49	37019.0	72798.	0.0	0.0	0.0	0.0	0.0	992.4	4502.	9020.	16419.	37567.	106720.	624308.
516131	18690.4	34902.	0.0	0.0	0.0	0.0	0.0	1137.0	3647.	5906.	9173.	19839.	51732.	308044.
LABE52	18876.3	35339.	0.0	0.0	0.0	0.0	0.0	1135.9	3643.	5946.	9164.	19840.	52087.	309463.
CON096	65262.0	125750.	0.0	0.0	0.0	0.0	0.0	2369.2	9909.	17340.	28373.	70138.	180693.	1207736.
LRLR53	65132.6	125501.	0.0	0.0	0.0	0.0	0.0	2364.5	9889.	17305.	28316.	69998.	180332.	1205321.
516231	4874.1	8898.	0.0	0.0	0.0	0.0	0.0	0.1	859.	1274.	2112.	5758.	14580.	74899.
516331	14903.1	25914.	0.0	0.0	0.0	0.0	0.0	219.1	2645.	4487.	7167.	17522.	44754.	209947.
GALA57	15061.8	26241.	0.0	0.0	0.0	0.0	0.0	217.8	2629.	4514.	7195.	17750.	45166.	212137.
CON108	92816.9	172137.	0.0	0.0	0.0	0.0	0.0	4083.8	13869.	24338.	40122.	101897.	263532.	1602019.
LRCA58	92771.9	172110.	0.0	0.0	0.0	0.0	0.0	4075.6	13850.	24289.	40054.	101859.	263391.	1601961.
433901	134406.4	237921.	0.0	0.0	357.2	1705.7	4691.2	14715.1	32239.	49546.	74288.	144517.	349855.	3310588.
BRWA41	134255.8	237842.	0.0	0.0	356.5	1701.9	4682.1	14685.7	32175.	49447.	74140.	144228.	349156.	3303970.
BRHB42	155841.2	271733.	0.0	0.0	353.0	1684.9	4667.6	15342.0	35382.	55209.	86697.	175362.	411311.	3503276.
CON111	262969.8	454423.	0.0	0.0	483.3	1963.1	6347.4	24858.0	53448.	86558.	134811.	300862.	685487.	4585996.
BRBR59	263998.1	459522.	0.0	0.0	478.4	1943.4	6283.6	24610.0	52914.	85693.	133466.	304014.	688445.	4572952.
516431	19601.5	38044.	0.0	0.0	0.0	0.0	0.0	564.6	2437.	4557.	7567.	18132.	61603.	354347.
516531	18688.9	35855.	0.0	0.0	0.0	0.0	0.0	301.1	1469.	3298.	6736.	19614.	58833.	296656.
NAEA66	24998.4	48157.	0.0	0.0	0.0	0.0	0.0	337.9	1739.	4013.	8219.	25474.	82086.	411558.
NABR67	30614.1	58151.	0.0	0.0	0.0	0.0	0.0	383.2	2078.	4813.	9756.	32120.	95746.	525438.
CON130	295423.4	501292.	0.0	0.0	654.9	2163.4	7348.4	28512.0	60610.	98701.	149142.	355587.	816933.	4856550.
CON147	322468.1	549224.	0.0	0.0	652.2	2296.7	7667.7	30031.0	66415.	102494.	158676.	379486.	903766.	5390970.
BRHE68	320500.8	546454.	0.0	0.0	646.4	2276.0	7598.7	29761.0	65817.	101572.	157249.	376071.	895644.	5342528.
292531	3597.9	6981.	0.0	0.0	0.0	0.0	0.0	0.0	568.	1614.	2501.	4775.	9646.	148840.
CON234	389207.0	611251.	0.0	0.0	651.8	2418.9	8487.1	39997.5	91710.	152067.	242423.	496668.	1049179.	6959821.
BRRI70	386874.2	607588.	0.0	0.0	647.8	2404.1	8436.1	39757.5	91159.	151155.	240969.	493690.	1042892.	6918116.
BRRO72	453228.1	669541.	0.0	0.0	641.3	2614.6	9147.6	57655.8	126281.	200055.	306419.	579087.	1175748.	7531104.
BRGM73	446734.4	661024.	0.0	0.0	632.6	2572.5	8999.5	56690.1	124149.	196678.	301296.	574498.	1160847.	7491199.

Table 8.13
Frequency Analysis of 1940-2007 BRAC8 Inflows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE 100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
DMAS09	5723.9	16624.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	154.	2820.	15058.	170160.
BRSE11	13908.4	35542.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	2161.	9891.	42186.	414568.
421331	6794.1	21654.	0.0	0.0	0.0	0.0	0.0	0.0	0.	42.	802.	3824.	17263.	254612.
CON036	34661.8	96793.	0.0	0.0	0.0	0.0	0.0	0.0	0.	693.	5326.	27437.	98782.	1399552.
BRSB23	34330.0	95869.	0.0	0.0	0.0	0.0	0.0	0.0	0.	686.	5273.	27163.	97846.	1386704.
515531	49143.9	112266.	0.0	229.1	334.5	677.4	2527.0	6221.5	10601.	15080.	20465.	41170.	131932.	1781832.
BRPP27	49887.9	113708.	0.0	0.0	0.0	340.4	2169.6	5858.6	10314.	14998.	20528.	43935.	134723.	1798194.
BRDE29	63511.2	145542.	0.0	0.0	0.0	376.4	2273.9	6423.2	12397.	16695.	25818.	57017.	171792.	2435600.
515631	72613.3	156846.	0.0	0.0	154.5	1741.5	4216.1	9203.6	15498.	23240.	34007.	67018.	192033.	2639156.
BRGR30	74231.5	160070.	0.0	0.0	153.6	1731.0	4189.4	9330.5	15640.	23439.	34619.	68743.	202610.	2695414.
409732	1307.8	2478.	0.0	0.0	0.0	0.0	0.0	0.0	291.	497.	812.	1418.	3176.	30604.
CON063	79769.7	168048.	0.0	0.0	178.1	1741.5	4470.6	10486.5	16951.	24984.	37957.	76009.	216697.	2789586.
515731	100986.3	194008.	0.0	0.0	287.8	2166.3	5883.0	13149.8	22271.	33332.	52477.	99777.	272562.	2942644.
BRAQ33	101828.7	195300.	0.0	0.0	287.8	2166.3	5883.0	13192.2	22300.	33548.	52825.	100455.	278973.	2960819.
515831	6698.9	14576.	0.0	0.0	0.0	0.0	0.0	0.0	321.	818.	1833.	6559.	20695.	187135.
CON070	116097.4	212439.	0.0	0.0	267.6	2349.8	5989.2	14063.0	25120.	39613.	64704.	125054.	324412.	3075976.
509431	32229.3	84588.	0.0	0.0	0.0	80.1	546.7	2389.4	4497.	7027.	13456.	33379.	81911.	1581689.
515931	9555.6	27422.	0.0	0.0	0.0	0.0	0.0	73.3	706.	1323.	2356.	5383.	22548.	320171.
LEHM46	10822.3	28343.	0.0	0.0	0.0	0.0	0.0	63.7	559.	1132.	2240.	6903.	27929.	266621.
LEGT47	16693.3	41662.	0.0	0.0	0.0	0.0	0.0	63.0	568.	1241.	2649.	12214.	47372.	375084.
516031	42302.0	77578.	0.0	0.0	0.0	0.0	0.0	2602.7	7246.	12333.	20408.	44321.	115210.	624695.
LEBE49	42304.2	77666.	0.0	0.0	0.0	0.0	0.0	2600.1	7239.	12321.	20388.	44276.	115095.	625804.
516131	20853.7	37643.	0.0	0.0	0.0	0.0	130.2	2030.3	4415.	6575.	9765.	22441.	59708.	308679.
LABE52	21140.0	38196.	0.0	0.0	0.0	0.0	130.0	2028.3	4411.	6568.	9755.	22419.	60416.	310105.
CON096	66591.5	123314.	0.0	0.0	0.0	0.0	0.0	3498.9	11862.	19284.	31388.	73539.	187495.	915725.
LRLR53	66458.3	123068.	0.0	0.0	0.0	0.0	0.0	3491.9	11838.	19245.	31326.	73392.	187120.	913893.
516231	4935.1	9026.	0.0	0.0	0.0	0.0	0.0	316.0	910.	1222.	2001.	5504.	14624.	74909.
516331	15877.3	26866.	0.0	0.0	0.0	0.0	0.0	1212.2	2429.	3906.	7546.	19834.	48208.	210097.
GALA57	16090.7	27236.	0.0	0.0	0.0	0.0	0.0	1205.7	2441.	3933.	7645.	20039.	48880.	212298.
CON108	101068.7	174991.	0.0	0.0	0.0	0.0	0.0	5701.2	17435.	28580.	50644.	121436.	295730.	1394836.
LRCA58	101033.3	174973.	0.0	0.0	0.0	0.0	0.0	5697.7	17414.	28546.	50609.	121418.	295537.	1394844.
433901	143360.5	260527.	0.0	418.8	1150.9	4478.6	8230.0	16450.3	30218.	46697.	76973.	150155.	374318.	3332584.
BRWA41	143174.4	260358.	0.0	417.9	1148.6	4469.6	8213.5	16417.4	30158.	46604.	76819.	151156.	373790.	3325921.
BRHB42	168019.4	294159.	0.0	0.0	0.0	2409.7	6248.7	15101.6	29995.	57926.	93780.	197207.	439492.	3538790.
CON111	288494.7	471058.	0.0	0.0	0.0	1027.9	6413.9	26163.3	56611.	93340.	172711.	362432.	758667.	4579194.
BRBR59	287804.2	470812.	0.0	0.0	0.0	1017.6	6349.8	25901.7	56046.	92407.	170990.	361587.	771239.	4533595.
516431	19856.5	35420.	0.0	0.0	0.0	0.1	43.7	1057.6	3167.	5283.	8015.	20120.	62672.	249646.
516531	19410.2	34231.	0.0	0.0	0.0	0.0	23.6	513.8	1730.	3816.	7335.	21060.	63415.	239896.
NAEA66	26061.6	45606.	0.0	0.0	0.0	0.0	23.5	664.5	2372.	4737.	9068.	27919.	87591.	309796.
NABR67	32517.5	54234.	0.0	0.0	0.0	0.0	59.3	826.9	3149.	6343.	11927.	37675.	108276.	381282.
CON130	335973.2	517531.	0.0	0.0	0.0	1519.3	8074.2	31470.0	69170.	120664.	204261.	428522.	940725.	4900865.
CON147	371751.2	567575.	0.0	0.0	0.0	1788.6	8497.5	35135.7	75013.	130701.	222695.	504307.	1094823.	5452128.
BRHE68	369577.2	565317.	0.0	0.0	0.0	1495.4	8139.2	34567.0	74042.	129288.	220452.	499543.	1096556.	5402860.
292531	3572.3	5461.	0.0	0.0	0.0	0.0	0.0	0.0	611.	1665.	2771.	5147.	9723.	59403.
CON234	405181.7	599581.	0.0	0.0	0.0	2120.1	8556.9	39206.6	92048.	157650.	255166.	555800.	1161514.	5791300.
BRRI70	402753.4	595988.	0.0	0.0	0.0	2107.3	8505.7	38971.4	91497.	156705.	253637.	552470.	1154554.	5756598.
BRRO72	483539.1	649383.	0.0	0.0	0.0	4839.0	17796.0	80590.5	156368.	233103.	349981.	647024.	1313377.	6247460.
BRGM73	478715.3	641370.	0.0	0.0	0.0	5168.6	17816.4	80098.4	153880.	232470.	344768.	646667.	1292227.	6143430.

Table 8.14
Frequency Analysis of 1900-2007 BRAC8 Inflows (acre-feet/month)

CONTROL POINT	MEAN	STANDARD DEVIATION	100%	99%	98%	95%	90%	75%	60%	50%	40%	25%	10%	MAXIMUM
			PERCENTAGE OF MONTHS WITH FLOWS EQUALING OR EXCEEDING VALUES SHOWN IN THE TABLE											
DMAS09	6640.0	17560.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	524.	4684.	19230.	195071.
BRSE11	15981.4	39022.	0.0	0.0	0.0	0.0	0.0	0.0	0.	0.	2576.	12858.	46728.	452211.
421331	6662.0	20149.	0.0	0.0	0.0	0.0	0.0	0.0	0.	70.	936.	3991.	17880.	254612.
CON036	37464.1	96599.	0.0	0.0	0.0	0.0	0.0	0.0	0.	862.	6520.	30125.	109698.	1399552.
BRSB23	37107.5	95684.	0.0	0.0	0.0	0.0	0.0	0.0	0.	853.	6457.	29843.	108657.	1386704.
515531	51872.0	110138.	0.0	177.6	267.1	493.5	1564.4	5617.6	10316.	14870.	21146.	45704.	143929.	1781832.
BRPP27	52510.0	111595.	0.0	0.0	0.0	176.0	1278.2	5293.8	10071.	14756.	21123.	48151.	148407.	1798194.
BRDE29	65334.4	137180.	0.0	0.0	0.0	197.6	1316.8	5886.0	12201.	17677.	26808.	64948.	184215.	2435600.
515631	73987.1	146952.	0.0	0.0	0.0	936.4	2691.3	8597.6	15516.	23767.	35906.	76054.	203814.	2639156.
BRGR30	75472.8	149727.	0.0	0.0	0.0	930.8	2675.1	8556.8	15640.	23922.	36579.	78375.	205983.	2695414.
409732	1623.7	3262.	0.0	0.0	0.0	0.0	0.0	0.0	308.	554.	915.	1747.	4140.	50627.
CON063	81099.0	158066.	0.0	0.0	0.0	957.9	2826.4	9374.7	17096.	26139.	38538.	84421.	219044.	2789586.
515731	101000.5	185040.	0.0	0.0	0.0	1296.1	4155.3	12119.8	22283.	34785.	54527.	108049.	271291.	2942644.
BRAQ33	101690.3	186128.	0.0	0.0	0.0	1296.1	4155.3	12119.8	22348.	35678.	54845.	108736.	275675.	2960819.
515831	6416.4	15157.	0.0	0.0	0.0	0.0	0.0	0.0	338.	794.	1644.	5434.	18963.	187135.
CON070	113358.6	201512.	0.0	0.0	0.0	1267.7	4281.7	12588.5	24284.	39613.	60905.	125600.	303994.	3075976.
509431	29757.3	74950.	0.0	0.0	32.2	125.5	888.5	2264.6	3991.	6558.	11738.	30036.	79260.	1581689.
515931	9020.1	27322.	0.0	0.0	0.0	0.0	0.0	71.3	731.	1385.	2350.	5354.	19340.	356254.
LEHM46	10323.5	27115.	0.0	0.0	0.0	0.0	0.0	58.5	547.	1075.	2240.	7332.	27083.	266621.
LEGT47	15543.4	40321.	0.0	0.0	0.0	0.0	0.0	57.8	557.	1129.	2512.	11577.	44281.	375084.
516031	39130.8	73378.	0.0	0.0	0.0	0.0	0.0	2060.7	7150.	11419.	18673.	40591.	112176.	625377.
LEBE49	39129.6	73450.	0.0	0.0	0.0	0.0	0.0	2058.6	7143.	11408.	18655.	40551.	112063.	627166.
516131	19236.2	34909.	0.0	0.0	0.0	0.0	0.0	1837.9	4267.	6470.	9806.	20680.	52027.	308679.
LABE52	19432.0	35356.	0.0	0.0	0.0	0.0	0.0	1836.1	4263.	6463.	9796.	21198.	52322.	310105.
CON096	67102.5	126434.	0.0	0.0	0.0	0.0	0.0	3235.5	12068.	19284.	31730.	72196.	185214.	1209164.
LRLR53	66969.4	126184.	0.0	0.0	0.0	0.0	0.0	3229.1	12044.	19245.	31667.	72052.	184844.	1206746.
516231	5007.6	8883.	0.0	0.0	0.0	0.0	0.0	338.8	954.	1404.	2340.	5900.	14672.	74909.
516331	15033.6	25929.	0.0	0.0	0.0	0.0	0.0	1053.2	2268.	3806.	7433.	18038.	45333.	210097.
GALA57	15224.1	26280.	0.0	0.0	0.0	0.0	0.0	1046.9	2254.	3886.	7551.	18191.	45819.	212298.
CON108	95854.1	173400.	0.0	0.0	0.0	0.0	0.0	4719.7	16114.	24962.	46780.	109582.	267498.	1604282.
LRCA58	95818.8	173382.	0.0	0.0	0.0	0.0	0.0	4710.2	16082.	24953.	46707.	109554.	267403.	1604234.
433901	136523.1	242247.	0.0	534.0	1127.3	2821.2	6144.8	15391.6	28672.	46697.	73788.	146332.	356967.	3332584.
BRWA41	136381.0	242192.	0.0	532.9	1125.0	2815.6	6132.5	15360.8	28615.	46604.	73640.	146040.	356253.	3325921.
BRHB42	160488.2	278902.	0.0	0.0	0.0	671.9	4270.7	13814.5	30088.	54318.	92088.	186661.	419261.	3538790.
CON111	275274.4	463236.	0.0	0.0	0.0	0.0	4268.6	24017.5	56611.	89131.	166030.	333005.	705118.	4579194.
BRBR59	275026.7	465218.	0.0	0.0	0.0	0.0	4225.9	23778.0	56046.	88243.	164374.	330259.	700413.	4533595.
516431	20049.6	38477.	0.0	0.0	0.0	0.0	40.4	731.7	2639.	4751.	7820.	18998.	62227.	356198.
516531	19145.5	36175.	0.0	0.0	0.0	0.0	19.0	427.7	1710.	3729.	6990.	20307.	60487.	297209.
NAEA66	25660.5	48495.	0.0	0.0	0.0	0.0	20.0	538.4	2331.	4678.	8564.	26169.	83324.	412107.
NABR67	31966.4	59392.	0.0	0.0	0.0	0.0	32.1	706.5	2798.	5896.	10833.	35074.	100622.	537211.
CON130	321890.8	518577.	0.0	0.0	0.0	0.0	5868.7	29348.1	67966.	113328.	193060.	409676.	856202.	4917121.
CON147	356481.7	572438.	0.0	0.0	0.0	26.2	6997.7	31222.6	72586.	120318.	210999.	451369.	990890.	5452128.
BRHE68	354254.0	569921.	0.0	0.0	0.0	0.0	6666.8	30701.0	71667.	118946.	208822.	447059.	986372.	5402860.
292531	3500.6	7008.	0.0	0.0	0.0	0.0	0.0	0.0	0.	1372.	2341.	4728.	9646.	148840.
CON234	391404.1	618912.	0.0	0.0	0.0	200.2	6908.0	35055.0	86728.	149511.	247067.	494207.	1062469.	7006333.
BRRI70	389058.5	615203.	0.0	0.0	0.0	199.0	6866.3	34845.0	86208.	148615.	245586.	491245.	1056103.	6964348.
BRRO72	469197.6	674516.	0.0	0.0	0.0	1092.8	13409.1	74971.0	147616.	224086.	330110.	600101.	1190878.	7581990.
BRGM73	464421.8	667509.	0.0	0.0	0.0	1210.3	13587.8	73943.0	146205.	221799.	325033.	592815.	1178557.	7550727.

Table 8.15
Comparison of 1940-1997 Mean Regulated and Unappropriated Flows for Brazos WAM

Control Point	Bwam3 Mean Flow Volumes			Bwam8 Mean Flow Volumes		
	Unappropriated (ac-ft/year)	Regulated (ac-ft/year)	Regulated (percent)	Unappropriated (ac-ft/year)	Regulated (ac-ft/year)	Regulated (percent)
DMAS09	44,460	88,053	198.0	74,326	101,397	136.4
BRSE11	132,042	233,257	176.7	178,075	241,783	135.8
421331	8,951	27,411	306.2	35,049	41,844	119.4
CON036	278,028	555,512	199.8	402,556	584,011	145.1
BRSB23	275,364	550,424	199.9	398,715	578,638	145.1
515531	303,632	384,792	126.7	465,534	592,643	127.3
BRPP27	316,850	408,920	129.1	480,509	615,211	128.0
BRDE29	470,426	588,834	125.2	657,726	798,754	121.4
515631	512,767	596,355	116.3	711,739	835,243	117.4
BRGR30	531,722	623,268	117.2	731,731	860,679	117.6
409732	0	887	–	0	571	–
CON063	578,540	686,902	118.7	782,041	923,324	118.1
515731	731,915	929,138	126.9	959,254	1,091,355	113.8
BRAQ33	740,903	940,449	126.9	969,080	1,102,840	113.8
515831	48,677	52,914	108.7	60,722	64,524	106.3
CON070	872,196	1,099,544	126.1	1,122,511	1,276,708	113.7
509431	252,848	272,511	107.8	292,855	312,169	106.6
515931	78,656	102,239	130.0	90,067	110,025	122.2
LEHM46	96,026	136,316	142.0	107,708	142,426	132.2
LEGT47	166,686	226,032	135.6	175,416	233,322	133.0
516031	295,847	336,579	113.8	328,387	350,421	106.7
LEBE49	295,561	338,900	114.7	328,436	352,779	107.4
516131	138,548	147,791	106.7	148,538	155,406	104.6
LABE52	140,036	150,354	107.4	150,167	158,037	105.2
CON096	482,706	582,109	120.6	530,433	632,730	119.3
LRLR53	481,740	583,445	121.1	529,371	634,026	119.8
516231	38,725	42,163	108.9	41,238	43,478	105.4
516331	130,594	143,349	109.8	153,830	166,571	108.3
GALA57	132,767	146,042	110.0	156,196	169,238	108.3
CON108	809,166	997,867	123.3	897,144	1,093,269	121.9
LRCA58	809,166	998,671	123.4	897,144	1,094,071	122.0
433901	1,071,925	1,387,535	129.4	1,362,088	1,603,789	117.7
BRWA41	1,070,603	1,392,926	130.1	1,360,186	1,608,739	118.3
BRHB42	1,331,914	1,729,830	129.9	1,675,680	2,011,520	120.0
CON111	2,298,411	2,988,582	130.0	2,794,518	3,371,666	120.7
BRBR59	2,311,411	3,111,116	134.6	2,786,947	3,491,627	125.3
516431	154,196	158,619	102.9	159,500	160,539	100.7
516531	127,535	136,225	106.8	160,434	167,282	104.3
NAEA66	200,401	225,945	112.7	236,450	256,843	108.6
NABR67	275,693	314,827	114.2	320,968	350,775	109.3
CON130	2,605,819	3,458,272	132.7	3,271,818	3,840,838	117.4
CON147	2,817,127	4,114,923	146.1	3,590,853	4,548,693	126.7
BRHE68	2,801,909	4,274,622	152.6	3,570,453	4,708,484	131.9
292531	7,770	10,032	129.1	43,331	46,691	107.8
CON234	3,530,902	4,665,109	132.1	4,013,004	5,203,132	129.7
BRRI70	3,509,744	4,642,283	132.3	3,988,957	5,179,261	129.8
BRRO72	4,308,064	4,547,382	105.6	4,939,478	5,116,054	103.6
BRGM73	4,251,567	4,251,567	100.0	4,895,393	4,895,393	100.0

Comparison of Regulated and Unappropriated Flows

In a conventional *WRAP-SIM* application with an input dataset from the TCEQ WAM System, the *SIM* simulation consists essentially of adjusting the naturalized flows read from the FLO file for the effects of the water rights described in the DAT file to compute regulated and unappropriated flows. The methodology for developing and applying condensed datasets focuses on unappropriated stream flows rather than regulated stream flows. Unappropriated flows are incorporated in a straight-forward manner in the creation and application of condensed datasets. Incorporation of regulated flows into a condensed model is more complicated than unappropriated flows because of the combined impacts of primary and secondary water rights on regulated flows. Without a RUF file, the *regulated flows* included in the output file created by a *SIM* simulation with a condensed input dataset are not consistent with the conventional definition of regulated flows. RUF file options may be adopted to better approximate regulated flows in a condensed model. The optional RUF file is needed only if regulated flows are of concern.

SIM options for applying the flow differences read from a regulated-unappropriated flow (RUF) file are controlled by the RUFIN and RUF switches on the *JO* record as described in Chapter 2. A RUF file contains differences between regulated less unappropriated flow volumes from the simulation results for an original dataset that are used within a *SIM* simulation with a condensed dataset to estimate regulated flows based on adjusting unappropriated flows.

Table 8.15 on the preceding page illustrates the significant differences between regulated and unappropriated flows in the Brazos WAM simulation. The 1940-1997 means of the regulated and unappropriated flow volumes read from the *SIM* simulation results output files created with the Bwam3 and Bwam8 input datasets from the TCEQ WAM System are tabulated for the 48 control points that are included in the BRAC datasets. The mean annual regulated flows are presented in Table 8.15 as a percentage of unappropriated flows as well as in acre-feet/year.

Brazos River Authority Condensed (BRAC) Data Files

The Brazos River Authority Condensed (BRAC) datasets were developed based on reducing the size of the Brazos WAM authorized and current use datasets as outlined in this chapter. The BRAC3 and BRAC8 FLO files were created from Bwam3 and Bwam8 *WRAP-SIM* simulation results using *WRAP-HYD* with the following *HYD* input files: BRAC3.HIN and BRAC8.HIN. The BRAC datasets for the authorized use scenario (BRAC3) and current use scenario (BRAC8) consist of the following *WRAP-SIM* input data files.

BRAC3.DAT	BRAC8.DAT
BRAC3_1940-2007.FLO	BRAC8_1940-2007.FLO
BRAC3_1940-2007.EVA	BRAC8_1940-2007.EVA
BRAC3_1940-2007.RUF	BRAC8_1940-2007.RUF
BRAC3_1900-2007.FLO	BRAC8_1900-2007.FLO
BRAC3_1900-2007.EVA	BRAC8_1900-2007.EVA
BRAC3_1900-2007.RUF	BRAC8_1900-2007.RUF

The BRAC3 and BRAC8 DAT files can be combined with the FLO and EVA files and optional RUF files covering either a 1900-2007 or 1940-2007 hydrologic period-of-analysis. A *SIM* simulation with the original 1940-1997 period-of-analysis can also be performed with the 1940-2007 FLO and EVA files. The hydrologic period-of-analysis is specified as the first two entries in the *JD* record of the DAT file. These parameters NYRS and YRST are the only data in the DAT file that refer to the period-of-analysis covered by the FLO, EVA, and RUF files. These *JD* record parameters may optionally be set as follows to specify simulation periods of 1900-2007, 1940-2007, or 1940-1997.

```
JD   108   1900
JD    68   1940
JD    58   1940
```

The BRAC datasets are available to simulate alternative reservoir system operating practices and water management and use scenarios for the system of 15 reservoirs and associated diversions at the 48 control points. The primary system is modeled by the DAT file with secondary water rights reflected in the FLO file. The primary system and its operation may be modified in any manner without altering the FLO file. However, changes to the secondary water rights would require repeating the procedure for developing the BRAC FLO file by applying the HIN file.

The BRAC3.DAT and BRAC8.DAT files were developed by extracting and modifying records from the Bwam3.DAT and Bwam8.DAT files. The number of control points, reservoirs, and water rights was greatly reduced. The two DAT files were further refined by various minor revisions that have no impact on simulation results. For example, the descriptive notes on the *WR* records to the right of the actual data fields were removed.

Return flows are included in the current use Bwam8 and BRAC8 but are not included in the authorized use Bwam3 and BRAC3 models. The Bwam3.DAT and BRAC3.DAT files include return flow *RF* records just as the Bwam8.DAT and BRAC8.DAT files, but the factor values are all zero. *RF* records are referenced by water right *WR* records. Values of zeros are also specified for constant return flow factors on the *WR* records. The BRAC3xRF.DAT file is a revised version of the BRAC3.DAT file with return flow data removed, with no effect on *SIM* simulation results.

Results of Condensing the Brazos WAM Datasets

The validity and accuracy of the condensed dataset is confirmed by reproducing the sequences of monthly diversions and diversion shortages, reservoir storage contents, and unappropriated flows contained in the Brazos WAM System simulation results associated with the 15 reservoirs and associated diversion targets and 48 control points. As discussed in the following Chapter 9, simulation results from the original Brazos WAM System datasets are properly reproduced by the Brazos River Authority Condensed (BRAC) datasets.

After completing the comparison of simulation results discussed in Chapter 9 that confirms that the datasets are correct, the simplified BRAC datasets are available thereafter to simulate alternative river/reservoir system operating rules and water management and use scenarios for the system of 15 reservoirs and associated diversions at the 48 control points. The primary system is modeled by the DAT file with secondary water rights reflected in the FLO file. The primary system may be modified in any manner without altering the FLO file. However, changes to the secondary water rights would require repeating the procedure for developing the BRAC FLO file. The optional RUF file is also modified any time the FLO file is changed.

CHAPTER 9
COMPARATIVE EVALUATION OF THE SIMULATION RESULTS FROM THE BRAC AND BRAZOS WAM DATASETS

The procedure outlined in Chapter 2 for condensing TCEQ WAM System datasets was applied to the Brazos WAM as described in Chapter 8 to develop much simpler BRAC datasets designed for studies of operations of the Brazos River Authority river/reservoir water management system. Simulation results obtained with the Brazos WAM versus condensed datasets are compared in the present Chapter 9. Alternative versions of the Bwam and BRAC datasets reflecting authorized versus current use scenarios and different hydrologic periods-of-analysis are also compared. Firm yield analyses performed with the BRAC and Bwam datasets are presented as the last section of the chapter. Chapter 9 is a comparative evaluation of the alternative models listed in Table 9.1.

Table 9.1
WRAP-SIM Input Datasets Discussed in Chapters 8 and 9

Filename	Water Use Scenario	Hydrologic Period-of-Analysis
	Original Brazos WAM Datasets	
Bwam3	authorized use (run 3)	January 1940 through December 2007
Bwam3	authorized use (run 3)	January 1900 through December 2007
Bwam8	current use (run 8)	January 1940 through December 2007
Bwam8	current use (run 8)	January 1900 through December 2007
	Brazos River Authority Condensed (BRAC) Datasets	
BRAC3	authorized use (run 3)	January 1940 through December 2007
BRAC3	authorized use (run 3)	January 1900 through December 2007
BRAC8	current use (run 8)	January 1940 through December 2007
BRAC8	current use (run 8)	January 1900 through December 2007

The Brazos WAM hydrologic period-of-analysis has been lengthened from 1940-1997 to 1900-2007 as described in Chapters 4, 5, 6, and 7. Versions of the BRAC model are developed with hydrologic periods-of-analysis of 1940-2007 and 1900-2007. The 1940-1997 hydrologic period-of-analysis in the original Brazos WAM dataset is a subset of the 1940-2007 period-of-analysis. Simulation results for 1940-1997 are also addressed in the comparative evaluation discussions of Chapter 9.

River System Inflows at the 48 BRAC Control Points

The 48 control points included in the Brazos River Authority Condensed (BRAC3 and BRAC8) datasets are listed in Table 9.2. Information describing these control points is provided in Tables 8.2, 8.3, and 8.4 and Figures 8.1 and 8.2 of Chapter 8. Twenty-two of the control points are USGS stream gaging stations, 15 control points are reservoirs, 10 control points are stream confluences, and the remaining control point is the basin outlet. The six-character control point identifiers listed in Table 9.2 are the same in the Bwam and BRAC datasets.

Table 9.2
BRAC Control Points

Control Points at Gaging Stations		Control Points at Reservoirs	
DMAS09	Double Mountain at Aspermont	515531	Possum Kingdom (POSDOM)
BRSE11	Brazos River at Seymour	515631	Granbury (GRNBRY)
BRSB23	Brazos River at South Bend	515731	Whitney (WHIT)
BRPP27	Brazos River at Palo Pinto	515831	Aquilla (AQUILA)
BRDE29	Brazos River at Dennis	509431	Waco (WACO)
BRGR30	Brazos River at Glen Rose	515931	Proctor (PRCTOR)
BRAQ33	Brazos River at Aquilla	516031	Belton (BELTON)
BRWA41	Brazos River at Waco	516131	Stillhouse Hollow (STLHSE)
BRHB42	Brazos River at Highbank	516231	Georgetown (GRGTWN)
LEHM46	Leon River at Hamilton	516331	Granger (GRNGER)
LEGT47	Leon River at Gatesville	516531	Limestone (LMSTNE)
LEBE49	Leon River at Belton	516431	Somerville (SMRVLE)
LABE52	Lampasas River at Belton	292531	Allens Creek (ALLENS)
LRLR53	Little River at Little River	421331	Hubbard Creek (HUBBRD)
GALA57	San Gabriel River Laneport	409732	Squaw Creek (SQWCRK)
LRCA58	Little River at Cameron		
BRBR59	Brazos River at Bryan		
NAEA66	Navasota River at Easterly		
NABR67	Navasota River at Bryan		
BRHE68	Brazos River at Hempstead		
BRRI70	Brazos River at Richmond		
BRRO72	Brazos River at Rosharon		

Control Points at Confluences and Basin Outlet	
CON036	Confluence of Hubbard Creek and Brazos River
CON063	Confluence of Squaw Creek and Brazos River
CON070	Confluence of Aquilla Creek and Brazos River
433901	Confluence of Bosque and Brazos River
CON096	Confluence of Lampasas and Little River
CON108	Confluence of Little River and San Gabriel
CON111	Confluence of Little River and Brazos River
CON130	Confluence of Yegua Creek and Brazos River
CON147	Confluence of Navasota River and Brazos River
CON234	Confluence of Allens Creek and Brazos River
BRGM73	Brazos River Outlet at the Gulf of Mexico

Sequences of monthly river system inflows are stored as *IN* records in the FLO input files for the BRAC3 and BRAC8 datasets. These inflows are plotted in Appendix E. Mean annual inflows for the 48 control points are tabulated in Table 8.8 of the preceding Chapter 8 for BRAC3 and BRAC8 1940-1997, 1940-2007, and 1900-2007 simulations. The 1940-1997 means for the original Brazos WAM (Bwam) naturalized flows are also included in Table 8.8. Program *TABLES* flow-frequency tables are provided as Tables 8.9 through 8.14 for the alternative inflow datasets. RUF files with differences between regulated and unappropriated flows are discussed in Chapter 8.

Confirmation of the Validity and Accuracy of the BRAC Datasets

As discussed in Chapter 2, if the primary system is operated in the same manner in both the condensed and original datasets, the water supply diversions and shortages, streamflow depletions, and storage volumes computed by the *SIM* simulation model should be the same. The condensed dataset should reproduce the simulation results for the primary system that are obtained with the original dataset. Unappropriated flows should also be reproduced. Thus, a comparison of simulation results provides a check on the accuracy and validity of the condensed datasets.

A key objective of the computational methodology is to reproduce the quantities connected directly to the water rights and reservoirs included in the condensed DAT file. Diversions and diversion shortages, return flows, streamflow depletions, and reservoir evaporation and storage volumes for primary system water rights and reservoirs should be the same in the *SIM* simulation results obtained from condensed versus original *SIM* input datasets.

Unappropriated flows should also match since they are included along with streamflow depletions less return flows in the FLO file inflows of the condensed *SIM* input dataset. Regulated flows do not match unless a RUF file is used. Regulated flows represent the actual physical flows at a control point. Unappropriated flows are the quantities remaining after all water rights have appropriated their allocated quantities of water in the simulation. Unappropriated flow at a particular control point in a particular month can not exceed regulated flow but may be less than regulated flow. *SIM* options for applying flow adjustments read from an optional RUF file may be activated to improve estimates of regulated flows in the condensed model simulation results.

Comparison of Simulation Results from the Alternative Datasets

The remainder of this chapter focuses on comparison of tables and plots that summarize the results of *WRAP-SIM* simulations with the input datasets listed in Table 9.1. The following comparisons show that the Brazos River Authority Condensed (BRAC) datasets do appropriately reproduce the simulation results of the original Brazos WAM (Bwam) datasets.

Water Supply Reliabilities Resulting from BRAC and Bwam Datasets

The reliability tables reproduced as Tables 9.3, 9.4, 9.5, 9.6, 9.7, 9.8, 9.9, and 9.10 were created with program *TABLES* from the results of *WRAP-SIM* simulations with the input datasets listed in Table 9.1. The reliabilities are for the aggregation of all diversion rights associated with each of the 15 BRAC3 reservoirs or 14 BRAC8 reservoirs. The reliabilities are listed by the control point identifiers of the reservoirs. A list of reservoirs and their control point identifiers is provided with the reliability tables. The Bwam3 versus BRAC3 reliabilities are compared by Tables 9.3 and 9.4 for the 1940-2007 simulations and Tables 9.5 and 9.6 for the 1900-2007 simulations. The Bwam8 versus BRAC8 reliabilities are compared by Tables 9.7 and 9.8 for the 1940-2007 simulations and Tables 9.9 and 9.10 for the 1900-2007 simulations.

In the Bwam8 and BRAC8 simulations reflected in Tables 9.7-9.10, the diversions from 12 of the 14 reservoirs have reliabilities of 100.00 percent. Diversions at Squaw Creek Reservoir (control point 409732) and Somerville Reservoir (control point 516431) are the only current use scenario diversions with reliabilities less than 100.00 percent. The diversion shortages and reliabilities associated with diversions from Squaw Creek and Somerville Reservoirs are essentially identical in the Bwam8 and BRAC8 simulations as they should. For example, for the 1940-2007 simulations reported in Tables 9.7 and 9.8, the volume reliabilities are 79.33 and 79.35 percent for Squaw Creek and 99.83 and 99.83 percent for Somerville for the Bwam8 and BRAC8 simulations.

Diversion shortages occur at seven of the 15 reservoirs in the Bwam3 and BRAC3 simulations reflected in Tables 9.3 through 9.6. For the 1940-2007 simulations of Tables 9.3 and 9.4, the total volume reliabilities for the Bwam3 and BRAC8 simulations are 97.77 and 97.93 percent, respectively. The Bwam3 and BRAC3 diversion shortages and associated reliabilities are not precisely identical in all cases but are very close.

Unappropriated Flows of BRAC and Bwam Datasets

Frequency tables for unappropriated flows were created with program *TABLES* from the results of *WRAP-SIM* simulations with the input datasets listed in Table 9.1. The frequency tables were then converted to the format of Tables 9.11 through 9.14. Exceedance frequencies are tabulated in the first column in Tables 9.11 through 9.14. Means and standard deviations of the monthly naturalized flows and the minimum and maximum naturalized flow are also included in the tables. BRAC simulated monthly unappropriated flow volumes are recorded in the tables as a percentage of the corresponding Bwam simulated unappropriated flows. The relationships between exceedance frequency versus BRAC flows as a percentage of Bwam flow are tabulated for each of the control points at which a reservoir is located.

The objective is to have a value of 100.0% entered in Tables 9.11 through 9.14 for the mean, standard deviation, and volumes associated with each exceedance frequency. For most of the control points, most of the entries in the tables are 100.0% or very close to 100.0%. The unappropriated flows are reproduced essentially perfectly at all of the control points with the exceptions of variations in very low flows at some control points. The Bwam and BRAC unappropriated flows are plotted in Figures 9.1 through 9.28 at the control points of all the reservoirs except Squaw Creek, at which there are no unappropriated flows in either simulation.

End-of-Month Reservoir Storage Contents

Reservoir storage contents are also closely reproduced in the *SIM* simulation results for the simplified condensed input datasets. BRAC3 and Bwam3 storage volumes are compared in Tables 9.15 and 9.16 for 1940-2007 and 1900-2007 hydrologic simulation periods. BRAC8 and Bwam8 storage volumes are compared in Tables 9.17 and 9.18. Exceedance frequencies are tabulated in the first column of the tables. End-of-month storage from the BRAC simulations expressed as a percentage of the corresponding Bwam volumes are shown for each exceedance frequency. Means and standard deviations are also shown. A perfect BRAC reproduction of Bwam storage levels would be indicated by all entries in Tables 9.15-9.18 being 100.0%, meaning the BRAC storage is 100% of the corresponding Bwam storage. The entries are almost all 100.0% or very close thereto.

BRAC3 versus Bwam3 and BRAC8 versus Bwam8 storage sequences are compared in Figures 9.29 through 9.57. The summation of storage in all the reservoirs is plotted in Figures 9.58 and 9.59. The plots represent Bwam storage as a regular line and BRAC storage as a dashed line. The two lines look like one line since the Bwam and BRAC storages are essentially the same.

Table 9.3
Bwam3 Reliabilities for 1940-2007 at 15 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	VOLUME (%)	+++++++++ PERCENTAGE OF MONTHS +++++++++ WITH DIVERSIONS EQUALING OR EXCEEDING							---------- PERCENTAGE OF YEARS ---------- PERCENTAGE OF TARGET DIVERSION AMOUNT						
					100%	95%	90%	75%	50%	25%	1%	100%	98%	95%	90%	75%	50%	1%
421331	56000.0	10124.41	80.15	81.92	80.1	80.4	80.4	80.9	82.0	82.4	83.0	63.2	63.2	64.7	66.2	73.5	82.4	98.5
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	23180.0	8231.25	54.90	64.49	54.9	56.1	56.5	58.7	63.2	70.6	78.2	30.9	33.8	38.2	41.2	50.0	64.7	98.5
515731	18894.9	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	90900.9	1944.94	95.47	97.86	95.5	95.5	95.6	95.8	99.6	99.8	100.0	91.2	91.2	94.1	95.6	97.1	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	313.19	99.02	99.54	99.0	99.1	99.1	99.4	99.5	99.6	99.6	95.6	95.6	97.1	97.1	100.0	100.0	100.0
516231	13610.0	195.69	98.41	98.56	98.4	98.4	98.4	98.4	98.5	98.7	98.8	94.1	95.6	95.6	95.6	98.5	98.5	100.0
516331	19840.0	45.51	99.63	99.77	99.6	99.6	99.6	99.6	99.6	99.8	99.9	97.1	97.1	98.5	98.5	100.0	100.0	100.0
516431	48000.0	161.56	99.26	99.66	99.3	99.3	99.3	99.3	99.4	99.5	99.6	97.1	97.1	97.1	98.5	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
292531	99650.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	944190.8	21016.57		97.77														

Table 9.4
BRAC3 Reliabilities for 1940-2007 at 15 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	VOLUME (%)	+++++++++ PERCENTAGE OF MONTHS +++++++++ WITH DIVERSIONS EQUALING OR EXCEEDING							---------- PERCENTAGE OF YEARS ---------- PERCENTAGE OF TARGET DIVERSION AMOUNT						
					100%	95%	90%	75%	50%	25%	1%	100%	98%	95%	90%	75%	50%	1%
421331	56000.0	10159.68	80.02	81.86	80.0	80.4	80.4	80.9	81.9	82.4	82.8	63.2	63.2	64.7	66.2	72.1	82.4	98.5
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	23180.0	8224.53	54.90	64.52	54.9	56.1	56.5	58.7	63.4	70.6	78.2	30.9	33.8	38.2	41.2	50.0	64.7	98.5
515731	18336.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	79877.0	224.02	98.90	99.72	98.9	98.9	98.9	99.0	100.0	100.0	100.0	97.1	97.1	97.1	98.5	100.0	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	313.14	99.02	99.54	99.0	99.1	99.1	99.4	99.5	99.6	99.6	95.6	95.6	97.1	97.1	100.0	100.0	100.0
516231	13610.0	195.66	98.41	98.56	98.4	98.4	98.4	98.4	98.5	98.7	98.8	94.1	95.6	95.6	95.6	98.5	98.5	100.0
516331	19840.0	45.41	99.63	99.77	99.6	99.6	99.6	99.6	99.6	99.8	99.9	97.1	97.1	98.5	98.5	100.0	100.0	100.0
516431	48000.0	161.43	99.26	99.66	99.3	99.3	99.3	99.3	99.4	99.5	99.6	97.1	97.1	97.1	98.5	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
292531	99650.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	932608.0	19323.89		97.93														

Reservoir	Control Point
Hubbard Creek	421331
Possum Kingdom	515531
Granbury	515631
Squaw Creek	409732
Whitney	515731
Aquilla	515831
Waco	509431

Reservoir	Control Point
Proctor	515931
Belton	516031
Stillhouse Hollow	516131
Georgetown	516231
Granger	516331
Somerville	516431
Limestone	516531
Allens Creek	292531

Table 9.5

Bwam3 Reliabilities for 1900-2007 at 15 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	+++++++++ PERCENTAGE OF MONTHS +++++++++ WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	---------- PERCENTAGE OF YEARS ---------- PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
421331	56000.0	9251.21	81.40	83.48	81.4	81.6	81.6	82.1	83.2	83.8	84.3	64.8	64.8	65.7	66.7	78.7	85.2	98.1
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	23180.0	5955.96	67.13	74.31	67.1	67.9	68.4	70.3	73.5	78.7	84.6	47.2	50.0	53.7	56.5	63.0	75.0	99.1
515731	18972.7	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	92810.8	2157.63	94.37	97.68	94.4	94.4	94.5	94.7	99.6	99.8	100.0	89.8	89.8	92.6	94.4	96.3	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	197.19	99.38	99.71	99.4	99.5	99.5	99.6	99.7	99.8	99.8	97.2	97.2	98.1	98.1	100.0	100.0	100.0
516231	13610.0	123.21	99.00	99.09	99.0	99.0	99.0	99.0	99.1	99.2	99.2	96.3	97.2	97.2	97.2	99.1	99.1	100.0
516331	19840.0	28.65	99.77	99.86	99.8	99.8	99.8	99.8	99.8	99.8	99.9	98.1	98.1	99.1	99.1	100.0	100.0	100.0
516431	48000.0	101.73	99.54	99.79	99.5	99.5	99.5	99.5	99.6	99.7	99.8	98.1	98.1	98.1	99.1	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
292531	99650.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	946178.5	17815.62		98.12														

Table 9.6

BRAC3 Reliabilities for 1900-2007 at 15 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	+++++++++ PERCENTAGE OF MONTHS +++++++++ WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	---------- PERCENTAGE OF YEARS ---------- PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
421331	56000.0	9363.98	81.33	83.28	81.3	81.6	81.6	81.9	83.0	83.5	84.0	64.8	64.8	65.7	66.7	75.9	85.2	97.2
515531	230750.0	0.02	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	64712.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	23180.0	5949.35	67.21	74.33	67.2	68.1	68.5	70.3	73.5	78.7	84.6	47.2	50.0	53.7	56.5	63.0	75.0	99.1
515731	18336.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	13896.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	79877.0	427.70	97.84	99.46	97.8	97.8	97.9	98.0	99.9	100.0	100.0	95.4	95.4	95.4	98.1	99.1	100.0	100.0
515931	19658.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	112257.0	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	197.16	99.38	99.71	99.4	99.5	99.5	99.6	99.7	99.8	99.8	97.2	97.2	98.1	98.1	100.0	100.0	100.0
516231	13610.0	123.19	99.00	99.09	99.0	99.0	99.0	99.0	99.1	99.2	99.2	96.3	97.2	97.2	97.2	99.1	99.1	100.0
516331	19840.0	28.59	99.77	99.86	99.8	99.8	99.8	99.8	99.8	99.8	99.9	98.1	98.1	99.1	99.1	100.0	100.0	100.0
516431	48000.0	101.64	99.54	99.79	99.5	99.5	99.5	99.5	99.6	99.7	99.8	98.1	98.1	98.1	99.1	100.0	100.0	100.0
516531	65074.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
292531	99650.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	932608.0	16191.65		98.26														

Reservoir	Control Point	Reservoir	Control Point
Hubbard Creek	421331	Proctor	515931
Possum Kingdom	515531	Belton	516031
Granbury	515631	Stillhouse Hollow	516131
Squaw Creek	409732	Georgetown	516231
Whitney	515731	Granger	516331
Aquilla	515831	Somerville	516431
Waco	509431	Limestone	516531
		Allens Creek	292531

Table 9.7
Bwam8 Reliabilities for 1940-2007 at 14 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	+++++++++ PERCENTAGE OF MONTHS +++++++++ WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	---------- PERCENTAGE OF YEARS ---------- PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	17536.0	3624.78	73.53	79.33	73.5	74.0	74.5	75.6	77.9	83.5	88.0	57.4	57.4	60.3	61.8	72.1	79.4	100.0
515731	18762.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	42935.6	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.5	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	81.69	99.51	99.83	99.5	99.6	99.6	99.6	99.6	99.8	99.9	97.1	97.1	98.5	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	478482.2	3706.48		99.23														

Table 9.8
BRAC8 Reliabilities for 1940-2007 at 14 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	+++++++++ PERCENTAGE OF MONTHS +++++++++ WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	---------- PERCENTAGE OF YEARS ---------- PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	17536.0	3621.49	73.53	79.35	73.5	74.0	74.5	75.7	77.9	83.5	88.0	57.4	57.4	60.3	61.8	72.1	79.4	100.0
515731	18336.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	38348.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.5	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	81.57	99.51	99.83	99.5	99.6	99.6	99.6	99.6	99.8	99.9	97.1	97.1	98.5	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	473468.4	3703.07		99.22														

Reservoir	Control Point	Reservoir	Control Point
Hubbard Creek	421331	Proctor	515931
Possum Kingdom	515531	Belton	516031
Granbury	515631	Stillhouse Hollow	516131
Squaw Creek	409732	Georgetown	516231
Whitney	515731	Granger	516331
Aquilla	515831	Somerville	516431
Waco	509431	Limestone	516531

Table 9.9
Bwam8 Reliabilities for 1900-2007 at 14 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	17536.0	2418.55	82.41	86.21	82.4	82.7	83.0	83.8	85.2	88.9	92.2	72.2	72.2	74.1	75.0	80.6	86.1	100.0
515731	18778.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	43163.6	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.3	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	51.44	99.69	99.89	99.7	99.8	99.8	99.8	99.8	99.8	99.9	98.1	98.1	99.1	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	478726.0	2469.99		99.48														

Table 9.10
BRAC8 Reliabilities for 1900-2007 at 14 Control points

NAME	TARGET DIVERSION (AC-FT/YR)	MEAN SHORTAGE (AC-FT/YR)	*RELIABILITY* PERIOD (%)	*RELIABILITY* VOLUME (%)	PERCENTAGE OF MONTHS WITH DIVERSIONS EQUALING OR EXCEEDING 100%	95%	90%	75%	50%	25%	1%	PERCENTAGE OF YEARS PERCENTAGE OF TARGET DIVERSION AMOUNT 100%	98%	95%	90%	75%	50%	1%
421331	9923.5	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515531	59482.2	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515631	36025.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
409732	17536.0	2415.99	82.41	86.22	82.4	82.7	83.0	83.8	85.2	89.0	92.2	72.2	72.2	74.1	75.0	80.6	86.1	100.0
515731	18336.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515831	2394.3	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
509431	38348.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
515931	14068.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516031	107737.3	0.01	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516131	67768.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516231	11943.4	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516331	2569.0	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
516431	48000.0	51.36	99.69	99.89	99.7	99.8	99.8	99.8	99.8	99.8	99.9	98.1	98.1	99.1	100.0	100.0	100.0	100.0
516531	39337.1	0.00	100.00	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total	473468.1	2467.35		99.48														

Reservoir	Control Point	Reservoir	Control Point
Hubbard Creek	421331	Proctor	515931
Possum Kingdom	515531	Belton	516031
Granbury	515631	Stillhouse Hollow	516131
Squaw Creek	409732	Georgetown	516231
Whitney	515731	Granger	516331
Aquilla	515831	Somerville	516431
Waco	509431	Limestone	516531

Table 9.11
BRAC3 Unappropriated Flows as Percentages of Bwam3 Unappropriated Flows for 1940-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531	292531
	1940-2007 BRAC3 Unappropriated Flows as a Percentage of Bwam3 Unappropriated Flows														
Mean	100.0%	94.8%	95.4%	-	100.2%	100.1%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	128.5%
Std Dev	100.0%	99.4%	99.4%	-	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	122.6%
Minimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
98%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40%	-	-	-	-	6.7%	-	-	-	-	-	-	-	-	-	-
30%	-	-	53.3%	-	100.9%	#DIV/0!	99.9%	-	-	-	15.4%	100.0%	100.1%	-	-
25%	-	-	80.5%	-	104.2%	109.3%	99.0%	-	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	-
20%	-	27.3%	79.1%	-	100.0%	100.2%	99.3%	55.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	-
15%	-	88.5%	87.5%	-	101.2%	100.4%	99.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	-
10%	-	90.4%	93.1%	-	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	217.0%
5%	-	93.8%	99.5%	-	101.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	132.8%
2%	99.8%	100.0%	100.0%	-	100.0%	100.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	125.4%
1%	100.0%	100.0%	91.6%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	118.5%
0.50%	100.0%	100.0%	100.0%	-	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	122.6%
Maximum	100.0%	100.0%	100.0%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	118.3%

Table 9.12
BRAC3 Unappropriated Flows as Percentages of Bwam3 Unappropriated Flows for 1900-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531	292531
	1900-2007 BRAC3 Unappropriated Flows as a Percentage of Bwam3 Unappropriated Flows														
Mean	100.0%	94.3%	94.9%	100.0%	100.2%	100.0%	99.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	136.7%
Std Dev	100.0%	98.9%	99.2%	99.9%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	124.8%
Minimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
98%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
40%	-	-	-	-	10.4%	-	-	-	-	-	-	-	-	-	-
30%	-	-	63.0%	-	100.0%	-	0.0%	-	-	-	100.0%	100.0%	100.1%	-	-
25%	-	-	78.8%	-	100.3%	93.7%	94.5%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	-
20%	-	50.6%	82.8%	-	100.7%	99.9%	100.6%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	-
15%	-	84.0%	94.4%	-	100.7%	100.0%	99.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	-
10%	-	90.0%	94.1%	-	100.0%	100.0%	101.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	758.9%
5%	-	90.6%	94.8%	-	100.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	147.6%
2%	-	100.0%	100.0%	-	100.1%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	132.7%
1%	100.0%	100.0%	100.0%	-	100.1%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	116.8%
0.50%	100.0%	98.3%	100.0%	-	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	130.3%
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	123.1%

A hyphen (-) means the monthly flow quantity is zero for both the Bwam and BRAC simulations.

Table 9.13
BRAC8 Unappropriated Flows as Percentages of Bwam8 Unappropriated Flows
for 1940-2007 at 14 Control Points

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531
	1940-2007 BRAC8 Unappropriated Flows as a Percentage of Bwam8 Unappropriated Flows													
Mean	100.0%	96.0%	96.0%	-	100.1%	100.1%	100.0%	99.9%	100.1%	100.2%	100.0%	100.2%	100.0%	100.0%
Std Dev	100.0%	99.2%	99.4%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	100.1%	100.0%	100.0%
Minimum	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99.50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
98%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50%	-	-	-	-	108.2%	-	-	-	-	-	-	99.1%	-	-
40%	-	76.4%	79.4%	-	100.4%	-	103.4%	-	-	-	-	101.0%	-	-
30%	-	85.3%	90.1%	-	100.0%	100.0%	101.3%	-	100.1%	110.1%	100.0%	100.3%	100.1%	99.9%
25%	-	95.3%	92.5%	-	100.0%	100.0%	97.8%	0.9%	102.6%	100.2%	101.9%	99.8%	100.0%	100.0%
20%	-	97.6%	95.6%	-	100.2%	100.0%	100.1%	97.4%	101.2%	99.8%	100.0%	100.6%	100.0%	100.0%
15%	-	90.8%	92.6%	-	100.0%	100.0%	100.1%	100.0%	100.8%	100.1%	100.0%	100.0%	100.0%	100.0%
10%	-	93.6%	94.6%	-	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%
5%	99.9%	97.9%	93.9%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2%	100.0%	100.0%	100.0%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1%	100.0%	100.0%	100.0%	-	100.0%	100.0%	100.0%	100.0%	100.0%	103.0%	100.0%	100.0%	100.0%	100.0%
0.50%	100.0%	100.0%	100.0%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maximum	100.0%	100.0%	100.0%	-	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 9.14
BRAC8 Unappropriated Flows as Percentages of Bwam8 Unappropriated Flows for 1900-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531
	1900-2007 BRAC8 Unappropriated Flows as a Percentage of Bwam8 Unappropriated Flows													
Mean	97.2%	95.1%	95.2%	100.8%	100.1%	100.1%	100.1%	99.9%	100.1%	100.3%	100.0%	100.3%	100.0%	100.0%
Std Dev	98.6%	98.4%	98.9%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%
Minimum	98.6%	98.4%	98.9%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%
99.50%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
99%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
98%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
95%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
85%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
80%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
75%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
70%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
60%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
50%	-	-	0.0%	-	112.4%	-	-	-	-	-	-	107.5%	-	-
40%	-	63.3%	77.8%	-	101.4%	-	102.3%	-	-	-	-	101.1%	-	-
30%	-	88.1%	87.3%	-	100.0%	99.9%	101.0%	-	100.4%	101.6%	100.2%	102.0%	100.2%	100.2%
25%	-	91.6%	89.8%	-	100.2%	99.9%	100.6%	1.7%	100.5%	104.4%	100.5%	100.0%	100.1%	99.9%
20%	-	94.2%	93.9%	-	100.0%	100.0%	100.0%	100.1%	100.3%	101.0%	100.0%	100.4%	100.0%	100.0%
15%	-	89.3%	89.1%	-	100.0%	100.0%	100.1%	100.0%	100.0%	100.1%	100.2%	100.2%	100.0%	100.0%
10%	-	93.9%	93.3%	-	100.0%	100.1%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
5%	98.5%	96.4%	95.0%	-	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2%	98.6%	100.0%	99.5%	-	100.0%	100.0%	100.0%	100.0%	100.4%	100.0%	100.0%	100.0%	100.0%	100.0%
1%	94.5%	100.0%	98.0%	135.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%
0.50%	100.0%	91.8%	100.0%	102.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maximum	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 9.15

BRAC3 Storage Volume as Percentages of Bwam3 Storage Volume for 1940-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531	292531
	1940-2007 BRAC3 Unappropriated Flows as a Percentage of Bwam3 Unappropriated Flows														
Mean	99.8%	100.0%	100.8%	100.1%	100.2%	100.1%	100.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	101.8%
Std Dev	100.0%	100.0%	95.0%	100.0%	98.4%	99.2%	103.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	79.3%
Minimum	-	100.0%	110.9%	-	100.4%	121.7%	74.6%	100.2%	100.1%	-	-	-	-	100.1%	431.9%
99.50%	-	100.0%	109.1%	-	100.4%	108.6%	77.4%	100.0%	100.0%	-	-	101.6%	-	100.1%	193.5%
99%	-	100.0%	110.4%	-	100.4%	104.5%	86.2%	100.0%	100.0%	100.0%	-	100.2%	100.0%	100.1%	152.9%
98%	-	100.0%	107.4%	-	100.7%	101.9%	96.3%	100.0%	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	140.8%
95%	-	100.0%	103.1%	-	101.0%	101.1%	100.2%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	113.3%
90%	-	100.0%	103.7%	-	100.2%	100.5%	100.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	107.3%
85%	-	100.0%	102.0%	-	100.4%	100.2%	101.9%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	105.4%
80%	64.2%	100.0%	102.0%	-	100.2%	100.3%	101.4%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	102.6%
75%	92.8%	100.0%	102.3%	-	100.1%	100.2%	101.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	101.7%
70%	99.7%	100.0%	101.7%	-	100.1%	100.2%	101.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	102.2%
60%	99.5%	100.0%	100.4%	-	100.4%	100.0%	101.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
50%	99.1%	100.0%	100.7%	100.0%	100.2%	100.1%	100.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
40%	99.3%	100.0%	100.0%	100.0%	100.5%	100.0%	101.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
30%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	101.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
25%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	101.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
20%	100.0%	100.0%	100.0%	100.2%	100.0%	100.0%	100.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
15%	100.0%	100.0%	100.0%	100.2%	100.0%	100.0%	100.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
10%	100.0%	100.0%	100.0%	100.3%	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.50%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 9.16

BRAC3 Storage Volume as Percentages of Bwam3 Storage Volume for 1900-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531	292531
	1900-2007 BRAC3 Storage Volume as a Percentage of Bwam3 Storage Volume														
Mean	99.7%	100.0%	100.9%	100.2%	100.3%	100.1%	100.5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	101.4%
Std Dev	100.0%	99.8%	93.3%	100.1%	99.2%	99.1%	106.3%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	83.1%
Minimum	-	100.0%	249.1%	-	100.0%	121.7%	72.8%	100.2%	100.1%	-	-	-	-	100.1%	431.9%
99.50%	-	100.0%	136.9%	-	100.0%	105.9%	74.2%	99.8%	100.0%	-	-	100.1%	100.2%	100.1%	175.7%
99%	-	100.5%	114.7%	-	100.0%	104.1%	75.9%	100.0%	100.0%	100.0%	100.8%	100.0%	100.0%	100.0%	148.5%
98%	-	100.2%	110.8%	-	100.0%	102.5%	81.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	116.1%
95%	-	100.2%	106.3%	-	100.4%	101.2%	95.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	108.5%
90%	-	100.1%	103.6%	-	100.2%	100.8%	102.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	105.2%
85%	-	100.2%	102.1%	-	100.5%	100.5%	101.6%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	104.1%
80%	91.8%	100.0%	101.4%	-	100.4%	100.2%	101.1%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	102.2%
75%	99.5%	100.0%	102.2%	-	100.4%	100.1%	100.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	101.7%
70%	100.0%	100.0%	100.9%	-	100.4%	100.2%	100.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	102.6%
60%	99.2%	100.0%	100.6%	100.7%	100.3%	100.2%	101.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
50%	99.5%	100.0%	100.4%	100.0%	100.2%	100.1%	101.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
40%	99.2%	100.0%	100.0%	100.1%	100.6%	100.0%	100.9%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
30%	99.3%	100.0%	100.0%	100.1%	100.2%	100.0%	101.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
25%	100.0%	100.0%	100.0%	100.4%	100.1%	100.0%	101.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
20%	99.9%	100.0%	100.0%	100.1%	100.0%	100.0%	100.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
15%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.7%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
10%	99.7%	100.0%	100.0%	100.3%	100.0%	100.0%	100.4%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
5%	100.0%	100.0%	100.0%	100.2%	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
0.50%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

A hyphen (-) means the monthly flow quantity is zero for both the Bwam and BRAC simulations.

Table 9.17
BRAC8 Storage Volume as Percentages of Bwam8 Storage Volume for 1940-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531
	1940-2007 Unappropriated Flows as a Percentage of Bwam3 Unappropriated Flows													
Mean	100.0%	100.0%	100.2%	100.0%	100.0%	100.1%	100.0%	100.1%	100.2%	100.5%	100.1%	100.4%	100.0%	100.0%
Std Dev	100.0%	99.9%	95.0%	100.0%	99.7%	98.5%	99.3%	99.8%	97.8%	96.2%	100.1%	87.8%	100.0%	100.0%
Minimum	100.0%	100.0%	103.4%	-	100.1%	100.9%	100.7%	100.0%	105.1%	115.2%	100.0%	108.1%	-	100.0%
99.50%	100.0%	100.0%	104.5%	-	100.1%	101.1%	100.7%	100.0%	104.5%	113.2%	100.0%	105.1%	100.5%	100.0%
99%	100.0%	100.0%	102.3%	-	100.1%	100.8%	100.5%	100.0%	104.2%	111.7%	100.0%	106.8%	100.0%	100.0%
98%	100.0%	100.0%	101.5%	-	100.1%	101.1%	100.1%	100.0%	104.1%	113.3%	100.0%	104.2%	100.0%	100.0%
95%	100.0%	100.0%	101.0%	-	99.9%	100.3%	100.0%	100.2%	102.0%	108.2%	100.0%	102.6%	100.0%	100.0%
90%	100.0%	100.0%	100.8%	-	99.9%	100.2%	100.1%	100.0%	101.5%	102.2%	100.0%	101.2%	100.0%	100.0%
85%	100.0%	100.0%	100.7%	-	100.0%	100.1%	100.1%	100.0%	100.5%	101.1%	100.0%	100.9%	100.0%	100.0%
80%	100.0%	100.0%	100.5%	-	100.1%	100.1%	100.0%	100.2%	100.3%	100.4%	100.3%	101.3%	100.0%	100.0%
75%	100.0%	100.0%	100.1%	66.7%	100.0%	100.2%	100.1%	100.1%	100.3%	100.2%	100.3%	101.1%	100.0%	100.0%
70%	100.0%	100.0%	100.3%	100.0%	100.0%	100.1%	100.1%	100.2%	100.1%	100.3%	100.5%	100.1%	100.0%	100.0%
60%	100.0%	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.2%	100.3%	100.6%	100.0%	100.0%	100.0%
50%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.2%	100.1%	100.0%	100.0%	100.0%
40%	100.0%	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.2%	100.0%	100.0%	100.0%
30%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
25%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
20%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
15%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
10%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
0.50%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%

Table 9.18
BRAC8 Storage Volume as Percentages of Bwam8 Storage Volume for 1900-2007

Control Points	421331	515531	515631	409732	515731	515831	509431	515931	516031	516131	516231	516331	516431	516531
	1900-2007 BRAC8 Unappropriated Flows as a Percentage of Bwam8 Unappropriated Flows													
Mean	100.0%	100.0%	100.2%	100.0%	100.0%	100.1%	100.0%	100.0%	100.2%	100.4%	100.1%	100.4%	100.0%	100.0%
Std Dev	100.2%	99.9%	94.8%	100.0%	99.4%	98.4%	99.2%	99.8%	98.1%	96.1%	100.0%	87.2%	100.0%	100.0%
Minimum	100.0%	100.0%	103.4%	-	100.1%	100.9%	100.7%	100.0%	103.6%	115.2%	100.0%	108.1%	-	100.0%
99.50%	100.0%	100.0%	103.1%	-	100.1%	101.0%	100.6%	100.0%	103.9%	113.1%	100.0%	105.8%	100.0%	100.0%
99%	100.0%	100.0%	103.0%	-	100.1%	100.7%	100.0%	102.3%	104.0%	112.9%	100.0%	103.1%	100.0%	100.0%
98%	99.2%	100.0%	101.5%	-	100.0%	100.6%	100.0%	100.7%	103.7%	114.8%	100.0%	102.9%	100.0%	100.0%
95%	99.7%	100.0%	101.2%	-	100.2%	100.4%	100.2%	100.0%	101.7%	105.9%	100.0%	101.9%	100.0%	100.0%
90%	99.8%	100.0%	100.6%	-	100.1%	100.2%	100.1%	100.0%	101.0%	101.8%	100.0%	101.2%	100.0%	100.0%
85%	100.0%	100.0%	101.3%	-	100.0%	100.2%	100.1%	100.0%	100.6%	101.2%	100.1%	100.9%	100.0%	100.0%
80%	100.0%	100.0%	100.5%	100.0%	100.1%	100.2%	100.1%	100.0%	100.2%	100.6%	100.2%	100.9%	100.0%	100.0%
75%	99.9%	100.0%	100.3%	100.8%	100.1%	100.2%	100.1%	100.1%	100.2%	100.4%	100.3%	100.9%	100.0%	100.0%
70%	100.0%	100.0%	100.2%	100.0%	100.1%	100.1%	100.1%	100.1%	100.1%	100.4%	100.4%	100.1%	100.0%	100.0%
60%	100.0%	100.0%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.2%	100.3%	100.1%	100.0%	100.0%	100.0%
50%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.2%	100.1%	100.2%	100.2%	100.0%	100.0%	100.0%
40%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
30%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
25%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
20%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
15%	100.0%	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
10%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
5%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
0.50%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%
Maximum	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.9%	100.0%	100.0%	100.0%	100.0%

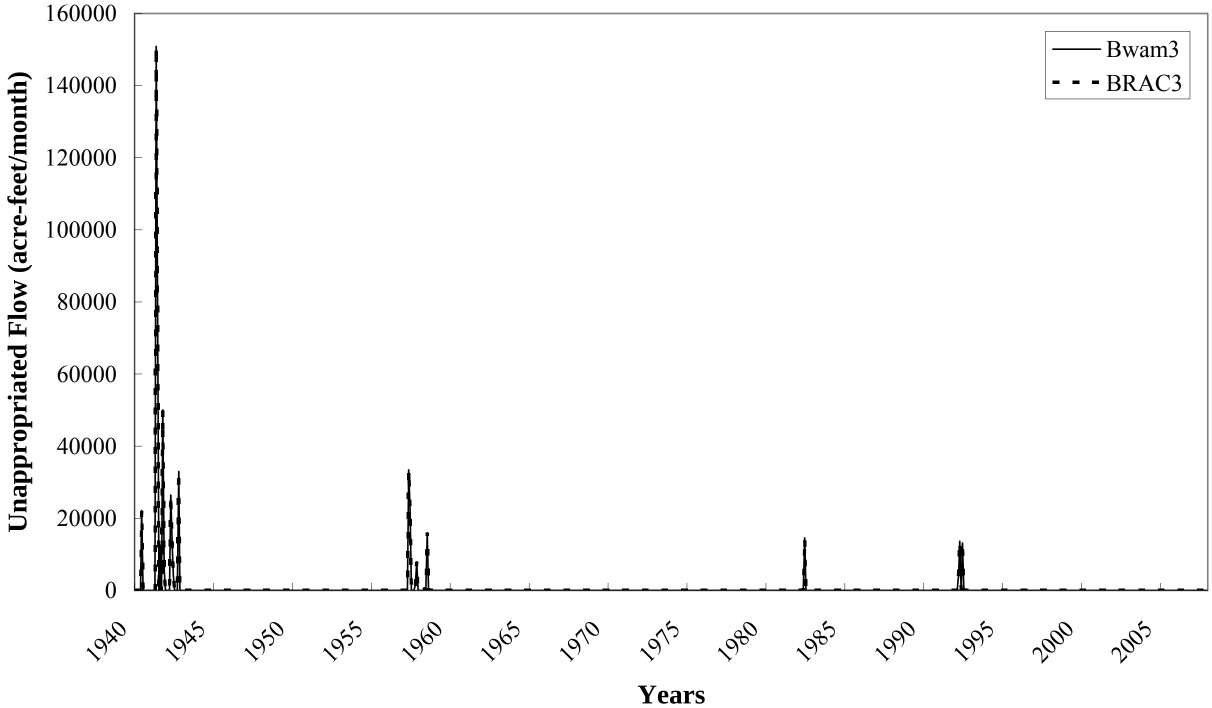

Figure 9.1 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Hubbard Creek Reservoir

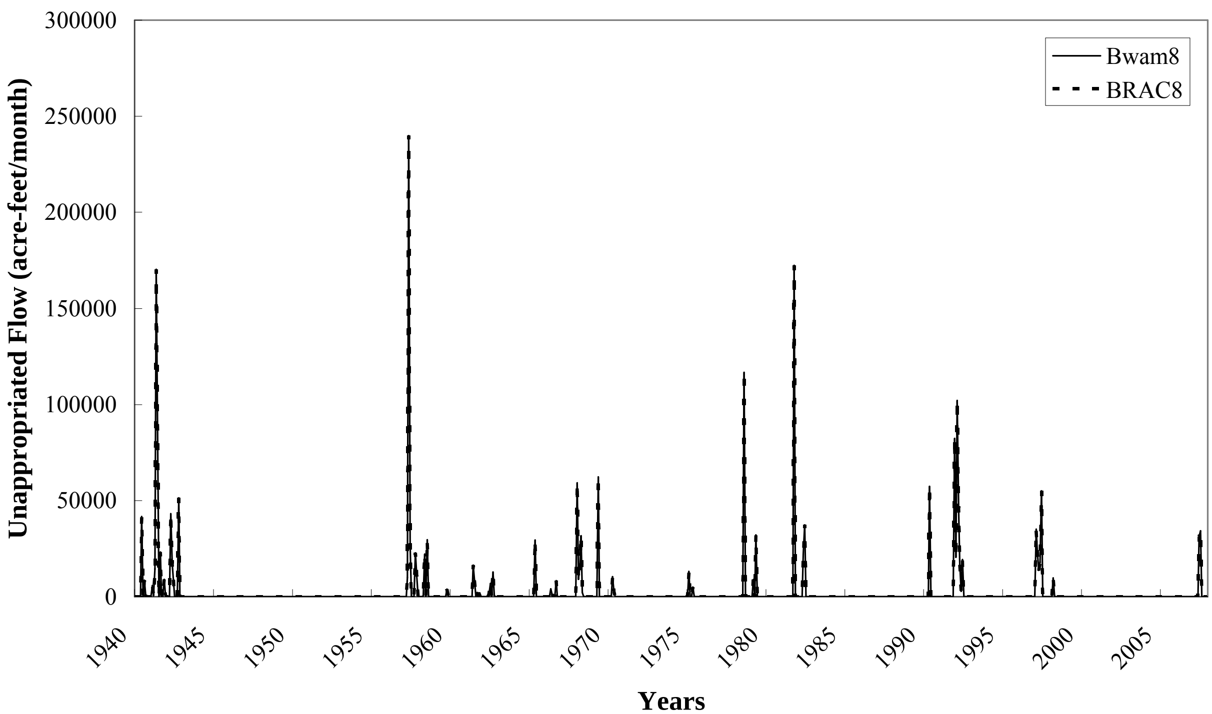

Figure 9.2 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Hubbard Creek Reservoir

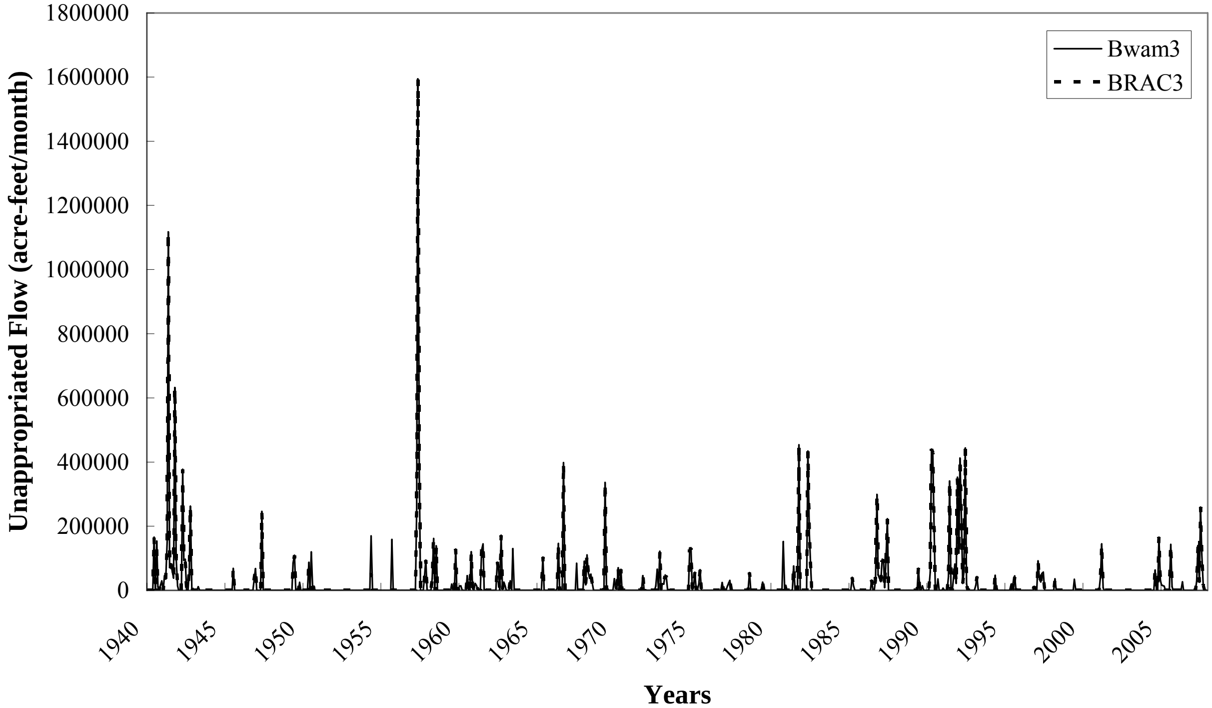

Figure 9.3 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Possum Kingdom Reservoir

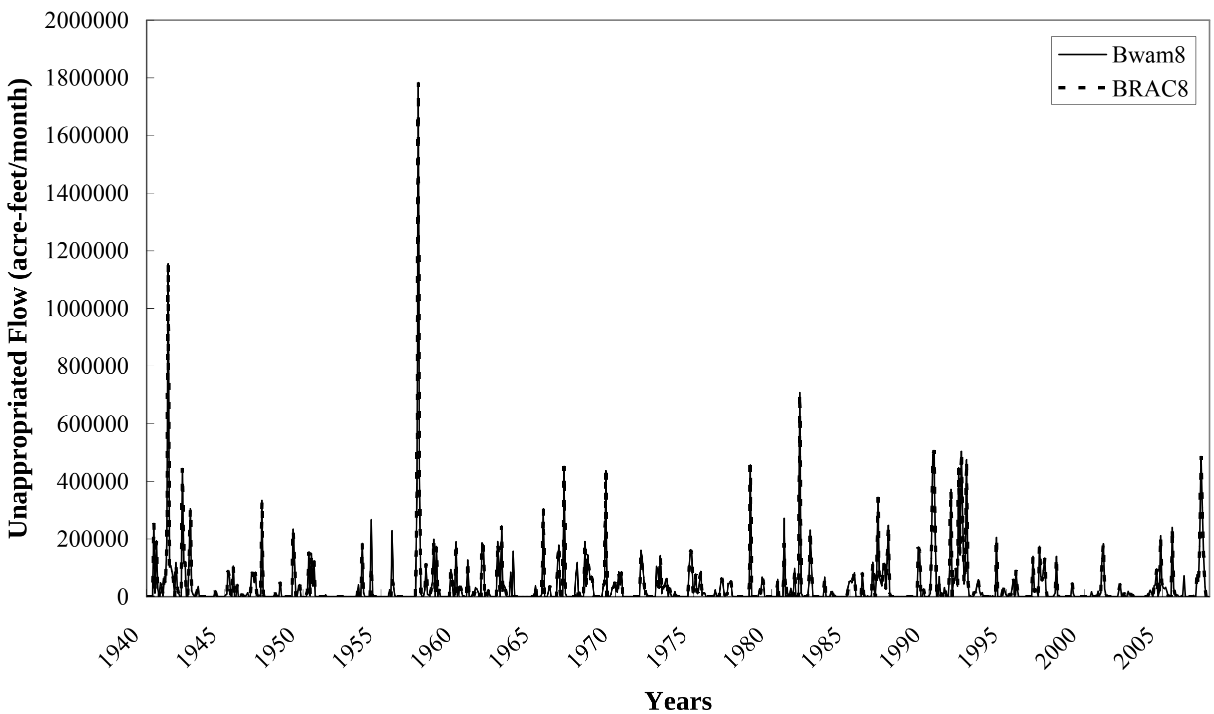

Figure 9.4 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Possum Kingdom Reservoir

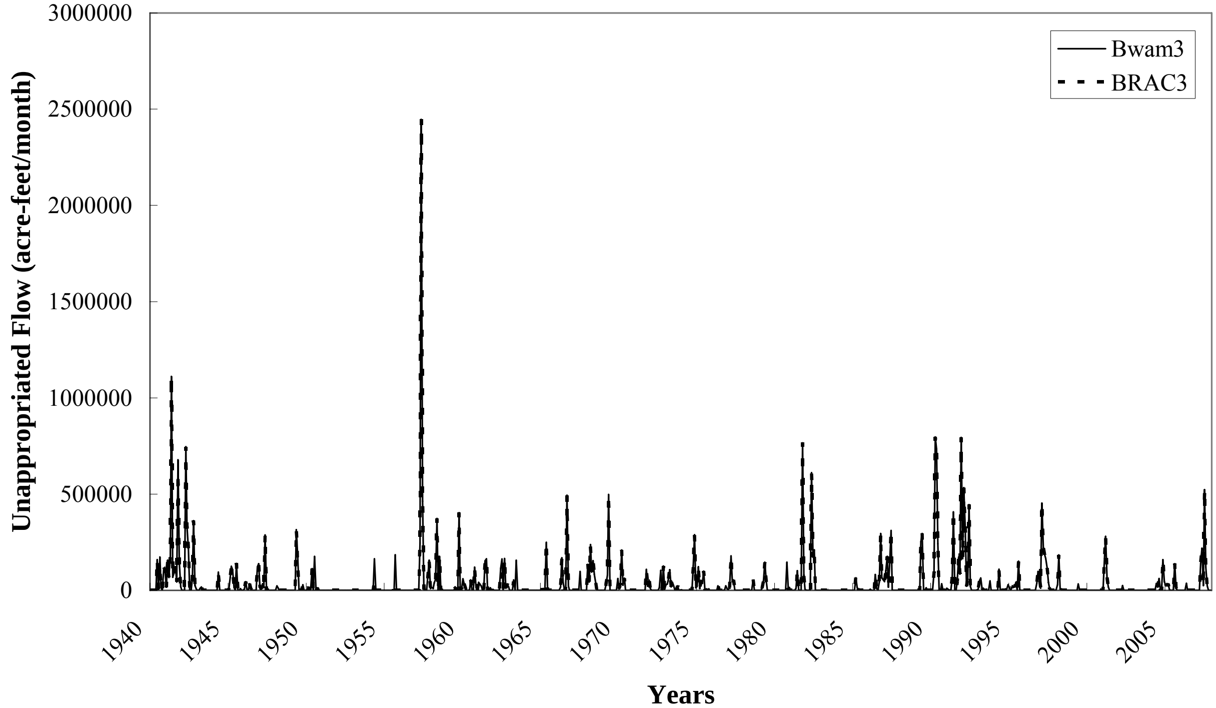

Figure 9.5 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Granbury Reservoir

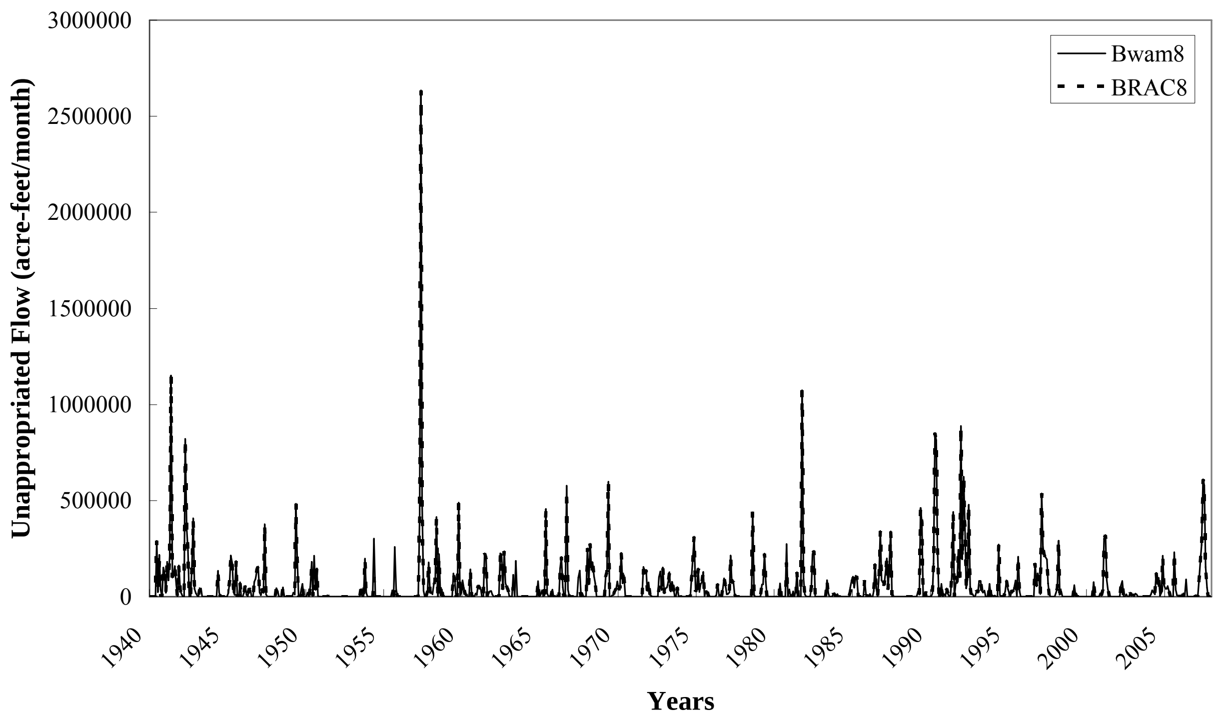

Figure 9.6 1940-2007 Bwam8 and BRAC83 Unappropriated Flows at Granbury Reservoir

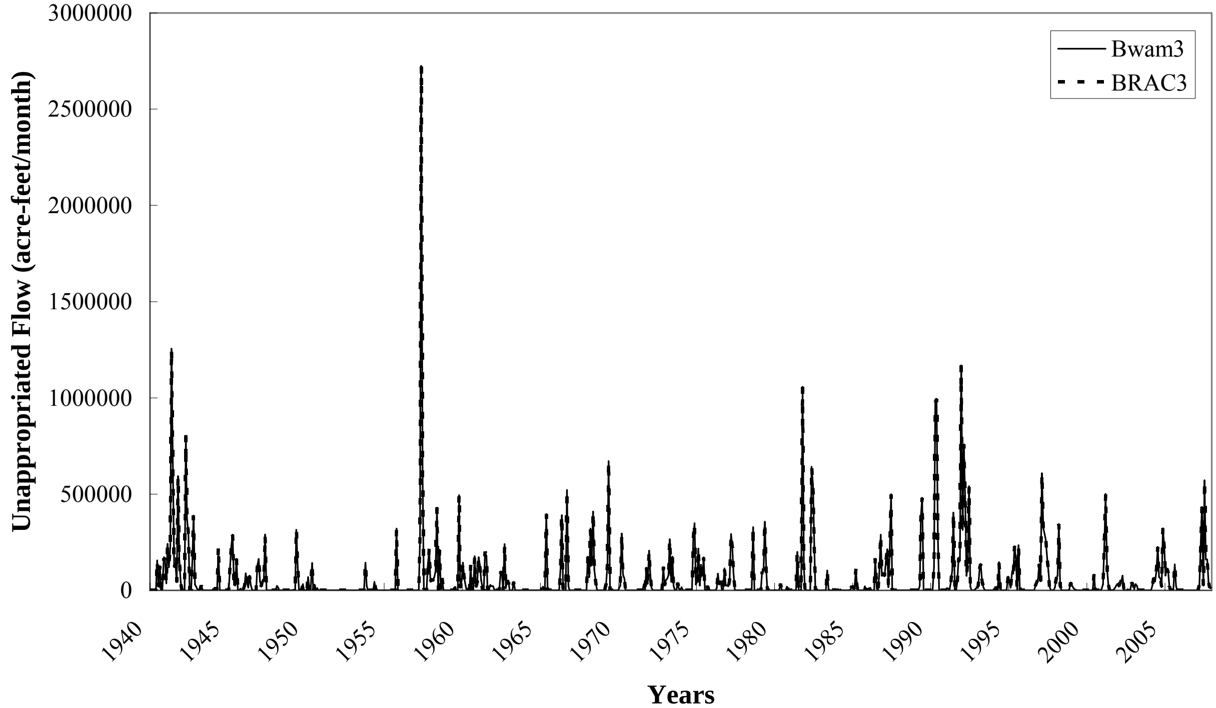

Figure 9.7 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Whitney Reservoir

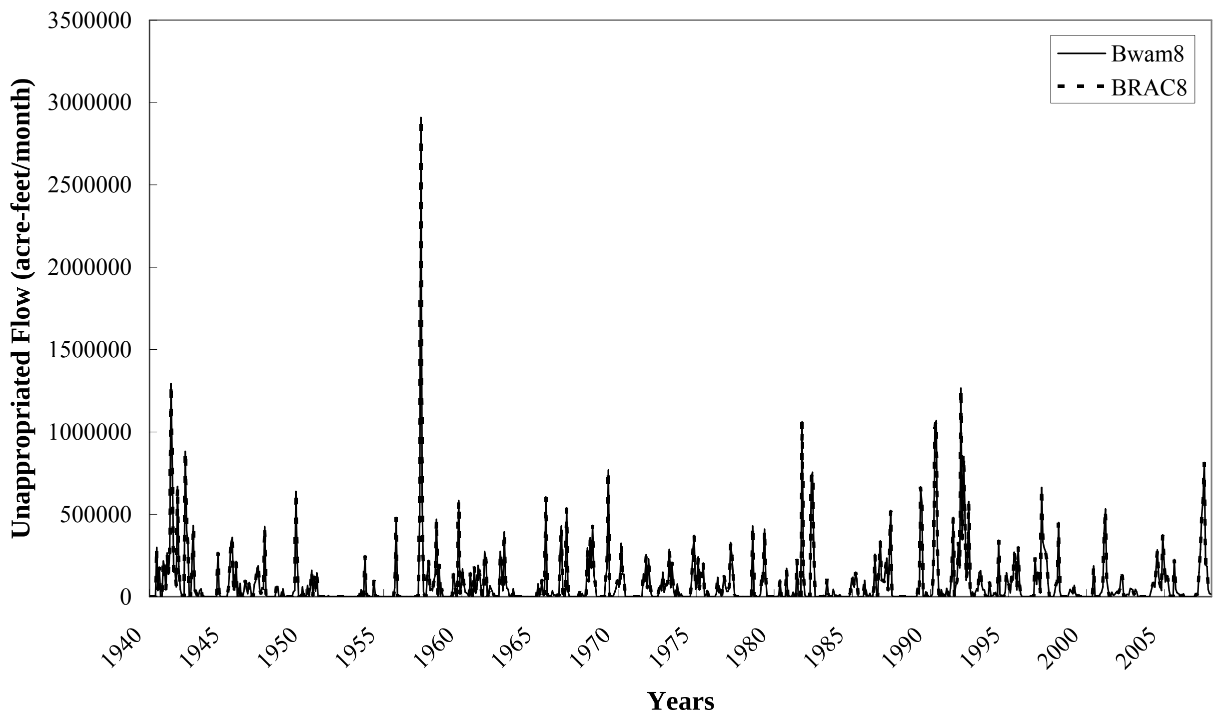

Figure 9.8 1940-2007 BRAC8 Unappropriated Flows at Whitney Reservoir

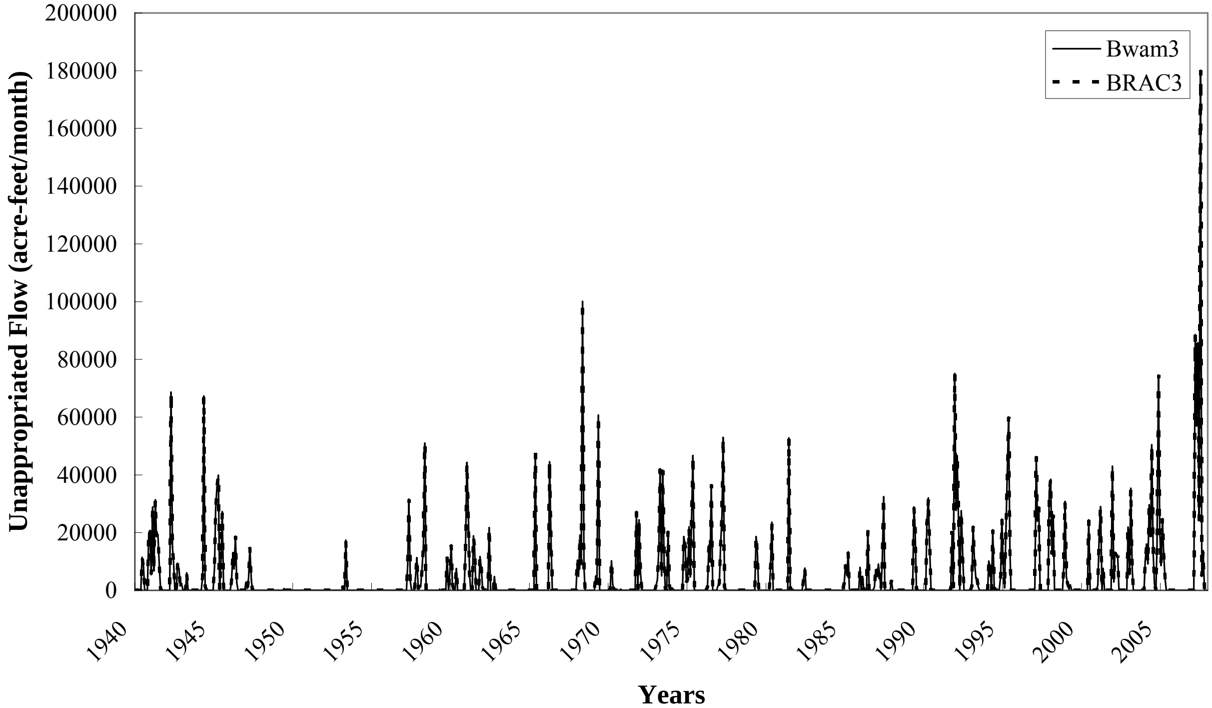

Figure 9.9 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Aquilla Reservoir

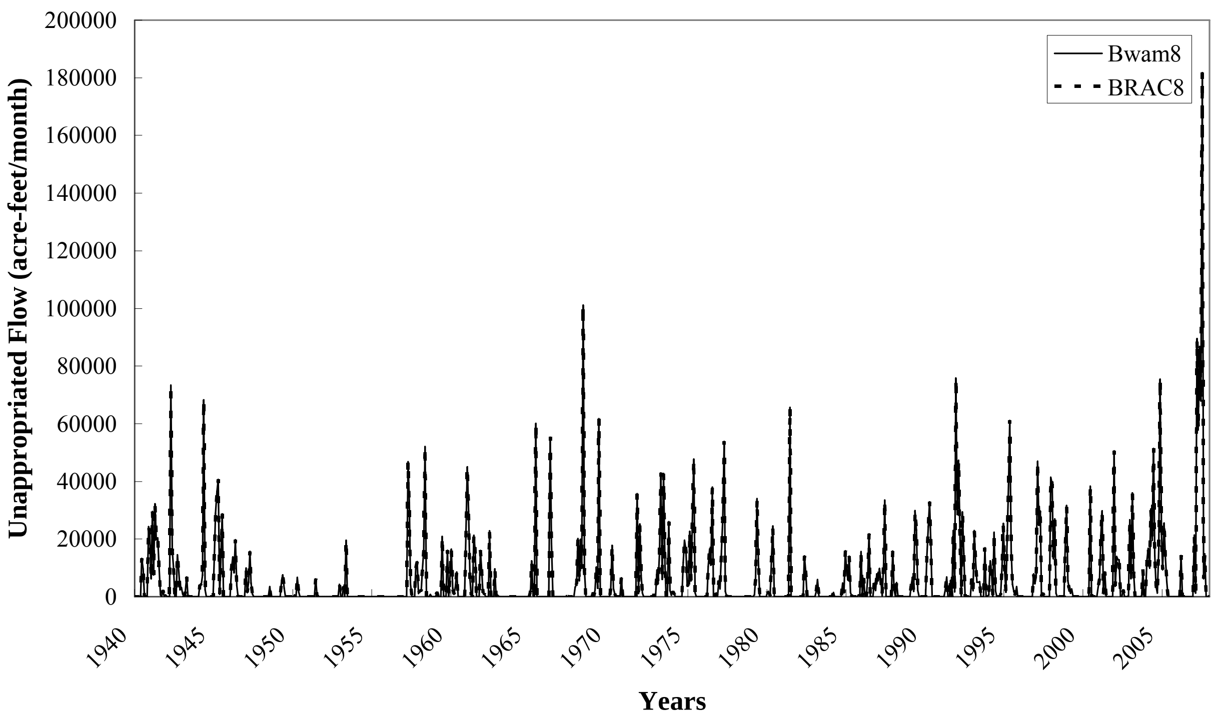

Figure 9.10 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Aquilla Reservoir

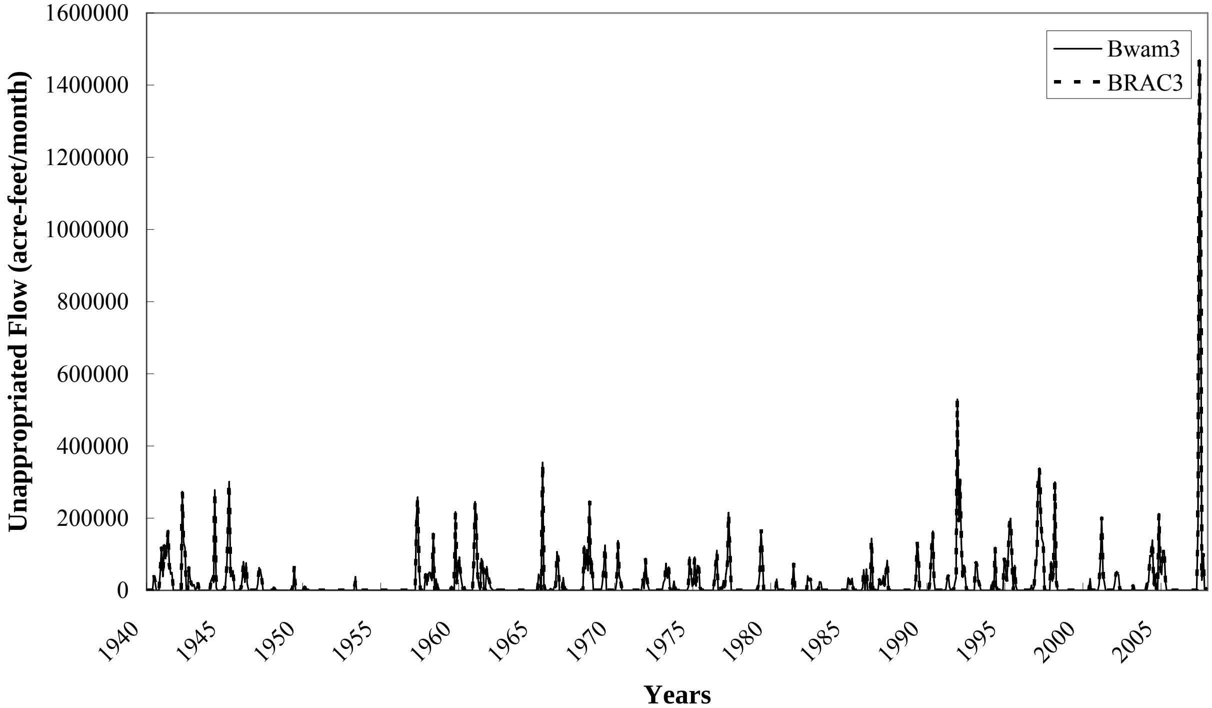

Figure 9.11 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Waco Reservoir

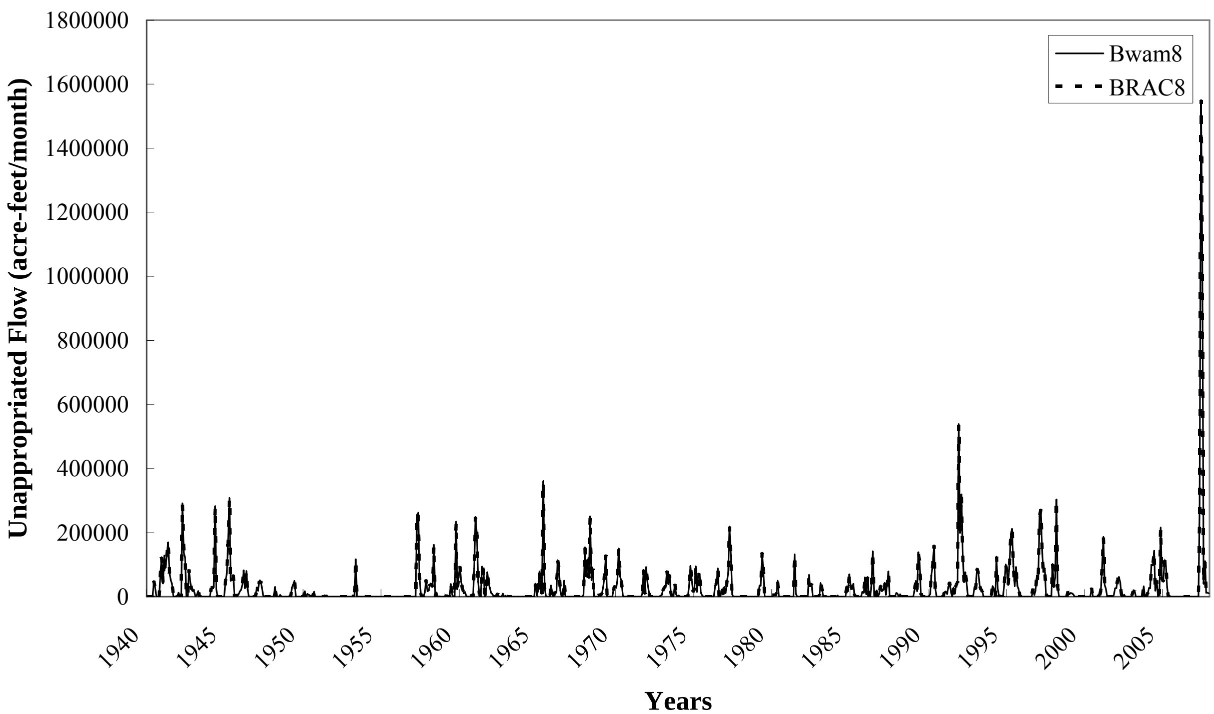

Figure 9.12 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Waco Reservoir

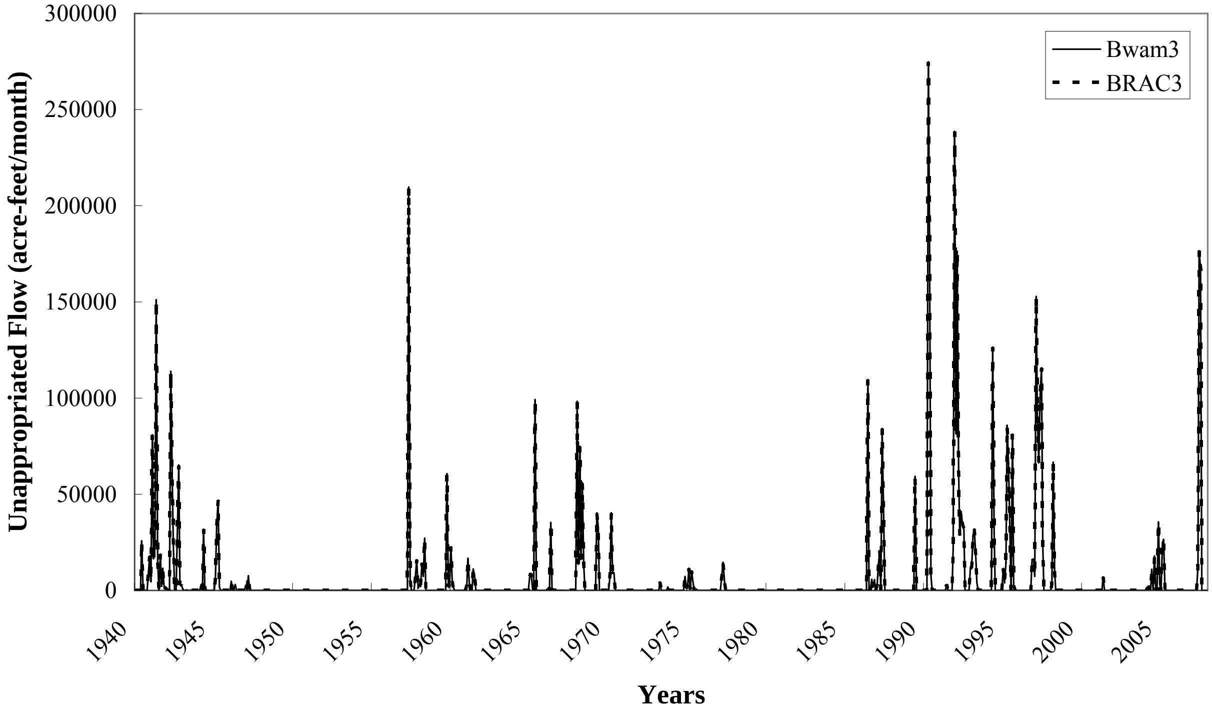

Figure 9.13 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Proctor Reservoir

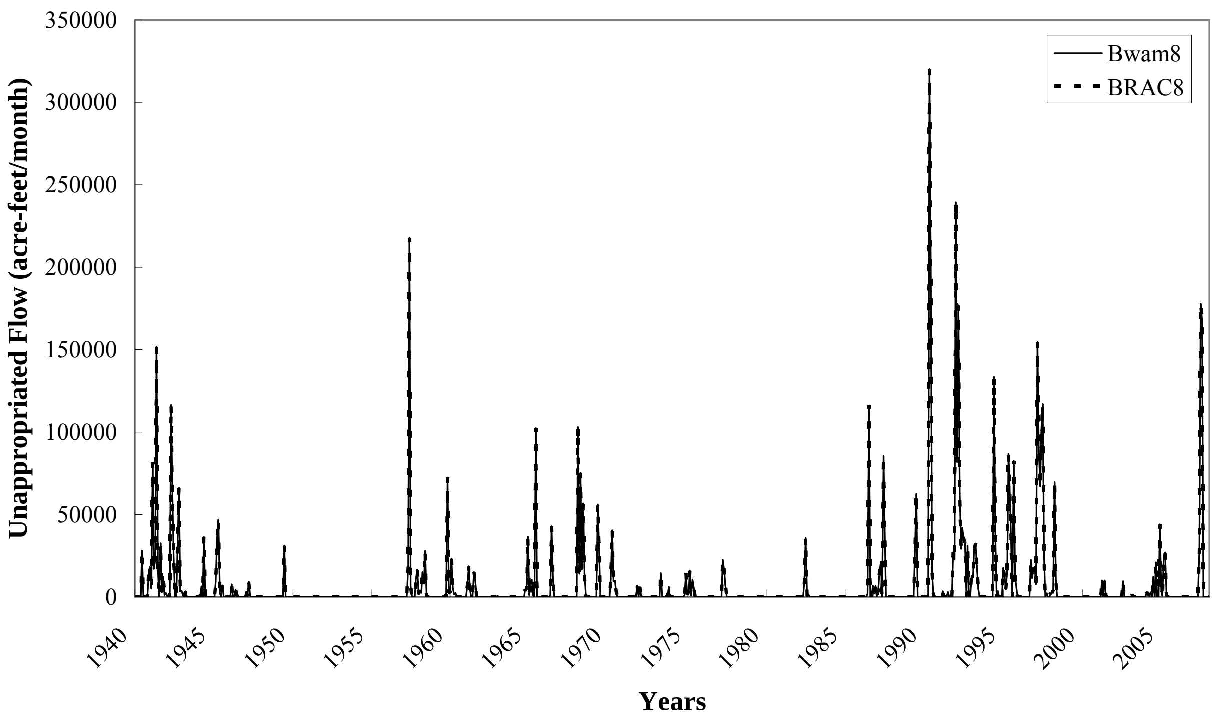

Figure 9.14 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Proctor Reservoir

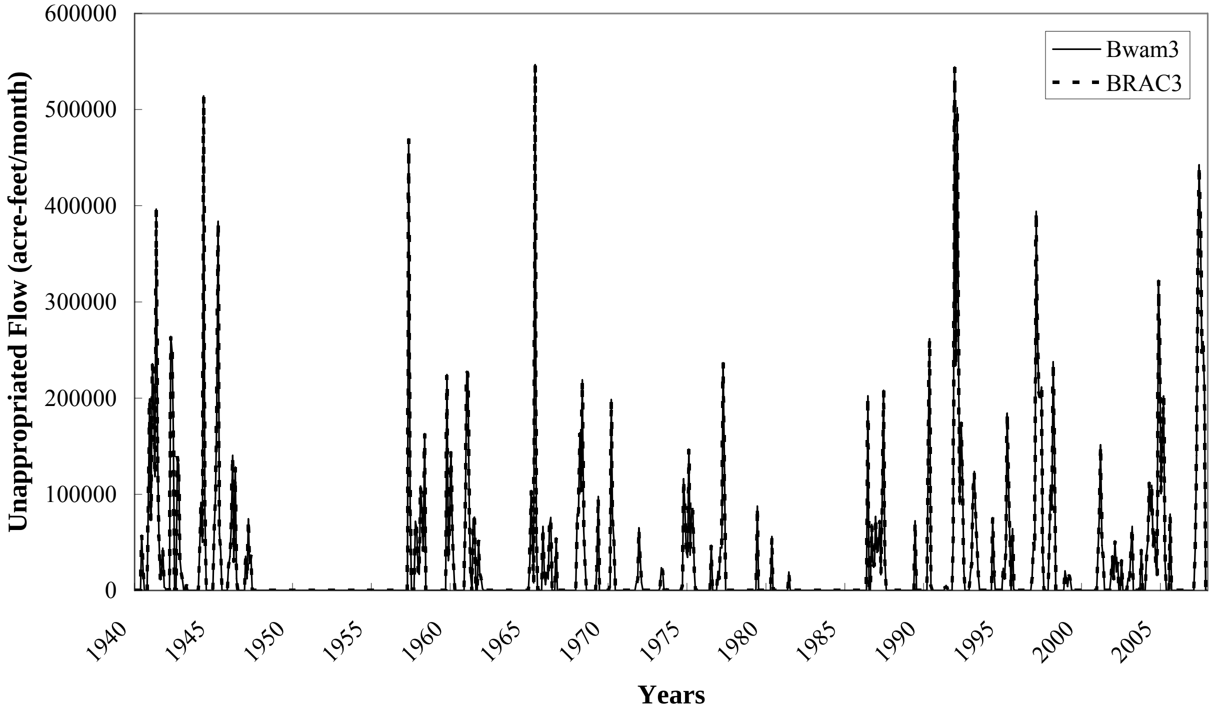

Figure 9.15 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Belton Reservoir

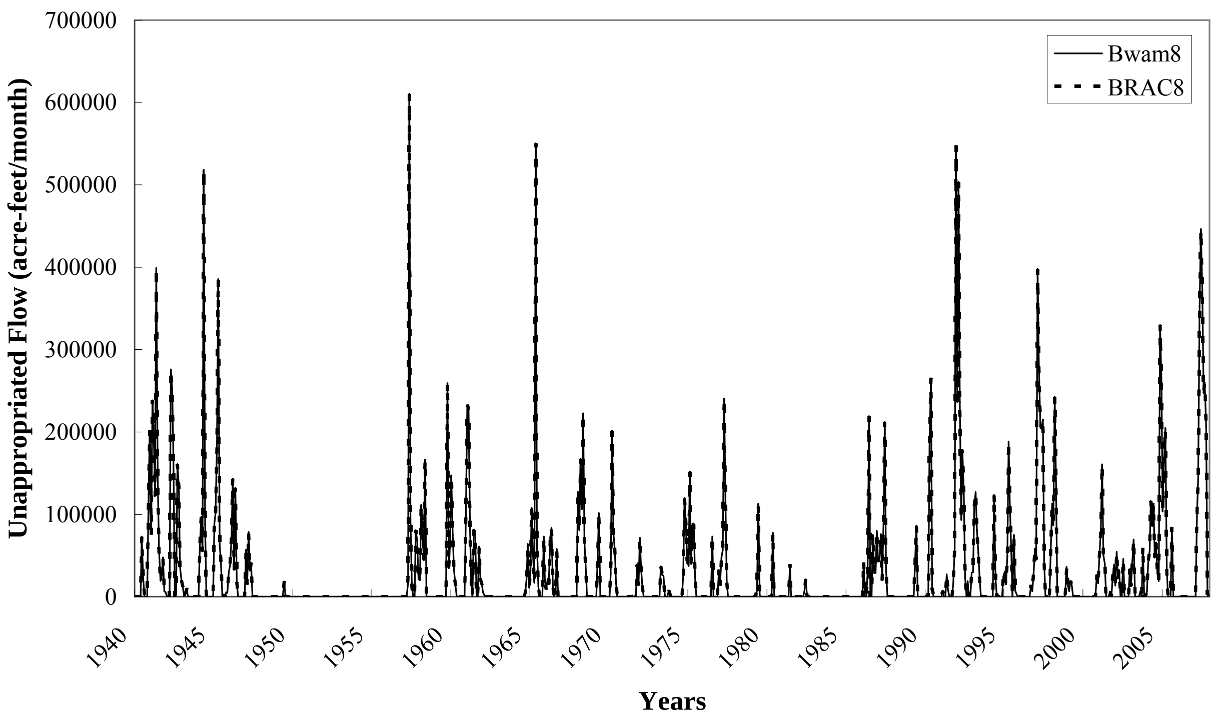

Figure 9.16 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Belton Reservoir

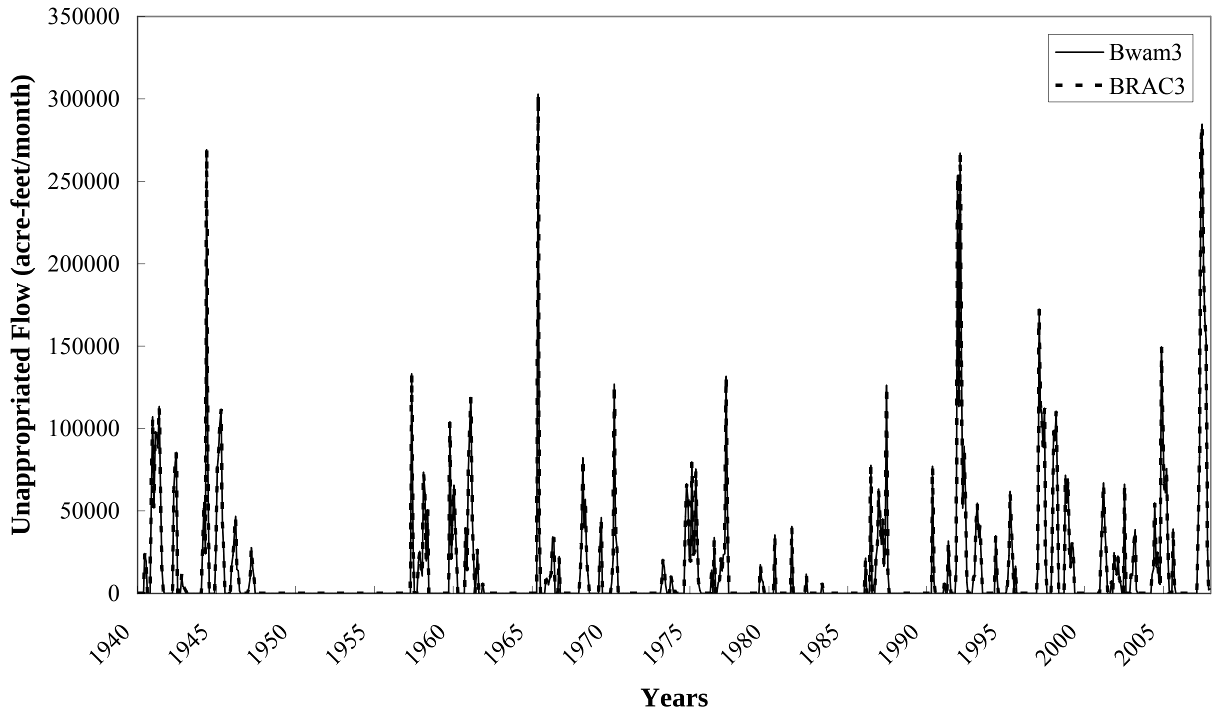

Figure 9.17 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Stillhouse Hollow Reservoir

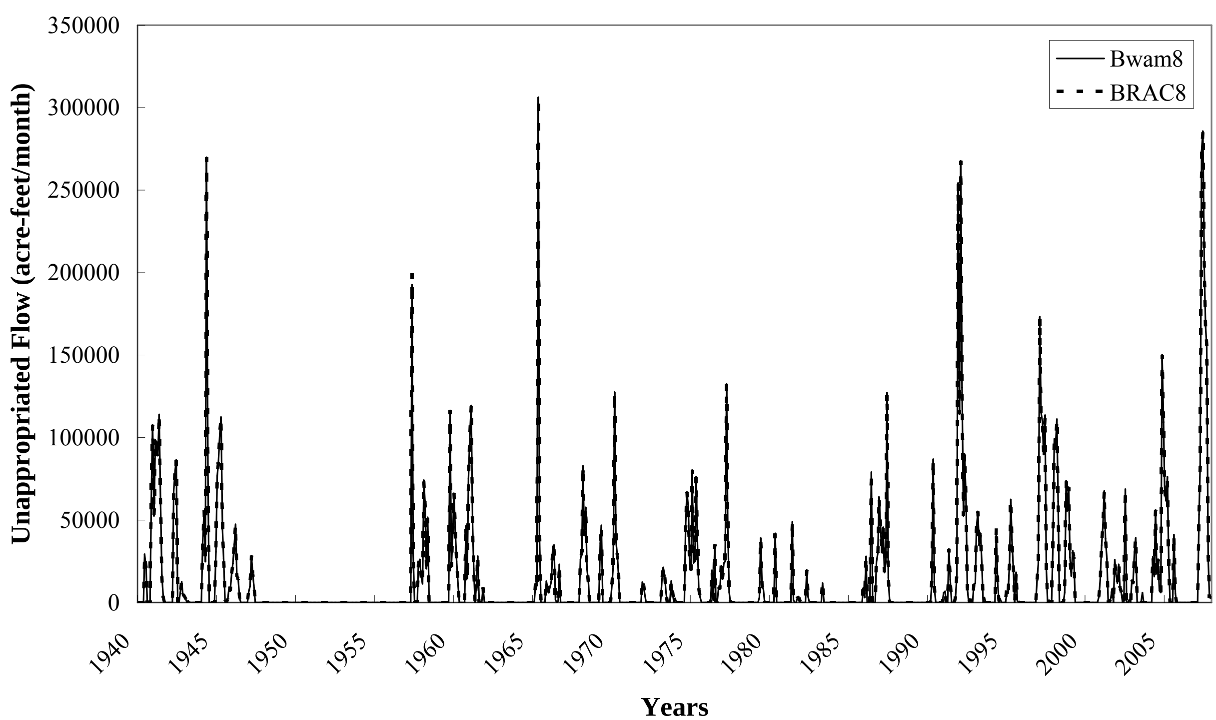

Figure 9.18 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Stillhouse Hollow Reservoir

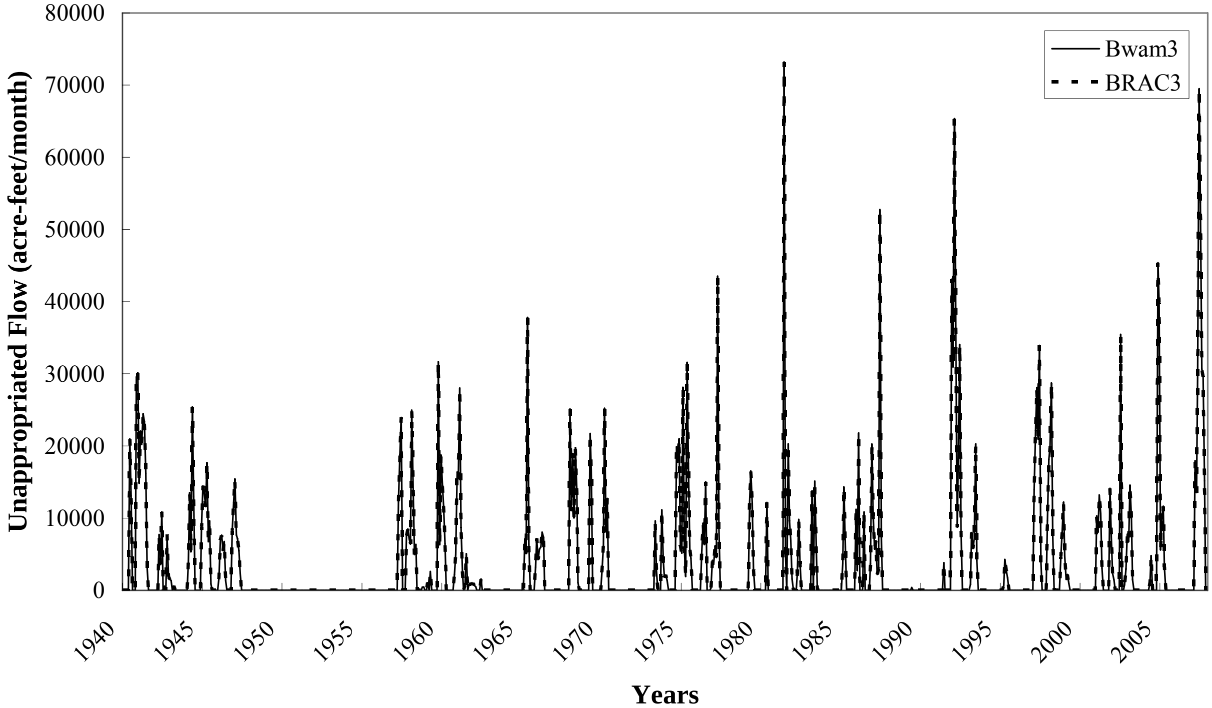

Figure 9.19 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Georgetown Reservoir

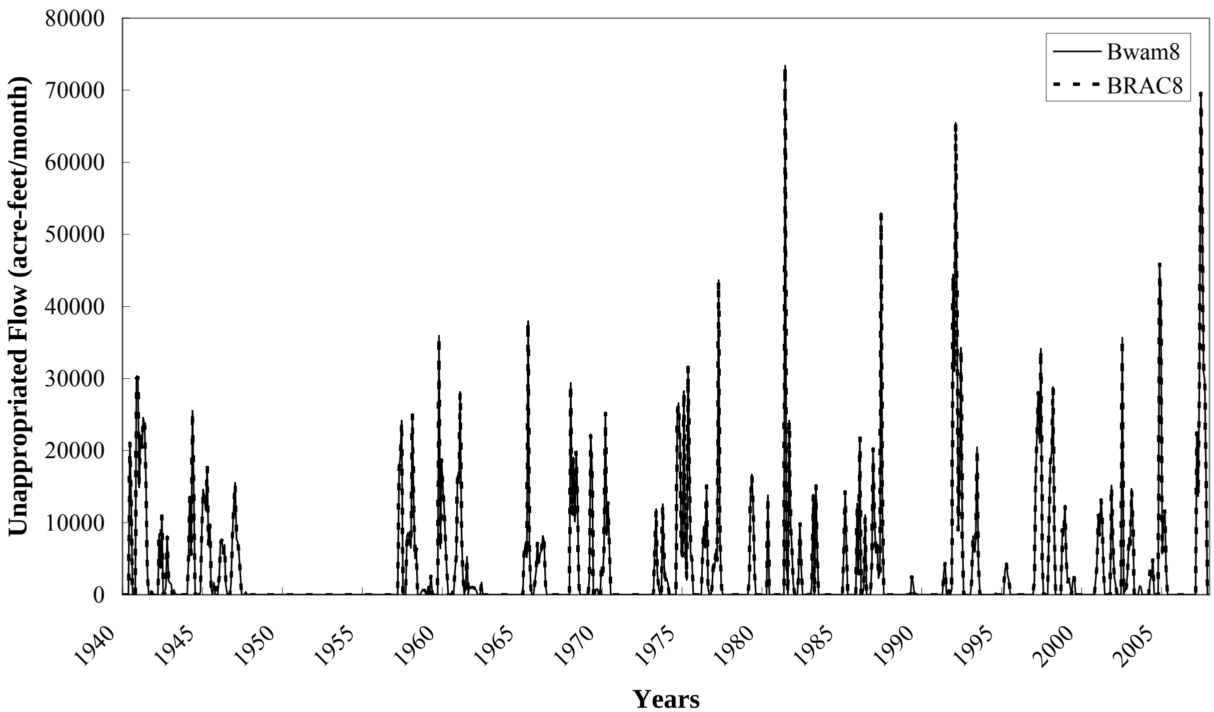

Figure 9.20 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Georgetown Reservoir

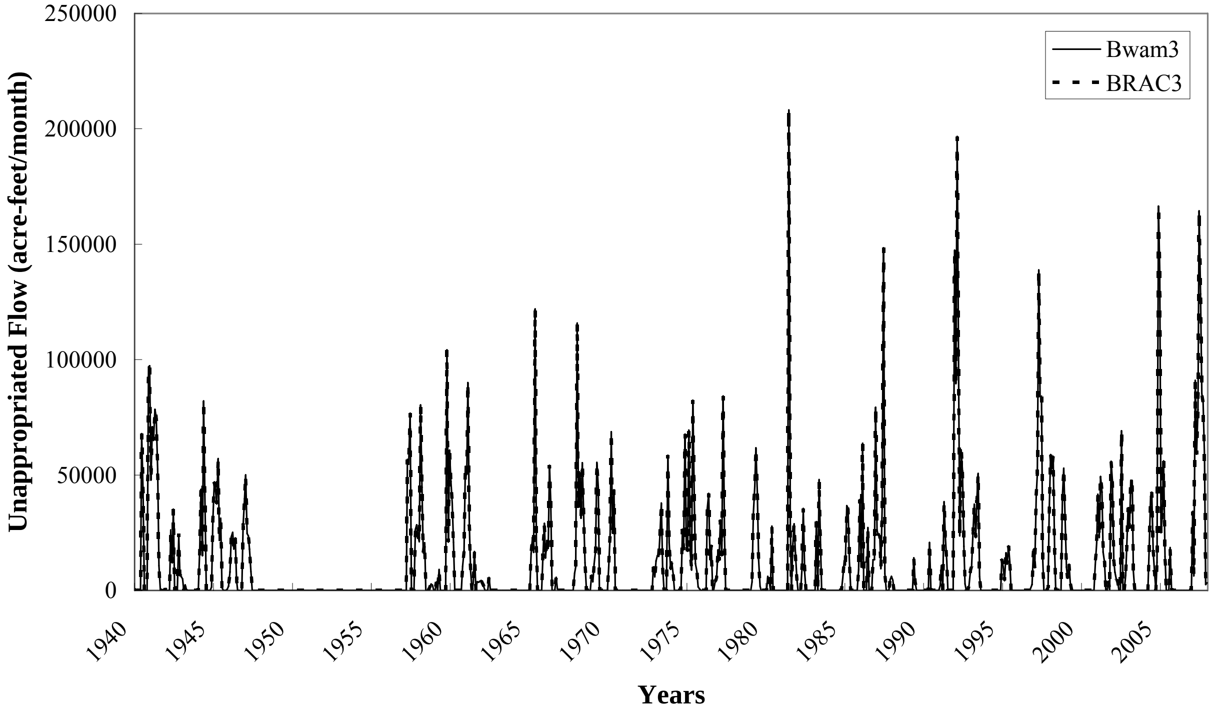

Figure 9.21 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Granger Reservoir

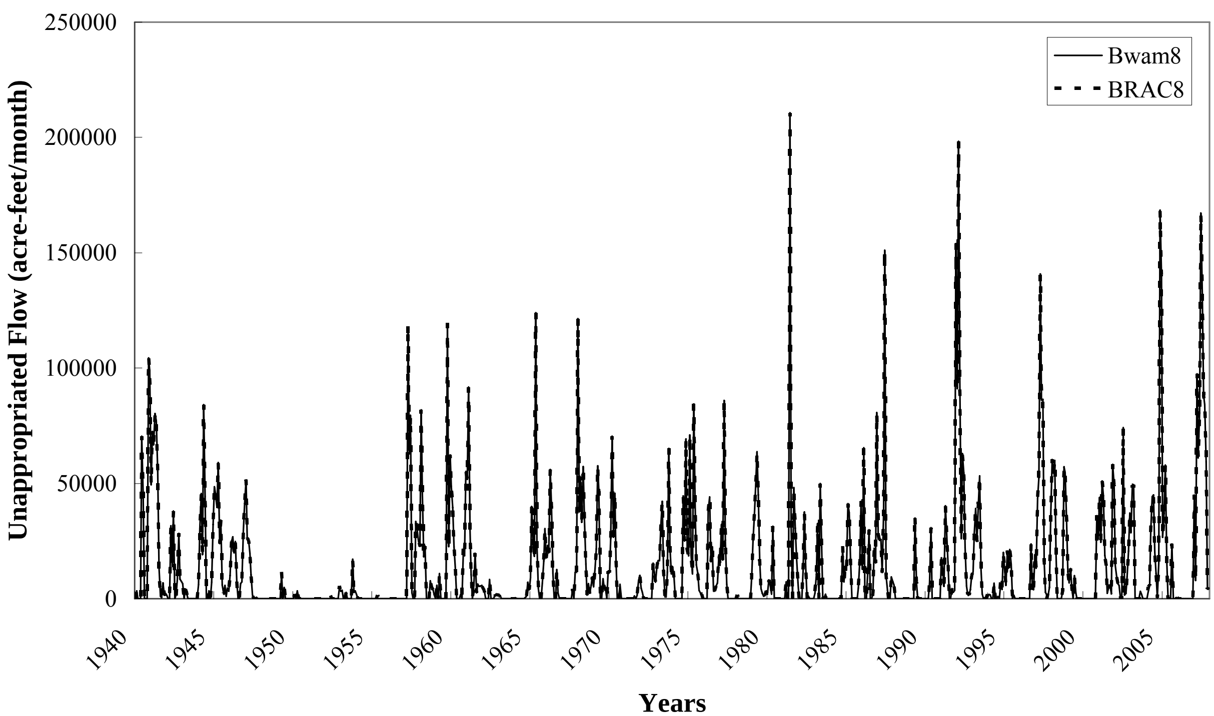

Figure 9.22 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Granger Reservoir

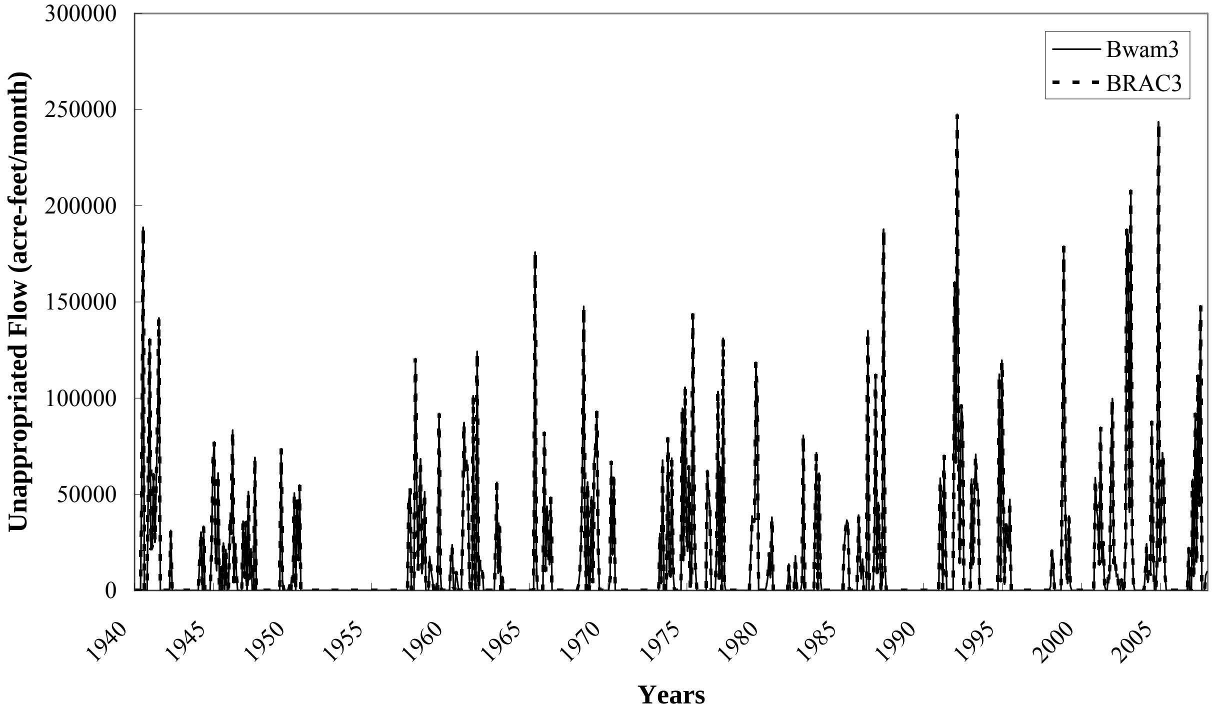

Figure 9.23 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Somerville Reservoir

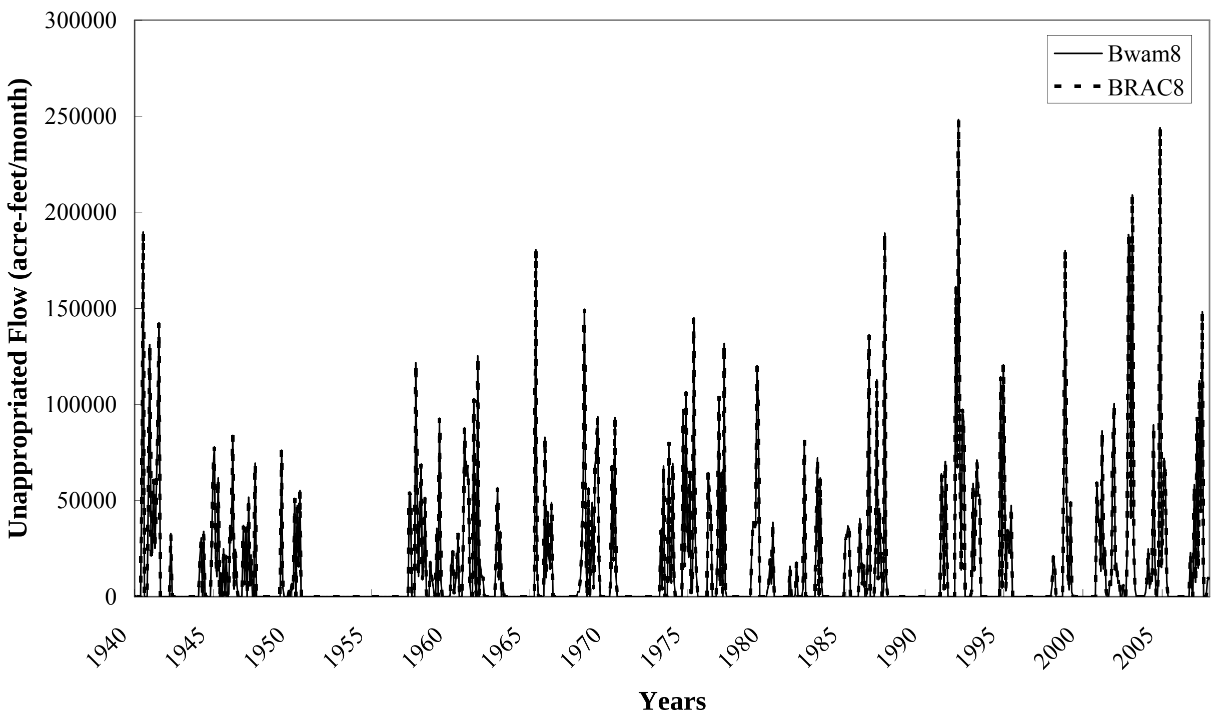

Figure 9.24 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Somerville Reservoir

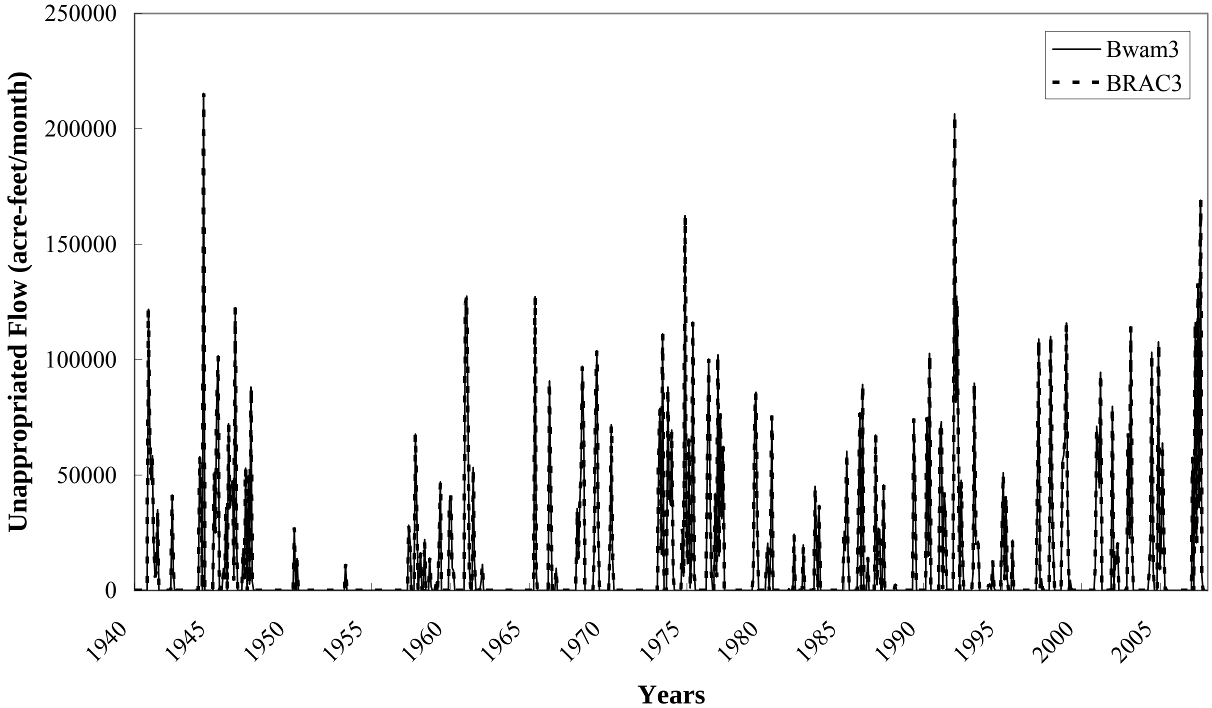

Figure 9.25 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Limestone Reservoir

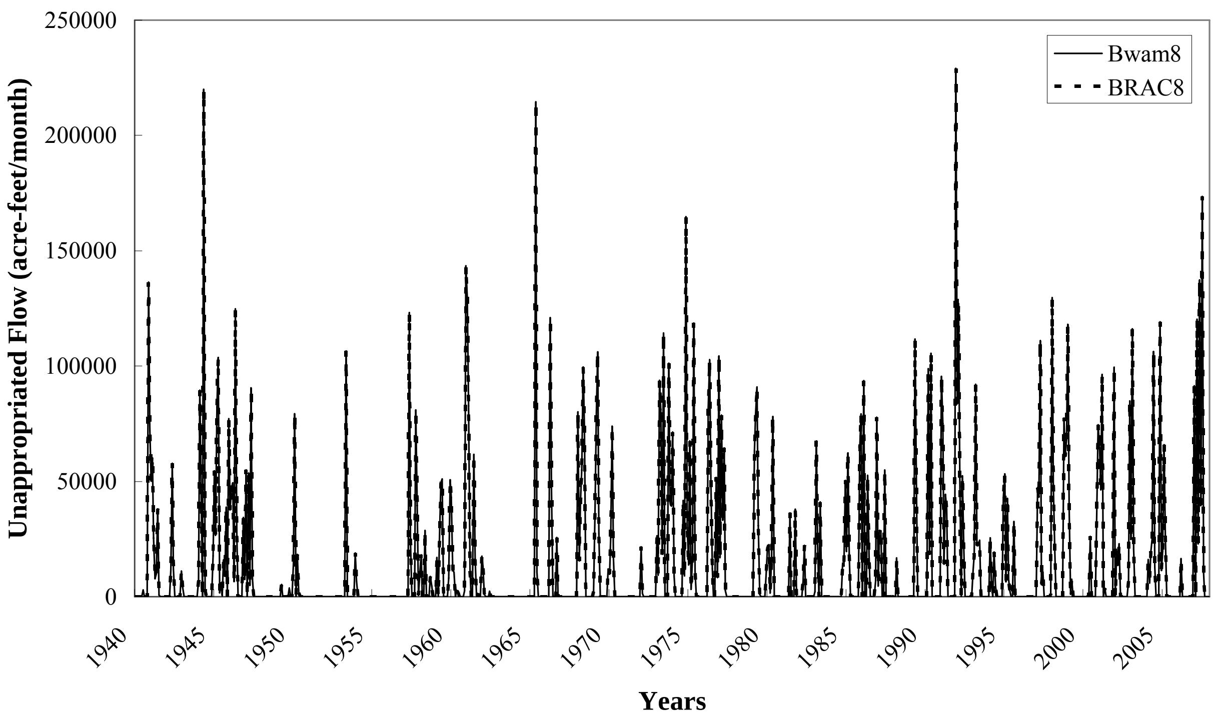

Figure 9.26 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Limestone Reservoir

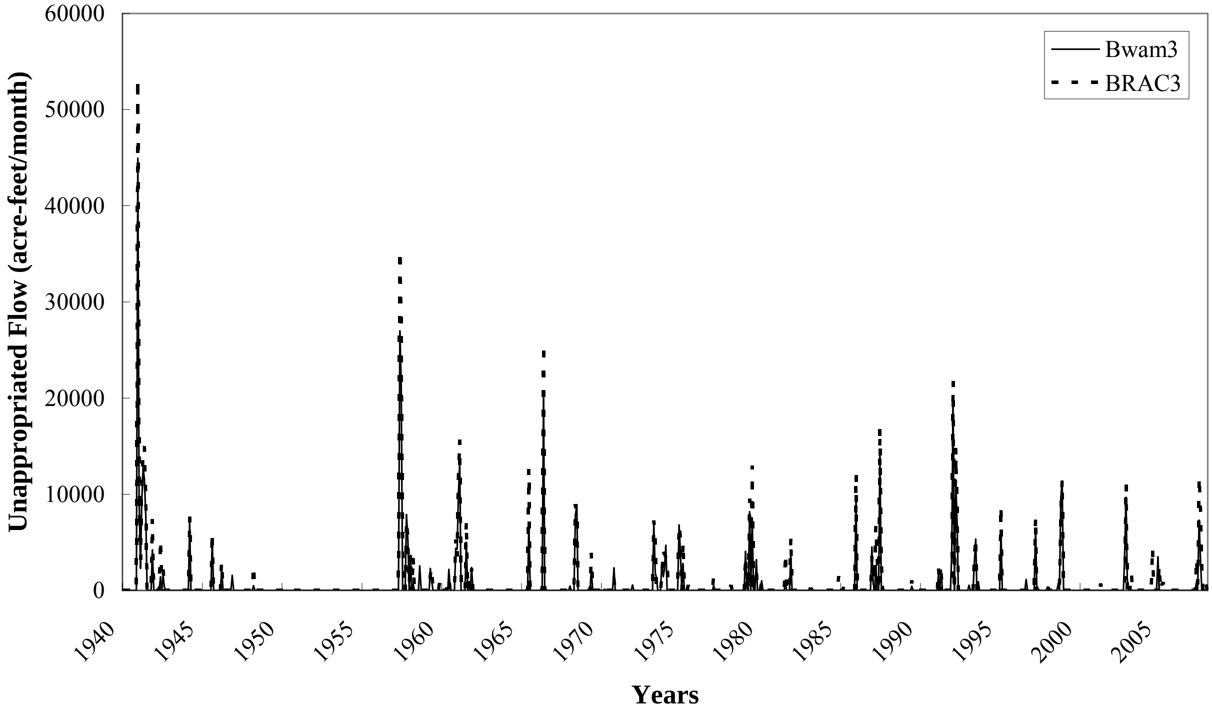

Figure 9.27 1940-2007 Bwam3 and BRAC3 Unappropriated Flows at Allens Creek Reservoir

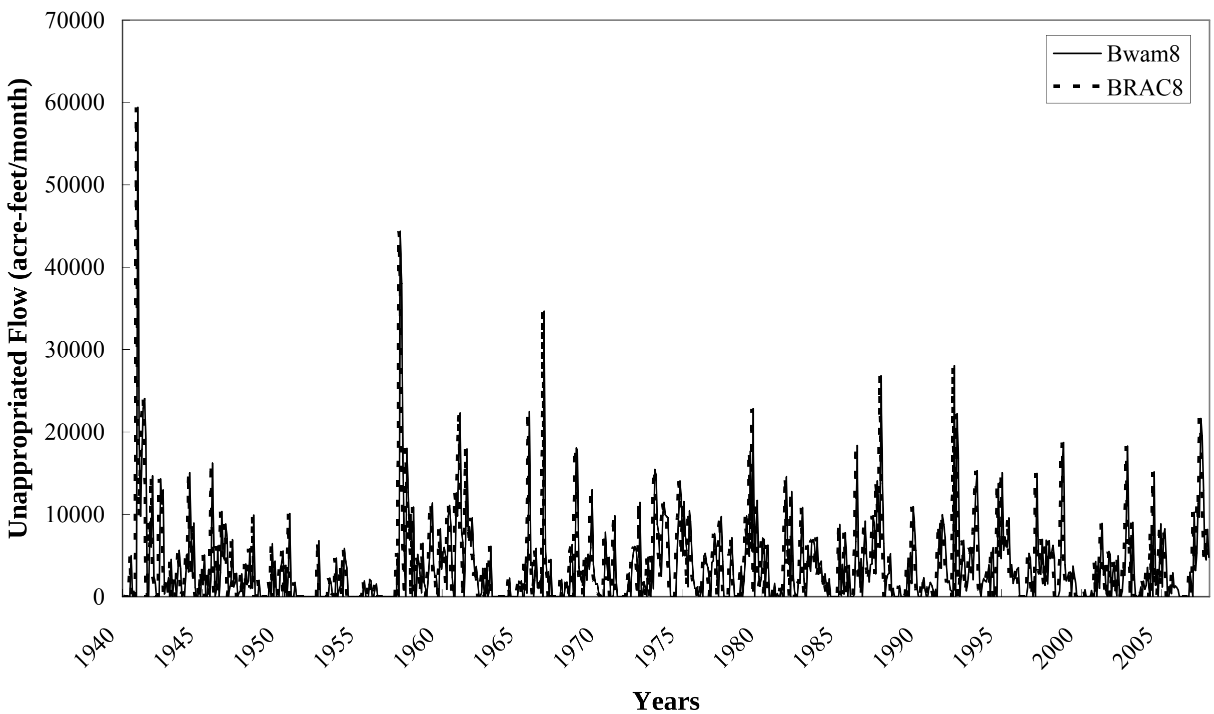

Figure 9.28 1940-2007 Bwam8 and BRAC8 Unappropriated Flows at Allens Creek Reservoir

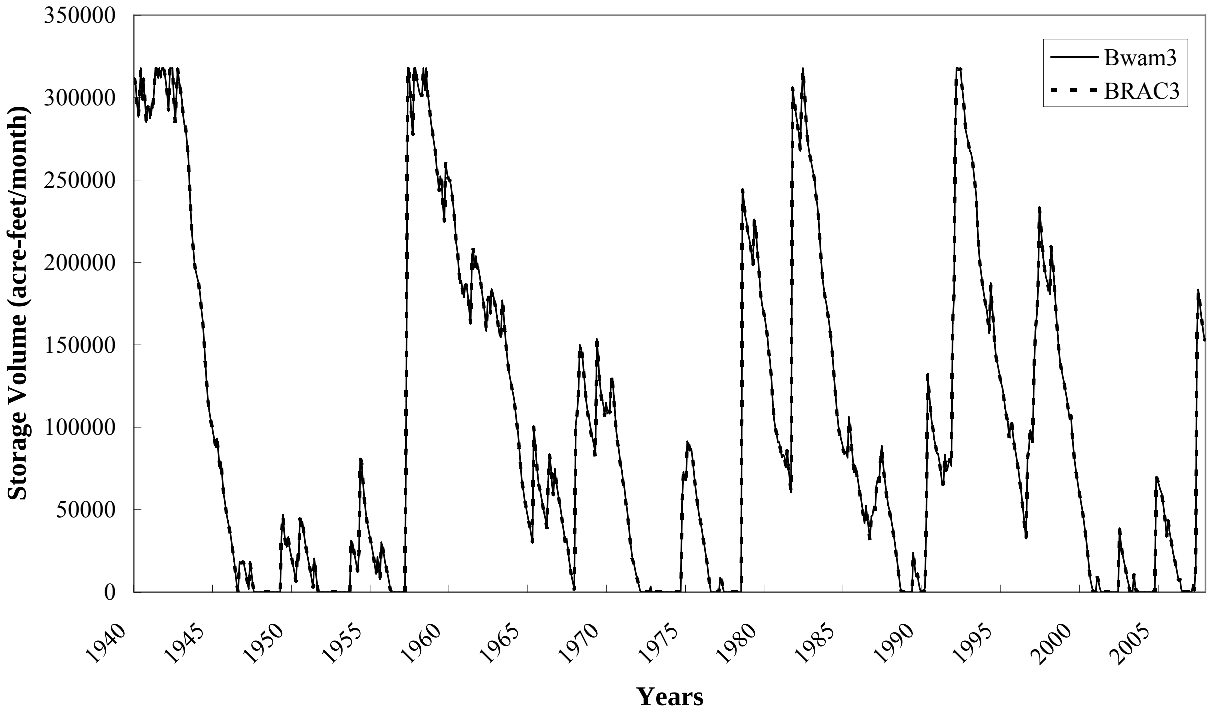

Figure 9.29 1940-2007 Bwam3 and BRAC3 Storage Volume of Hubbard Creek Reservoir

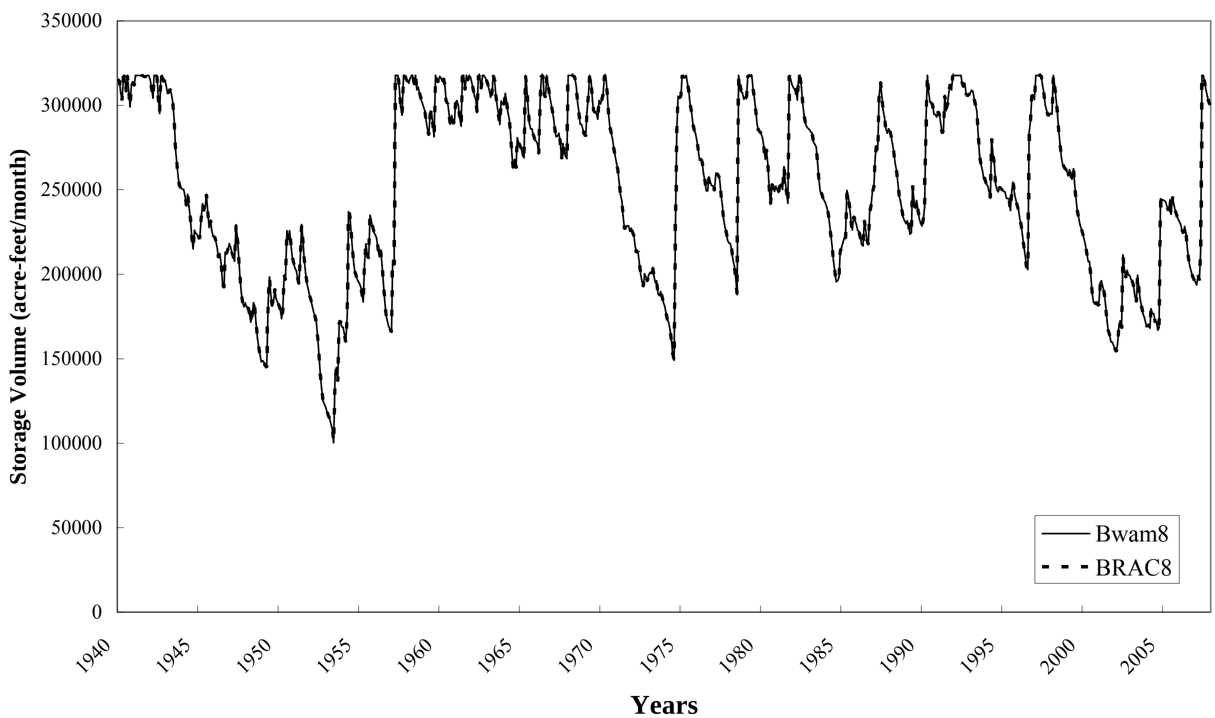

Figure 9.30 1940-2007 Bwam8 and BRAC8 Storage Volume of Hubbard Creek Reservoir

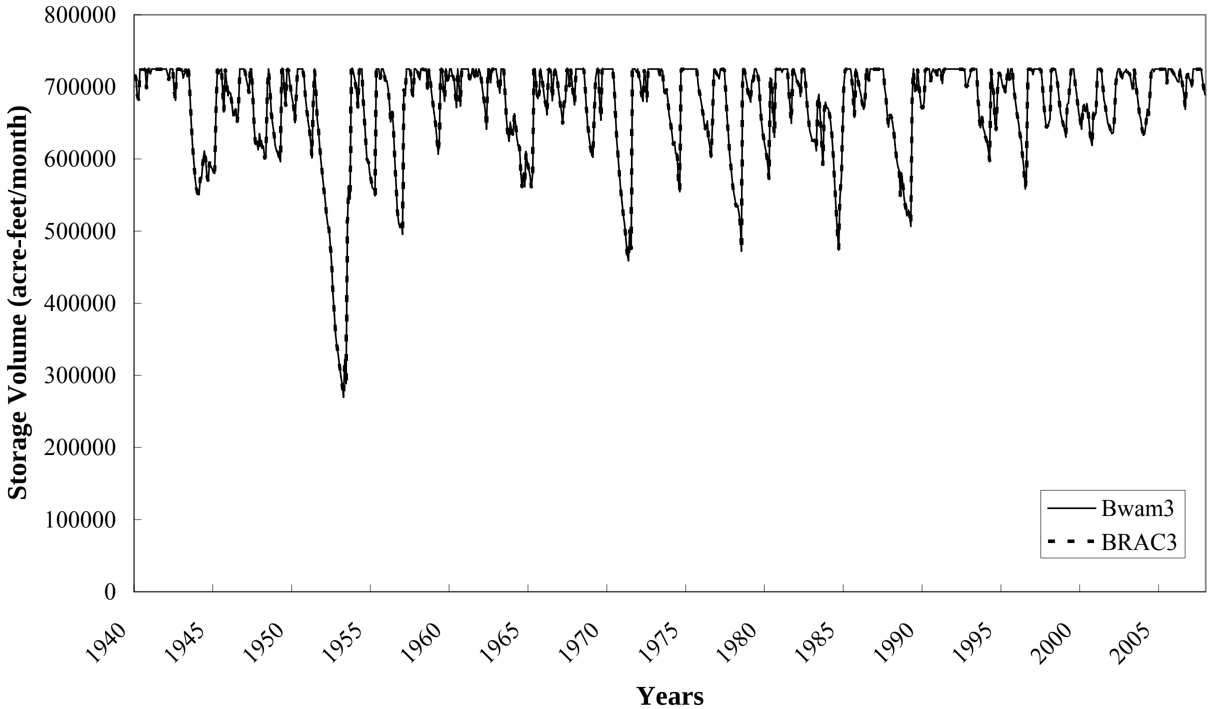

Figure 9.31 1940-2007 Bwam3 and BRAC3 Storage Volume of Possum Kingdom Reservoir

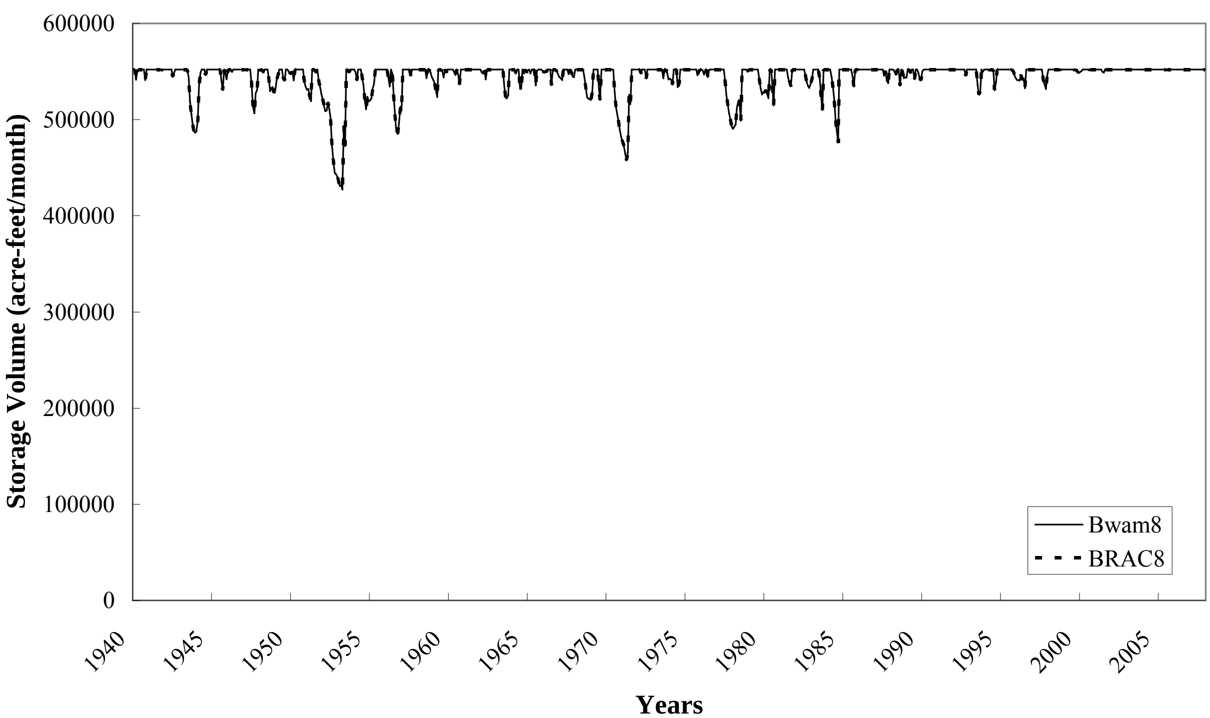

Figure 9.32 1940-2007 Bwam8 and BRAC8 Storage Volume of Possum Kingdom Reservoir

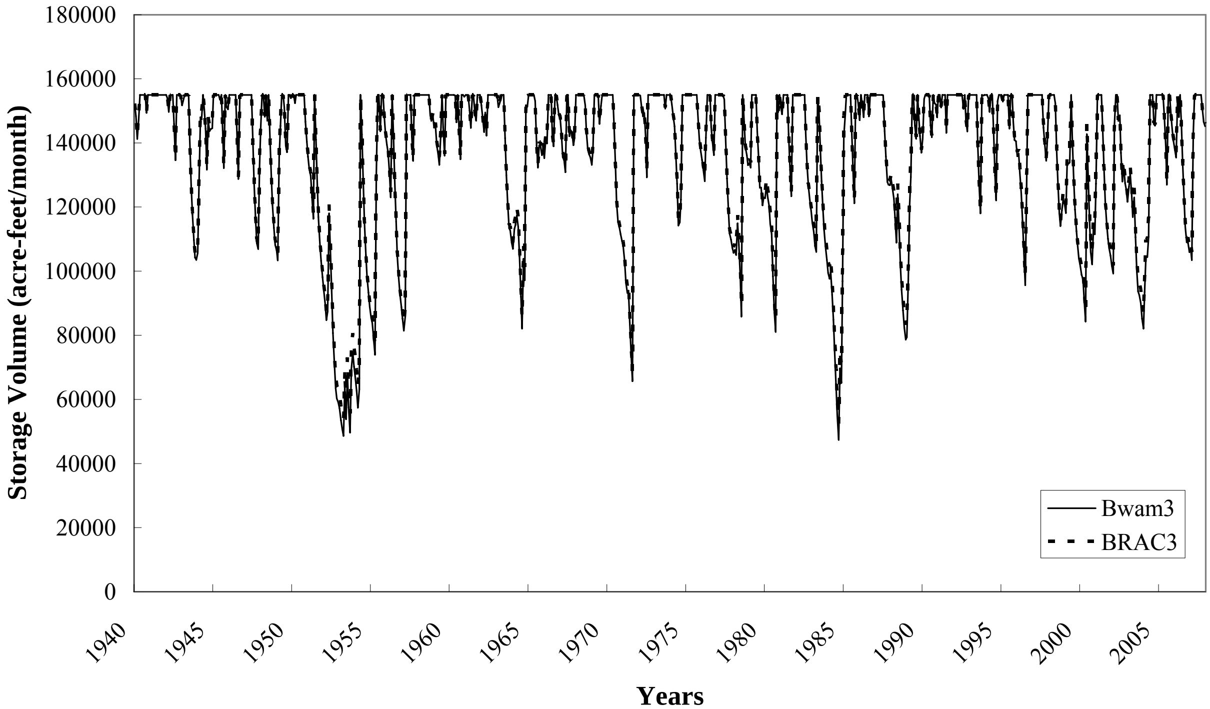

Figure 9.33 1940-2007 Bwam3 and BRAC3 Storage Volume of Granbury Reservoir

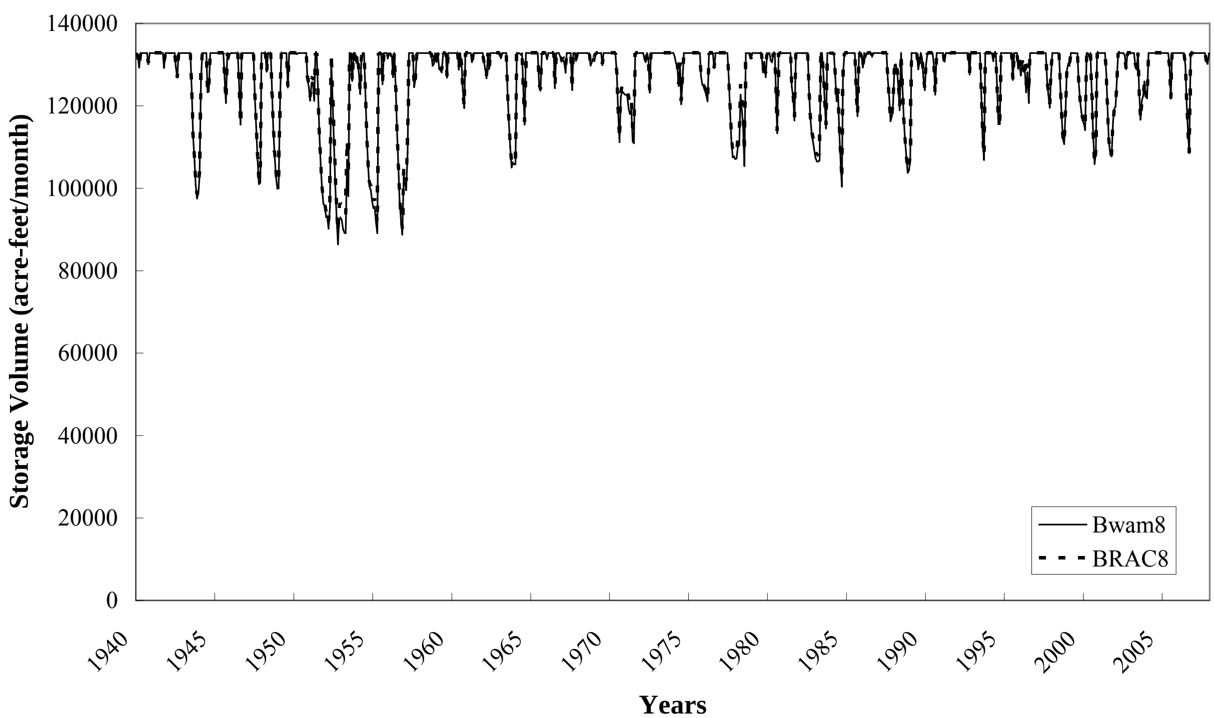

Figure 9.34 1940-2007 Bwam8 and BRAC8 Storage Volume of Granbury Reservoir

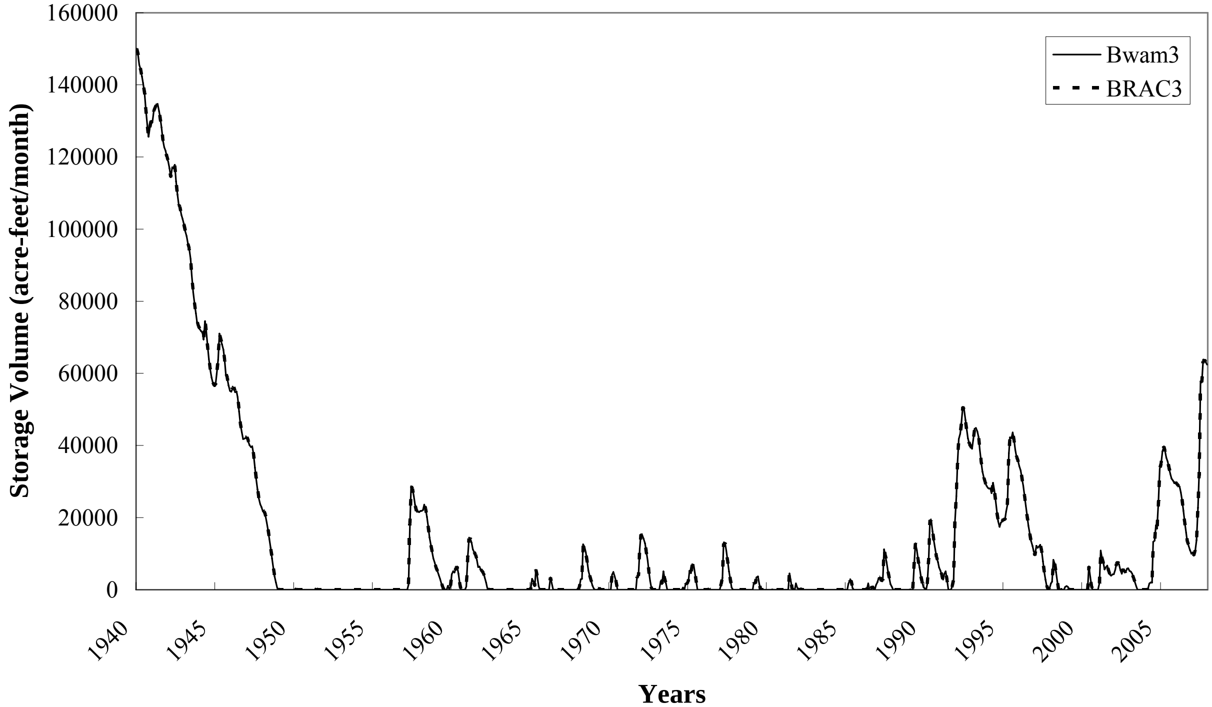

Figure 9.35 1940-2007 Bwam3 and BRAC3 Storage Volume of Squaw Creek Reservoir

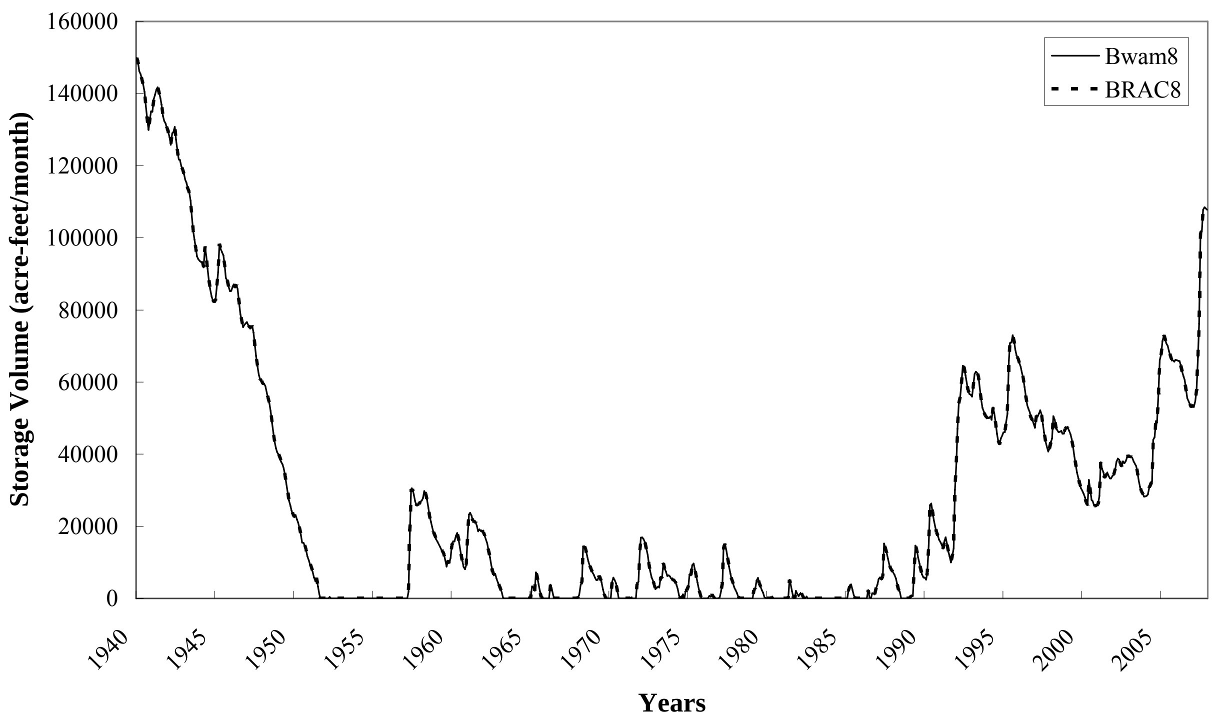

Figure 9.36 1940-2007 Bwam8 and BRAC8 Storage Volume of Squaw Creek Reservoir

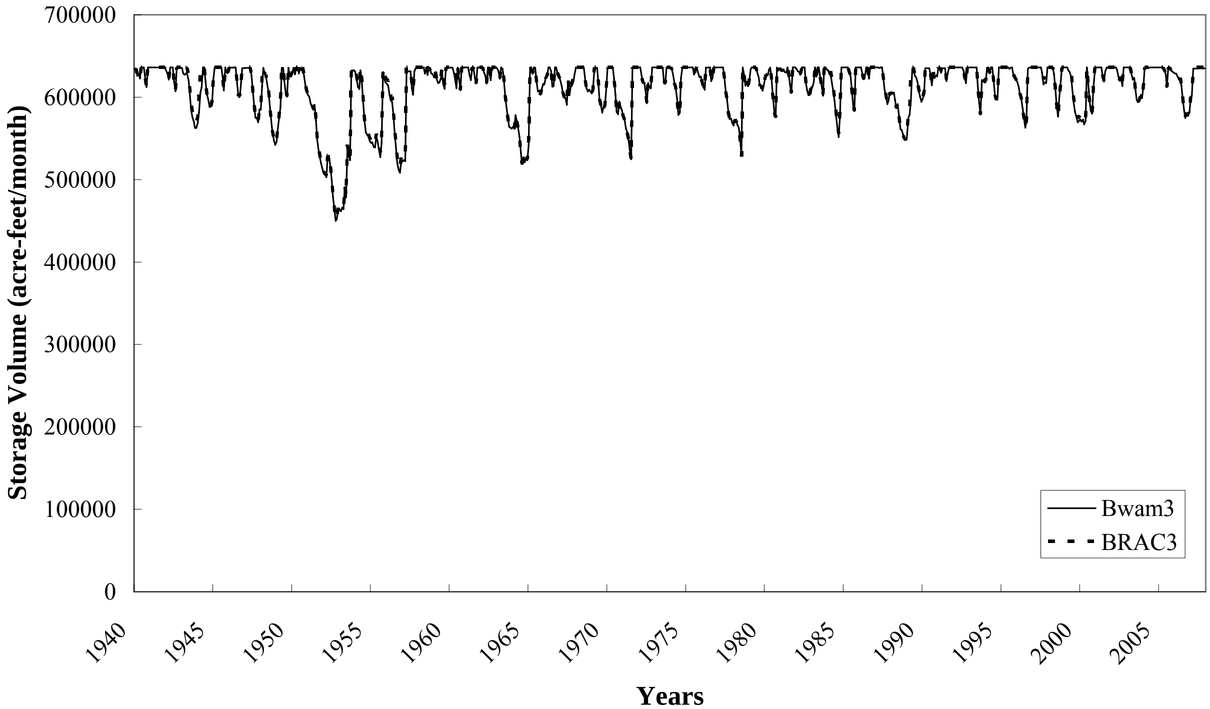

Figure 9.37 1940-2007 Bwam3 and BRAC3 Storage Volume of Whitney Reservoir

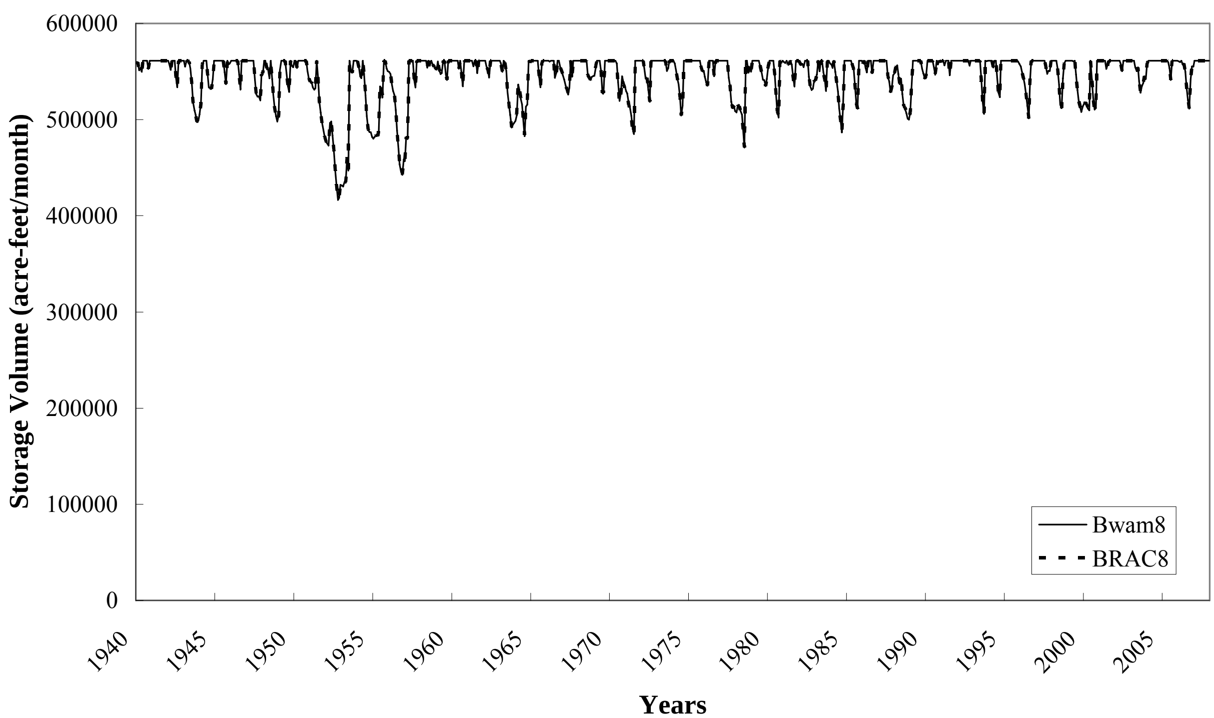

Figure 9.38 1940-2007 Bwam8 and BRAC8 Storage Volume of Whitney Reservoir

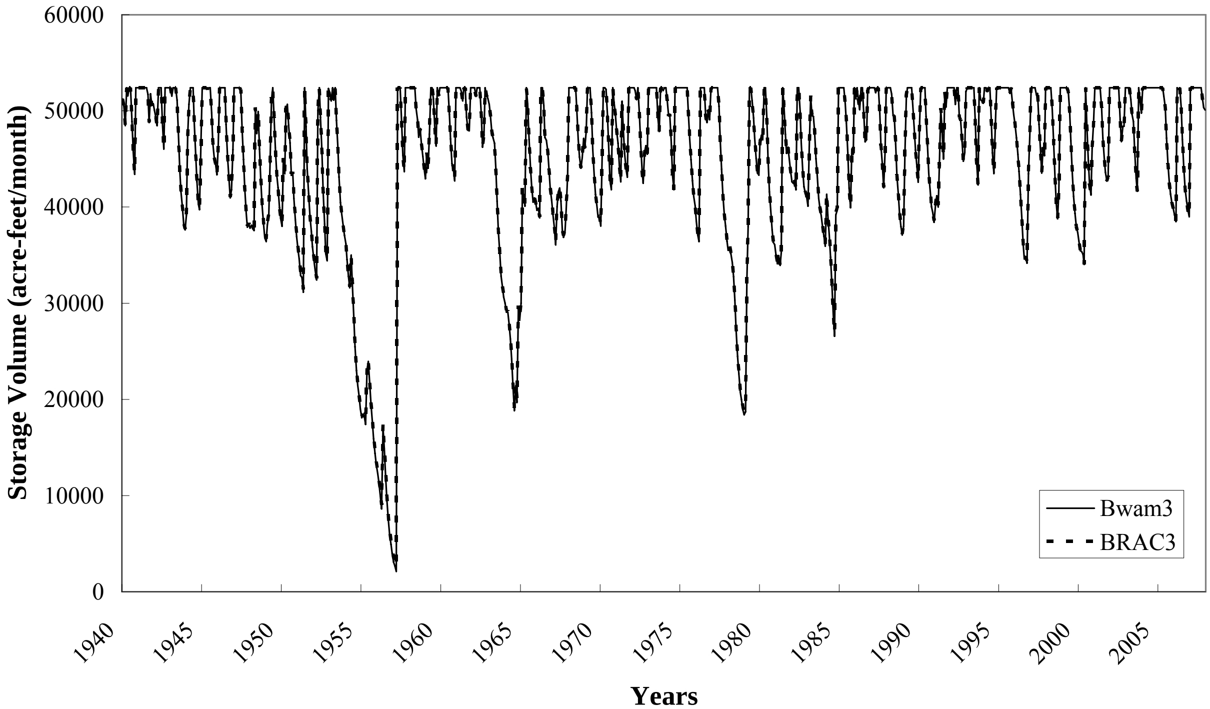

Figure 9.39 1940-2007 Bwam3 and BRAC3 Storage Volume of Aquilla Reservoir

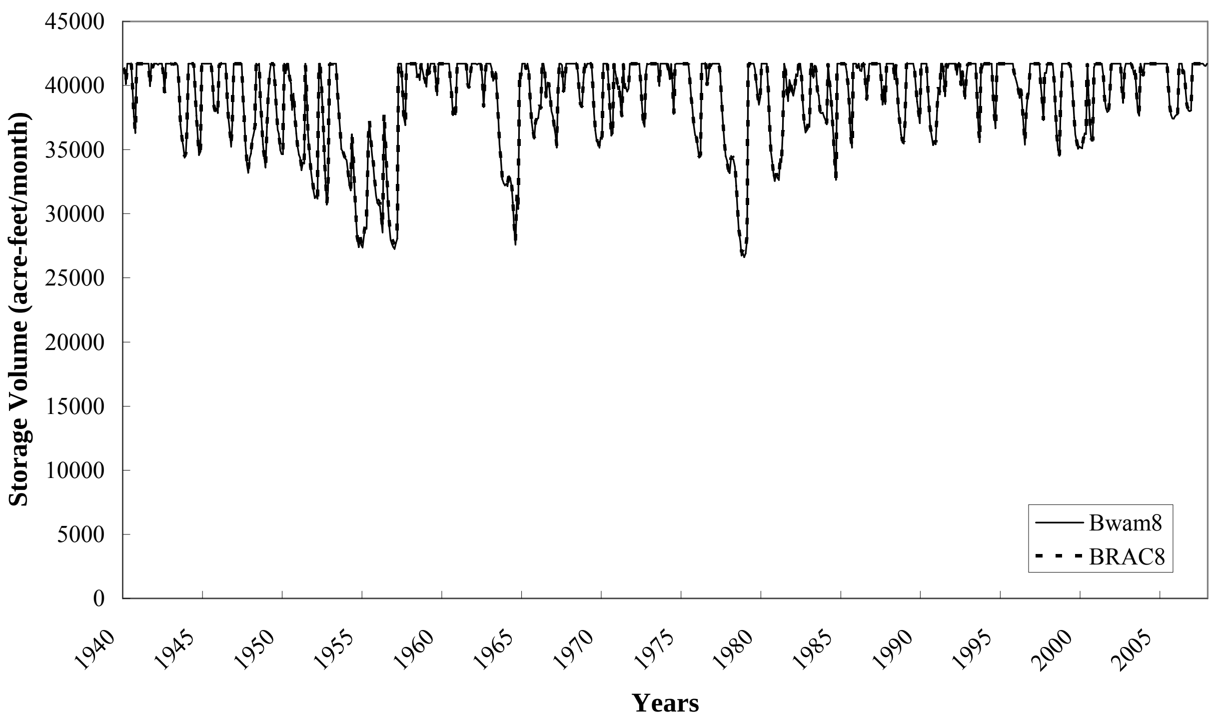

Figure 9.40 1940-2007 Bwam8 and BRAC8 Storage Volume of Aquilla Reservoir

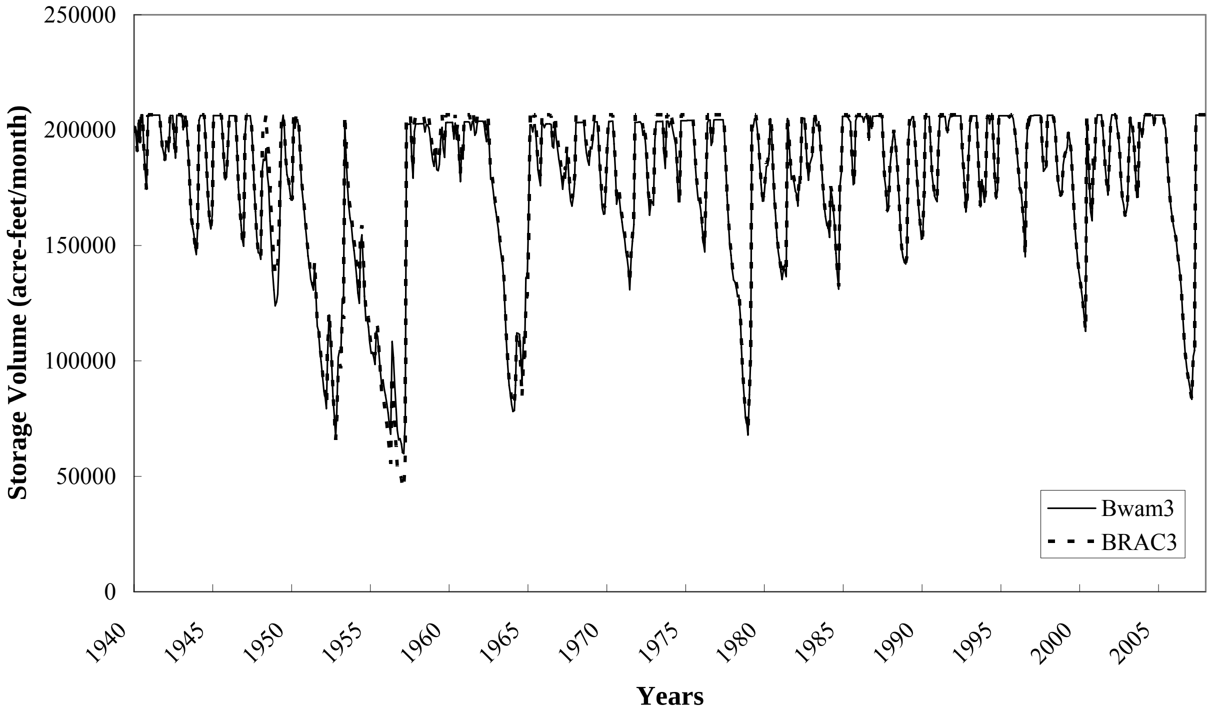

Figure 9.41 1940-2007 Bwam3 and BRAC3 Storage Volume of Waco Reservoir

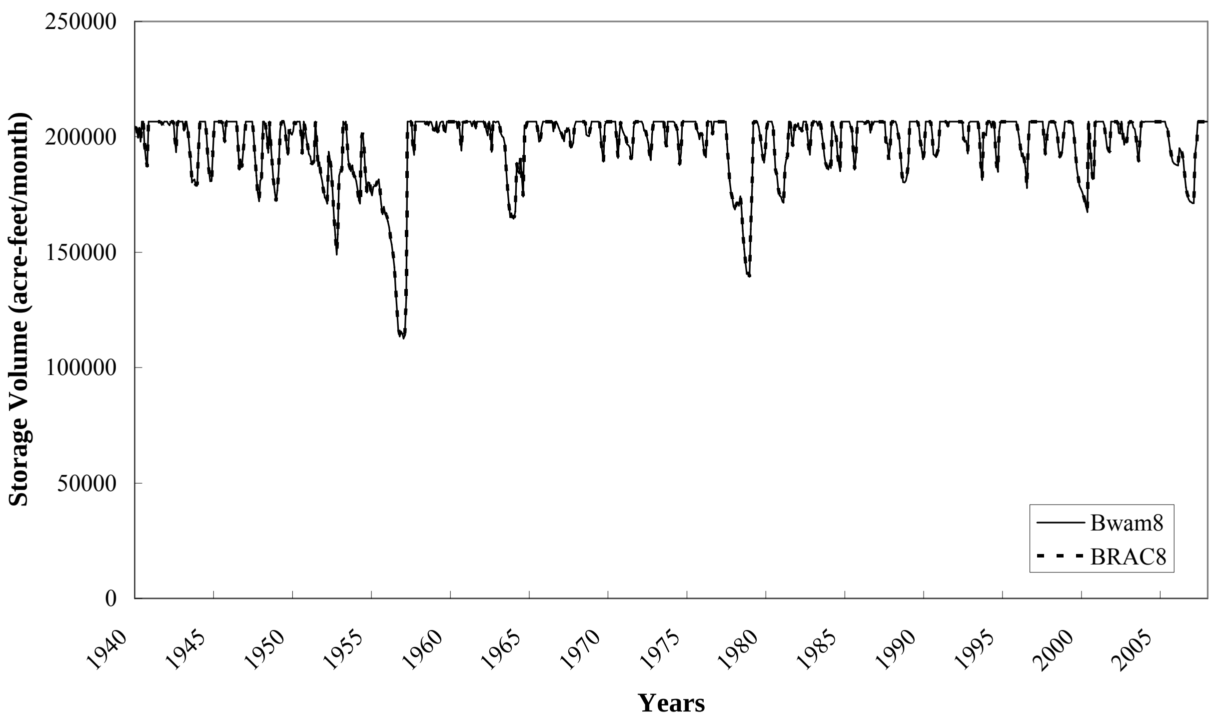

Figure 9.42 1940-2007 Bwam8 and BRAC8 Storage Volume of Waco Reservoir

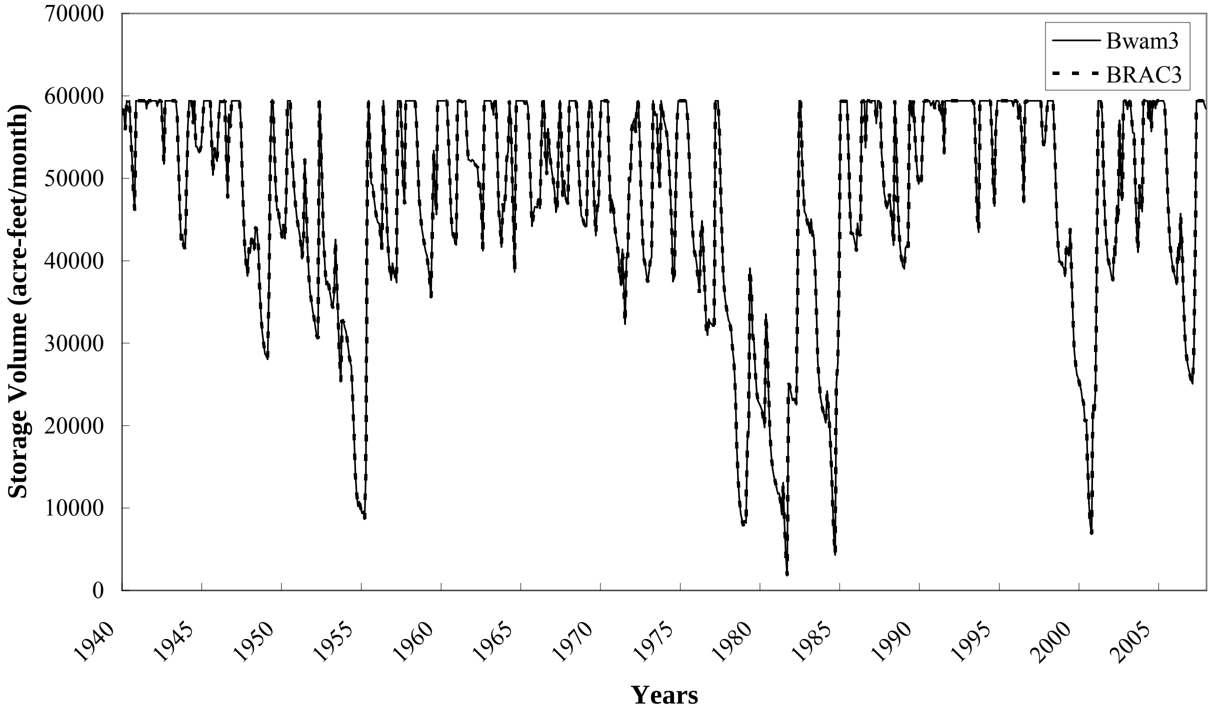

Figure 9.43 1940-2007 Bwam3 and BRAC3 Storage Volume of Proctor Reservoir

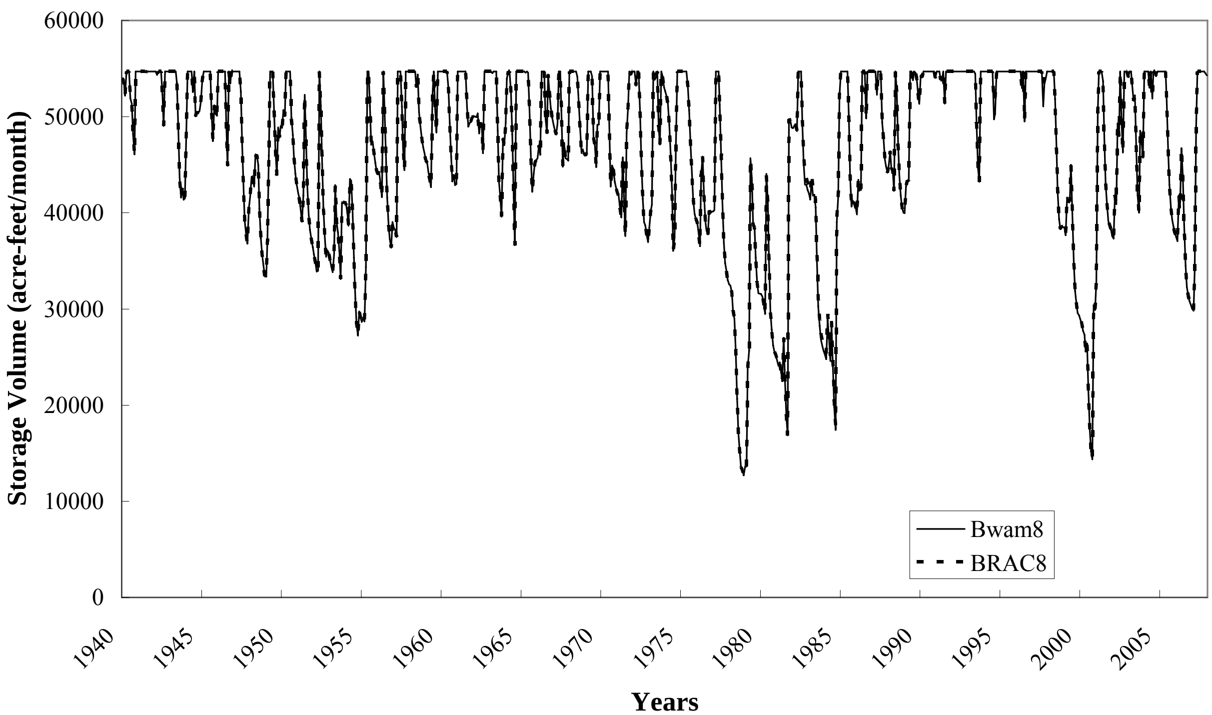

Figure 9.44 1940-2007 Bwam8 and BRAC8 Storage Volume of Proctor Reservoir

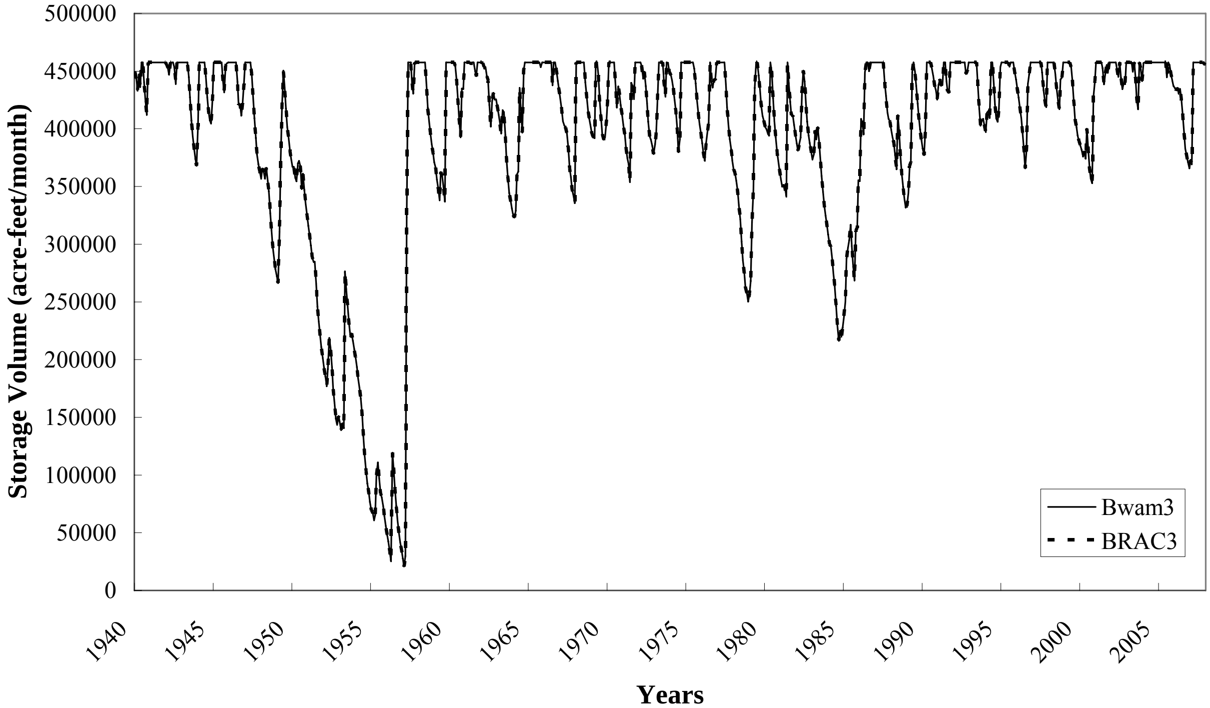

Figure 9.45 1940-2007 Bwam3 and BRAC3 Storage Volume of Belton Reservoir

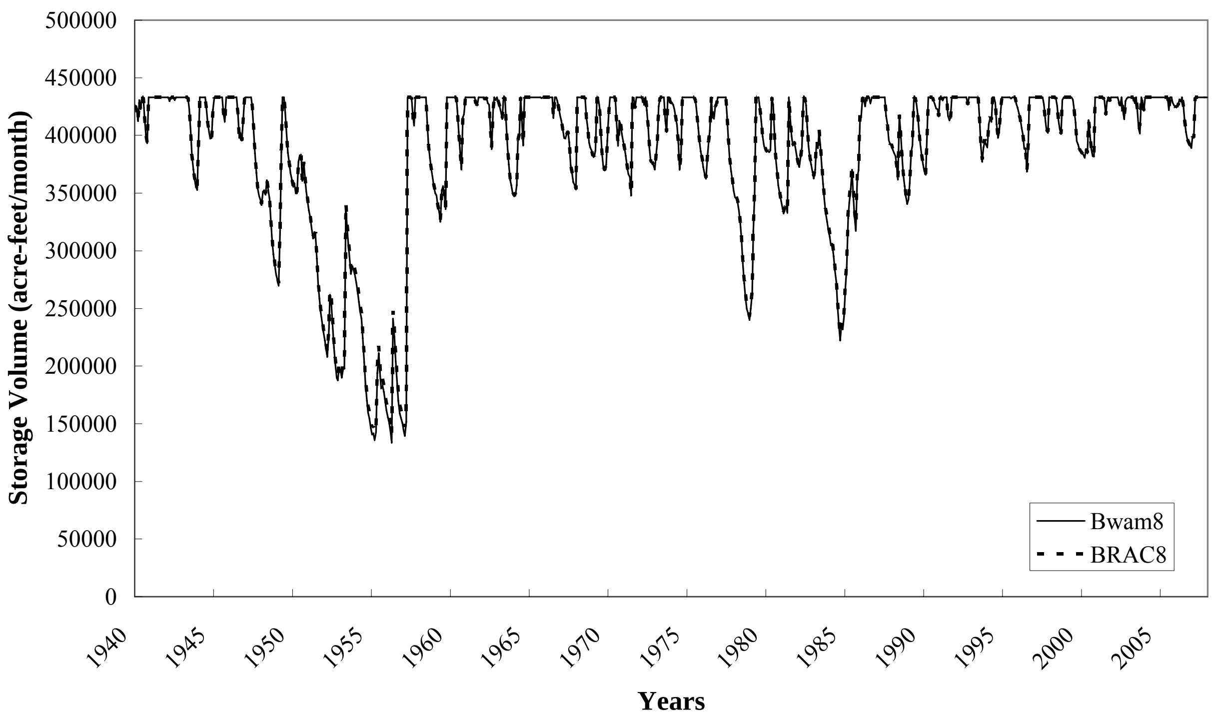

Figure 9.46 1940-2007 Bwam8 and BRAC8 Storage Volume of Belton Reservoir

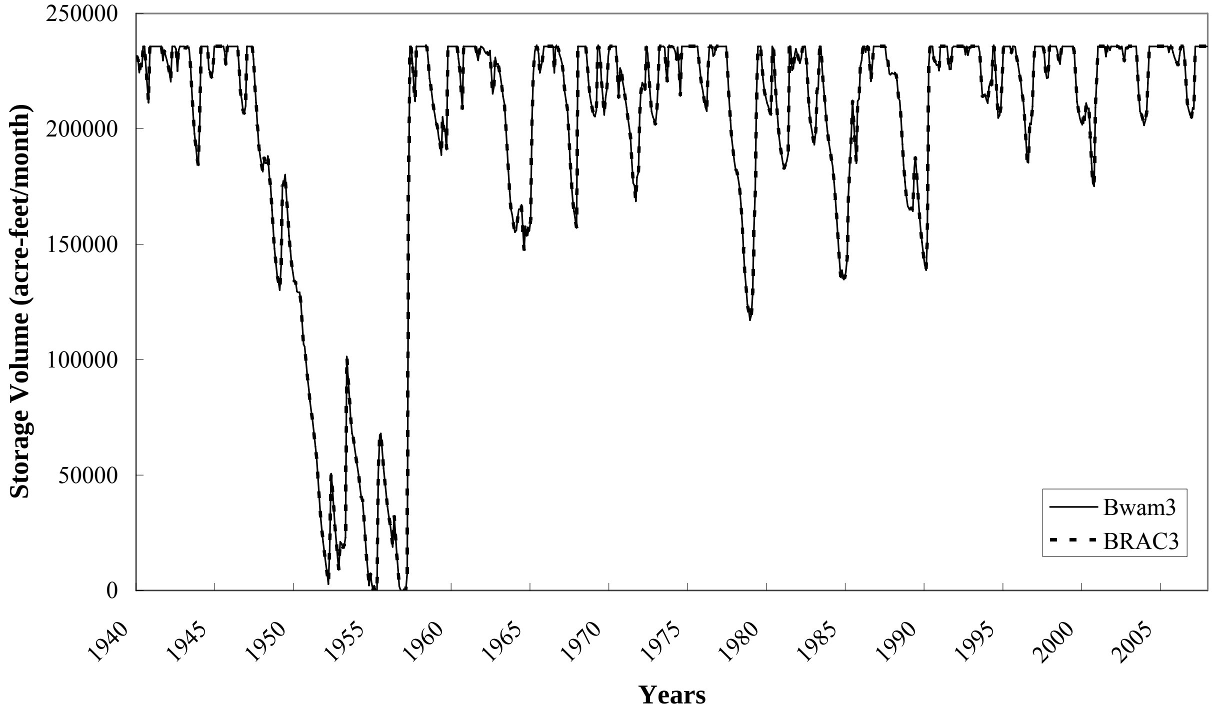

Figure 9.47 1940-2007 Bwam3 and BRAC3 Storage Volume of Stillhouse Hollow Reservoir

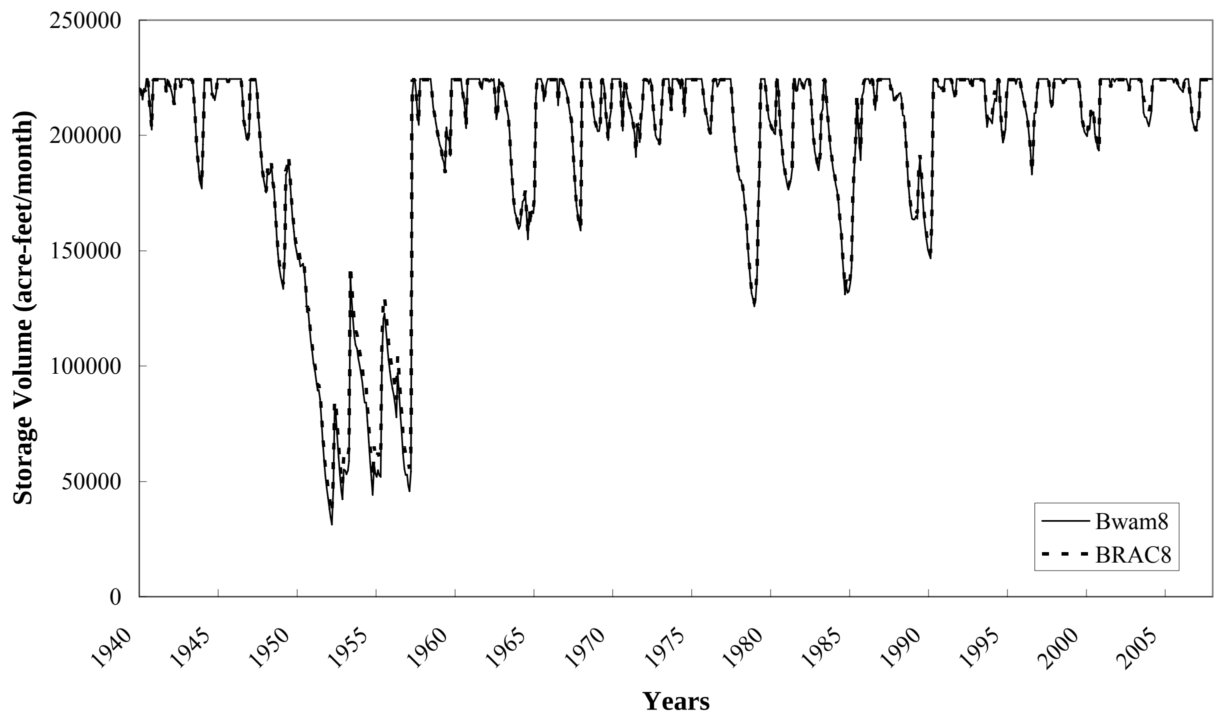

Figure 9.48 1940-2007 Bwam8 and BRAC8 Storage Volume of Stillhouse Hollow Reservoir

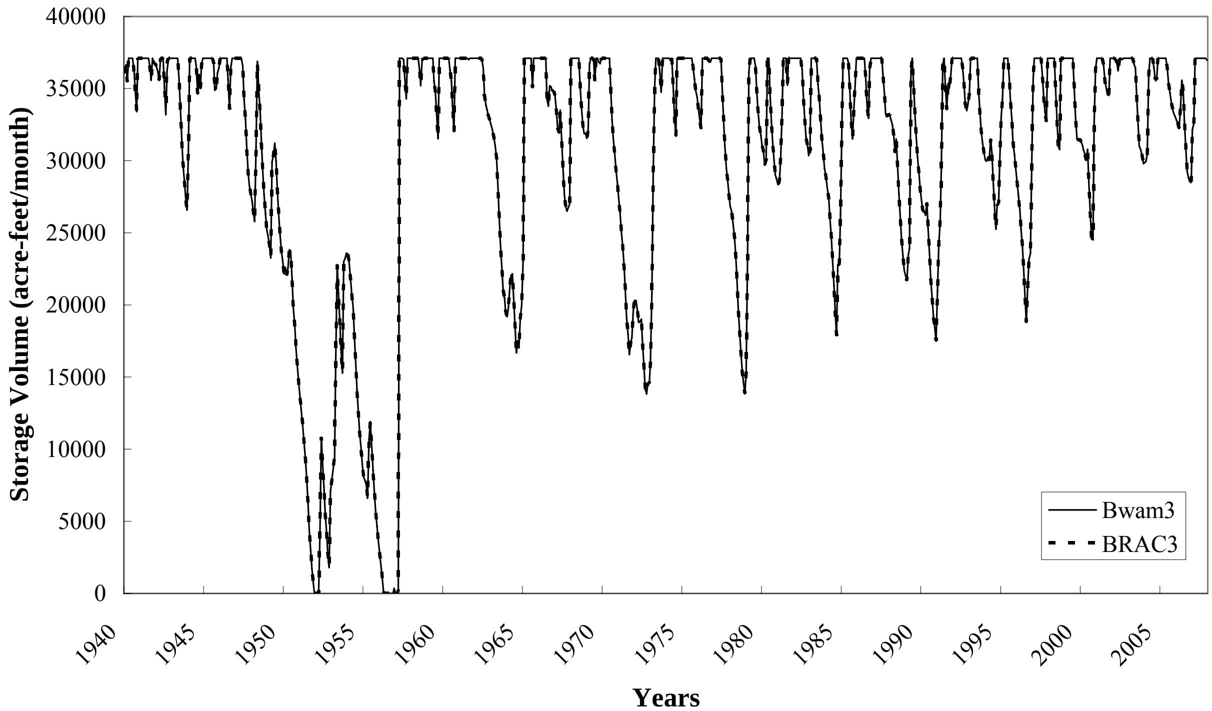

Figure 9.49 1940-2007 Bwam3 and BRAC3 Storage Volume of Georgetown Reservoir

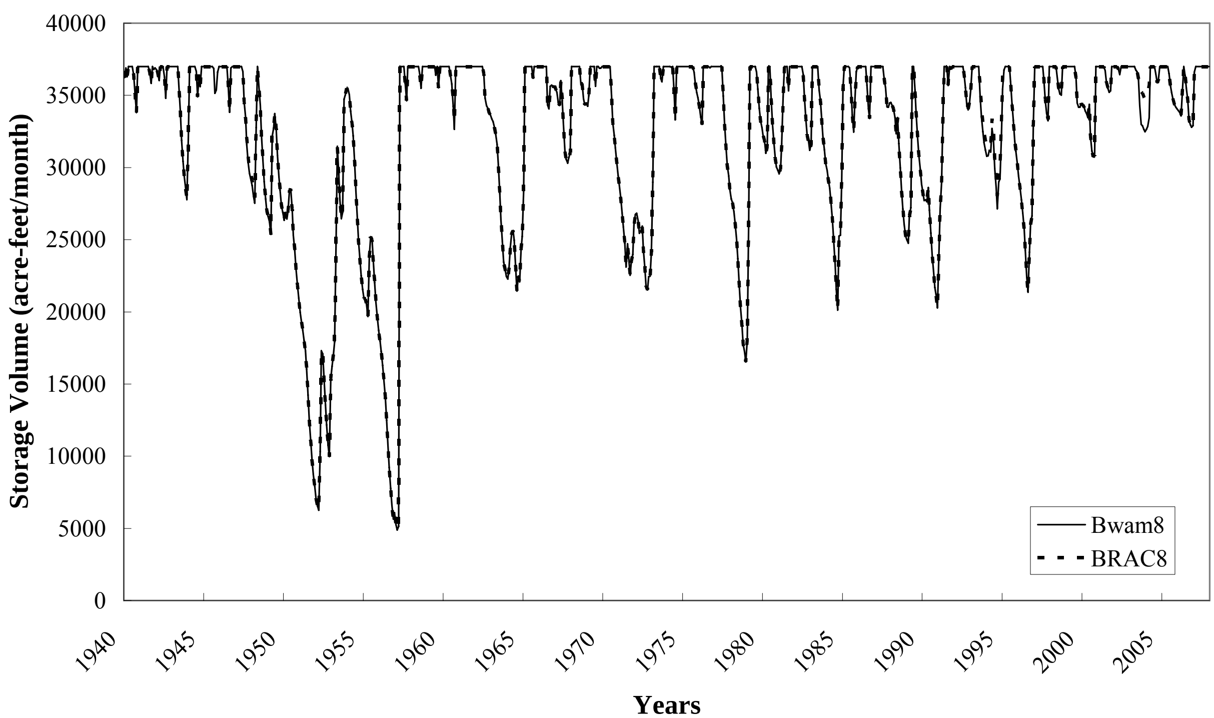

Figure 9.50 1940-2007 Bwam8 and BRAC8 Storage Volume of Georgetown Reservoir

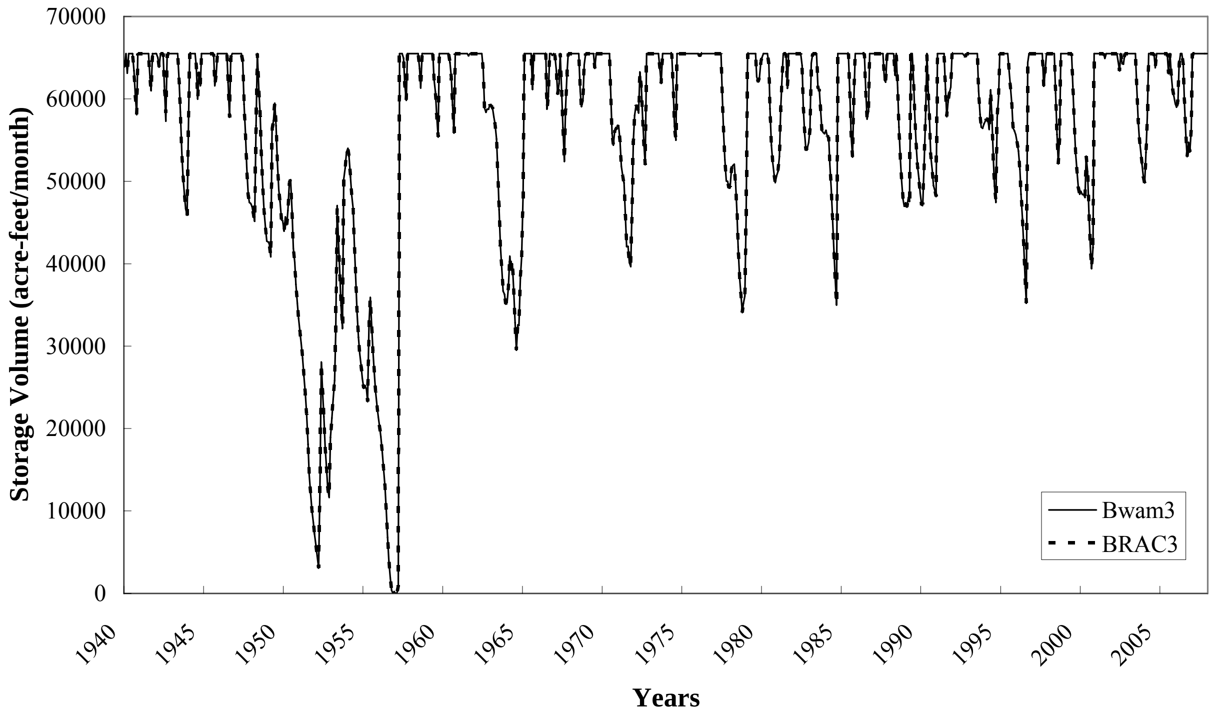

Figure 9.51 1940-2007 Bwam3 and BRAC3 Storage Volume of Granger Reservoir

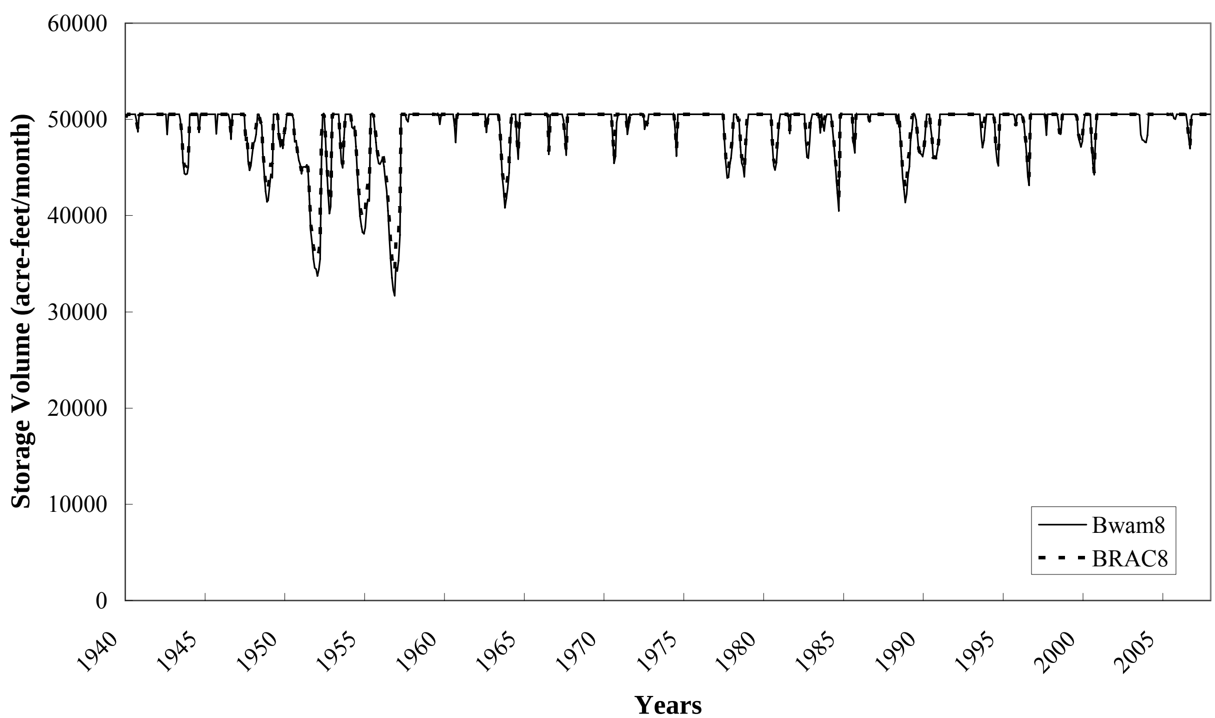

Figure 9.52 1940-2007 Bwam8 and BRAC8 Storage Volume of Granger Reservoir

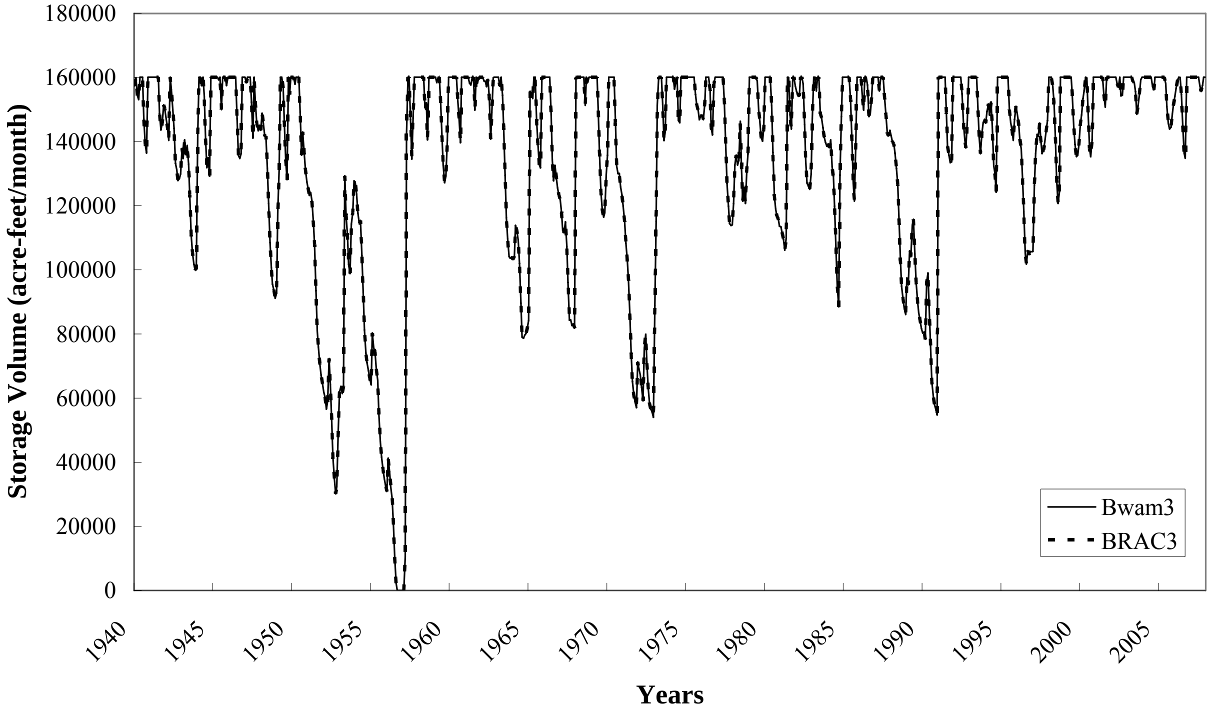

Figure 9.53 1940-2007 Bwam3 and BRAC3 Storage Volume of Somerville Reservoir

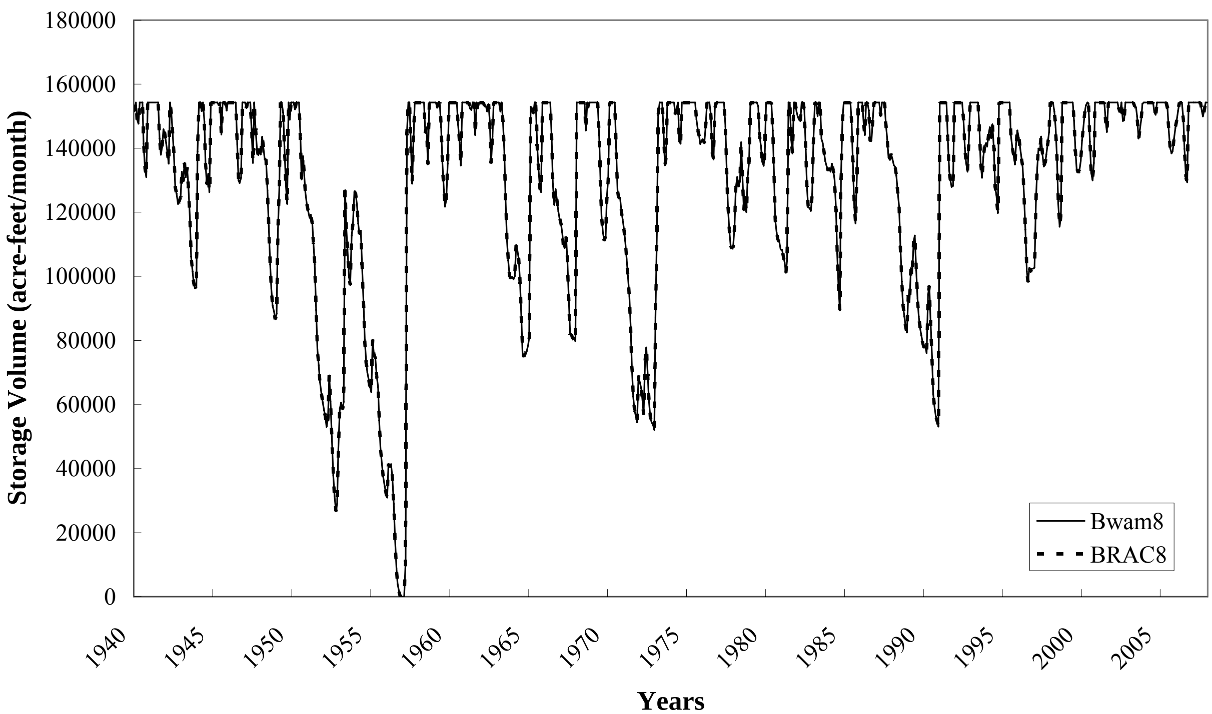

Figure 9.54 1940-2007 Bwam8 and BRAC8 Storage Volume of Somerville Reservoir

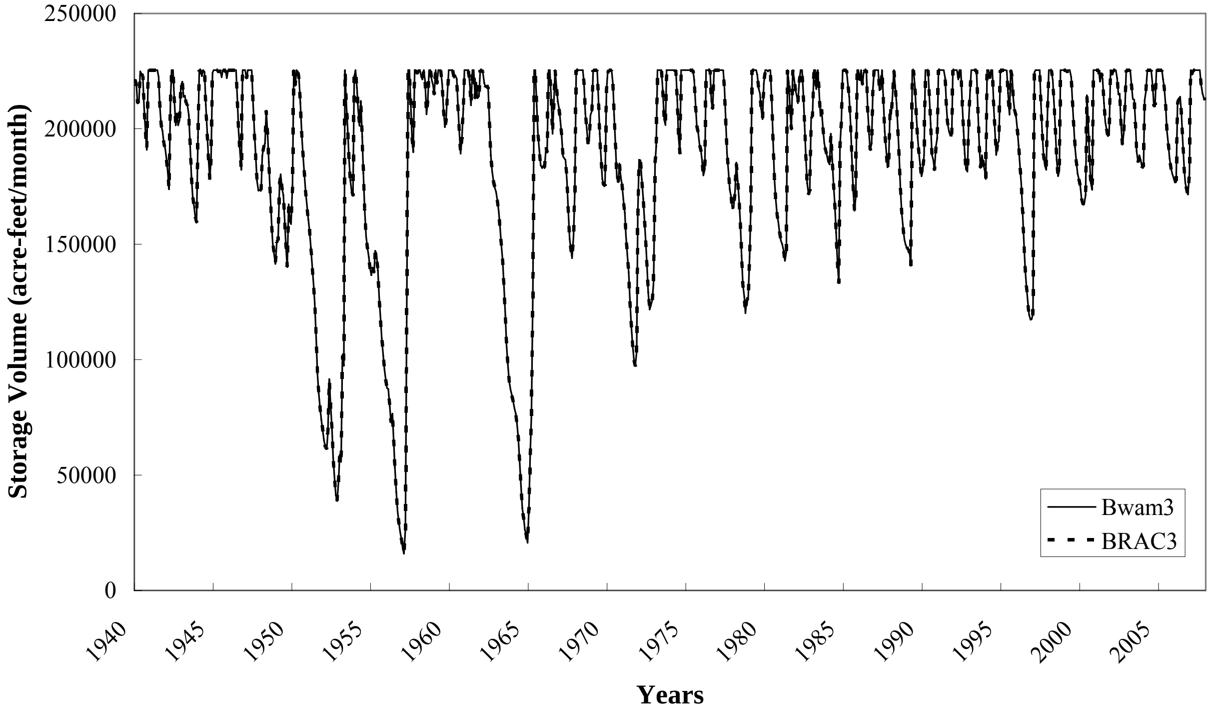

Figure 9.55 1940-2007 Bwam3 and BRAC3 Storage Volume of Limestone Reservoir

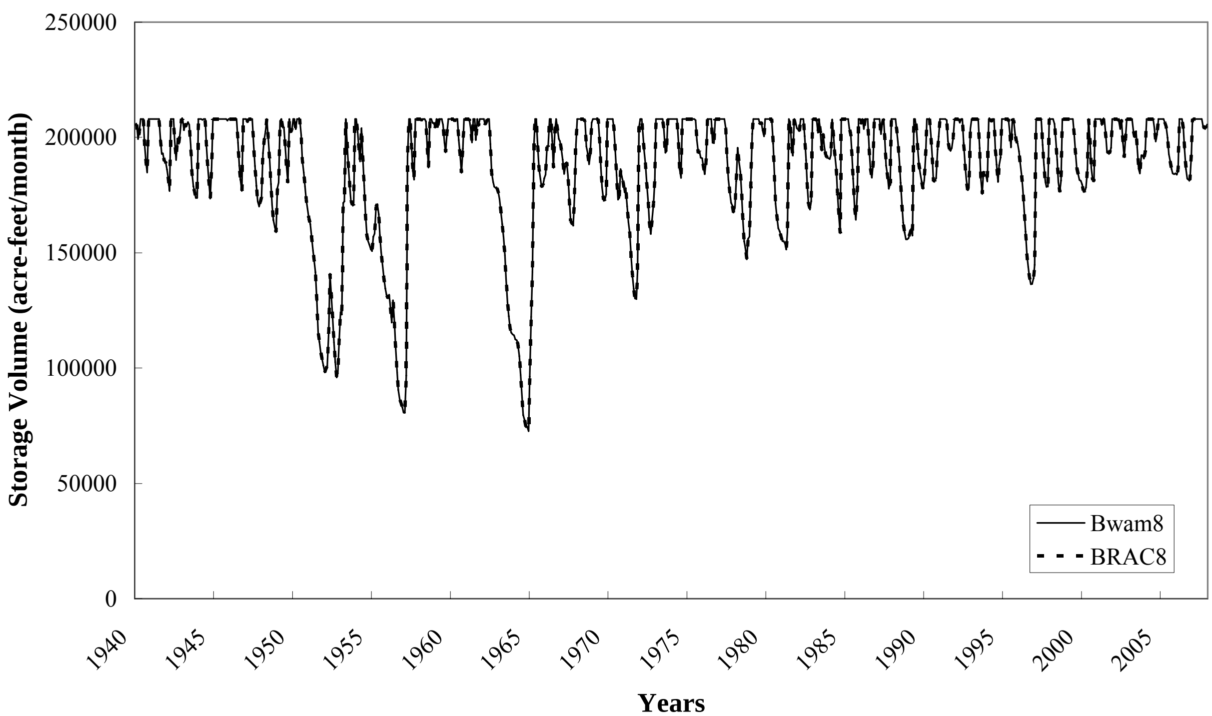

Figure 9.56 1940-2007 Bwam8 and BRAC8 Storage Volume of Limestone Reservoir

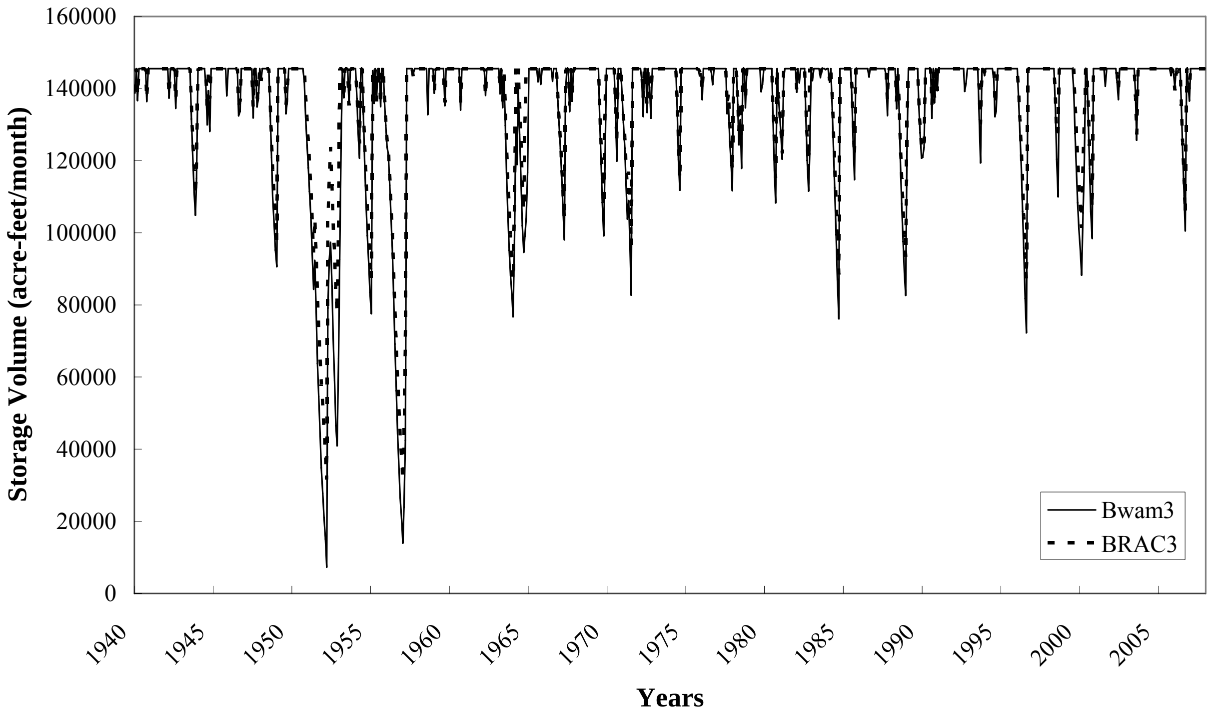

Figure 9.57 1940-2007 Bwam3 and BRAC3 Storage Volume of Allens Creek Reservoir

Allens Creek Reservoir is not included in the current use scenario Bwam8 and BRAC8 datasets.

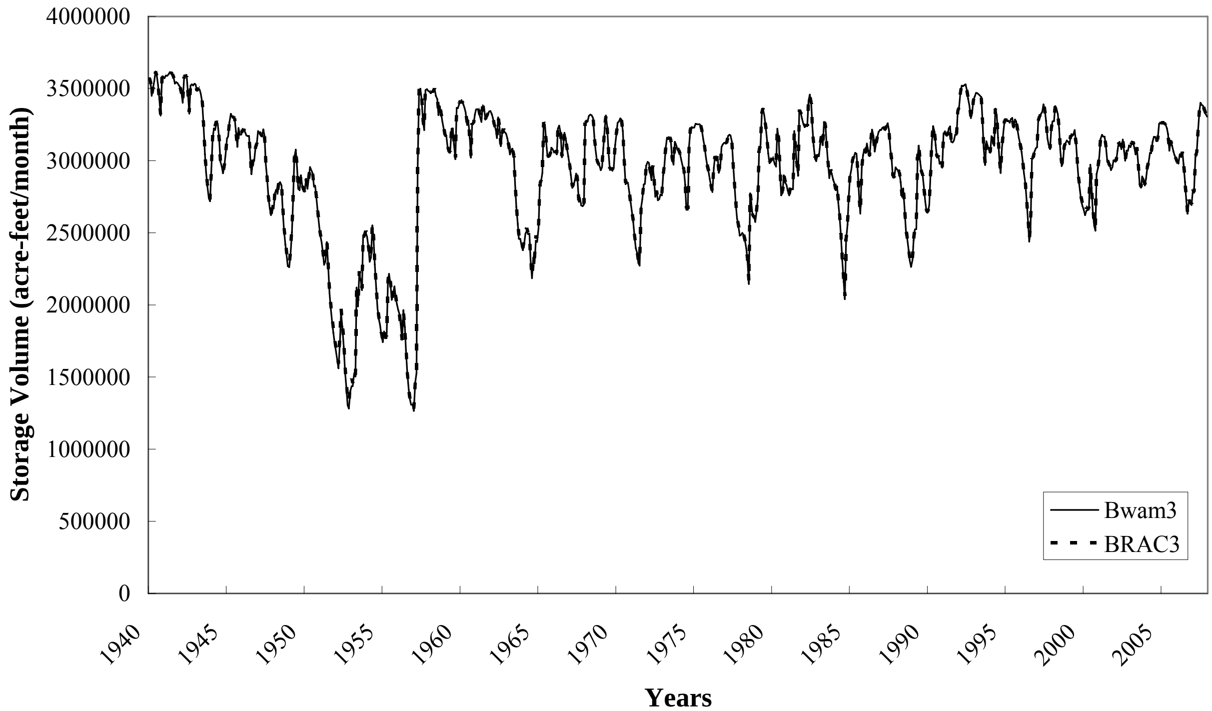

Figure 9.58 1940-2007 Bwam3 and BRAC3 Total Storage Volume of 15 Reservoirs

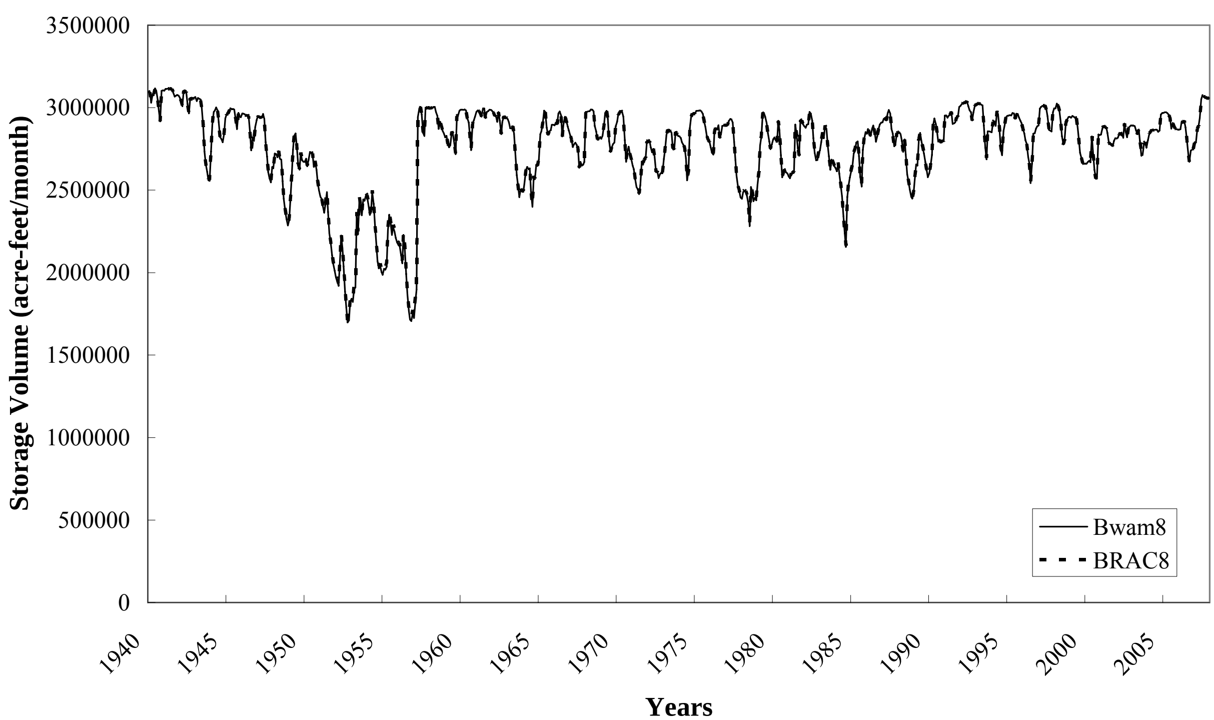

Figure 9.59 1940-2007 Bwam8 and BRAC8 Total Storage Volume of 14 Reservoirs

Firm Yield Analyses

Computation of firm yields represents one of a variety of types of applications of condensed datasets. Firm yield analysis strategies with the condensed BRAC datasets and complete WAM System Bwam datasets are presented for comparison in this final section of Chapter 9.

Alternative Versions of Firm Yield Estimates

Firm yield is a computed index of water supply capabilities. The term *firm yield* is defined as the maximum annual diversion rate that can be supplied continuously during a simulation for a specified hydrologic period-of-analysis based upon all of the premises and assumptions reflected in the simulation model. The firm yield is the maximum value of a hypothetical annual demand target that has volume and period reliabilities as defined in WRAP of 100.0 percent. The *WRAP-SIM* firm yield *FY* record feature facilitates the estimation of firm yields by automating the iterative *SIM* simulations on which firm yield computations are based.

Firm yields shown in Tables 9.19 through 9.30 are computed with *SIM* based upon modified versions of the BRAC3, BRAC8, and Bwam3 input datasets and alternative strategies defining basic modeling premises. The following two alternative strategies for defining and computing firm yields are applied.

1. The firm yield is determined for a single diversion that replaces certain existing water right permit diversions. This approach is limited to the condensed BRAC datasets.
2. The firm yield is determined for an additional new diversion without removing or impacting any of the existing water right permit diversions. This approach is applied with both full WAM Bwam and condensed BRAC datasets.

These two alternative strategies for defining firm yields are each applied to both individual reservoirs and two multiple-reservoir system scenarios. An individual reservoir firm yield represents a diversion at a reservoir supplied by that single reservoir. A multiple-reservoir system firm yield represents a diversion at a site that is supplied by releases from two or more reservoirs located upstream. Systems with four and nine reservoirs are adopted for purposes of the firm yield study. Multiple-reservoir system firm yields are estimated with and without consideration of unregulated flows from spills and inflows entering the river between the dams and the diversion site.

Negative Incremental Stream Flow Options

WRAP-SIM options for dealing with negative incremental flow options are described in detail in Chapter 3 of the *WRAP Reference Manual*. Options are selected by the switch NEGINC on the *JD* record. Naturalized flows or otherwise adjusted stream flows entered on inflow *IN* records in a FLO file generally increase in a downstream direction. Negative incremental refers to a situation in which the flow in a month is less at a particular control point than at one or more (multiple tributaries) control points located upstream. The amount of water available to each water right in a *SIM* simulation depends upon stream flows at the control point of the water right and at all downstream control points and may be affected by choice of negative incremental flow option. Choice of negative incremental flow option is a significant issue in applying either the original datasets from the TCEQ WAM System or condensed datasets.

Inflows in the FLO file of a condensed dataset are defined differently than the naturalized stream flows in a WAM FLO file. Thus, the negative incremental flow options have a different physical meaning and modeling relevance for condensed datasets. The occurrence of negative incremental flows may be caused either partially or completely by the secondary water rights reflected in the FLO file of a condensed dataset. Also, reducing the over 3,000 closely-spaced control points in the Brazos WAM to the 48 control points in the condensed dataset tends to decrease the number and magnitude of negative incremental flows.

Alternative negative incremental flow options 1 and 4 are applied for the firm yield simulations for strategy 1 described on the preceding page with the condensed BRAC3 and BRAC8 datasets. Option 1 is considered most appropriate. Option 4 is also applied for comparison.

- With negative incremental flow option 1, the effects of secondary water rights on unappropriated stream flows at downstream control points may affect the amount of water available to a primary water right at a particular control point.
- With negative incremental option 4, in applying firm yield strategy 1, the effects of secondary water rights on unappropriated stream flows at downstream control points do not affect the amount of water available to a primary water right.

Alternative negative incremental flow options 4 and 5 are applied for the firm yield simulations performed with the Bwam3 dataset. Option 5 is activated in the full dataset from the TCEQ WAM System. Option 4 is also applied for comparison.

Firm Yield Analysis Strategy 1 − Individual Reservoir Firm Yields for Hypothetical Diversions that Replace the Primary System Water Right Permit Diversions

The BRAC3 and BRAC8 individual reservoir firm yields presented in Tables 9.19 through 9.22 are computed with *SIM* using the *FY* record feature. The firm yields in Tables 9.19 and 9.20 are based on negative incremental flow option 1. The firm yields in Tables 9.21 and 9.22 are based on negative incremental flow option 4. The FLO and EVA files in the BRAC3 and BRAC8 datasets are used without modification. The DAT files are modified as follows.

- Each reservoir is modeled individually with a single diversion and storage refilling water right at that reservoir. The municipal monthly water use distribution factors and reservoir storage capacity in the BRAC DAT files are adopted. The reservoir storage content is assumed to be full to capacity at the beginning of the simulation period. The firm yield as an annual diversion in acre-feet/year is computed by the iterative *SIM* routine activated by the *FY* record.

- All other water rights are removed when the firm yield for a particular reservoir is computed with the following exception. For reservoirs located in series, upstream reservoirs are included in the model with a diversion set at their firm yield in order to reflect their impacts on inflows to downstream reservoirs. Other water rights or removal thereof can affect firm yields.

Proctor Reservoir is located upstream of Belton Reservoir. Thus, the firm yield for Proctor Reservoir is computed first. The firm yield for Belton Reservoir is computed with Proctor Reservoir included in the model with a diversion set at its previously computed firm yield. Likewise, Georgetown Reservoir is located upstream of Granger Reservoir, necessitating the same sequencing strategy. Hubbard Creek, Possum Kingdom, Granbury, and Whitney Reservoirs are located in series. The firm yield for Possum Kingdom Reservoir is computed with Hubbard Creek Reservoir included in the model with a diversion equal to its firm yield. Likewise, the firm yield for Granbury Reservoir reflects the impacts of Hubbard Creek and Possum Kingdom Reservoirs on inflows to Granbury Reservoir. Whitney has three upstream reservoirs which affect its inflows.

Whitney and Waco Reservoirs are divided into component reservoirs in the Brazos WAM as shown in Table 3.5 of Chapter 3. The evaporation allocation *EA* record feature is activated. Whitney is modeled as three component reservoirs. Waco is modeled as four component reservoirs. For purposes of the first firm yield modeling strategy with results presented in Tables 9.19, 9.20, and 9.21, the *EA* records are removed from the BRAC3 and BRAC8 DAT files and Whitney and Waco Reservoirs are modeled without using the component reservoir option.

Lake Whitney has a conservation pool capacity of 636,100 acre-feet in the Bwam3 and BRAC3 datasets and 561,074 acre-feet in the Bwam8 and BRAC8 datasets. The conservation pool is actually used for water supply, hydroelectric power, and recreation. However, water supply diversions from only 50,000 acre-feet of the storage capacity of Lake Whitney is actually authorized by water right permit. Hydroelectric power is generated without a water right permit. Alternative firm yields for Lake Whitney are presented in Tables 9.19 and 9.20 based on using only the top 50,000 acre-feet of the conservation pool and alternatively hypothetically assuming the entire conservation pool is used for water supply. The firm yield for the 50,000 acre-feet storage capacity is modeled by setting an inactive pool of 586,100 (BRAC3) and 511,074 (BRAC8) acre-feet.

With the exception of 50,000 acre-feet permitted storage at Lake Whitney, the firm yields are computed for the entire conservation pool storage capacity without considering that a portion of the conservation pool may be inactive. Lakes Possum Kingdom and Whitney actually have significant inactive storage pools set by hydroelectric power facilities. Lake Granbury has an inactive pool capacity set by the invert elevation of lakeside water supply pumping facilities. The firm yields shown for Lakes Possum Kingdom and Granbury are significantly reduced from the amounts shown in the tables if inactive pools are designated in the datasets.

Negative incremental flow option 1 was selected by the *JD* record parameter NEGINC for the *SIM* simulations resulting in the firm yields presented in Tables 9.19 and 9.20. With option 1, the effects of secondary water rights on flows at downstream control points are reflected in the firm yield computations. The firm yields presented in Tables 9.21 and 9.22 were computed in exactly the same manner as those in Tables 9.19 and 9.20 with the exception of replacing negative incremental flow option 1 with option 4. With option 4, flows at downstream control points have no affect on the firm yields for the initial strategy adopted here. The negative incremental flow options affect firm yields differently with the alternative firm yield modeling strategy presented later.

The firm yields in Tables 9.19 and 9.20 are based on the BRAC FLO files and thus are based essentially on the premise of protecting all secondary water rights. Only water available to the primary system after consideration of the quantities allocated to all secondary water rights within the water rights priority sequence are reflected in the FLO files. However, the water right permit priorities are not considered in allocating firm yields between the individual reservoirs of the BRAC primary system. An approximation in capturing the effects of secondary water rights described in the next paragraph is inherent in this approach in which relative priorities between the primary system reservoirs are not assigned.

Table 9.19
BRAC3 Individual Reservoir Firm Yields
(Negative Incremental Flow Option 1)

Reservoir	Storage Capacity (acre-feet)	Permitted Diversion (acre-feet)	Firm Yield 1940-1997 (ac-ft/yr)	Firm Yield 1900-2007 (ac-ft/yr)	Firm Yield 1940-2007 (ac-ft/yr)
Hubbard Creek	317,750	56,000	21,100	21,100	21,100
Possum Kingdom	724,739	230,750	347,500	332,100	347,500
Granbury	155,000	64,712	62,800	64,000	62,800
Whitney (permit)	50,000	18,336	34,400	30,300	34,400
Whitney (total)	636,100	–	173,200	134,000	173,200
Aquilla	52,400	13,896	14,800	14,800	14,800
Waco	206,562	79,877	89,900	85,500	89,900
Proctor	59,400	19,658	21,200	21,200	21,200
Belton	457,600	112,257	115,500	115,500	115,500
Stillhouse Hollow	235,700	67,768	64,400	64,400	64,400
Georgetown	37,100	13,610	11,400	11,400	11,400
Granger	65,500	19,840	18,800	18,800	18,800
Limestone	225,400	65,074	68,100	68,100	68,100
Somerville	160,110	48,000	43,800	43,800	43,800

Table 9.20
BRAC8 Individual Reservoir Firm Yields (Option 1)

Reservoir	Storage Capacity (acre-feet)	Firm Yield 1940-1997 (ac-ft/yr)	Firm Yield 1900-2007 (ac-ft/yr)	Firm Yield 1940-2007 (ac-ft/yr)
Hubbard Creek	317,750	35,000	35,000	35,000
Possum Kingdom	552,013	250,900	193,300	250,900
Granbury	132,821	57,900	57,900	57,900
Whitney (permit)	50,000	36,500	36,500	36,500
Whitney (total)	561,074	160,400	147,100	160,400
Aquilla	41,700	12,900	11,800	12,900
Waco	206,562	69,500	69,500	69,500
Proctor	54,702	20,800	20,800	20,800
Belton	432,978	125,600	125,600	125,600
Stillhouse Hollow	224,279	68,000	68,000	68,000
Georgetown	36,980	12,400	12,400	12,400
Granger	50,540	13,300	13,300	13,300
Limestone	208,017	69,300	69,300	69,300
Somerville	154,254	45,300	45,300	45,300

Table 9.21
BRAC3 Individual Reservoir Firm Yields
(Negative Incremental Flow Option 4)

Reservoir	Storage Capacity (acre-feet)	Permitted Diversion (acre-feet)	Firm Yield 1940-1997 (ac-ft/yr)	Firm Yield 1900-2007 (ac-ft/yr)	Firm Yield 1940-2007 (ac-ft/yr)
Hubbard Creek	317,750	56,000	21,100	21,100	21,100
Possum Kingdom	724,739	230,750	351,800	335,000	351,800
Granbury	155,000	64,712	84,600	65,300	84,600
Whitney (permit)	50,000	18,336	34,400	29,900	34,400
Whitney (total)	636,100	–	168,400	133,600	168,400
Aquilla	52,400	13,896	14,800	14,800	14,800
Waco	206,562	79,877	90,100	85,900	90,100
Proctor	59,400	19,658	21,200	21,200	21,200
Belton	457,600	112,257	115,500	115,500	115,500
Stillhouse Hollow	235,700	67,768	64,400	64,400	64,400
Georgetown	37,100	13,610	11,400	11,400	11,400
Granger	65,500	19,840	18,800	18,800	18,800
Limestone	225,400	65,074	68,100	68,100	68,100
Somerville	160,110	48,000	43,800	43,800	43,800

Table 9.22
BRAC8 Individual Reservoir Firm Yields (Option 4)

Reservoir	Storage Capacity (acre-feet)	Firm Yield 1940-1997 (ac-ft/yr)	Firm Yield 1900-2007 (ac-ft/yr)	Firm Yield 1940-2007 (ac-ft/yr)
Hubbard Creek	317,750	35,100	35,100	35,100
Possum Kingdom	552,013	265,100	201,200	265,100
Granbury	132,821	80,100	78,300	80,100
Whitney (permit)	50,000	38,100	38,100	38,100
Whitney (total)	561,074	162,100	147,700	162,100
Aquilla	41,700	12,900	11,900	12,900
Waco	206,562	72,400	72,400	72,400
Proctor	54,702	20,800	20,800	20,800
Belton	432,978	127,800	127,800	127,800
Stillhouse Hollow	224,279	70,800	70,800	70,800
Georgetown	36,980	12,700	12,700	12,700
Granger	50,540	14,300	14,300	14,300
Limestone	208,017	69,300	69,300	69,300
Somerville	154,254	45,400	45,400	45,400

The condensed dataset concept facilitates this general strategy of first allocating all secondary water rights appropriate quantities of water and then assuming flexibility in managing the FLO file water quantities that is available to the primary system defined by the condensed dataset. However, the individual reservoir firm yield analysis strategy adopted here is based on ignoring all reservoirs except upstream reservoirs when computing the firm yield for a particular reservoir. Flows at downstream control points are considered within *SIM* in determining water availability. These flows reflect secondary water rights but do not reflect the other omitted primary reservoirs. Thus, the individual reservoir firm yields presented here may be high for some of the reservoirs.

The authorized annual diversion amounts from the water right permits for each reservoir are tabulated in Tables 3.10 and 3.11 of Chapter 3 and are also included in Table 9.19 for comparison with the firm yields. The authorized diversion amounts for the 12 Brazos River Authority reservoirs total to 753,778 acre-feet/year.

The firm yield computations are repeated for the three alternative hydrologic simulation periods: 1940-1997, 1900-2007, and 1940-2007. Lakes Possum Kingdom, Granbury, Whitney Waco, and Aquilla have firm yields that are controlled by critical draw-downs occurring prior to 1940 in either one or both of the BRAC3 or BRAC8 models. These firm yield estimates controlled by critical reservoir drawdowns during the 1910's involve greater modeling uncertainties due to few stream gaging stations being in operation during this period. The critical drawdown periods for the other eight reservoirs occur during 1940-1997 in both the BRAC3 and BRAC8 models, meaning the firm yields are the same for the alternative 1900-2007, 1940-2007, and 1940-2007 hydrologic simulation periods. The 1998-2007 extension has no effect on firm yield estimates.

The Proctor Reservoir firm yield of 21,200 acre-feet/year shown in Table 9.19 is provided by a conservation pool storage capacity of 59,400 acre-feet and inflows from the BRAC3 FLO file. Net evaporation-precipitation rates are from the BRAC3 EVA file. The firm yield diversion is the only diversion in the DAT file, and Proctor is the only reservoir. The 21,200 ac-ft/year firm yield is a little larger than the 19,658 acre-feet/year diversion in the water right permit shown in Table 8.2 of Chapter 8. The storage plot of Figure 9.43 indicates that the critical drawdown period for the 19,658 acre-feet/year permitted diversion occurs during the 1980’s.

The Belton Reservoir firm yield of 115,500 acre-feet/year presented in Table 9.19 is provided by a conservation pool storage capacity of 457,600 acre-feet and inflows from the BRAC3 FLO file. Lake Proctor is located upstream of Lake Belton. Proctor is included in the DAT file with a storage capacity of 59,400 acre-feet, diversion of 21,200 acre-feet/year, and priority senior to the water right at Lake Belton in order to model the impacts of Proctor on inflows to Lake Belton.

Georgetown Reservoir has a firm yield of 11,400 acre-feet/year shown in Table 9.19 based on its BRAC3 storage capacity of 37,100 acre-feet and the inflows from the BRAC3 FLO file and net reservoir surface evaporation less precipitation rates from the BRAC3 EVA file. The Granger Reservoir BRAC3-based firm yield of 18,800 acre-feet/year provided by a storage capacity of 65,500 acre-feet also shown in Table 9.19 is computed with Lake Georgetown located upstream with its firm yield diversion of 11,400 acre-feet/year.

The firm yields in Tables 9.19 and 9.20 were computed with negative incremental flow option 1 activated in *WRAP-SIM*. The firm yields in Tables 9.21 and 9.22 were computed in exactly the same manner as those in Tables 9.19 and 9.20 with the exception of replacing negative incremental flow option 1 with option 4. With option 1, the effects of secondary water rights on flows at downstream control points are reflected in the firm yield computations along with the other causes of negative incrementals. With negative incremental option 4, flows at downstream control points have no affect on the firm yields in Tables 9.21 and 9.22. A comparison of Tables 9.21 and 9.22 with Tables 9.19 and 9.20 indicates that the firm yields are identical with either option 1 or 4 for some of the reservoirs but differ for other reservoirs. The effects of choice of negative incremental flow option are most pronounced at Possum Kingdom and Granbury Reservoirs and are also significant at Whitney and Waco Reservoirs for either the BRAC3 and/or BRAC8 models. As discussed later, the individual reservoir firm yields ignore the effects of other primary system reservoirs that may decrease available streamflow. Thus the individual firm yields may be high.

Multiple-Reservoir System Firm Yields for Hypothetical Diversions
that Replace the Primary System Water Right Permit Diversions

The multiple-reservoir system firm yields presented in Table 9.23 are modeled as either a diversion at control point LRCA58 which is the Cameron gage on the Little River or a diversion at control point BRRI70 which is the Richmond gage on the Brazos River. Operating rules for releases from multiple selected reservoirs located upstream are based on balancing the percentage storage depletion in the reservoirs. In a given month, the release is made at the reservoir that is most full in terms of storage contents as a percentage of capacity. The firm yield simulations are performed alternatively with negative incremental flow options 1 and 4 activated.

The diversion at control point LRCA59 located at the Cameron gage on the Little River is supplied by releases from the following four reservoirs:

Belton Reservoir
Stillhouse Hollow Reservoir
Georgetown Reservoir
Granger Reservoir

These four reservoirs are operated only for the firm yield diversion at control point LRCA58. There are no other diversions in the model at these four reservoirs. Proctor Reservoir affects the inflows to Belton Reservoir and the flows at the Cameron gage. Proctor is included in the DAT file with a diversion set at its individual reservoir firm yield shown in Tables 9.19 and 9.20 and its priority set at most senior. Priorities are set by upstream-to-downstream sequencing in the river system, not water right permits. Effects of the eight other reservoirs are not considered in this modeling strategy.

The diversion at control point BRRI70 on the Brazos River (Richmond gage) is supplied by releases from the following nine reservoirs:

Possum Kingdom, Granbury,
Aquilla, Limestone, Somerville,
Belton, Stillhouse Hollow, Georgetown, Granger

These nine reservoirs are operated in the model only for the firm yield diversion at control point BRRI70. The four other reservoirs listed in Tables 9.19 and 9.20 are operated as individual reservoirs with a lakeside diversion at each reservoir set at its firm yield. Priorities are set by the natural upstream-to-downstream sequencing in the river system, not water right permits.

Table 9.23
Multiple-Reservoir System Firm Yields

Water Right Type 1 or 2	BRAC3 Firm Yield 1940-1997 (ac-ft/yr)	BRAC3 Firm Yield 1900-2007 (ac-ft/yr)	BRAC3 Firm Yield 1940-2007 (ac-ft/yr)	BRAC8 Firm Yield 1940-1997 (ac-ft/yr)	BRAC8 Firm Yield 1900-2007 (ac-ft/yr)	BRAC8 Firm Yield 1940-2007 (ac-ft/yr)
Negative Incremental Flow Option 1						
Diversion at Control Point LRCA58 (Cameron Gage)						
Type 2	215,900	215,900	215,900	219,200	219,200	219,200
Type 3	206,100	206,100	206,100	204,600	204,600	204,600
Diversion at Control Point BRRI70 (Richmond Gage)						
Type 2	900,500	904,000	900,500	719,400	719,400	719,400
Type 3	708,700	707,200	708,700	581,000	550,000	581,000
Negative Incremental Flow Option 4						
Diversion at Control Point LRCA58 (Cameron Gage)						
Type 2	220,500	220,500	220,500	240,500	240,500	240,500
Type 3	203,800	203,800	203,800	219,000	219,000	219,000
Diversion at Control Point BRRI70 (Richmond Gage)						
Type 2	951,600	955,300	951,600	881,800	821,800	881,800
Type 3	719,900	720,200	719,900	670,000	586,100	670,000

The type 2 and type 3 water right modeling features in *WRAP-SIM* allow firm yields to be computed with and without consideration of *"excess"* flows representing unregulated surface and subsurface inflows entering the river downstream of the dams and spills from full conservation pools. In computing firm yields for diversions located alternatively at the Cameron and Richmond gages, the diversion is modeled in *SIM* alternatively as either a type 2 or type 3 water right. Water right types are specified on *WR* records as described in the *WRAP Reference and Users Manuals*.

- A type 2 water right diverts stream flow without making reservoir releases if stream flow is available. Reservoir releases are made as necessary to supplement available stream flow.

- A type 3 water right supplies the diversion only from releases from the system reservoirs. Unregulated stream flow is not diverted.

WRAP-SIM type 2 and 3 water rights do not refill reservoir storage in the model. Thus, additional type 1 water rights to refill storage in the system reservoirs are included in the DAT file with priorities placing storage refilling both before and after the multiple-reservoir system diversion right in the water right priority sequence.

Comparison of Firm Yields

The firm yields from Tables 9.19, 9.20, and 9.23 are copied into Tables 9.24 and 9.25 for comparison. BRAC3 and BRAC8 firm yields are compared. Multiple-reservoir system firm yields with and without use of excess flows (type 2 versus type 3 rights) are compared with the summation of individual reservoir firm yields. The firms yields compiled in Tables 9.24 and 9.25 were all computed based on the BRAC3 and BRAC8 condensed datasets. The TCEQ WAM System Bwam3 and Bwam8 datasets are not amenable to the modeling strategy adopted in computing the firm yields of Tables 9.24 and 9.25. However, an alternative firm yield modeling strategy is presented in the next section which is amenable to use of either the full WAM or condensed datasets.

Table 9.24
Firm Yield Summary for Five BRA Reservoirs in Little River Subbasin
Based on BRAC Datasets with 1940-2007 Period-of-Analysis and
Negative Incremental Inflow Option 1

	BRAC3	BRAC8
	Firm Yield	
	(ac-ft/yr)	(ac-ft/yr)
Individual Reservoirs		
Proctor	21,200	20,800
Belton	115,500	125,600
Stillhouse Hollow	64,400	68,000
Georgetown	11,400	12,400
Granger	18,800	13,300
Total − 5 Reservoirs	231,300	240,100
Total − 4 System Reservoirs with the exclusion of Proctor Reservoir	210,100	219,300
Multiple-Reservoir System		
Type 2 diversion at LRCA58 (4 reservoirs)	215,900	219,200
Proctor Reservoir	21,200	20,800
Total	237,100	240,000
Type 3 diversion at LRCA58 (4 reservoirs)	206,100	204,600
Proctor Reservoir	21,200	20,800
Total	227,300	225,400

In some cases BRAC8 firm yields are larger than BRAC3 firm yields, and in other cases the BRAC3 firm yields are larger. The BRAC8 firm yields differ from the BRAC3 firm yields due to differences in stream inflows and reservoir storage capacity. The BRAC3 and BRAC8 datasets are derived from the authorized use scenario (run 3) and current use scenario (run 8) Brazos WAM System datasets as defined in Chapters 1, 3, and 8. Whereas the authorized use scenario reservoir storage capacities are generally the capacities cited in the water right permits, the current use scenario reservoir storage capacities are based on estimated year 2000 conditions of sedimentation.

The BRAC3 FLO file is based on the premise that secondary water rights receive the full amount of water authorized in their permits subject to stream flow availability. The BRAC8 FLO file reflects current water use by secondary water rights, as defined in Chapter 1, which is generally significantly less than authorized use.

Table 9.25
Firm Yield Summary for 12 Brazos River Authority Reservoirs
Based on BRAC Datasets with 1940-2007 Period-of-Analysis
and Negative Incremental Inflow Option 1

	BRAC3	BRAC8
	Firm Yield	
	(ac-ft/yr)	(ac-ft/yr)
Individual Reservoirs		
Five reservoirs in Little River Subbasin	231,300	240,100
Possum Kingdom	347,500	250,900
Granbury	62,800	57,900
Whitney (50,000 acre-feet)	34,400	36,500
Aquilla	14,800	12,900
Waco	89,900	69,500
Limestone	68,100	69,300
Somerville	43,800	45,300
Total − 12 BRA Reservoirs	892,600	782,400
Total − 9 System Reservoirs	747,100	655,600
Multiple-Reservoir System		
Type 2 diversion at BRRI70 (9 reservoirs)	900,500	719,400
Proctor Reservoir	21,200	20,800
Waco Reservoir	89,900	69,500
Whitney Reservoir	34,400	36,500
Total	1,046,000	846,200
Type 3 diversion at BRRI70 (9 reservoirs)	708,700	581,000
Proctor Reservoir	21,200	20,800
Waco Reservoir	89,900	69,500
Whitney Reservoir	34,400	36,500
Total	854,200	707,800

Multiple-reservoir system firm yields are compared with individual reservoir firm yields in Tables 9.24 and 9.25. The following two considerations increase system firm yields relative to the summation of individual reservoir firm yields. Assuming the critical draw-down period differs at least somewhat between the component reservoirs, the balancing of storage depletions between reservoirs through system operations results in multiple-reservoir system firm yields (water right types 2 and 3) being greater than the summation of individual reservoir firm yields. The reservoirs are sharing the risk of being emptied and thus unable to supply the diversion target. Having access to the excess flows entering the river below the dams or spilling from full conservation pools (water right type 2) also increases the firm yield be reducing the amount of water released from storage.

WRAP-SIM does not apply channel losses to the reservoir releases for type 2 and type 3 water right diversions. Thus, the firm yield estimates must reflect the amount of losses of released water between the dam and diversion site as well as the amount diverted.

Table 9.24 provides a comparison of individual reservoir and multiple-reservoir system firm yields for the reservoirs located in the Little River Subbasin. The BRAC3 firm yields for Belton, Stillhouse Hollow, Georgetown, and Granger Reservoirs are compared as follows.

Summation of individual reservoir firm yields for 4 reservoirs	=	210,100 ac-ft/yr
Four-reservoir system firm yield for type 2 diversion	=	215,900 ac-ft/yr (102.8%)
Four-reservoir system firm yield for type 3 diversion	=	206,100 ac-ft/yr (98.1%)

The four-reservoir system firm yield for the type 2 and type 3 water right diversions are 102.8 and 98.1 percent of the summation of the four individual reservoir firm yields.

Table 9.25 provides a comparison of individual reservoir and multiple-reservoir system firm yields for nine BRA reservoirs. The BRAC3 firm yields for Belton, Stillhouse Hollow, Georgetown, Granger, Possum Kingdom, Granbury, Aquilla, Limestone, and Somerville Reservoirs are compared as follows.

Summation of individual reservoir firm yields for 9 reservoirs	=	747,100 ac-ft/yr
Nine-reservoir system firm yield for type 2 diversion	=	900,500 ac-ft/yr (120.5%)
Nine-reservoir system firm yield for type 3 diversion	=	708,700 ac-ft/yr (94.9%)

The nine-reservoir system firm yield for the type 2 and type 3 water right diversions are 120.5 and 94.9 percent of the summation of the four individual reservoir firm yields.

Multiple-reservoir system firm yields should be greater than the summation of individual reservoir firm yields. However, the individual reservoir firm yields are high because the effects of most of the 12 other reservoirs on streamflow availability at downstream control points were ignored in the computation of the firm yield for each individual reservoir. The effects of only those reservoirs located upstream were considered. The inflows at all control points on *IN* records in the FLO file reflect removal of water appropriated by secondary water rights. Thus, all 48 control points and all primary water rights should be included in a simulation and negative incremental flow option 1 should be activated in order to assure proper consideration of all secondary rights. Strictly speaking, individual reservoir firm yields can not be defined independently of other reservoirs.

The condensed datasets facilitate the firm yield analysis approach addressed by Tables 9.19 through 9.25 and the preceding discussion. The basic concept is to allocate appropriate amounts of water to the secondary water rights as reflected in the FLO file in the condensed dataset. The FLO file represents the water available to the primary system. However, the priorities from the water right permits (and WAM datasets) are not used in allocating water between the components of the primary system in the firm yield analyses. The alternative firm yield analysis strategy presented next preserves all existing water rights and the complete water right priority system. The computations can be performed with either the full WAM or condensed datasets.

Firm Yield Analysis Strategy 2 − Firm Yields for an
Additional Diversion Based on Bwam3 and BRAC3 Datasets

Firm yields defined in a somewhat different manner are computed based on the original TCEQ WAM System Bwam3 dataset which has a hydrologic period-of-analysis of 1940-1997. The firm yield computations are repeated in the same manner with the BRAC3 dataset for comparison. The Bwam3 dataset is adopted without modification except for the addition of a firm yield diversion and application of the dual simulation option to prevent existing water rights from increasing their streamflow depletions. Likewise, the BRAC3 dataset is adopted without modification except for the addition of a firm yield diversion and application of the dual simulation option to prevent existing water rights from increasing their streamflow depletions. The resulting individual reservoir firm yields computed with the Bwam3 and BRAC3 datasets are tabulated in Tables 9.26, 9.27, 9.28, and 9.29, respectively. Multiple-reservoir system firm yields are presented in Table 9.30. The firm yield simulations are repeated with alternative negative incremental flow options for comparison. The firm yields in Tables 9.26−9.30 are based on a 1940-1997 hydrologic period-of-analysis.

The firm yield diversion for the individual reservoir firm yields tabulated in Tables 9.26, 9.27, 9.28, and 9.29 is a new diversion added to the reservoir without modifying any existing water rights including the existing water rights at that reservoir. The firm yield for a new additional diversion is non-zero only at those reservoirs at which the existing diversions are supplied with volume and period reliabilities of 100.00 percent. The same firm yield simulations using the *SIM FY* record feature are repeated with the Bwam3 and BRAC3 datasets, with alternative negative incremental flow options. The annual diversion targets included in the tables include: (1) summation of all existing diversion rights at the reservoir, (2) the new firm yield diversion right, and (3) total of existing and new diversion rights. The hydrologic period-of-analysis is 1940-1997.

The firm yield for a new diversion right added at a reservoir is zero unless all of the existing diversion rights with more senior priorities at that same reservoir have volume and period reliabilities of 100.00 percent. Thus, this firm yield modeling strategy is relevant only if the storage capacity of the reservoir is not already being fully utilized for existing water supply diversions.

The dual simulation option described in the *WRAP Reference and Users Manuals* is applied to address the following issue. The new firm yield diversion is given a priority that is junior to all other water rights. Thus, the new diversion in a given month does not affect other water rights in that same month. However, the new diversion does result in the storage contents of the reservoir being drawn down. The next month begins with less water in storage. Refilling of storage by old more senior rights at the reservoir affects other water rights located elsewhere in the river basin. The dual simulation option is activated to prevent this impact on other water rights resulting from the reservoir storage draw-downs resulting from the new firm yield diversion.

The dual simulation option consists of the simulation being automatically performed twice each month. The first simulation is used for the sole purpose of recording streamflow depletions for selected water rights. The first-simulation streamflow depletions serve as maximum limits constraining streamflow depletions by these water rights during the second simulation. The WRAP term *streamflow depletion* is defined as the volume of water appropriated from stream flow in a given month by a water right to supply diversion requirements and refill reservoir storage while accounting for net evaporation-precipitation losses at the reservoir.

Table 9.26
Bwam3 Individual Reservoir Firm Yields (Negative Incremental Flow Option 5)

Reservoir	Storage Capacity (acre-feet)	Diversions: Existing Rights (ac-ft/yr)	New Firm Yield (ac-ft/yr)	Total (ac-ft/yr)
Hubbard Creek	317,750	56,000	0	56,000
Possum Kingdom	724,739	230,750	149,200	379,950
Granbury	155,000	64,712	26,200	90,912
Whitney	636,100		N/A	
Whitney	50,000	18,336	14,900	33,236
Aquilla	52,400	13,896	700	14,596
Waco	206,562	79,877	7500	87,377
Proctor	59,400	19,658	600	20,258
Belton	457,600	112,257	3200	115,457
Stillhouse Hollow	235,700	67,768	0	67,768
Georgetown	37,100	13,610	0	13,610
Granger	65,500	19,840	0	19,840
Limestone	225,400	65,074	4600	69,674
Somerville	160,110	48,000	0	48,000

Table 9.27
BRAC3 Individual Reservoir Firm Yields (Negative Incremental Flow Option 1)

Reservoir	Storage Capacity (acre-feet)	Diversions: Existing Rights (ac-ft/yr)	New Firm Yield (ac-ft/yr)	Total (ac-ft/yr)
Hubbard Creek	317,750	56,000	0	56,000
Possum Kingdom	724,739	230,750	114,100	344,850
Granbury	155,000	64,712	25,300	90,012
Whitney	636,100	18,336	163,600	181,936
Whitney	50,000	18,336	16,000	34,336
Aquilla	52,400	13,896	900	14,796
Waco	206,562	79,877	22,500	102,377
Proctor	59,400	19,658	600	20,258
Belton	457,600	112,257	3200	115,457
Stillhouse Hollow	235,700	67,768	0	67,768
Georgetown	37,100	13,610	0	13,610
Granger	65,500	19,840	0	19,840
Limestone	225,400	65,074	4100	69,174
Somerville	160,110	48,000	0	48,000

Table 9.28
Bwam3 Individual Reservoir Firm Yields (Negative Incremental Flow Option 4)

Reservoir	Storage Capacity (acre-feet)	Diversions Existing Rights (ac-ft/yr)	New Firm Yield (ac-ft/yr)	Total (ac-ft/yr)
Hubbard Creek	317,750	56,000	0	56,000
Possum Kingdom	724,739	230,750	80,700	311,450
Granbury	155,000	64,712	14,500	79,212
Whitney	636,100		N/A	
Whitney	50,000	18,336	9600	27,936
Aquilla	52,400	13,896	700	14,596
Waco	206,562	79,877	11,400	91,277
Proctor	59,400	19,658	1100	20,758
Belton	457,600	112,257	4000	116,257
Stillhouse Hollow	235,700	67,768	0	67,768
Georgetown	37,100	13,610	0	13,610
Granger	65,500	19,840	0	19,840
Limestone	225,400	65,074	5300	70,374
Somerville	160,110	48,000	0	48,000

Table 9.29
BRAC3 Individual Reservoir Firm Yields (Negative Incremental Flow Option 4)

Reservoir	Storage Capacity (acre-feet)	Diversions Existing Rights (ac-ft/yr)	New Firm Yield (ac-ft/yr)	Total (ac-ft/yr)
Hubbard Creek	317,750	56,000	0	56,000
Possum Kingdom	724,739	230,750	122,300	353,050
Granbury	155,000	64,712	23,500	88,212
Whitney	636,100	18,336	162,400	180,736
Whitney	50,000	18,336	16,000	34,336
Aquilla	52,400	13,896	900	14,796
Waco	206,562	79,877	22,500	102,377
Proctor	59,400	19,658	600	20,258
Belton	457,600	112,257	3200	115,457
Stillhouse Hollow	235,700	67,768	0	67,768
Georgetown	37,100	13,610	0	13,610
Granger	65,500	19,840	0	19,840
Limestone	225,400	65,074	4100	69,174
Somerville	160,110	48,000	0	48,000

Table 9.30
Multiple-Reservoir System Firm Yields

Diversion Location	Firm Yield (acre-feet/year)			
	Bwam3 (Option 5)		BRAC3 (Option 1)	
	Type 2	Type 3	Type 2	Type 3
Negative Incremental Flow Option 5 for Bwam3 and Option 1 for BRAC3				
Cameron gage (control point LRCA58)	5,700	4,100	5,300	4,100
Richmond gage (control point BRRI70)	164,300	108,800	164,400	107,400
Negative Incremental Flow Option 4 for Both Bwam3 and BRAC3				
Cameron gage (control point LRCA58)	18,100	15,500	5,300	4,100
Richmond gage (control point BRRI70)	164,200	92,800	167,800	92,700

The individual reservoir firm yield computations are repeated in the same manner with the Bwam3 and BRAC3 datasets. The Bwam3 individual reservoir firm yields are tabulated in Tables 9.26 and 9.28, and the BRAC3 firm yields are tabulated in Tables 9.27 and 9.29.

Multiple-reservoir system firm yields are presented in Table 9.30 for diversions at the Cameron and Richmond gages. The multiple-reservoir systems include the same reservoirs as those reflected Table 9.23. The diversion at control point LRCA58 on the Little River (Cameron gage) is supplied by releases from the following four reservoirs: Belton, Stillhouse Hollow, Georgetown, and Granger. The diversion at control point BRRI70 on the Brazos River (Richmond gage) is supplied by releases from the following nine reservoirs: Possum Kingdom, Granbury, Aquilla, Limestone, Somerville, Belton, Stillhouse Hollow, Georgetown, and Granger. However, unlike the previous analyses summarized by Table 9.23, in the analyses of Table 9.30, all existing water rights remain in place without modification as the new firm yield diversion is added at either control point LRCA58 or control point BRRI70.

In computing the firm yield for the diversion located alternatively at either the Cameron or Richmond gage, the diversion is modeled in *SIM* alternatively as either a type 2 or type 3 water right. If stream flow is available at the diversion site, a type 2 water right diverts the stream flow without making unnecessary releases from the upstream reservoir. Reservoir releases are made only as necessary to supplement available stream flow. A type 3 water right supplies the diversion only from releases from the system reservoirs. Unregulated stream flow is not used even if available.

The firm yields for incremental new diversions tabulated in Tables 9.26, 9.27, 9.28, 9.29, and 9.30 are based on simulations using the authorized use scenario Bwam3 and BRAC3 datasets. The firm yields are for additional new diversion and storage refilling rights that are junior to all of the existing water rights that are already supplied by the fixed existing reservoir storage capacities. As indicated by Tables 9.3 and 9.4, the existing diversions at several of the reservoirs have reliabilities of less than 100 percent. The requirements to supply existing diversion rights at Hubbard Creek, Stillhouse Hollow, Georgetown, Granger, and Somerville Reservoirs result in a firm yield of zero for an additional new diversion at these reservoirs. These reservoirs are already fully committed from a firm yield perspective. The last column of Tables 9.26−9.29 is the summation of the previous two columns, and does not necessarily represent a firm yield since existing diversions may have reliabilities of less than 100 percent.

The choice of negative incremental flow option is shown to significantly affect the firm yields. The Bwam3 simulations of Tables 9.26 and 9.28 were performed with negative incremental flow options 5 and 4, respectively. The BRAC3 simulations of Tables 9.27 and 9.29 were performed with negative incremental flow options 1 and 4, respectively. Multiple-reservoir system firm yields are tabulated in Table 9.30 for alternative negative incremental flow options.

Firm Yield Analysis Summary

Firm yield estimates vary significantly with variations in the basic premises reflected in the simulation model input dataset. Key factors affecting firm yields include but are not limited to:

- schemes for modeling interactions between multiple reservoirs and multiple water users
- reservoir storage considerations including capacity reductions due to sedimentation, storage allocations and system operating rules, and beginning-of-simulation storage contents
- hydrologic period-of-analysis and other aspects of river basin hydrology

The condensed dataset concept of separation of secondary water rights reflected in the FLO file from the primary system water rights included in the DAT file is useful in firm yield analyses. However, the concept of an individual reservoir firm yield is flawed even with a condensed dataset because the firm yield of each reservoir is not really independent of the other reservoirs in the primary system. The firm yield for a particular reservoir is affected by storage and diversions at other reservoirs which may be located either on different tributaries or upstream or downstream on the same stream. The firm yield for a particular diversion is also affected by other diversions and storage rights at the same reservoir. Thus, though not pursued in the strategy 1 analyses reported here, all primary reservoirs along with some devised scheme for assigning diversions and priorities should be included in the BRAC dataset for either individual reservoir or system firm yield analyses.

Negative incremental flows and *SIM* options for dealing with them are a significant issue needing further research. Negative incremental flows are an important consideration in performing firm yield analyses with either a complete WAM dataset or a condensed dataset but important from different perspectives. Negative incremental inflows in a condensed dataset reflect the effects of secondary water rights as well as the hydrology related factors associated with negative incremental flows in a complete WAM dataset. Negative incremental flows are also significantly different in a BRAC dataset with inflows at only 48 control points compared to a Bwam dataset with flows at over three thousand control points. Whereas option 4 is recommended for full WAM datasets, option 1 is perhaps the most appropriate negative incremental flow option for a condensed dataset.

Critical drawdowns occur during the 1950's drought for the majority of the reservoirs in the firm yield analyses. However, in some cases, critical drawdowns occur during the 1970'-1980's or 1910's-1920's. Firm yield estimates controlled by critical reservoir drawdowns during the 1910's-1920's involve greater modeling uncertainties due to few stream gaging stations being in operation during this period. The 1998-2007 extension of the simulation period has no effect on firm yields.

CHAPTER 10
SUMMARY AND CONCLUSIONS

The Texas Water Availability Modeling (WAM) System consists of the generalized Water Rights Analysis Package (WRAP) river/reservoir system simulation model and WRAP input datasets for all of the river basins of the state. River basin hydrology is represented in the WAM System by WRAP simulation input files of naturalized stream flow volumes and net reservoir surface evaporation less precipitation depths. This report documents a research investigation of methodologies for modifying the WAM System input datasets for the purposes listed below and the impacts of the modifications.

1. Extension of the hydrology forward to reflect the accumulation of observed data since completion of the WAM original datasets.
2. Extension of the hydrology backward in time to further lengthen the hydrologic period-of-analysis.
3. Reduction of the dataset in size to create a simpler model focused on a particular water management system with the effects of all other water management and use in the river basin being reflected in the stream flow inflows.

Methodologies are outlined in Chapters 1 and 2 from the perspective of their generic application to the WAM System datasets of any of the Texas river basins. The remainder of the report focuses on the WAM System dataset for the Brazos River Basin and San Jacinto-Brazos Coastal Basin, which is referred to as the Brazos WAM. The authorized use scenario (Bwam3) and current use scenario (Bwam8) datasets, last updated by the TCEQ in August 2007, are used in the study. The three tasks listed above were performed for the Brazos WAM as follows.

1. The original Brazos WAM hydrologic period-of-analysis of 1940-1997 was updated to span 1940-2007. The tasks of converting gaged flows to naturalized flows and distributing flows from gaged to ungaged control points are both important in the hydrology update. The report includes analyses of the impacts of the hydrology update on water availability modeling results.

2. The period-of-analysis was also extended backward to include 1900-1939 using data developed in a research study performed at Texas A&M University in 1986-1988. Gaged flows during 1900-1939 were adopted as naturalized flows with essentially no modification. The 1900-1939 extension deals primarily with using limited data at a few gaging stations to synthesize flows at numerous ungaged control points. The flows synthesized at numerous remote control points are not accurate enough to support various conventional decision-support activities. However, the uniquely long 108-years 1900-2007 *WRAP* simulation model provides meaningful insights into the impacts on water availability studies of incorporating 1900-1939 hydrology in the analyses.

3. The Brazos WAM datasets have 3,830 (Bwam3) and 3,834 (Bwam8) control points and 670 (Bwam3) and 711 (Bwam8) reservoirs. The Brazos River Authority Condensed (BRAC) datasets have 48 control points (BRAC3 and BRAC8) and 15 (BRAC3) and 14 (BRAC8) reservoirs. The effects of all of the other water rights are incorporated in the river inflows in the FLO input files. The purpose of the much simpler-to-apply model provided by the BRAC datasets is to facilitate studies of operations of the Brazos River Authority system.

Methodology for Updating the Hydrologic Period-of-Analysis

River basin hydrology is represented in the Texas WAM System by datasets of monthly naturalized flow volumes and reservoir evaporation-precipitation depths that were developed during 1997-2001 based on observed data collected during the preceding several decades. Additional hydrologic measurements have continued to accumulate since compilation of the original WAM System datasets. Updating the WAM System datasets by lengthening the hydrologic period-of-analysis consists of extending both the evaporation-precipitation data in the EVA file and naturalized flow data in the FLO file. However, the proposed procedure focuses on extending the sequences of monthly naturalized flow volumes. Extending the monthly evaporation-precipitation depths is treated as a component task within the procedure of extending the naturalized flows.

Developing the original naturalized flow data during the 1997-2001 implementation of the WAM System required considerable resources and expense. The procedure investigated in this report is designed to significantly reduce the effort required to extend the naturalized flow sequences by using the information now available in the WAM System input DAT files. A DAT file representing actual water resources development, allocation, management, and use during the period-of-extension is used to convert observed gaged stream flows to naturalized flows. The actual use DAT file is developed by modifying a WAM System current use scenario (run 3) DAT file.

The methodology consists of iteratively applying the WRAP programs *SIM* and *HYD* in combination. New features have recently been added to *SIM* and *HYD* to facilitate the flow extension procedure. *HYD* adjusts naturalized flows based on *SIM* simulation results. Iterative repetitions of the procedure are required since naturalized flows are required as input to the *SIM* simulation required to develop *HYD* adjustments to observed flows to compute naturalized flows. The iterations begin and end with naturalized flows. The objective is to develop a FLO file of naturalized flows that when input to *SIM* along with the actual use DAT file and updated EVA and revised DIS files produce simulated regulated flows that closely reproduce actual observed flows.

Consideration of the strengths and weaknesses of the proposed methodology for extending naturalized flow sequences focuses largely on the following two perspectives.

1. The accuracy and efficiency of the iterative computational methodology in finding a set of naturalized flows that result in simulated regulated flows that very closely match observed flows.

2. The effort and resources required to develop the actual use DAT file and the accuracy of the actual use DAT file in representing actual water resources development, allocation, management, and use during the period of time of concern.

Other key considerations addressed in the following discussion include compilation of observed gaged stream flow data, synthesis of naturalized flows at ungaged control points, and compilation of net evaporation-precipitation rates.

Iterative *SIM/HYD* Computational Methodology

The computational methodology was found to work well. With the new features added, the August 2008 version of *HYD* allows efficient iterative adjustments to the naturalized flows. The updated Brazos WAM dataset results in *SIM* simulated regulated flows that very closely reproduce the observed 1998-2007 gaged flows at the 48 control points for which 1998-2007 gaged flows are available. Converging on a set of naturalized flows that result in regulated flows that match gaged flows does not appear to be a problem.

Although the requirement for iterative repetitions of the *SIM* simulation and *HYD* flow adjustments complicate the methodology somewhat, the iterations can be performed quickly and easily. Twenty iterations were performed for the Brazos WAM flow extension computations presented in this report. Performing 20 iterations requires relatively little more time than performing just one simulation. After the necessary datasets are completed and the model is operational, each additional repetition of the computational procedure requires only a few minutes.

Most of the adjustments to the naturalized flows occur in the first three iterations, but further refinements can be achieved by additional iterations. For the Brazos WAM, the naturalized flows were no longer changing by 20 iterations, and further iterations pass 20 served no purpose. The criterion for stopping the iterations is that regulated flows match gaged flows, in which case the naturalized flows will automatically no longer be changing.

Initial estimates for the naturalized flows are required for the iterative procedure. However, the final set of naturalized flows resulting from the computational procedure is not very sensitive to the initial set of naturalized flows. The 75% exceedance frequency approach adopted for the Brazos WAM study seems reasonable. Naturalized flows at the 48 gaged control points were initially set as the naturalized flow for each of the 12 months of the year that is equaled or exceeded in 75% of the 58 years for the original 1940-1997 naturalized flows.

The extent to which the initially estimated set of naturalized flows can affect the final results depends somewhat upon the extent to which reservoir storages and diversions are fixed by the flow adjustments. For the Brazos WAM, the *HYD* adjustments included storage shortages in meeting observed storage levels specified on *OS* records and diversion shortages associated with 22 reservoirs. If the *HYD* flow adjustments include *OS* record storage shortages for all reservoirs and shortages for all diversions, the final computed naturalized flows should be the same regardless of the initial estimate adopted for the naturalized flows. However, if the diversions and storage levels are not thus fixed, the initial naturalized flow estimates may have some impact on final results.

Actual Use DAT File Dataset

The regulated flows computed by *SIM* represent actual flows such as those measured by a gaging station to the extent that the *SIM* input DAT file represents actual water resources development, allocation, management, and use. The computational procedure will result in a set of naturalized flows that allow *SIM* simulated regulated flows to match gaged flows even if the actual use DAT file does not accurately represent actual water management/use conditions. However, the accuracy of the naturalized flows is dependent on the accuracy of the actual use DAT file, which depends on the extent to which data are available for modifying the current use DAT file to better model actual conditions during each of the 120 months of January 1998 through December 2007.

The flow extension procedure provides flexibility in improving the accuracy of the naturalized flows generated for the extension period by increasing the effort and resources devoted to the endeavor or vise versa reducing data compilation/manipulation efforts with a corresponding decrease in accuracy. The adjustments to the current use scenario DAT file made in developing the actual use scenario version of the DAT file can be developed at varying levels of detail. However, at some point, the potential incremental improvements in accuracy no longer justify the incremental increase in effort required. Also, some data are simply not available and must be approximated.

The actual use Bwam8A DAT file was developed by modifying the current use Bwam8 DAT file. Various modifications are described in Chapter 4. However, with the exception of these modifications, water resources development, management, and use during 1998-2007 are approximated by the information contained in the Bwam8 current use DAT file. Several key data compilation considerations are discussed as follows.

The observed storage *OS* record feature introduced with the August 2008 version of *SIM* significantly improves capabilities for accurately modeling actual water management and use. In addition to allowing the *SIM* simulation to reproduce actual observed conservation storage volumes, the observed storage levels include storage encroachments into flood control and surcharge pools, thus modeling multiple-purpose, multiple-reservoir system operations. In the Brazos WAM flow extension computations, the observed storage levels were specified on *OS* records for 22 reservoirs that represent 87.5 percent of the total conservation storage capacity and 100 percent of the flood control storage capacity of the 706 reservoirs in the Bwam8A dataset. The 22 reservoirs are the only reservoirs for which 1998-2007 storage volumes are available in the USGS National Water Information System and Texas Water Development Board online databases.

The naturalized flow adjustment methodology results in *OS* record storage levels being exactly reproduced at reservoirs located at or near gaged control points, but observed storages are only approximately reproduced in reservoirs at ungaged control points. Naturalized flows at 48 gaged control points were computed by adjusting gaged flows. The flows at all the other control points were computed based upon flow distribution techniques. The several largest of the 22 reservoirs are located close enough to gaged control points to exactly reproduce the observed storage levels. However, due to the flow distribution computations, the *OS* record storage levels are not reached in some months at the majority of the 22 reservoirs located at ungaged control points.

The target series *TS* record can be used to reproduce actual observed diversion volumes. The *TS* record feature was already available in *SIM* for reproducing water supply diversions and instream flow requirements. However, with the exception of diversions from Proctor Reservoir, *TS* records were not adopted due to difficulties in compiling actual water supply diversion data. *TS* records were used for Proctor Reservoir diversions along with use of reservoir releases to provide measured actual stream flows. Use of *TS* records to model actual observed diversions at more selected sites represents a next step that could possibly be taken to improve the accuracy of the Bwam8A dataset. However, effort would be required to compile the actual observed diversion data.

The Bwam8 diversion targets remain unaltered in the Bwam8A DAT file with the exception of Proctor Reservoir noted in the paragraph above and the Brazos River Authority system diversions noted in the next paragraph. Annual water supply diversion targets in the current use scenario (run 8) dataset for each individual water right are the maximum use in any year of the ten year period 1988-1997. Diversions and diversion shortages computed in the *SIM* simulation with the Bwam8A dataset result in a volume reliability of 86.6 percent for the total aggregate of all diversion targets.

The Brazos River Authority (BRA) meets commitments for diversions from the lower reach of the Brazos River by combining releases from multiple reservoirs with excess river flows. The BRA reservoirs are also operated for hydroelectric power generation and flood control. In the Bwam3 and Bwam8 datasets, all diversions are placed at individual reservoirs, and flood control and hydropower operations are not modeled. BRA multiple-reservoir, multiple-purpose operations are approximated in the actual use Bwam8A dataset as follows. Observed storages are specified for the BRA reservoirs on *OS* records. The observed storage levels reflect actual real-world reservoir system operations. Although the total of all BRA diversion targets are the same in the Bwam8A DAT file as in the Bwam8 DAT file, 26 percent of the total diversion target amount is moved to the Richmond gage control point in the Bwam8A dataset to represent the portion of the BRA commitments that are diverted from the lower Brazos River.

Reservoir storage capacities for the larger reservoirs in the Bwam8 dataset reflect year 2000 sedimentation. The Bwam8 storage capacity data remains unaltered in the Bwam8A dataset. Updating of storage capacities for continuing sedimentation or to reflect recent sediment surveys may be possible but will likely not have a major effect on the results of converting 1998-2007 gaged river flows to naturalized flows.

Gaged and Ungaged Control Points

The availability of stream flow measurements is also a key issue. The observed stream flow data at 48 control points used in the 1998-2007 Brazos WAM flow extension were based on measurements at 47 U.S. Geological Survey (USGS) streamflow gaging stations and measured releases from one reservoir (Lake Proctor). Establishing actual stream flows at other locations might be possible by obtaining data from other sources such as reservoir release measurements recorded by reservoir operators. Of course, additional time and effort would be required.

The USGS has discontinued measurements at a number of gaging stations in the Brazos River Basin. The discontinued gaging stations include three on the upper Leon River including the gage just below Proctor Dam which is the site of control point LEHS45. The 1998-2007 naturalized flows at control point LEHS45 estimated by conventional flow distribution techniques were found to result in simulated storage volumes in Lake Proctor that were not representative of actual observed storage volumes. Consequently, Proctor Reservoir releases were adopted as the measured flows at control point LEHS45.

Naturalized flows at gaged control points can reasonably be expected to be significantly more accurate than naturalized flows at ungaged control points. Naturalized flows at control points located at gaging stations are developed by adjusting observed measured flow data. Naturalized flows at ungaged control points are developed by proportioning or distributing known naturalized flows at gaged control points to the ungaged control points. Thus, the accuracy of the naturalized flows at ungaged control points are dependent upon the accuracy of both the naturalized flows at gaged control points and the accuracy of flow distribution methods and parameters.

The Brazos WAM Bwam3 and Bwam8 datasets contain 3,830 and 3,834 control points, respectively. Naturalized flows at the over 3,750 ungaged control points are computed within the *SIM* simulation with flow distribution option 6 which combines channel losses with the drainage area ratio method. Naturalized flows at 77 primary control points are provided as *IN* records in a

FLO input file that is shared by both the Bwam3 and Bwam8 datasets. Three of the 77 primary control points are ungaged outlets of the Brazos River and streams in the adjoining coastal basin. Two of the control points had pre-1998 measured flows in the form of reservoir release data available from reservoir owners. The other 72 primary control points in the original Bwam3 and Bwam8 1940-1997 datasets are USGS gaging stations. However, only 20 of these gaging stations have periods-of-record that span the entire WAM 1940-1997 period-of-analysis.

The 1998-2007 flow extension computations incorporate measured flow data at 48 gaging stations representing 48 of the original 77 primary control points. Complete 1998-2007 sequences of gaged flows are available at 41 of the 48 gaging stations. Reservoir releases were adopted for one site. Various manipulations were applied to develop complete 1998-2007 observed flow sequences at the six other gaging stations. Flows are distributed from these 48 control points to the 29 other original primary control points for which gaged flow data are not available for 1998-2007.

The new flow distribution option 10 was added with the August 2008 version of *SIM* and *HYD* for use primarily with flow extension applications. Flow distribution option 10 is based upon ratios of mean 1940-1997 naturalized flows at the gaged control points. The basic concept is to assign 1998-2007 naturalized flows at each of the 30 unknown-flow control points based on proportioning 1998-2007 naturalized flows at one or more of the 47 known-flow control points using 1940-1997 mean flow ratios. Mean flow ratios are applied similarly as drainage area ratios.

The flow extension process resulted in 1998-2007 naturalized flows at 77 control points, including the 48 with and 29 without 1998-2007 gaged flows. Bwam3 and Bwam8 1940-2007 naturalized flows at 77 primary control points are recorded in the FLO file and distributed within the *SIM* simulation to the over 3,750 ungaged secondary control points using flow distribution option 6 which combines channel losses with the drainage area ratio method.

<u>Net Evaporation-Precipitation Depths</u>

The Brazos WAM study documented by this report simply adopted the standard monthly evaporation and precipitation depth data averaged by quadrangle available from the Texas Water Development Board (TWDB) online database. The TWDB has updated the database through 2004. Monthly evaporation and precipitation depths obtained from the TWDB database for January 1998 through December 2004 were combined to obtain 1998-2004 monthly net evaporation less precipitation depths. Mean net evaporation-precipitation depths during 1940-2004 for each of the 12 months of the year were adopted for 2005, 2006, and 2007.

<u>Levels of Detail for Extending the Hydrologic Period-of-Analysis</u>

The following possible types of analyses involving extensions to hydrologic periods-of-analysis of the WAM System datasets reflect varying levels of detail and accuracy.

1. Plots of actual observed reservoir storage volumes combined with current use scenario simulated storage volumes can provide a convenient preliminary screening of WAM System datasets to assess whether extending the hydrologic period-of-analysis will likely affect critical reservoir drawdown periods prior to actually performing computations to extend the hydrologic period-of-analysis.

2. An approximate dataset for various preliminary screening investigations may be created based on an actual use scenario DAT file created with minimal or no revisions to the current use scenario DAT file.

3. The hydrologic period-of-analysis may be updated using the methodology outlined in this report to a level of accuracy comparable to or perhaps even exceeding that of the original WAM datasets. The extension of the Brazos WAM hydrologic period-of-analysis presented in this report is designed to actually update the WAM dataset. However, further refinements to the actual use Bwam8A DAT file and other aspects of the data and computations could potentially result in improvements in the accuracy of the extended sequences of naturalized flows and net evaporation-precipitation rates.

Reservoir storage plots such as those in presented in this report provide a visual display of the variation of hydrologic conditions including severe droughts occurring over a particular several-decade long period-of-analysis. This concept allows implementation of the following preliminary screening strategy performed without actually performing the flow extension computations. The objective is to expeditiously analyze whether or not extending the hydrologic period-of-analysis will likely affect the critical reservoir drawdown period. Reservoir drawdown has traditionally been used as an index in defining critical drought periods that control firm yield analyses and other similar types of water availability analyses.

For the Brazos WAM, a *SIM* simulation can be performed with the Bwam8 current use dataset to develop the 1940-1997 sequences of storages in selected major reservoirs such as those plotted in Appendix D. Without the 1998-2007 extension, the Bwam8 storage sequences cover the period 1940-1997. Actual observed storage volumes are plotted in Appendix C for the period 1998-2007. The observed storage plots can also be extended back for some period before 1998 for comparison with the Bwam8 simulated 1940-1997 storage volumes. Thus, plots of 1940-1997 Bwam8 *SIM* simulated reservoir storage sequences can be extended through 1998-2007 simply by plotting observed 1998-2007 storage volumes. The plots display the magnitude of reservoir drawdowns during various sub-periods of the overall 1940-2007 period-of-analysis.

Approximations are of course inherent in this methodology since 1940-1997 Bwam8 simulated storages and 1998-2007 observed storages reflect different scenarios of water management and use. Appendix C provides comparisons of 1998-2007 observed and Bwam8 simulated storage volumes. The Bwam8 and observed storages are close enough for the strategy to correctly predict for the Brazos WAM whether extending the period-of-analysis will likely redefine critical drought periods in the model. Much of the difference between the observed and Bwam8 simulated storage levels plotted in Appendix C is due to the WAM datasets constraining storage volumes to not exceed conservation storage capacities even though real-world reservoir storage levels rise into flood control and surcharge storage pools.

Storage plots thus developed provide a quick and easy means to predict whether extending the hydrologic period-of-analysis will likely change critical reservoir drawdown periods and associated firm yield analyses and other related types of water availability analyses. Preliminary screenings of this nature will support assessments of the importance of extending the hydrologic periods-of-analysis for WAM datasets for the various river basins. However, extending the hydrologic period-of-analysis improves the validity and accuracy of reliability and frequency analyses even if the critical drought period does not include any portion the extended period.

Applications of the procedure for extending hydrologic simulation periods outlined in this report may vary significantly in level of detail and accuracy depending largely on the extent to which a current use scenario WAM dataset is modified to develop an actual use dataset for the period of extension. Other aspects of the procedure are also characterized by judgments regarding appropriate levels of detail and accuracy. Many of the issues related to extending the hydrologic period-of-analysis were also relevant during the development of the original WAM System datasets.

A fundamental concept of the procedure outlined in this report is to both improve accuracy and reduce the effort required to update the WAM System FLO files by utilizing the information available in the current use scenario DAT files. An approximate dataset for preliminary screening investigations may be created based on an actual use DAT file created with minimal or no revisions to the current use DAT file. Improvements in accuracy are achieved by devoting greater effort and resources to modifying the current use dataset to create an extension-period actual use dataset. The flow extension methodology outlined by the report may be implemented at levels of detail that provide extended sequences of naturalized flow at comparable or higher levels of accuracy as the naturalized flows for the original period-of-analysis.

The Brazos WAM hydrology update presented in this report is designed to provide a sufficient level of accuracy for adoption as a final updated dataset. However, further refinements are always possible by expending more time and effort to compile more detailed data.

Impacts of 1998-2007 Hydrology Extension on Brazos WAM Simulation Results

The sequences of monthly naturalized flows at the 77 primary control points are plotted in Appendix A. Naturalized flows vary greatly spatially throughout the river basin and between years and months at any given location. However, in general, for most of the Brazos River Basin and adjoining coastal basin, an abundance of stream flow occurred during the 10-year period 1998-2007 as compared to the 58-year period 1940-1997.

At the Richmond gage on the lower Brazos River, the 1998-2007 mean of the naturalized flows is 130.1 percent of the 1940-1997 mean. The year 2007 has the highest naturalized flow volume of any year of the 68-year 1940-2007 period-of-analysis and accounts for 24.8% of the total naturalized flow volume at the Richmond gage during the ten years 1998-2007. The lowest annual naturalized flow volume at the Richmond gage during 1940-2007 occurs in 1951 and the second smallest is in 1956. The smallest annual naturalized flow volume at the Richmond gage during 1998-2007 occurs in 2006 and is 206% of the 1951 naturalized flow volume.

The year 2007 also has the largest stream flow of any year during 1940-2007 at the Cameron gage located on the Little River about 20 miles upstream of its confluence with the Brazos River. The 2007 naturalized flow at the Cameron gage accounts for 29.5% of the total 1998-2007 naturalized flow volume. The years 1954 and 1951 have the lowest and second lowest flows of any year during 1940-2007. The smallest annual naturalized flow volume at the Cameron gage during 1998-2007 also occurred in 2006 and is 330% of the 1951 naturalized flow volume. The 1998-2007 and 1940-2007 mean naturalized flow volumes are 157.1% and 108.1% of the 1940-1997 mean.

Although extending the period-of-analysis increased the mean stream flow volumes and the volumes associated with the full range of exceedance frequencies, the impacts on water supply diversion reliabilities are relatively minimal. The authorized use Bwam3 volume reliabilities for the aggregate total of all diversions is 89.97%, 89.79%, and 89.94%, respectively, for the periods 1940-1997, 1998-2007, and 1940-2007. The current use Bwam8 volume reliabilities for the total of all diversions are 94.18%, 94.73%, and 94.27%, respectively, for the periods 1940-1997, 1998-2007, and 1940-2007. Many of the diversions from the larger reservoirs have reliabilities of 100.0% with or without extending the period-of-analysis.

In general, the extension of the Brazos WAM period-of-analysis does not dramatically change water supply reliabilities and stream flow and storage frequency relationships. However, a fundamental concept of statistical analysis is that a longer period-of-analysis provides more accurate frequency and reliability estimates. A 68 year period-of-analysis provides better estimates of the probability of meeting 75% of a diversion target at least 75% of the time than a 58 year period-of-analysis. Likewise, estimates of stream flow-frequency and reservoir storage-frequency relationships have greater validity if based upon 68 years of data rather than 58 years of data. The accuracy of conditional reliability modeling analyses is improved with more years of hydrology.

Ending the hydrologic period-of-analysis with the extremely wet year 2007 coincidentally helps with the following minor water availability and water supply reliability analysis issue. The WAM datasets incorporate the premise that all reservoirs are full to capacity to the beginning of the simulation. Reservoir drawdowns at the end-of-the simulation represent water made available to meet diversion requirements in excess of the natural stream flow occurring during the simulation period-of-analysis. A wet end-of-simulation year minimizes end-of-simulation reservoir drawdowns. Reservoirs are full (or near full) to capacity at both the beginning and end of the simulation.

Reservoir storage contents provide a meaningful index of drought conditions. Bwam3 and Bwam8 monthly storage volumes during 1900-2007 for each of 14 of the largest reservoirs in the Brazos River Basin are plotted in Appendix D. These 14 reservoirs contain 73.5% and 76.8% of the total conservation storage capacity of the 665 and 706 reservoirs, respectively, in the Bwam3 and Bwam8 datasets. The 14 individual reservoirs represent different regions of the river basin. The Figures D.29 and D.30 plots of total storage in the 14 reservoirs in the Bwam3 and Bwam8 simulation results provide an index of aggregated basin-wide conditions of water availability.

The reservoir storage plots in Appendix D provide a visual index of wet and dry periods including severe droughts occurring during January 1940 through December 2007. The Bwam3 and Bwam8 storage drawdowns exhibit patterns that, though generally similar, do show significant differences at some of the reservoirs. Bwam3 drawdowns are more severe than Bwam8 drawdowns as expected since Bwam3 diversions are greater. However, the patterns and timing of major drawdown periods also vary between Bwam3 and Bwam8 at some of the reservoirs.

Storage depletions during 1998-2007 are relatively minimal in the majority of the reservoirs compared to earlier drought periods. None of the major reservoirs have their most severe Bwam3 or Bwam8 drawdown occurring during the January 1998 through December 2007 extension period. The critical drought period for most of the Brazos River Basin began gradually during 1951 and ended abruptly with the flood of April-May 1957. The prominence of the 1950's drought at the majority of the reservoirs is evident from the reservoir plots of Appendix D. However, as discussed in the following paragraphs, there are exceptions in which more severe or almost as severe depletions of reservoir storage occur during periods other than the 1950's.

The simulated storage sequences for Lakes Alan Henry and Hubbard Creek are very different than the other reservoirs. These reservoirs exhibit dramatic differences in storage levels between the authorized use scenario Bwam3 and current use scenario Bwam8 simulations. Bwam3 storage drawdowns in Lakes Alan Henry and Hubbard Creek are frequent and severe, with the reservoirs being empty during much of the simulation.

Lake Proctor is also unusual in that multiple drawdowns of comparable magnitude occur in the simulations. The longest Bwam3 and Bwam8 droughts during 1940-2007 for Lake Proctor extend from the late 1970's through early 1980's with the 1950's drought causing the second longest severe storage drawdowns. Bwam3 and Bwam8 drawdowns of Lake Proctor during 1999-2001 has a minimum storage level occurring in October 2000 that is comparable but not quite as low as the minimum storage levels of the 1950's and 1970's-1980's.

Although the 1950's is the worst drought period for Lake Waco, major Bwam3 storage depletions also occur during the 1960's, 1970's, and early 2000's. Bwam3 drawdowns during 1999-2003 are large at Lake Granbury, though even lower storage levels occur in the 1950's and 1980's.

Lengthening the Hydrologic Period-of-Analysis to Include 1900-1939

Wurbs et al (1988) document a water availability modeling study for the Brazos River Basin conducted at Texas A&M University during 1986-1988 that included developing January 1900 through December 1984 sequences of naturalized stream flows at 20 USGS gaging stations which all happen to be included in the 77 Brazos WAM primary control points. The 1900-1939 portions of these flow sequences were adopted for the present study. Although compilation of naturalized flows during the 1986-1988 study included adjustments to 1900-1984 gaged streamflows to remove the impacts of 21 reservoirs and selected diversions, only one small reservoir with records dating back to 1936 was included in the flow adjustments prior to 1940. Thus, 1900-1939 naturalized flows are essentially the same as the gaged flows. The compilation of 1900-1939 flows focused on distributing flows from gaged to ungaged sites in both the 1986-1988 and current studies.

Records of flow measurements at 24 stream gage stations were used in the 1986-1988 investigation to fill in missing data and develop complete 1900-1984 naturalized flow sequences at 20 gaging stations. Wurbs, et al. (1988) synthesized monthly flows for the periods of missing records using the *MOSS-IV Monthly Streamflow Synthesis* computer model developed by the Texas Water Development Board (Beard 1973). MOSS-IV fills in gaps in monthly streamflow data based on measured streamflow at multiple nearby gaging stations. The program uses a multiple linear regression algorithm based on the transformed incremental logarithm of the monthly flow volumes, with a random component included to reproduce the distribution of random departures from the regression model observed in the basic data.

Eleven of the 20 gages have records dating back to 1924 or before. The USGS gaging station on the Brazos River at Waco has a continuous record from October 1898 to the present. This is the only gage with a continuous record during 1900-1939. Gages on the Brazos River at Richmond and Bryan have records beginning in 1903 and 1899, respectively, but also have long periods of missing data. The gage on the Little River at Cameron has continuous recorded monthly flows dating back to November 1916.

The same flow distribution methodology based on 1940-1997 mean flows was used in the current investigation for both the 1998-2007 and 1900-1939 flow extensions. The 1900-1939 monthly flows at 20 control points was distributed to 57 other control points. The 1900-2007 flows at the 77 Brazos WAM primary control points are plotted in Appendix A. These naturalized flows are distributed to over 3,700 other secondary control points in the *WRAP-SIM* simulation.

The 1940-1997 means of the net evaporation-precipitation depths for each of the 12 months of the year were adopted for each of the years 1900 through 1939.

The 1900-39 flows synthesized at the numerous remote control points are not accurate enough for various conventional WRAP modeling applications. Flows before 1924 are based on even fewer active gaging stations than the flows during 1924-1939. However, the 1900-2007 hydrologic period-of-analysis is useful for some applications of WRAP, such as conditional reliability modeling studies. The 108-year hydrologic period-of-analysis provides meaningful insights into the river basin hydrology of 1900-1939 and the impacts on water availability analyses of incorporating this early hydrology into the model simulations.

Impacts of the 1900-1939 Hydrology Extension on Brazos WAM Simulation Results

The 1900-2007 flows at 77 control points are plotted in Appendix A. The 1900-1939 versus 1940-1997 sub-periods of plotted flows look similar. In general, the statistical characteristics of the 1900-1939 and 1940-1997 flows are similar. Means of the 1900-1939, 1998-2007, and 1900-2007 naturalized flows at the Cameron, Waco, and Richmond gaging stations are shown below as a percentage of the 1940-1997 mean naturalized flows at these sites.

	Mean Flow as Percentage of 1940-1949 Mean		
Gage	1900-1939	1998-2007	1900-2007
Little River at Cameron	100.8%	154.9%	105.4%
Brazos River at Waco	95.5%	109.7%	99.4%
Brazos River at Richmond	97.2%	130.1%	101.7%

Means of flows tend to be dominated by flood flows. The 50% (median) and 90% exceedance frequency naturalized flows shown below are more representative of normal and low flows. Median naturalized flows equaled or exceeded in 50 percent of the months of the periods-of-analysis are tabulated below as a percentage of the 1940-1997 median naturalized flows.

	Median Flow as Percentage of 1940-1949 Median Flow		
Gage	1900-1939	1998-2007	1900-2007
Little River at Cameron	91.7%	188.8%	103.1%
Brazos River at Waco	102.1%	124.6%	103.7%
Brazos River at Richmond	102.5%	136.4%	103.7%

Naturalized monthly flow volumes that are equaled or exceeded 90% of the time are shown below as a percentage of the corresponding 90% naturalized flows at these sites for 1940-1997.

	90% Flow as Percentage of 1940-1949 Flow		
Gage	1900-1939	1998-2007	1900-2007
Little River at Cameron	107.5%	335.6%	114.5%
Brazos River at Waco	67.6%	334.3%	90.0%
Brazos River at Richmond	85.3%	172.6%	98.4%

Results are similar for 1900-1939 and 1940-1997 simulations. Volume reliabilities for the aggregate total of all water supply diversions in the authorized use scenario (Bwam3) and current use scenario (Bwam8) simulations with alternative simulation periods are tabulated as follows.

Period-of-Analysis	Bwam3	Bwam8
1900-1939	90.16%	94.37%
1900-2007	89.94%	94.27%
1940-1997 (begin 1900)	89.83%	94.13%
1940-1997 (begin 1940)	89.97%	94.18%

From the perspective of basin-wide total diversions, extending the hydrologic period-of-analysis to incorporate 1900-1939 has only minimal effect on reliabilities. If rounded to the nearest percentage, the Bwam3 reliabilities tabulated above are all 90 percent and the Bwam8 reliabilities are all 94 percent. The reliabilities for the period 1940-1997 are shown alternatively for simulations beginning in January 1900 and January 1940. The difference between the 89.83% and 89.97% reliabilities is due to the storage contents of each reservoir at the beginning of January 1940. Initial storage contents for all reservoirs at the beginning of the simulations were set at capacity.

Reliabilities for diversions from 14 large reservoirs which include Alan Henry, Hubbard Creek, and the 12 Brazos River Authority reservoirs, are tabulated below. Most of the diversion shortages are associated with Lakes Alan Henry and Hubbard Creek. Diversions from the 12 BRA reservoirs have reliabilities of 100% or near 100% in all six simulations.

Simulation Period	Bwam3	Bwam8
1900-1939	97.76%	100%
1940-1997	96.76%	99.98%
1940-2007	96.53%	99.98%

Bwam3 and Bwam8 simulated 1900-2007 end-of-month storage volumes for the 14 reservoirs are plotted in Appendix D. The Bwam3 storage plots show severe drawdowns during 1909-1913 and 1917-1918 at most of the reservoirs that are in some cases comparable to the 1950's. However, these early major droughts occur during periods before 1924 in which few gaging stations were in operation and thus water availability modeling results are highly uncertain.

Condensed WAM Datasets

The primary reason for developing condensed datasets is to provide a much simpler model that can be conveniently and effectively applied in studies dealing with a particular river/reservoir water management system. Condensed datasets also provide a mechanism for allocating water between a primary system of concern and all of the other water rights in the river basin that can be useful in certain types of modeling applications.

Conceptual Basis for Reducing the Size of WAM Datasets

The control points, reservoirs, and water rights included in a condensed DAT file are called the *primary* system. The control points, reservoirs, and water rights that are not included in the primary system comprise the secondary system. The effects of all secondary water rights on river flows available to primary water rights are reflected in the FLO file inflow *IN* record stream flows. The inflows provided in the FLO file of an original WAM System dataset are naturalized flows. The inflows contained in the FLO file of a condensed dataset represent the river flows available to the primary system after considering all the other water rights removed from the DAT file.

The DAT input file for a condensed dataset includes only control points, water rights, and related information for the primary system. Many of the control point *CP* records are removed and the remaining *CP* records are revised as appropriate. Channel loss factors are aggregated to reflect the combining of river reaches with removal of control points. Inflows are provided in the FLO file for all control points included in the condensed dataset. Thus, there is no flow distribution DIS file.

The WRAP program *HYD* provides features for developing a FLO or DSS file for a condensed dataset from data read from the *SIM* simulation results output file for a full WAM system dataset. The river inflows stored on *IN* records in the FLO file or DSS records in a hydrology DSS file for a reduced-in-size condensed dataset is comprised of the summation of the following quantities from the *SIM* simulation results of the original complete WAM model.

- addition of stream flow depletions for the primary system water rights properly cascaded downstream accounting for the effects of channel losses
- subtraction of return flows from the primary system diversion rights cascaded downstream accounting for the effects of channel losses
- subtraction of reservoir releases from storage in primary system reservoirs made specifically to meet instream flow requirements or generate hydroelectric power also cascaded downstream accounting for the effects of channel losses
- addition of unappropriated flows at the primary system control points

The reservoir releases for instream flow requirements to be subtracted in developing the primary system inflows for the condensed dataset FLO file includes only those releases from storage in designated reservoirs specified on *IF* records as *IFMETH* options 3 or 4, not the more common situation of just passing inflows through reservoirs for instream flow requirements. The priority sequencing of the *IF* record instream flow rights requiring releases from storage may somewhat complicate the development of a condensed dataset as noted in the following paragraphs.

Same-month return flows can be a problem in developing a condensed dataset just like they are a problem in performing conventional *SIM* simulations. The next-month return flow option is applied instead of the same-month option in most cases in the TCEQ WAM System datasets. The *WRAP Reference Manual* describes the return flow options and the water rights priority sequence complexity that the next-month return flow option is designed to address. The problem is that, with the same-month return flow option activated, senior water rights do not have access to return flows associated with junior water rights. The next month return flow option solves this problem by adding the return flows to the *IN* record inflows (naturalized or otherwise defined inflows) at the beginning of the water rights priority sequence in the next month.

Reservoir releases for hydroelectric energy generation involve essentially the same issue. Hydropower releases are analogous to diversions with 100 percent return flows. The problem is likewise solved by the next-month hydropower option provided in *SIM*.

A similar problem occurs with releases from reservoir storage to meet instream flow requirements at downstream control points. The releases form storage increase stream flow and may affect water availability for other diversion and storage rights in the priority sequence. The partitioning of water rights between primary and secondary in the development of a condensed dataset may affect the relative access of other rights to the additional flow made available by the releases from reservoir storage. The problem does not occur if the *IF* record right in the WAM dataset is more senior than all other affected rights. The effects may be relatively minimal in many cases even with *IF* record rights inserted within the priority sequence.

As noted in the next paragraph, a properly developed condensed dataset will reproduce certain simulation results from the original full WAM dataset. The match of simulation results should normally be perfectly exact. However, the *SIM* input data features discussed in the preceding paragraphs and listed below can potentially prevent the match from being precisely exact. The basic problem is related to water taken from reservoir storage that increases the stream flow available to multiple water rights in the water rights priority sequence, with the flow availability being altered by partitioning between primary and secondary water rights.

- *same-month* diversion return flows
- *same-month* hydroelectric power releases
- instream flow *IF* record rights with *IFMETH* options 3 or 4 which specify releases from storage in designated reservoirs

With the primary system operated in the same manner in both the condensed and original datasets, the water supply diversions and shortages, streamflow depletions, and reservoir storage volumes computed by the *SIM* simulation model will be the same. The condensed dataset will reproduce the simulation results for the primary system that are obtained with the original dataset. Unappropriated flows are also reproduced. Thus, a comparison of simulation results provides a check on the accuracy and validity of the condensed dataset. With a validated operational condensed dataset, studies can be performed in which various alternative operating plans, management strategies, and water use scenarios are simulated for the primary system. The river inflows for the condensed dataset do not include flows appropriated by the secondary water rights and thus represent only flows that are actually available to the primary system.

The methodology for developing and applying condensed datasets focuses upon properly modeling unappropriated rather than regulated flows. An optional regulated-unappropriated flow (RUF) file is required if but only if conventionally-defined regulated flows are of concern. A RUF file created with program *HYD* contains differences between unappropriated flows and regulated flows from the *SIM* simulation results for a complete WAM dataset. Options recently added to *SIM* allow the data from a RUF file of a condensed dataset to be applied to adjust unappropriated flows to obtain regulated flows.

Brazos River Authority Condensed (BRAC3 and BRAC8) Datasets

The purpose of the Brazos River Authority Condensed (BRAC) datasets are to provide a much simpler model that facilitates operational planning studies and other decision support activities for the Brazos River Authority (BRA). The datasets designed for modeling BRA river/reservoir water management system operations consist of DAT, FLO, EVA, and RUF files. Alternative versions of the datasets have hydrologic periods-of-analysis of 1900-2007 and 1940-2007. The 1940-1997 simulation period is embedded within the 1940-2007 dataset. Alternative versions of the files with filename roots BRAC3 and BRAC8 were created by reducing the size of the original full Brazos WAM authorized use scenario Bwam3 and current use scenario Bwam8 files. The effects of removing secondary water rights and control points from the Bwam3 and Bwam8 DAT files are incorporated into the primary system stream inflows stored in files with filenames BRAC3.FLO and BRAC8.FLO using the methodology outlined in the preceding section.

The BRAC3 and BRAC8 input datasets properly reproduce the relevant *SIM* simulation results of the original full Brazos WAM Bwam3 and Bwam8 datasets. The match between Brazos WAM and BRAC simulation results for the primary system is not perfectly exact but is very close. The small differences are caused by complexities related primarily to two instream flow rights requiring releases from storage, a few rights with same-month return flows, and certain channel losses of return flows. Removal of control points in creating the BRAC dataset resulted in changes in the control points at which return flows are returned which affects channel losses in some cases.

The Brazos WAM authorized use scenario (Bwam3) dataset contains 1,634 water right *WR* records, 122 instream flow *IF* records, 670 reservoirs, and 3,830 control points. The Brazos WAM current use scenario (Bwam8) dataset is slightly larger. Naturalized flows are input on inflow *IN* records in a FLO file for 77 primary control points and distributed within *SIM* to the other ungaged secondary control points as specified by 3,138 flow distribution *FD* records in a DIS file. The size of the Brazos WAM dataset is dramatically reduced in developing the simplified BRAC dataset.

The primary system incorporated in the BRAC3 and BRAC8 datasets includes 48 control points, the 12 BRA reservoirs and three other reservoirs, and associated water rights. The permitted but not yet constructed Allens Creek Reservoir is included in the authorized use scenario Bwam3 and BRAC3 datasets but is not included in the current use scenario Bwam8 and BRAC8 datasets. Thus, the BRAC3 and BRAC8 versions of the reduced dataset have 15 and 14 reservoirs, respectively.

Net reservoir surface evaporation less precipitation depths are provided in the EVA file for the reservoir control points. These are adjusted evaporation-precipitation depths read by program *HYD* from the *SIM* simulation output OUT file for the original Brazos WAM.

River flows are included in the BRAC3 and BRAC8 versions of the FLO file for all of the 48 control points. There is no flow distribution DIS file. Only water rights associated with the 15 BRAC3 reservoirs or 14 BRAC8 reservoirs are included in the two versions of the condensed DAT input file. The impacts of the over 650 reservoirs and numerous water rights removed from the Brazos WAM dataset are reflected in the *IN* record flows in the FLO files developed for the condensed datasets. The river system inflows in the BRAC3 and BRAC8 versions of the FLO file for the 48 control points are plotted in Appendix E.

WRAP-SIM and WRAP-HYD Input Datasets

The *WRAP* input files listed below are primary products of this work and are now available for use. The following inventory of datasets also provides a summary of this report.

Examples in Chapter 2

Two simple examples are presented in Chapter 2 to demonstrate the general methodologies developed in this study. The first example illustrates new *SIM* and *HYD* features developed to support the procedure for extending the hydrologic period-of-analysis. The second example illustrates the methodology for developing a condensed dataset. These examples provide a convenient means for experimenting with the modeling methods without having to deal with a massive dataset for an actual large river basin such as the Brazos. The *SIM* and *HYD* input files for the two examples are listed as follows along with the Chapter 2 tables in which the files are printed. Example 2 also includes a *TABLES* input TIN file.

Example 2.1	
Example1.DAT	Table 2.1
Example1Initial.FLO	−
Example1Final.FLO	Table 2.2
Example1.EVA	Table 2.4
Example1.DIS	Table 2.3
Example1HYD.HIN	Table 2.6
Example1HYD.FLO	Table 2.5

Example 2.2	
Exam2O.DAT	Table 2.14
Exam2O.FLO	Table 2.11
Exam2O.EVA	Table 2.12
Exam2O.DIS	Table 2.13
Exam2C.HIN	Table 2.17
Exam2C.DAT	Table 2.19
Exam2C.FLO	Table 2.18
Exam2C.RUF	Table 2.23

Brazos WAM Dataset Described in Chapter 3

The Brazos WAM dataset consists of the following program *SIM* input files for the authorized use scenario (run3) and current use scenario (run 8) which were last updated by the TCEQ in August 2007. The FLO and EVA files are the same for Bwam3 and Bwam8. The FLO file contains 1940-1997 sequences of monthly naturalized flows for 77 control points. The EVA file contains 67 sequences of 1940-1997 monthly net evaporation-precipitation depths.

Bwam3.DAT	Bwam8.DAT
Bwam3.FLO	Bwam8.FLO
Bwam3.EVA	Bwam8.EVA
Bwam3.DIS	Bwam8.DIS

Extended Hydrology Data Covered in Chapters 4, 5, 6, and 7

The hydrologic period-of-analysis for which monthly river flow volumes and monthly net evaporation-precipitation rates are provided in the FLO and EVA files was extended to include 1998-2007 as outlined in Chapter 4 and was further extended to include 1900-1939 as described in Chapter 5. Naturalized flows for the different periods are compared in Chapter 6. The effects of extending the hydrologic period-of-analysis on *WRAP-SIM* simulation results are investigated in Chapter 7. The 1940-2007 and 1900-2007 sequences of naturalized flows at 77 control points and evaporation-precipitation depths assigned to 67 control points are stored in the following files which can be applied with either Bwam3 or Bwam8 DAT and DIS files.

Bwam1940-2007.FLO
Bwam1940-2007.EVA

Bwam1900-2007.FLO
Bwam1900-2007.EVA

The 1998-2007 naturalized flow extension covered in Chapter 4 is based on adjusting gaged flows at 48 control points for the effects of actual 1998-2007 water resources development, management, and use as described in a 1998-2007 actual use scenario Bwam8A *SIM* input dataset created by modifying the current use scenario Bwam8 dataset. The following *SIM* and *HYD* input files are described in the last section of Chapter 4.

Bwam8A.DAT	1998-2007 actual use scenario DAT file
Bwam8A.BES	beginning of January 1998 reservoir storage volumes
Bwam8A.DIS	flow distribution specifications and parameters
Bwam8A.EVA	net evaporation-precipitation rates
Bwam8A75%.FLO	75% frequency naturalized flows used in initial iteration
Bwam8A.FLO	final naturalized flows determined by iterative procedure
Bwam8AH.FLO	gaged flows at 48 control points (*HYD* input file)
Bwam8AHfirst.HIN	*HYD* input file for first 12 iterations
Bwam8AHlast.HIN	*HYD* input file for last 8 iterations

Brazos River Authority Condensed (BRAC) Datasets Covered in Chapters 8 and 9

The authorized use scenario BRAC3 and current use scenario BRAC8 condensed datasets for modeling the Brazos River Authority (BRA) reservoir system consist of the following sets of *WRAP-SIM* input files.

BRAC3.DAT	BRAC8.DAT
BRAC3_1940-2007.FLO	BRAC8_1940-2007.FLO
BRAC3_1940-2007.EVA	BRAC8_1940-2007.EVA
BRAC3_1940-2007.RUF	BRAC8_1940-2007.RUF
BRAC3_1900-2007.FLO	BRAC8_1900-2007.FLO
BRAC3_1900-2007.EVA	BRAC8_1900-2007.EVA
BRAC3_1900-2007.RUF	BRAC8_1900-2007.RUF

The BRAC3 and BRAC8 DAT files can be combined with the FLO and EVA files covering either a 1900-2007 or 1940-2007 hydrologic period-of-analysis. A *SIM* simulation with the original 1940-1997 hydrologic period-of-analysis can also be performed with the 1940-2007 FLO and EVA files.

The BRAC3 and BRAC8 datasets were developed based on reducing the size of the Bwam3 and Bwam8 datasets as outlined in Chapter 8. The BRAC3 and BRAC8 FLO files and RUF files were created from Bwam3 and Bwam8 simulation results using program *HYD* with the following *HYD* input files.

BRAC3.HIN
BRAC8.HIN

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Beard, Leo R., *Transfer of Streamflow Data within Texas*, Report No. 104, Center for Research in Water Resources, University of Texas at Austin, August 1973.

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Wurbs, R. A., C. E. Bergman, P. E. Carriere, and W. B. Walls, *Hydrologic and Institutional Water Availability in the Brazos River Basin*, Technical Report 144, Texas Water Resources Institute, August 1988. http://twri.tamu.edu/reports.php

Wurbs, R. A., *Water Rights Analysis Package (WRAP) Modeling System Reference Manual*, Technical Report 255, Texas Water Resources Institute, 5th Edition, August 2008.

Wurbs, R. A., *Water Rights Analysis Package (WRAP) Modeling System Users Manual*, Technical Report 256, Texas Water Resources Institute, 5th Edition, August 2008.

Appendix A

1900-2007 Monthly Naturalized Flows at the 77 Primary Control Points

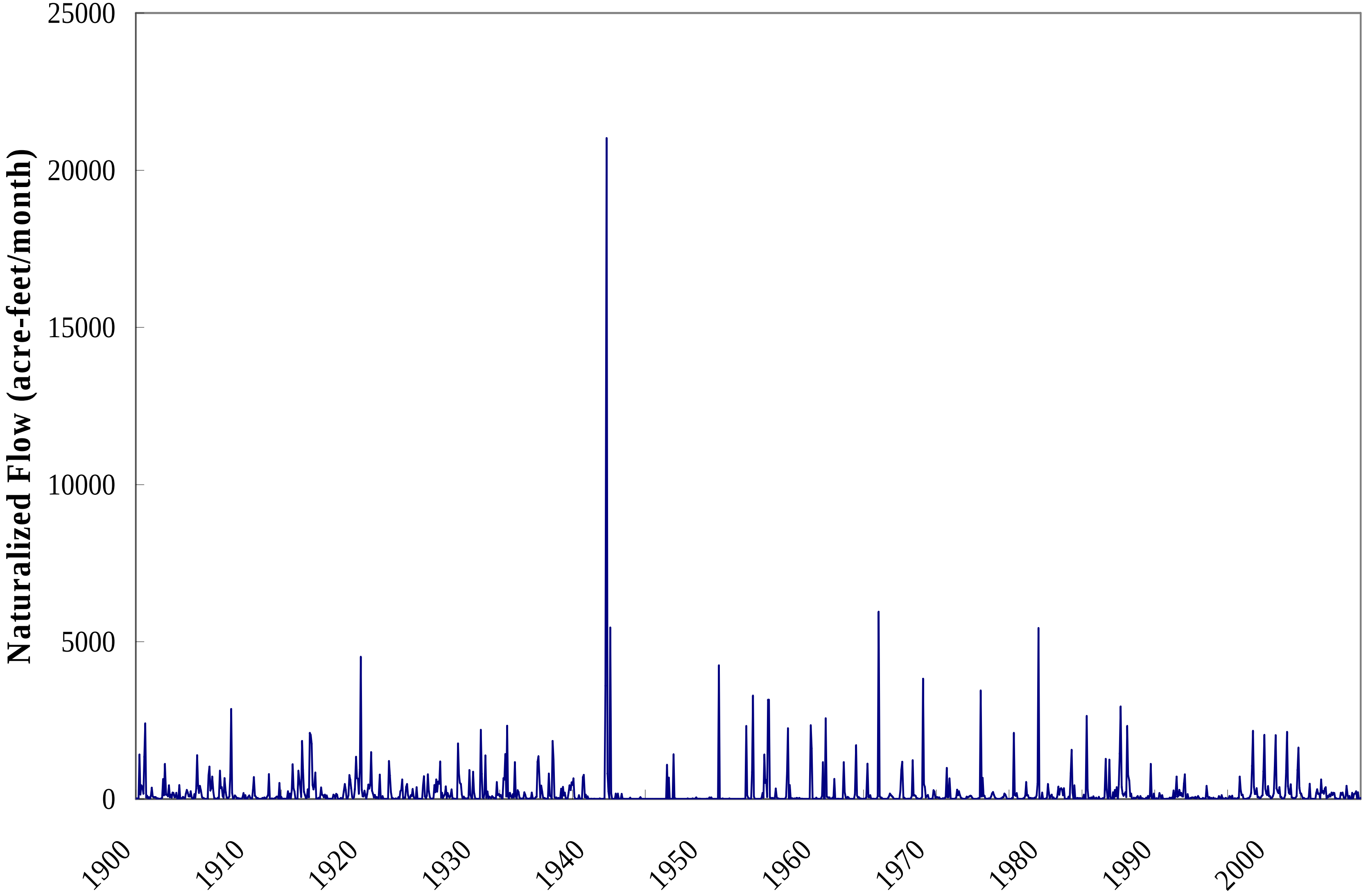

Figure A.1 Monthly Naturalized Flow at RWPL01 – Running Water Draw at Plainview

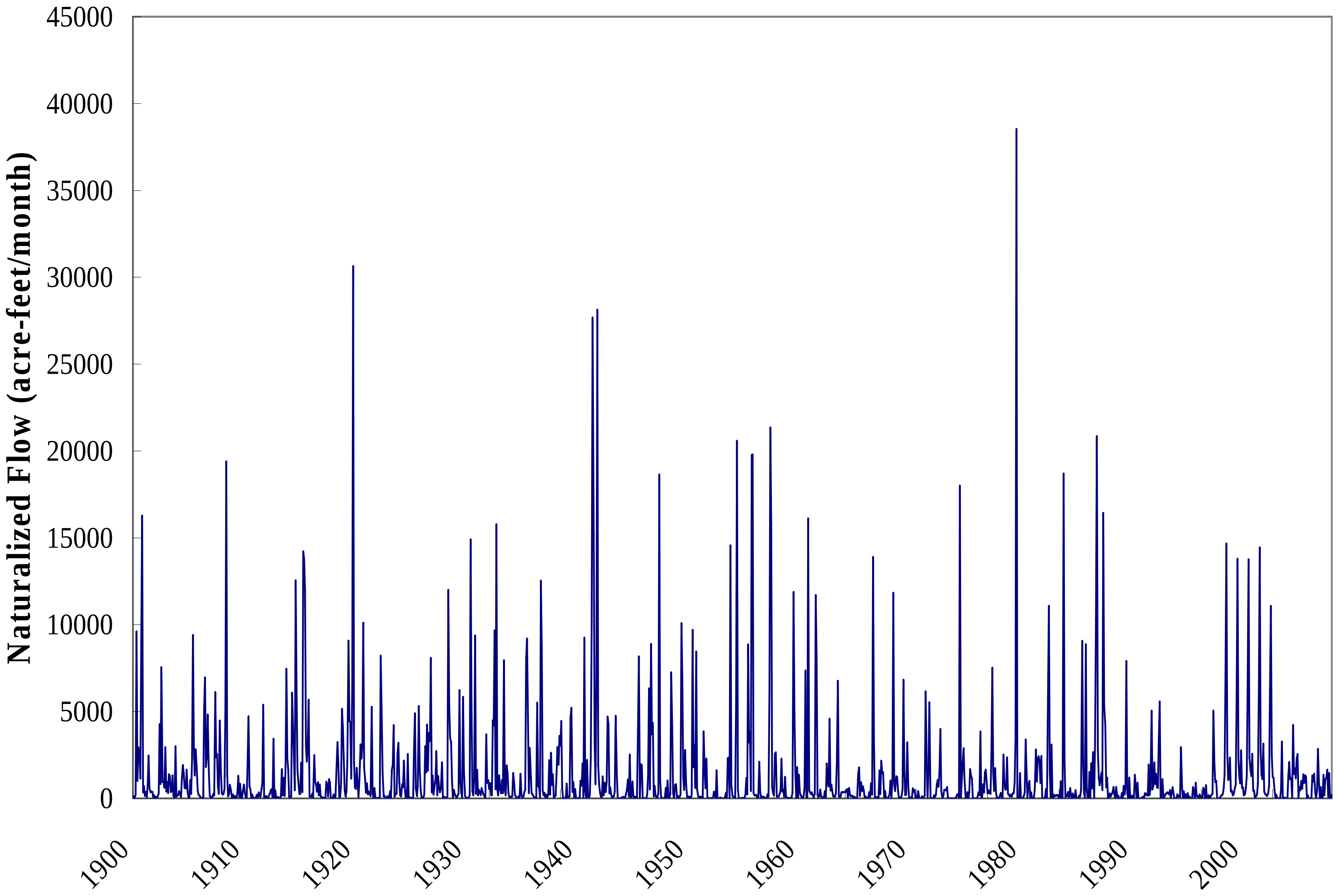

Figure A.2 Monthly Naturalized Flow at WRSP02 – White River Reservoir near Spur

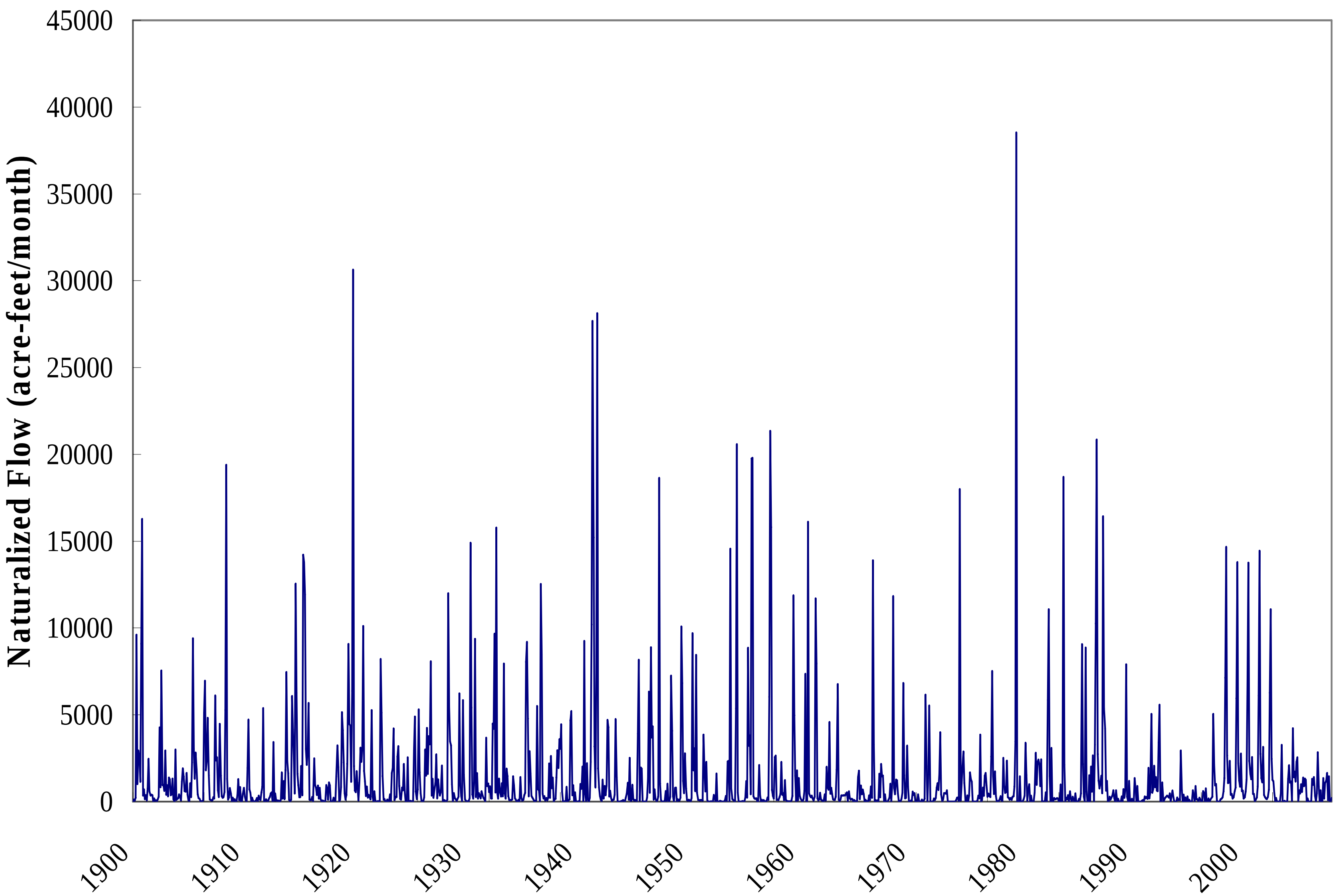

Figure A.3 Monthly Naturalized Flow at DUGI03 – Duck Creek near Girard

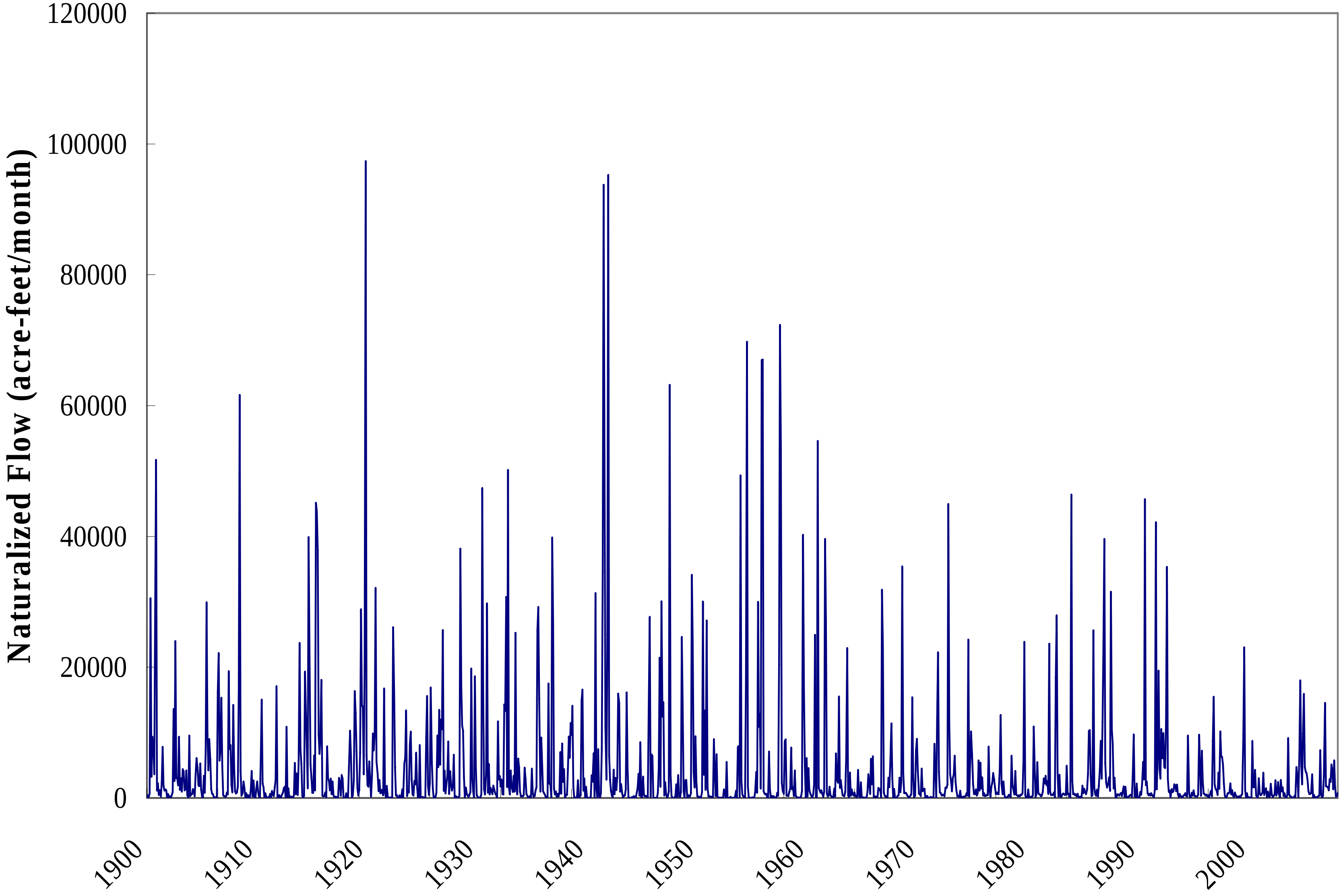

Figure A.4 Monthly Naturalized Flow at SFPE04 – Salt Fork Brazos River Near Peacock

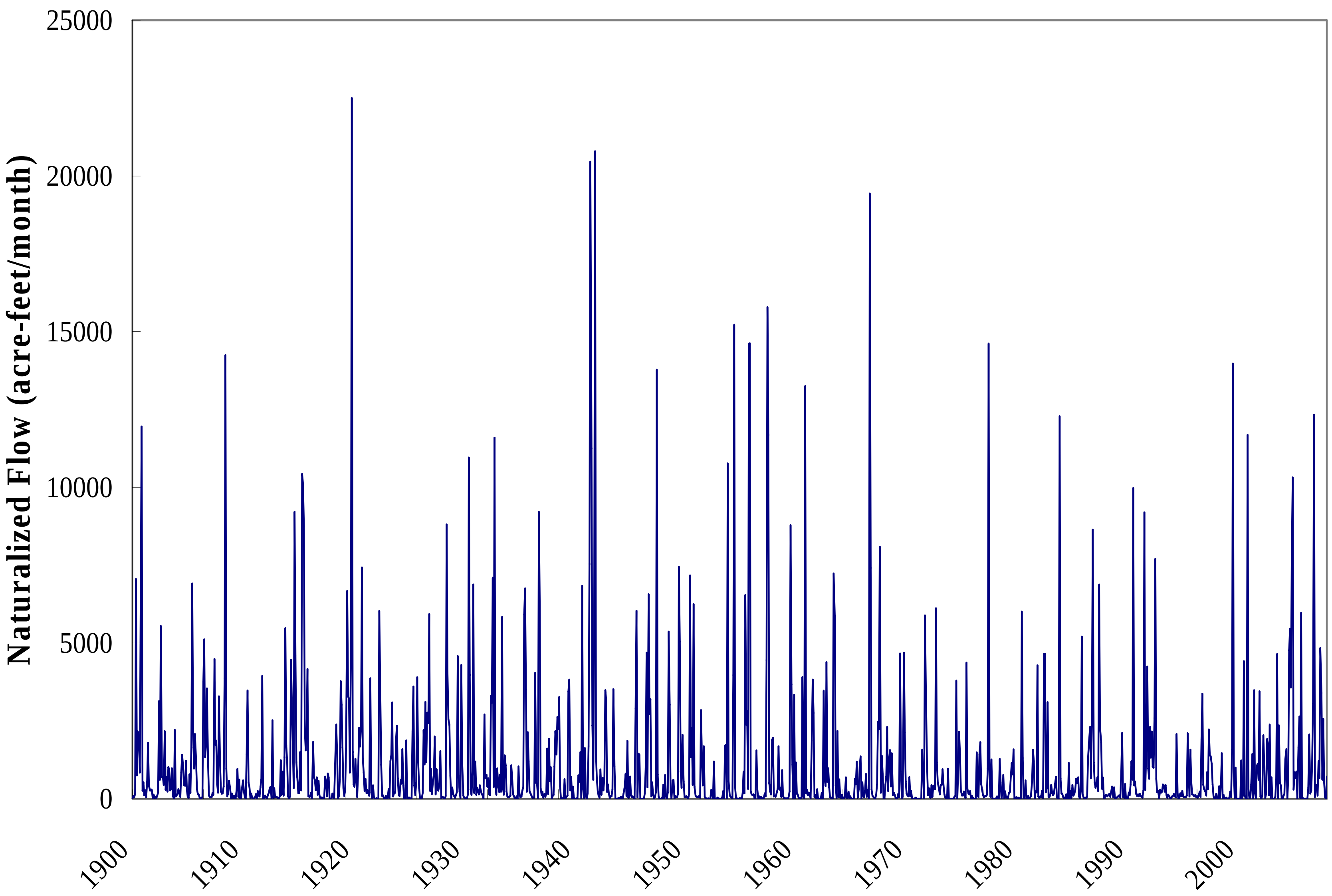

Figure A.5 Monthly Naturalized Flow at CRJA05 – Croton Creek near Jayton

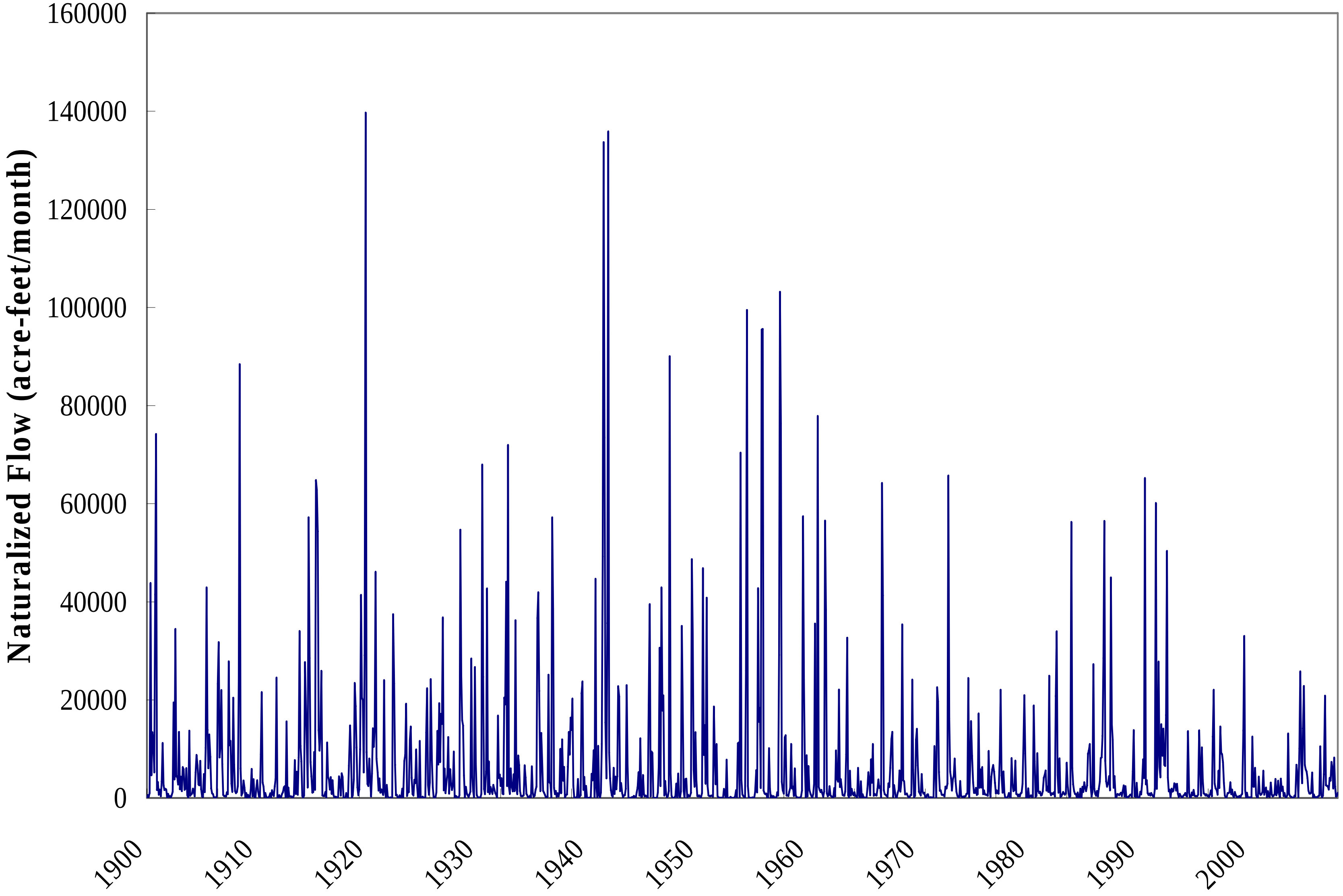

Figure A.6 Monthly Naturalized Flow at SFAS06 – Salt Fork Brazos River near Lubbock

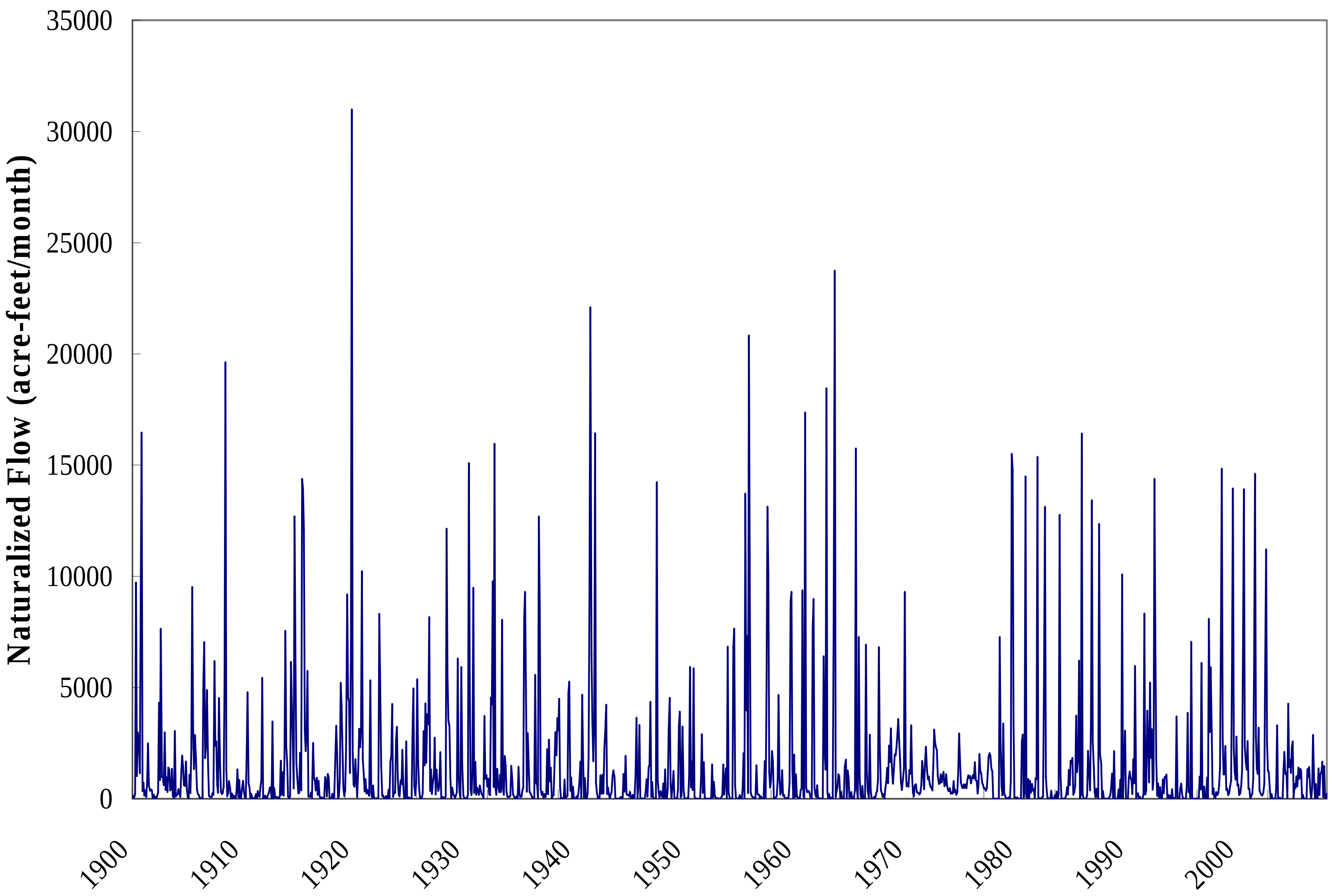

Figure A.7 Monthly Naturalized Flow at BSLU07 – Buffalo Springs Lake near Lubbock

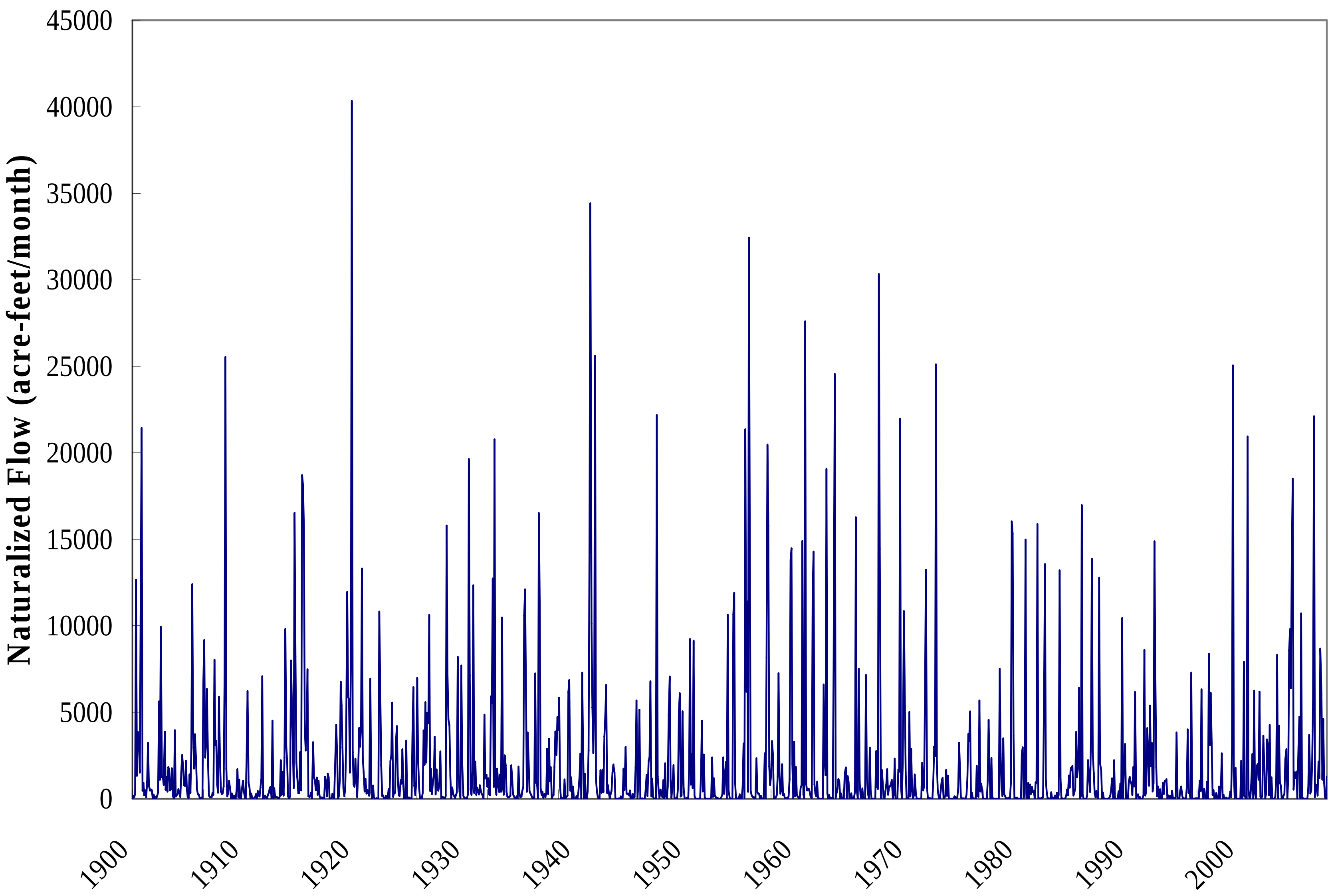

Figure A.8 Monthly Naturalized Flow at DMJU08 – Double Mountain Fork Brazos River near Justiceburg

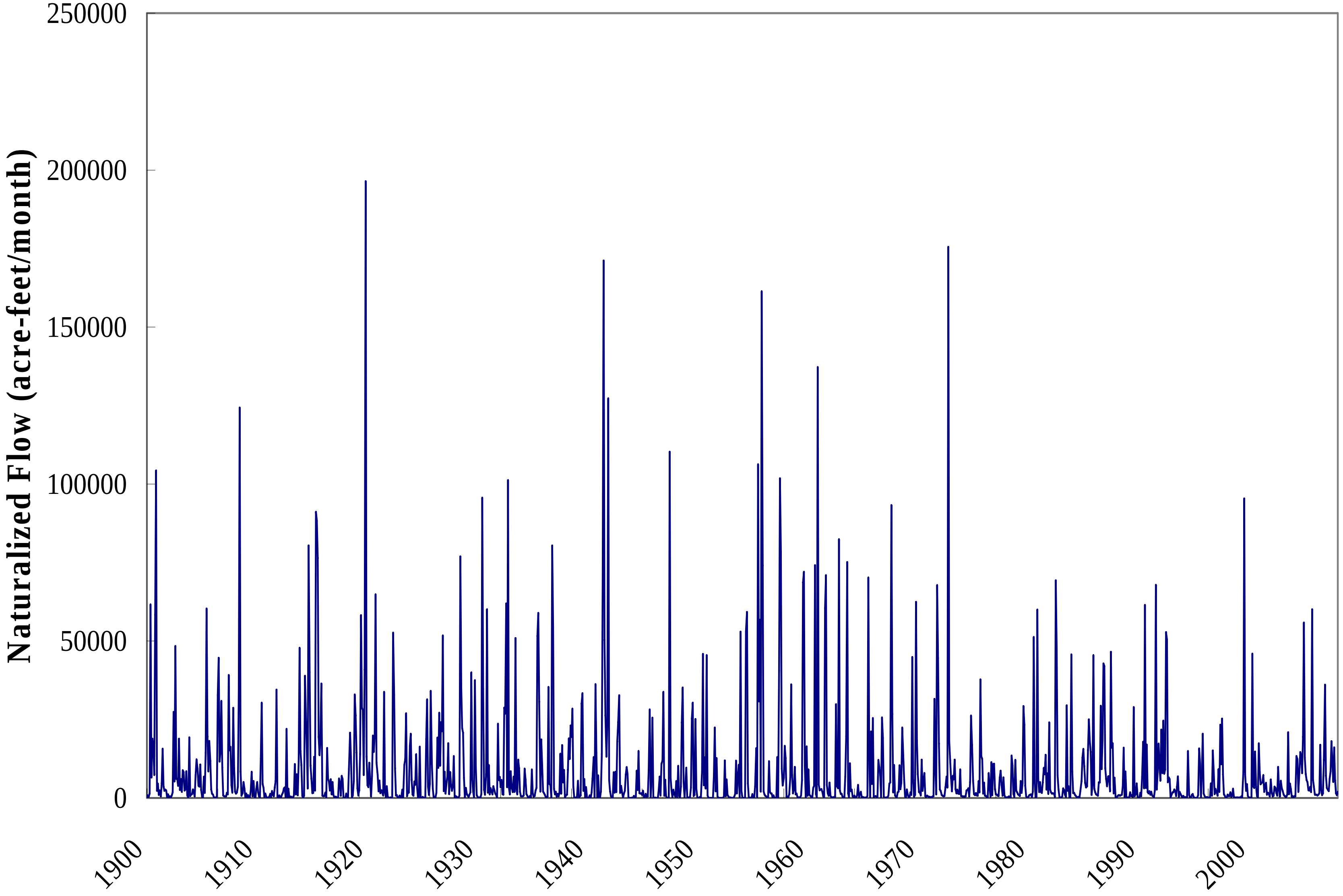

Figure A.9 Monthly Naturalized Flow at DMAS09 – Double Mountain Fork Brazos River near Aspermont

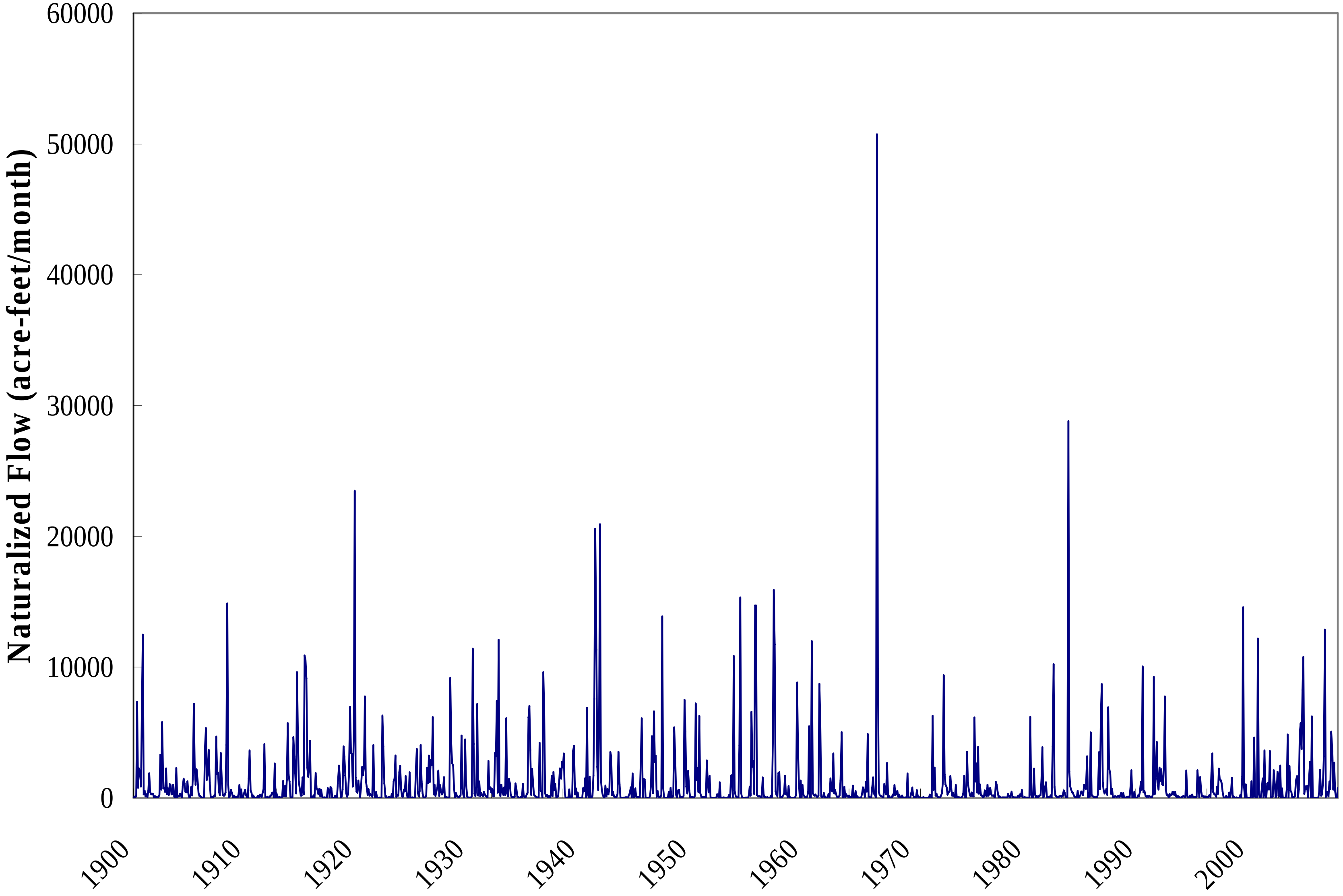

Figure A.10 Monthly Naturalized Flow at NCKN10 – North Croton Creek Near Knox

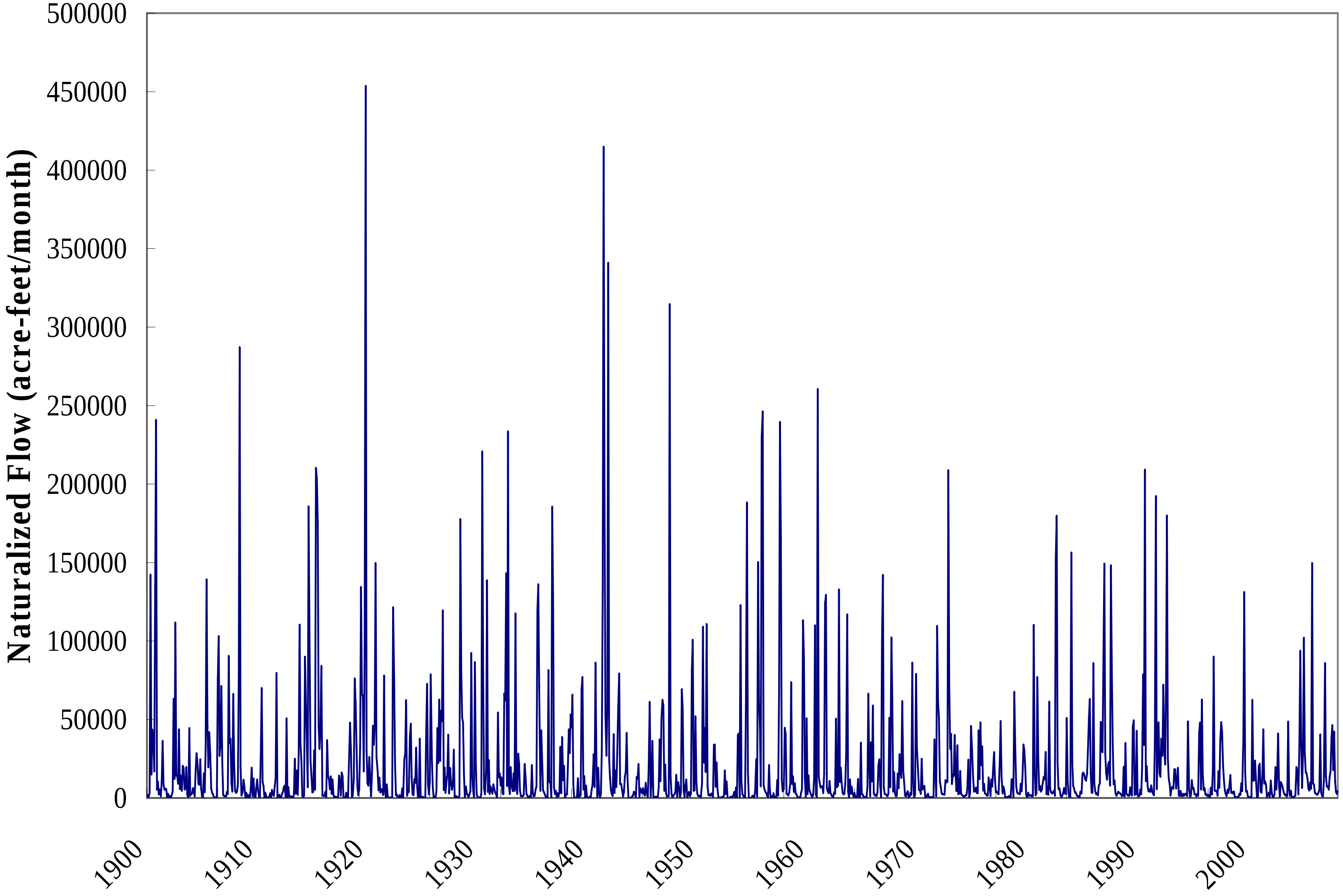

Figure A.11 Monthly Naturalized Flow at BRSE11 – Brazos River at Seymour

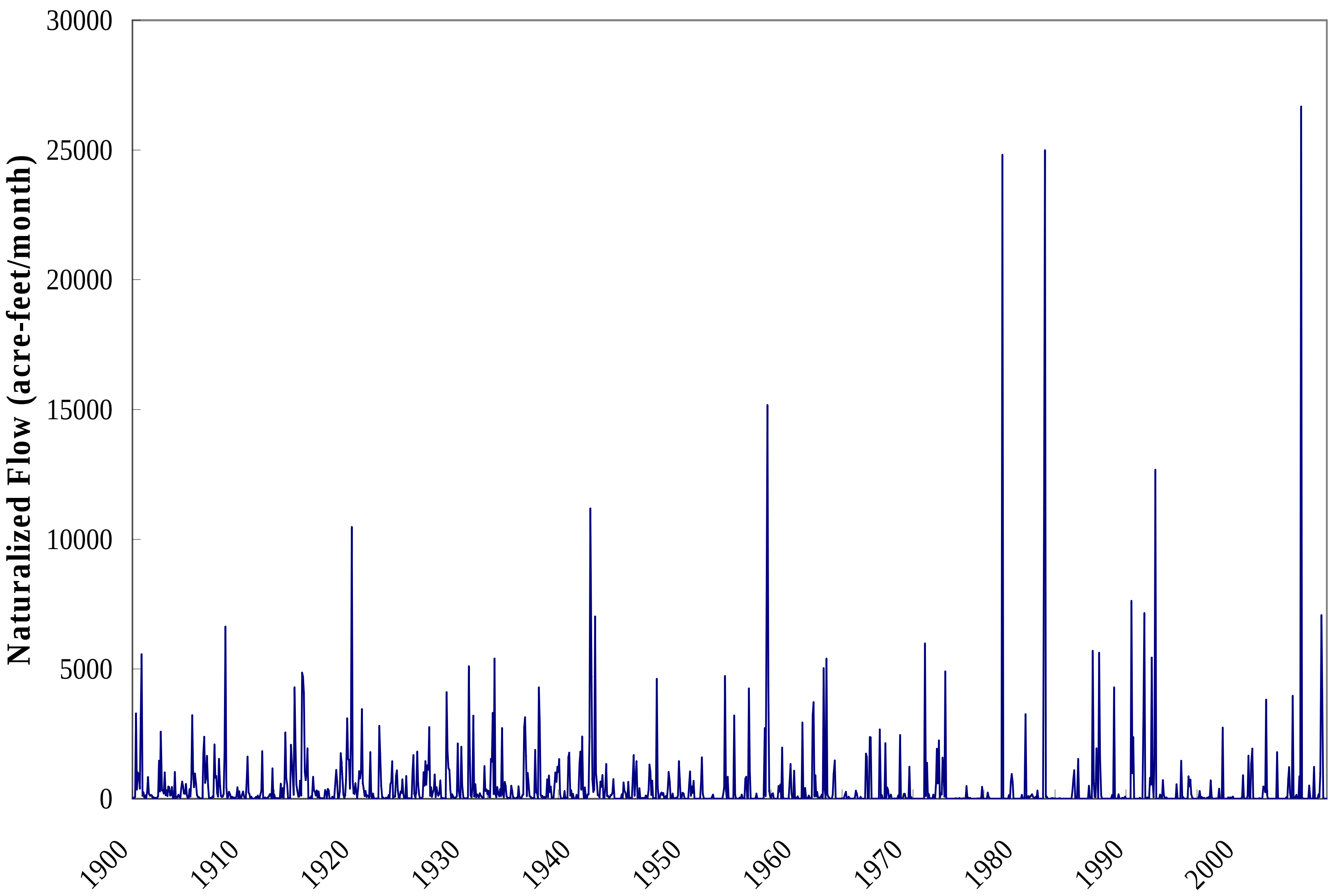

Figure A.12 Monthly Naturalized Flow at MSMN12 – Millers Creek near Munday

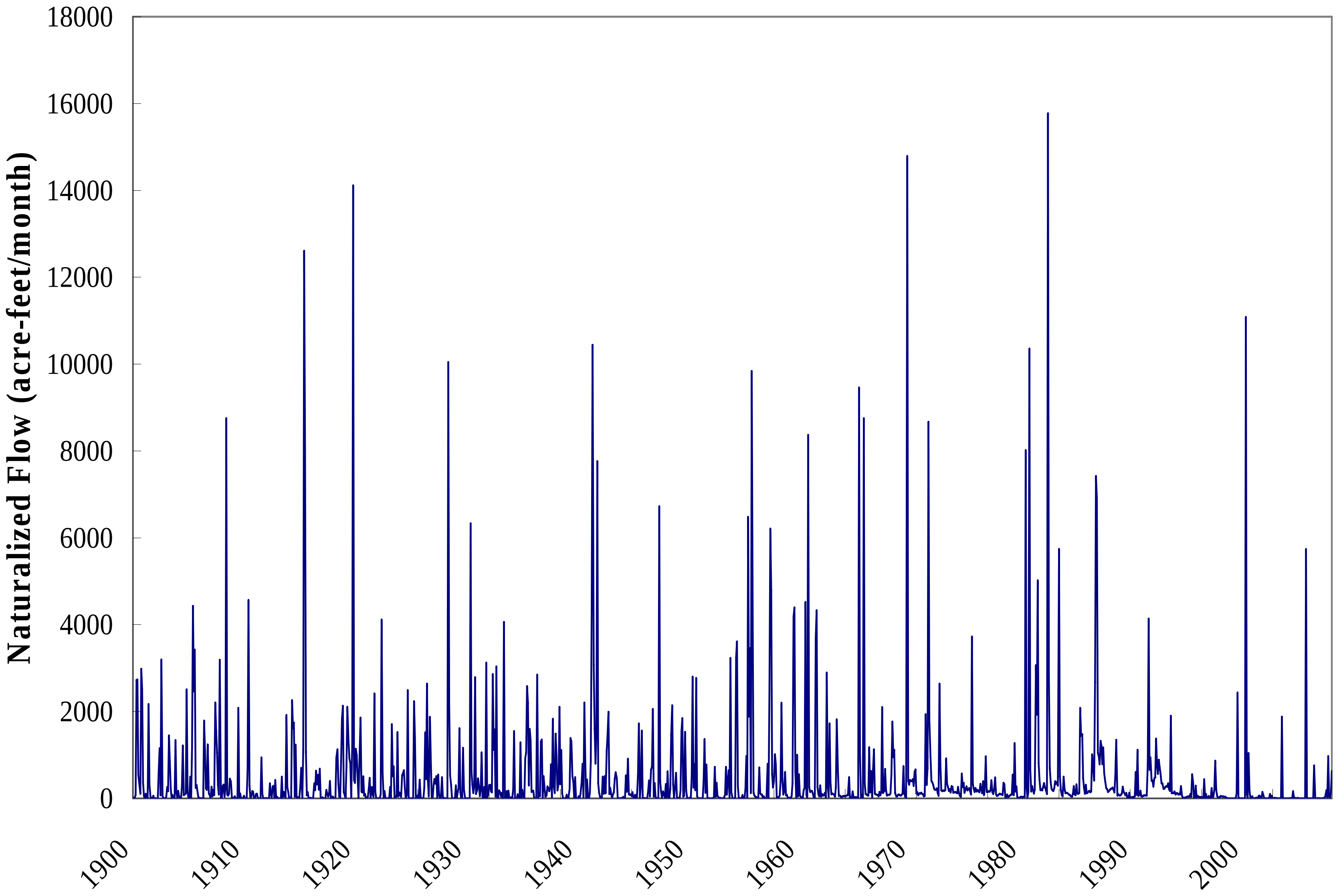

Figure A.13 Monthly Naturalized Flow at CFRO13 – Clear Fork Brazos River near Roby

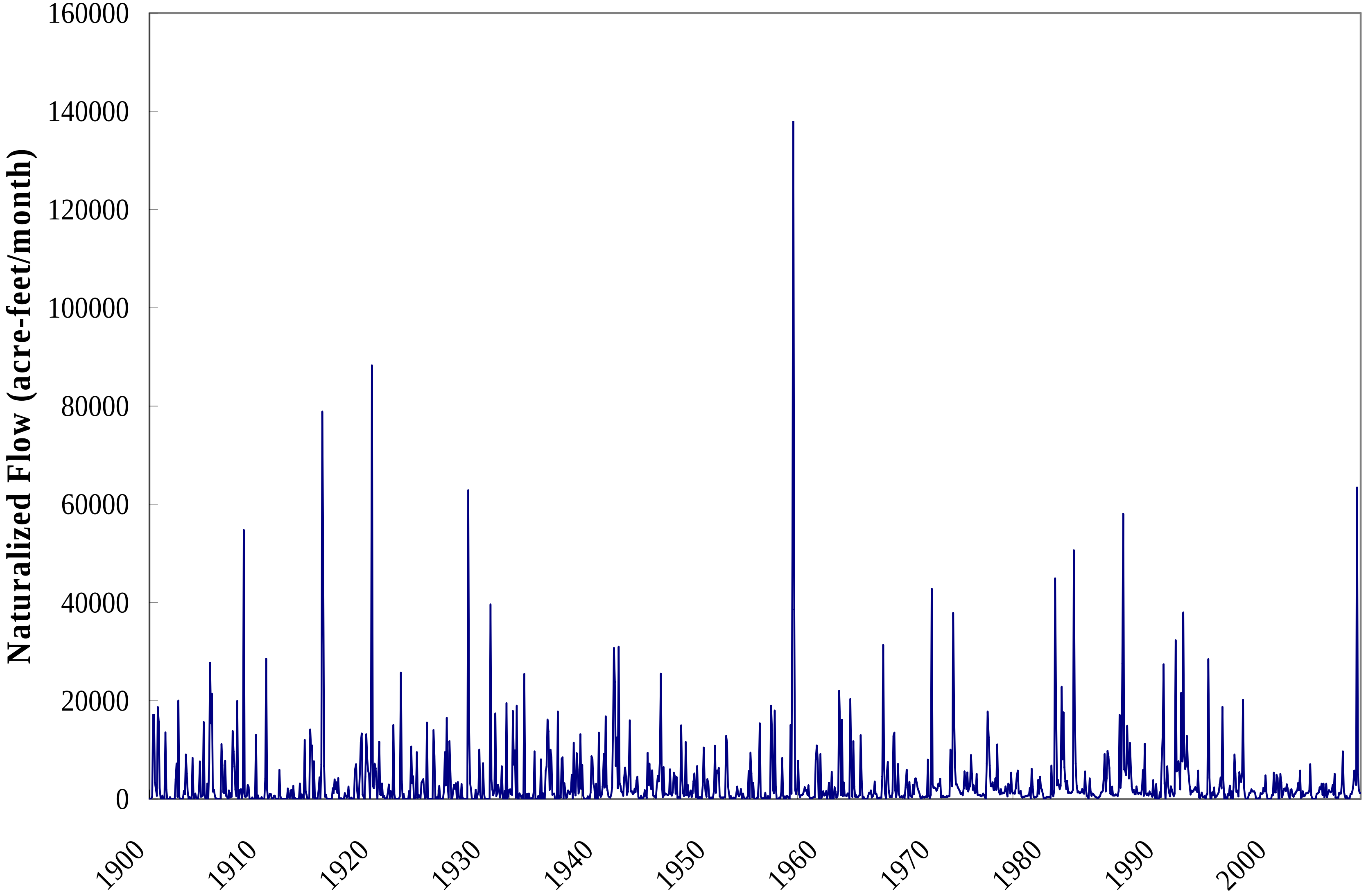

Figure A.14 Monthly Naturalized Flow at CFHA14 – Clear Fork Brazos River at Hawley

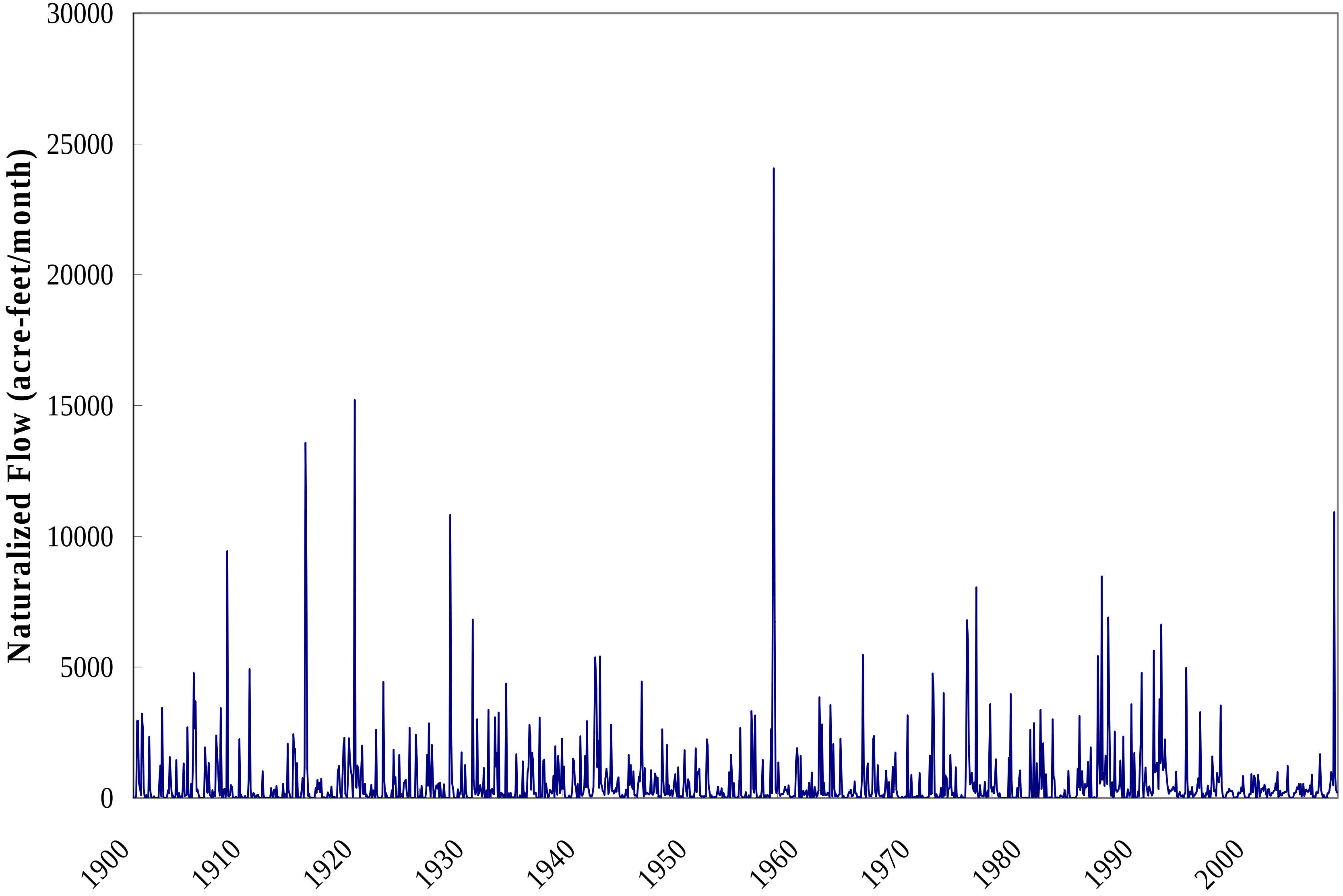

Figure A.15 Monthly Naturalized Flow at MUHA15 – Mulberry Creek near Hawley

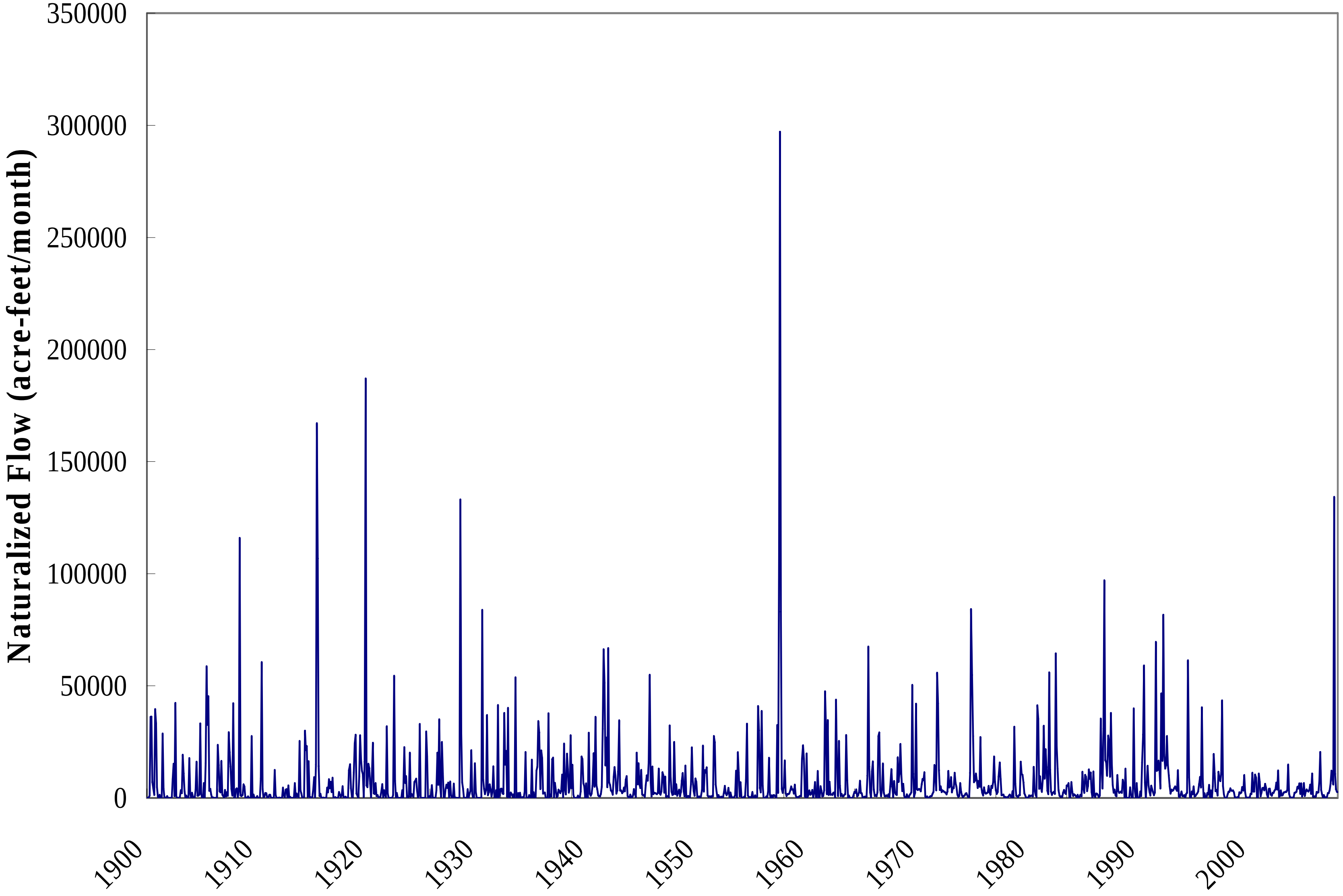

Figure A.16 Monthly Naturalized Flow at CFNU16 – Clear Fork Brazos River at Nugent

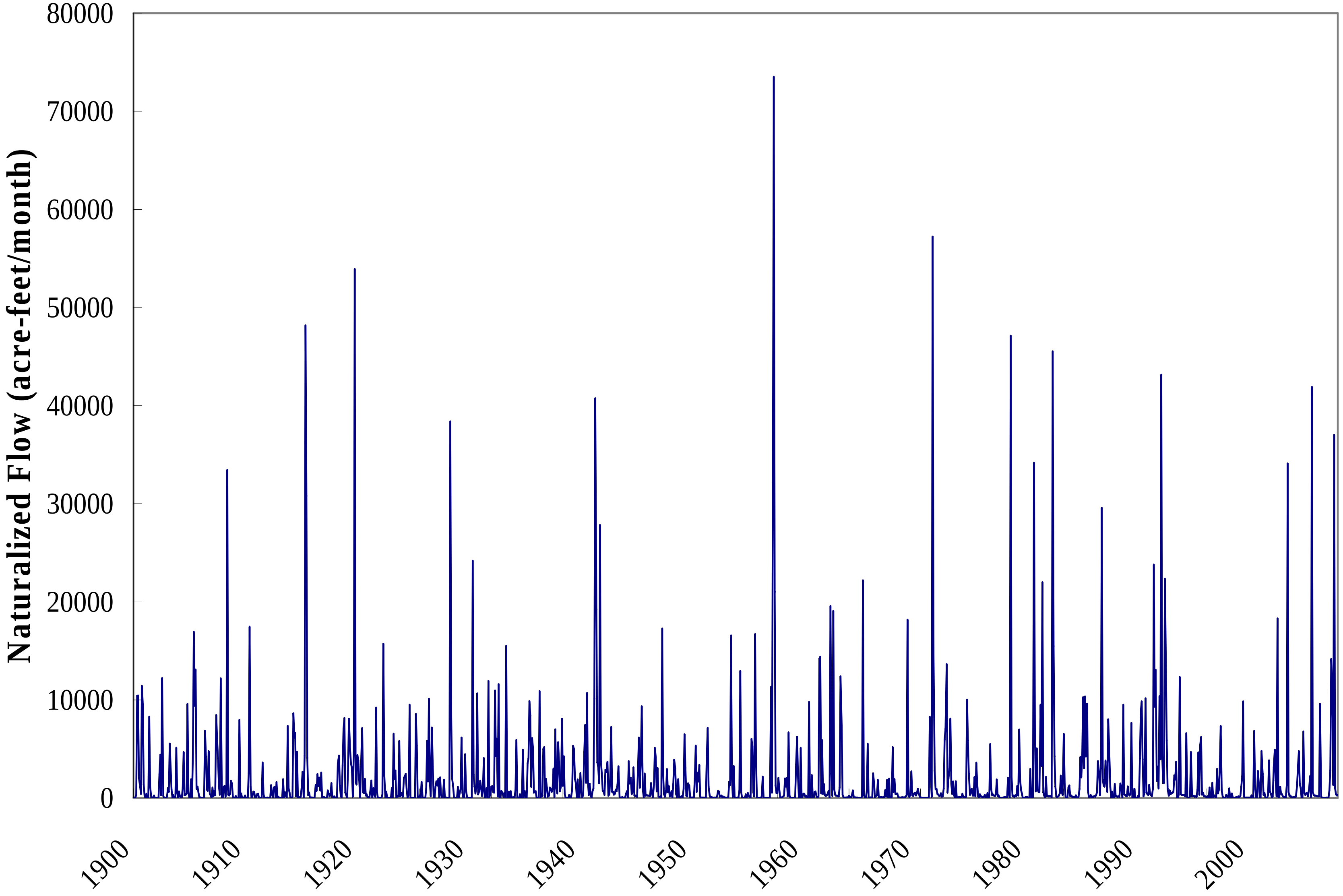

Figure A.17 Monthly Naturalized Flow at CAST17 – California Creek near Stamford

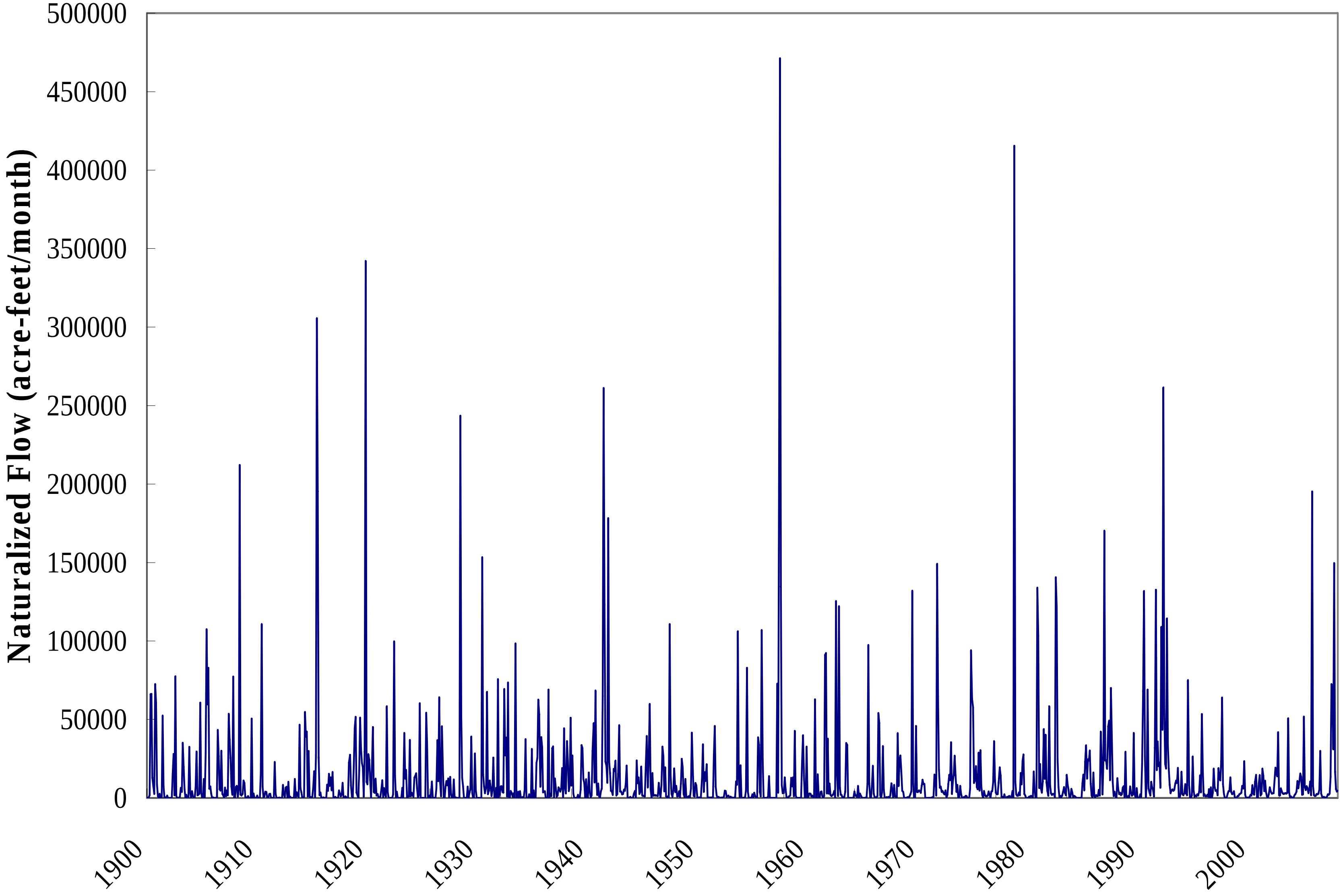

Figure A.18 Monthly Naturalized Flow at CFFG18 – Clear Fork Brazos River at Fort Griffin

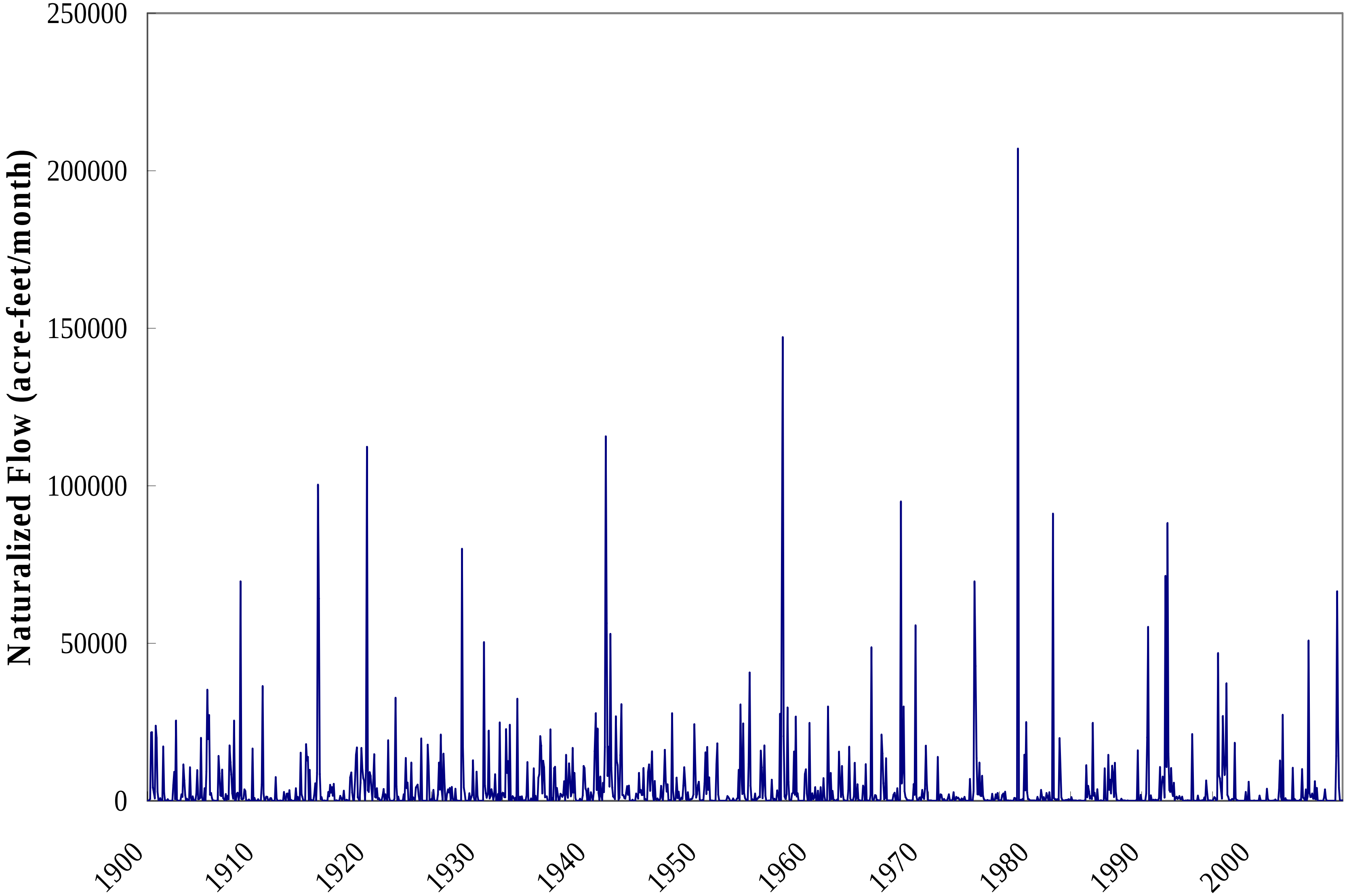

Figure A.19 Monthly Naturalized Flow at HCAL19 – Hubbard Creek below Albany

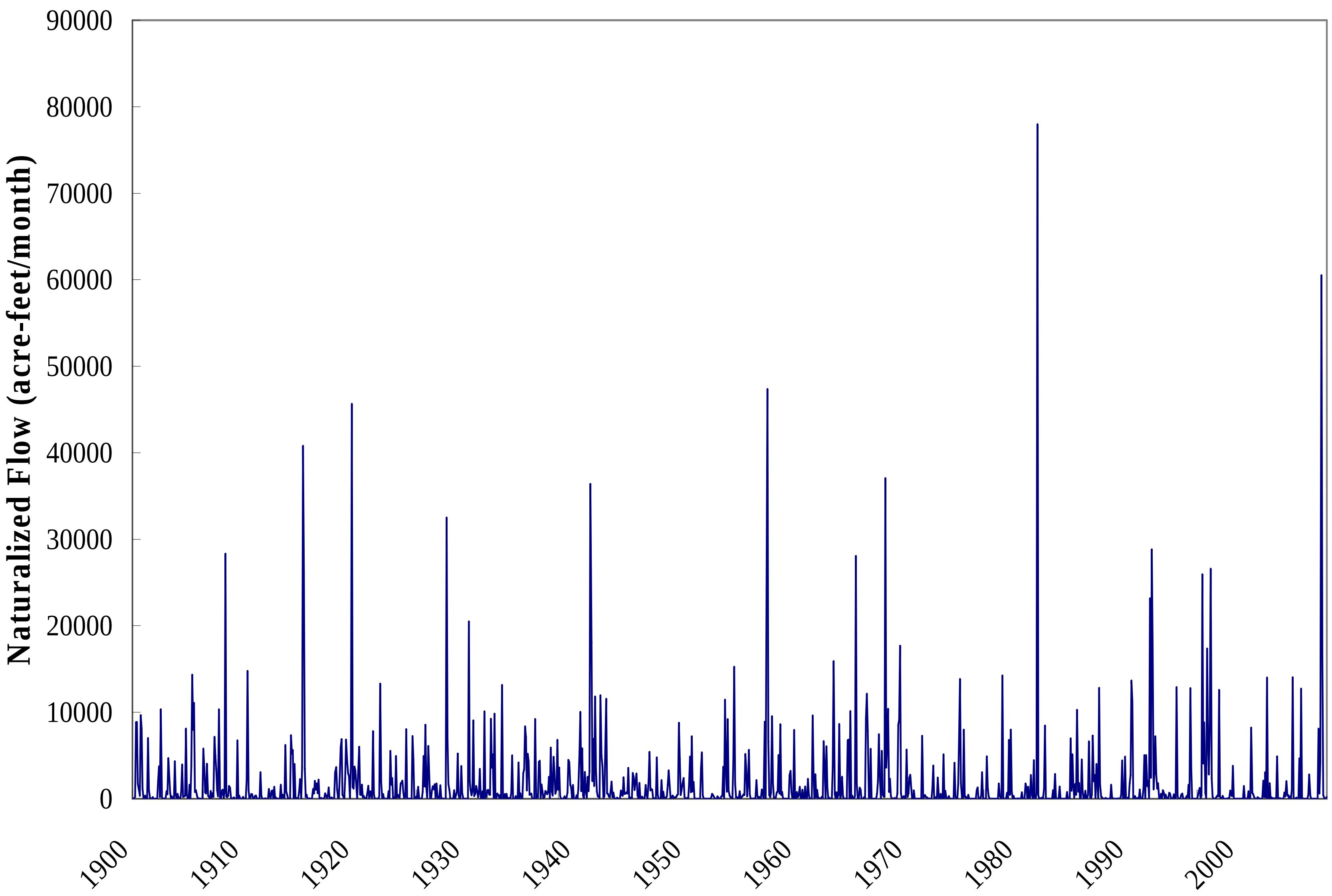

Figure A.20 Monthly Naturalized Flow at BSBR20 – Big Sandy Creek above Breckenridge

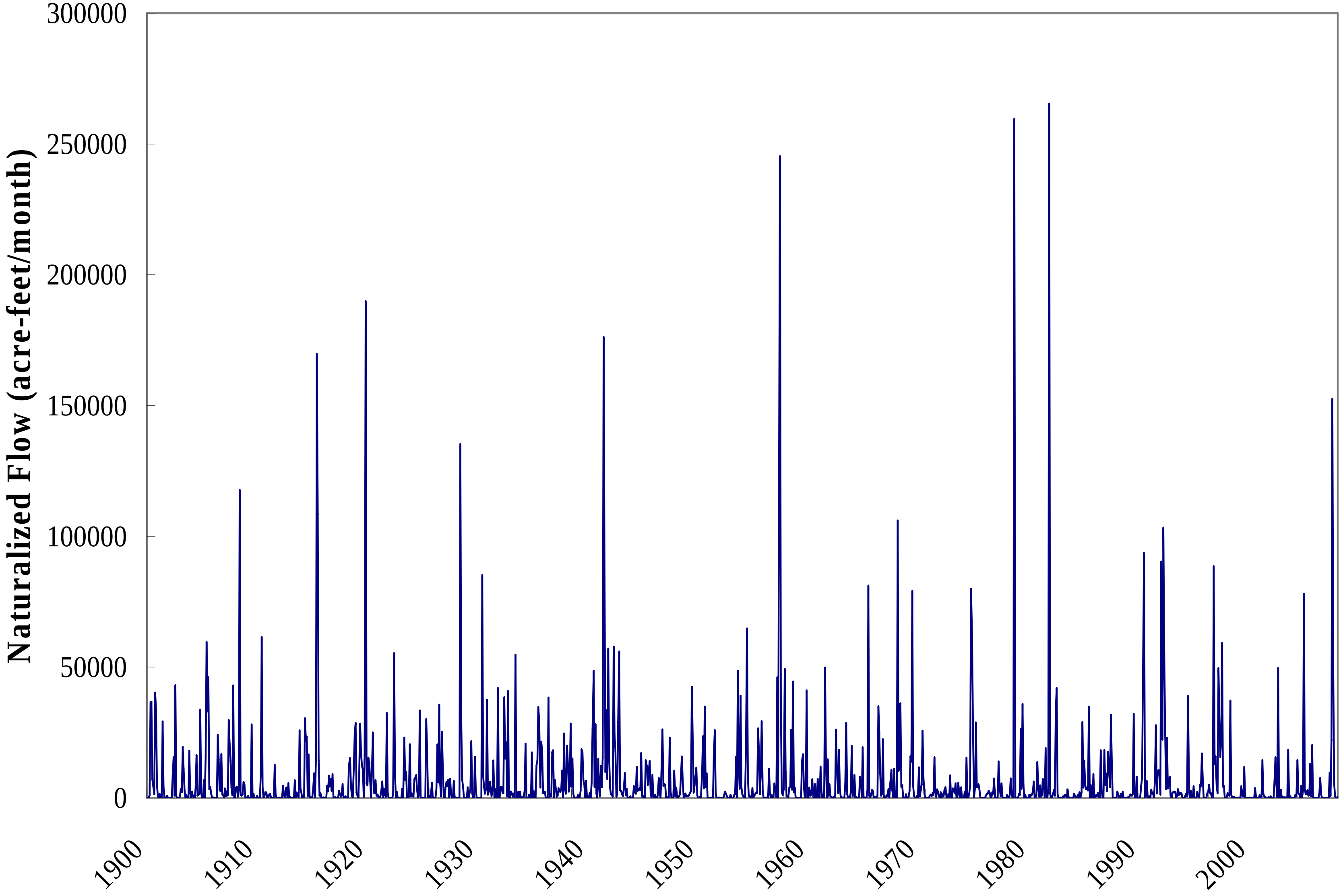

Figure A.21 Monthly Naturalized Flow at HCBR21 – Hubbard Creek near Breckenridge

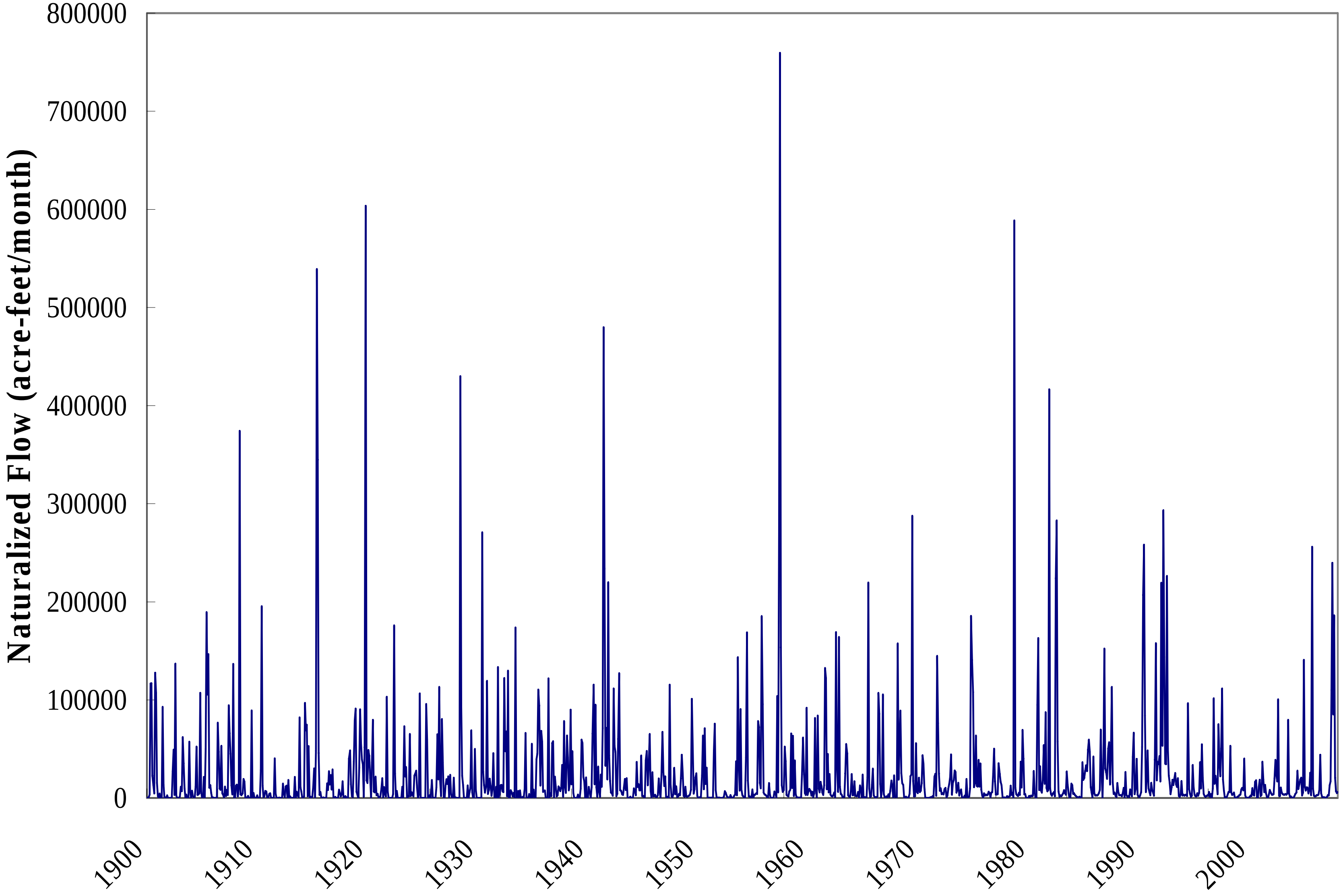

Figure A.22 Monthly Naturalized Flow at CFEL22 – Clear Fork Brazos River at Eliasville

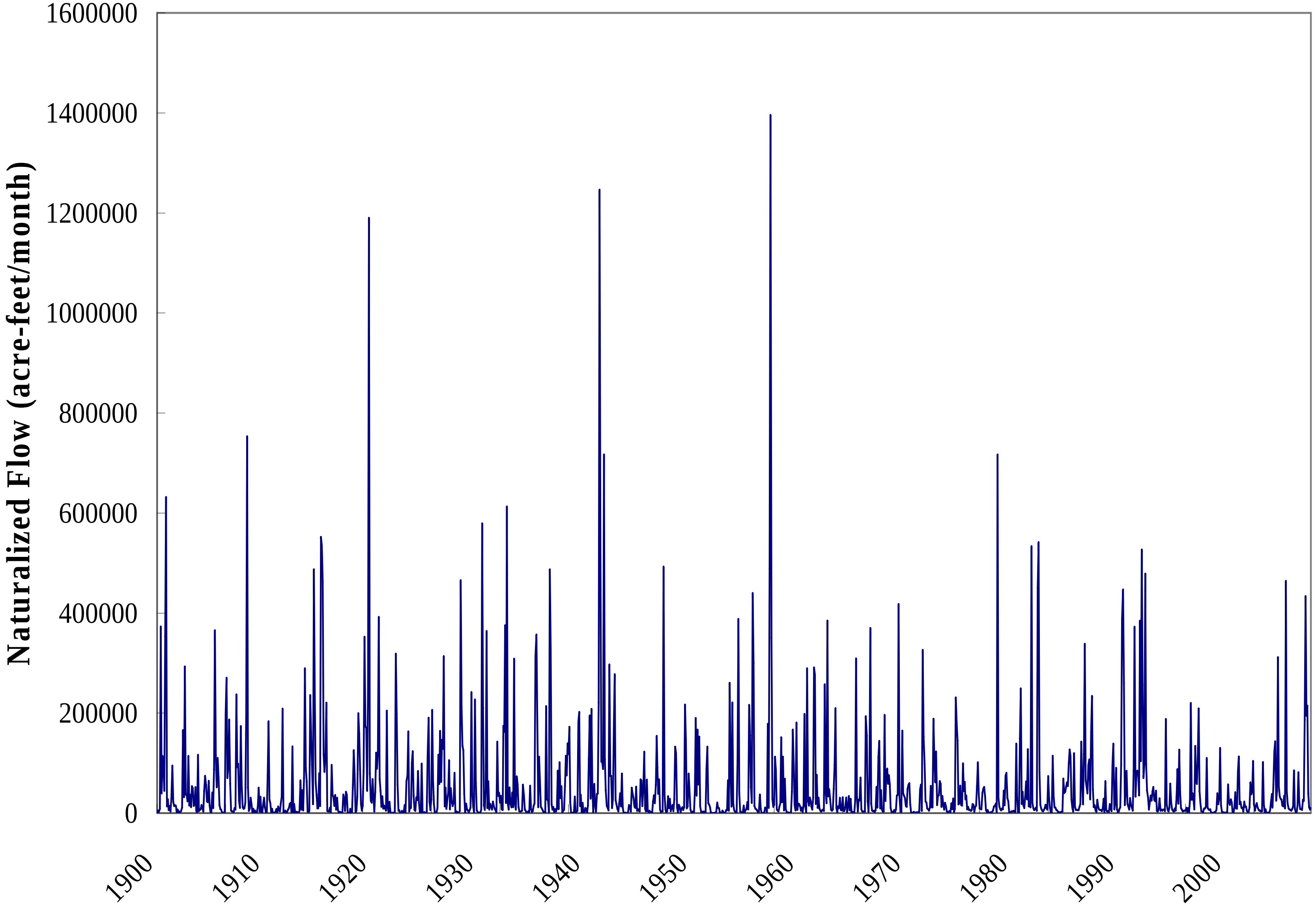

Figure A.23 Monthly Naturalized Flow at BRSB23 – Brazos River near South Bend

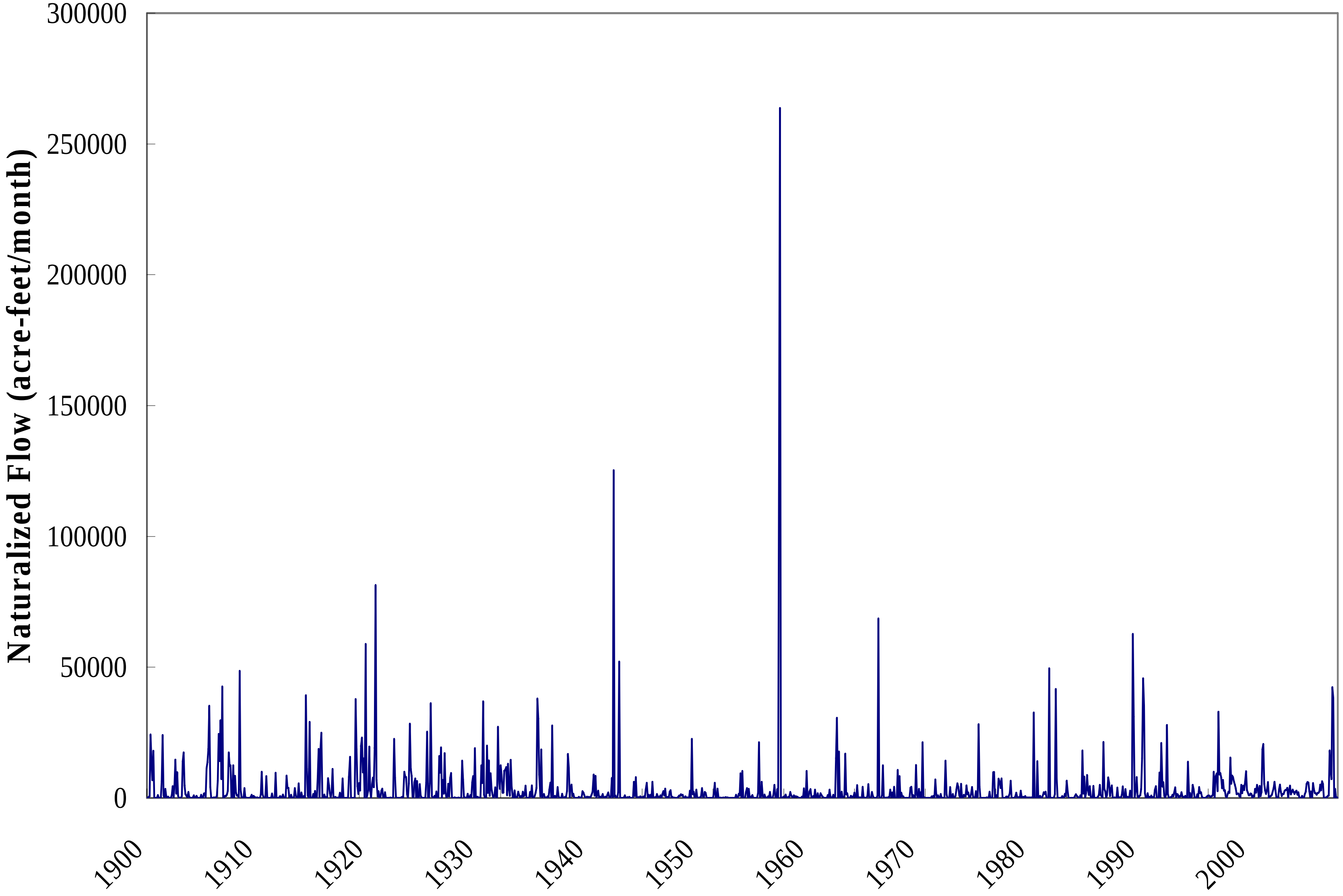

Figure A.24 Monthly Naturalized Flow at GHGH24 – Lake Graham near Graham

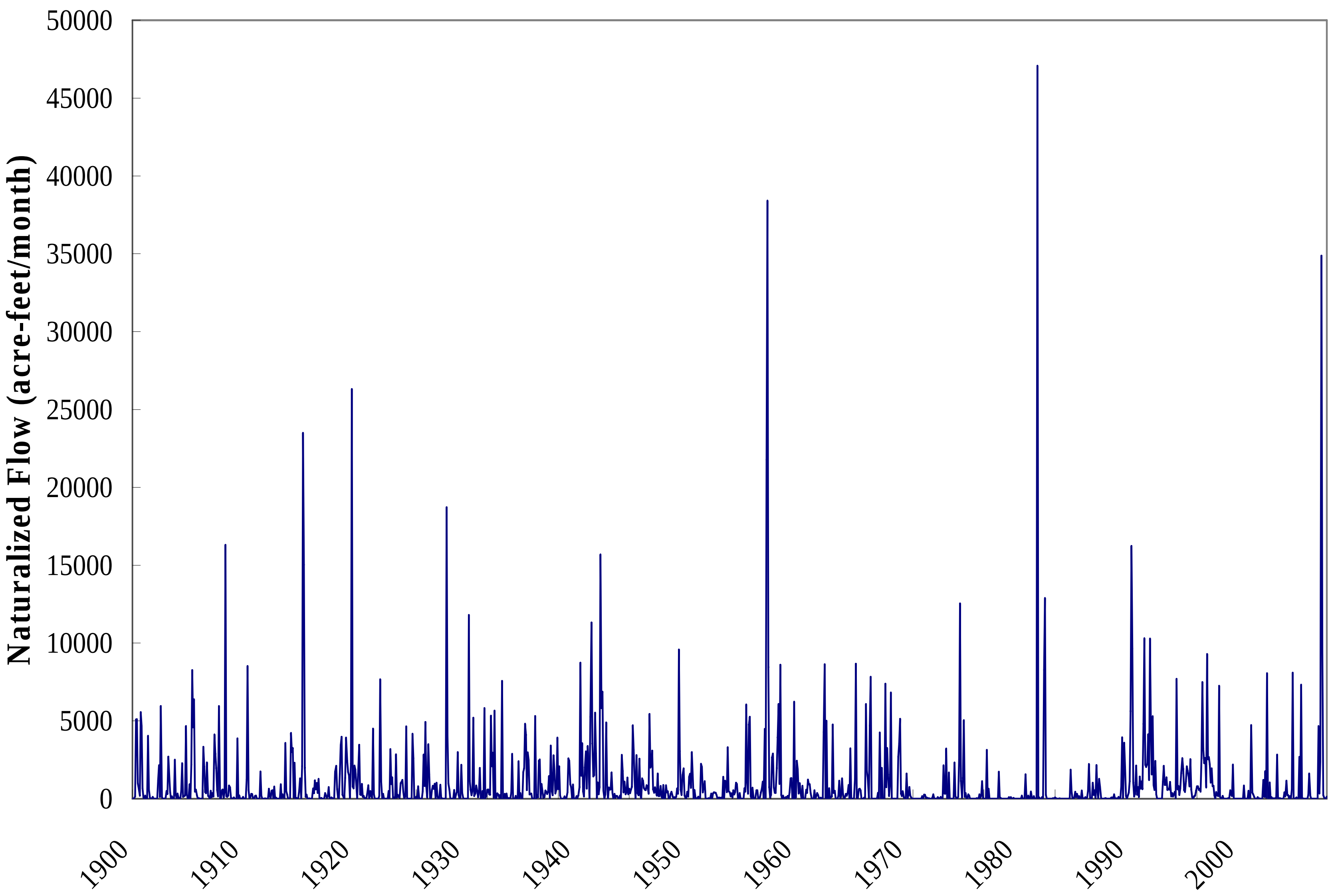

Figure A.25 Monthly Naturalized Flow at CCIV25 – Big Cedar Creek near Ivan

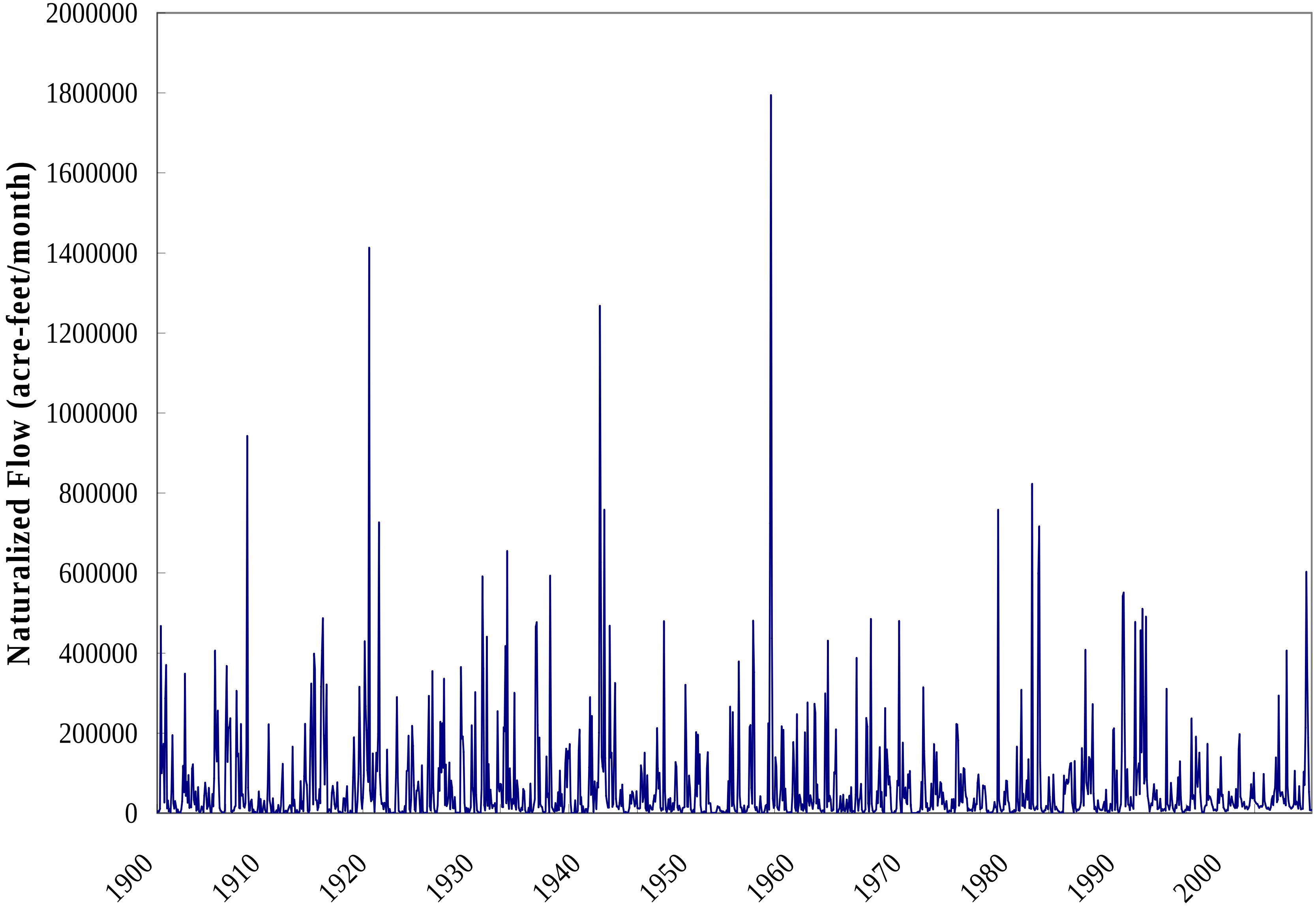

Figure A.26 Monthly Naturalized Flow at SHGR26 – Brazos River at Morris Sheppard Dam near Graford

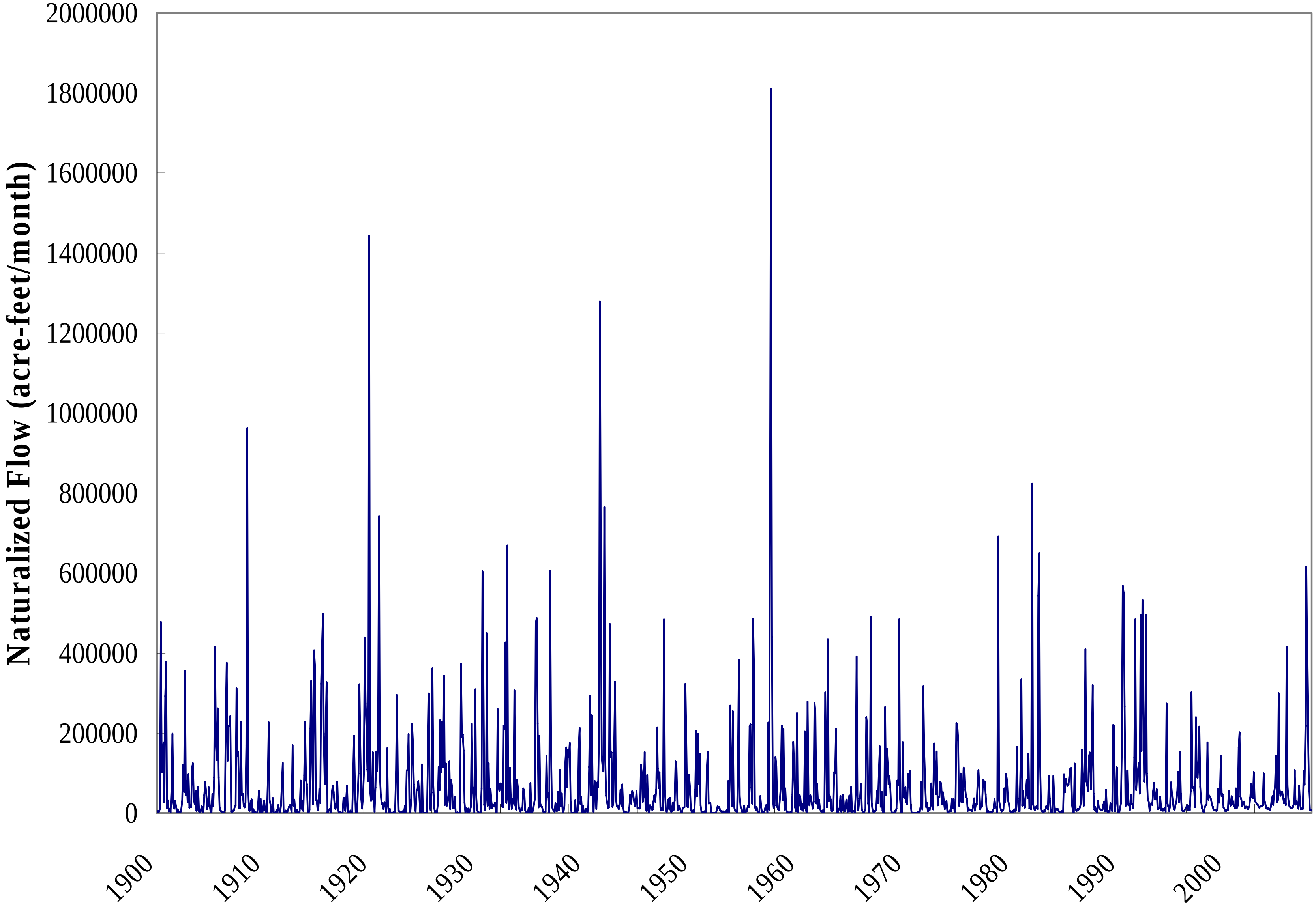

Figure A.27 Monthly Naturalized Flow at BRPP27 – Brazos River near Palo Pinto

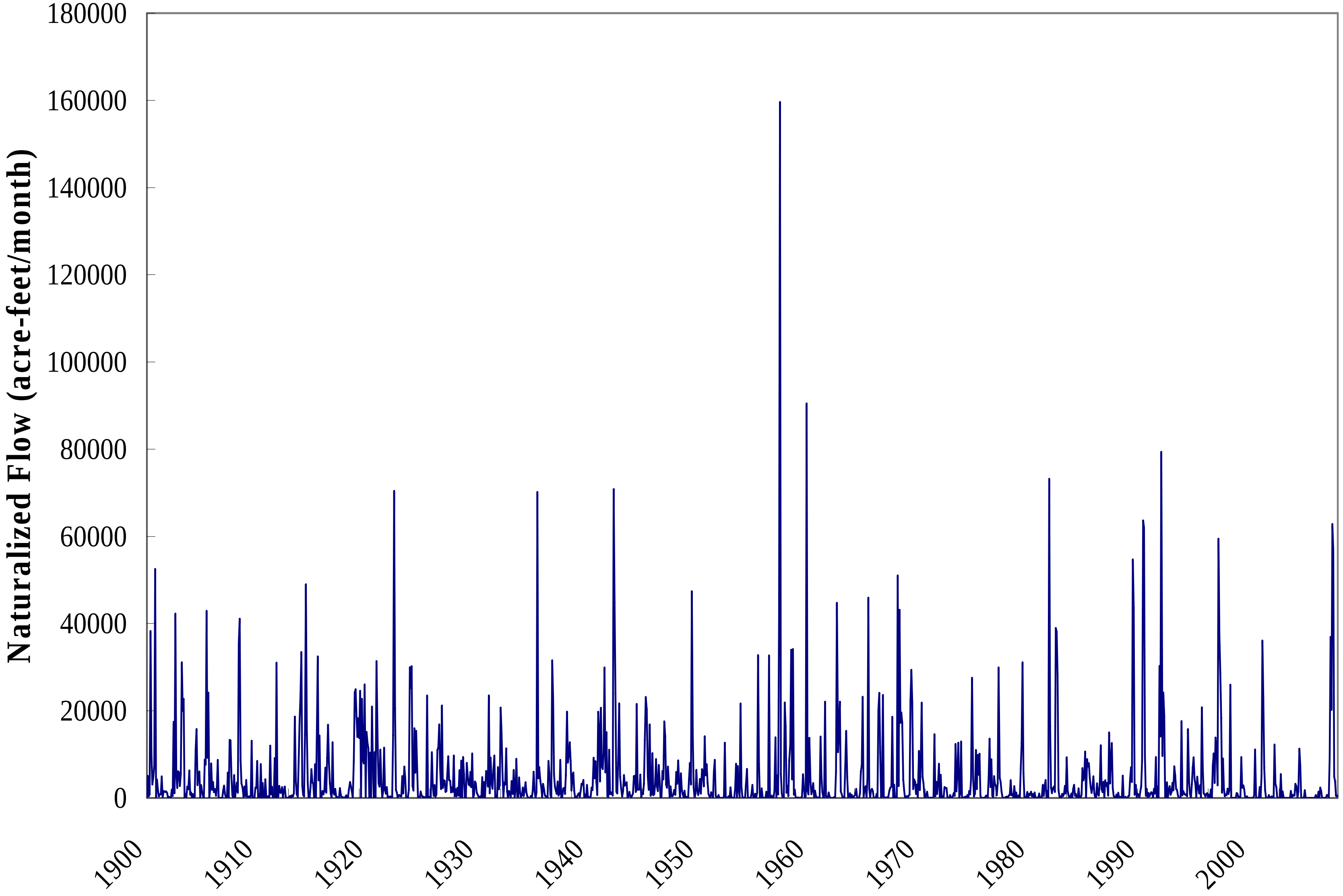

Figure A.28 Monthly Naturalized Flow at PPSA28 – Palo Pinto Creek near Santo

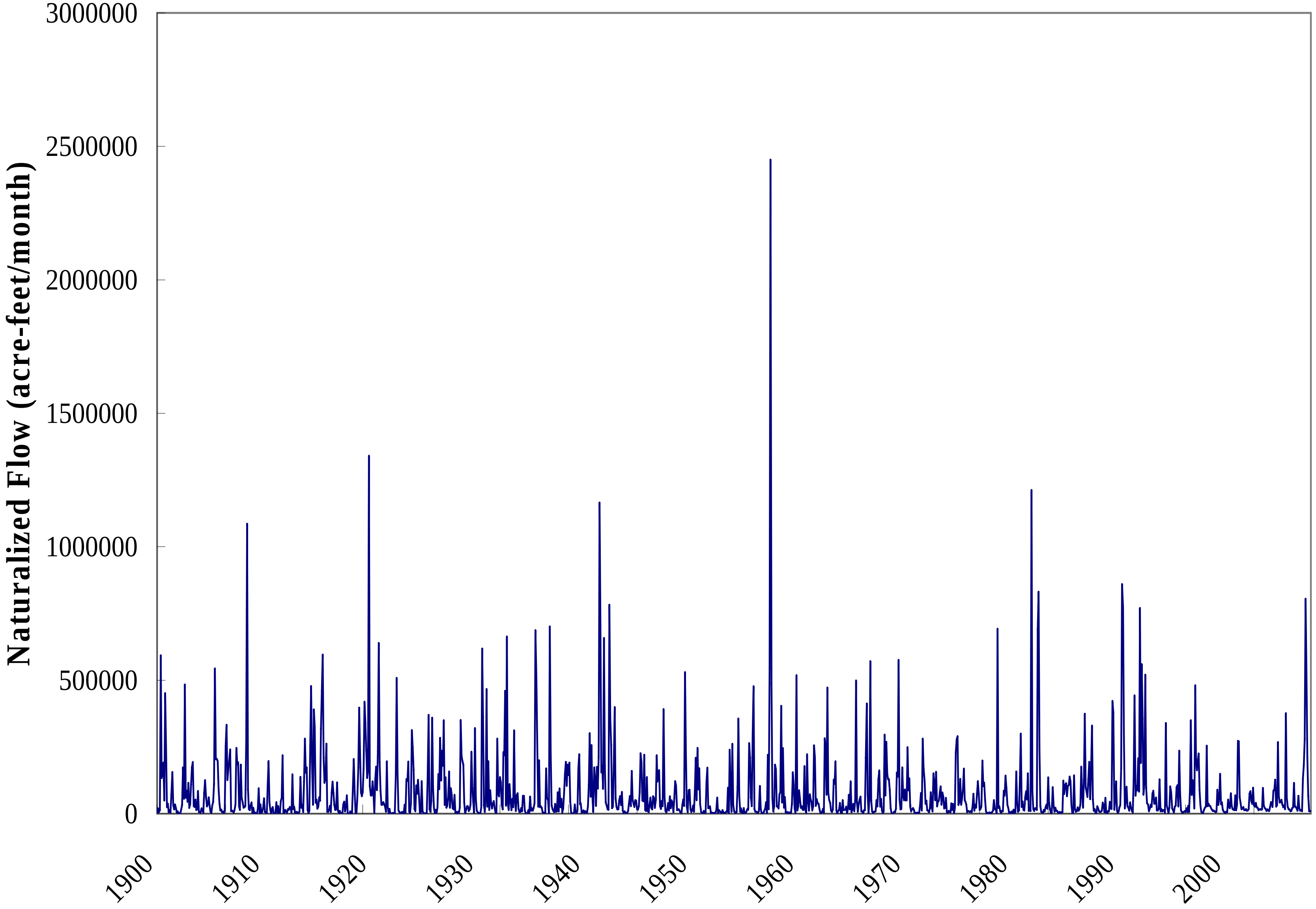

Figure A.29 Monthly Naturalized Flow at BRDE29 – Brazos River near Dennis

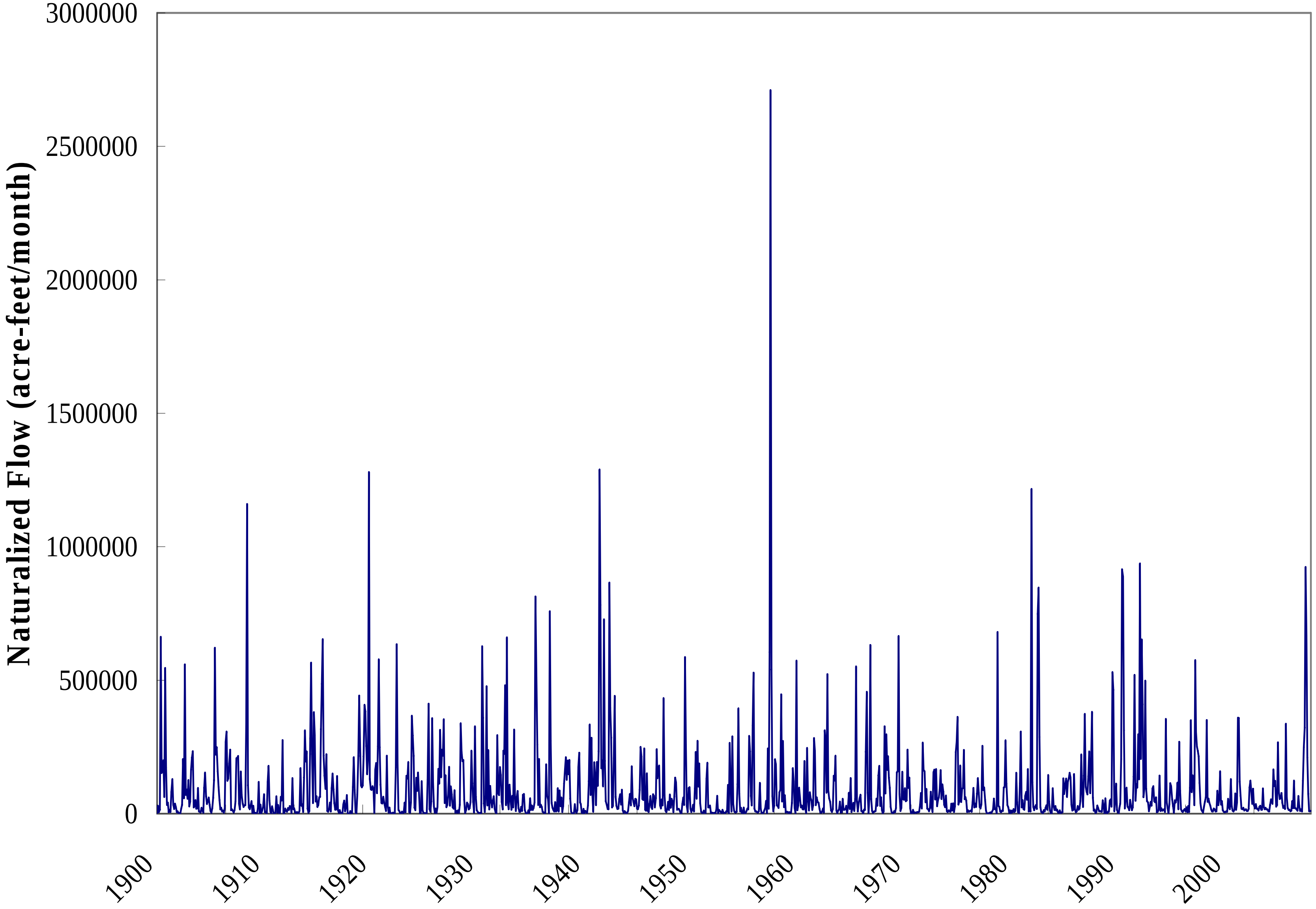

Figure A.30 Monthly Naturalized Flow at BRGR30 – Brazos River near Glen Rose

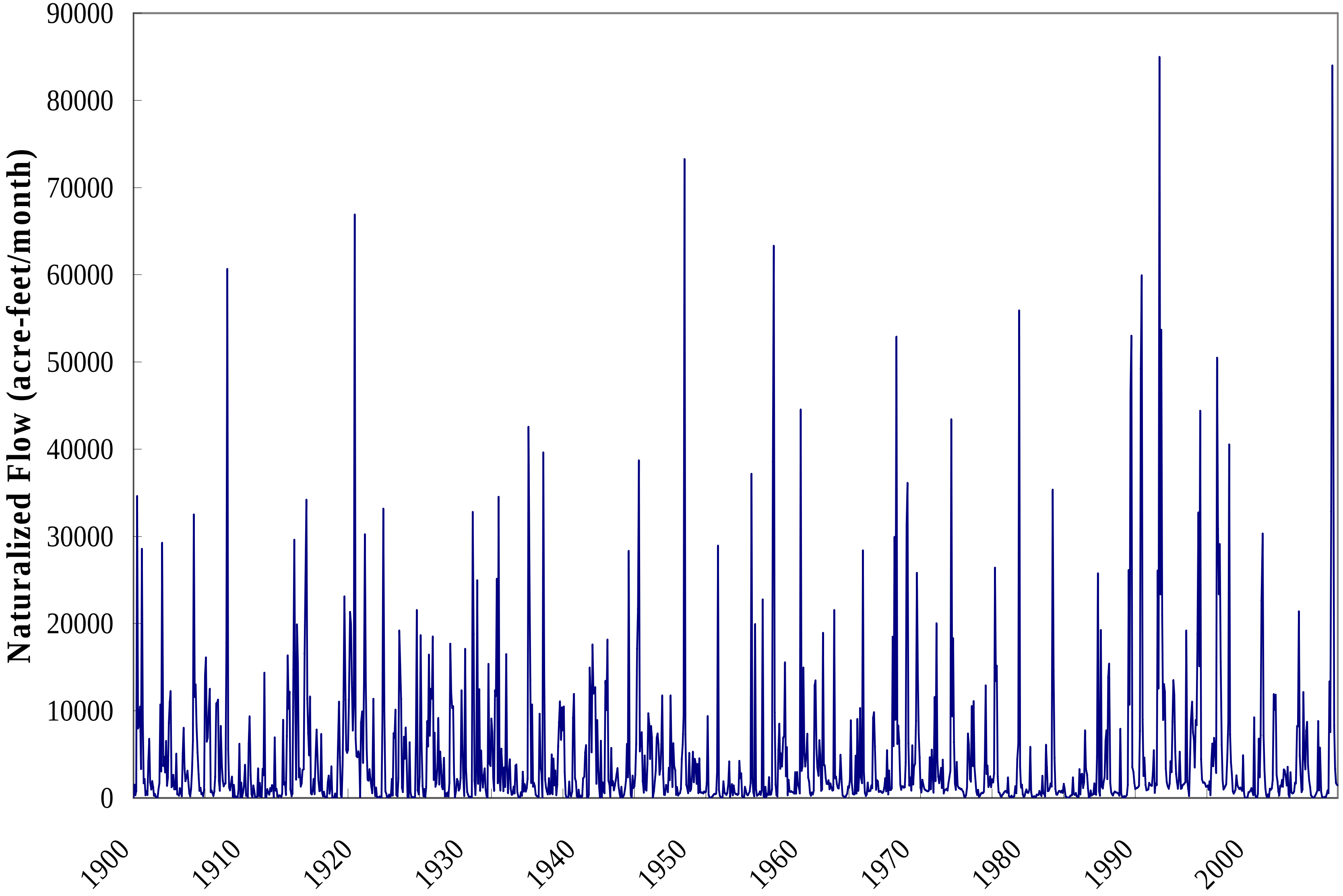

Figure A.31 Monthly Naturalized Flow at PAGR31 – Paluxy River at Glen Rose

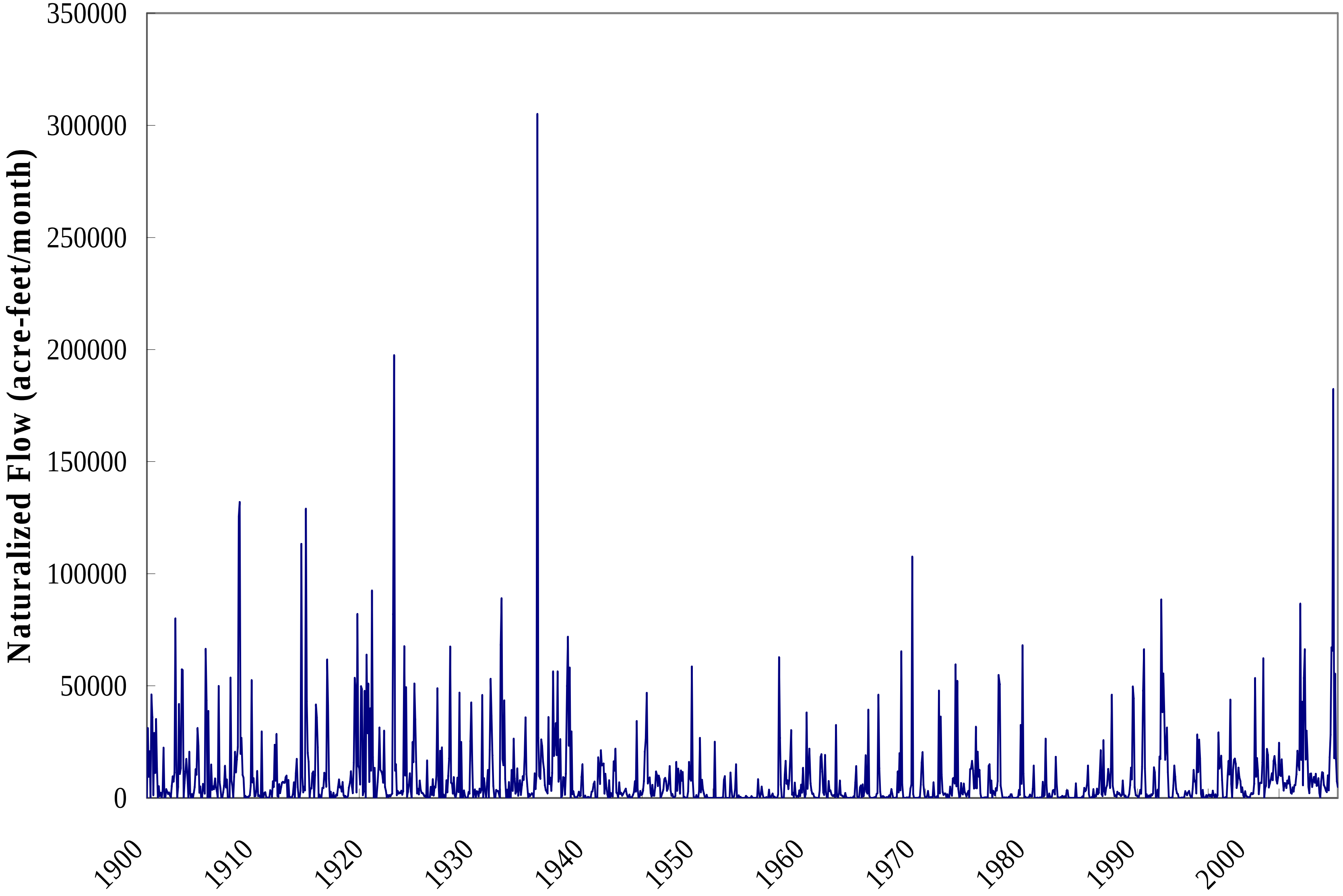

Figure A.32 Monthly Naturalized Flow at NRBL32 – Nolan River at Blum

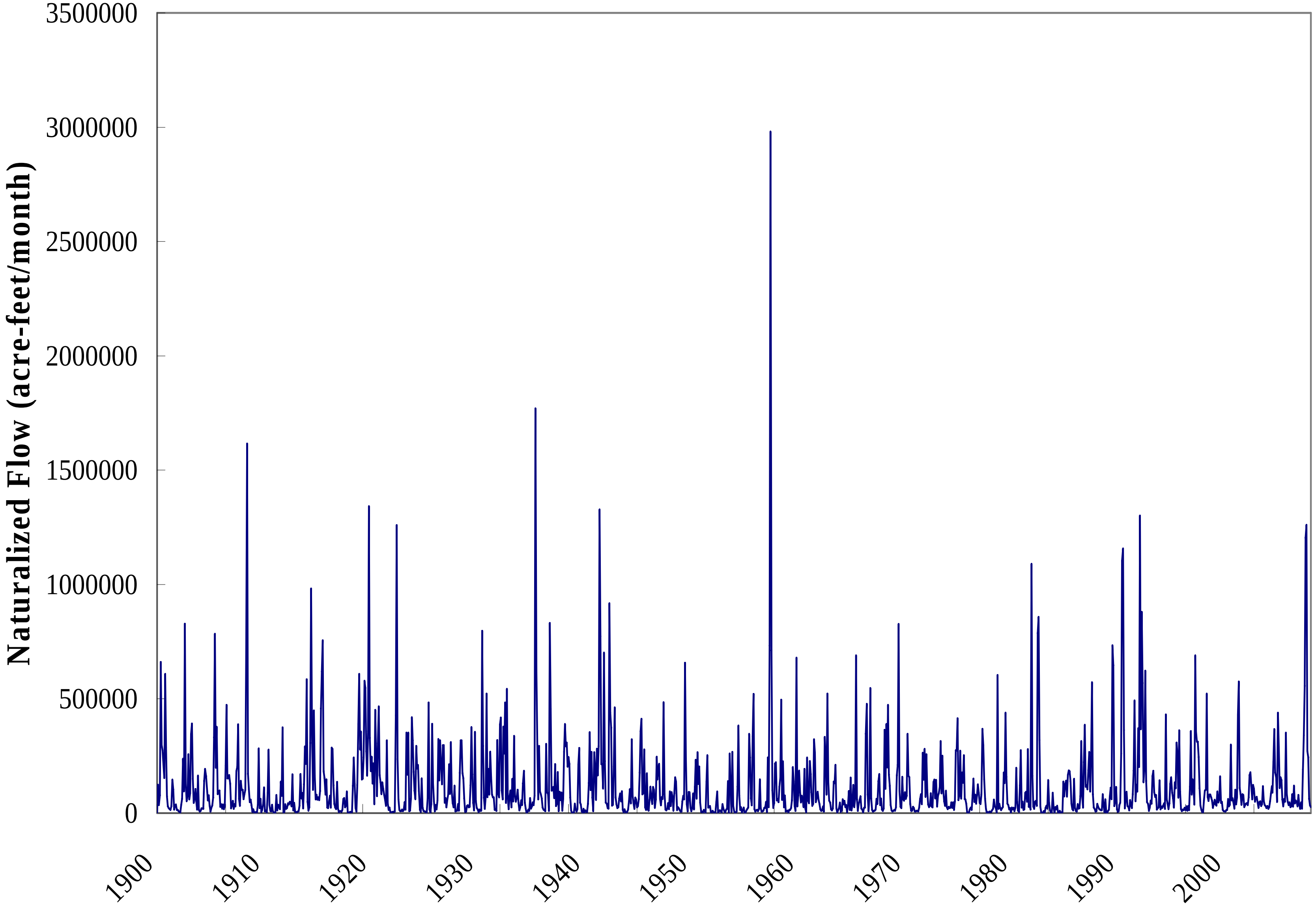

Figure A.33 Monthly Naturalized Flow at BRAQ33 – Brazos River near Aquilla

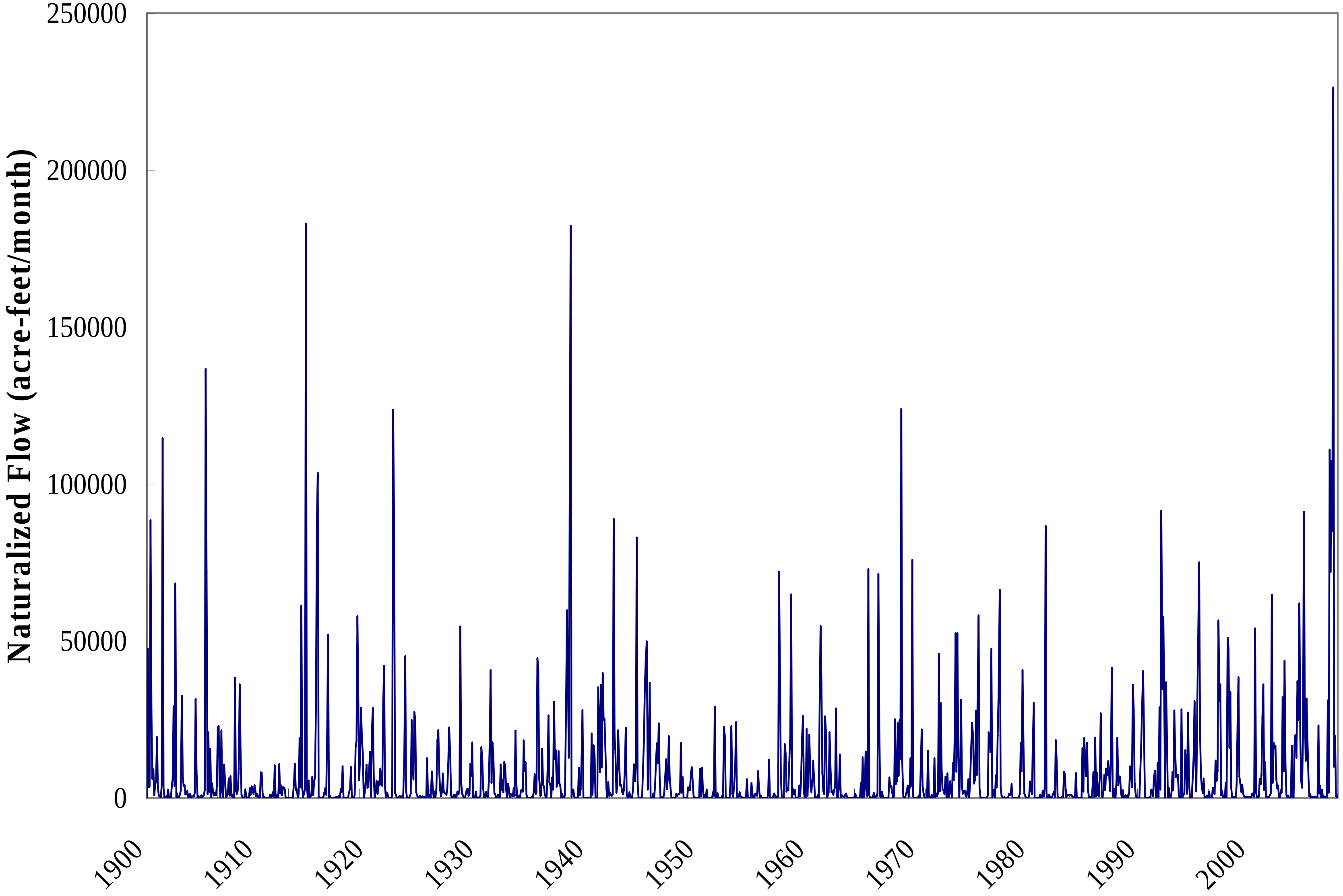

Figure A.34 Monthly Naturalized Flow at AQAQ34 – Aquilla Creek near Aquilla

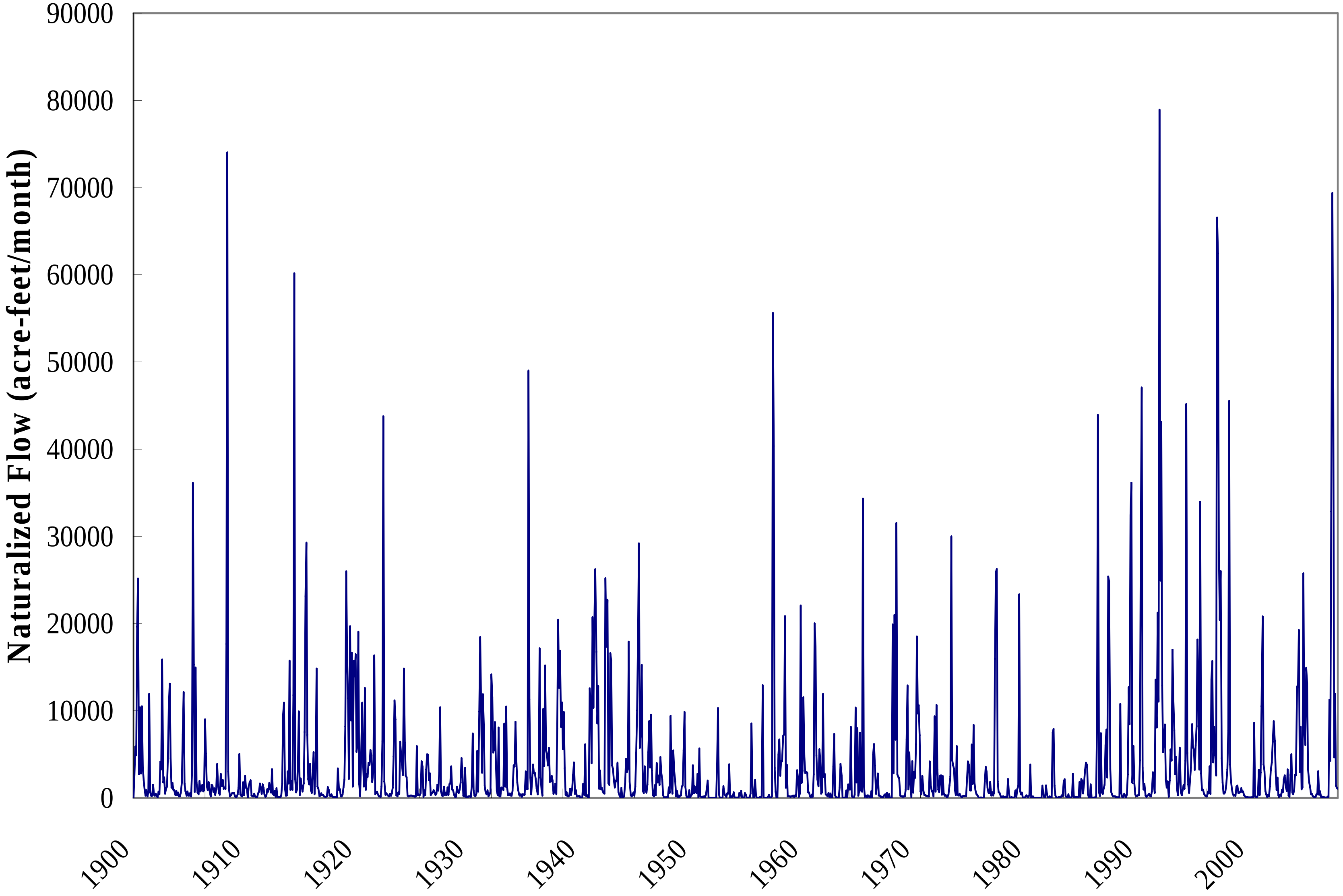

Figure A.35 Monthly Naturalized Flow at NBHI35 – North Bosque River at Hico

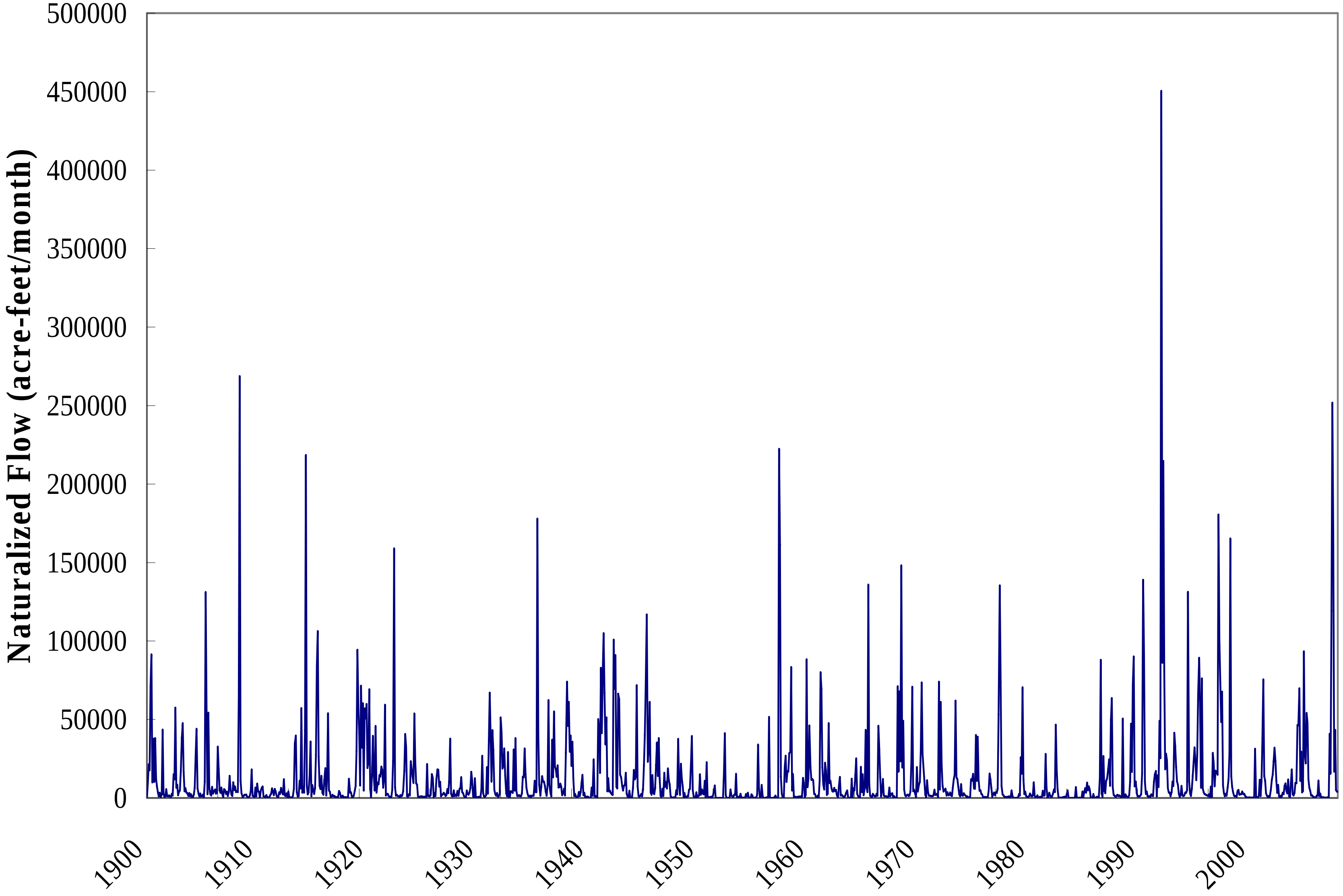

Figure A.36 Monthly Naturalized Flow at NBCL36 – North Bosque River near Clifton

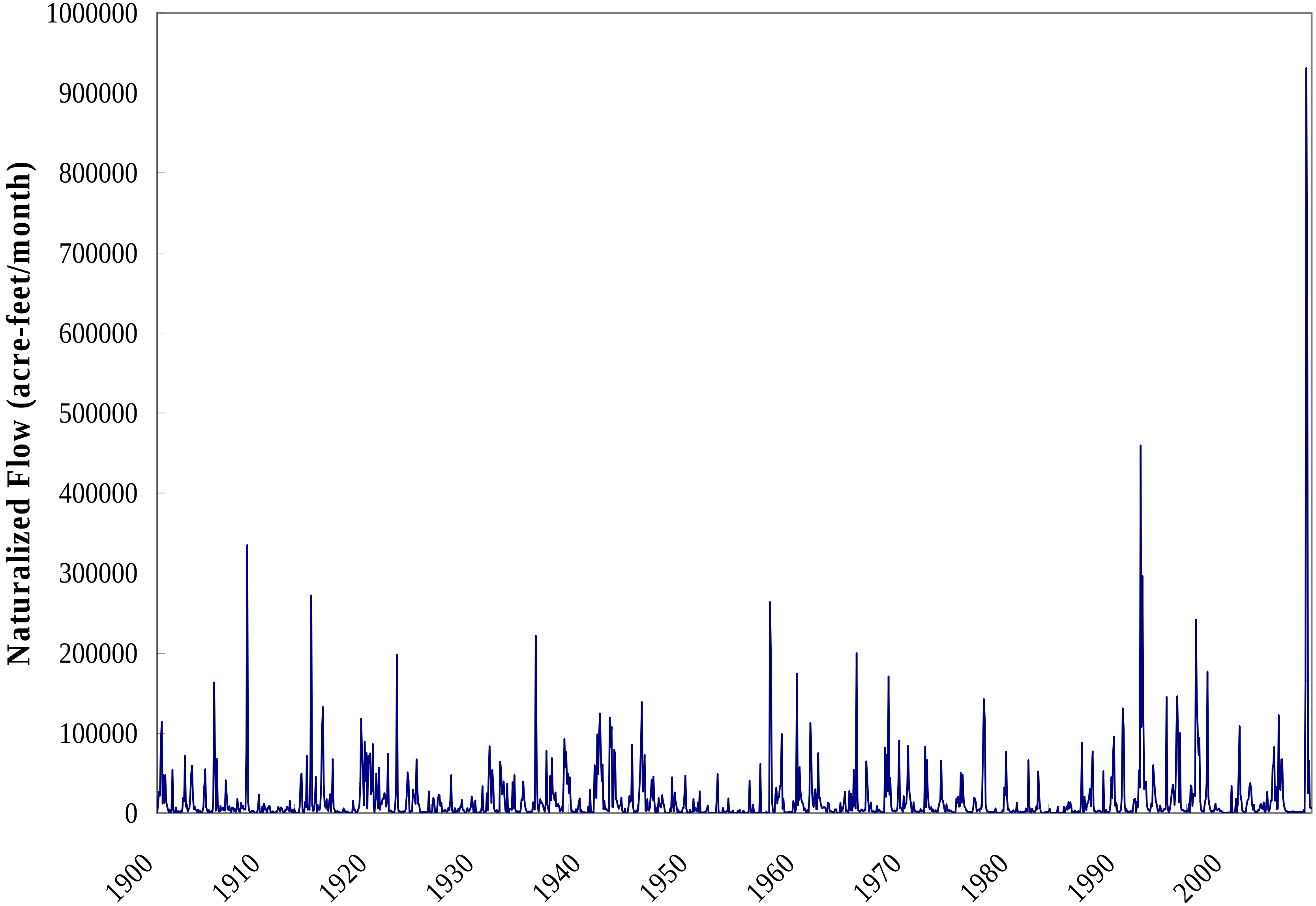

Figure A.37 Monthly Naturalized Flow at NBVM37 – North Bosque River at Valley Mills

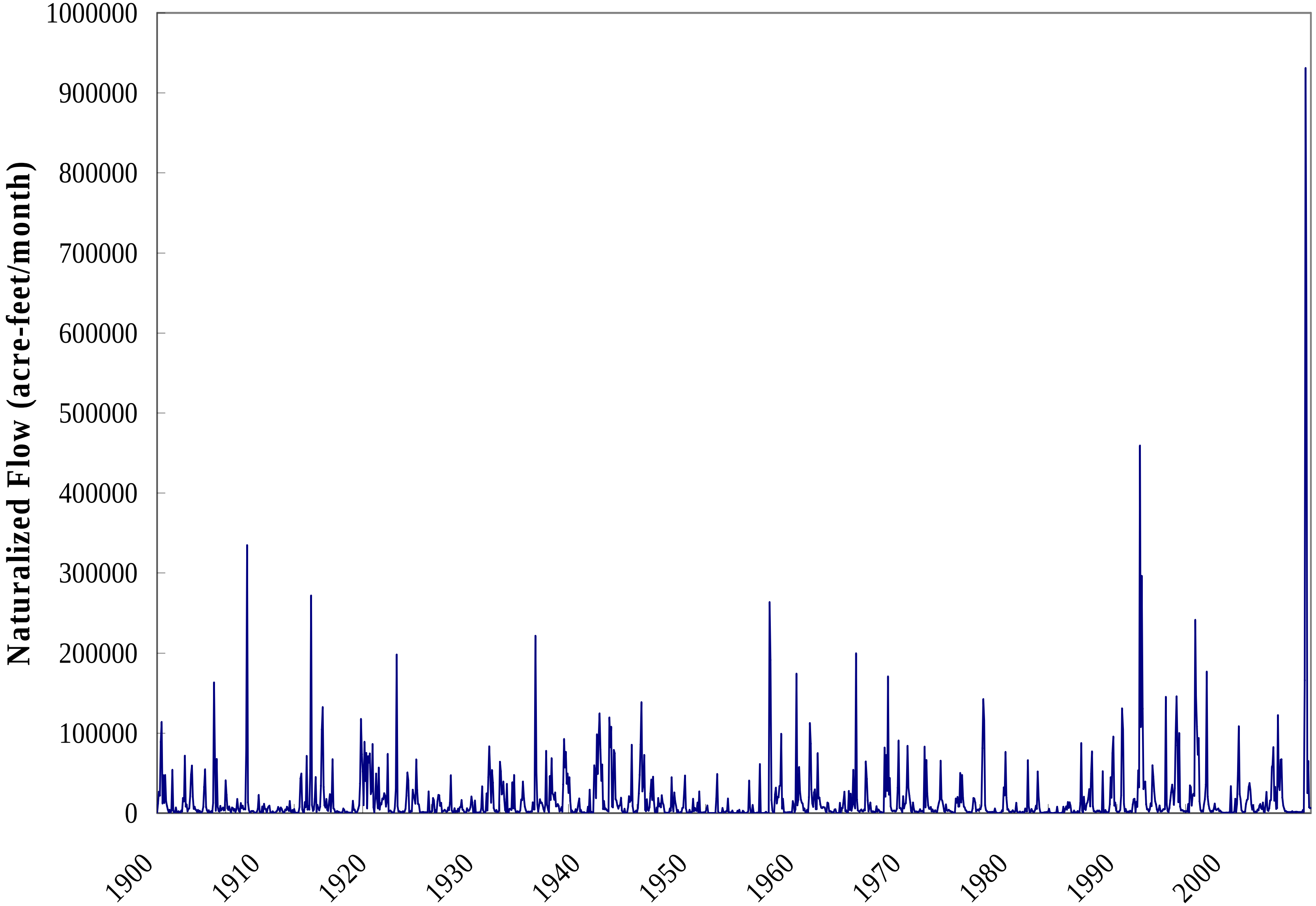

Figure A.38 Monthly Naturalized Flow at MBMG38 – Middle Bosque River near McGregor

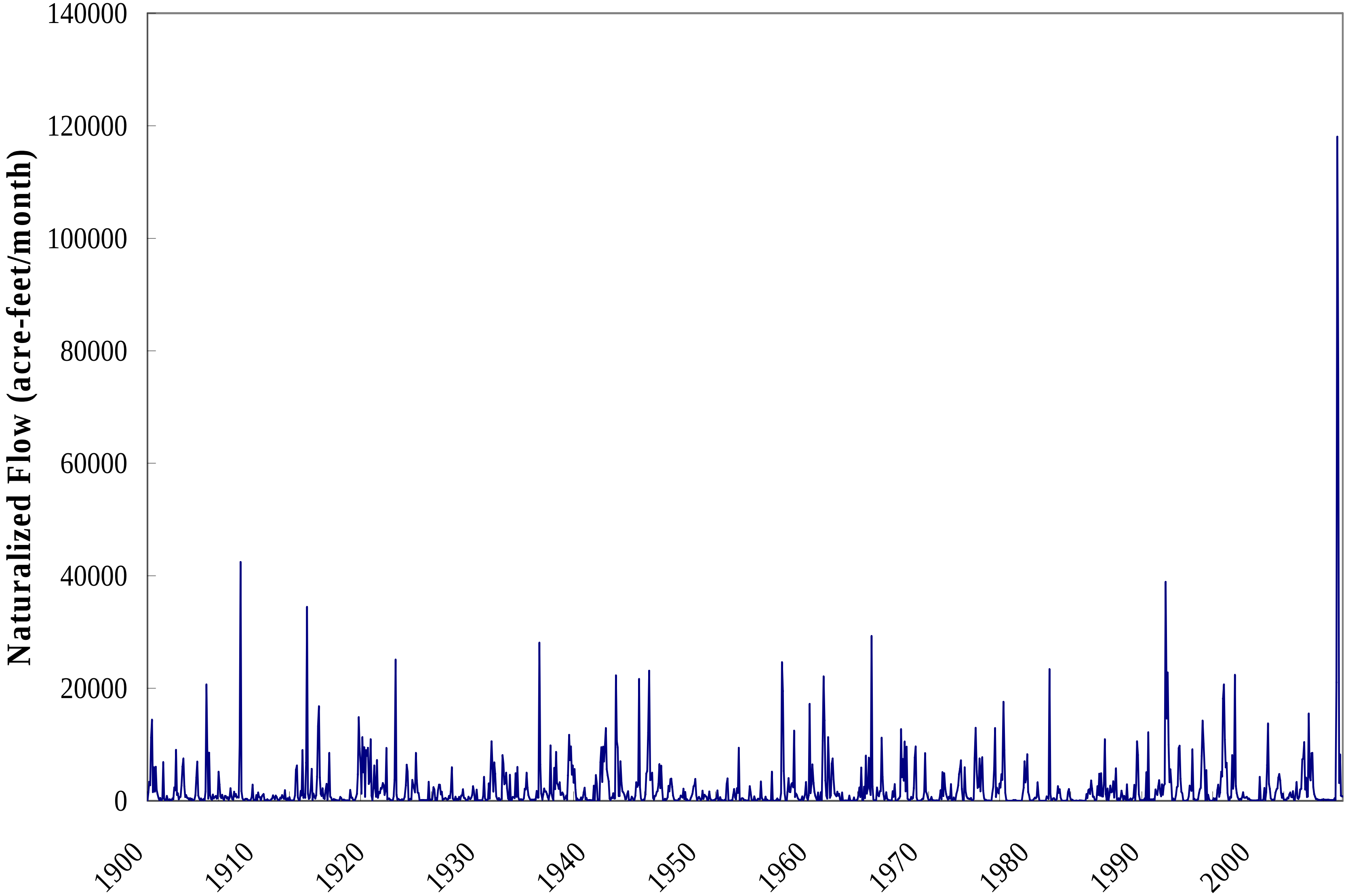

Figure A.39 Monthly Naturalized Flow at HGCR39 – Hog Creek near Crawford

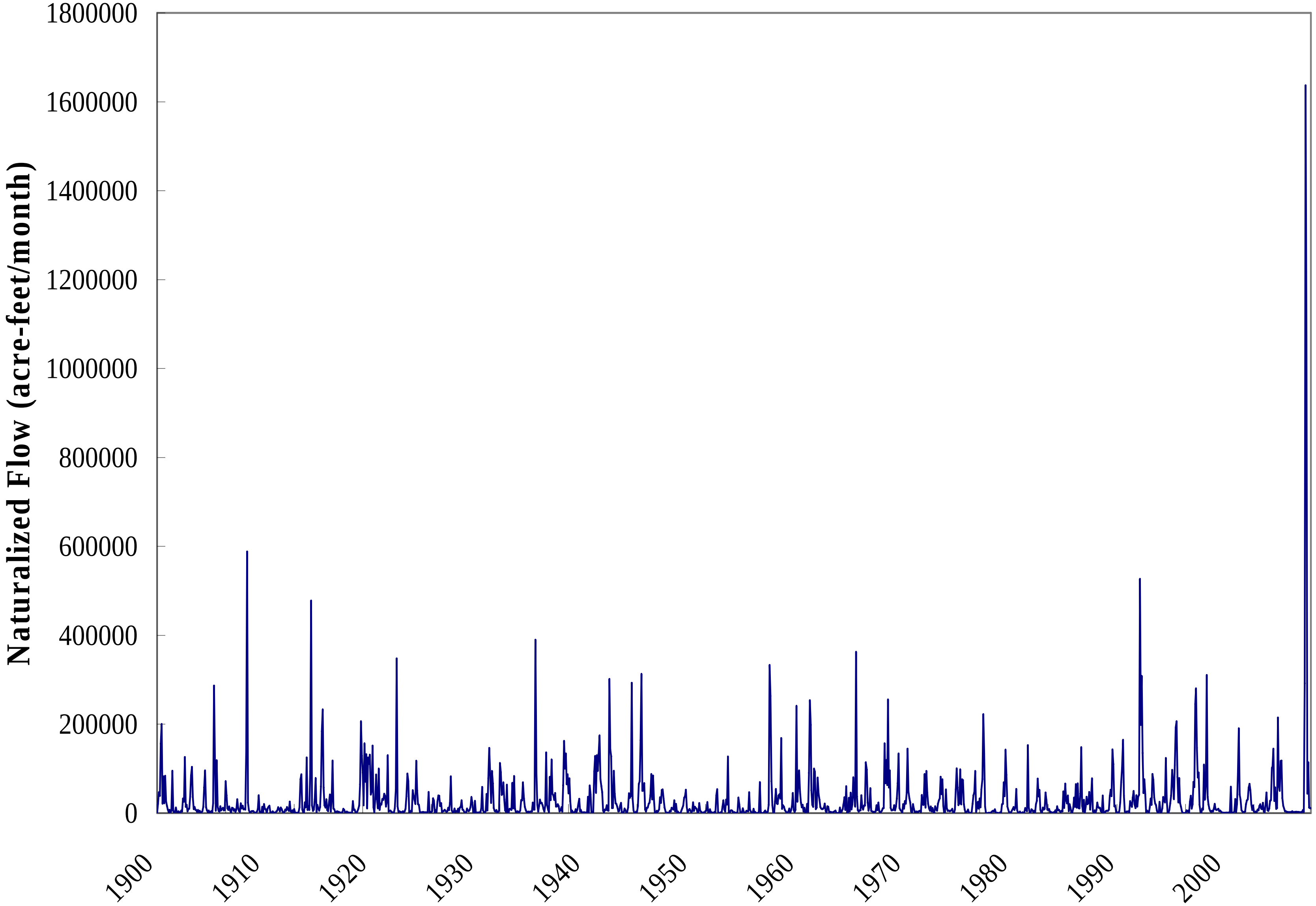

Figure A.40 Monthly Naturalized Flow at BOWO40 – Bosque River near Waco

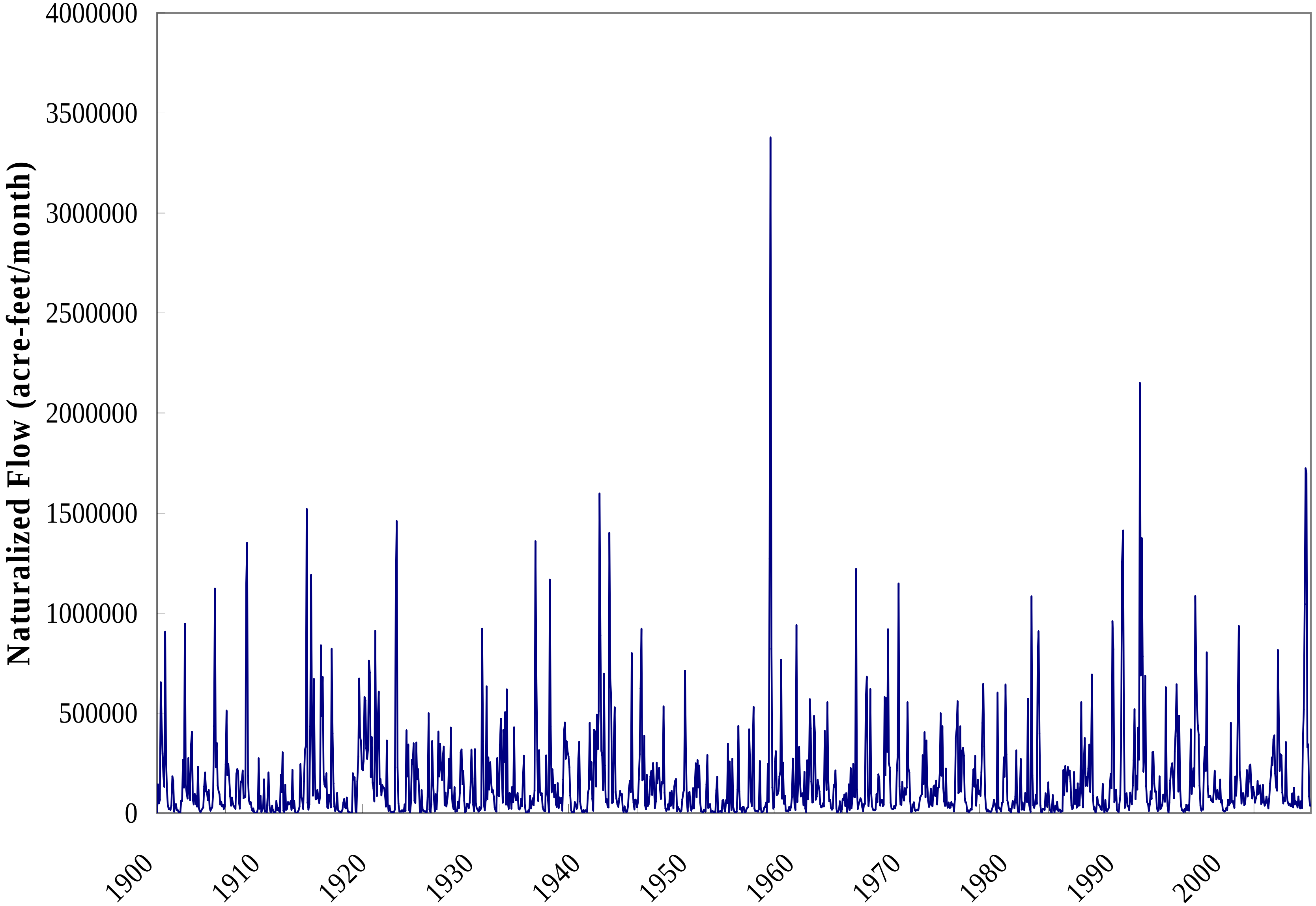

Figure A.41 Monthly Naturalized Flow at BRWA41 – Brazos River at Waco

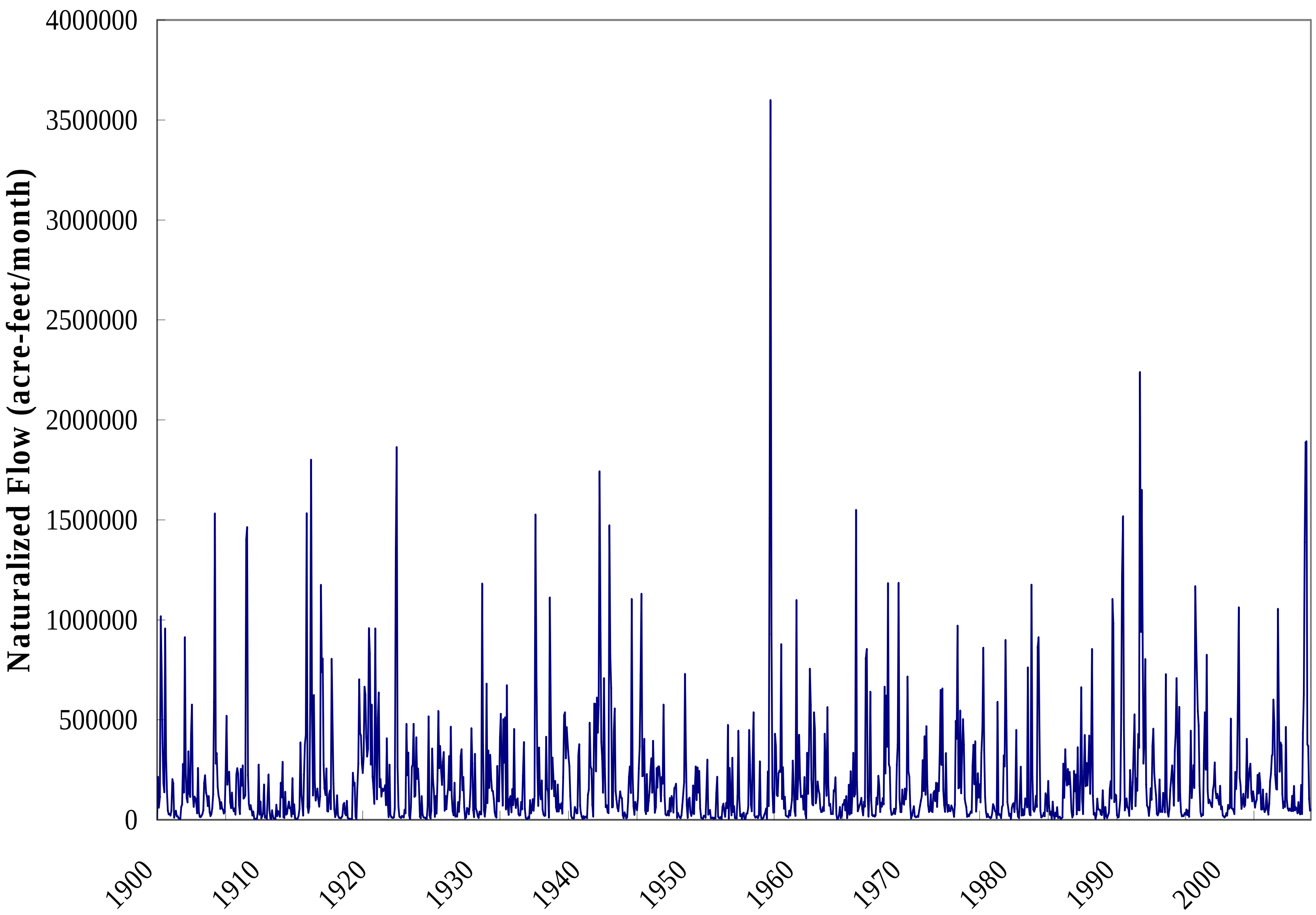

Figure A.42 Monthly Naturalized Flow at BRHB42 – Brazos River near Highbank

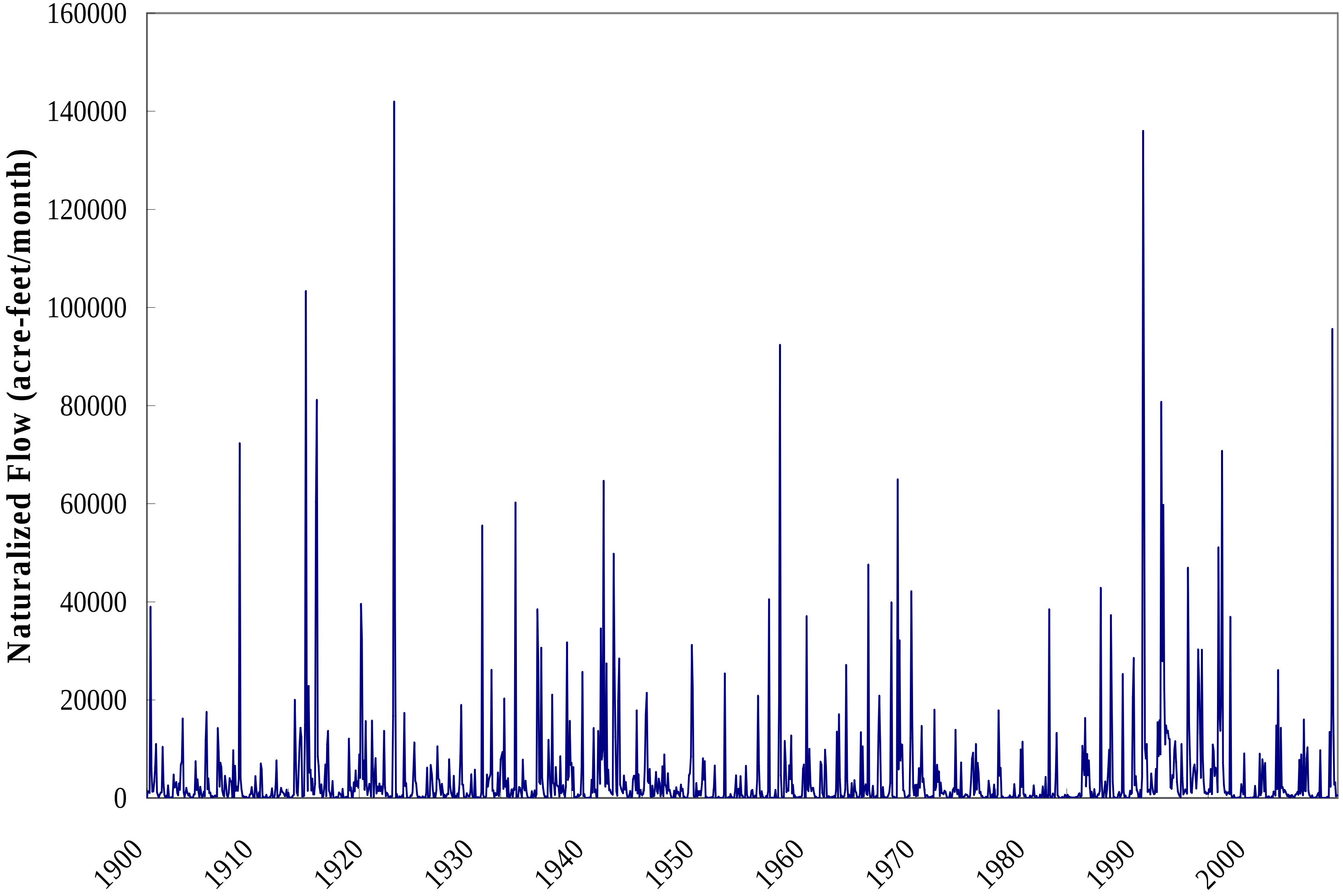

Figure A.43 Monthly Naturalized Flow at LEDL43 – Leon River near De Leon

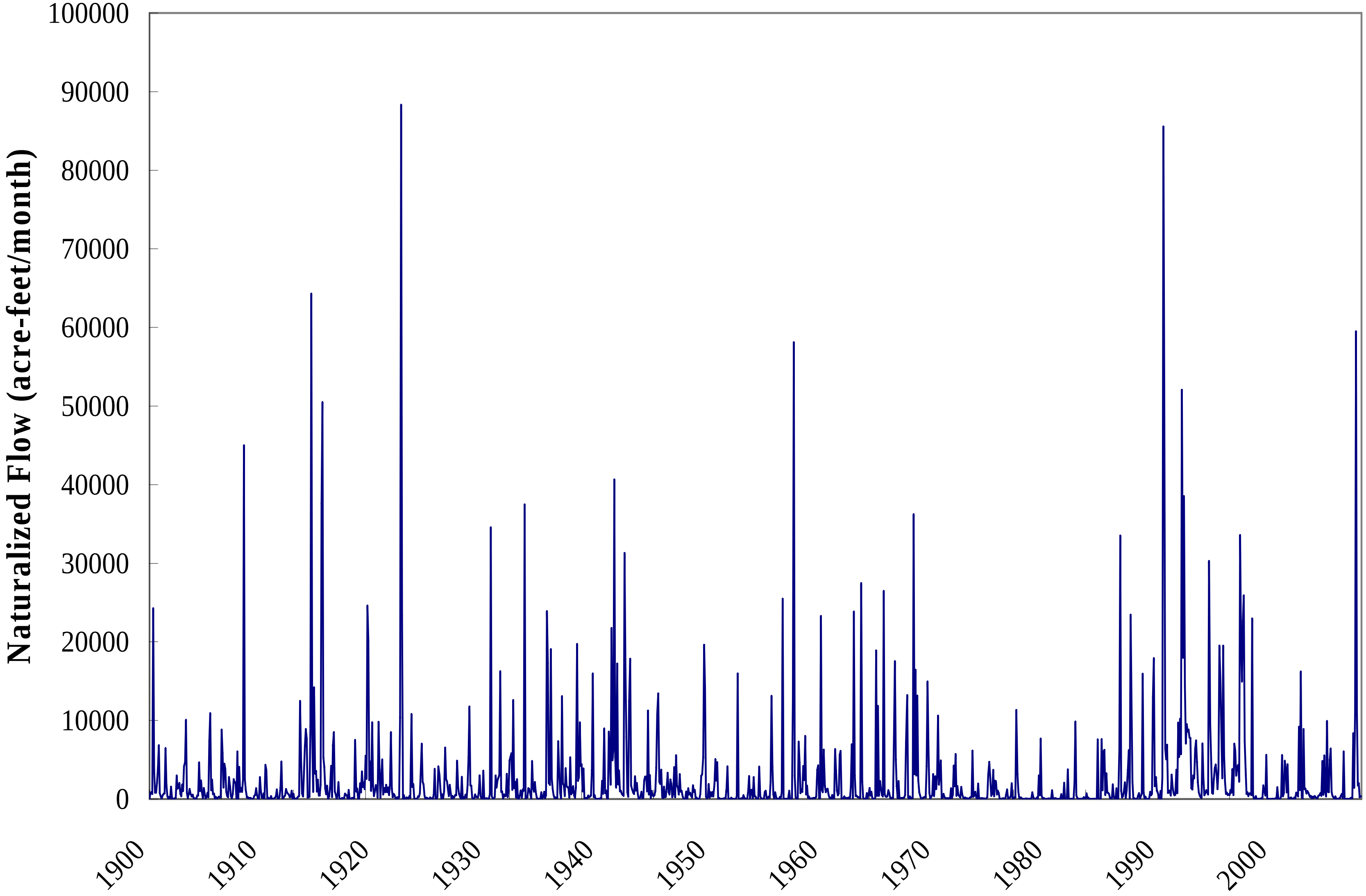

Figure A.44 Monthly Naturalized Flow at SADL44 – Sabana River near De Leon

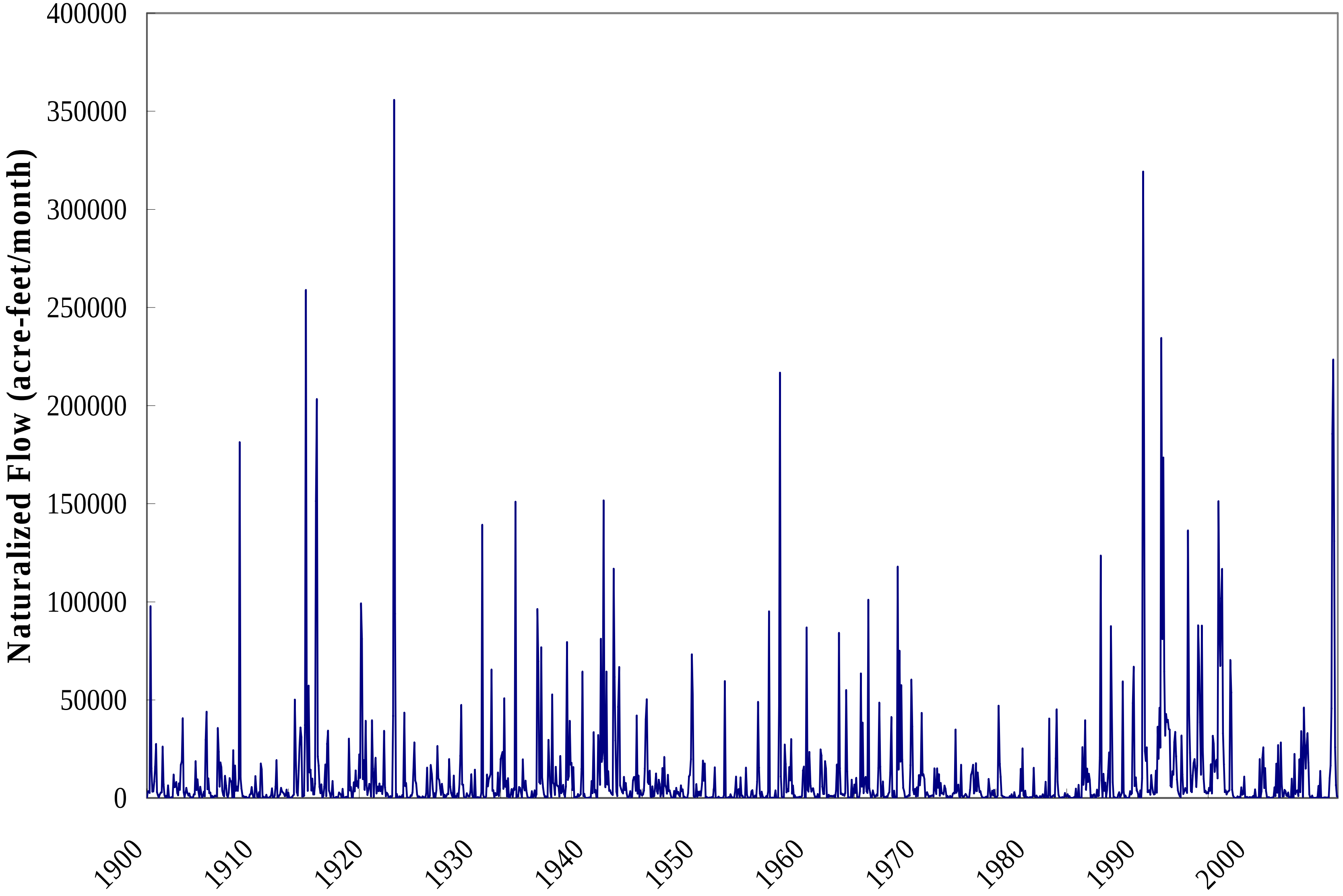

Figure A.45 Monthly Naturalized Flow at LEHS45 – Leon River near Hasse

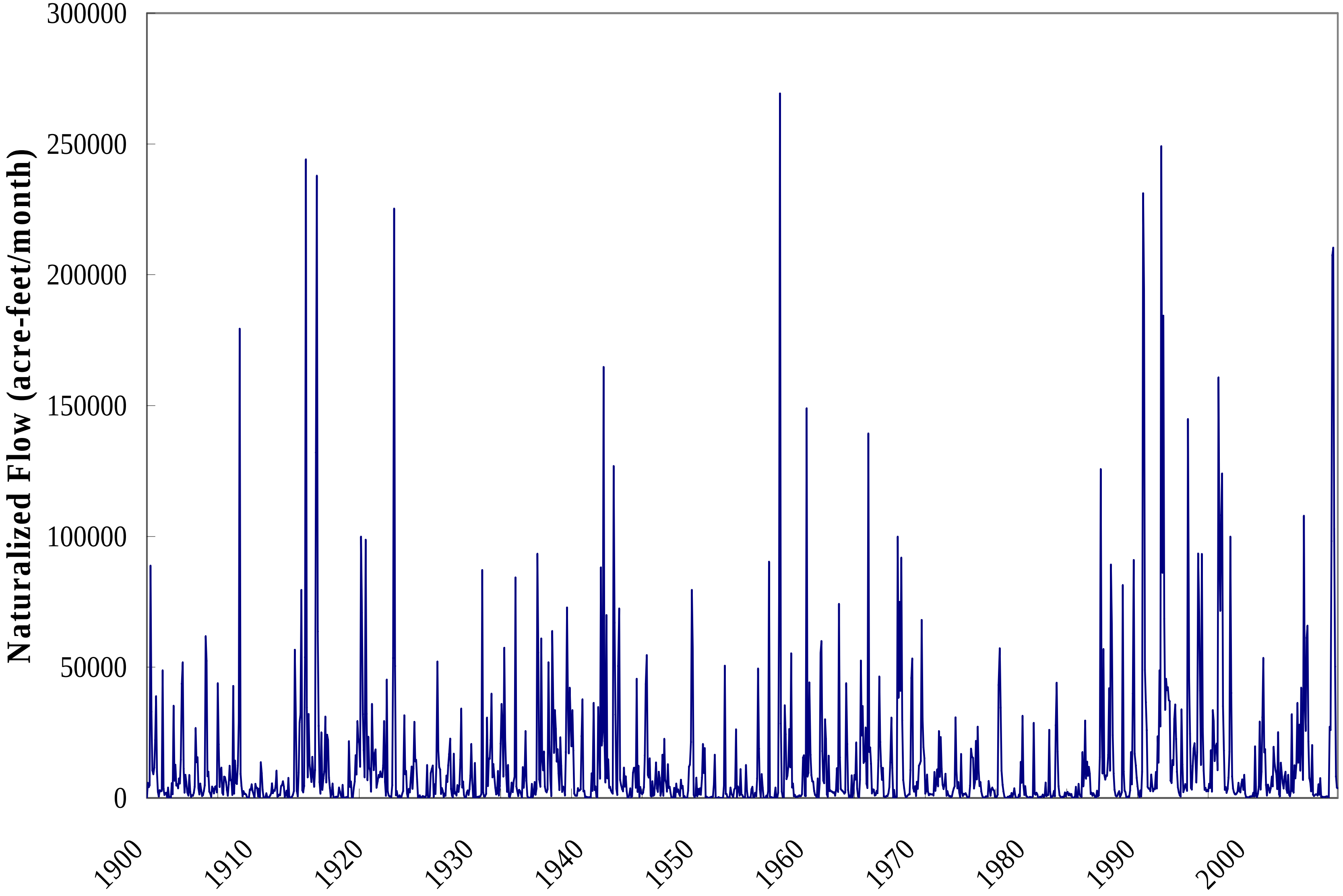

Figure A.46 Monthly Naturalized Flow at LEHM46 – Leon River Hamilton

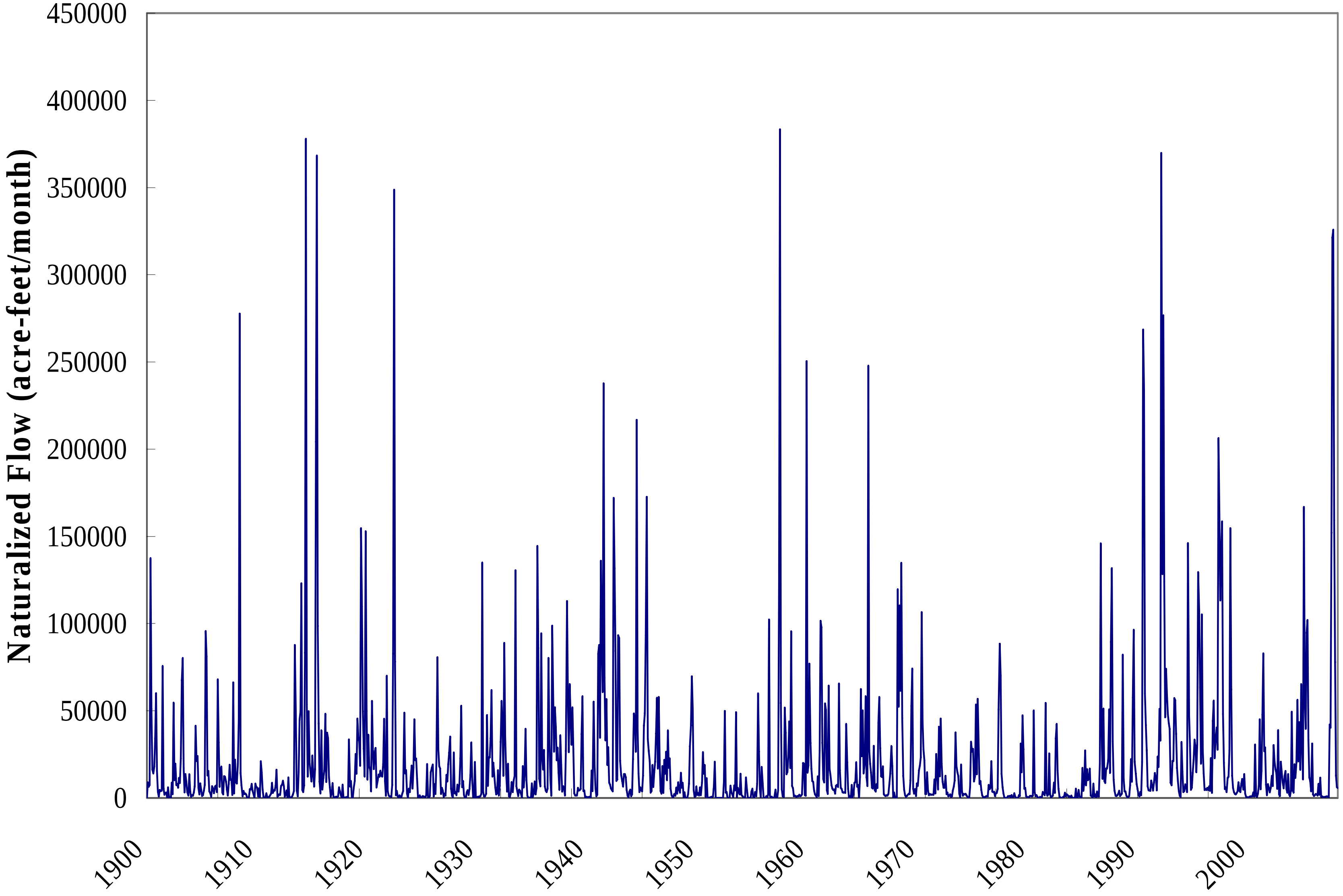

Figure A.47 Monthly Naturalized Flow at LEGT47 – Leon River at Gatesville

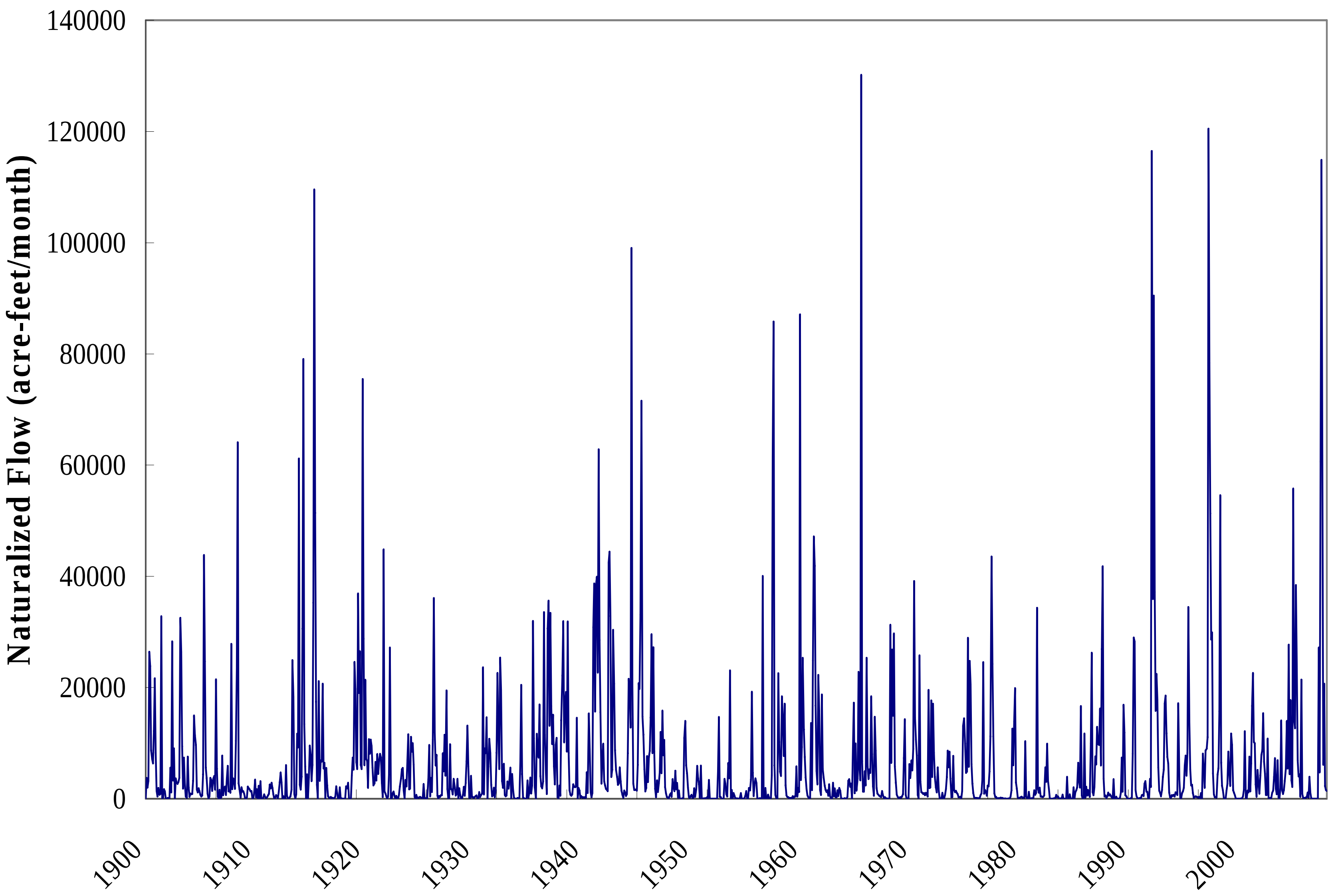

Figure A.48 Monthly Naturalized Flow at COPI48 – Cowhouse Creek at Pidcoke

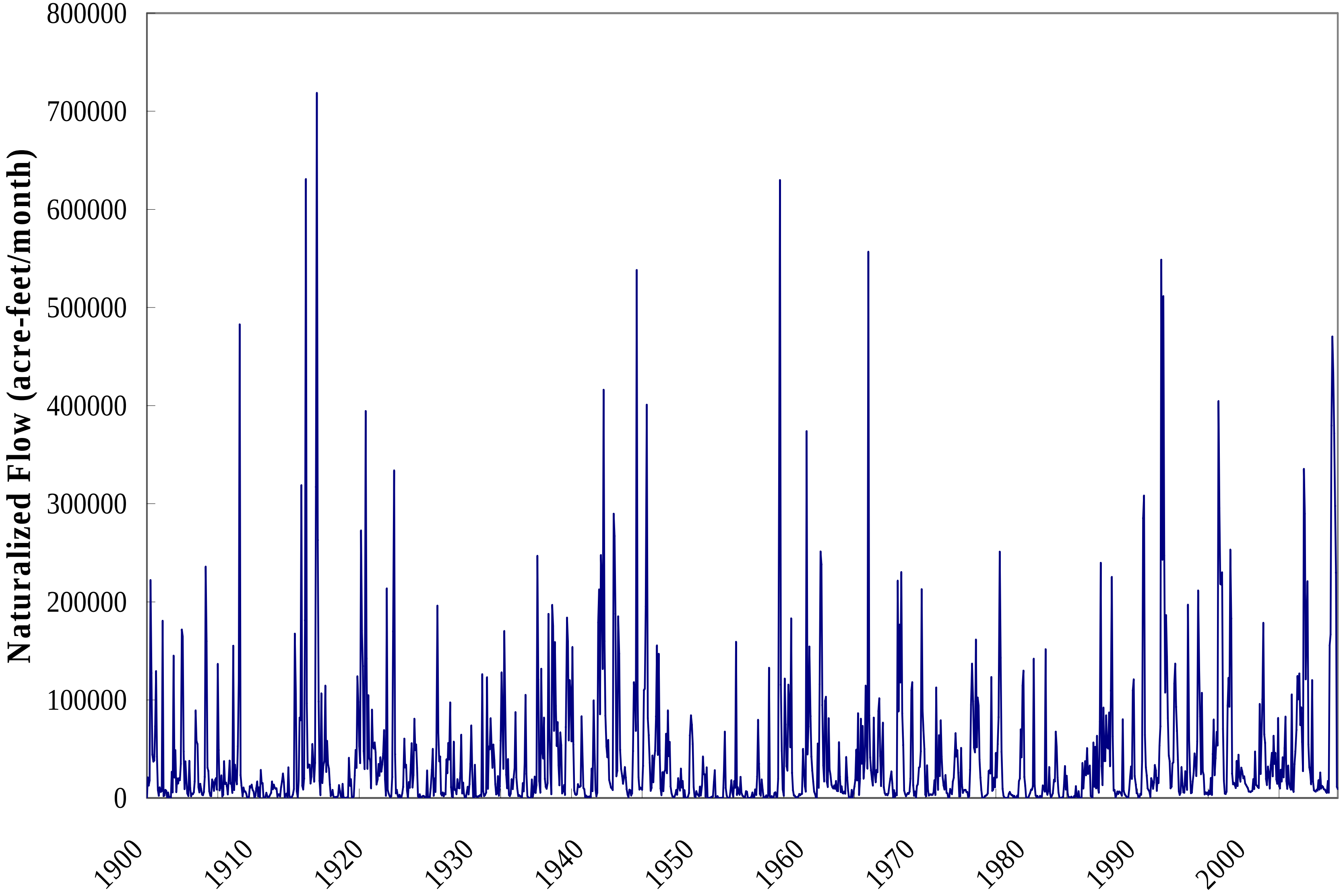

Figure A.49 Monthly Naturalized Flow at LEBE49 – Leon River near Belton

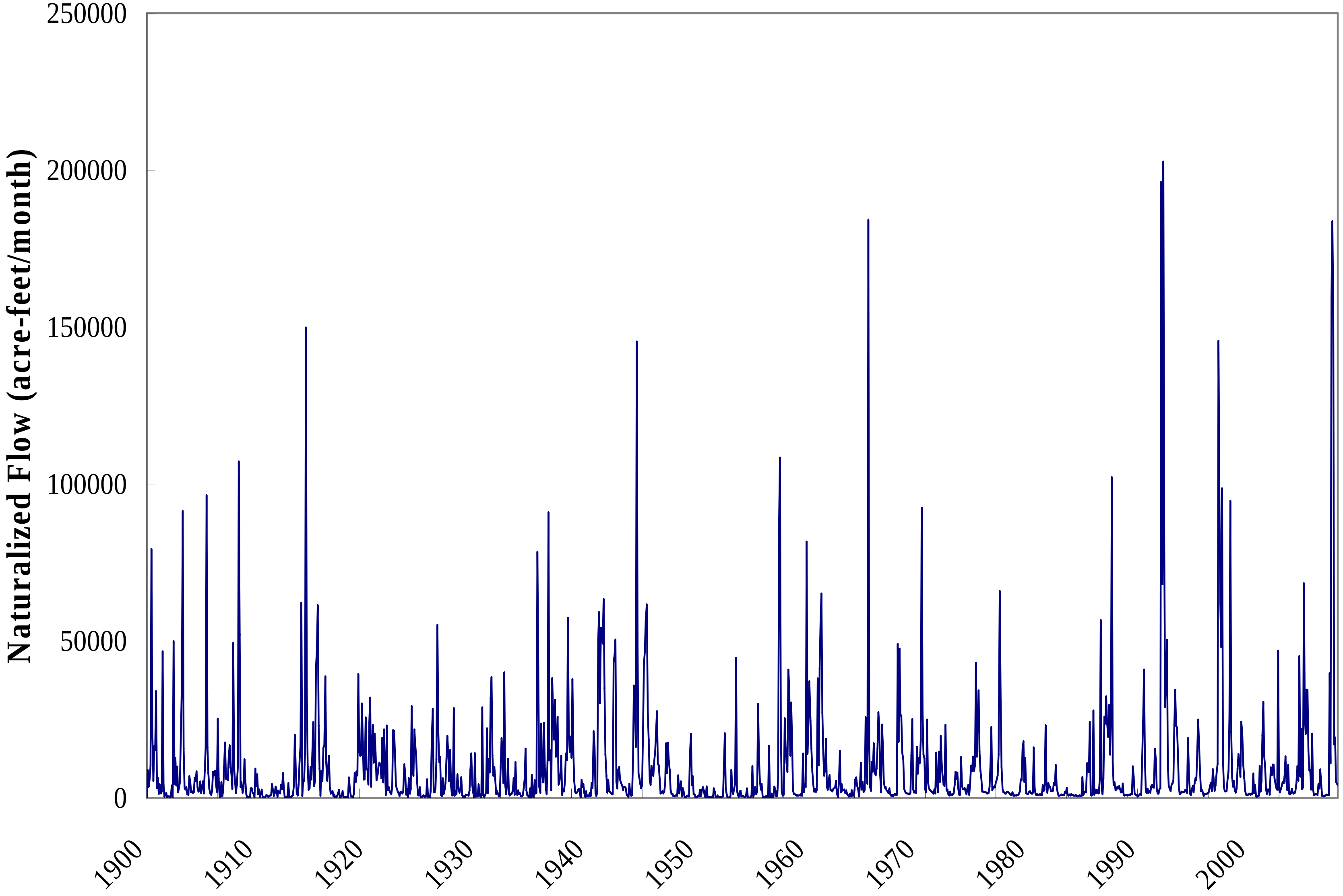

Figure A.50 Monthly Naturalized Flow at LAKE50 – Lampasas River near Kempner

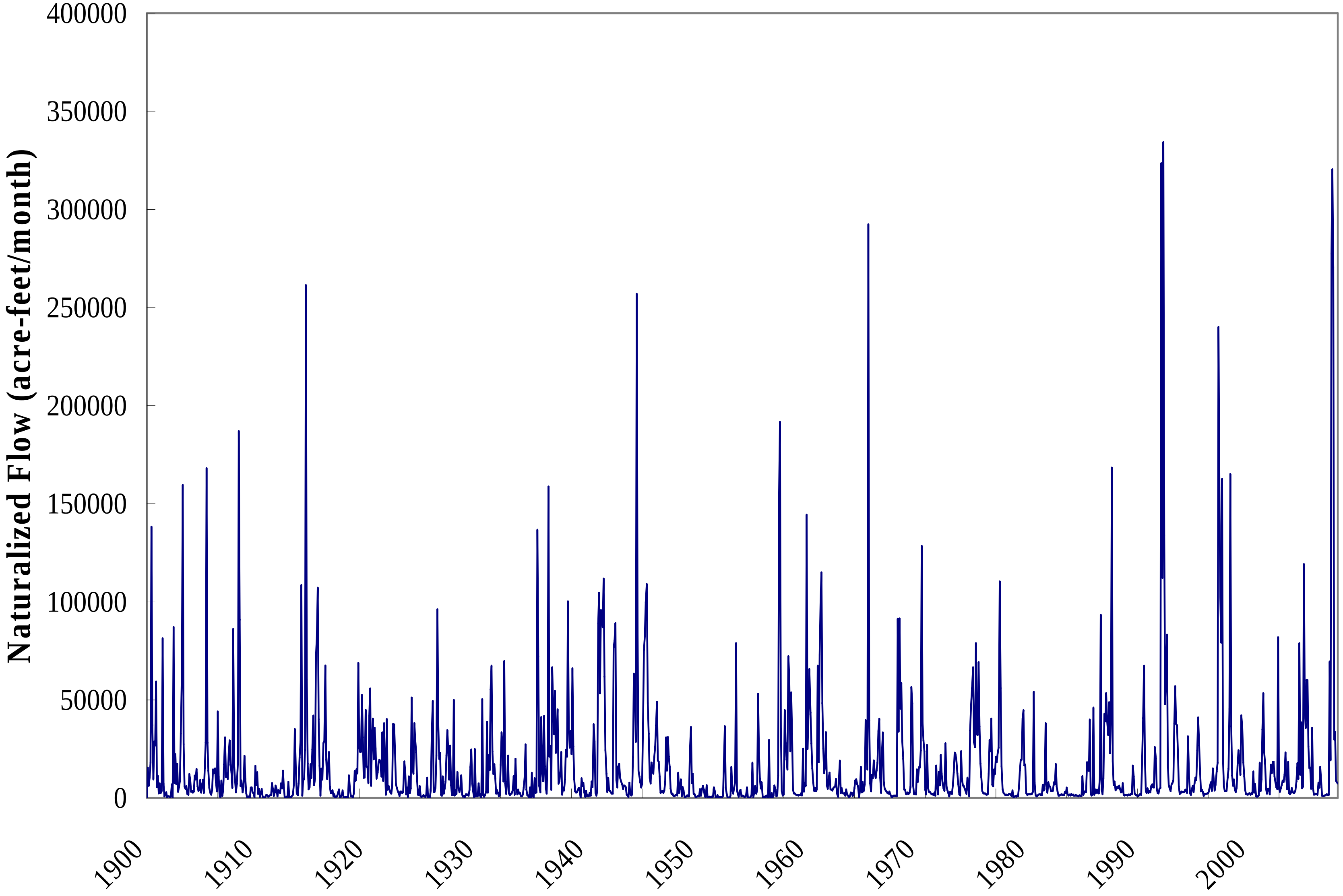

Figure A.51 Monthly Naturalized Flow at LAYO51 – Lampasas River at Youngsport

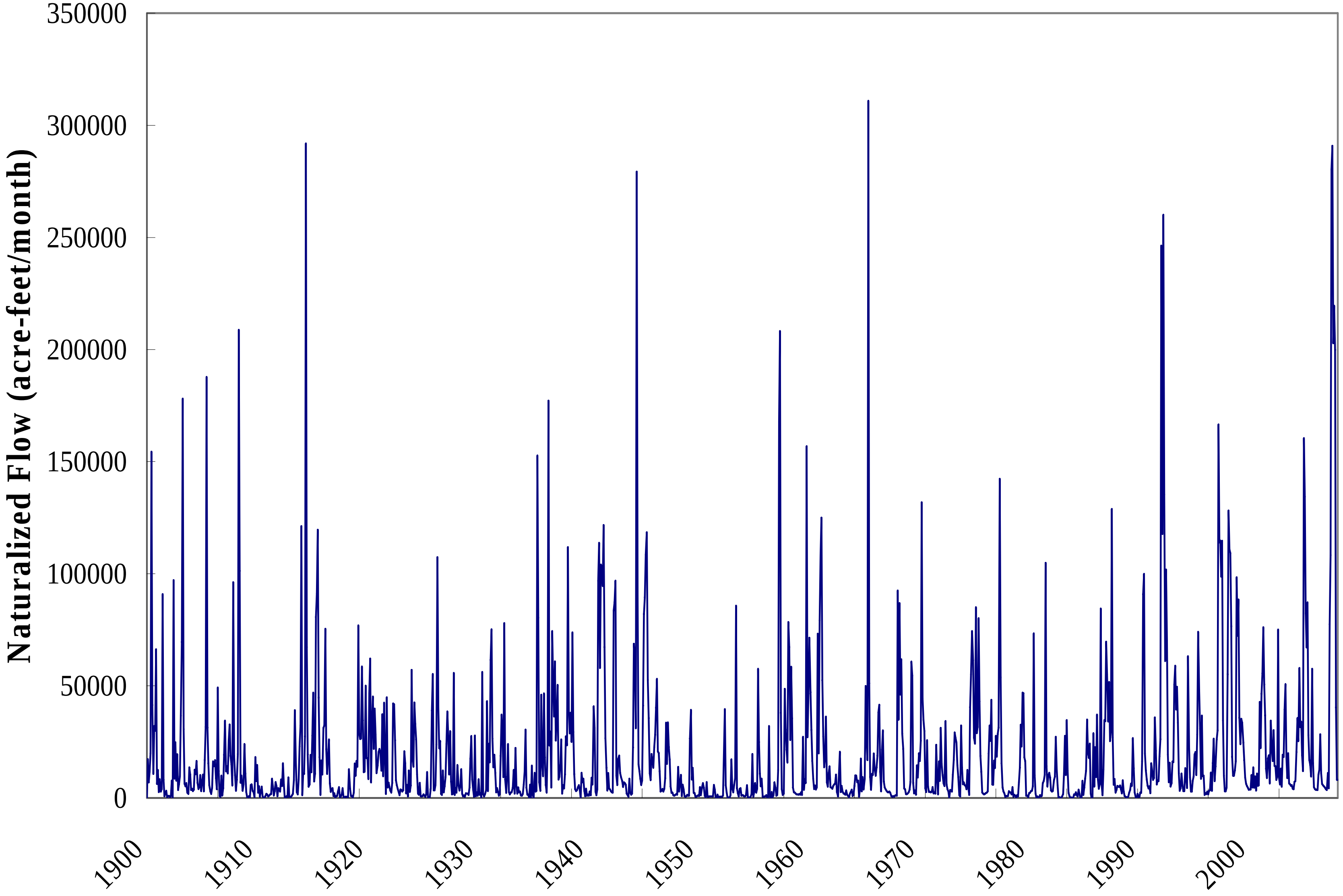

Figure A.52 Monthly Naturalized Flow at LABE52 – Lampasas River near Belton

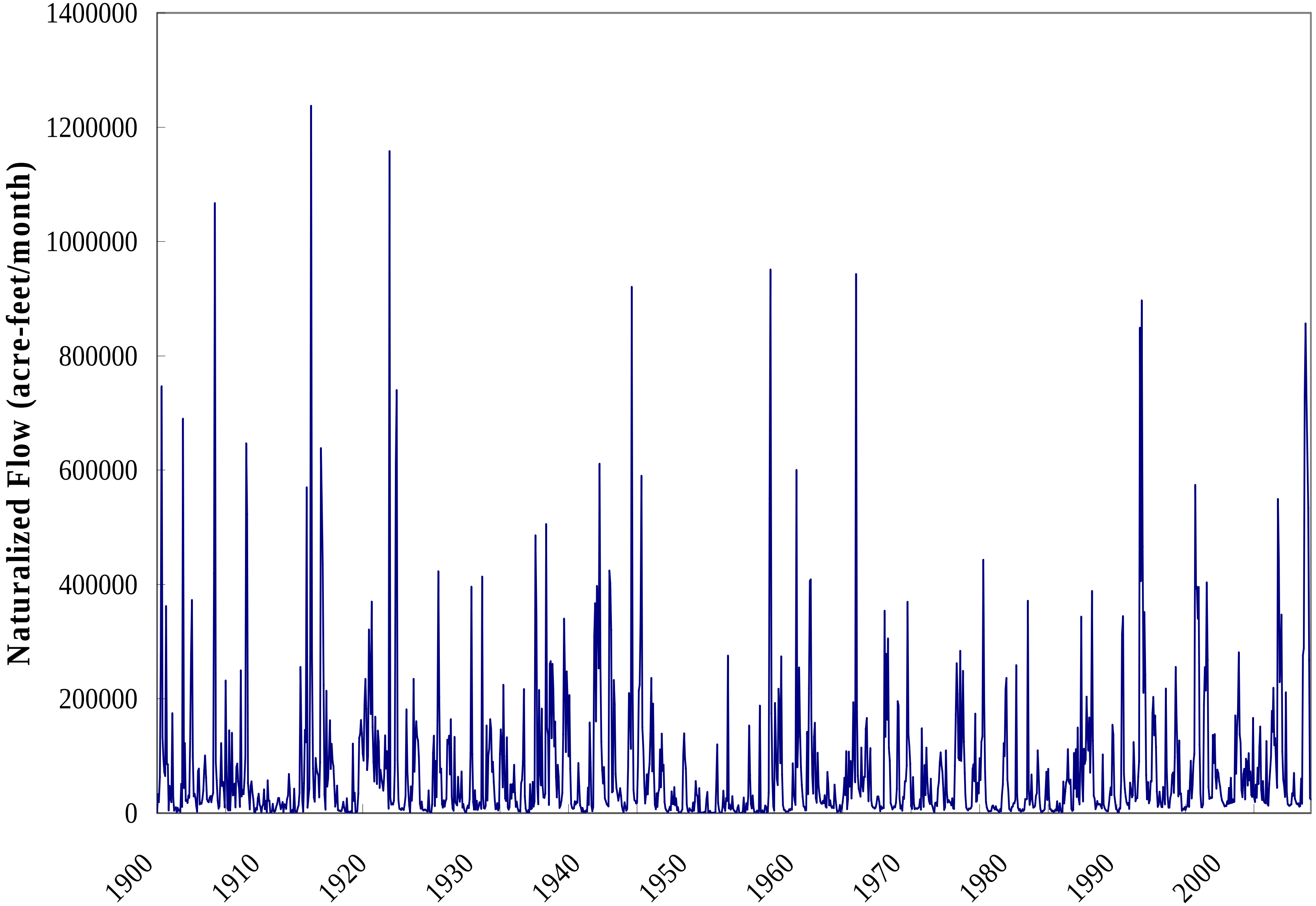

Figure A.53 Monthly Naturalized Flow at LRLR53 – Little River near Little River

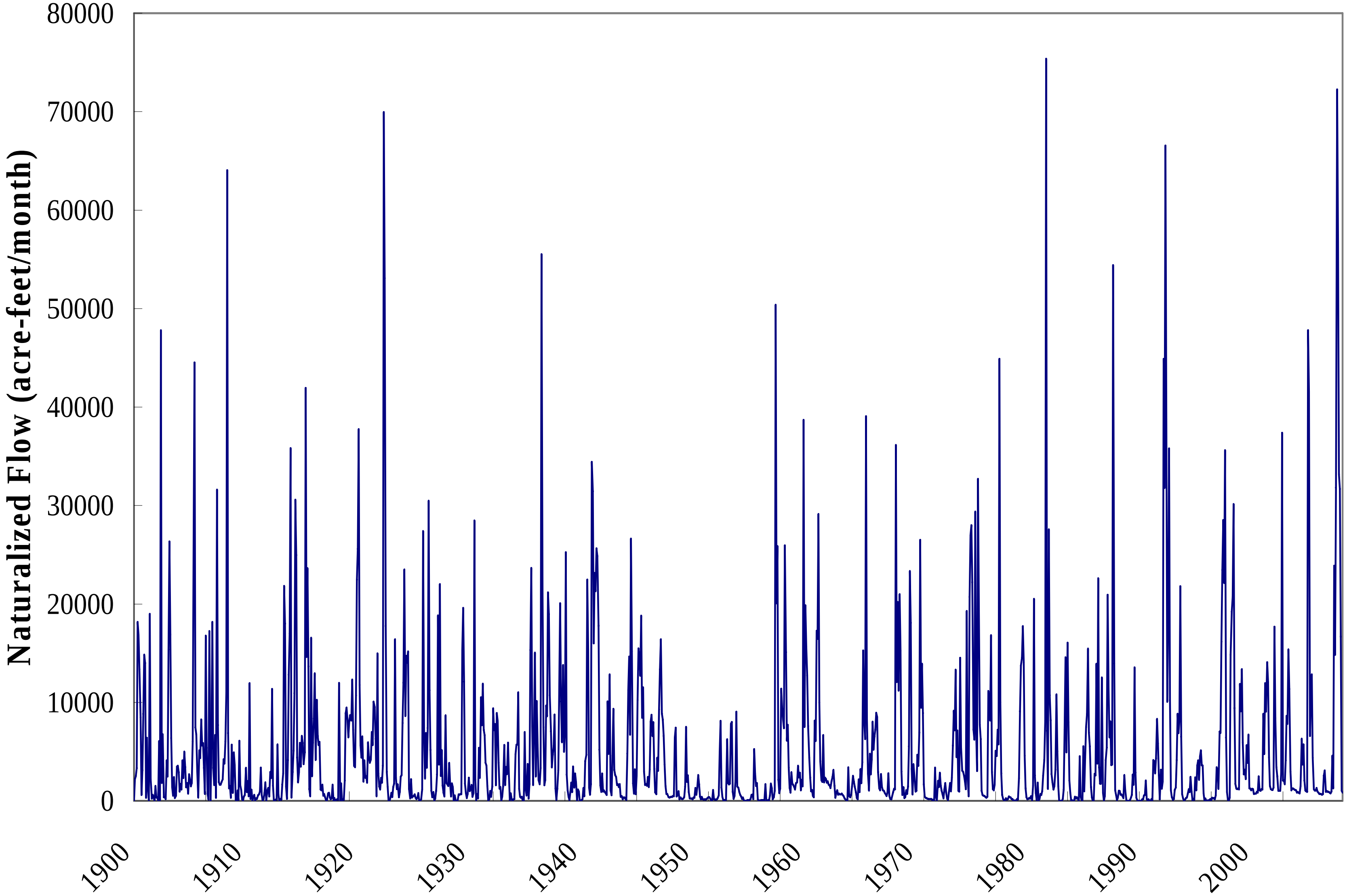

Figure A.54 Monthly Naturalized Flow at NGGE54 – North Fork San Gabriel River at Georgetown

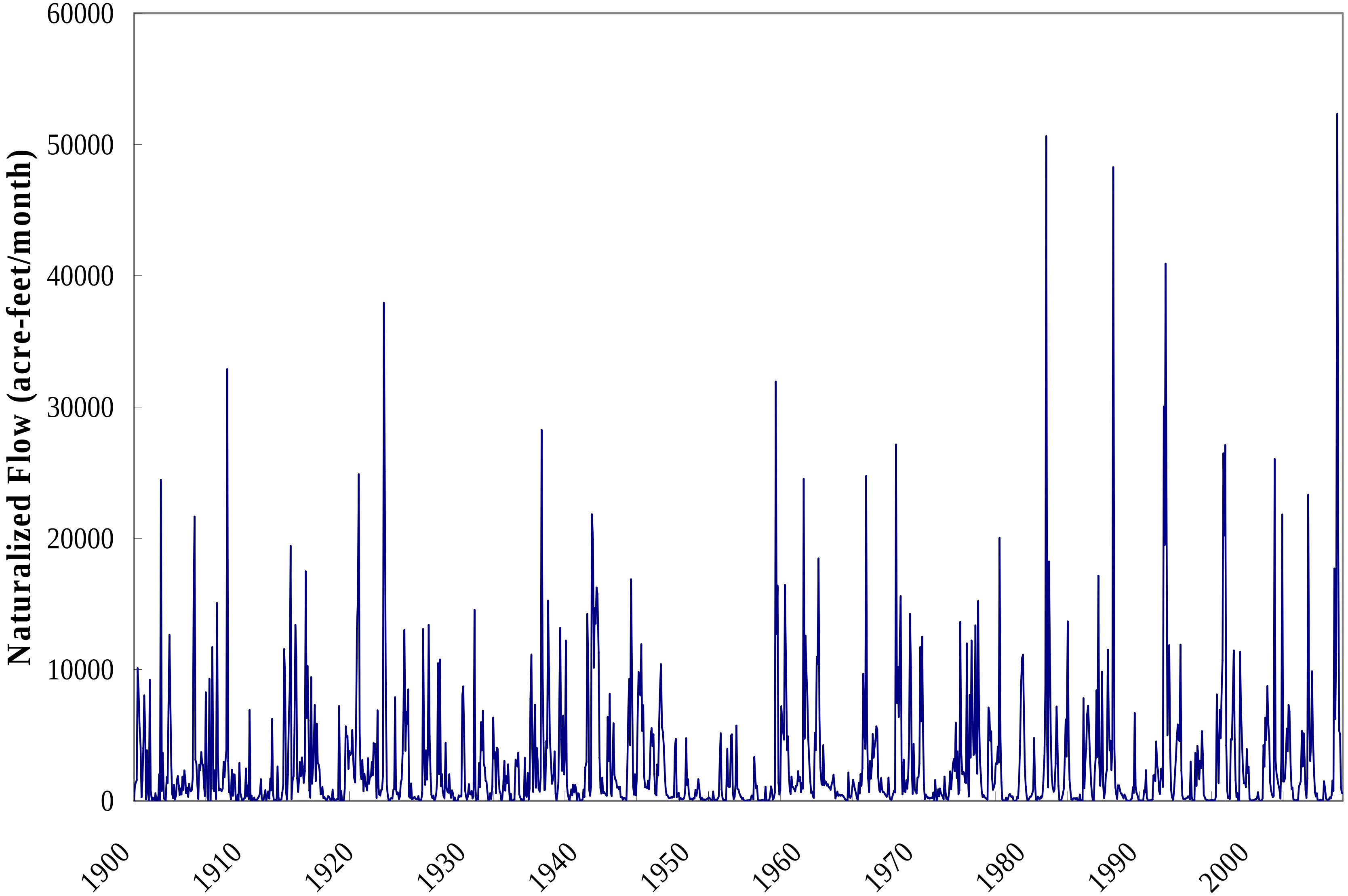

Figure A.55 Monthly Naturalized Flow at SGGE55 – South Fork San Gabriel River at Georgetown

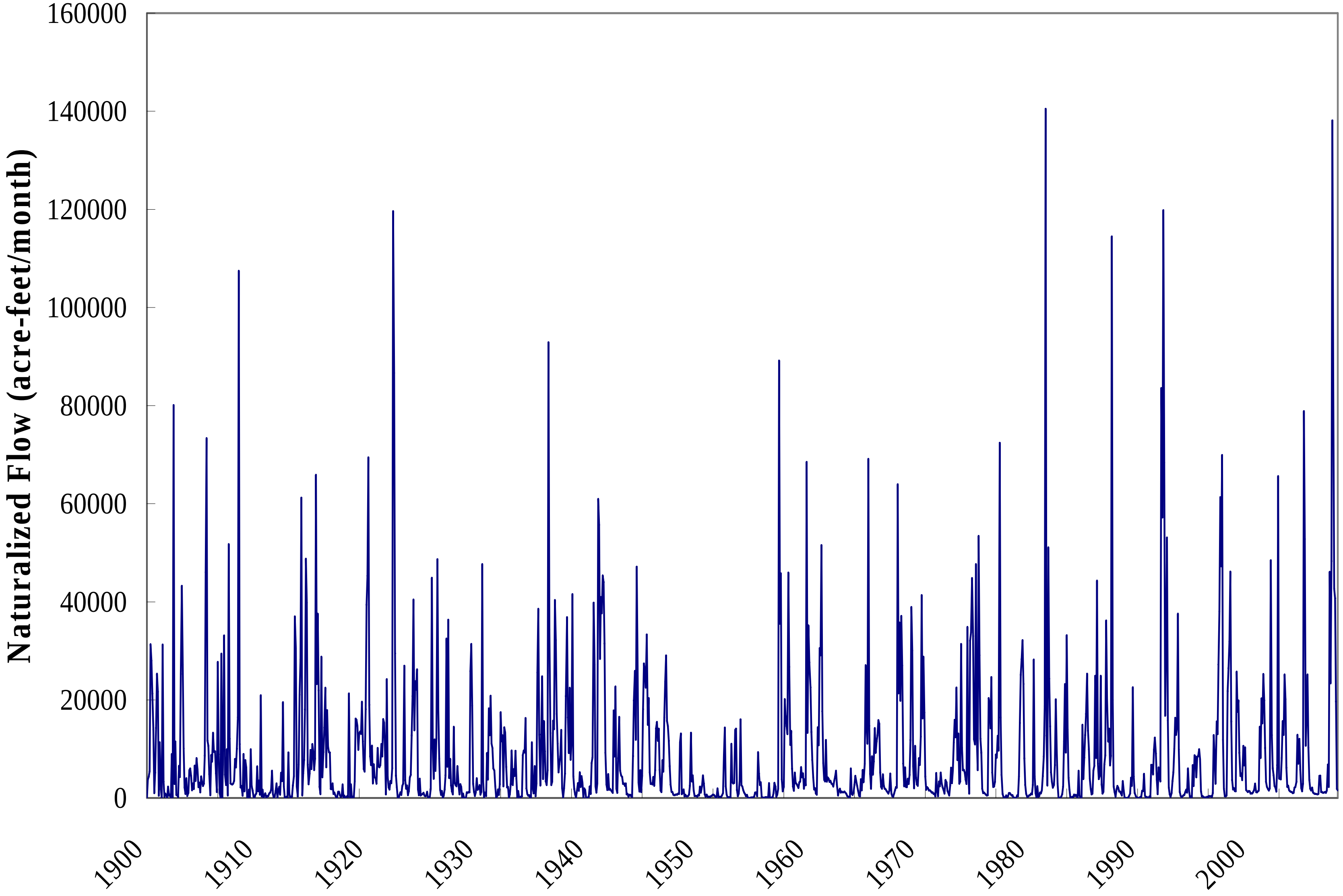

Figure A.56 Monthly Naturalized Flow at GAGE56 – San Gabriel River at Georgetown

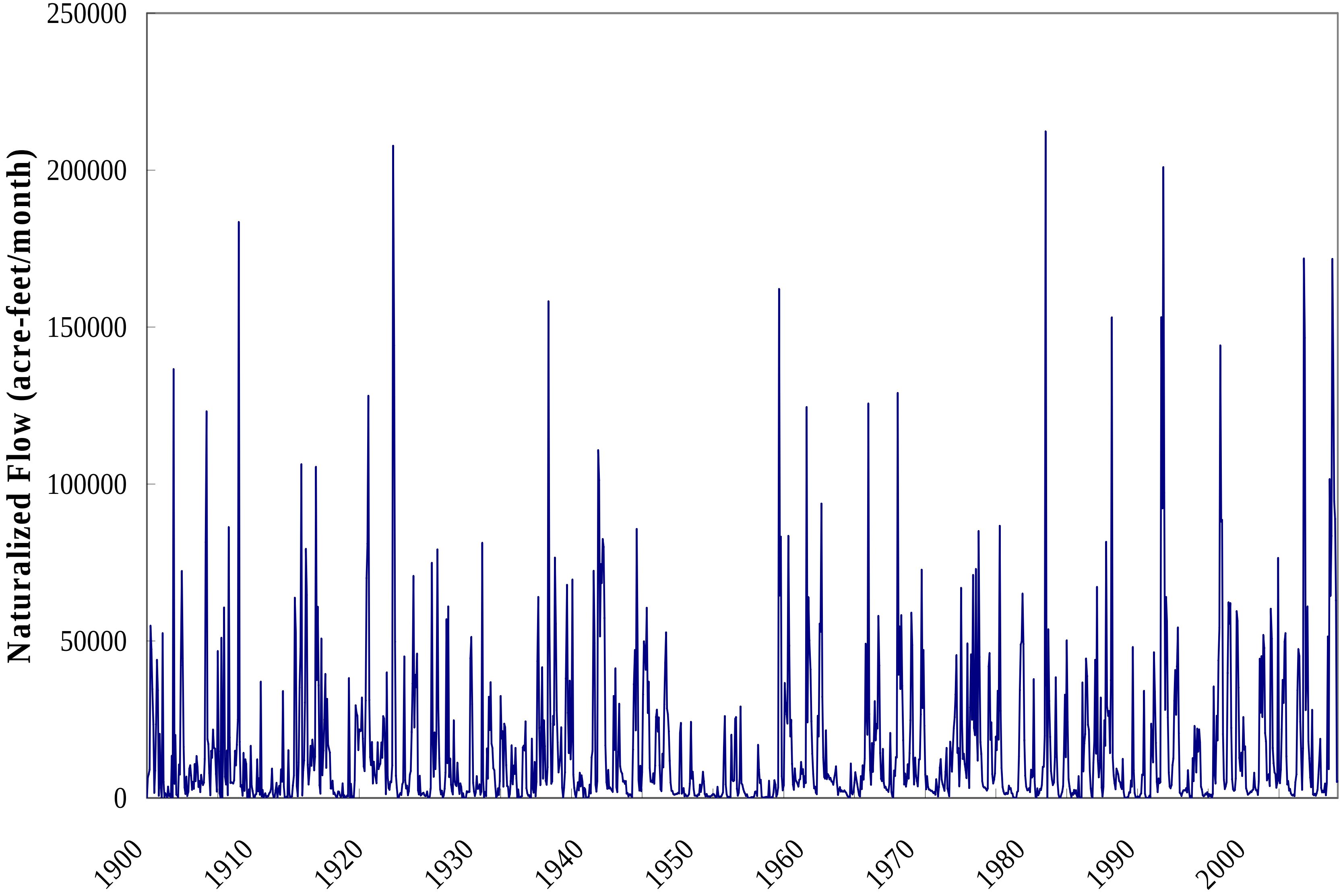

Figure A.57 Monthly Naturalized Flow at GALA57 – San Gabriel River at Laneport

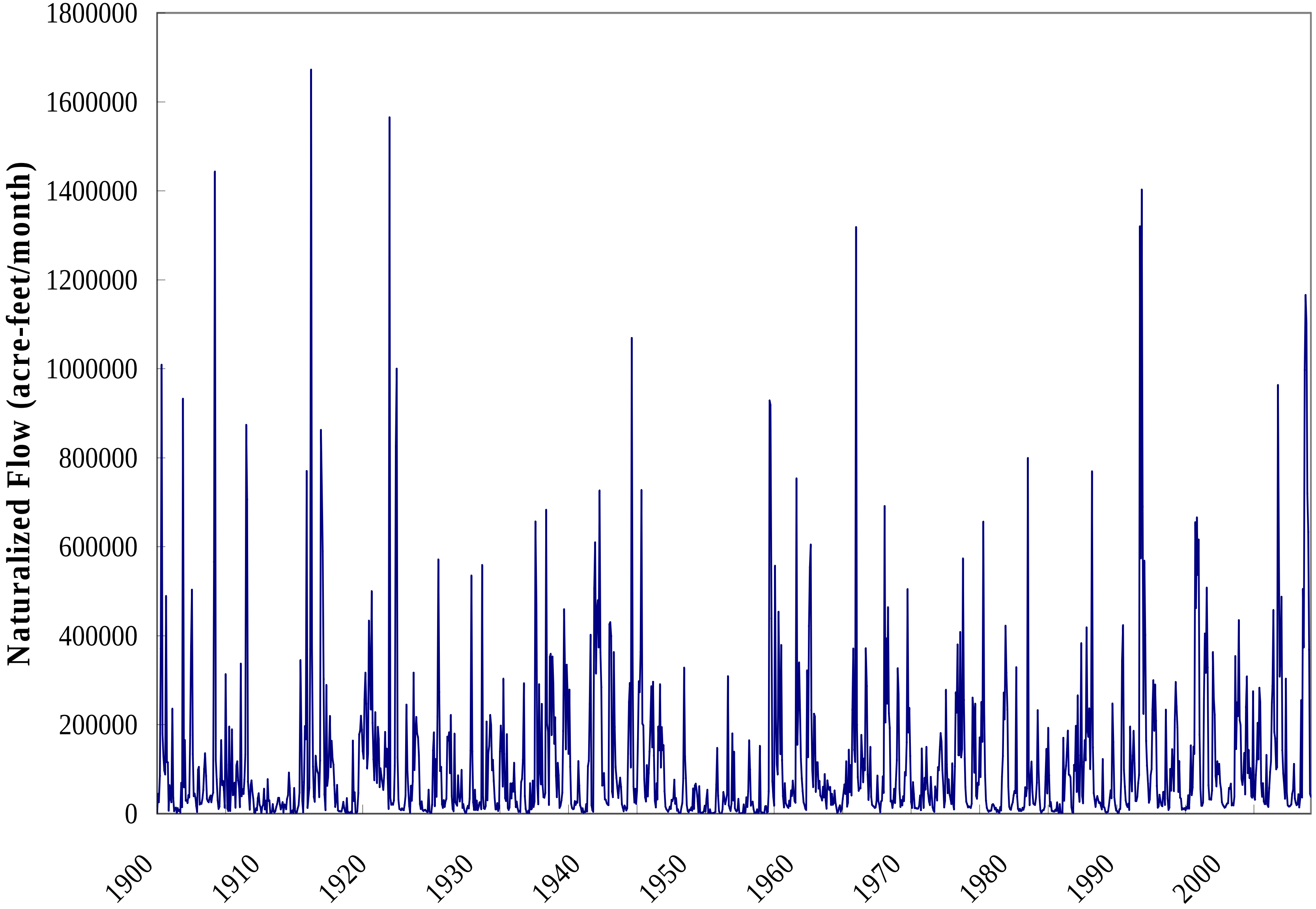

Figure A.58 Monthly Naturalized Flow at LRCA58 – Little River at Cameron

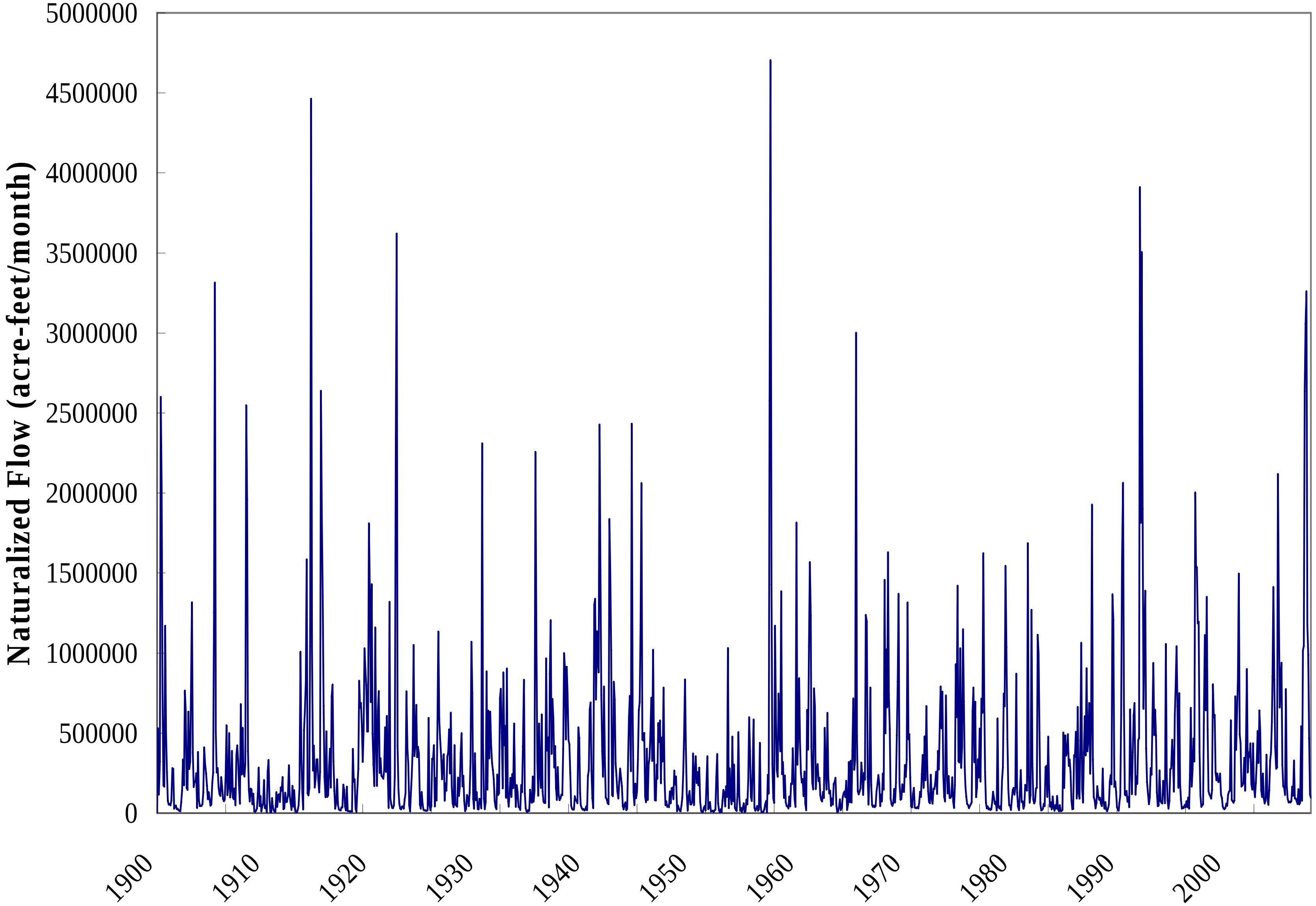

Figure A.59 Monthly Naturalized Flow at BRBR59 – Brazos River near Bryan

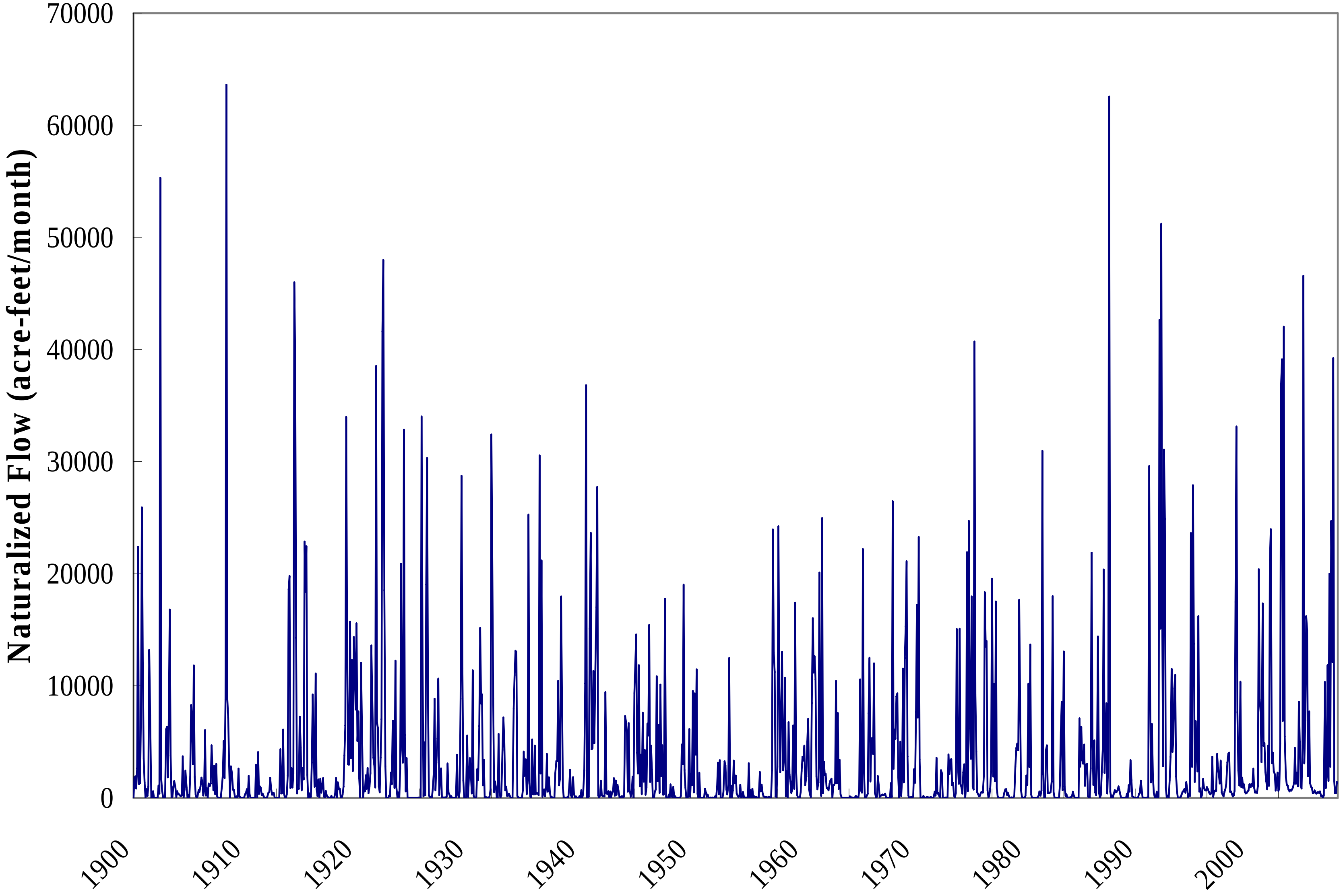

Figure A.60 Monthly Naturalized Flow at MYDB60 – Middle Yegua Creek near Dime Box

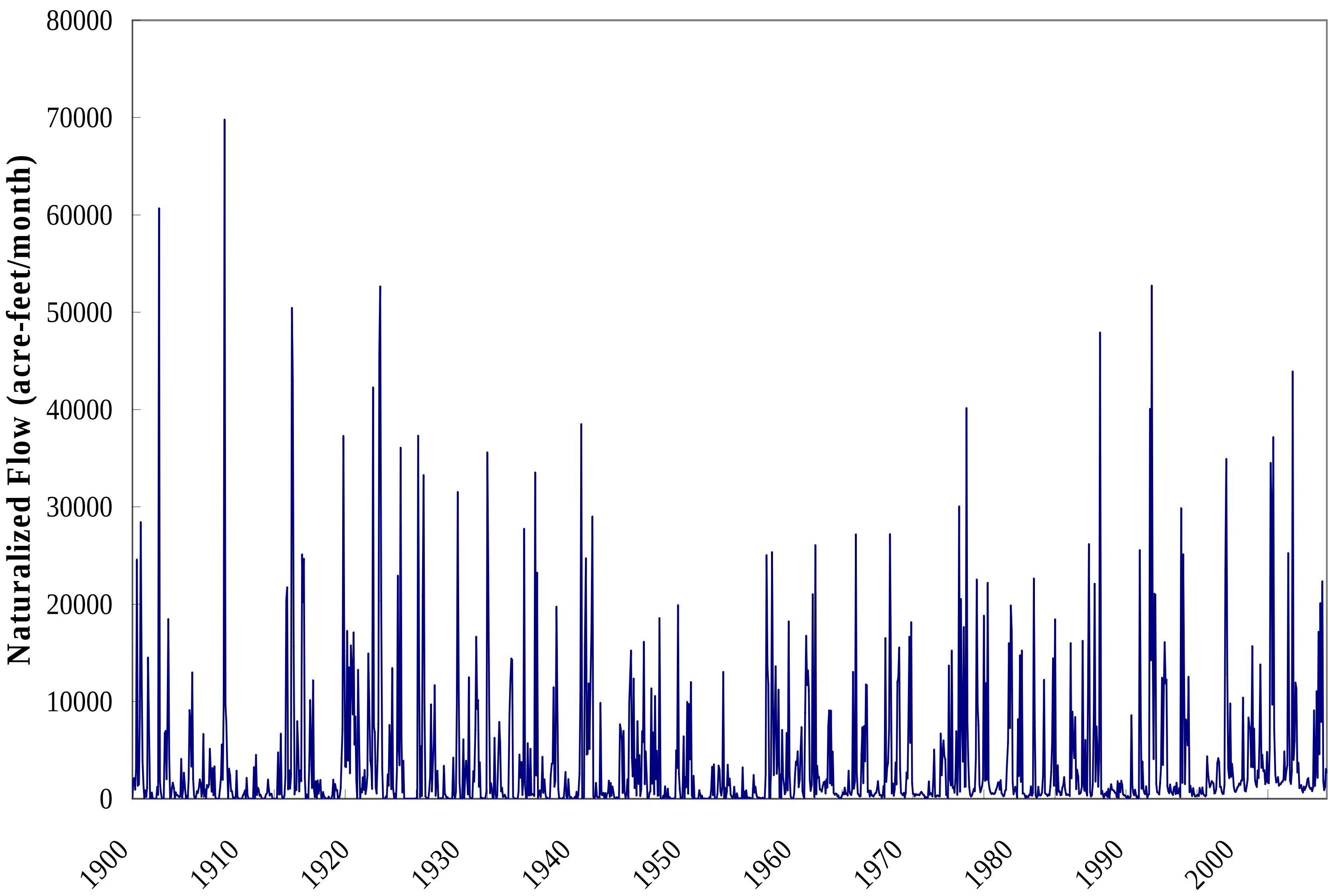

Figure A.61 Monthly Naturalized Flow at EYDB61 – East Yegua Creek near Dime Box

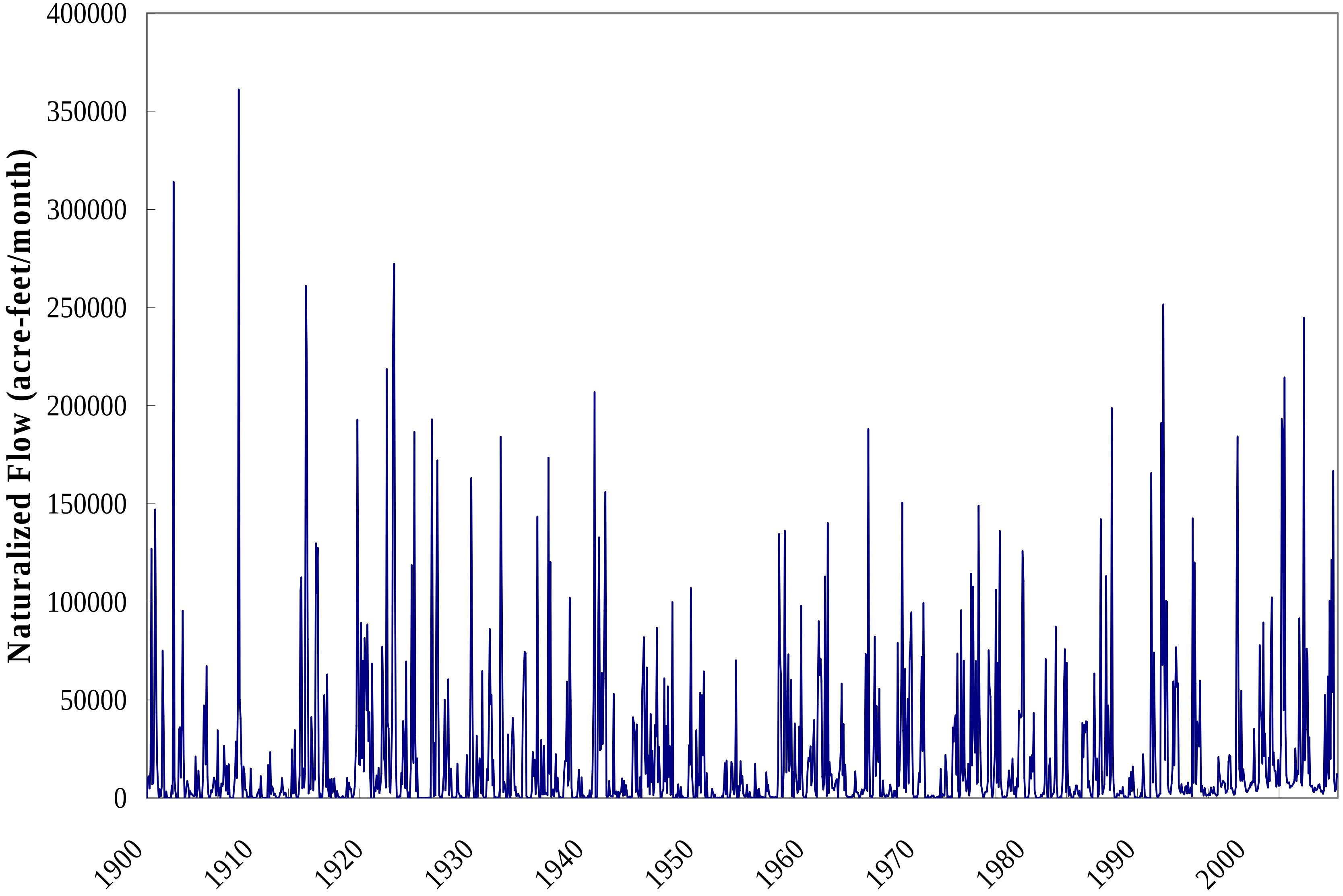

Figure A.62 Monthly Naturalized Flow at YCSO62 – Yegua Creek near Somerville

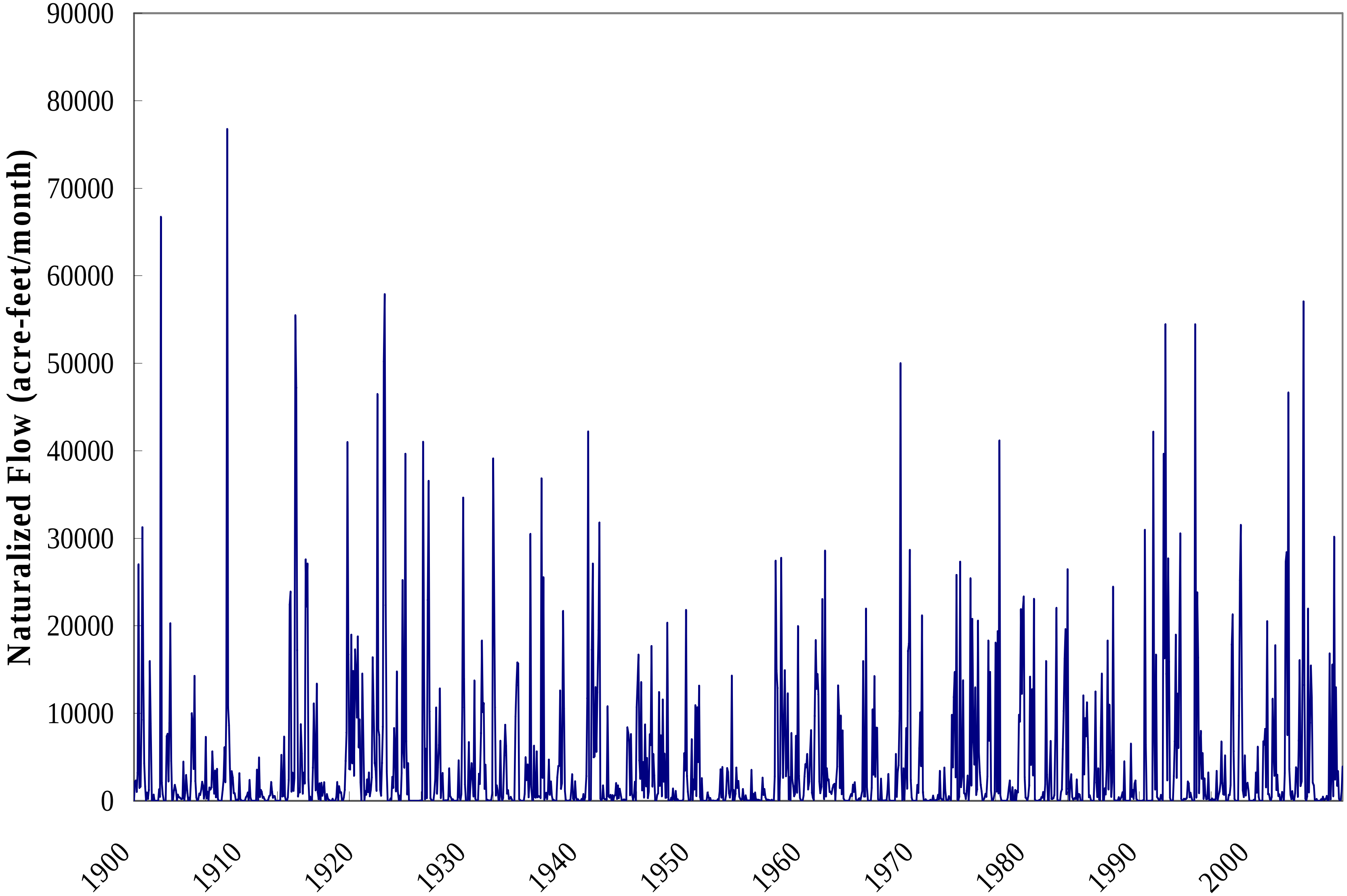

Figure A.63 Monthly Naturalized Flow at DCLY63 – Davison Creek near Lyons

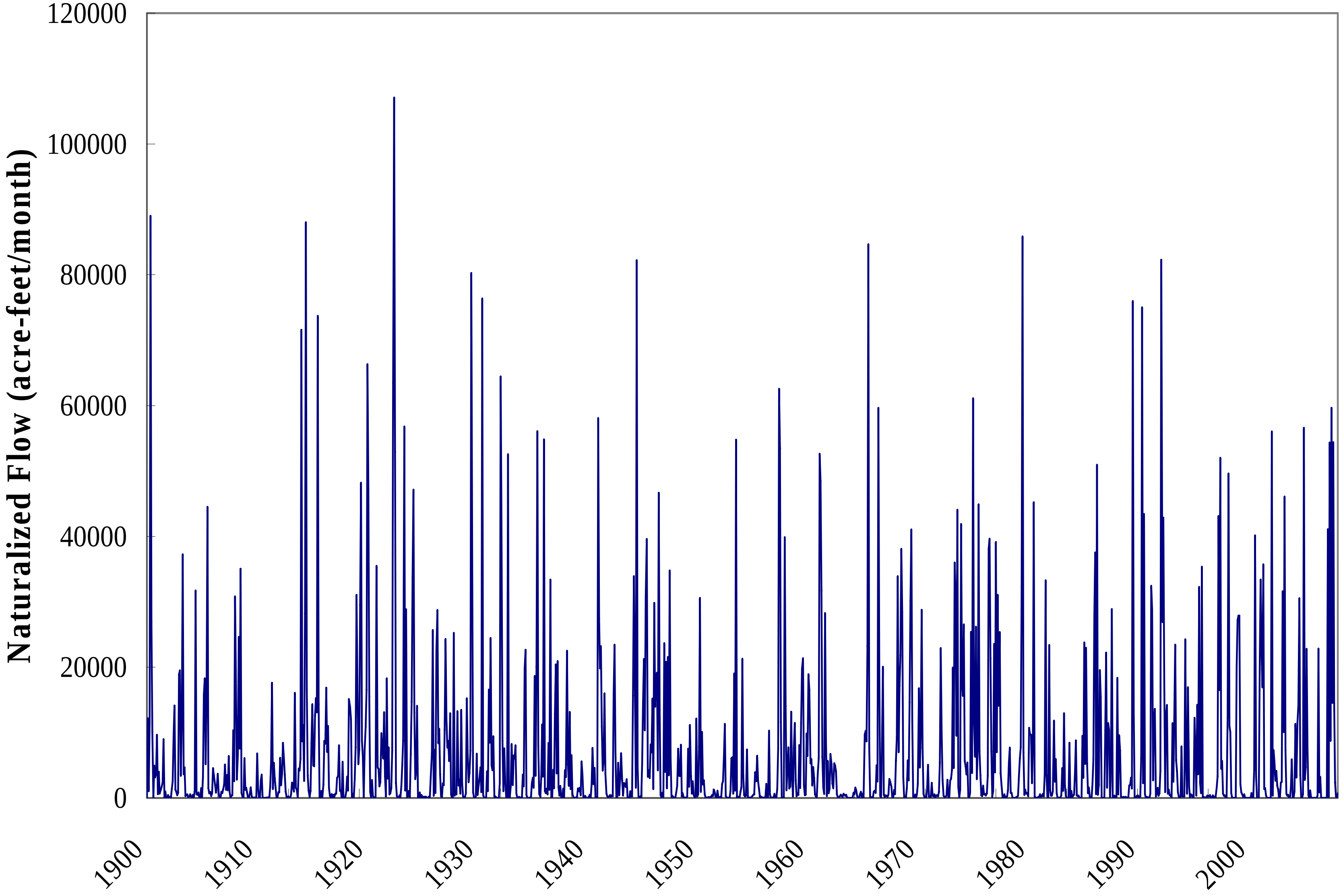

Figure A.64 Monthly Naturalized Flow at NAGR64 – Navasota River above Groesbeck

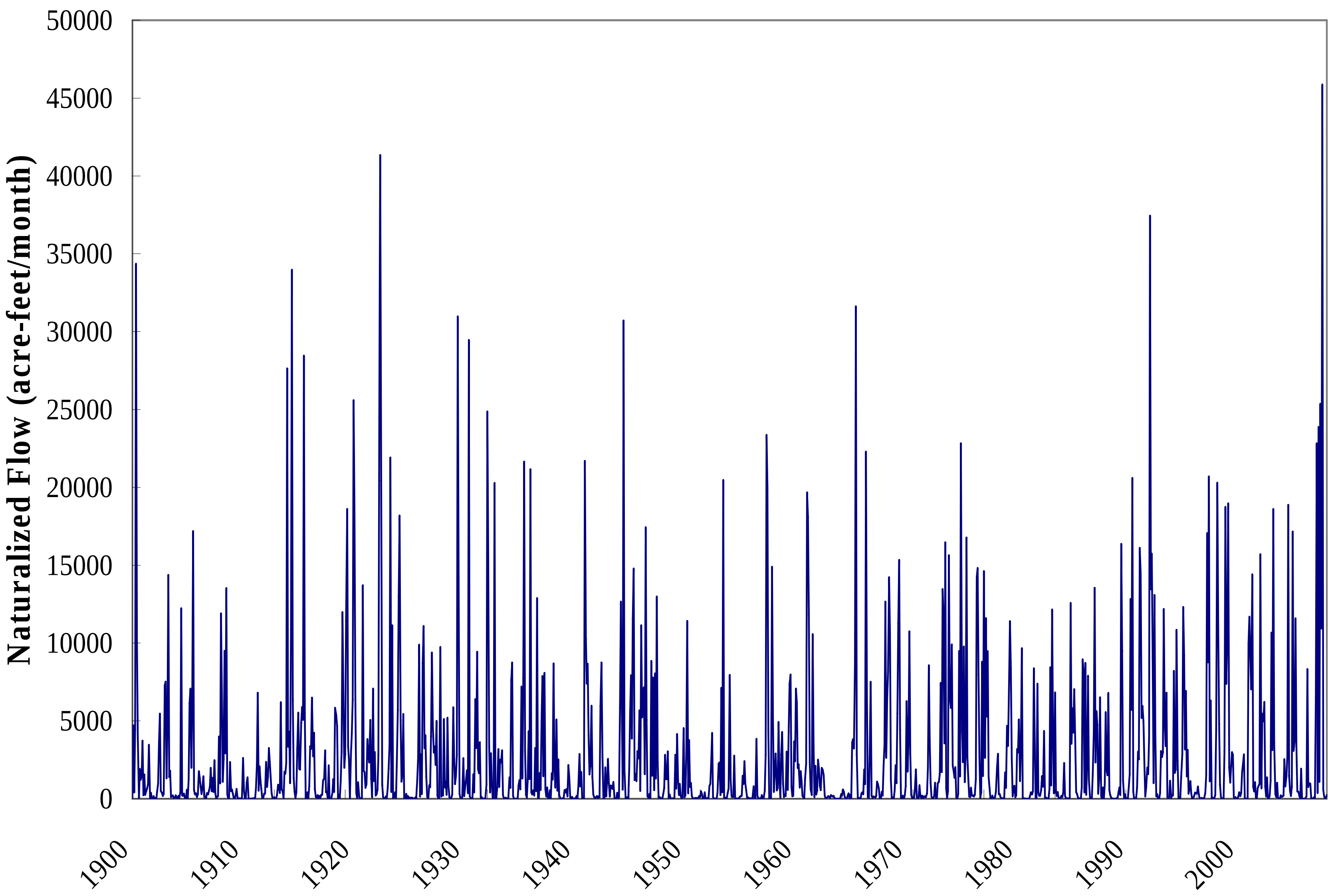

Figure A.65 Monthly Naturalized Flow at BGFR65 – Big Creek near Freestone

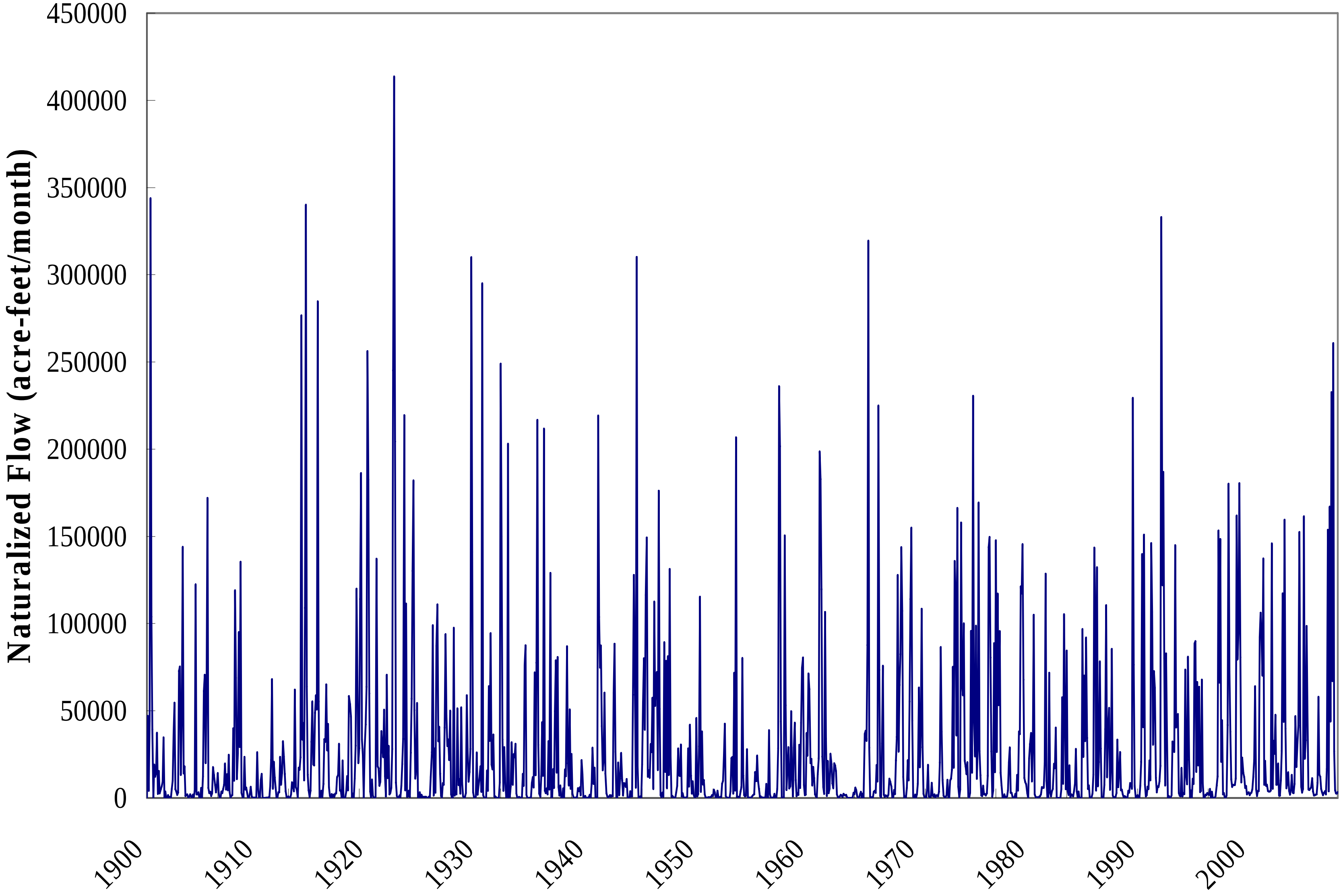

Figure A.66 Monthly Naturalized Flow at NAEA66 – Navasota River near Easterly

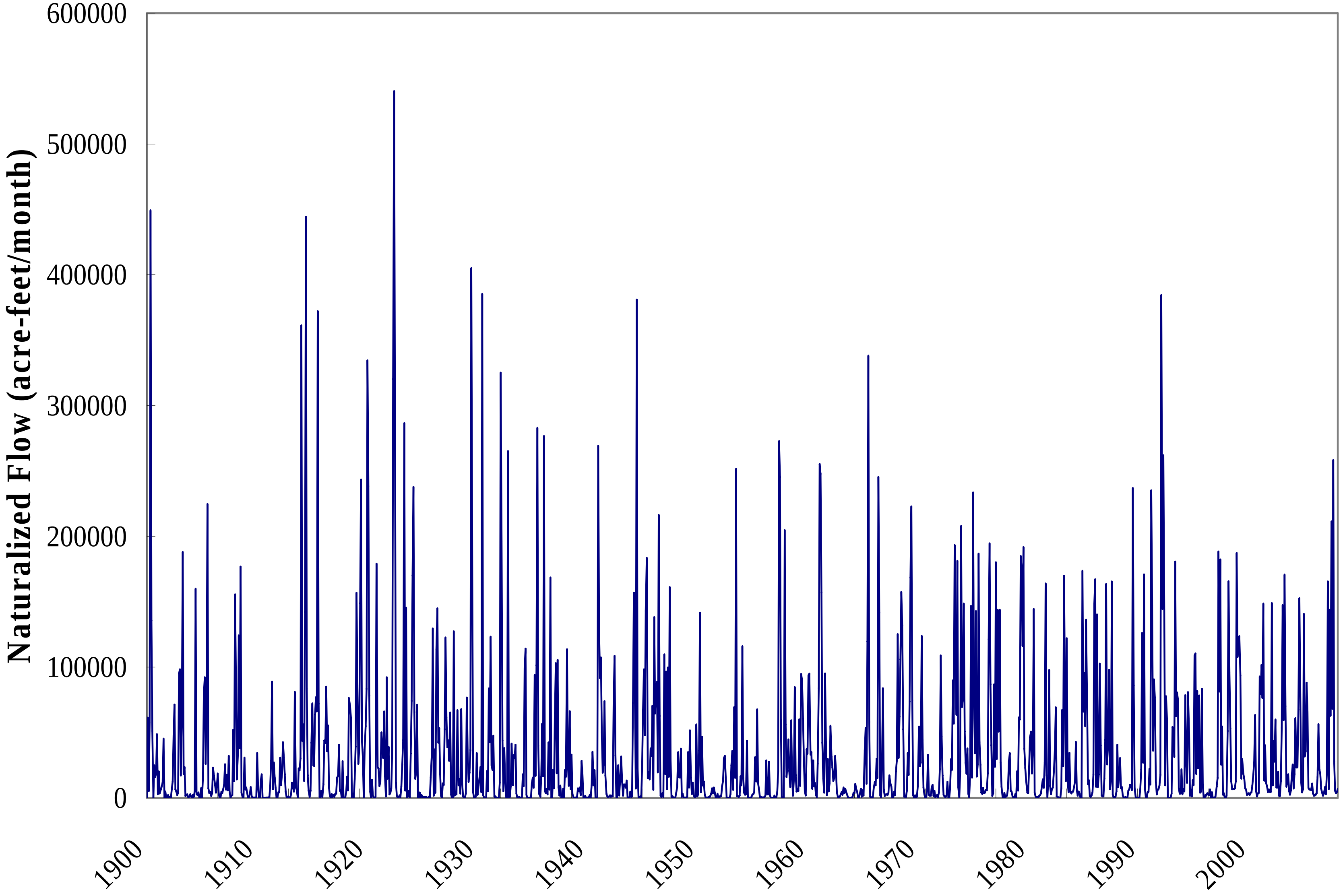

Figure A.67 Monthly Naturalized Flow at NABR67 – Navasota River near Bryan

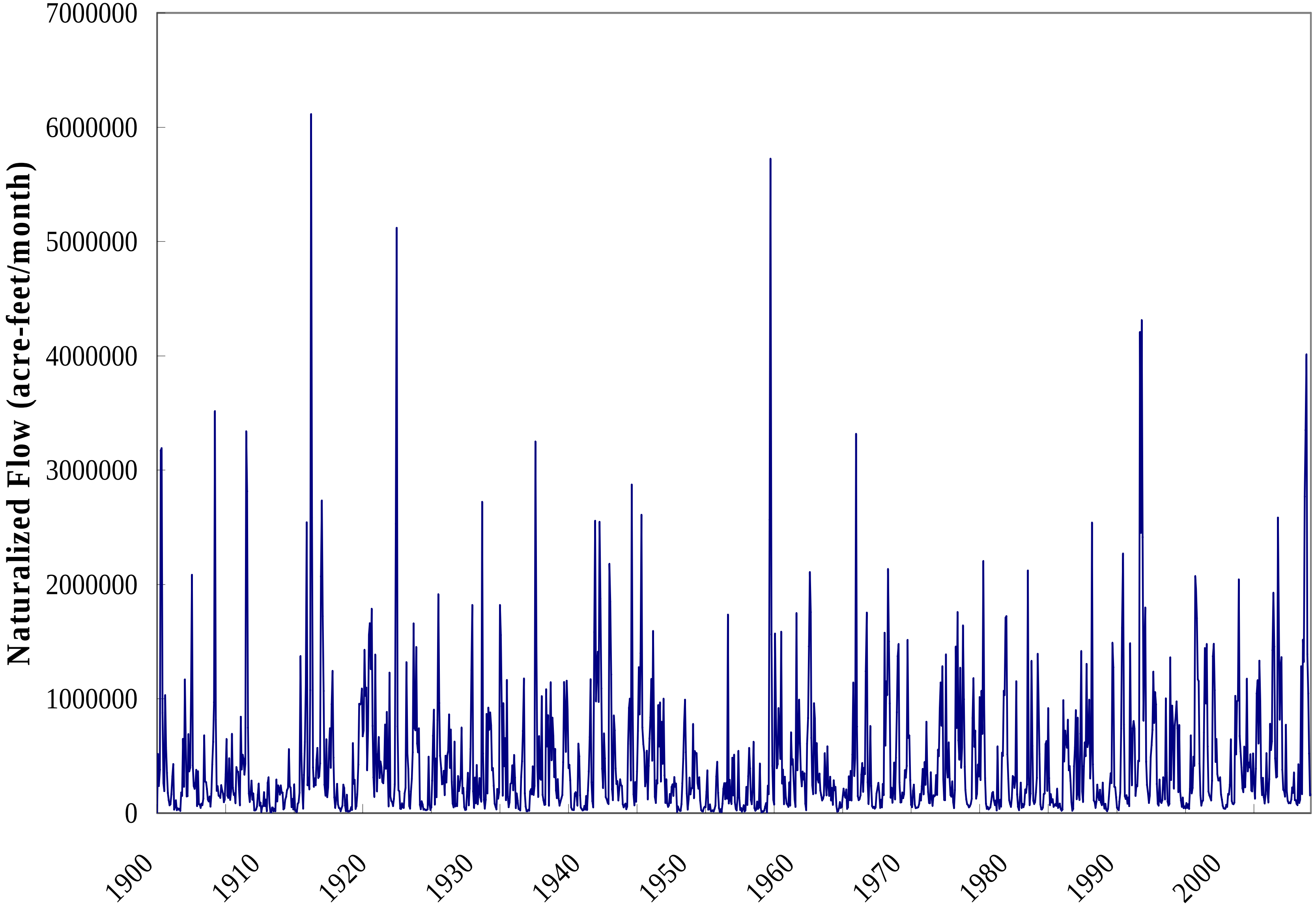

Figure A.68 Monthly Naturalized Flow at BRHE68 – Brazos River near Hempstead

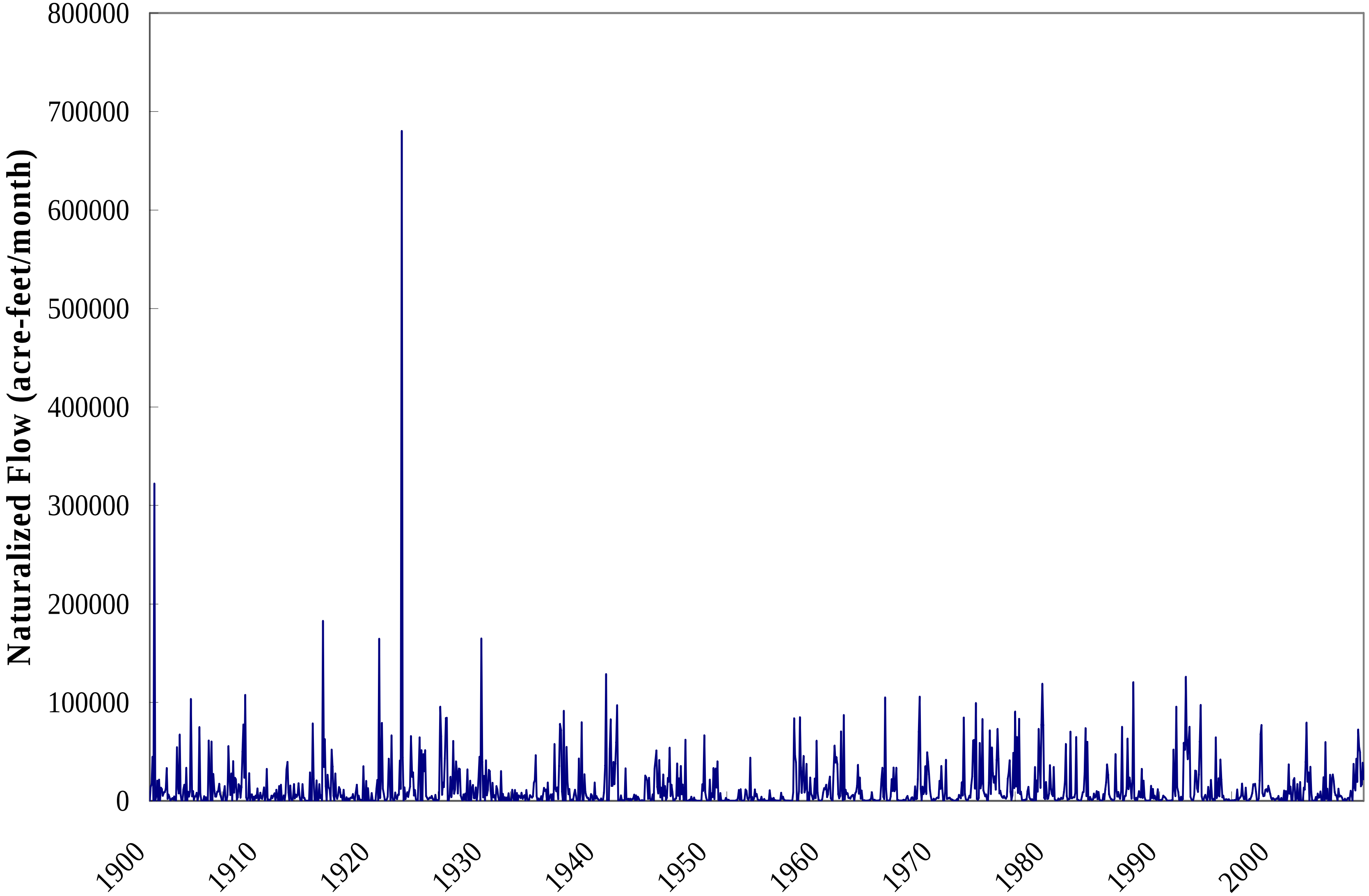

Figure A.69 Monthly Naturalized Flow at MCBL69 – Mill Creek near Bellville

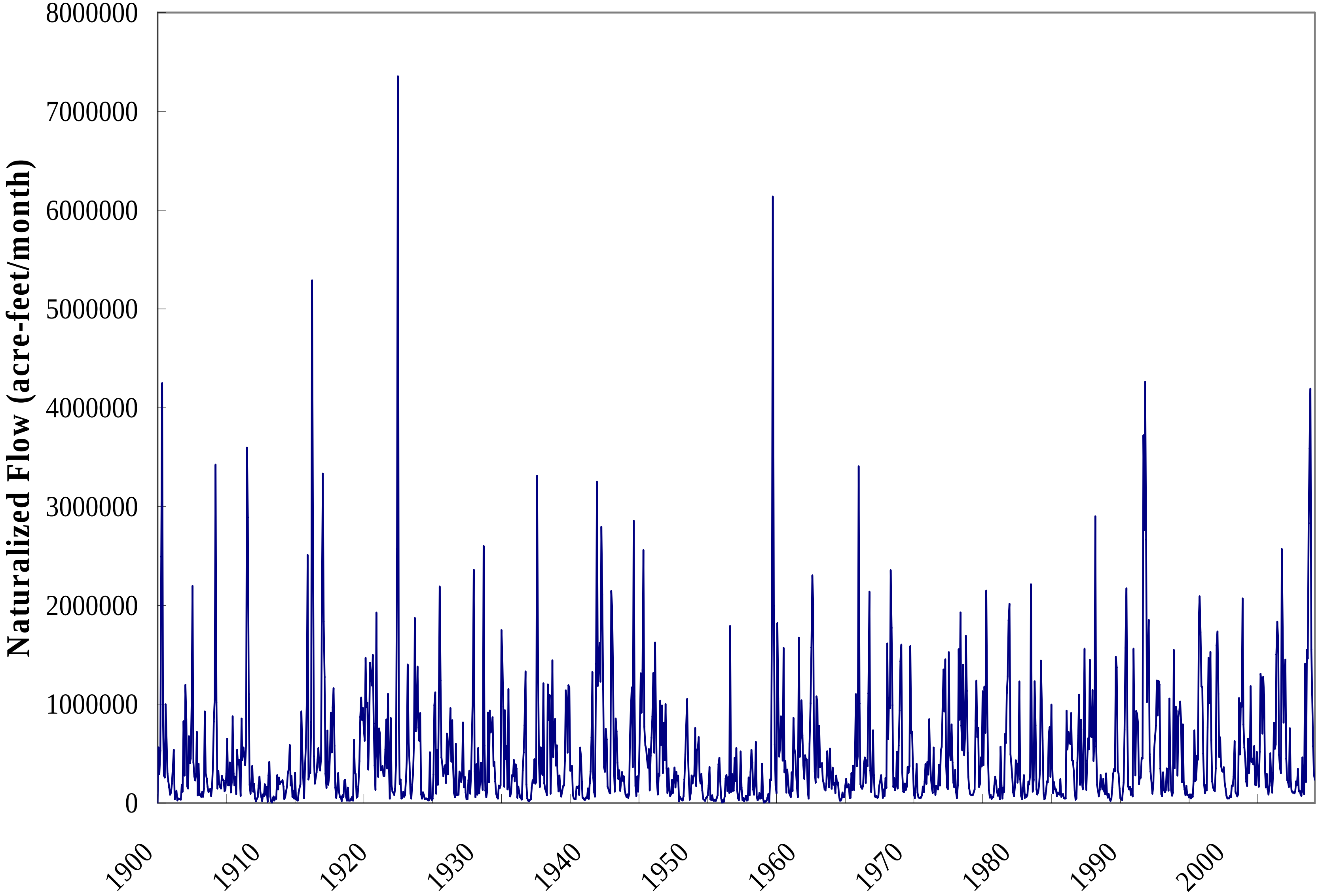

Figure A.70 Monthly Naturalized Flow at BRRI70 – Brazos River at Richmond

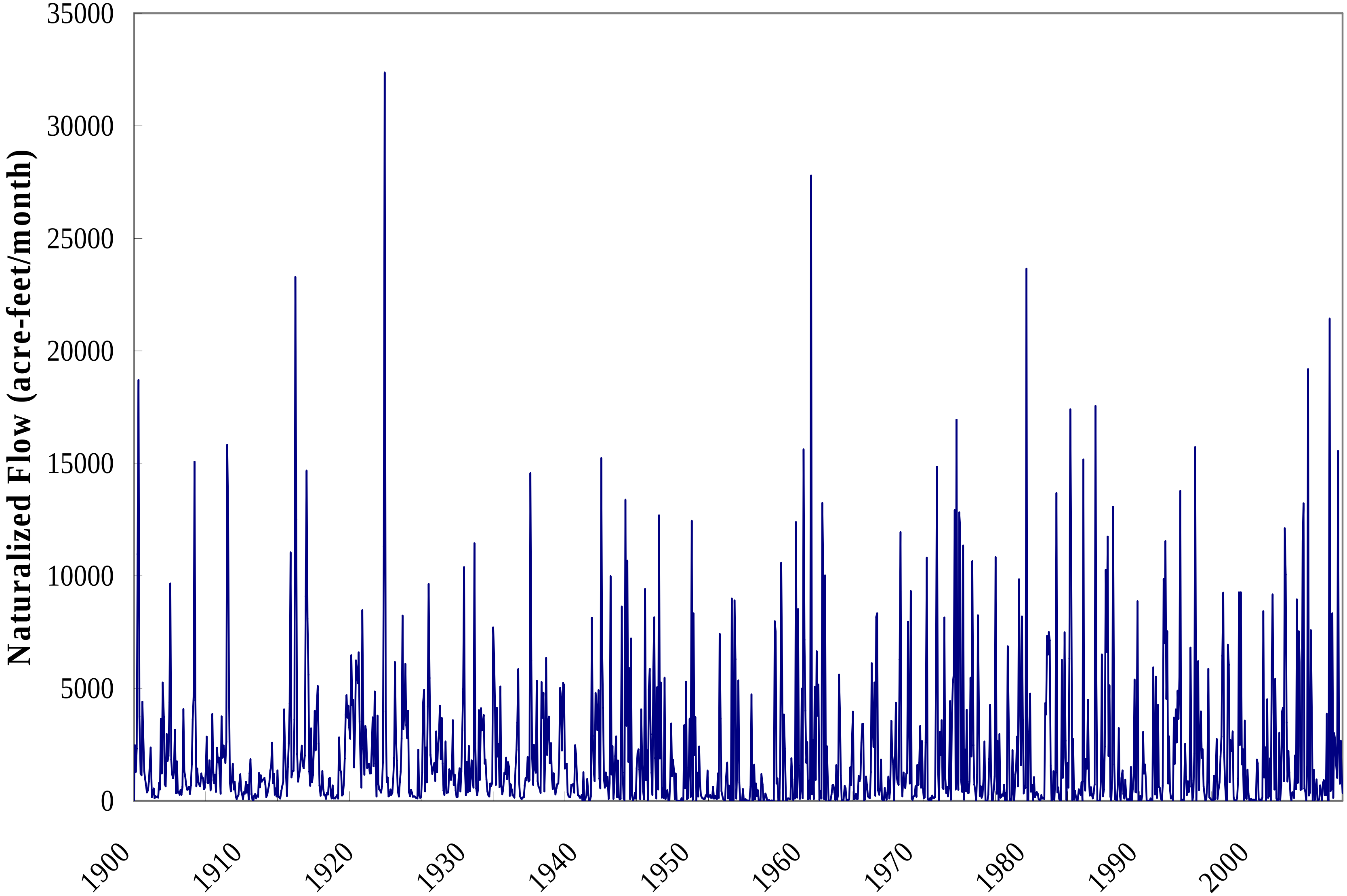

Figure A.71 Monthly Naturalized Flow at BGNE71 – Big Creek near Needville

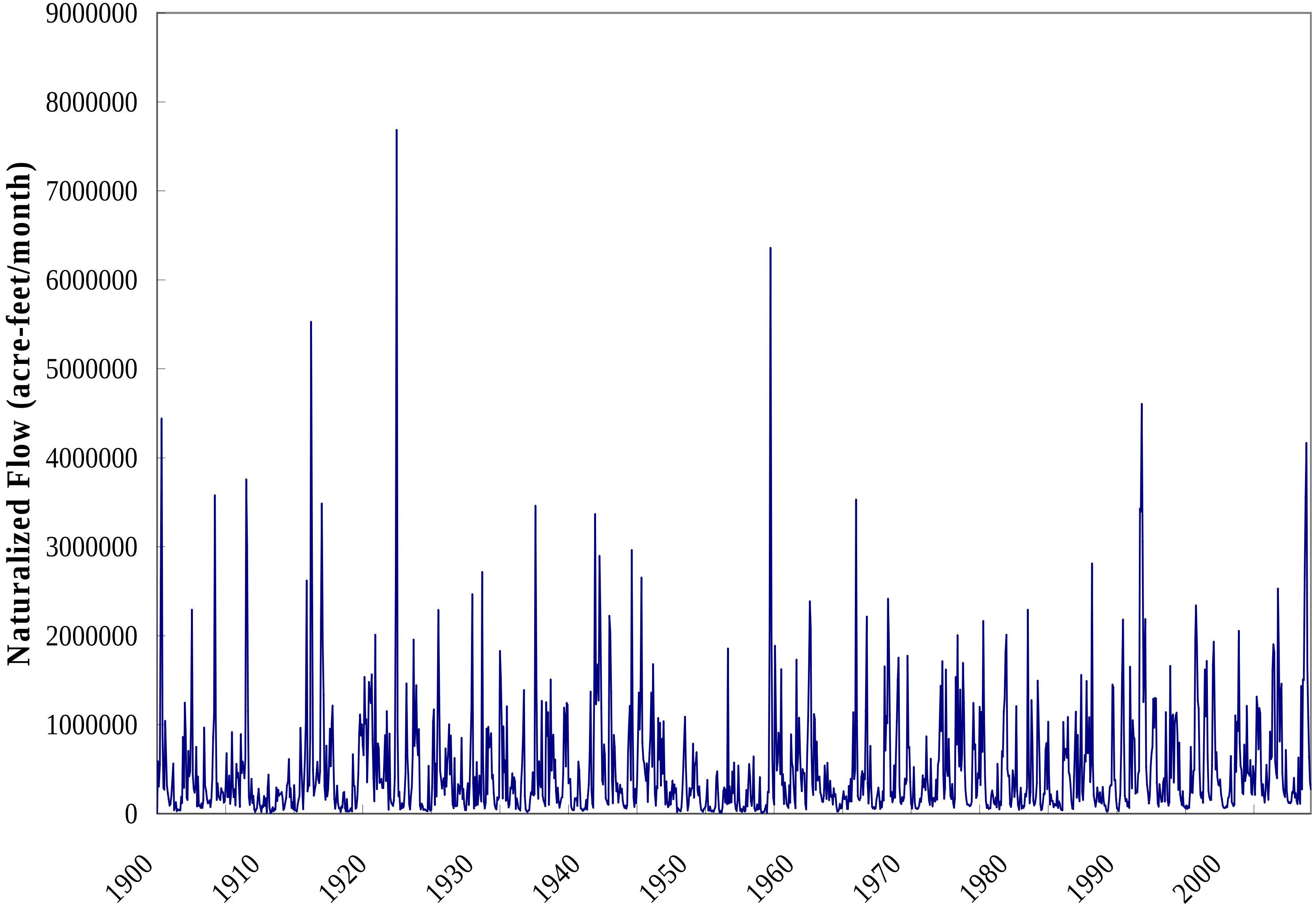

Figure A.72 Monthly Naturalized Flow at BRRO72 – Brazos River at Rosharon

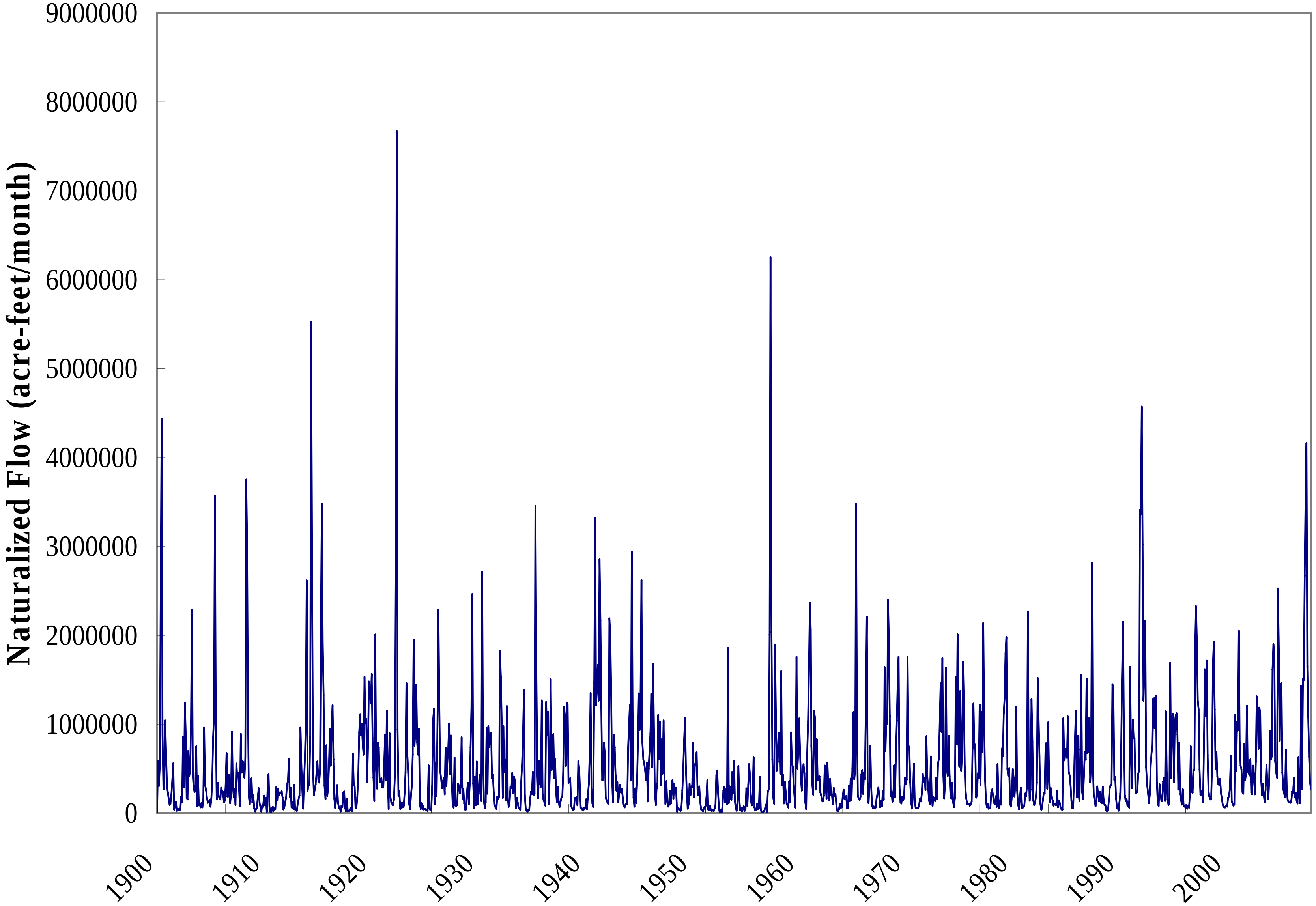

Figure A.73 Monthly Naturalized Flow at BRGM73 – Brazos River at Gulf of Mexico

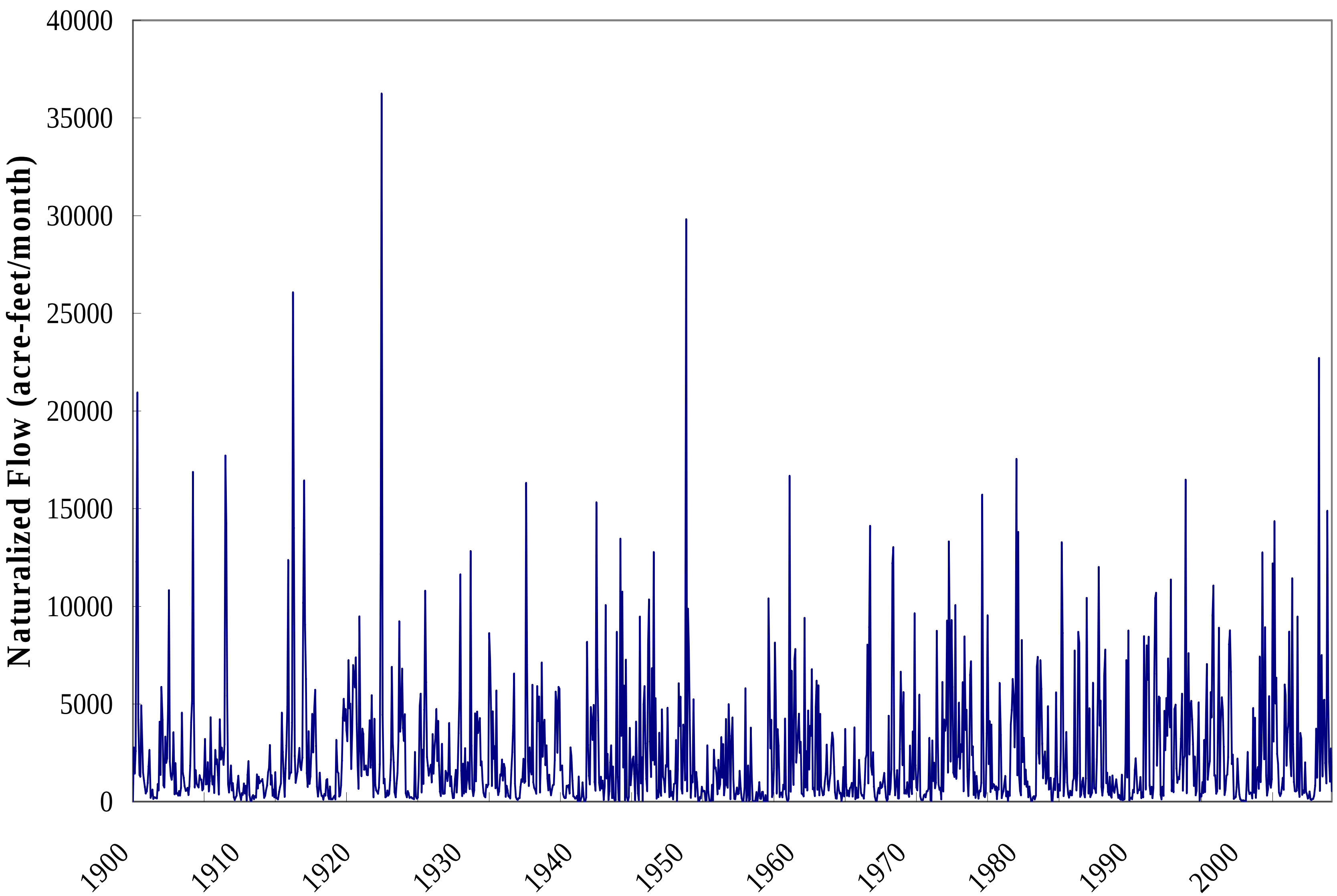

Figure A.74 Monthly Naturalized Flow at CLPEC1 – Clear Creek near Pearland

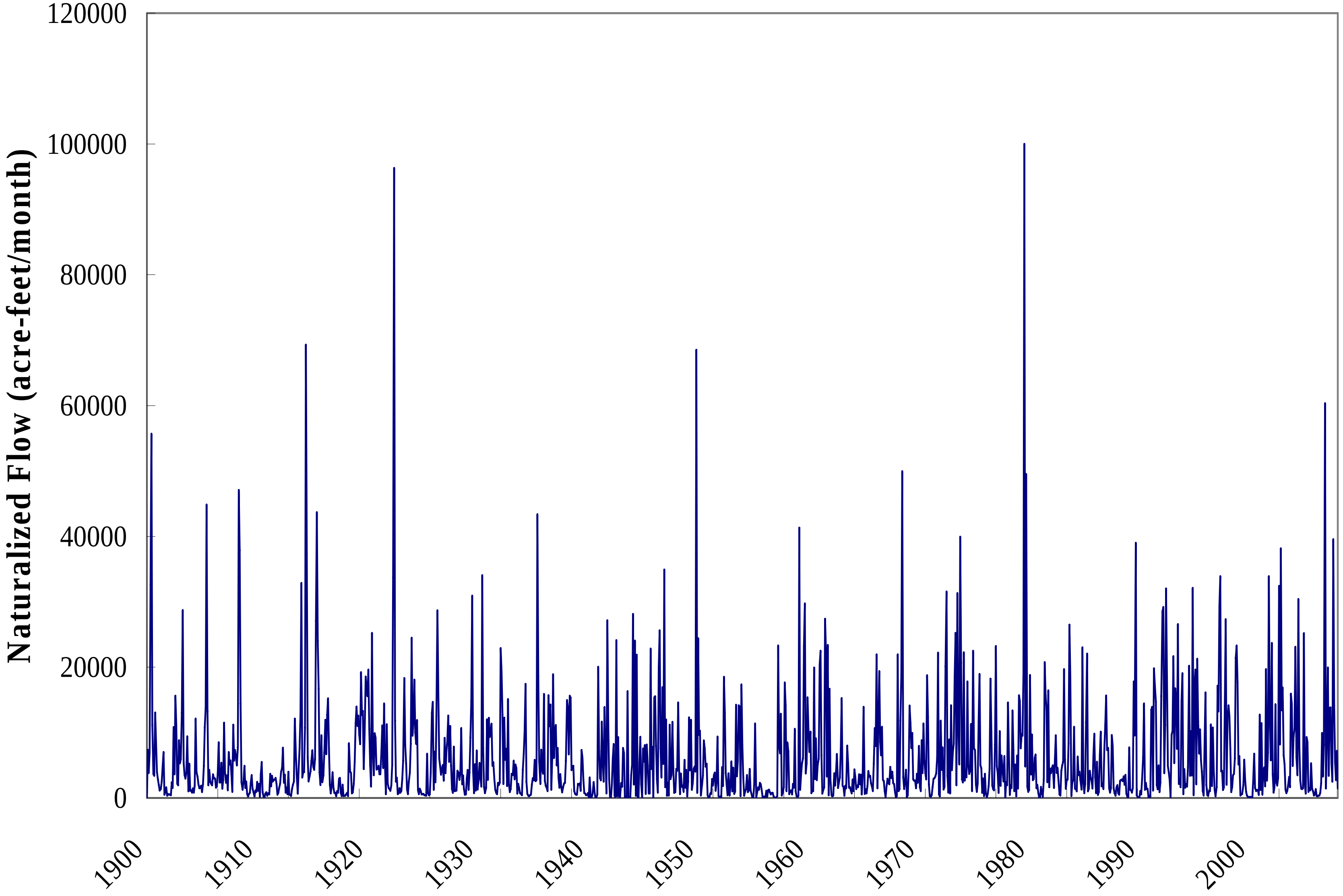

Figure A.75 Monthly Naturalized Flow at CBALC2 – Chocolate Bayou near Alvin

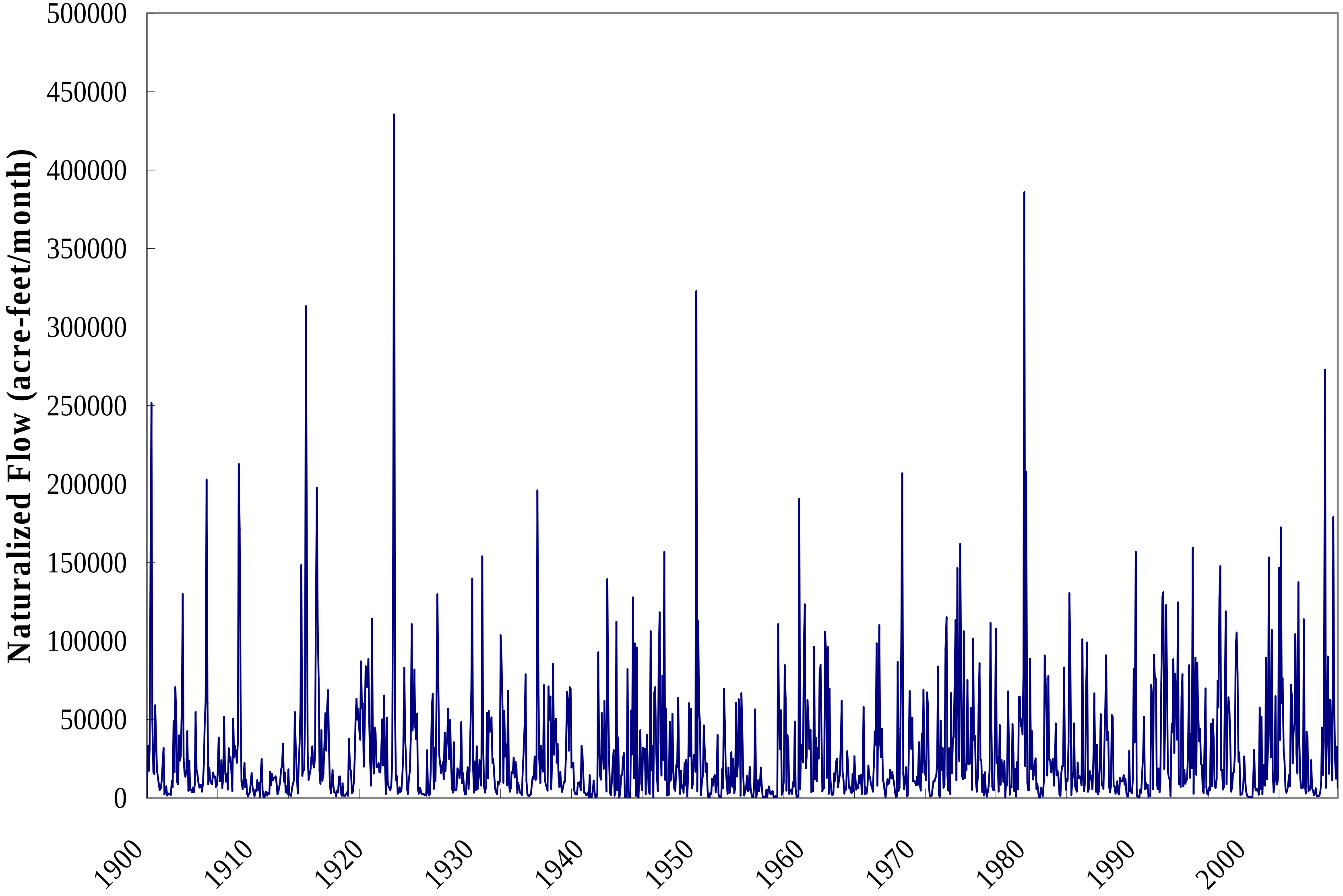

Figure A.76 Monthly Naturalized Flow at SJGBC3 – San Jacinto-Brazos Coastal Basin at Galveston Bay

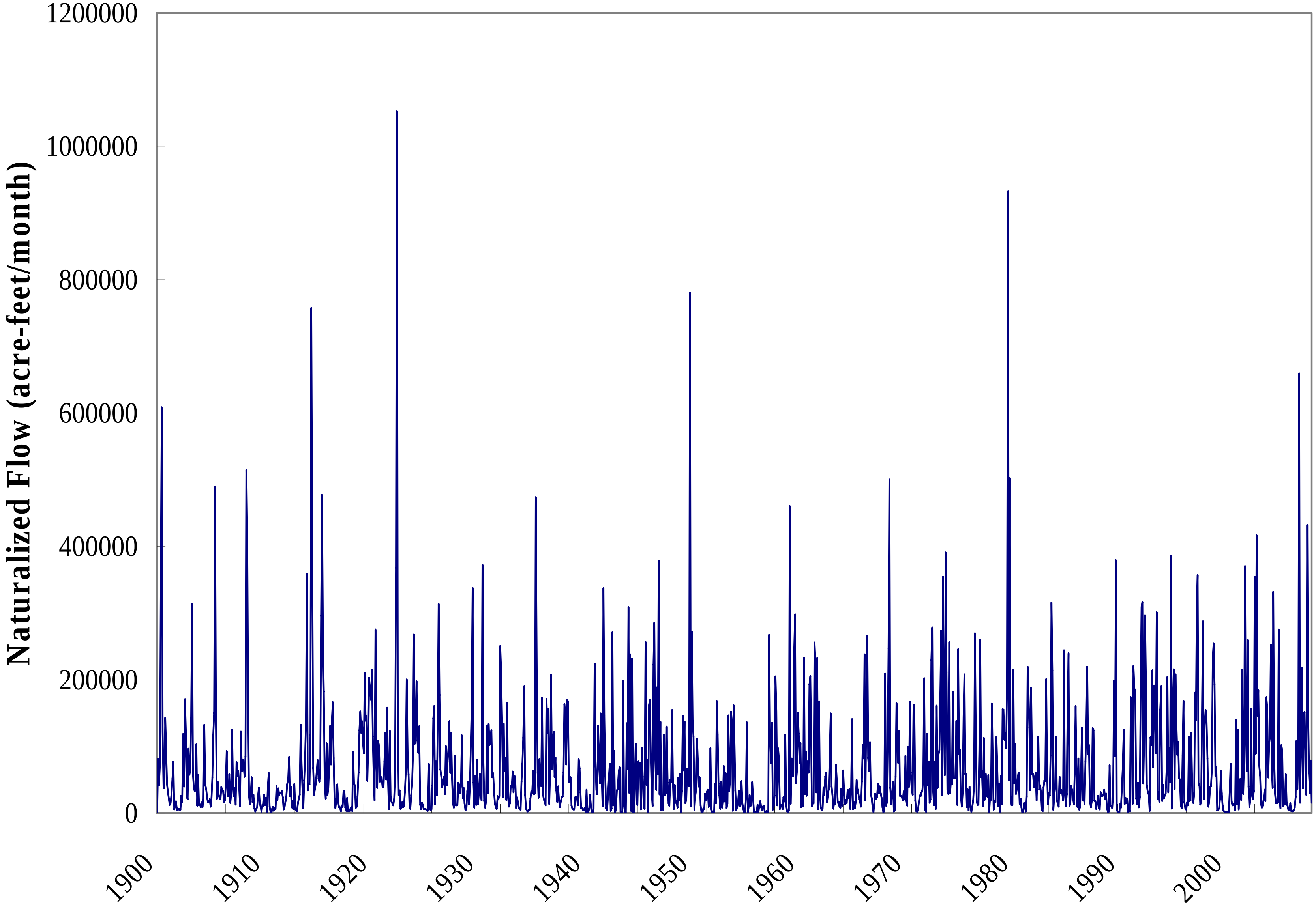

Figure A.77 Monthly Naturalized Flow at SJGMC4 – San Jacinto-Brazos Coastal Basin at the Gulf of Mexico

Appendix B

Plots of 1998-2007 Gaged and Naturalized Flows at 48 Control Points

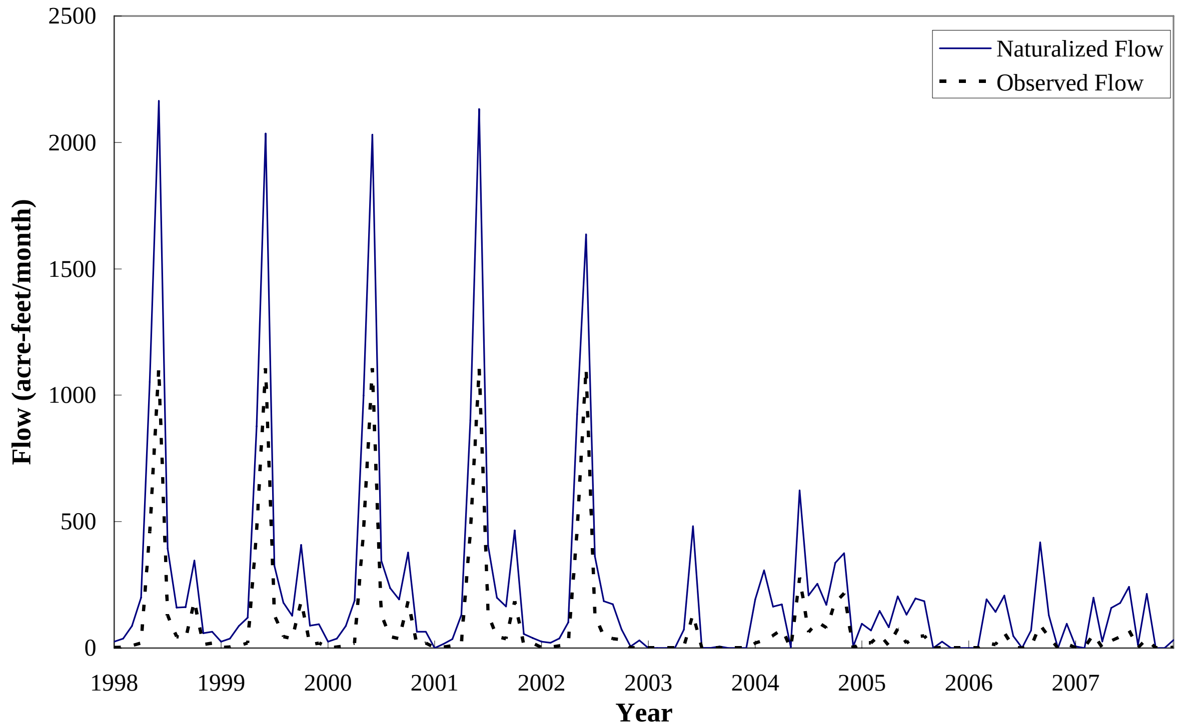

Figure B.1 Monthly Naturalized and Observed Flows at RWPL01

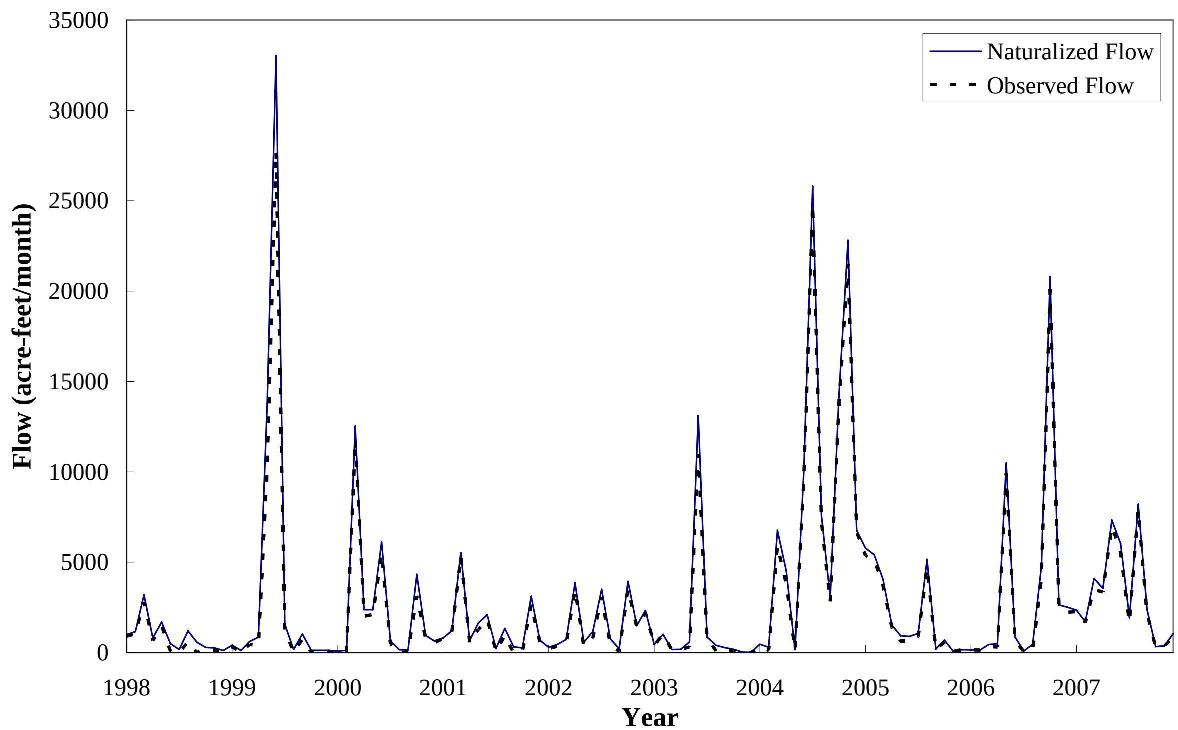

Figure B.2 Monthly Naturalized and Observed Flows at SFAS06

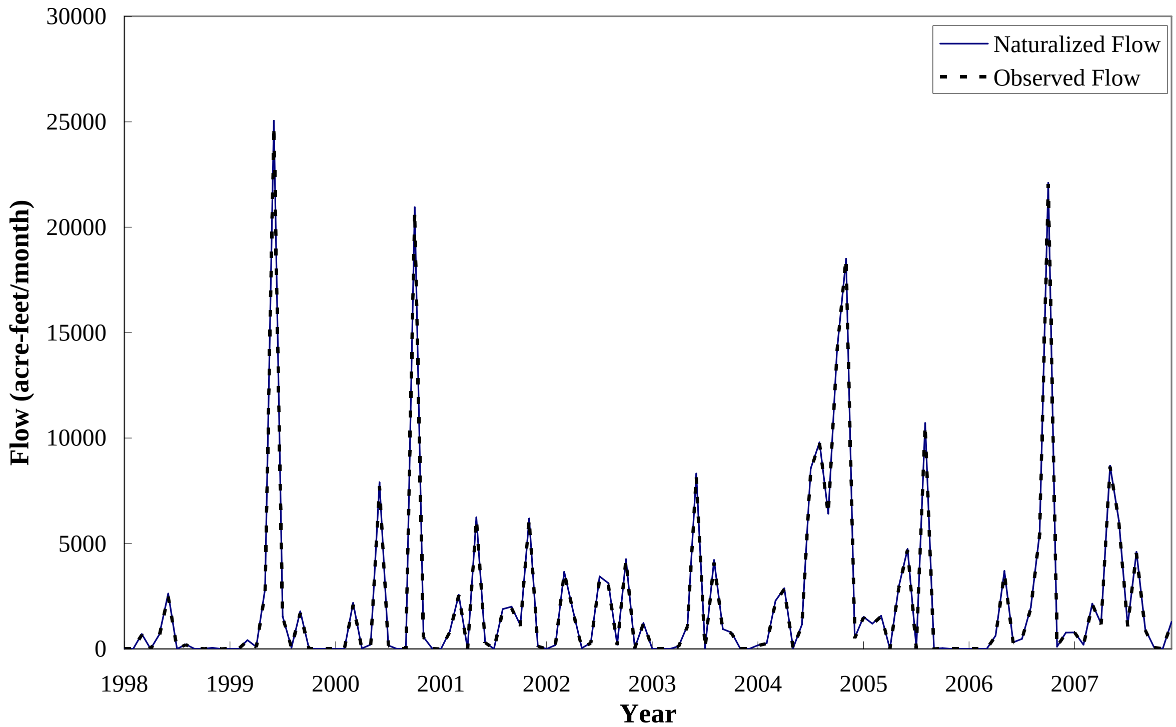

Figure B.3 Monthly Naturalized and Observed Flows at DMJU08

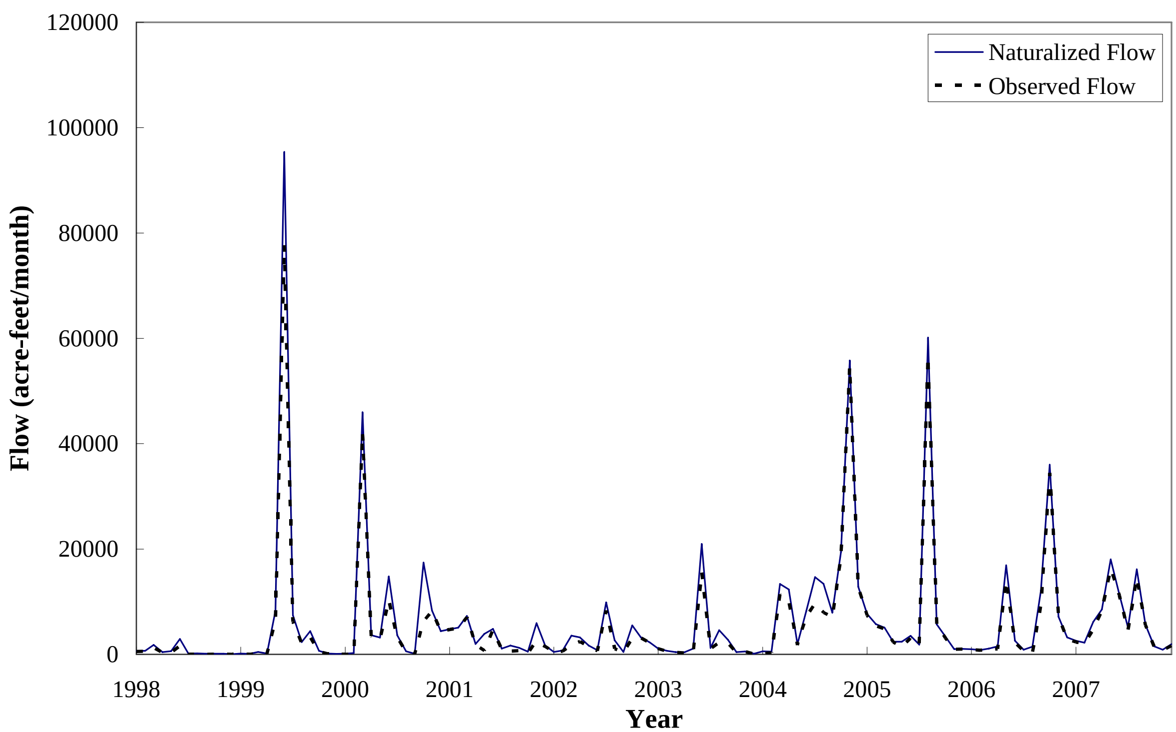

Figure B.4 Monthly Naturalized and Observed Flows at DMAS09

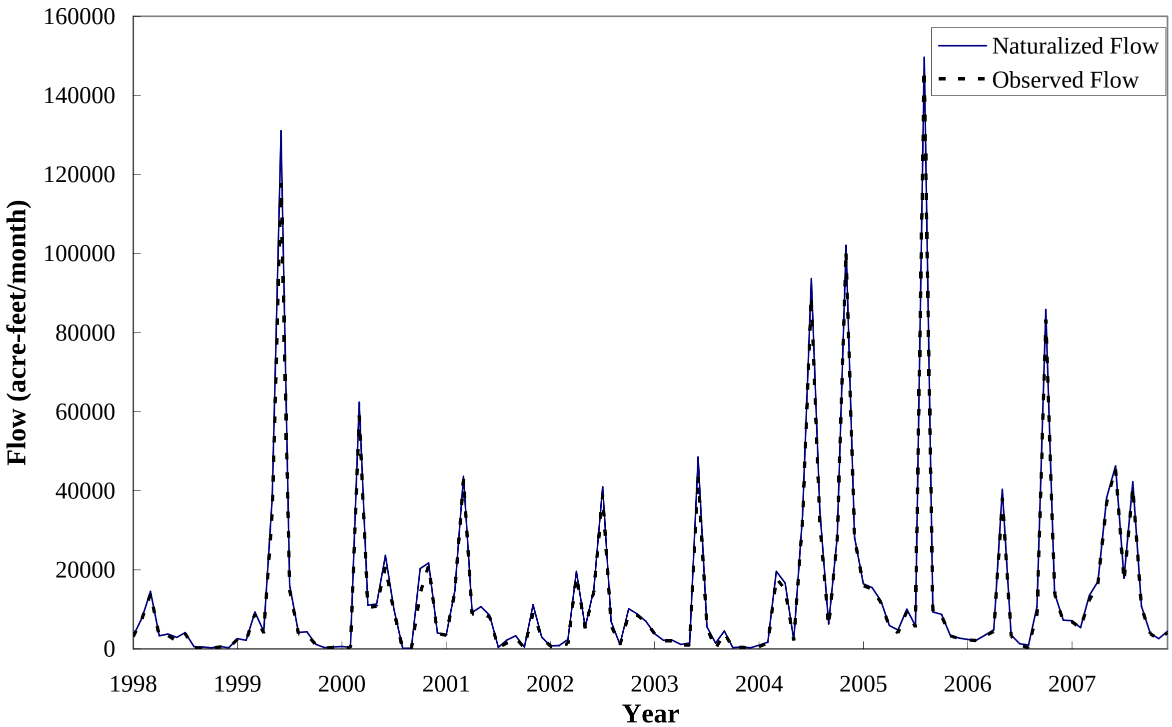

Figure B.5 Monthly Naturalized and Observed Flows at BRSE11

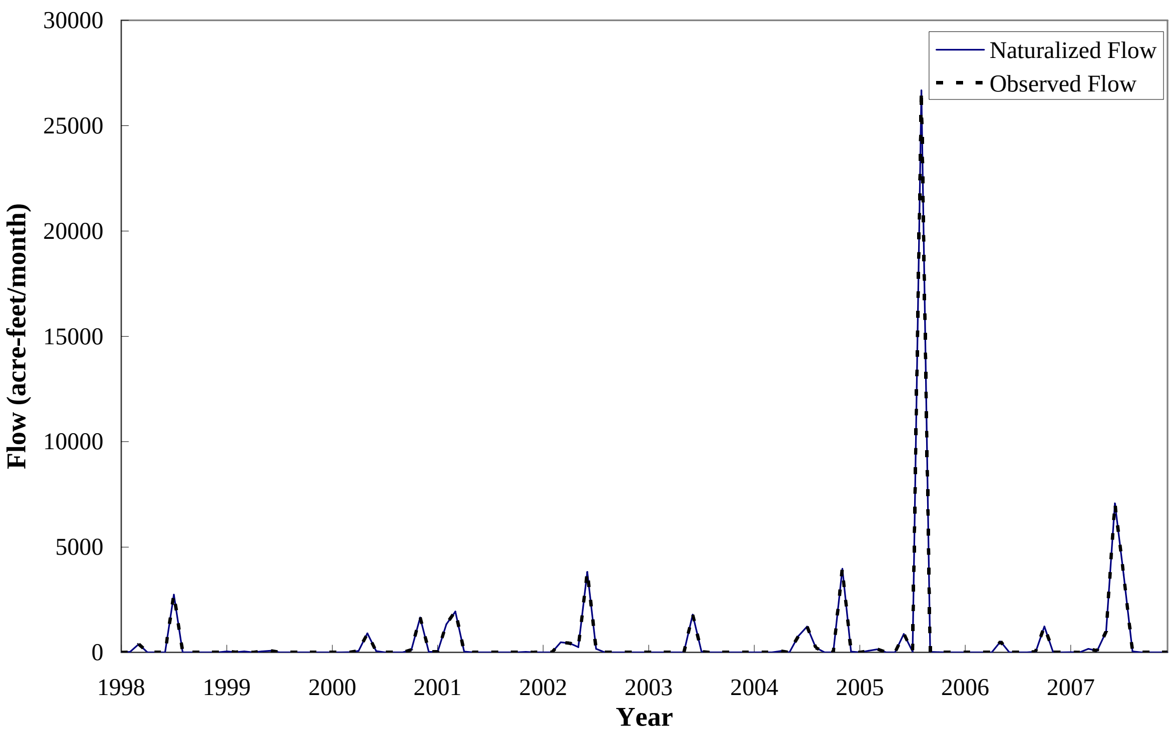

Figure B.6 Monthly Naturalized and Observed Flows at MSMN12

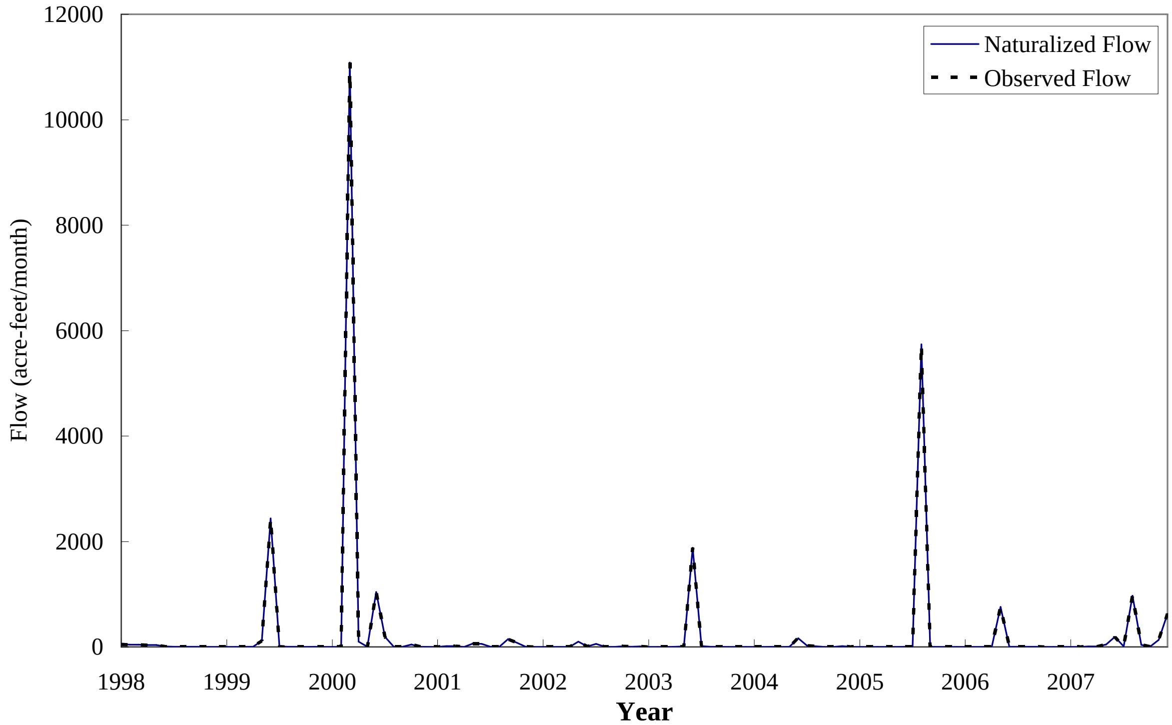

Figure B.7 Monthly Naturalized and Observed Flows at CFRO13

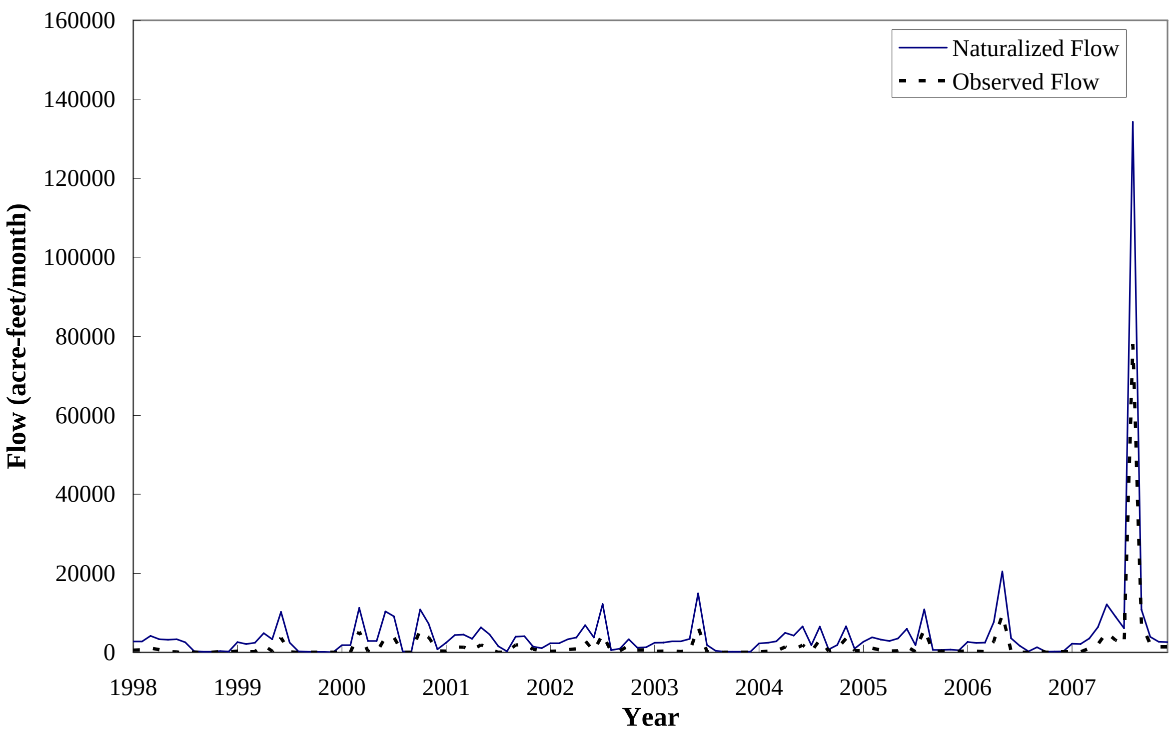

Figure B.8 Monthly Naturalized and Observed Flows at CFNU16

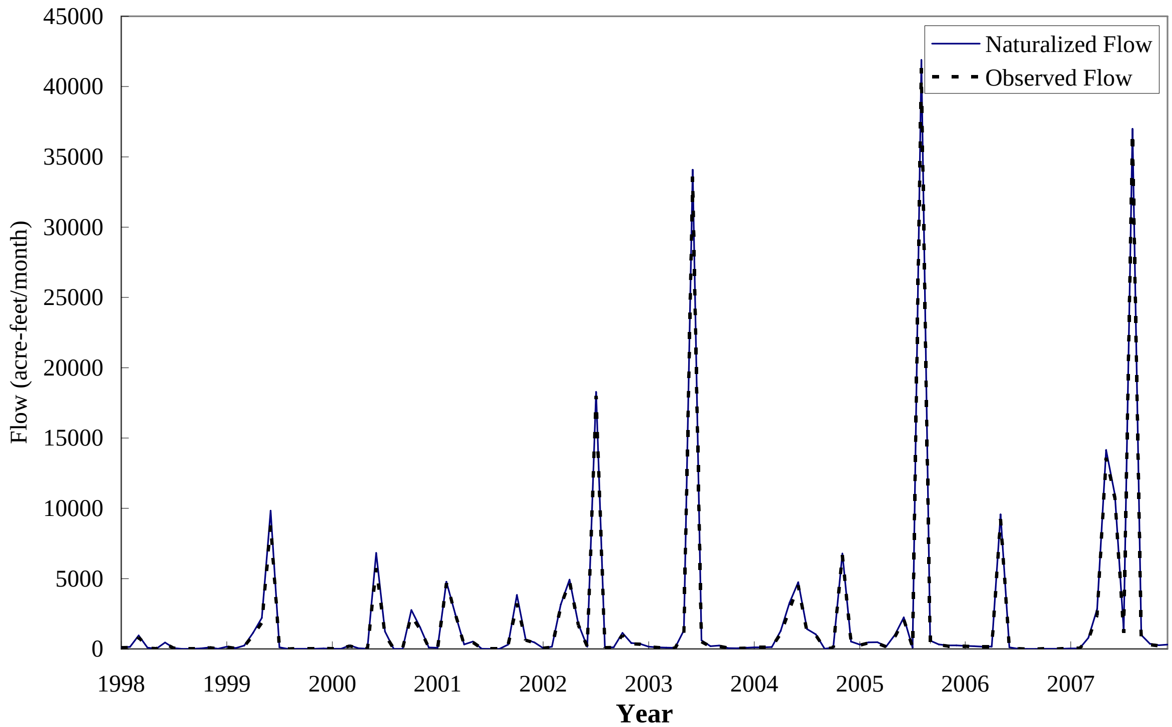

Figure B.9 Monthly Naturalized and Observed Flows at CAST17

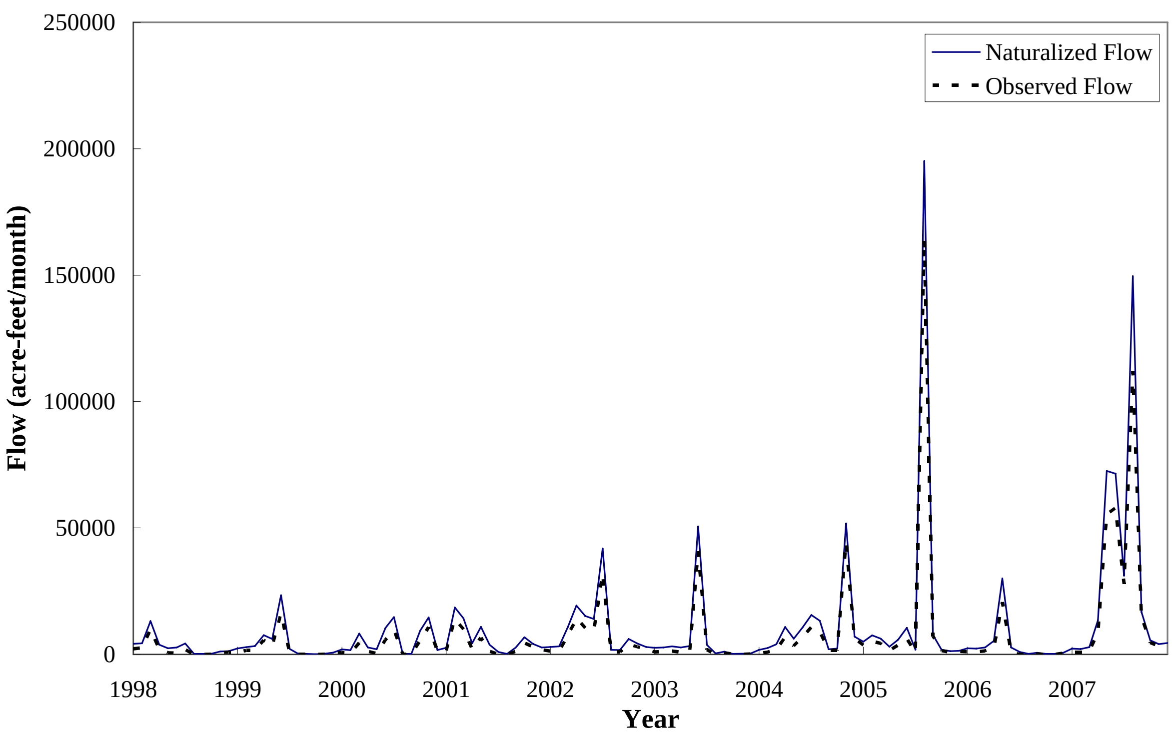

Figure B.10 Monthly Naturalized and Observed Flows at CFFG18

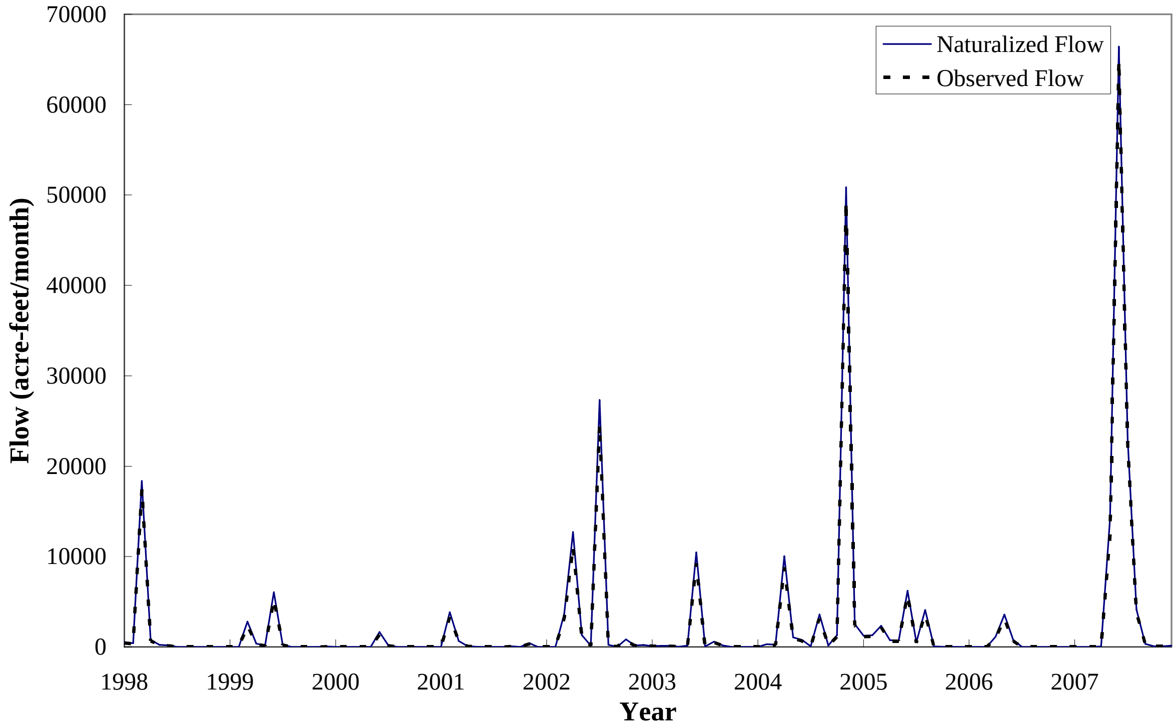

Figure B.11 Monthly Naturalized and Observed Flows at HCAL19

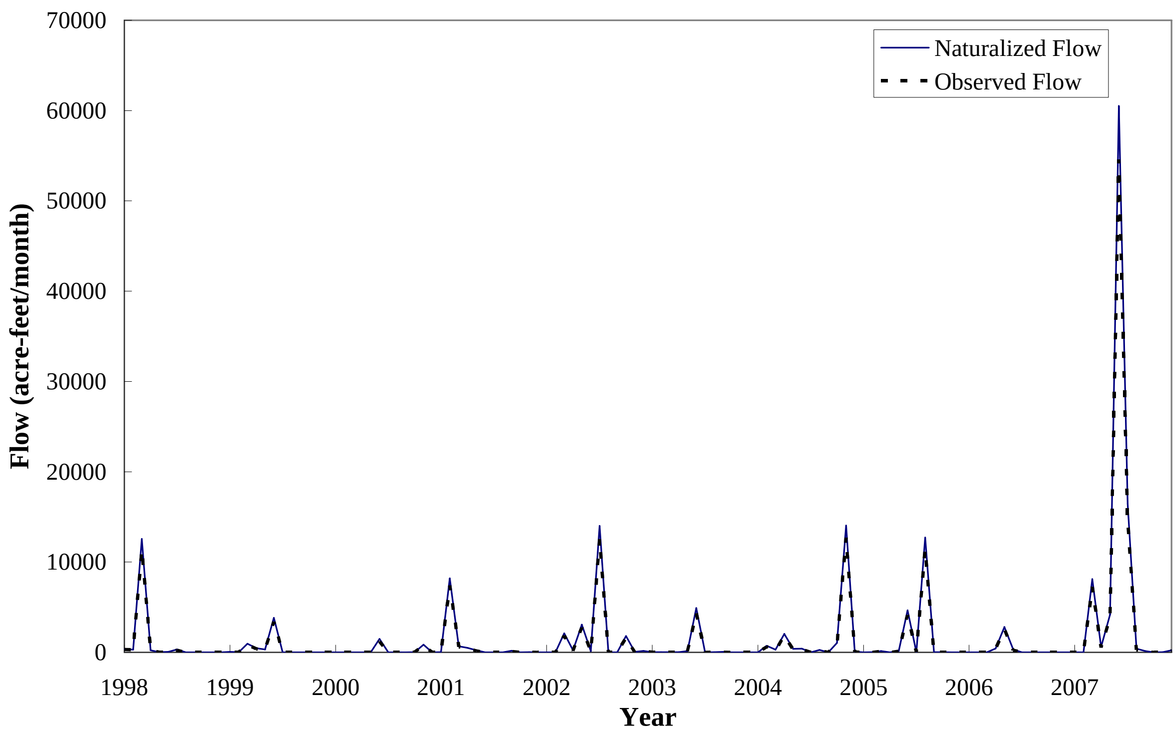

Figure B.12 Monthly Naturalized and Observed Flows at BSBR20

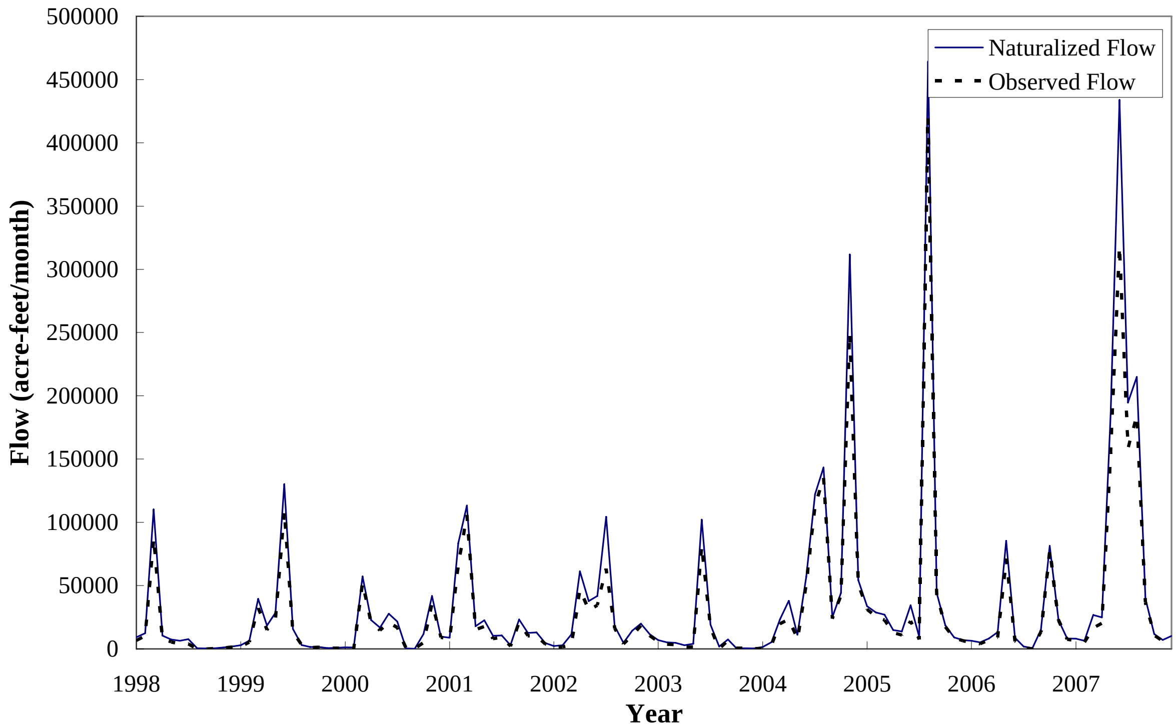

Figure B.13 Monthly Naturalized and Observed Flows at BRSB23

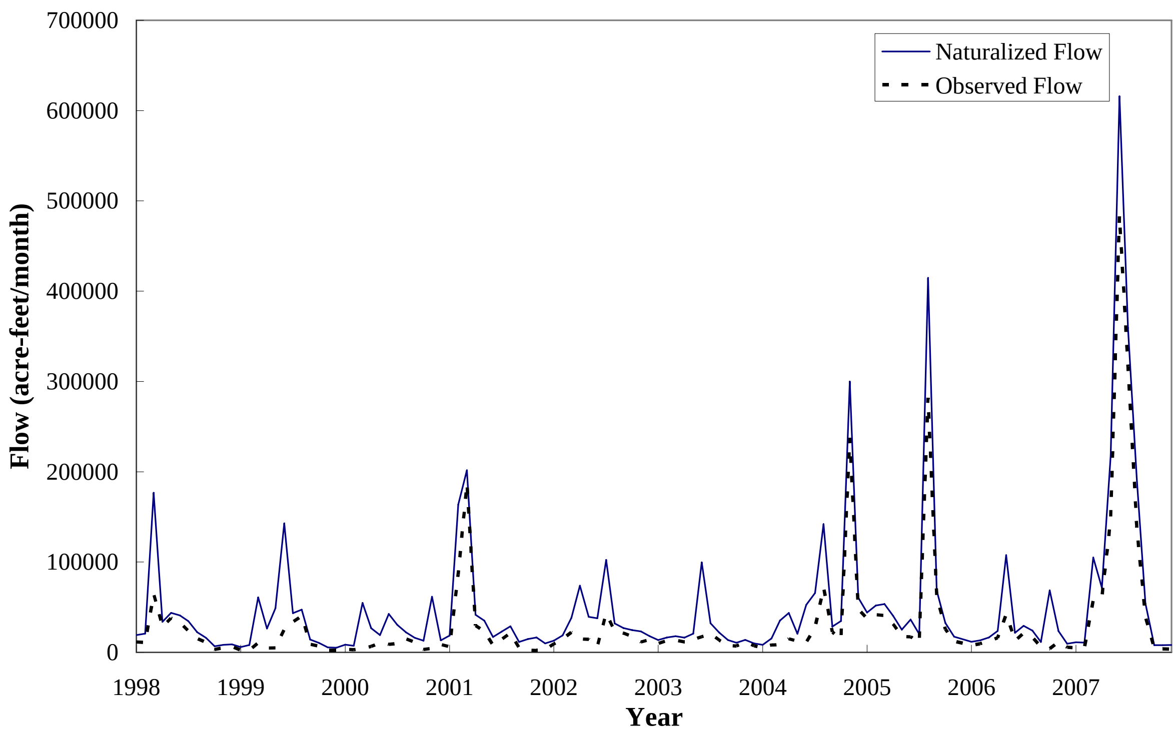

Figure B.14 Monthly Naturalized and Observed Flows at BRPP27

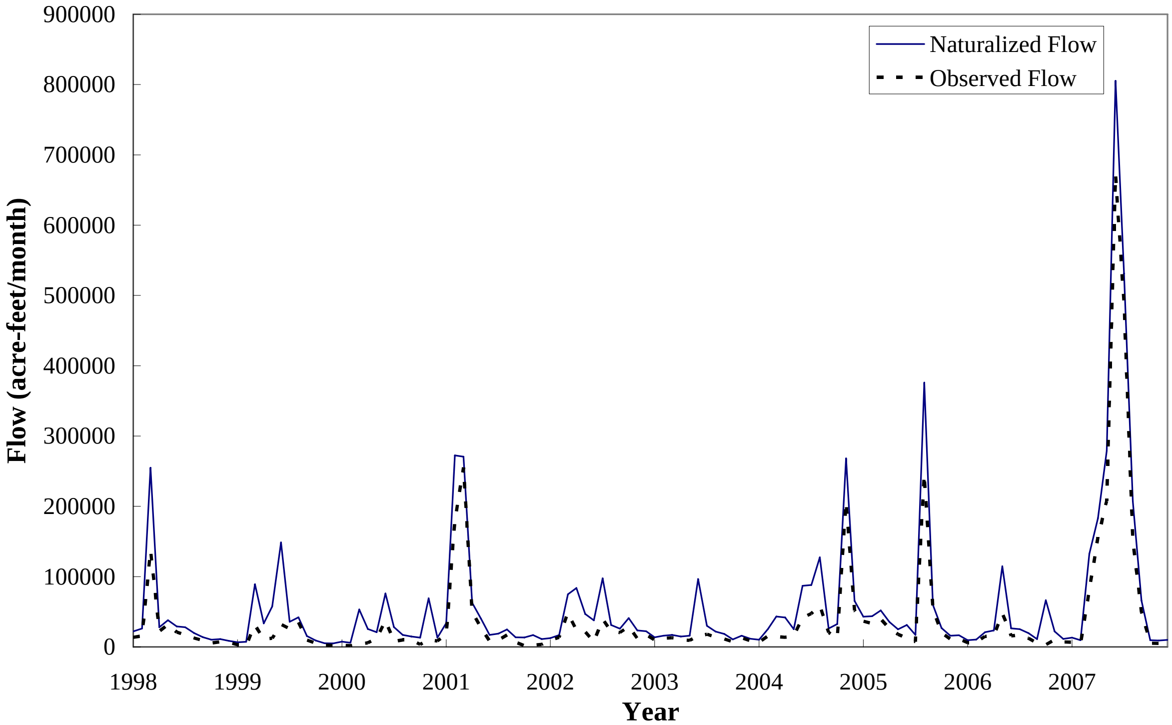

Figure B.15 Monthly Naturalized and Observed Flows at BRDE29

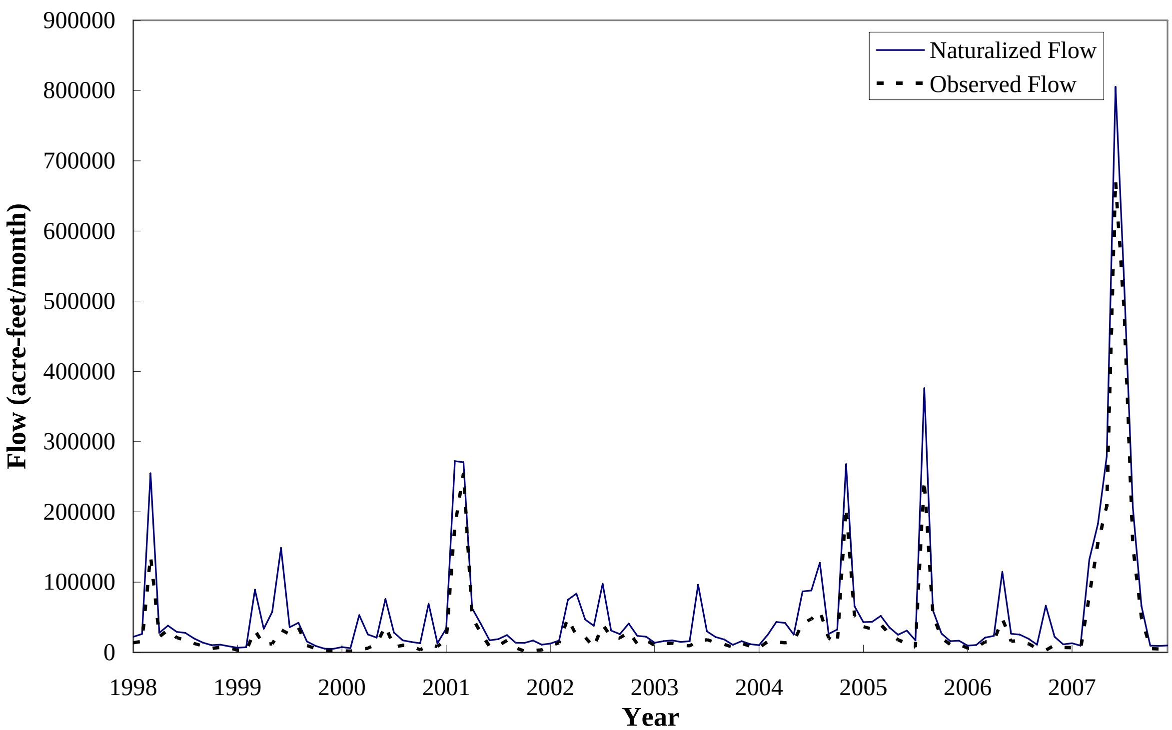

Figure B.16 Monthly Naturalized and Observed Flows at BRGR30

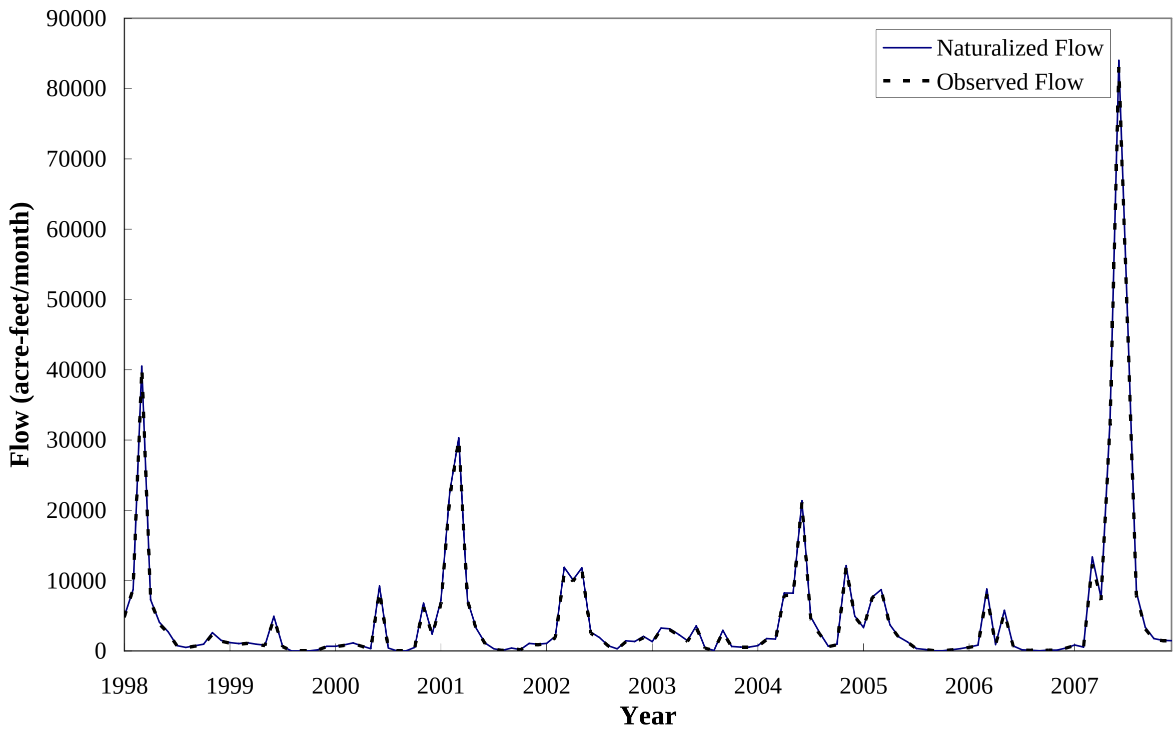

Figure B.17 Monthly Naturalized and Observed Flows at PAGR31

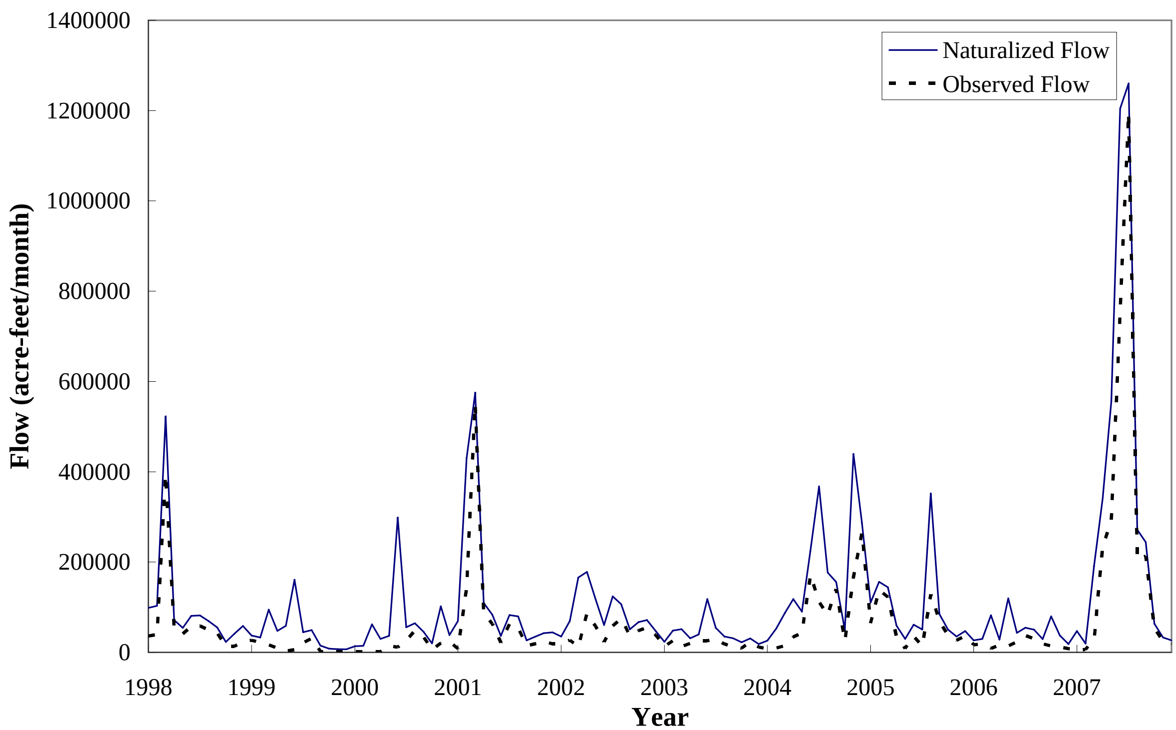

Figure B.18 Monthly Naturalized and Observed Flows at BRAQ33

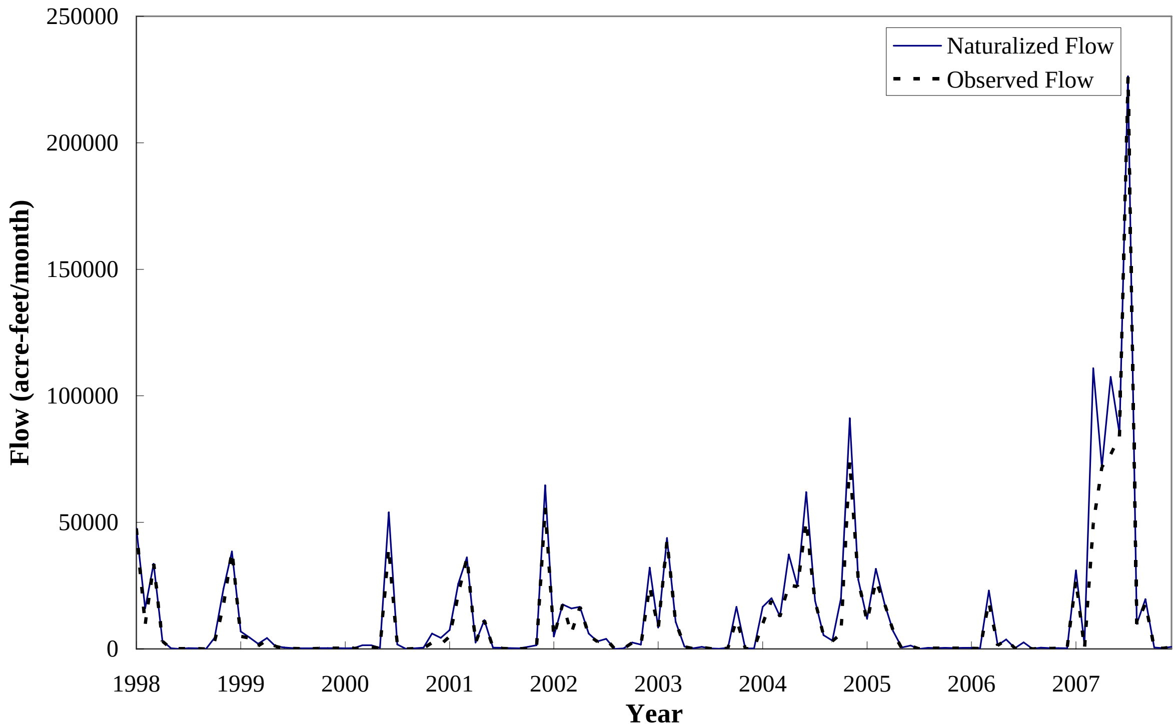

Figure B.19 Monthly Naturalized and Observed Flows at AQAQ34

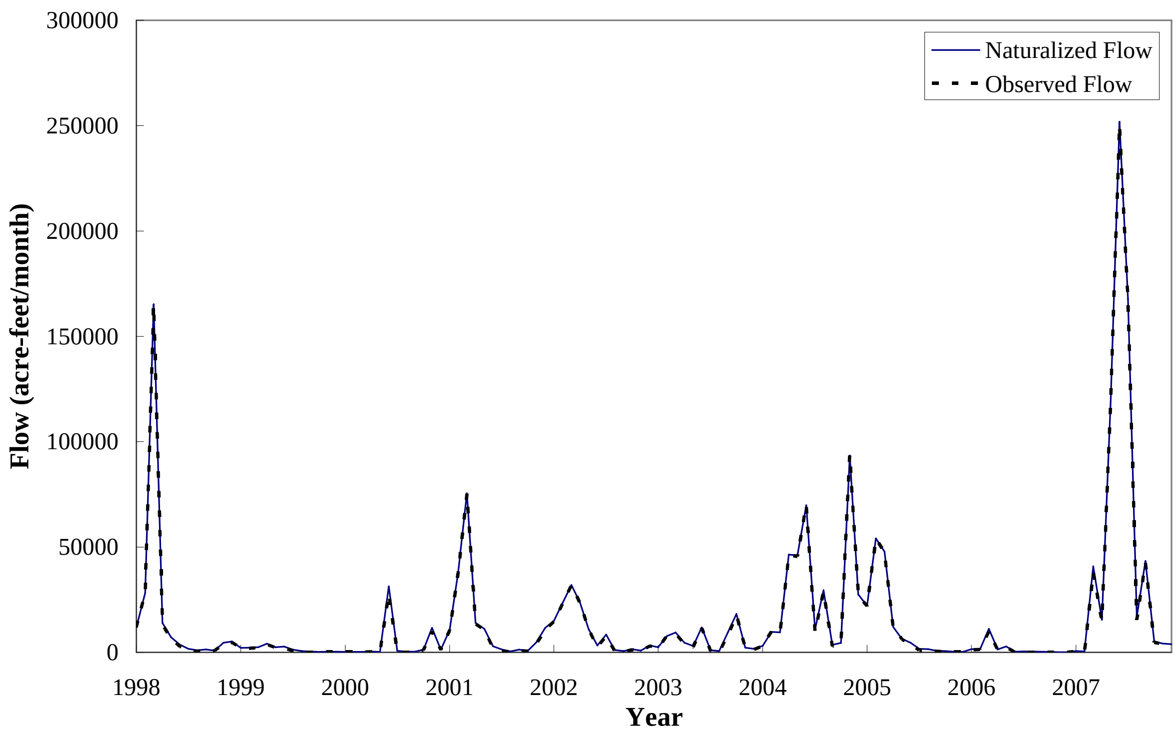

Figure B.20 Monthly Naturalized and Observed Flows at NBCL36

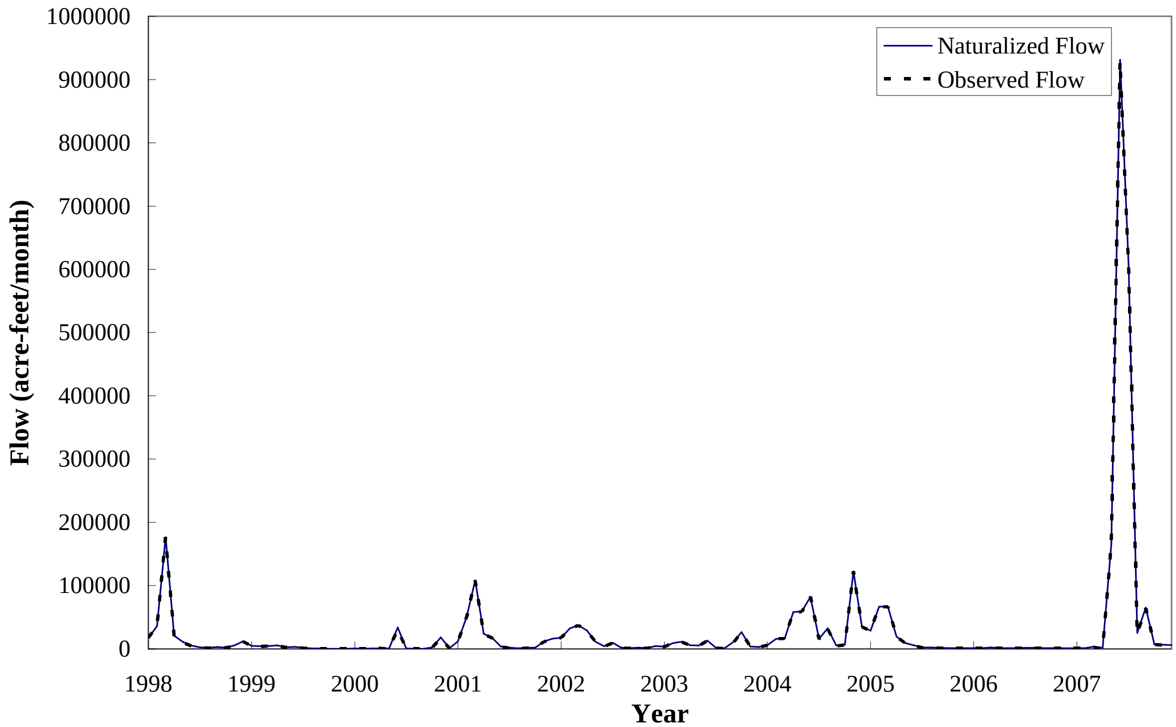

Figure B.21 Monthly Naturalized and Observed Flows at NBVM37

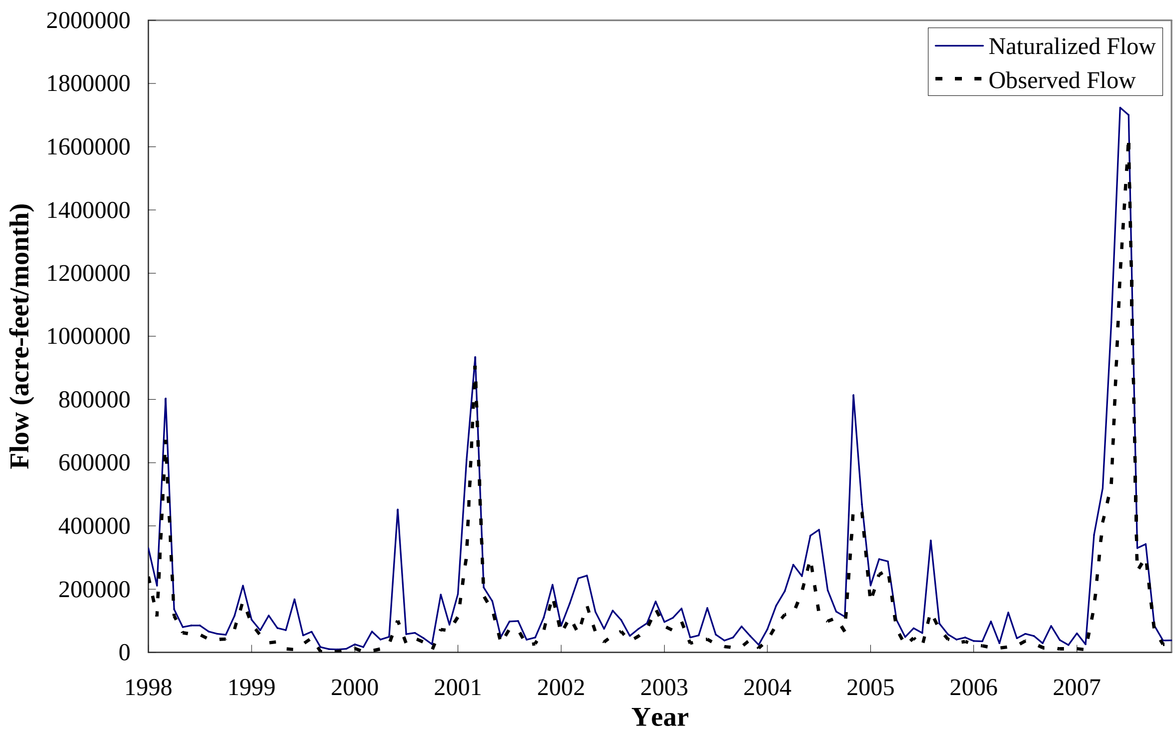

Figure B.22 Monthly Naturalized and Observed Flows at BRWA41

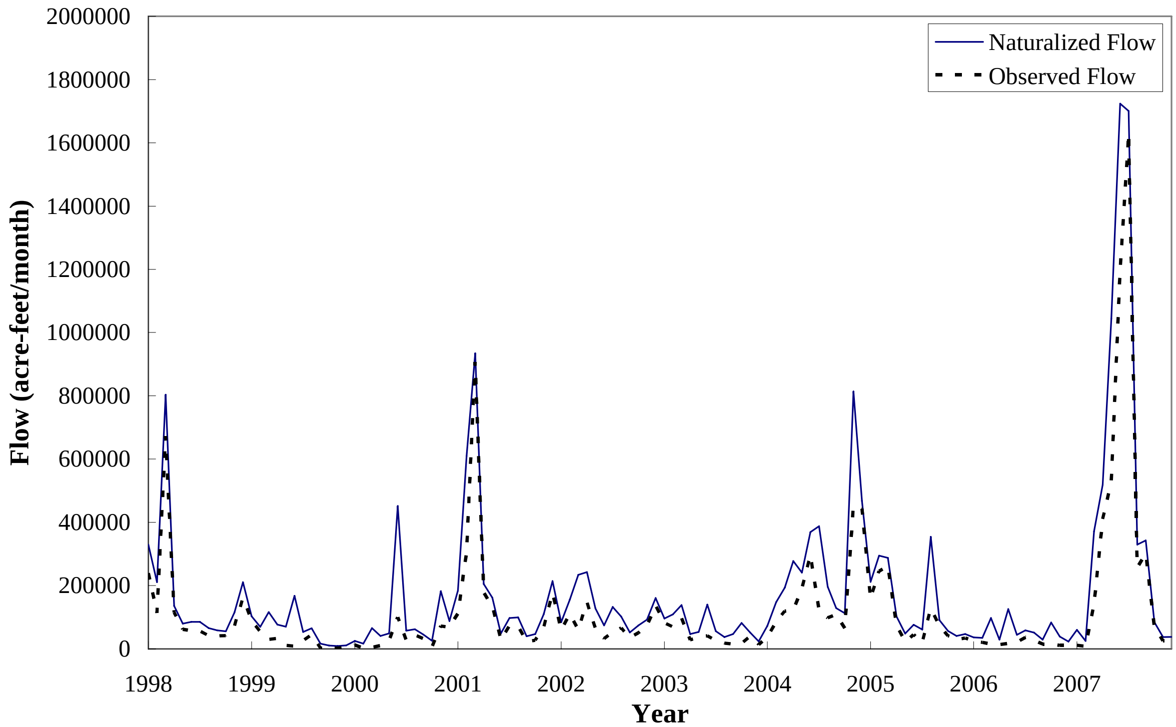

Figure B.23 Monthly Naturalized and Observed Flows at BRHB42

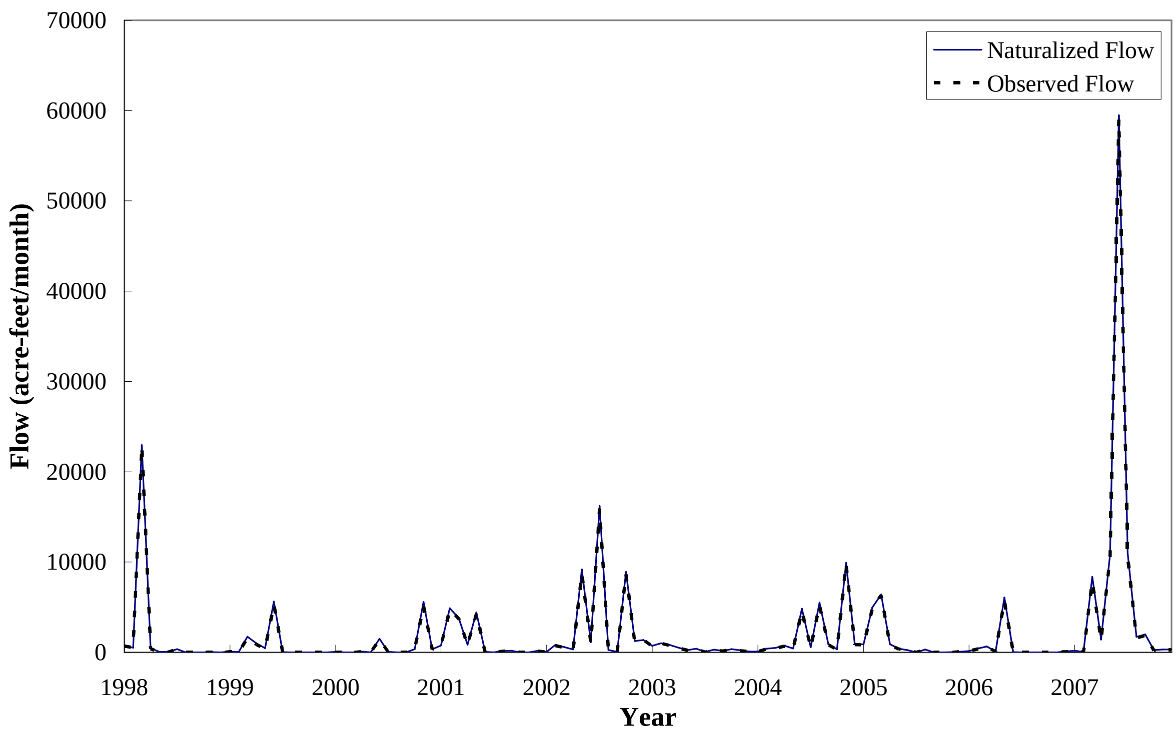

Figure B.24 Monthly Naturalized and Observed Flows at SADL44

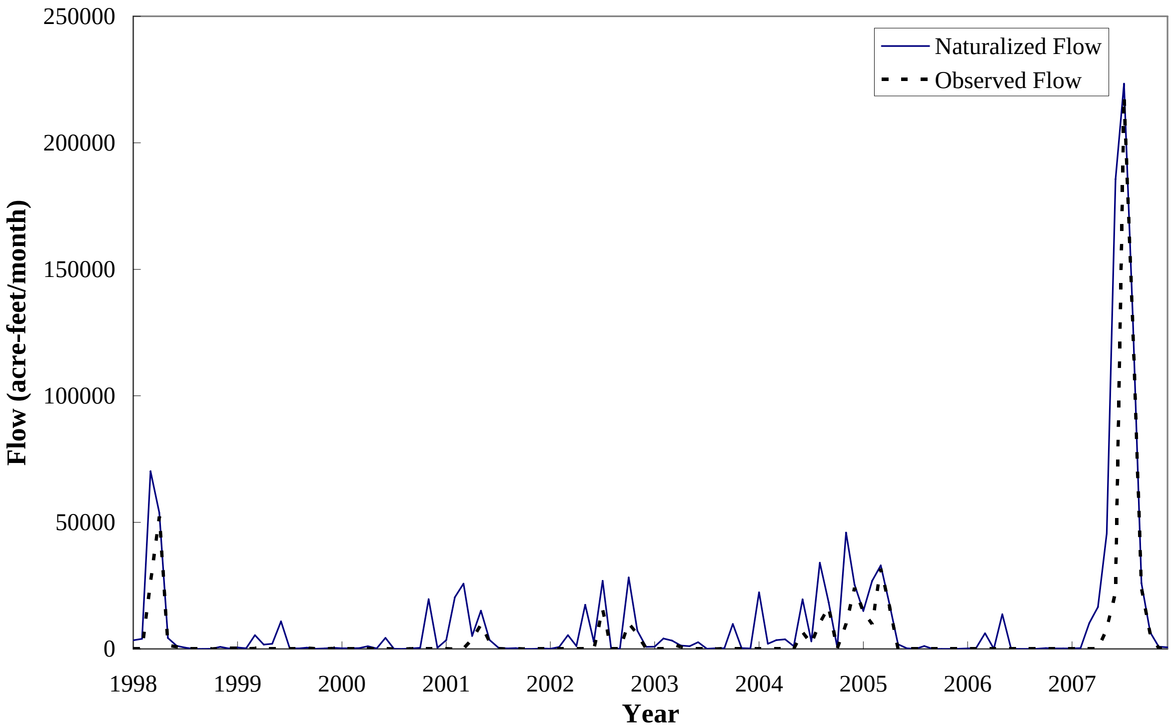

Figure B.25 Monthly Naturalized and Observed Flows at LEHS45

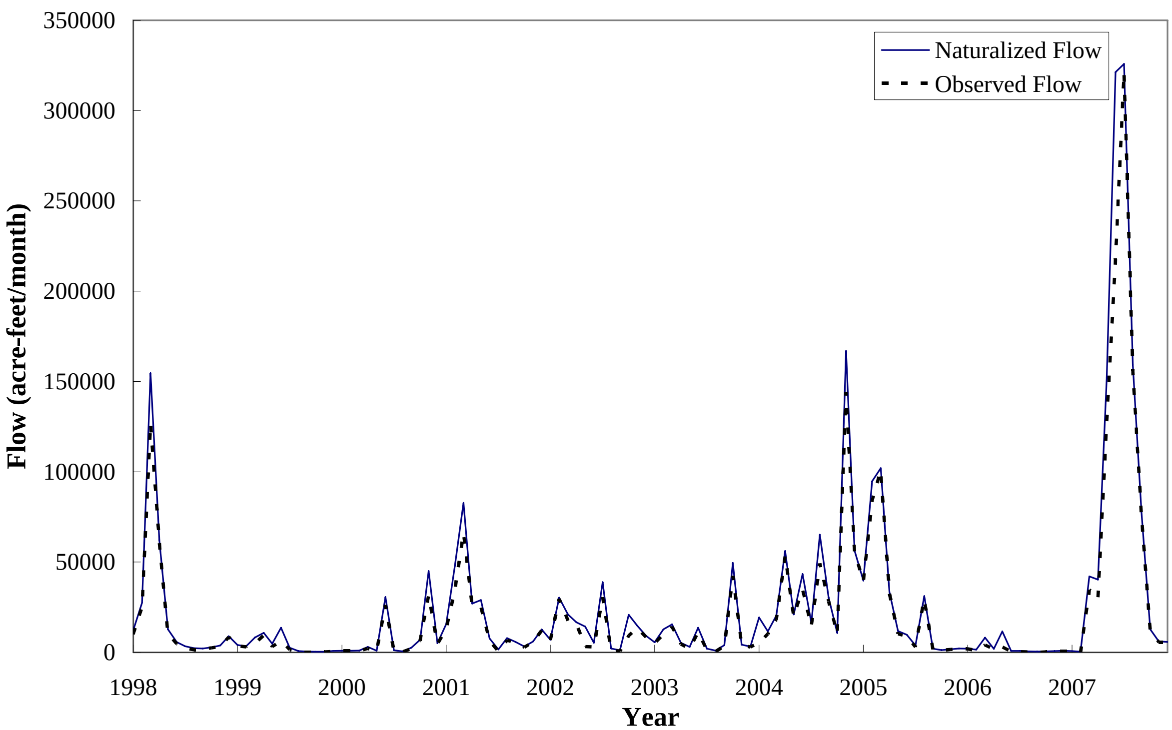

Figure B.26 Monthly Naturalized and Observed Flows at LEGT47

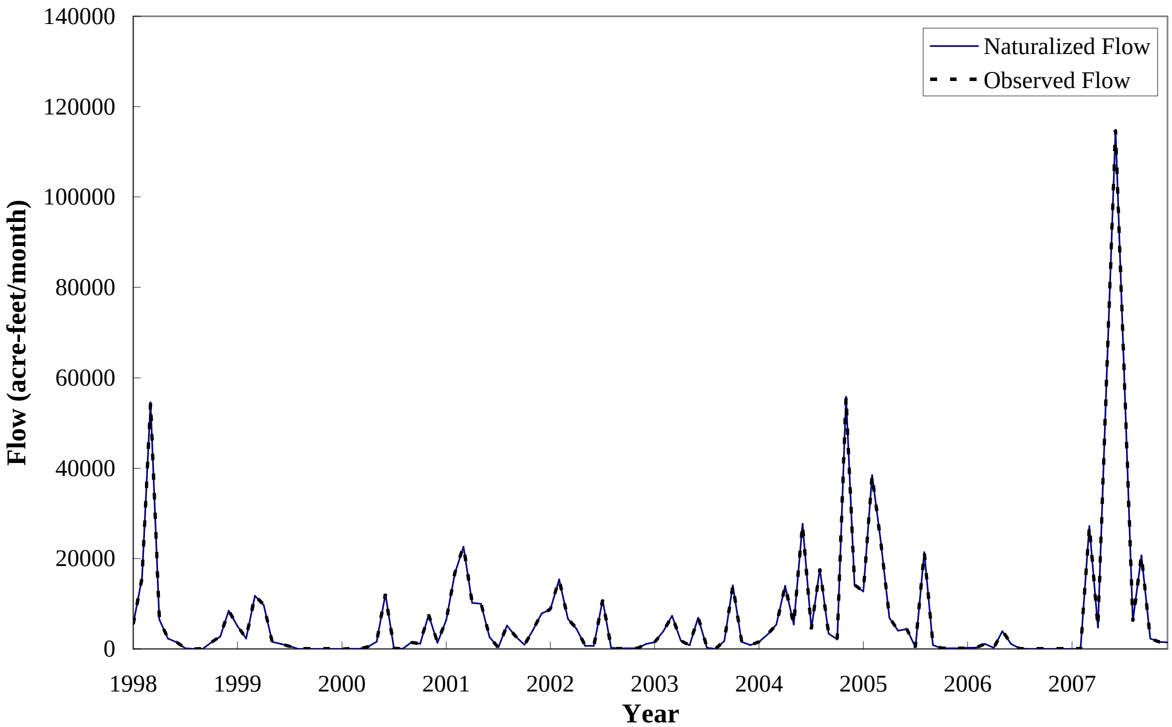

Figure B.27 Monthly Naturalized and Observed Flows at COPI48

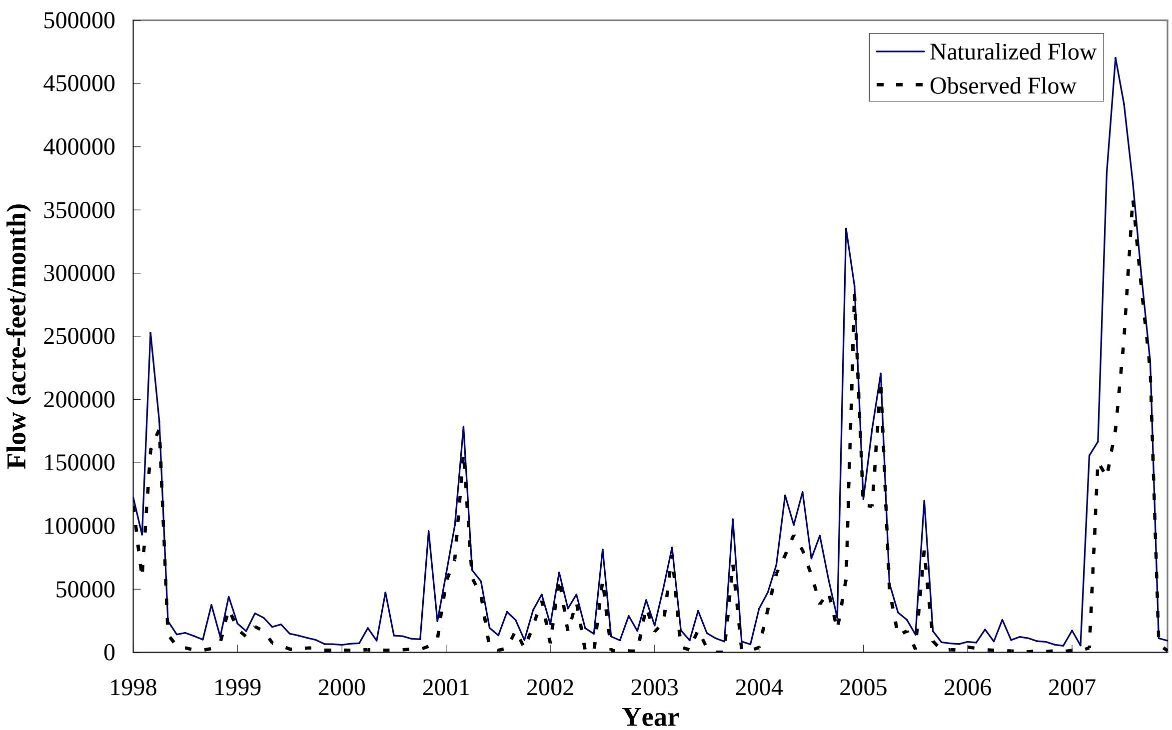

Figure B.28 Monthly Naturalized and Observed Flows at LEBE49

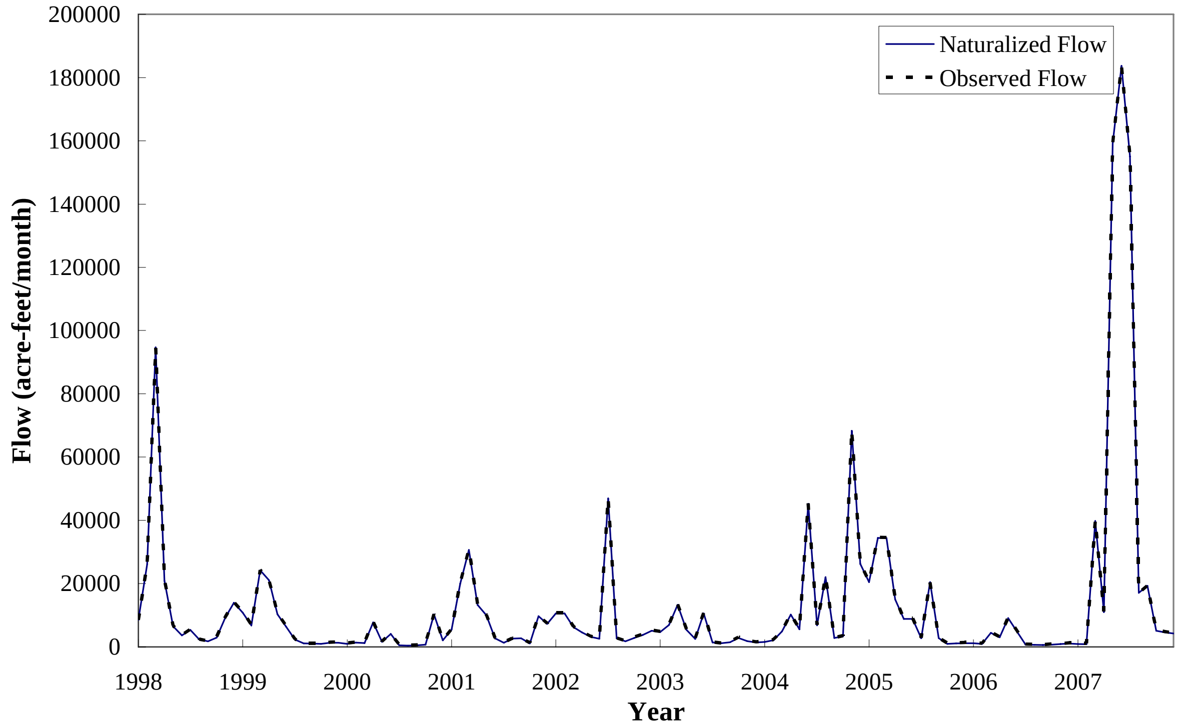

Figure B.29 Monthly Naturalized and Observed Flows at LAKE50

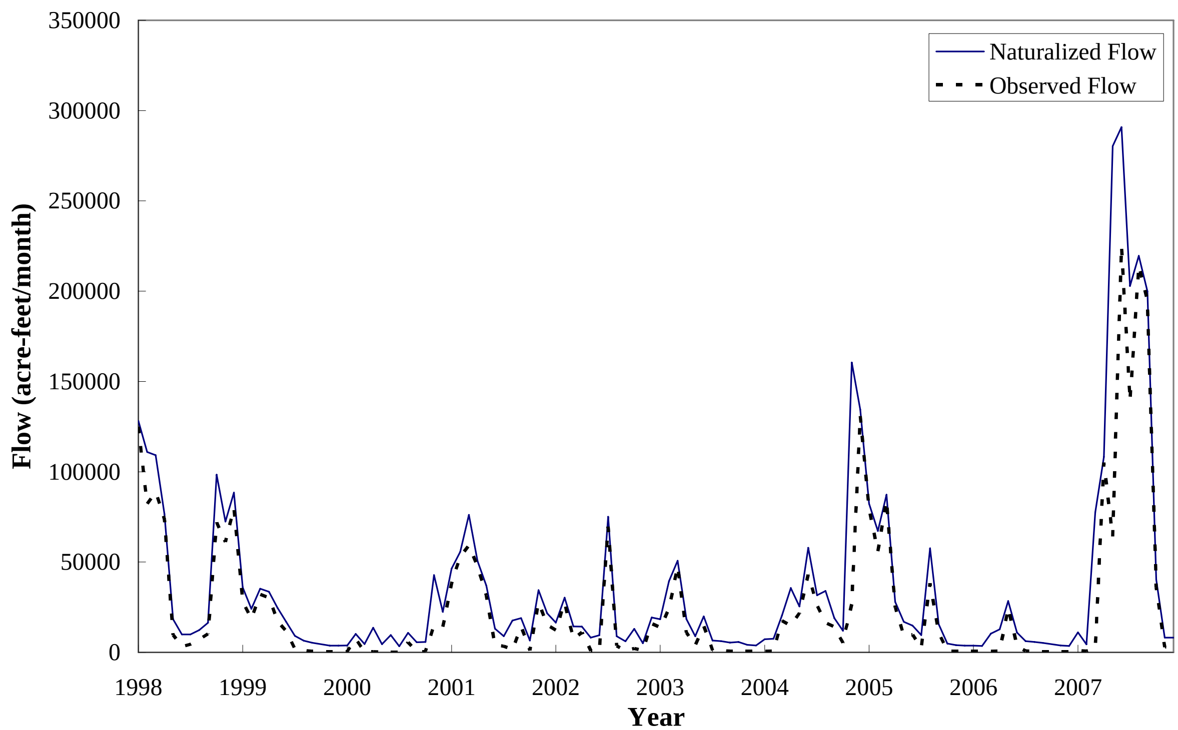

Figure B.30 Monthly Naturalized and Observed Flows at LABE52

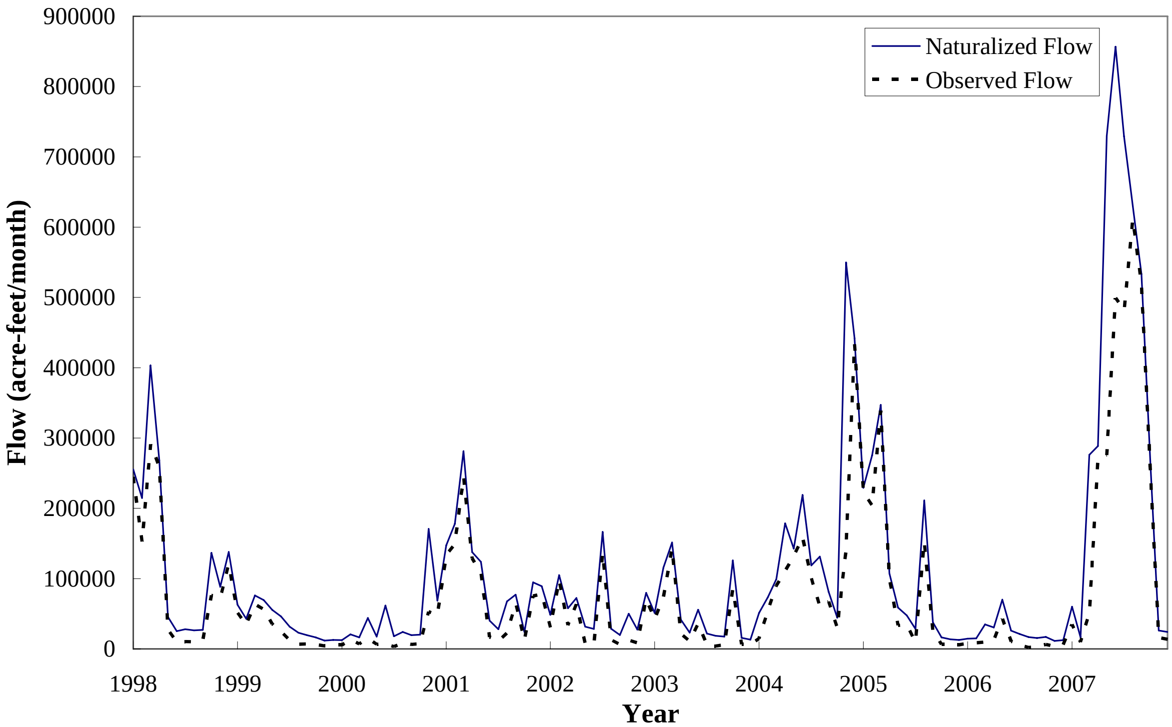

Figure B.31 Monthly Naturalized and Observed Flows at LRLR53

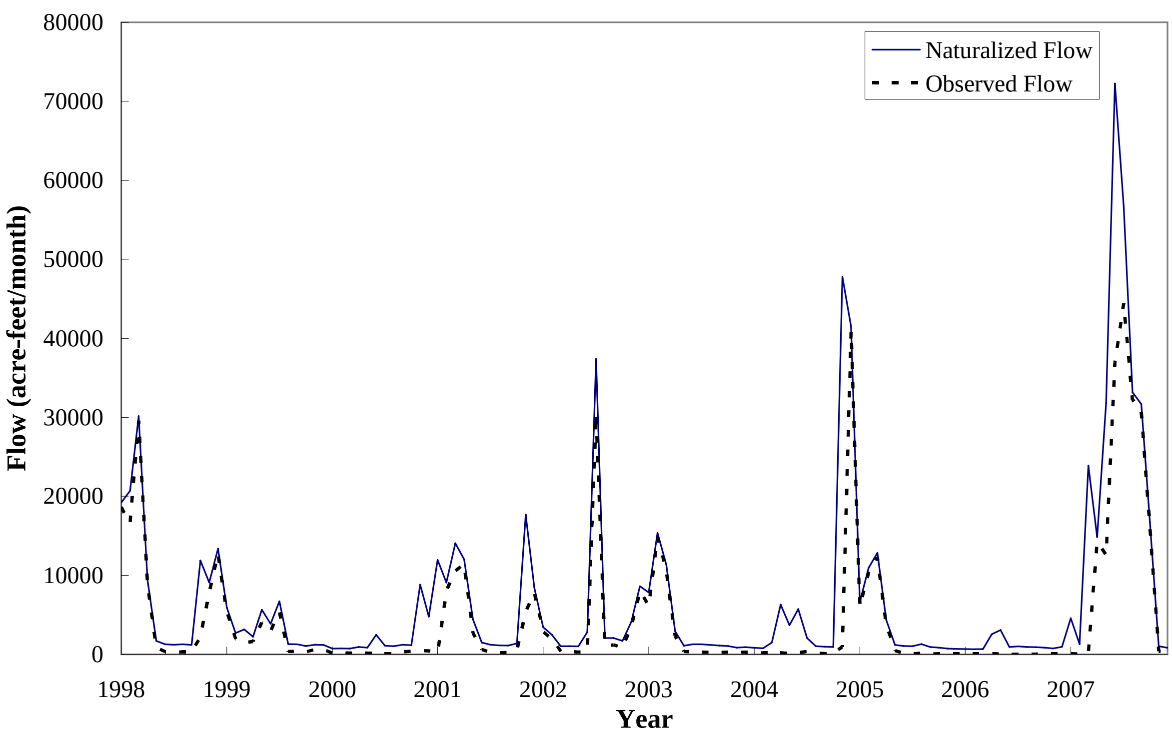

Figure B.32 Monthly Naturalized and Observed Flows at NGGE54

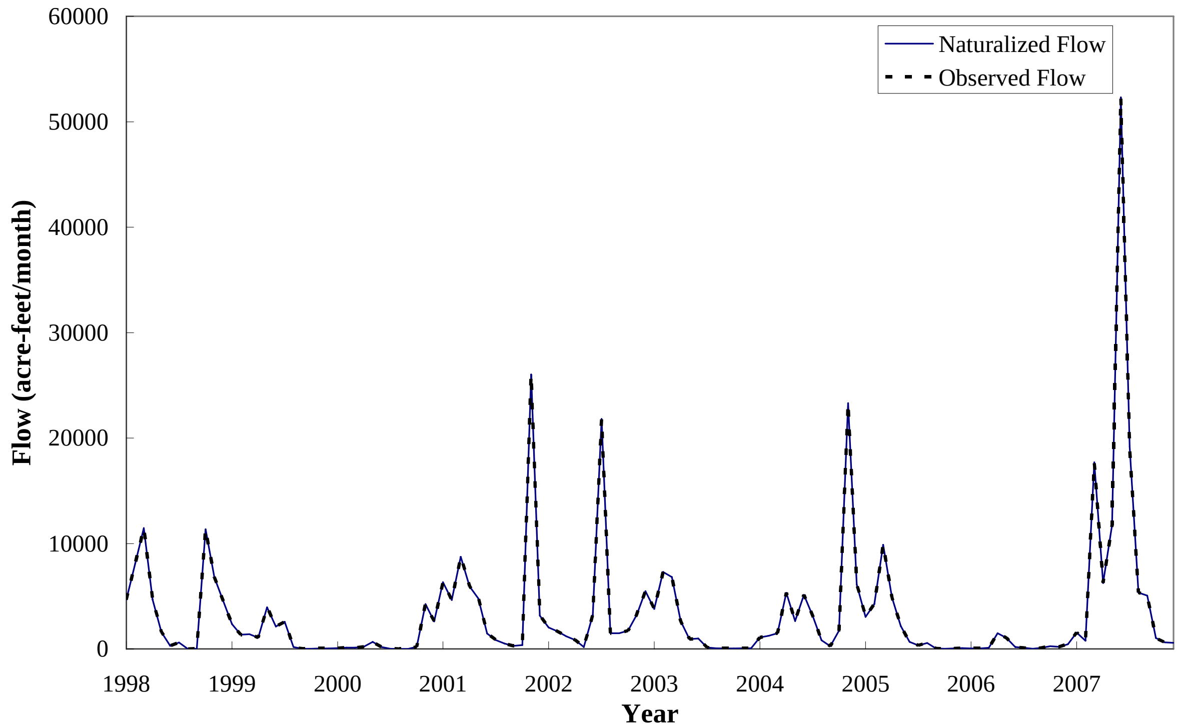

Figure B.33 Monthly Naturalized and Observed Flows at SGGE55

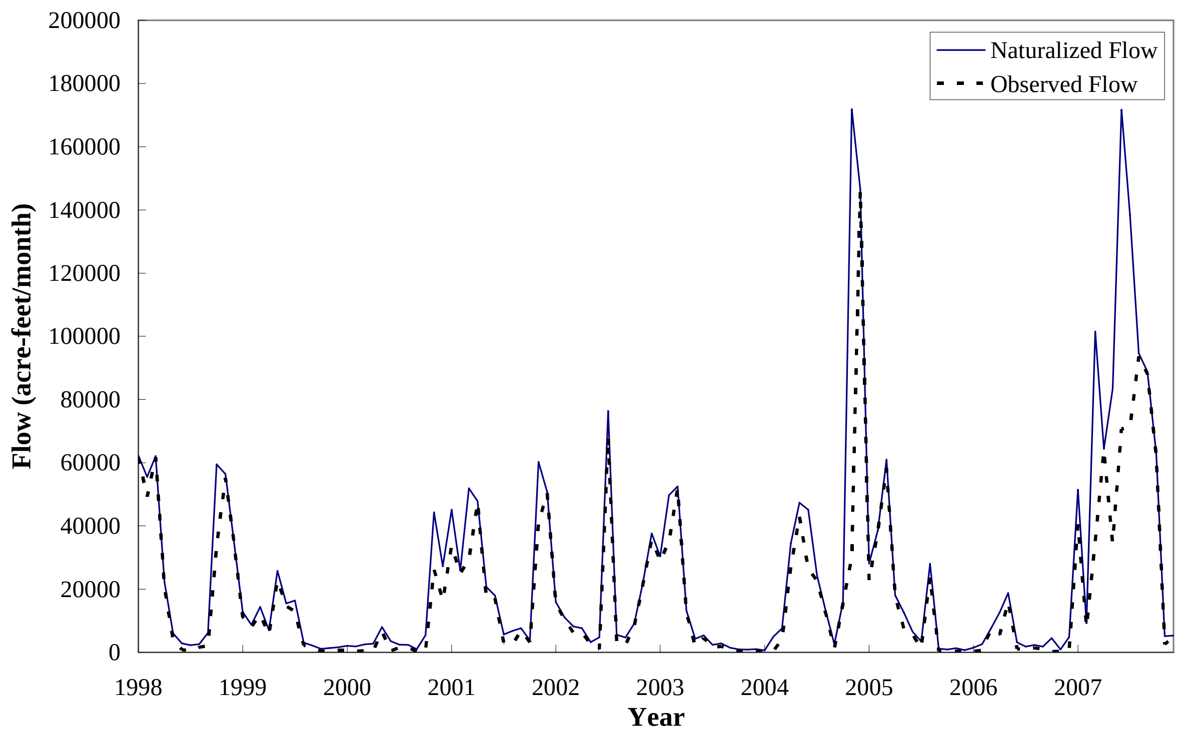

Figure B.34 Monthly Naturalized and Observed Flows at GALA57

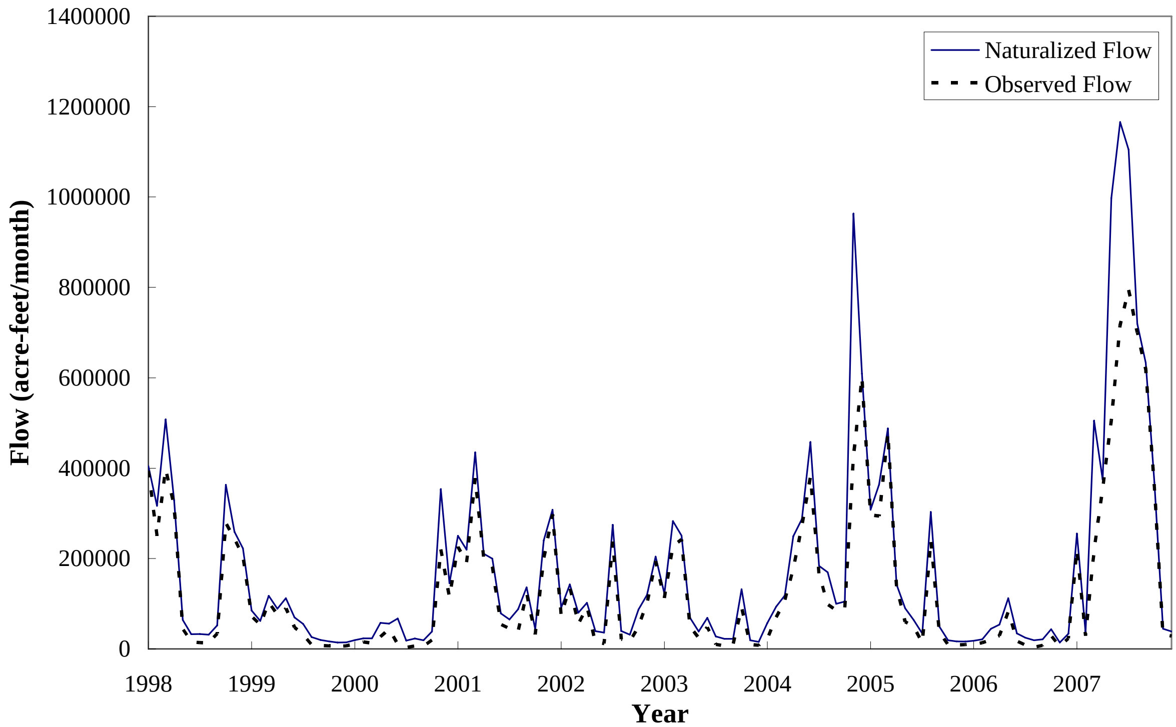

Figure B.35 Monthly Naturalized and Observed Flows at LRCA58

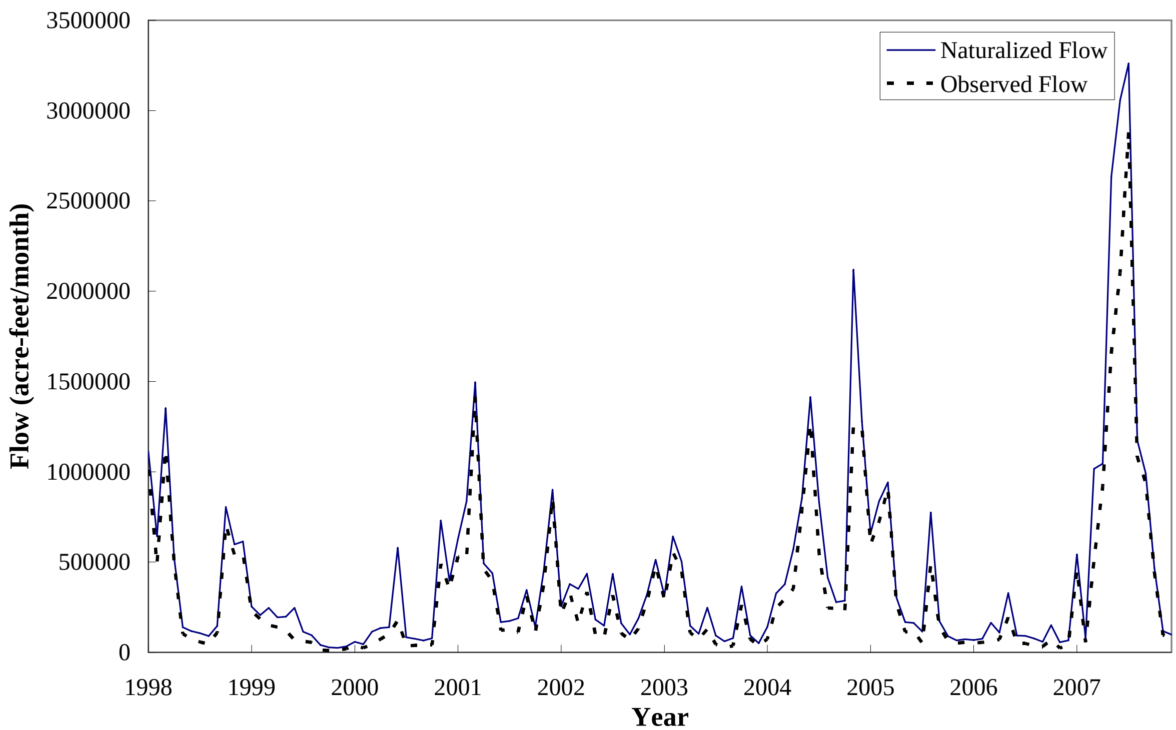

Figure B.36 Monthly Naturalized and Observed Flows at BRBR59

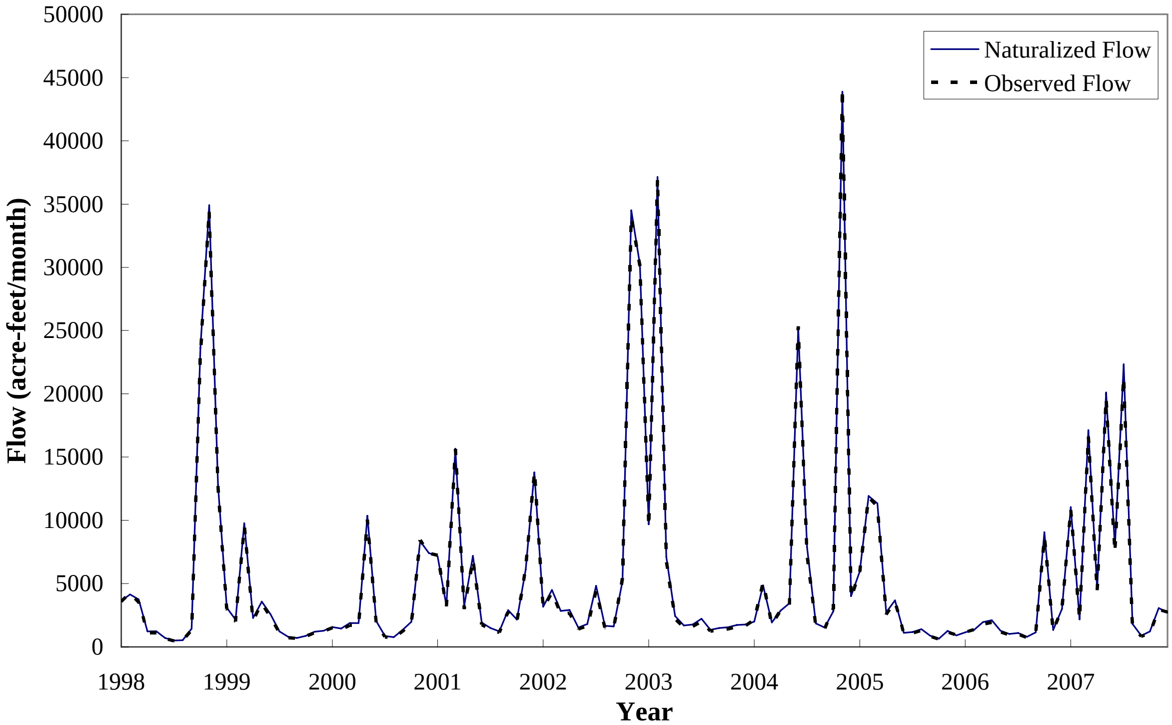

Figure B.37 Monthly Naturalized and Observed Flows at MYDB60

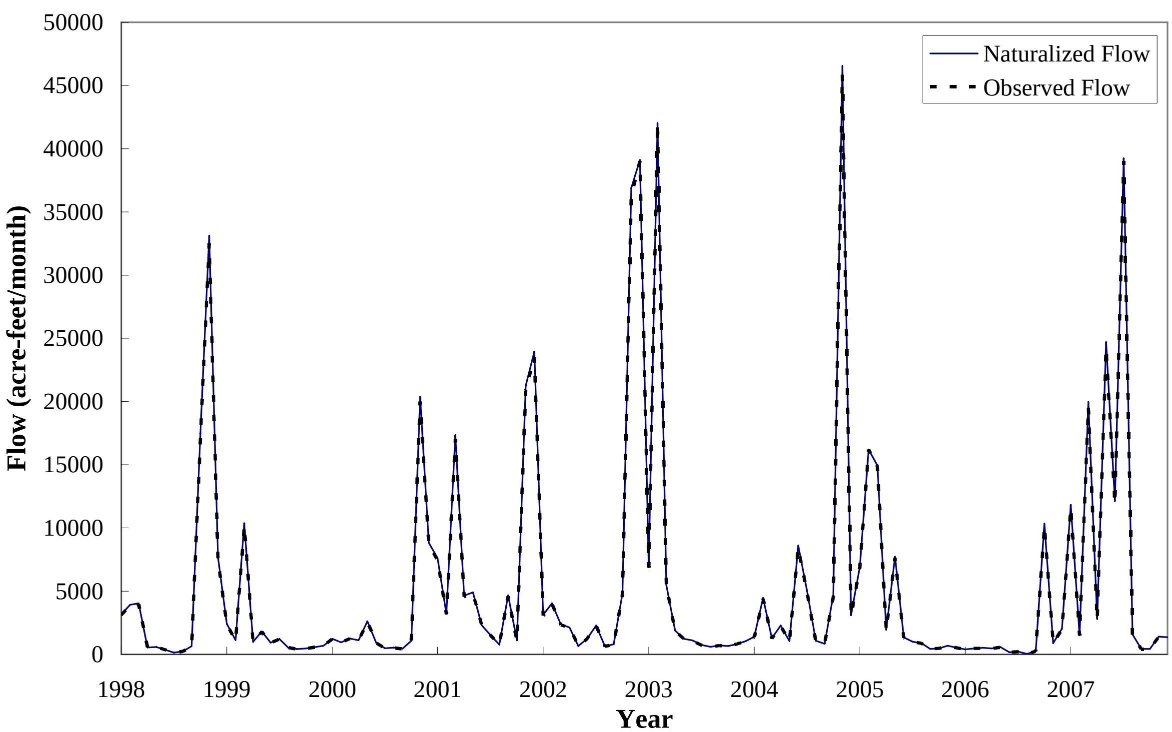

Figure B.38 Monthly Naturalized and Observed Flows at EYDB61

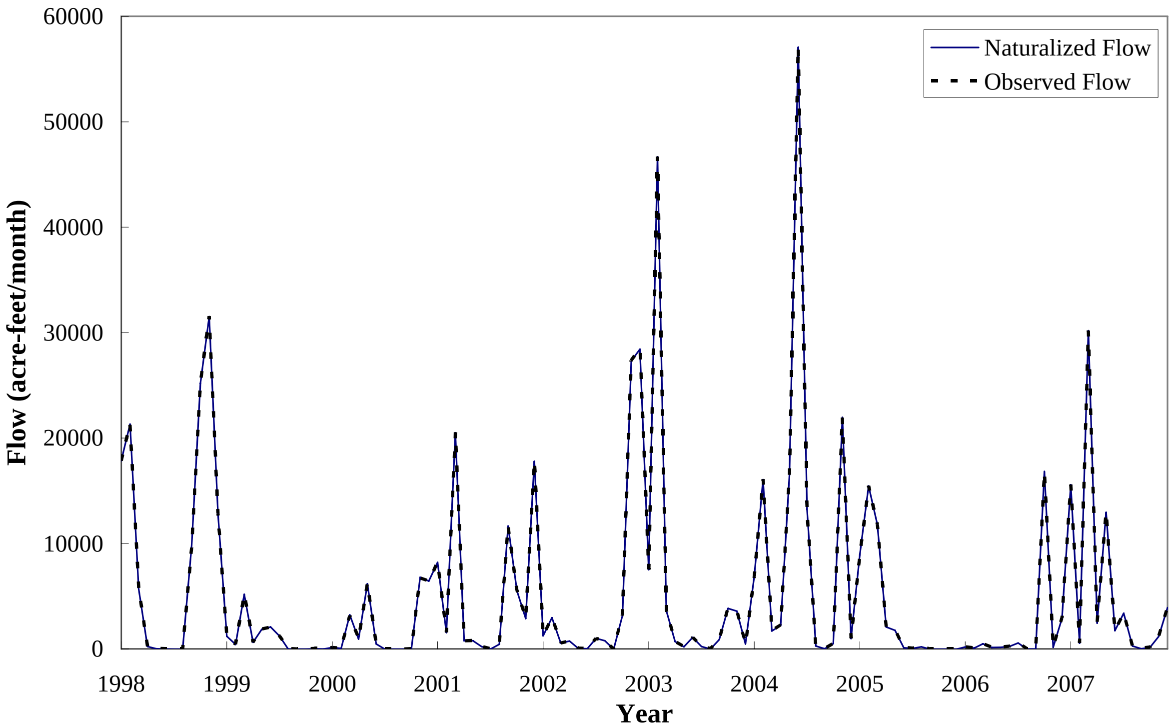

Figure B.39 Monthly Naturalized and Observed Flows at DCLY63

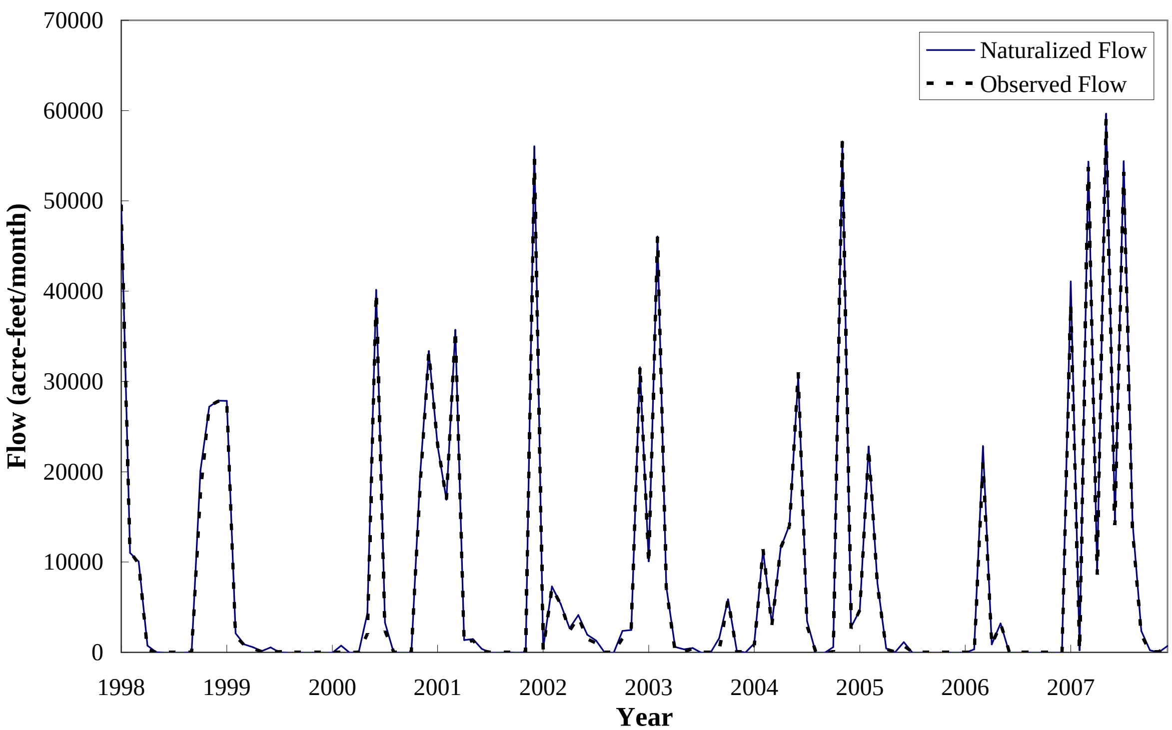

Figure B.40 Monthly Naturalized and Observed Flows at NAGR64

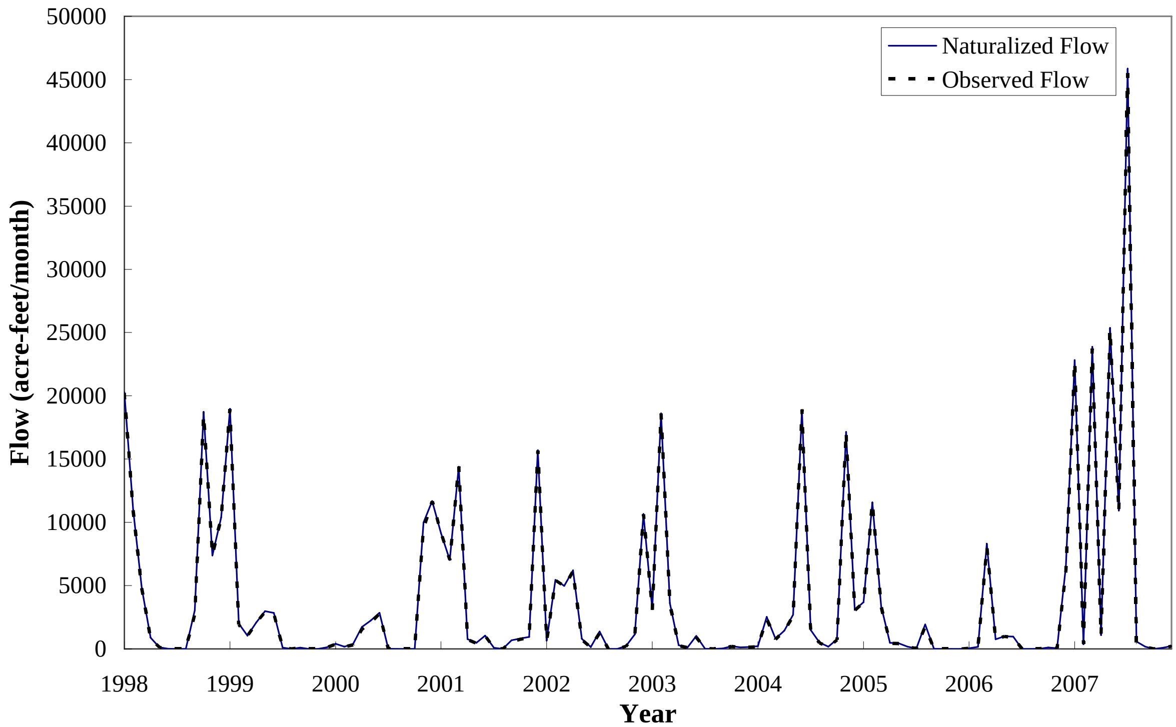

Figure B.41 Monthly Naturalized and Observed Flows at BGFR65

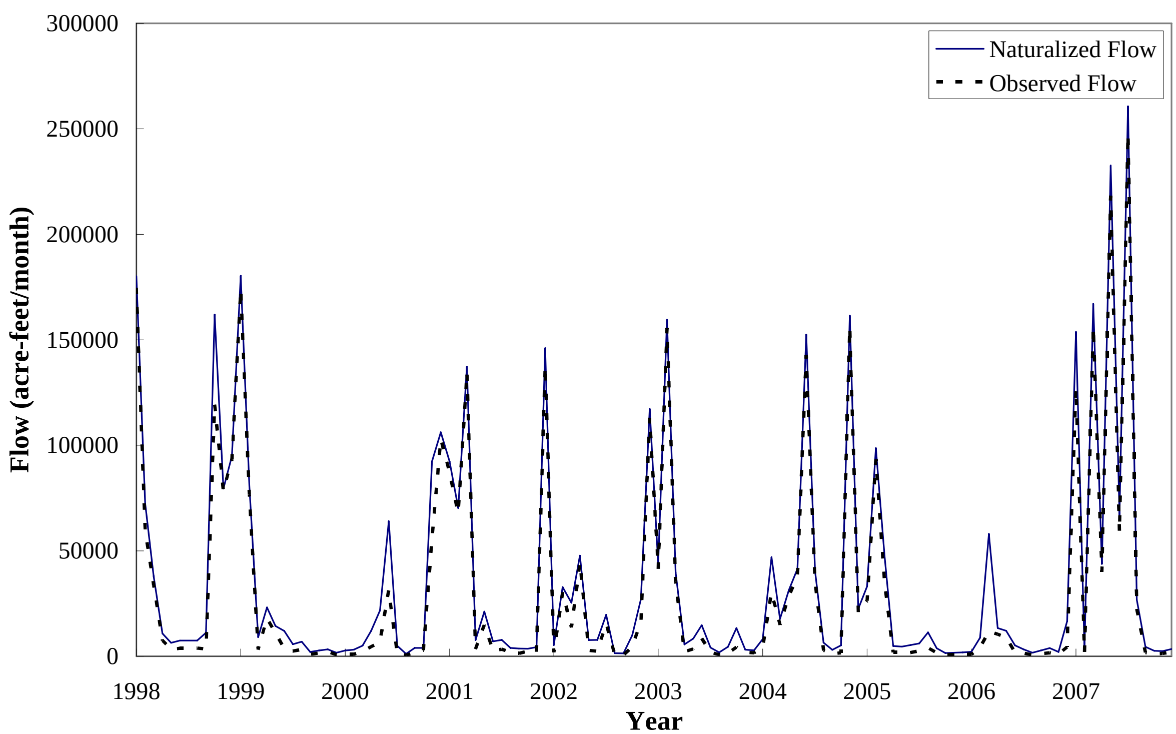

Figure B.42 Monthly Naturalized and Observed Flows at NAEA66

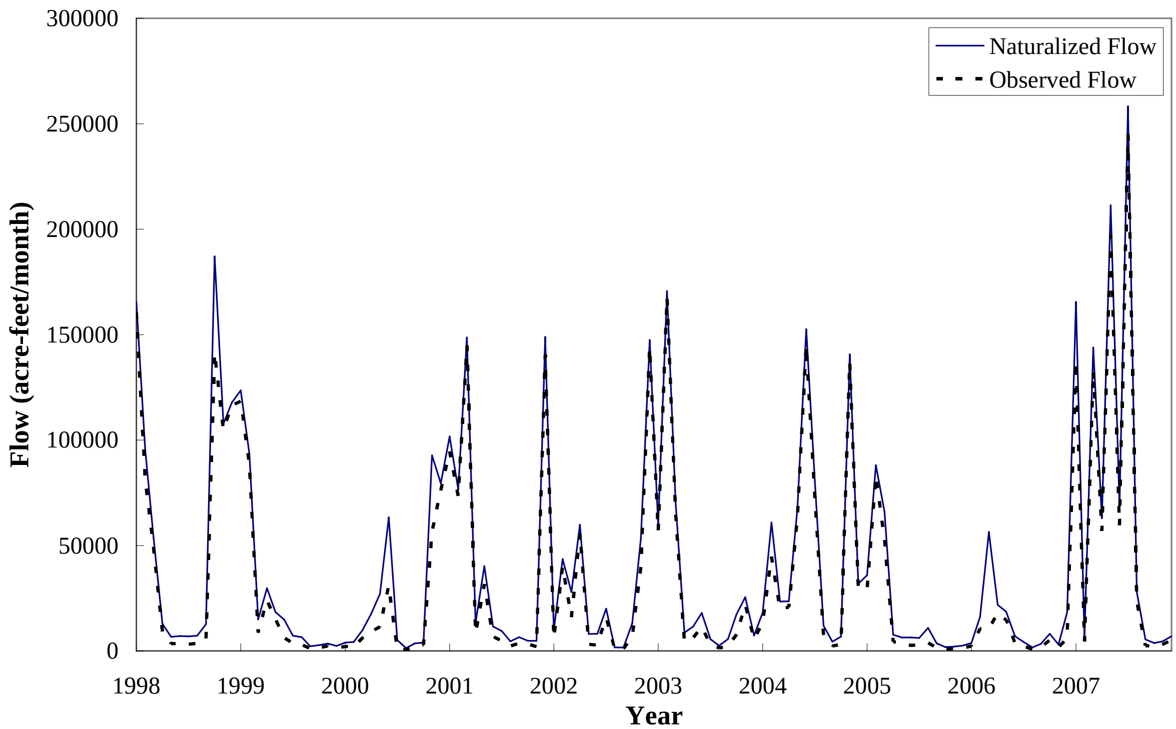

Figure B.43 Monthly Naturalized and Observed Flows at NABR67

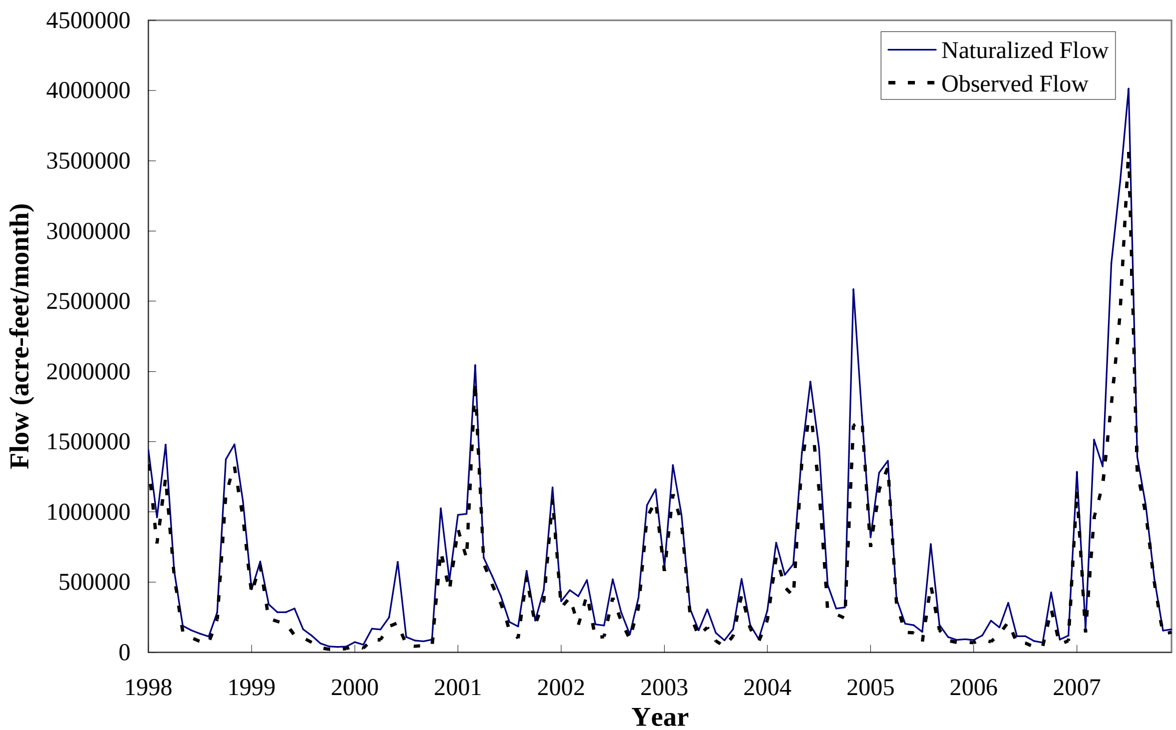

Figure B.44 Monthly Naturalized and Observed Flows at BRHE68

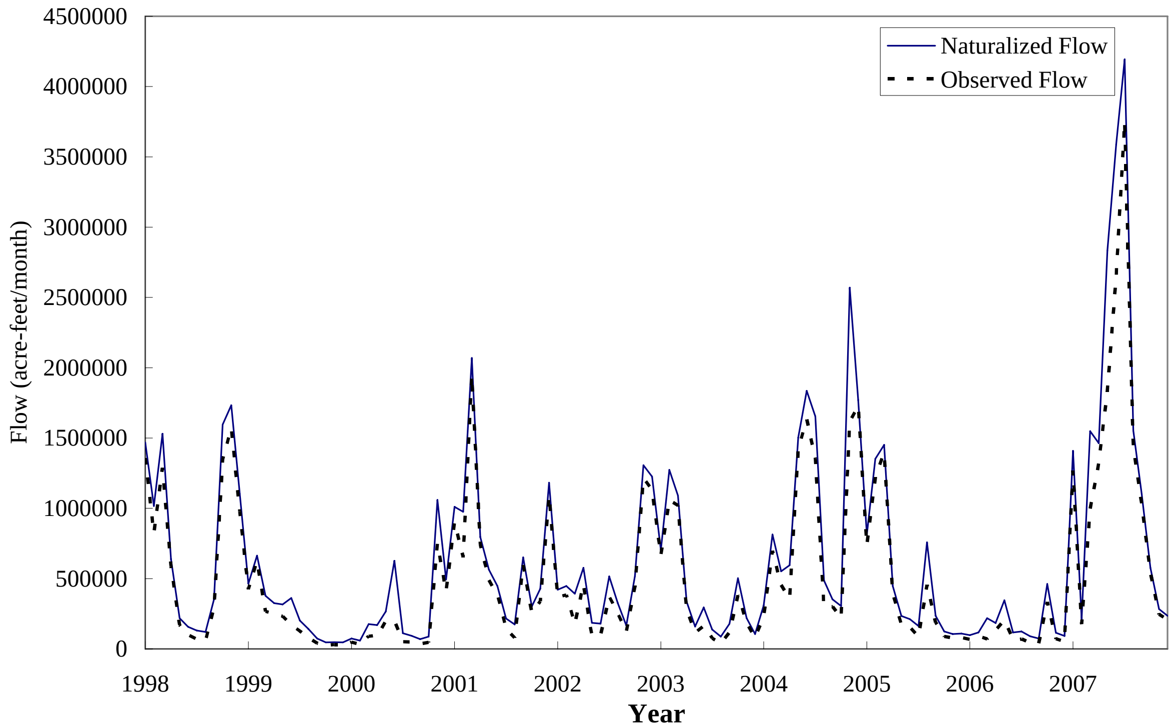

Figure B.45 Monthly Naturalized and Observed Flows at BRRI70

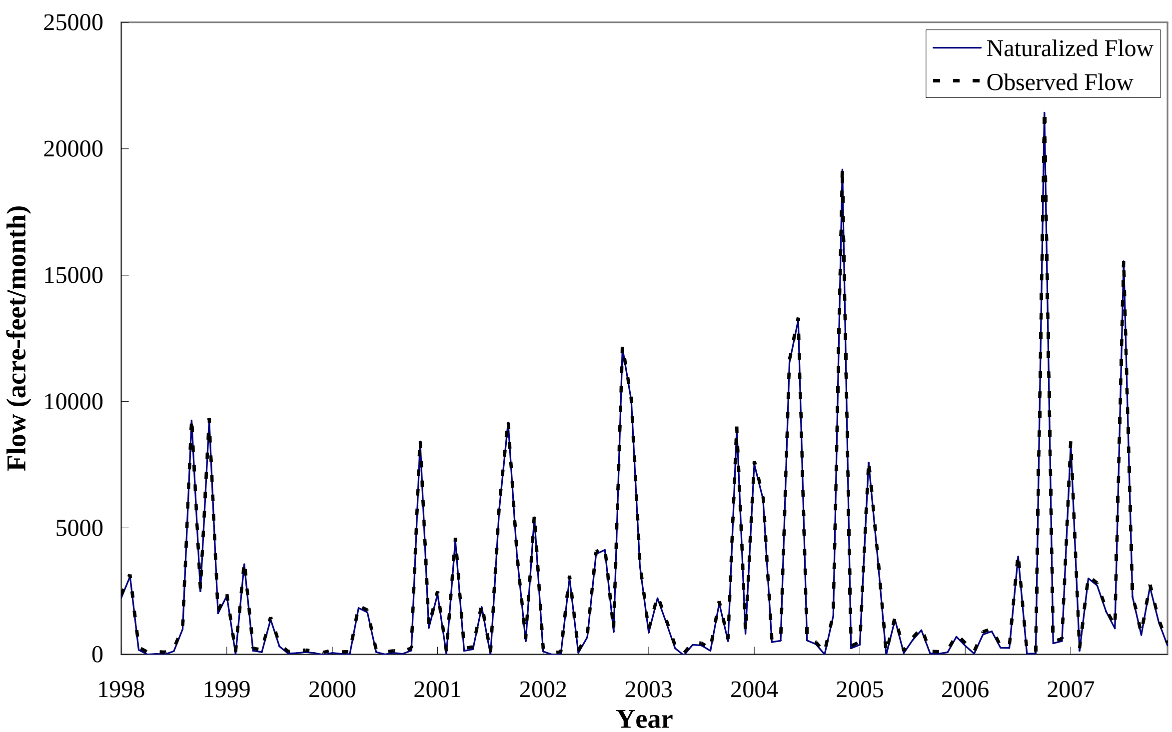

Figure B.46 Monthly Naturalized and Observed Flows at BGNE71

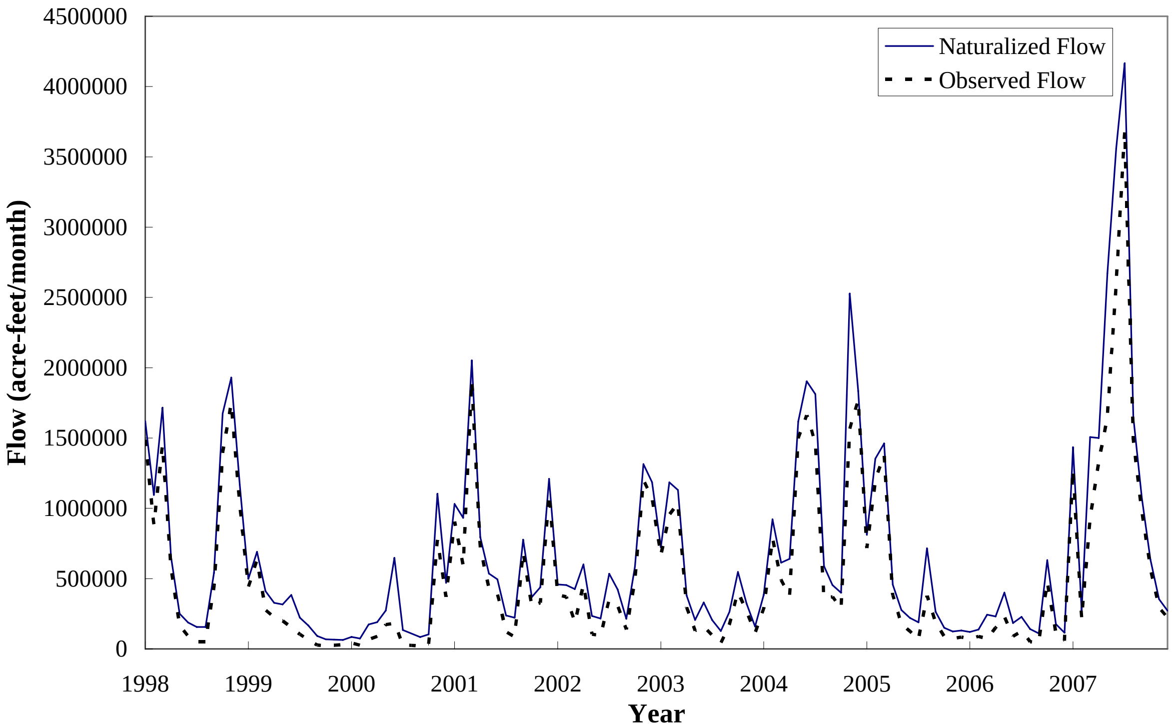

Figure B.47 Monthly Naturalized and Observed Flows at BRRO72

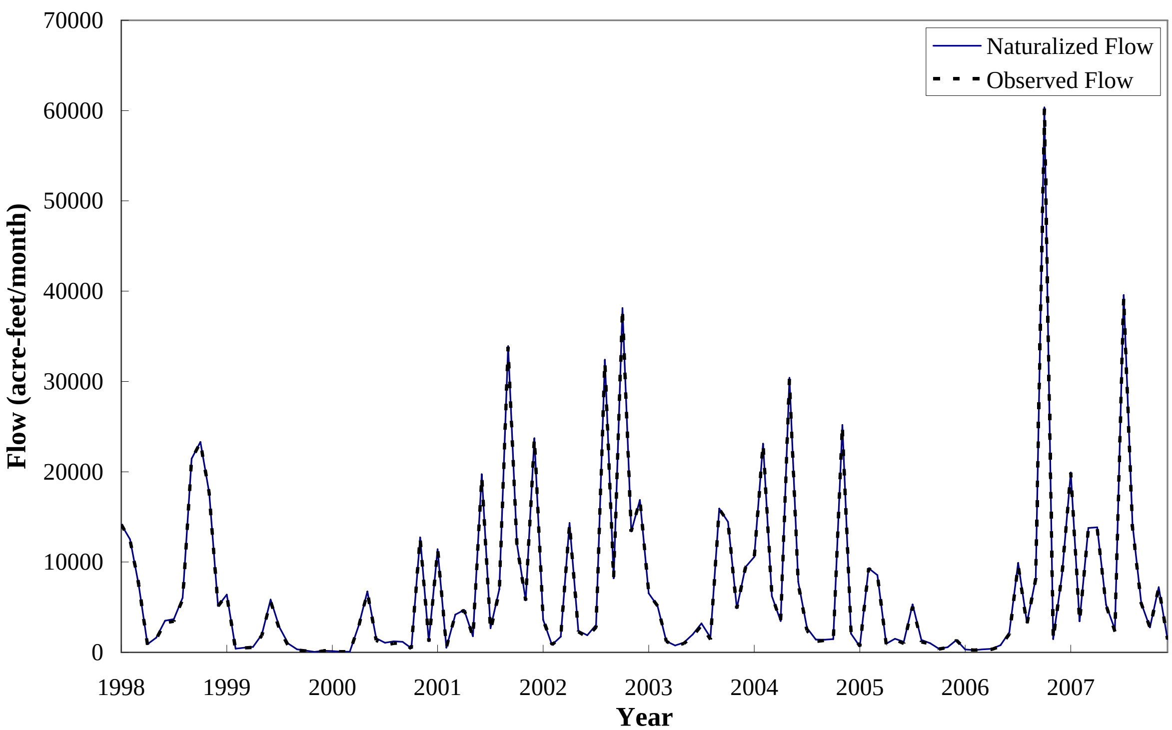

Figure B.48 Monthly Naturalized and Observed Flows at CBALC2

Appendix C

Plots of 1998-2007 Storage Volume at 14 Reservoirs

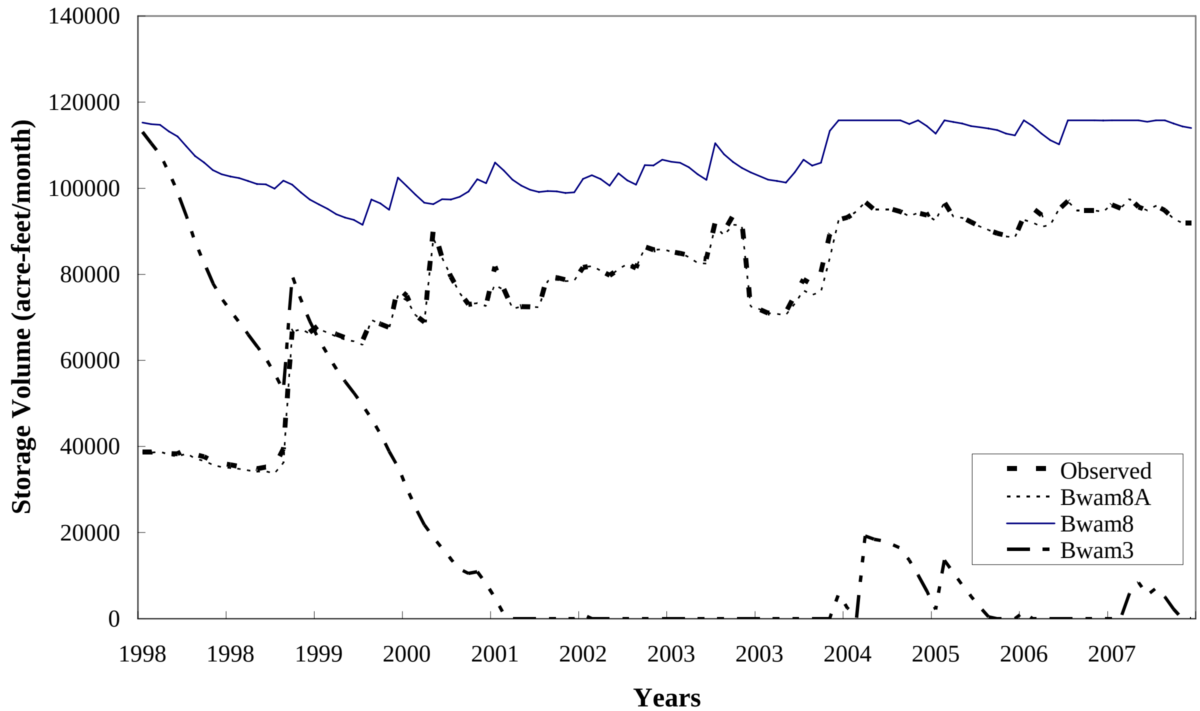

Figure C.1 Storage Volume at Alan Henry Reservoir
(Bwam3 and Bwam8 Capacities = 115,937 and 115,773 acre-feet)

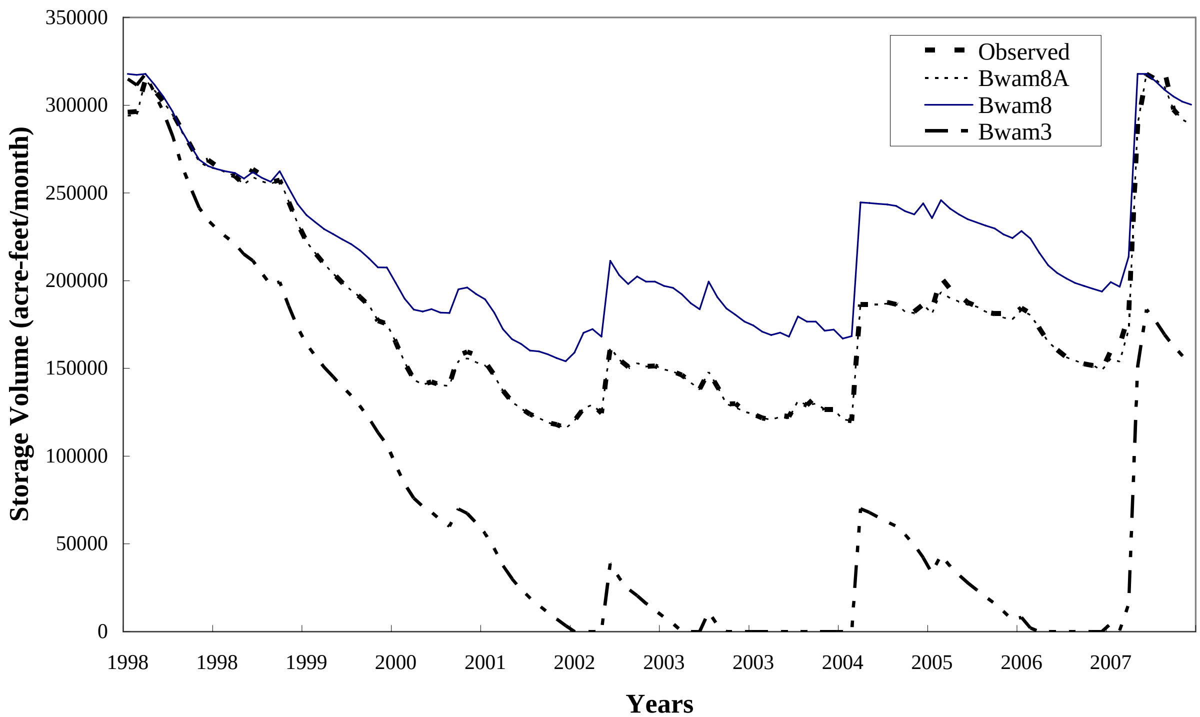

Figure C.2 Storage Volume at Hubbard Creek Reservoir
(Bwam3 and Bwam8 Capacities = 317,750 and 317,750 acre-feet)

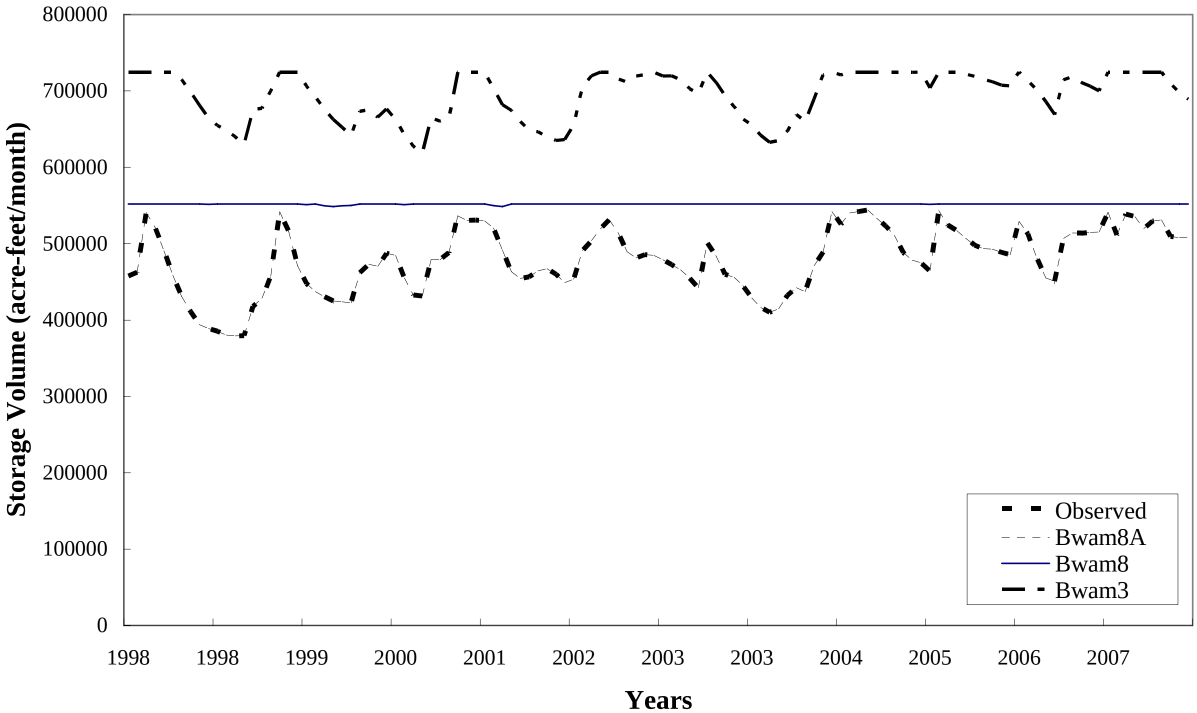

Figure C.3 Storage Volume at Possum Kingdom Reservoir
(Bwam3 and Bwam8 Capacities = 724,739 and 552,013 acre-feet)

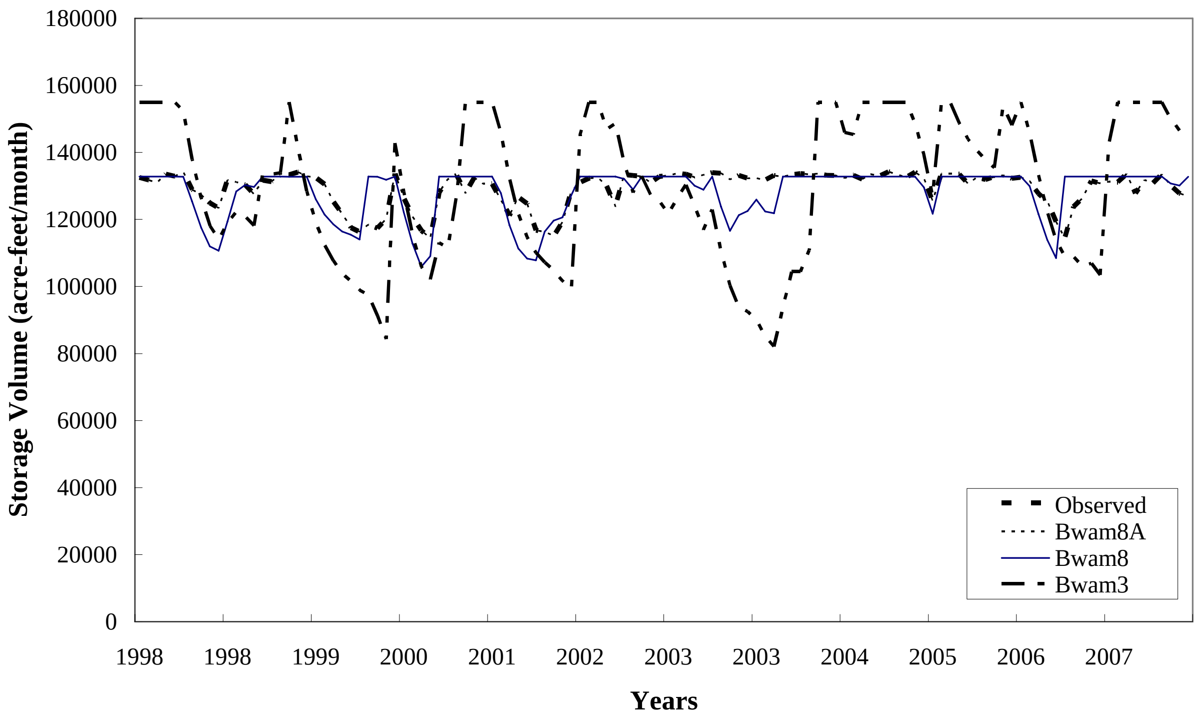

Figure C.4 Storage Volume at Granbury Reservoir
(Bwam3 and Bwam8 Capacities = 155,000 and 132,821 acre-feet)

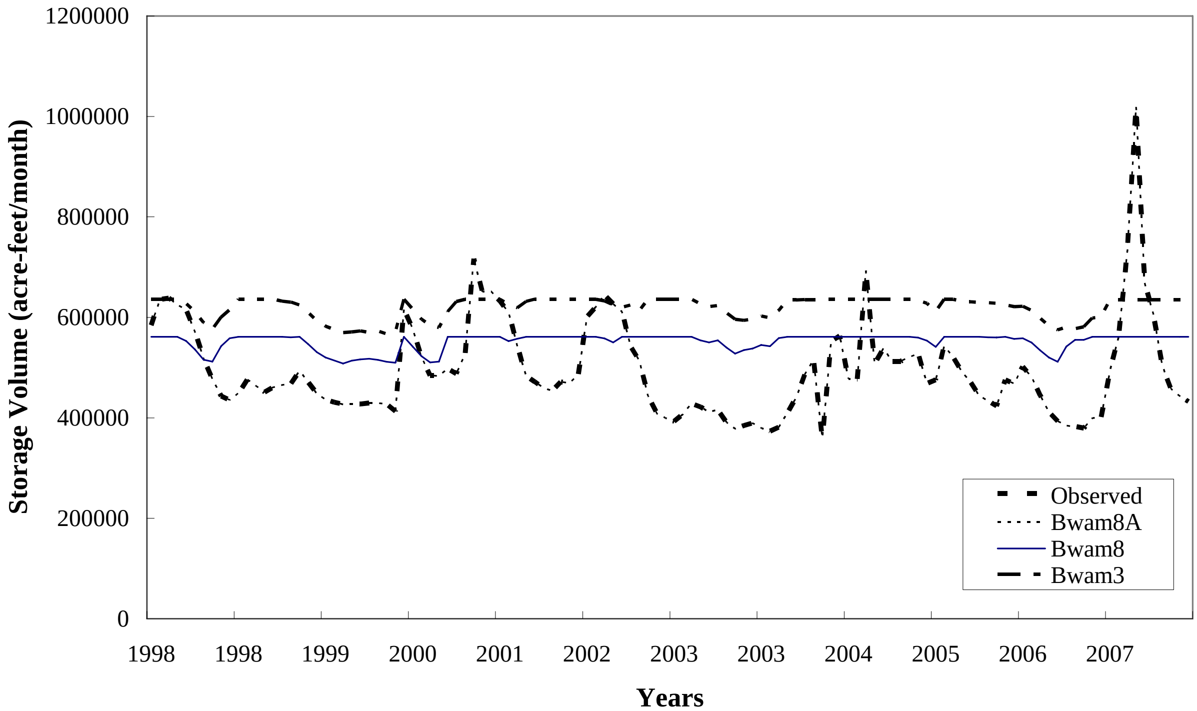

Figure C.5 Storage Volume at Whitney Reservoir
(Bwam3 and Bwam8 Capacities = 636,100 and 561,074 acre-feet)

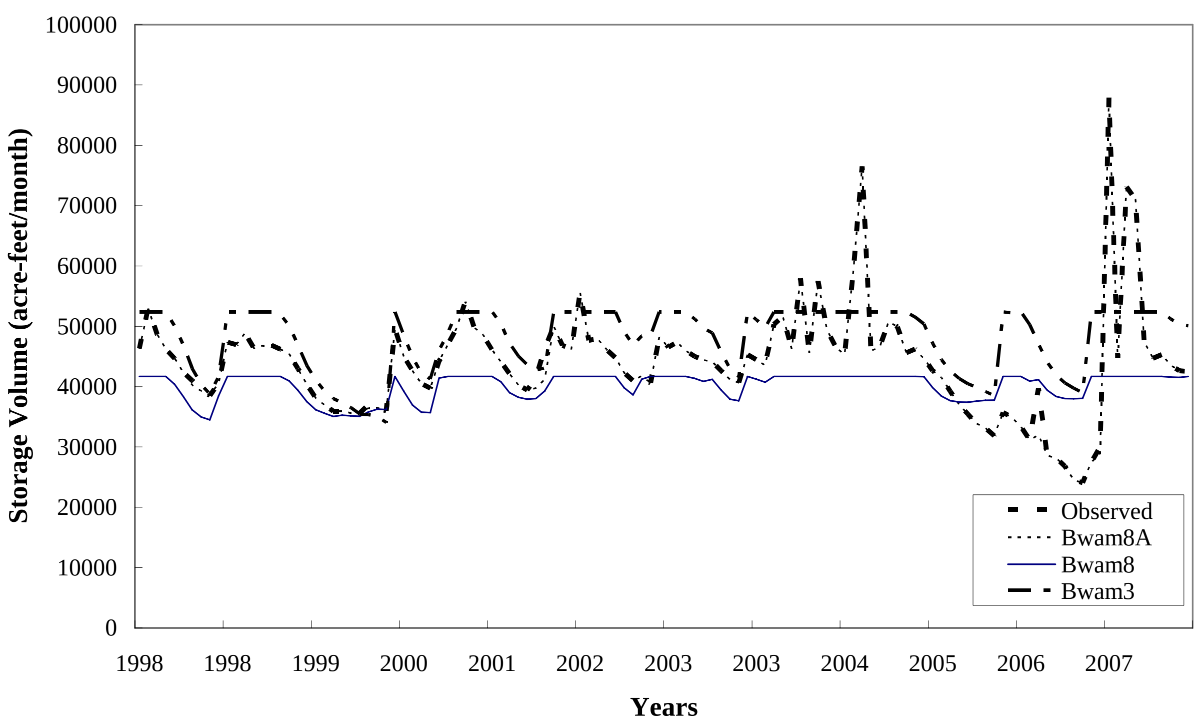

Figure C.6 Storage Volume at Aquilla Reservoir
(Bwam3 and Bwam8 Capacities = 52,400 and 41,700 acre-feet)

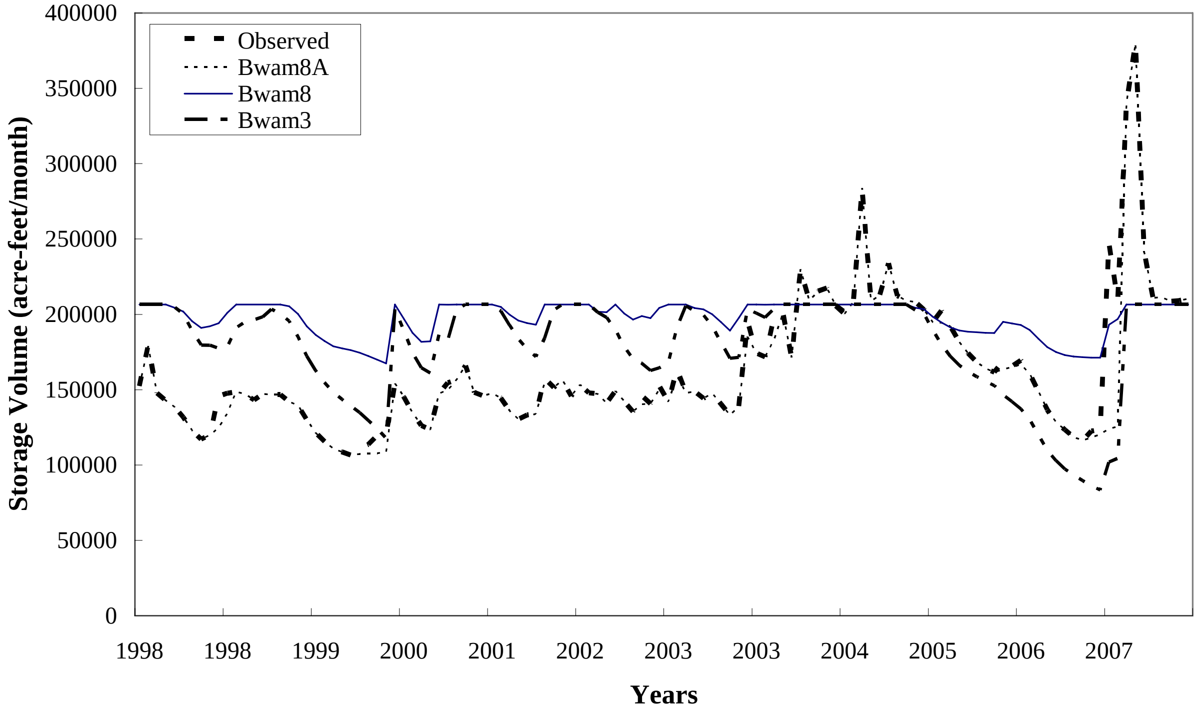

Figure C.7 Storage Volume at Waco Reservoir (Bwam3 and Bwam8 Capacities = 206,562 ac-ft)
The designated top of conservation pool elevation of Lake Waco was raised in
September 2003 reallocating flood control storage capacity to conservation capacity.

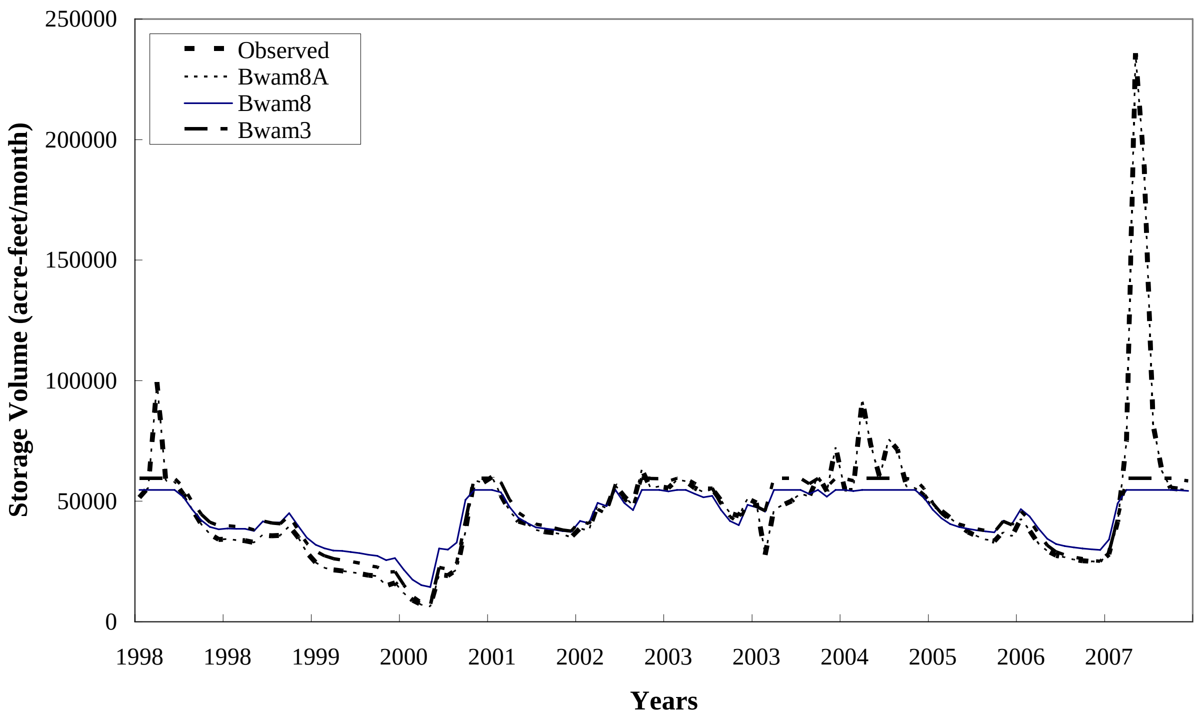

Figure C.8 Storage Volume at Proctor Reservoir
(Bwam3 and Bwam8 Capacities = 59,400 and 54,702 acre-feet)

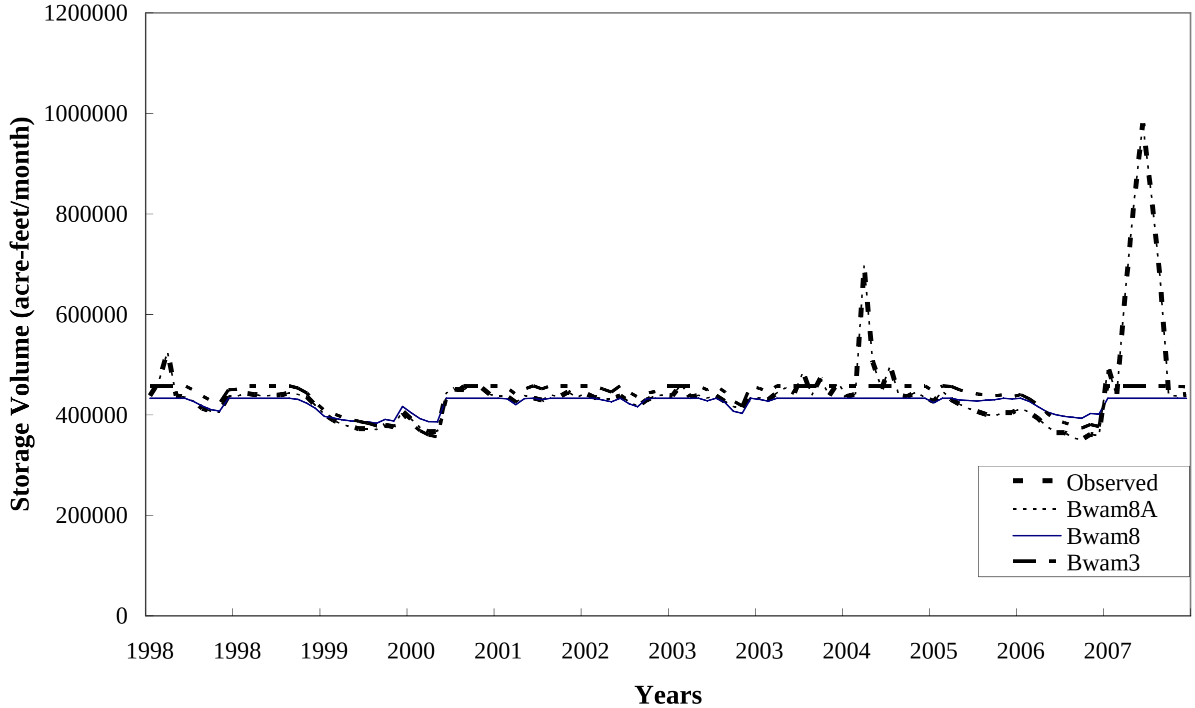

Figure C.9 Storage Volume at Belton Reservoir
(Bwam3 and Bwam8 Capacities = 457,600 and 432,978 acre-feet)

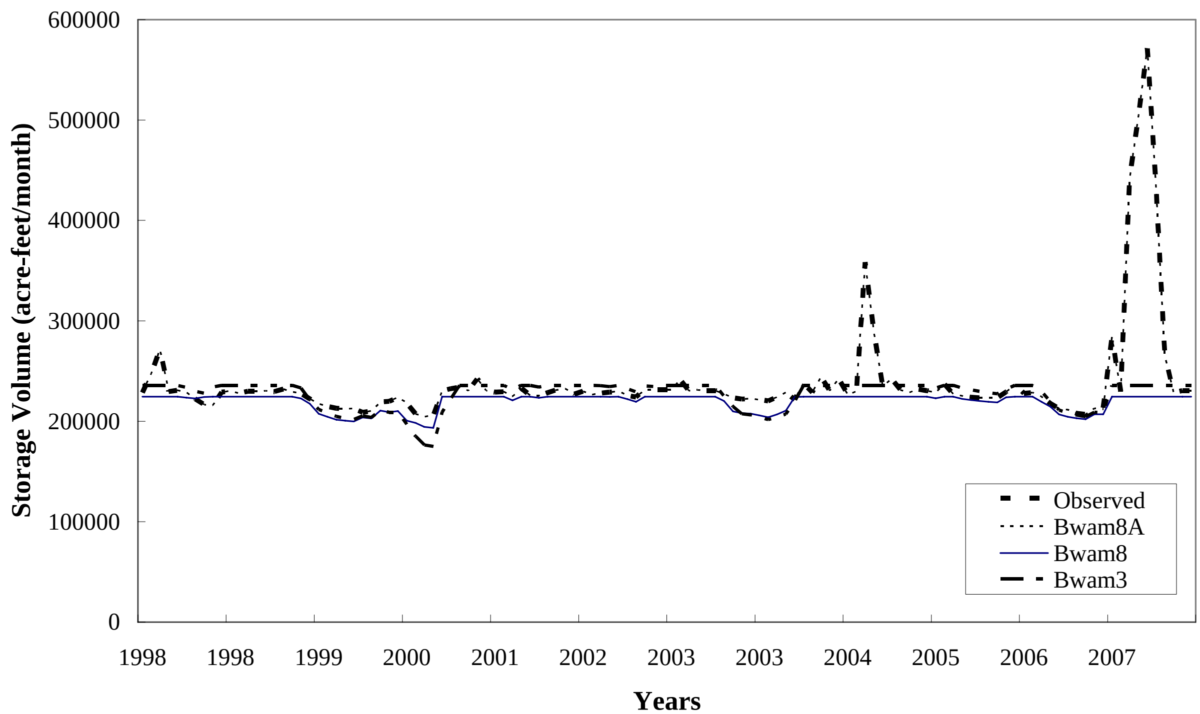

Figure C.10 Storage Volume at Stillhouse Hollow Reservoir
(Bwam3 and Bwam8 Capacities = 235,700 and 224,279 acre-feet)

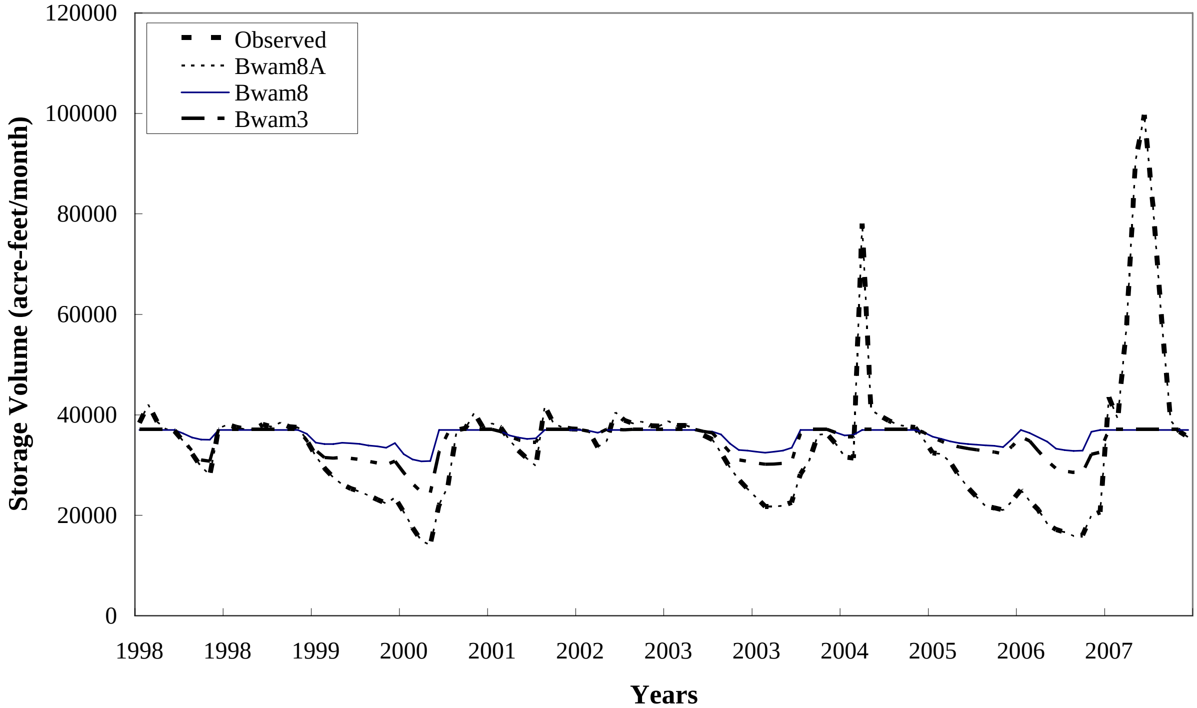

Figure C.11 Storage Volume at Georgetown Reservoir
(Bwam3 and Bwam8 Capacities = 37,100 and 36,980 acre-feet)

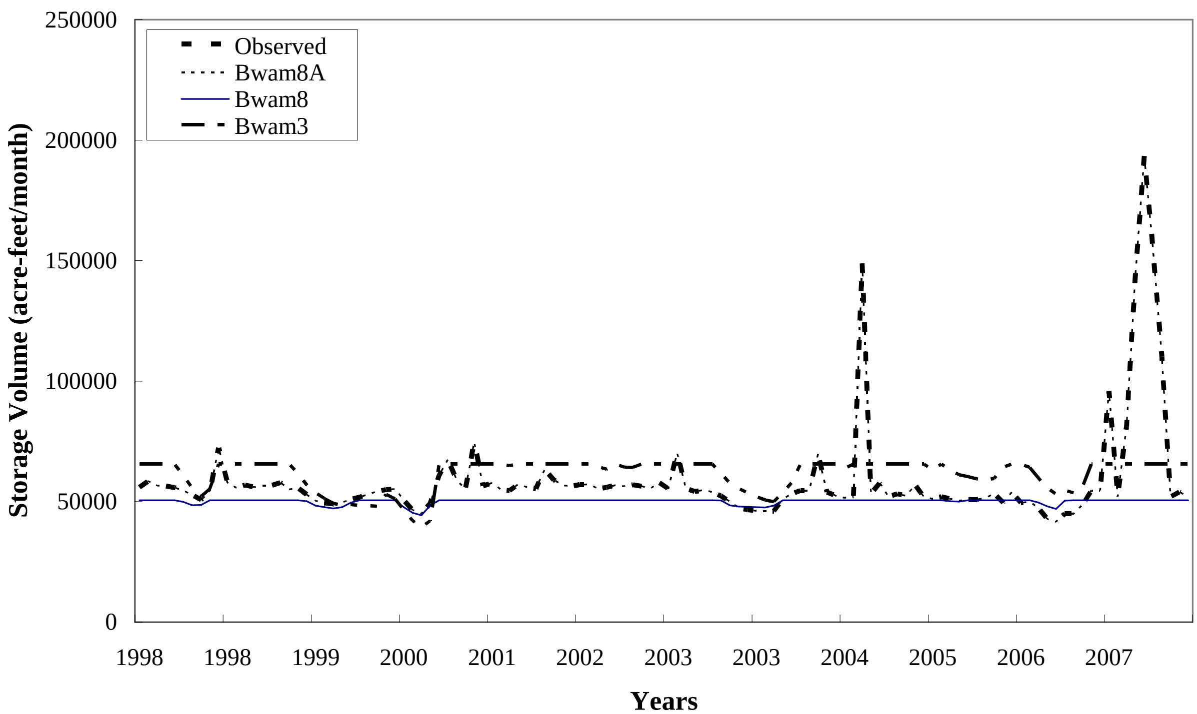

Figure C.12 Storage Volume at Granger Reservoir
(Bwam3 and Bwam8 Capacities = 65,500 and 50,540 acre-feet)

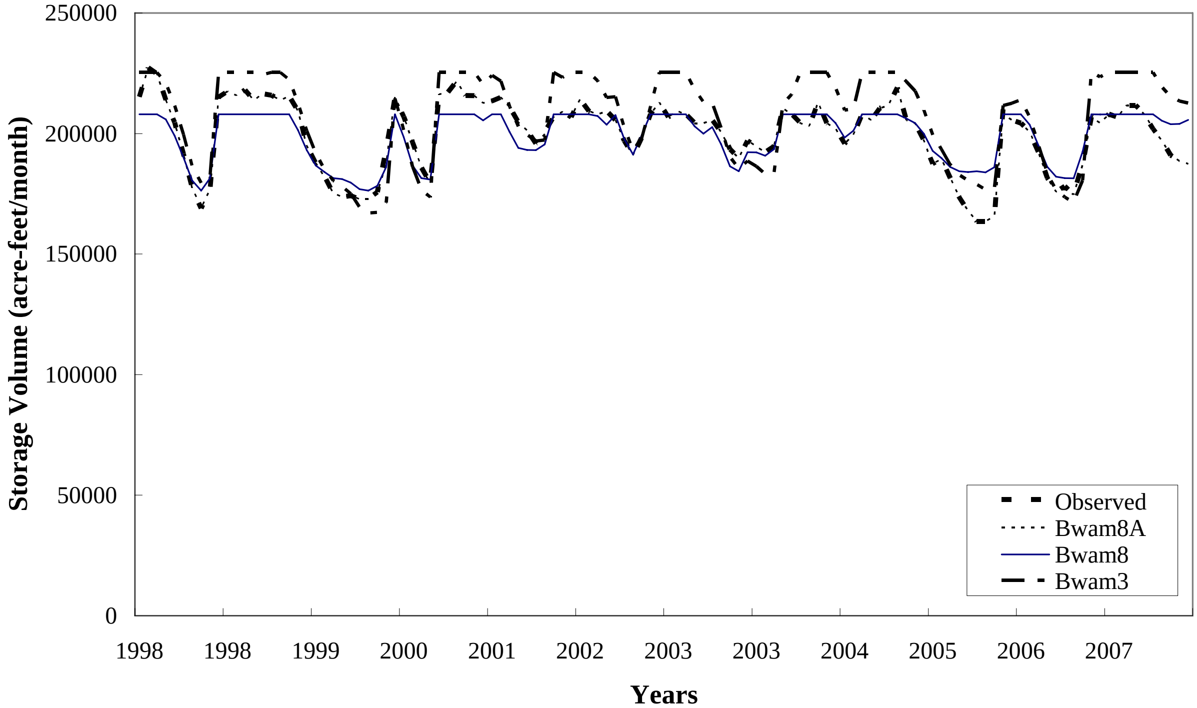

Figure C.13 Storage Volume at Limestone Reservoir
(Bwam3 and Bwam8 Capacities = 225,400 and 208,017 acre-feet)

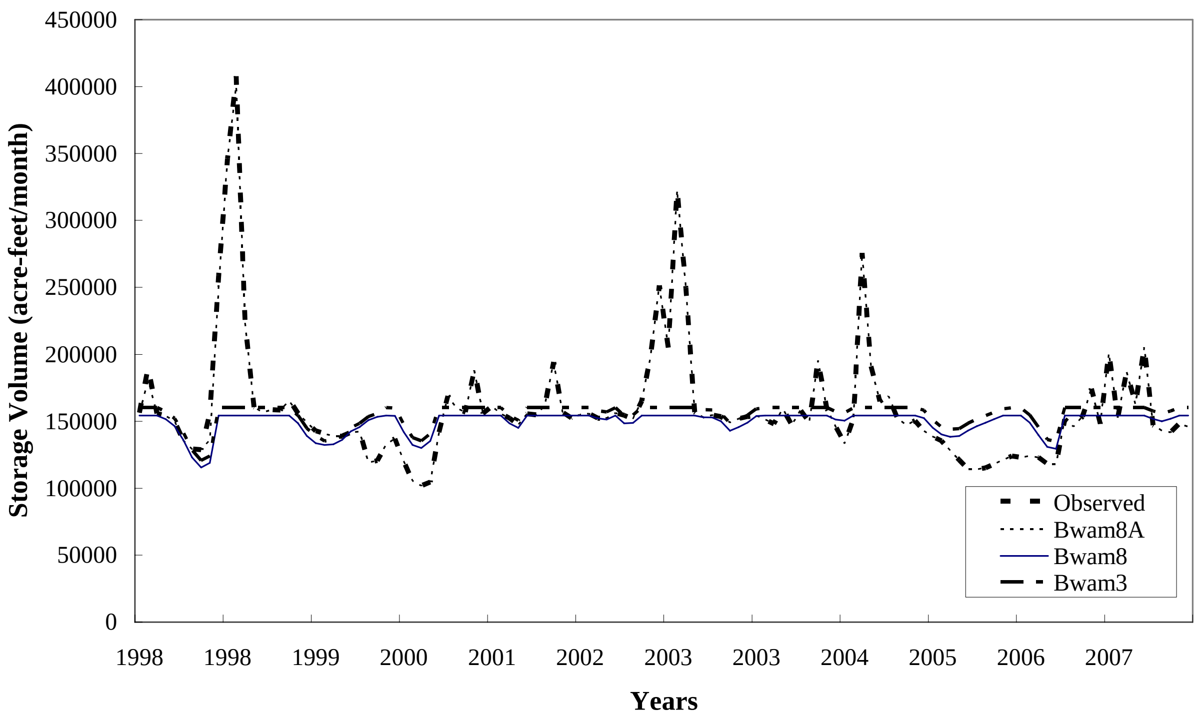

Figure C.14 Storage Volume at Somerville Reservoir
(Bwam3 and Bwam8 Capacities = 160,110 and 154,254 acre-feet)

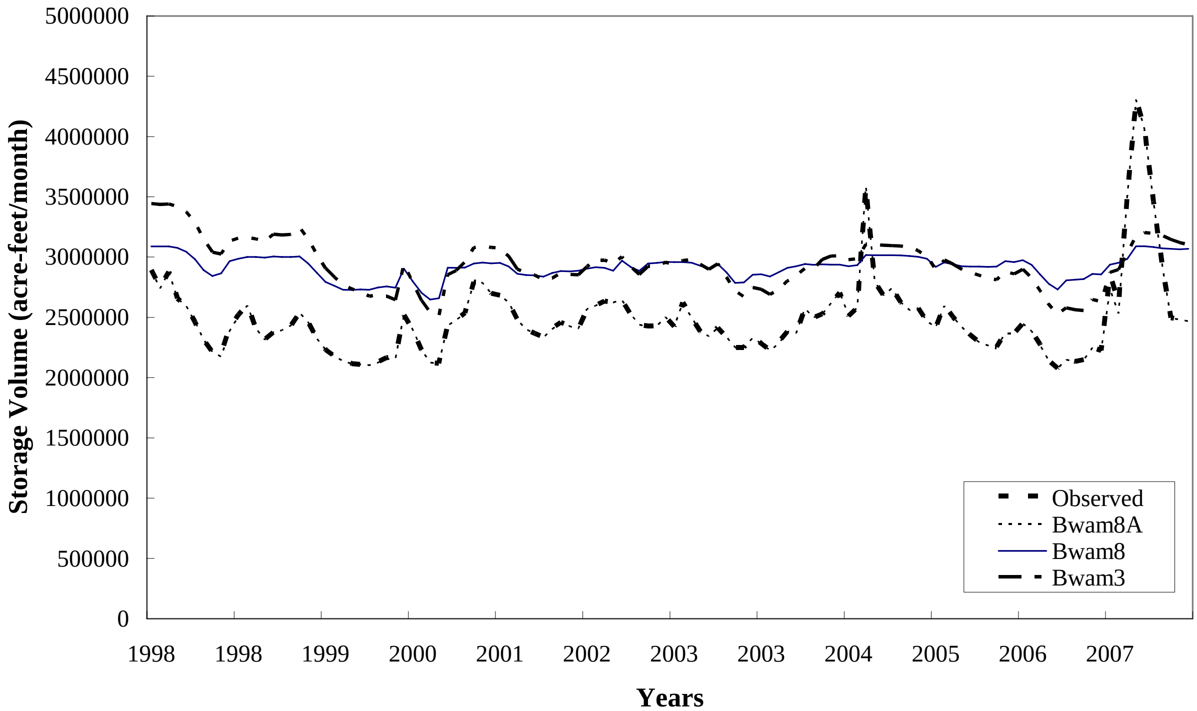

Figure C.15 Storage Volume at 14 Reservoirs
(Bwam3 and Bwam8 Capacities = 3,594,831 and 3,089,443 acre-feet)

Appendix D

Plots of 1900-2007 End-of-Month Storage Volume at 14 Reservoirs

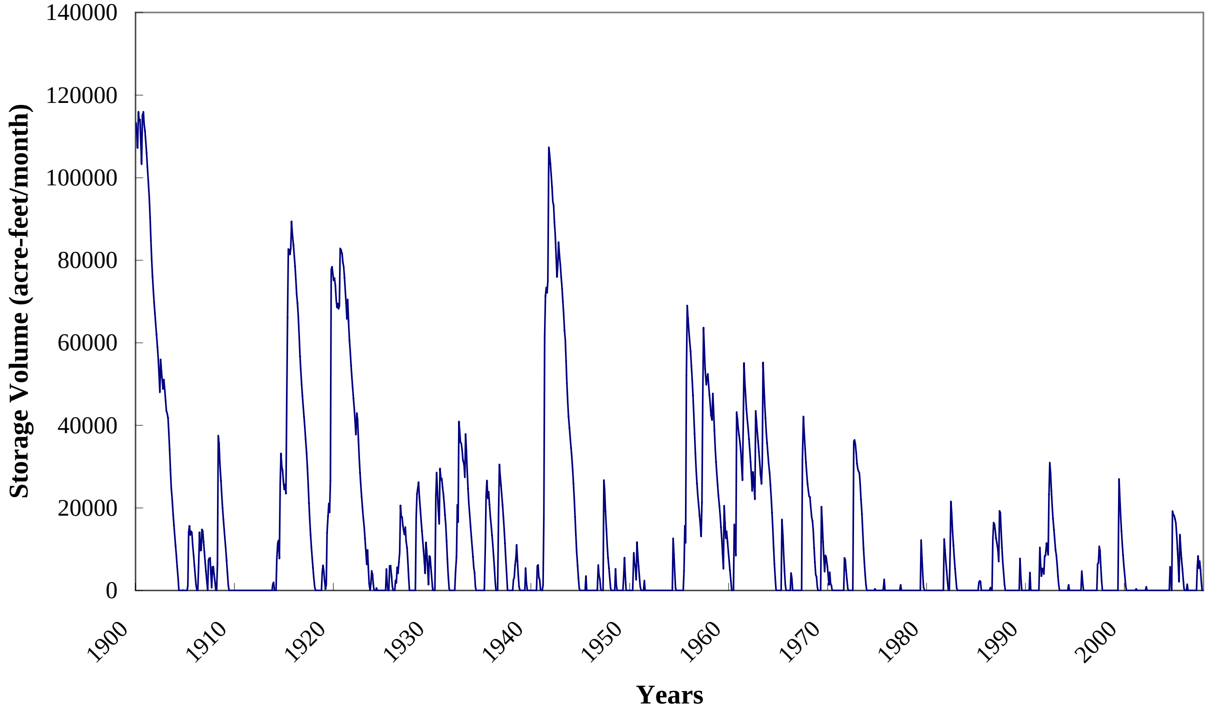

Figure D.1 Bwam3 Storage Volume of Alan Henry Reservoir

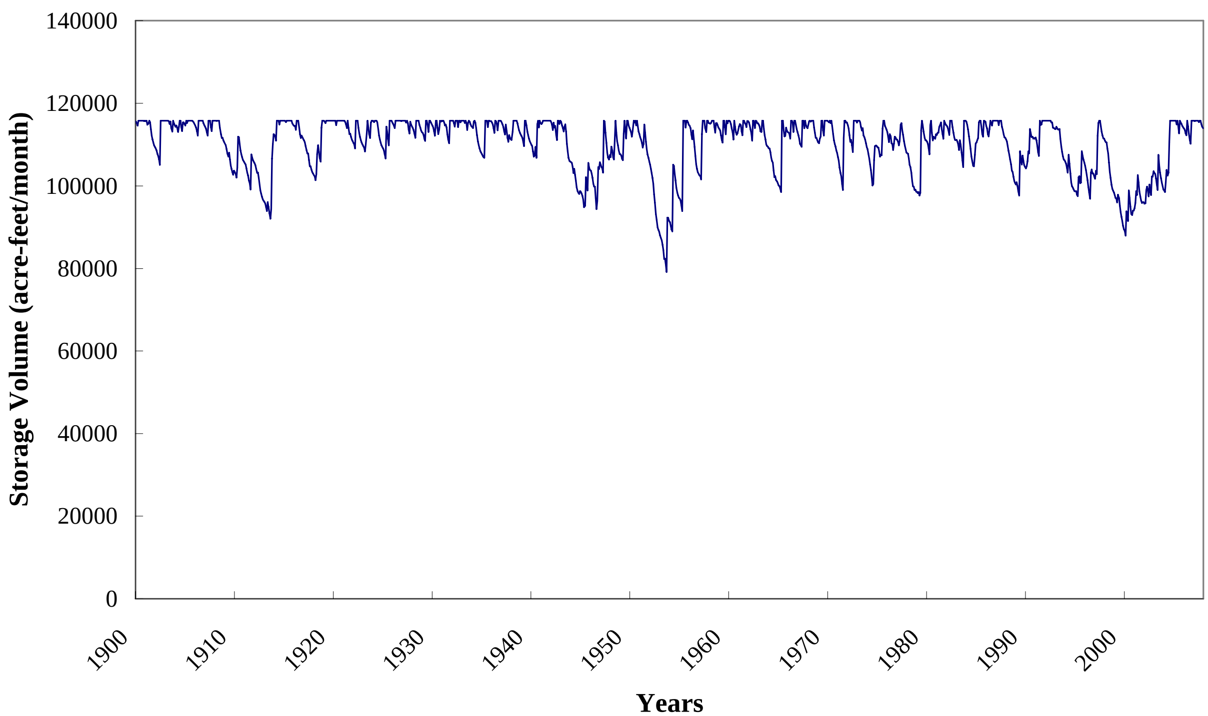

Figure D.2 Bwam8 Storage Volume of Alan Henry Reservoir

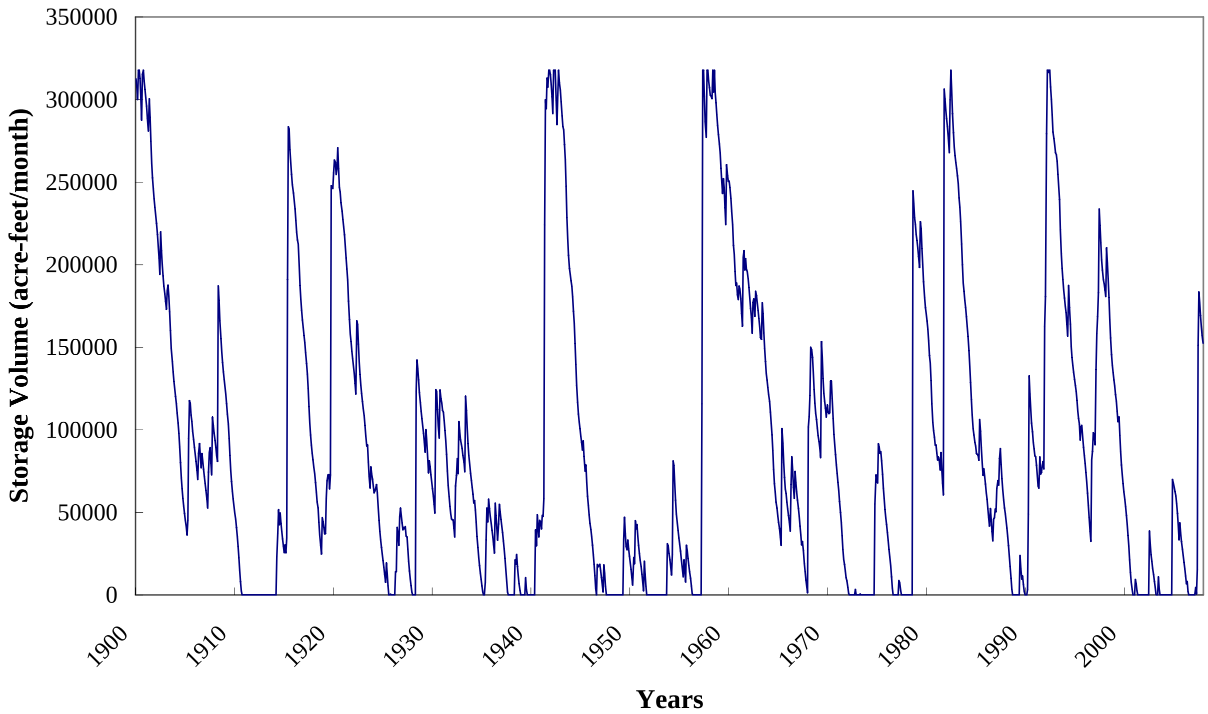

Figure D.3 Bwam3 Storage Volume of Hubbard Creek Reservoir

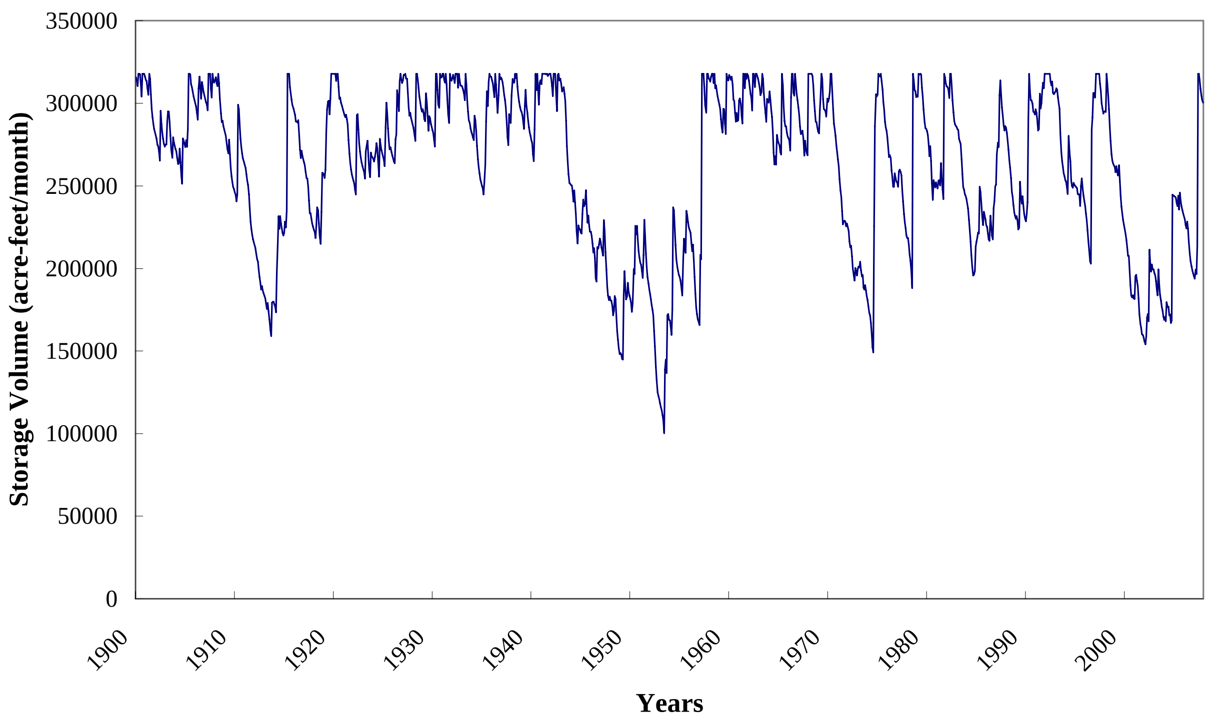

Figure D.4 Bwam8 Storage Volume of Hubbard Creek Reservoir

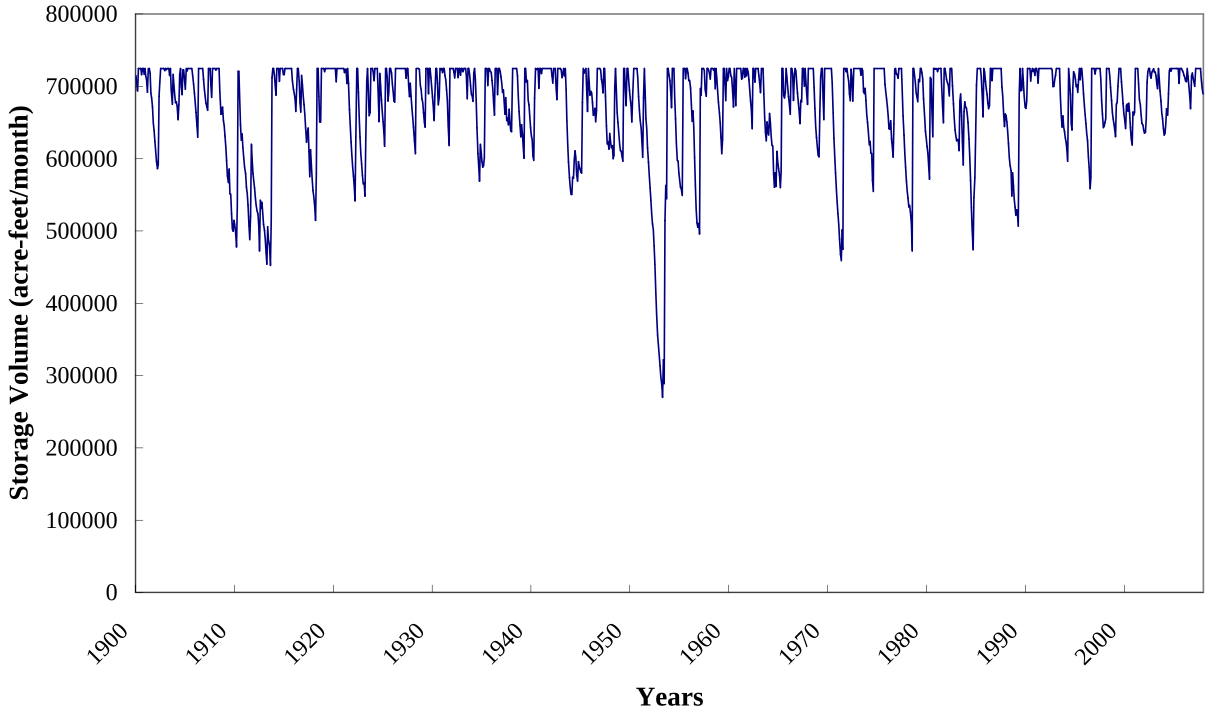

Figure D.5 Bwam3 Storage Volume of Possum Kingdom Reservoir

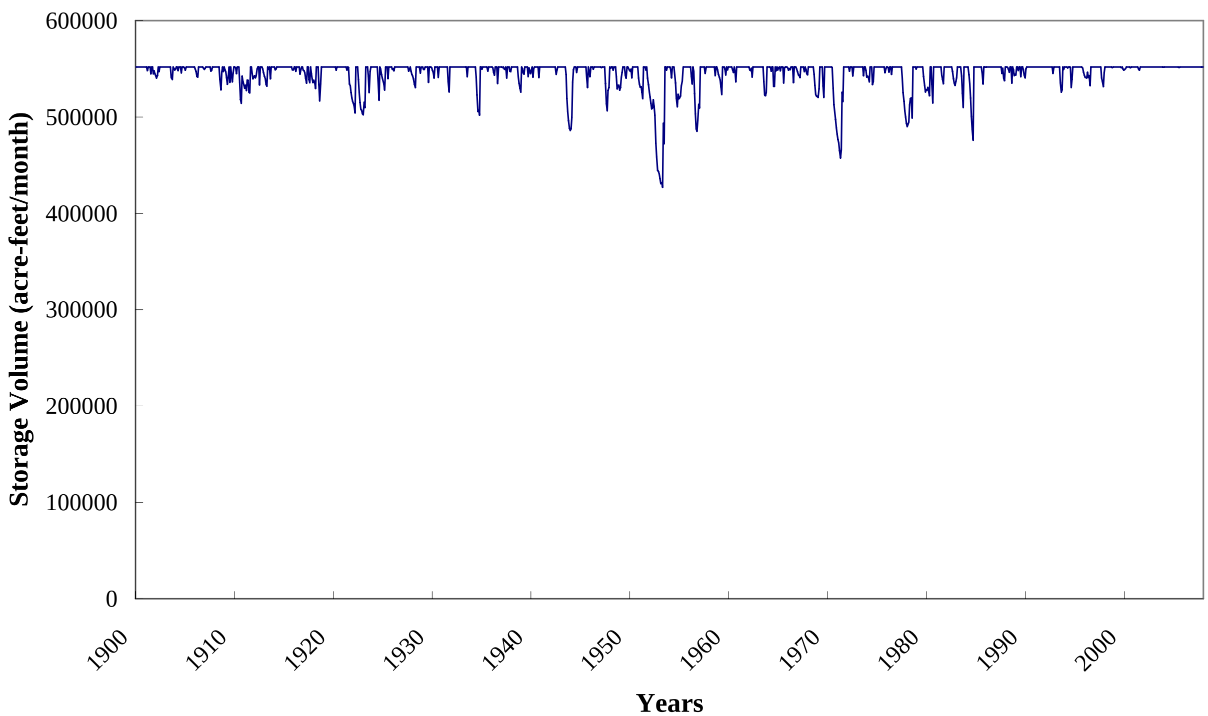

Figure D.6 Bwam8 Storage Volume of Possum Kingdom Reservoir

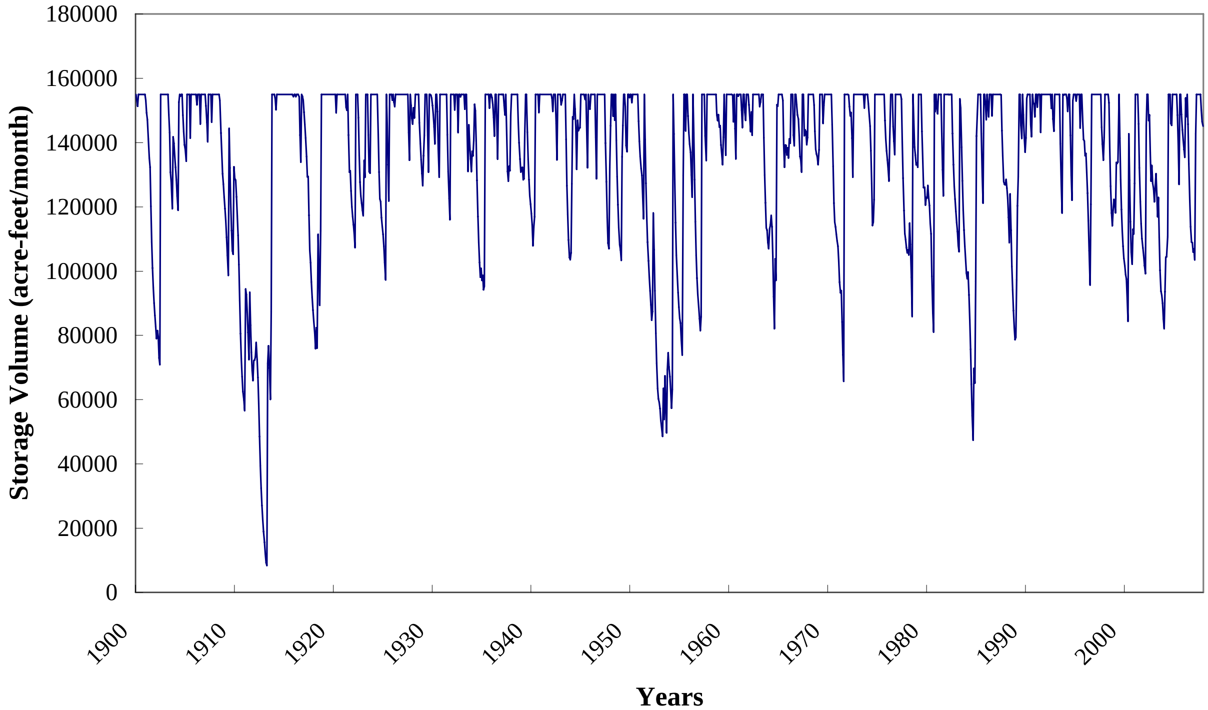

Figure D.7 Bwam3 Storage Volume of Granbury Reservoir

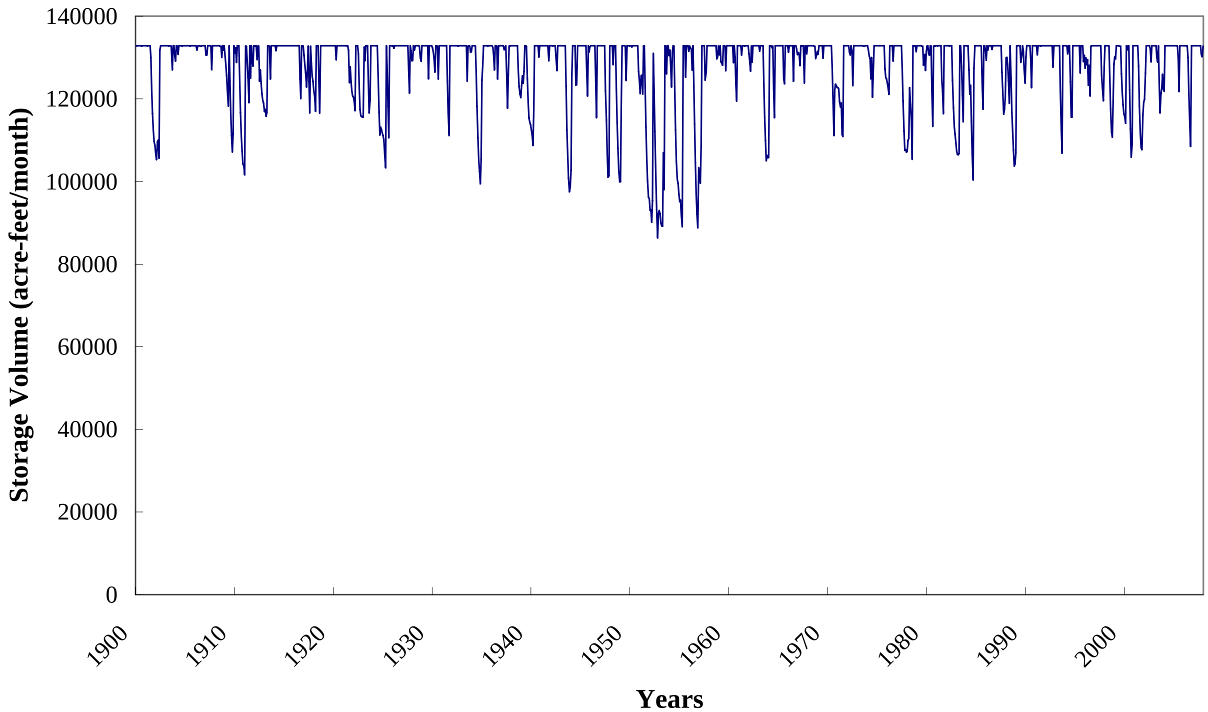

Figure D.8 Bwam8 Storage Volume of Granbury Reservoir

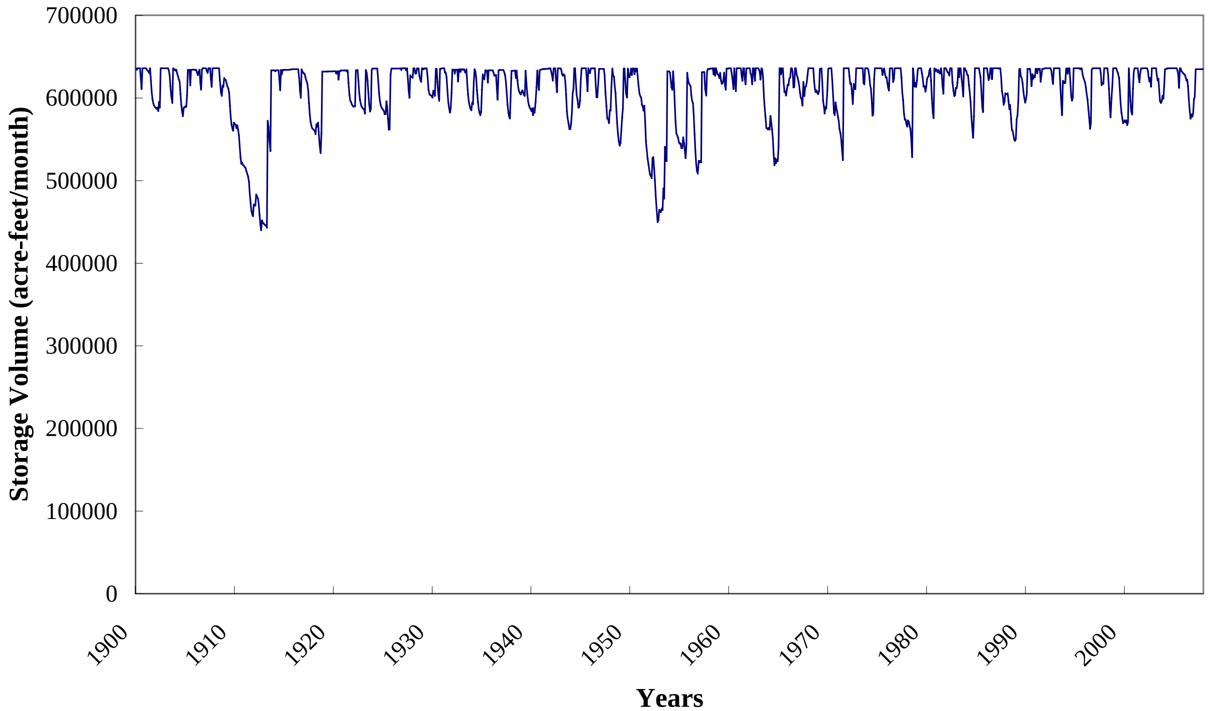

Figure D.9 Bwam3 Storage Volume of Whitney Reservoir

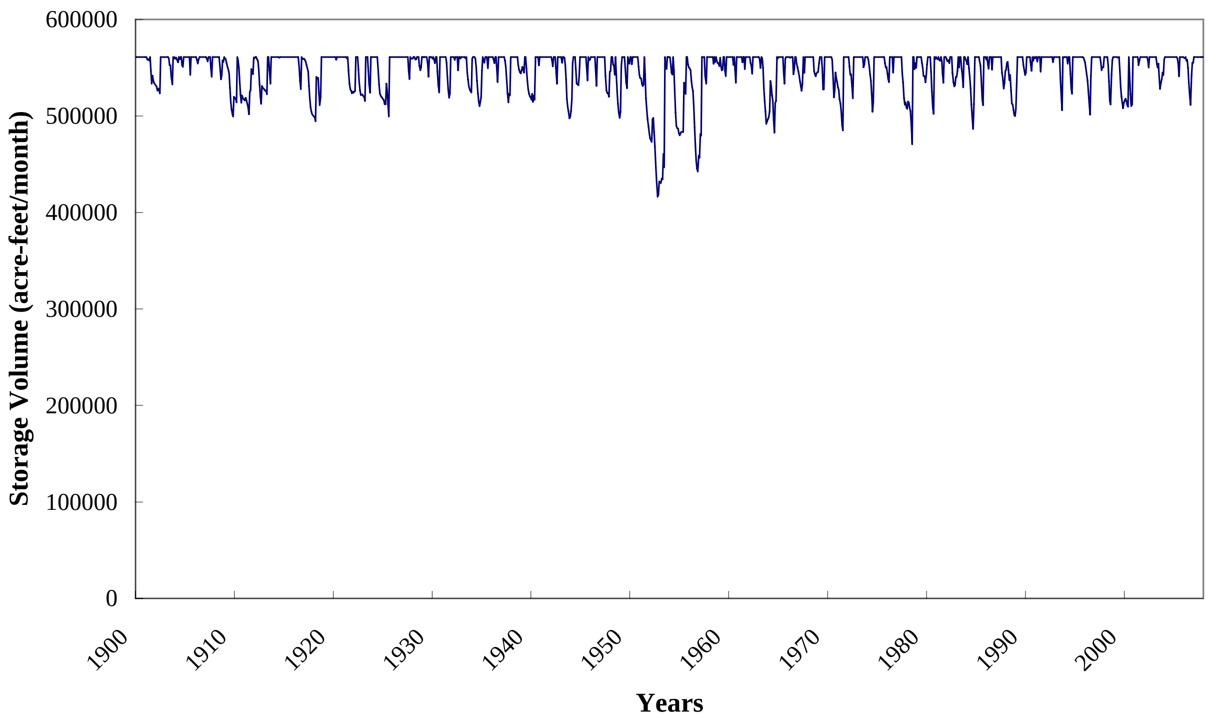

Figure D.10 Bwam8 Storage Volume of Whitney Reservoir

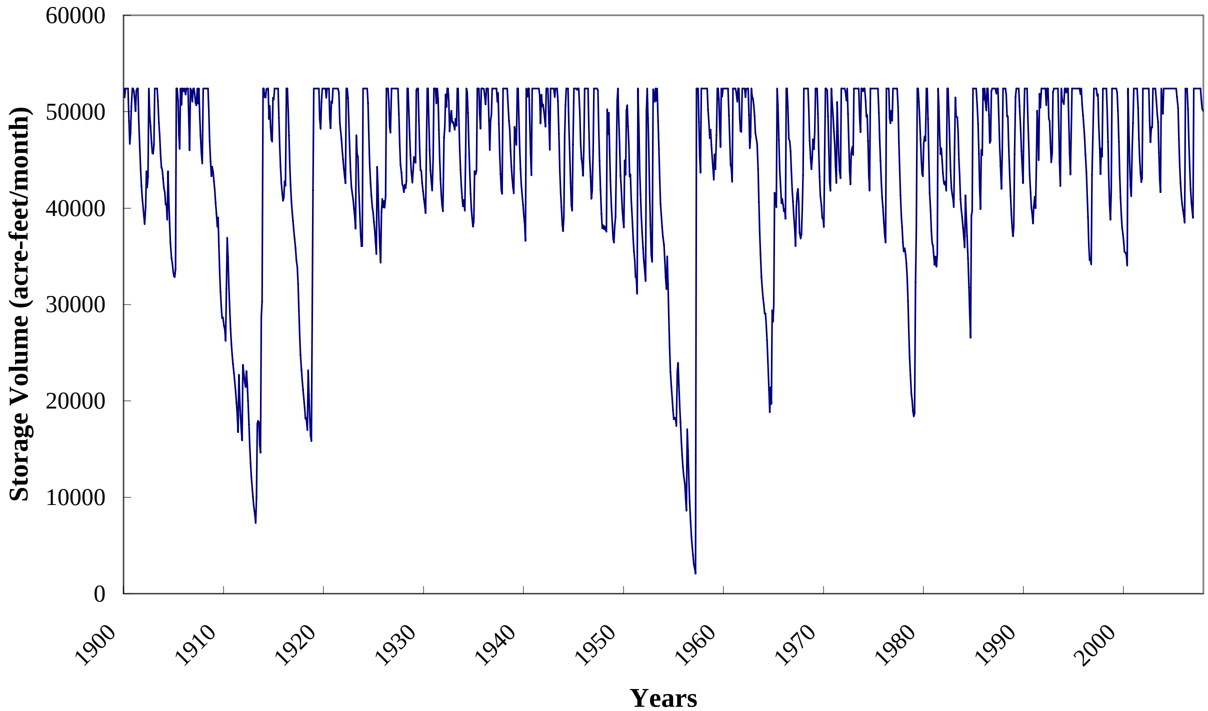

Figure D.11 Bwam3 Storage Volume of Aquilla Reservoir

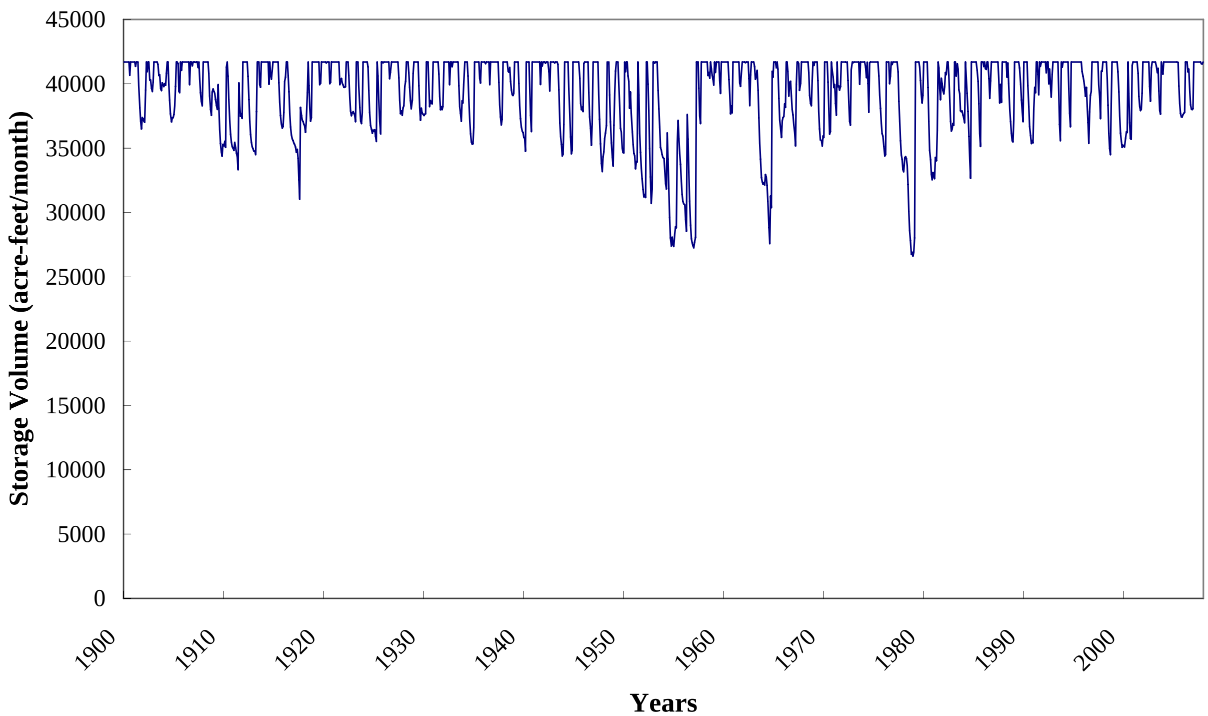

Figure D.12 Bwam8 Storage Volume of Aquilla Reservoir

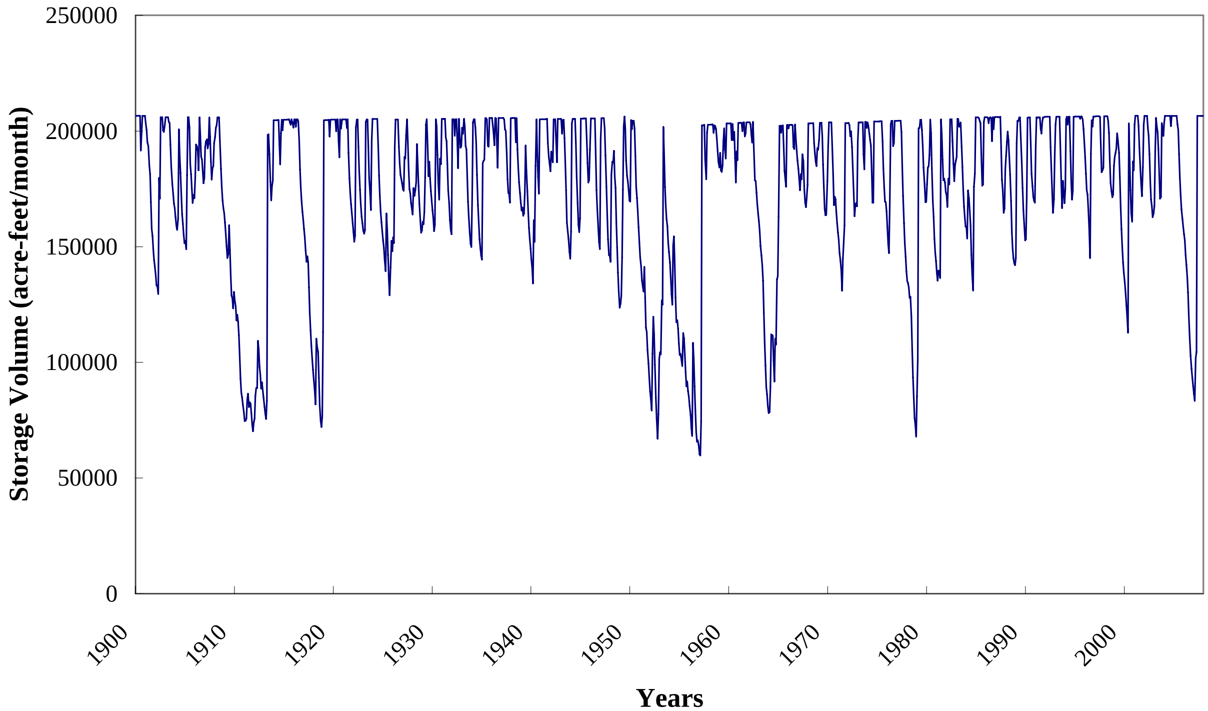

Figure D.13 Bwam3 Storage Volume of Waco Reservoir

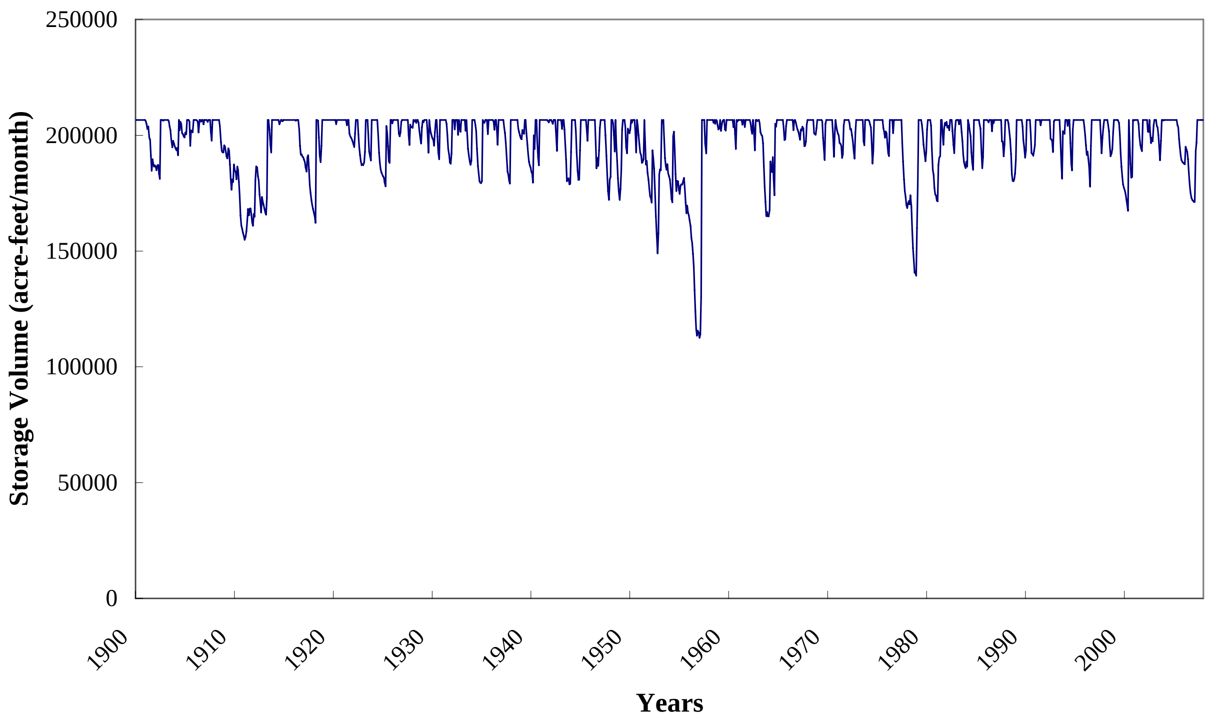

Figure D.14 Bwam8 Storage Volume of Waco Reservoir

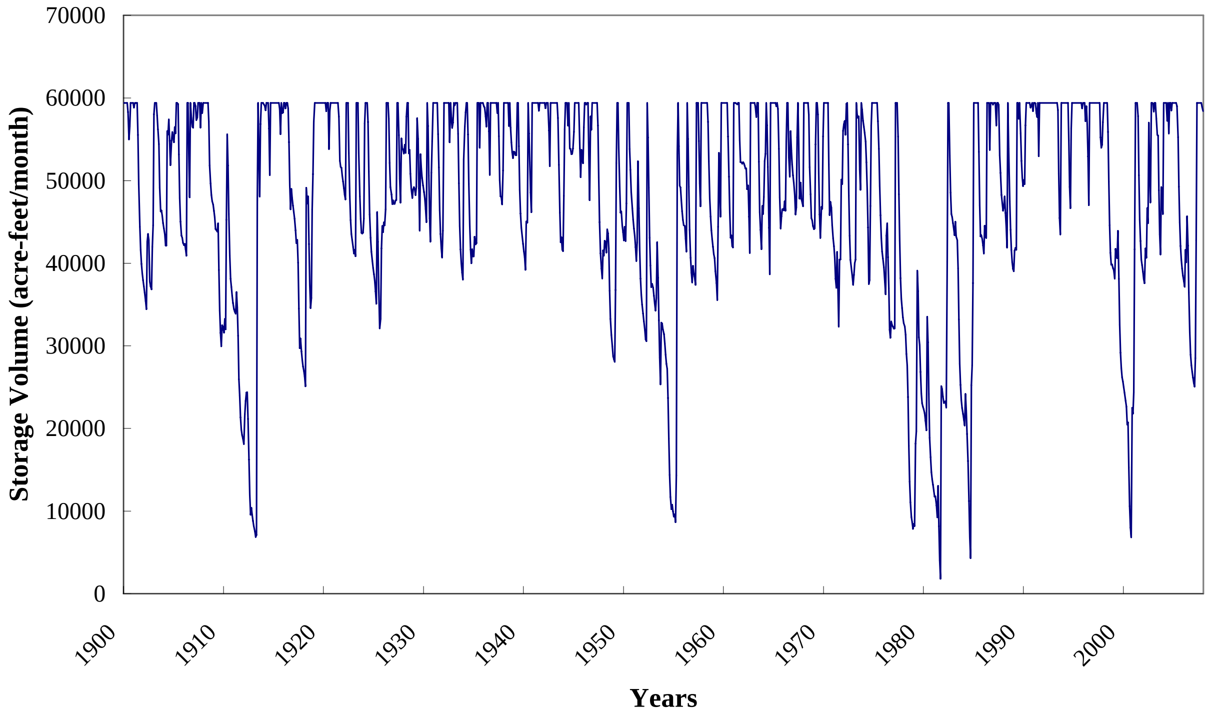

Figure D.15 Bwam3 Storage Volume of Proctor Reservoir

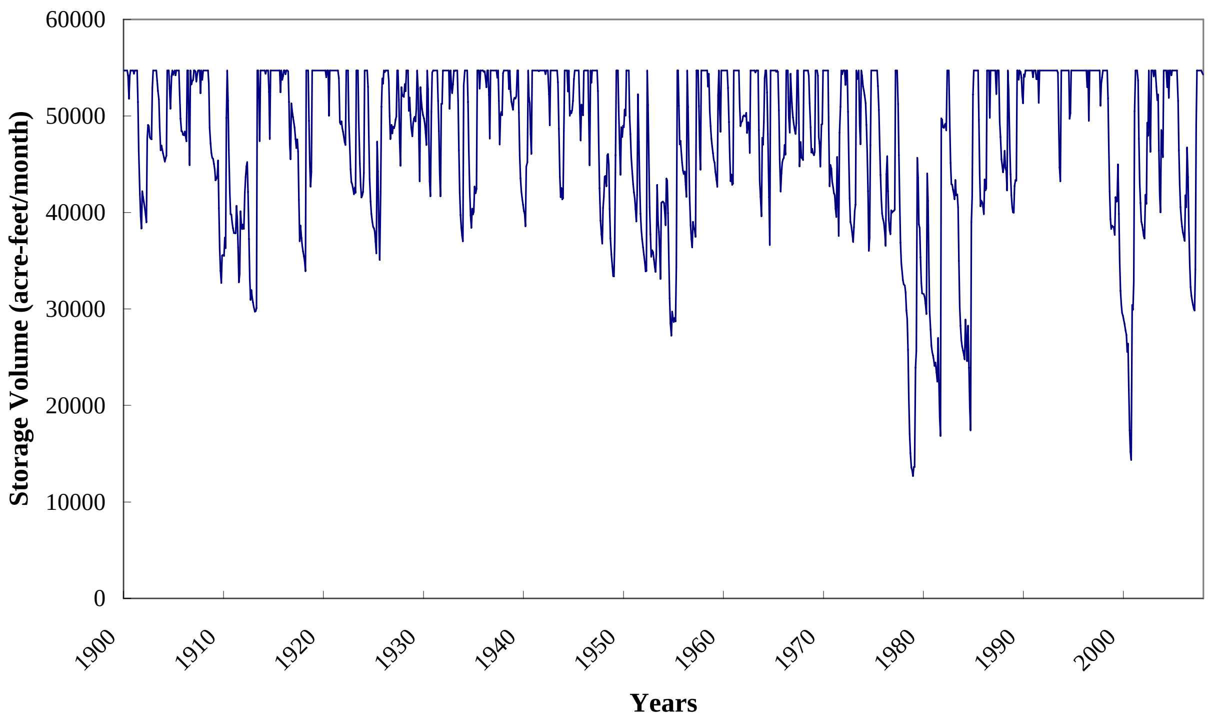

Figure D.16 Bwam8 Storage Volume of Proctor Reservoir

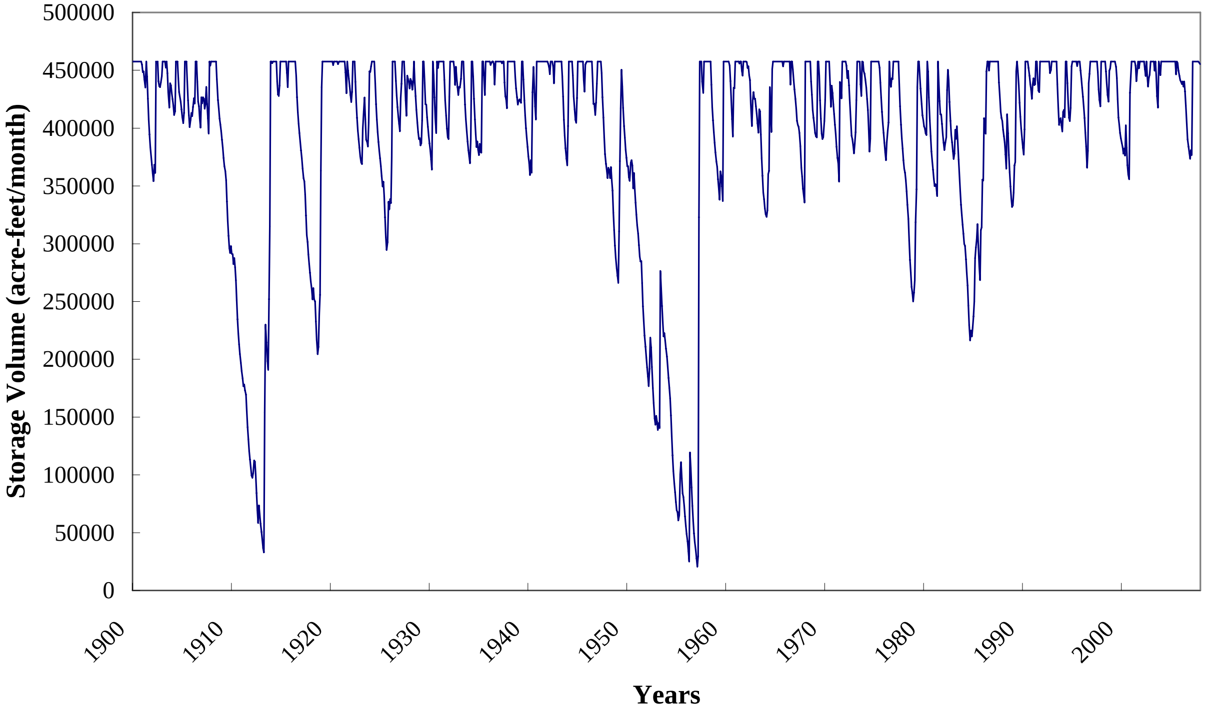

Figure D.17 Bwam3 Storage Volume of Belton Reservoir

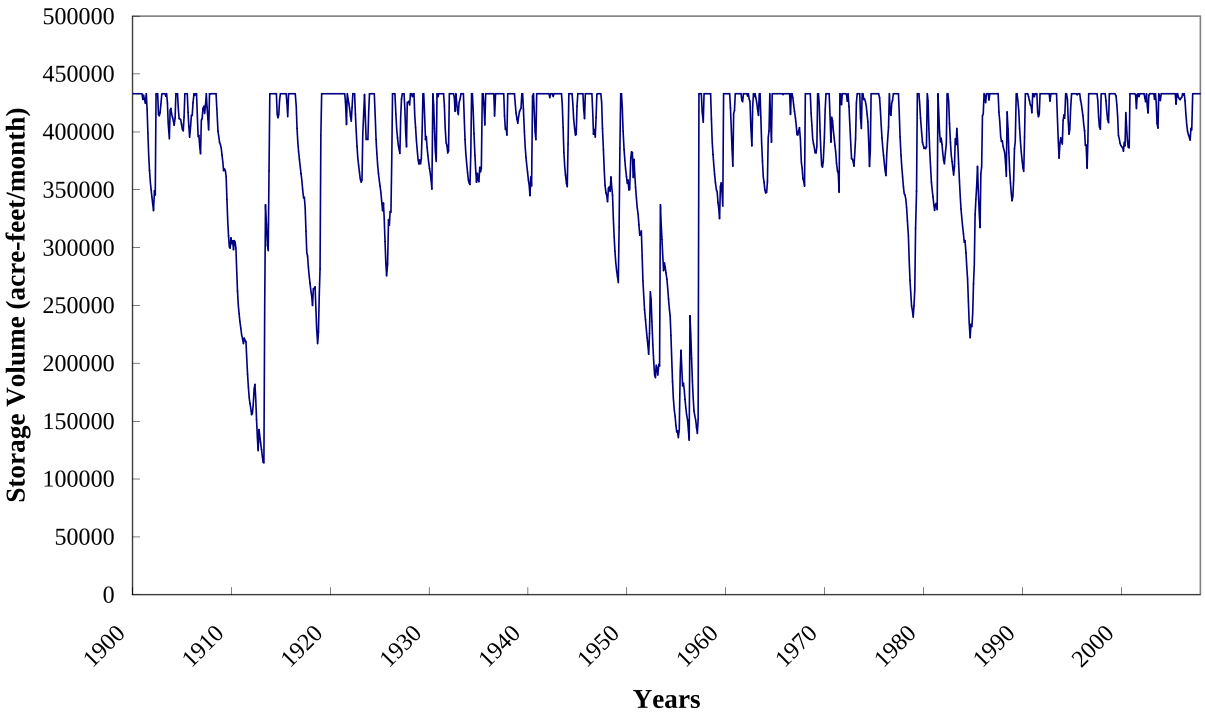

Figure D.18 Bwam8 Storage Volume of Belton Reservoir

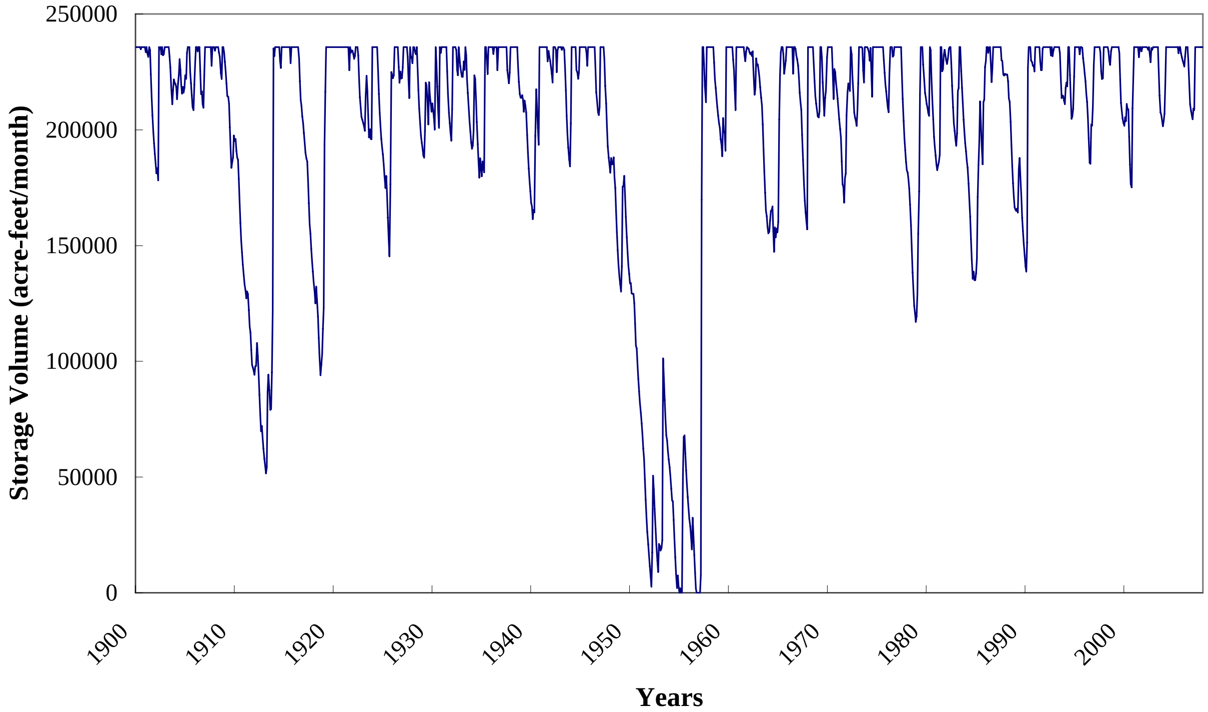

Figure D.19 Bwam3 Storage Volume of Stillhouse Hollow Reservoir

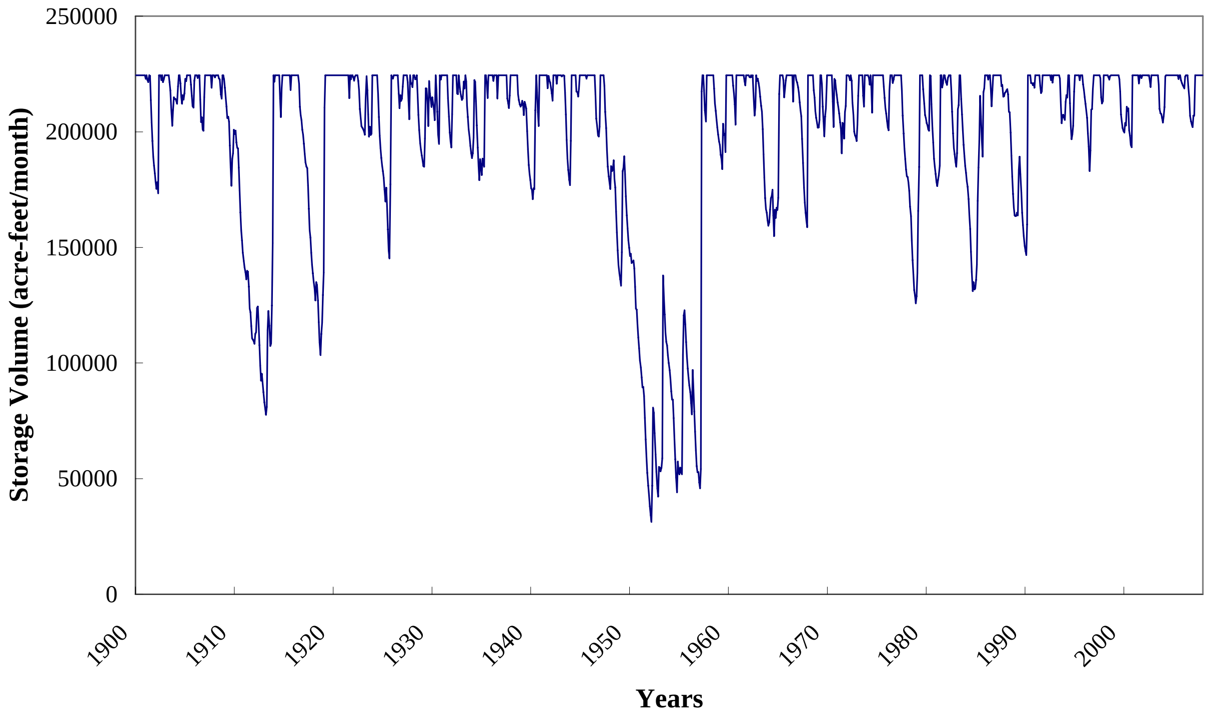

Figure D.20 Bwam8 Storage Volume of Stillhouse Hollow Reservoir

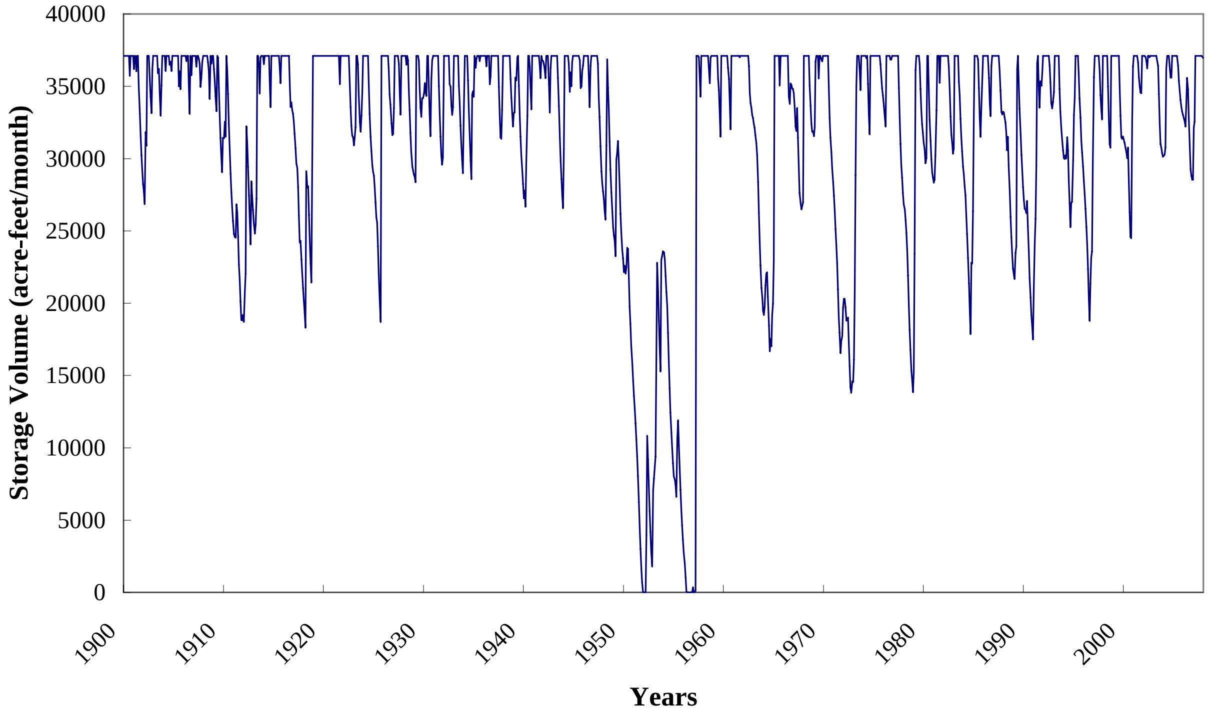

Figure D.21 Bwam3 Storage Volume of Georgetown Reservoir

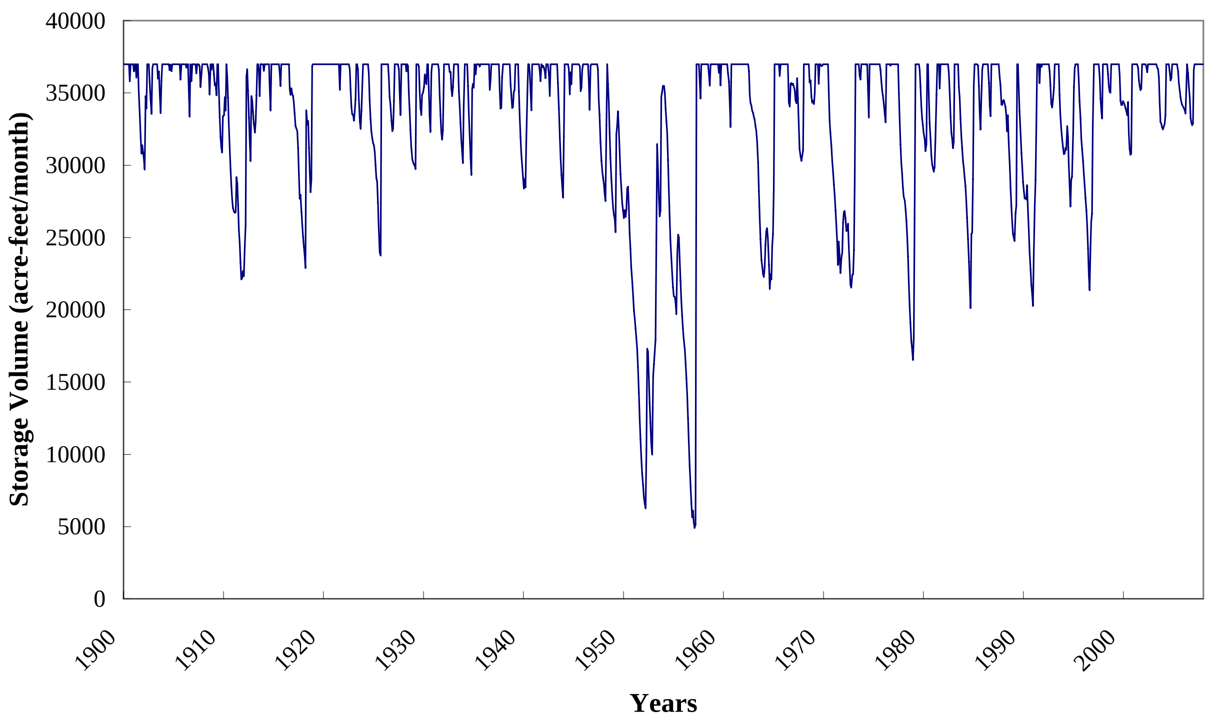

Figure D.22 Bwam8 Storage Volume of Georgetown Reservoir

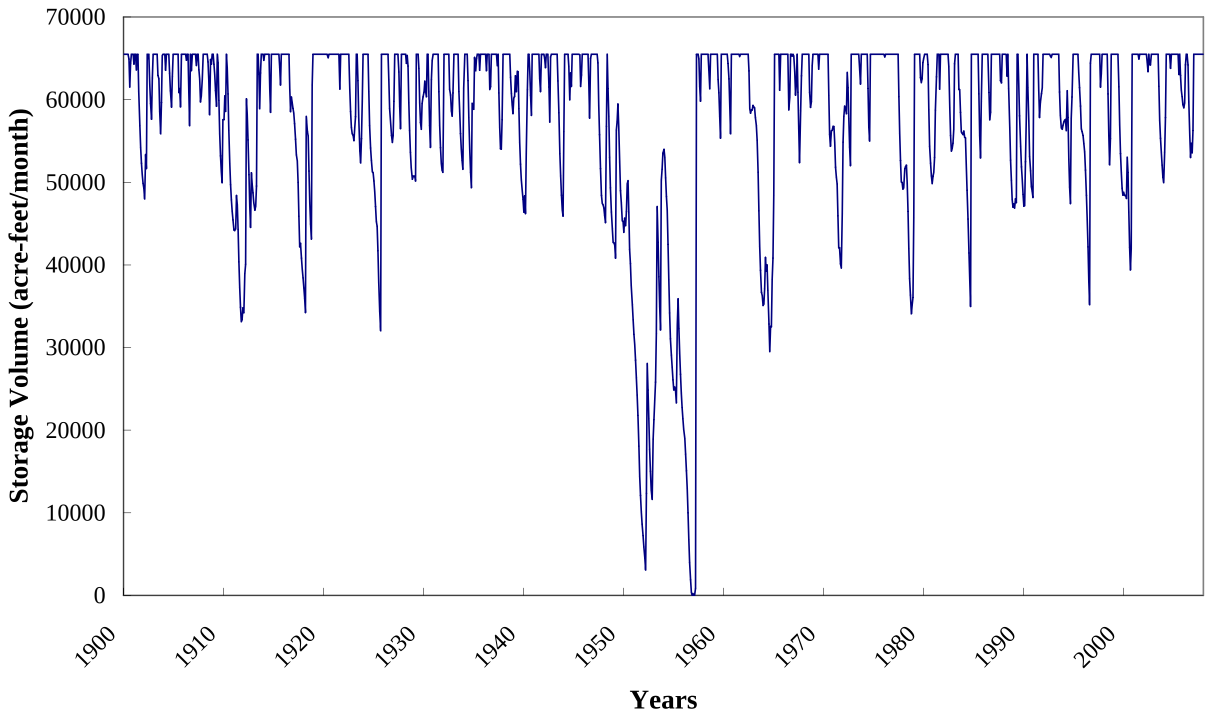

Figure D.23 Bwam3 Storage Volume of Granger Reservoir

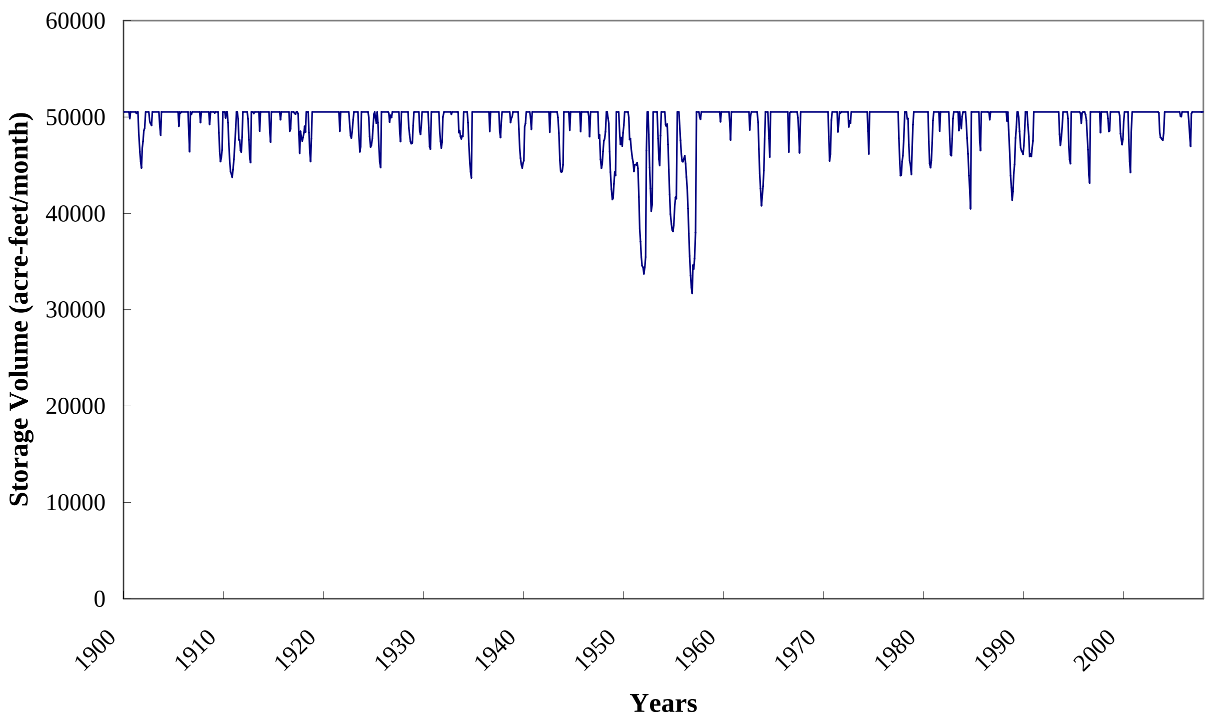

Figure D.24 Bwam8 Storage Volume of Granger Reservoir

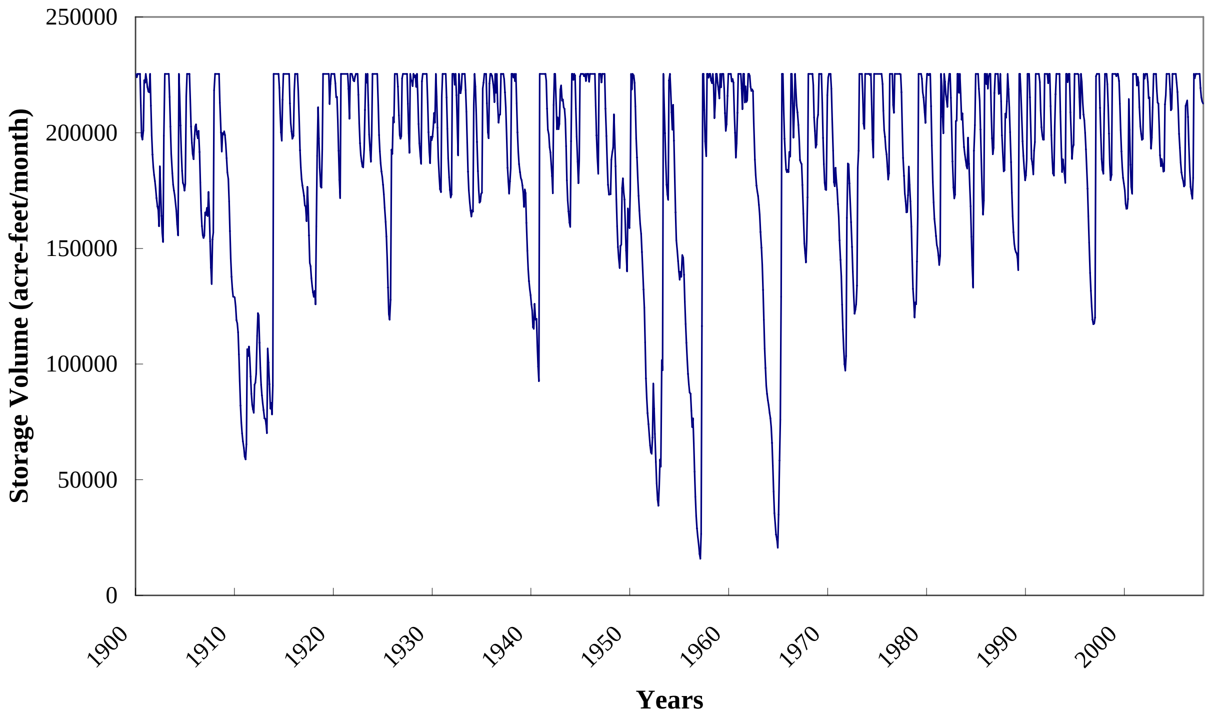

Figure D.25 Bwam3 Storage Volume of Limestone Reservoir

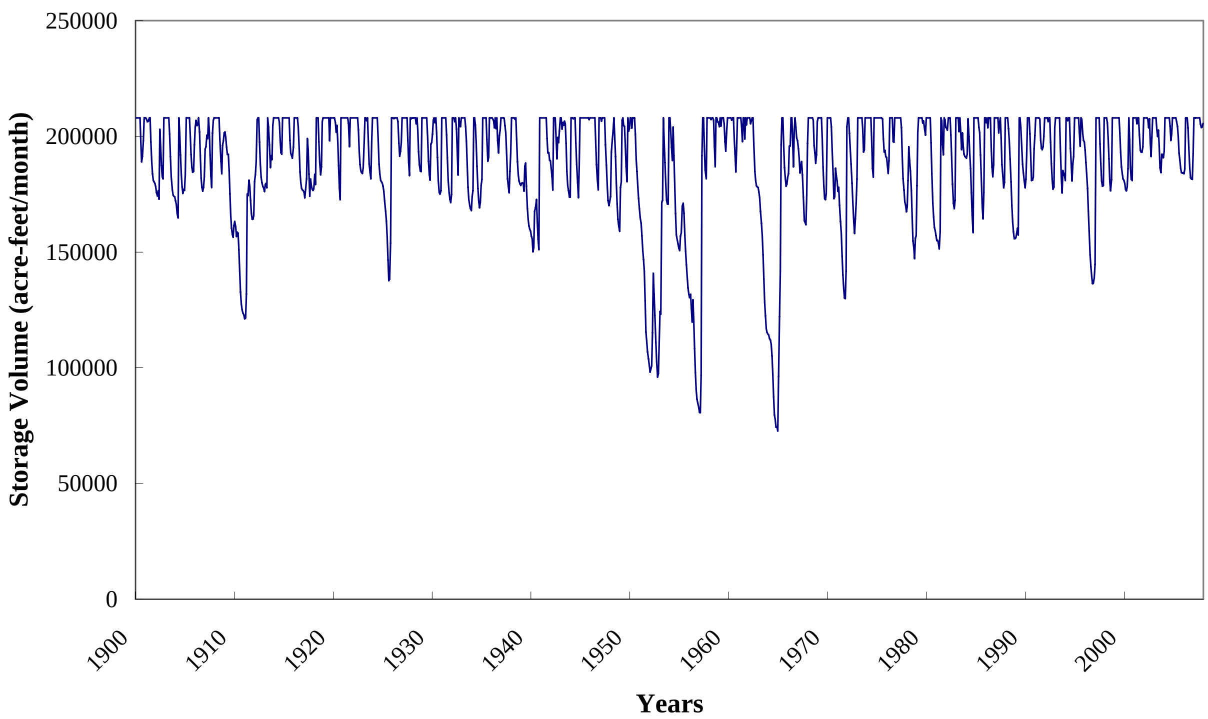

Figure D.26 Bwam8 Storage Volume of Limestone Reservoir

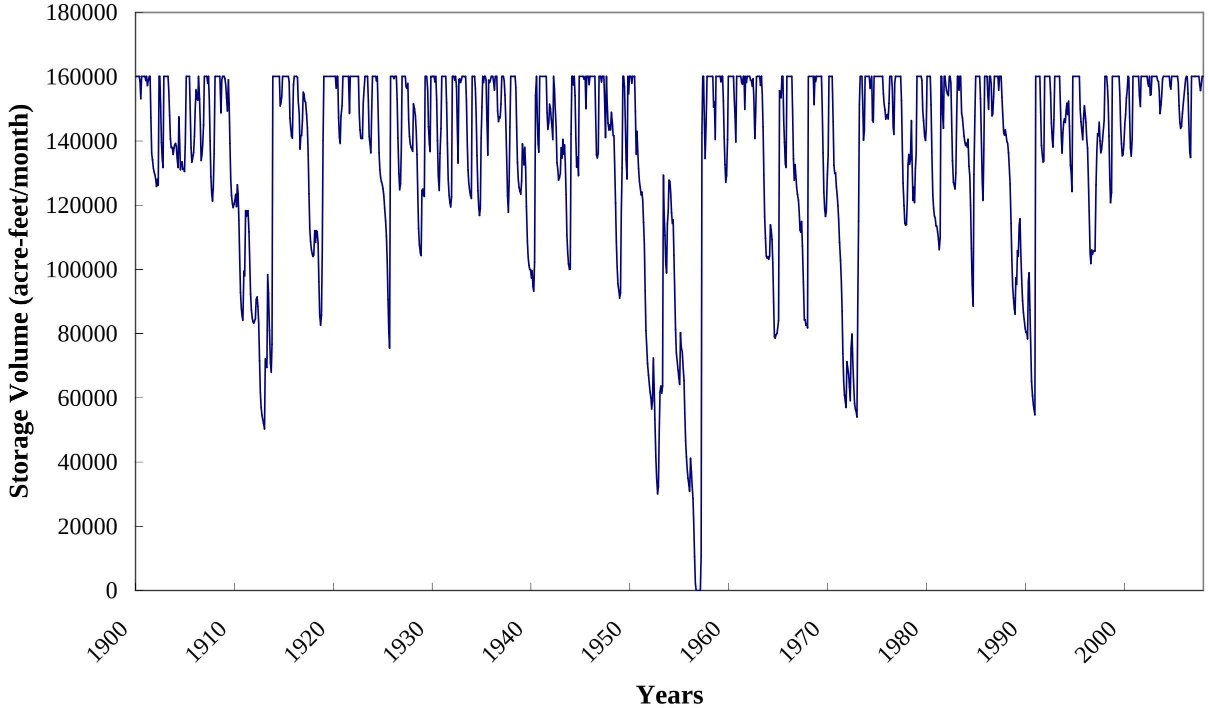

Figure D.27 Bwam3 Storage Volume of Somerville Reservoir

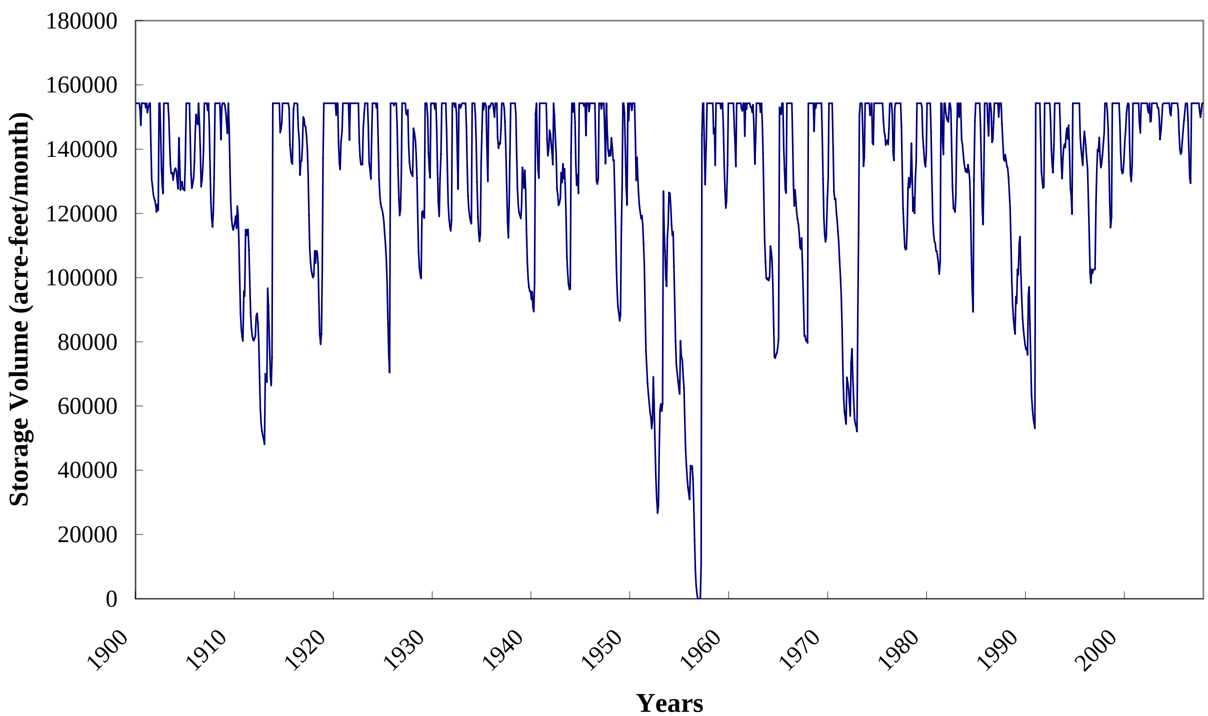

Figure D.28 Bwam8 Storage Volume of Somerville Reservoir

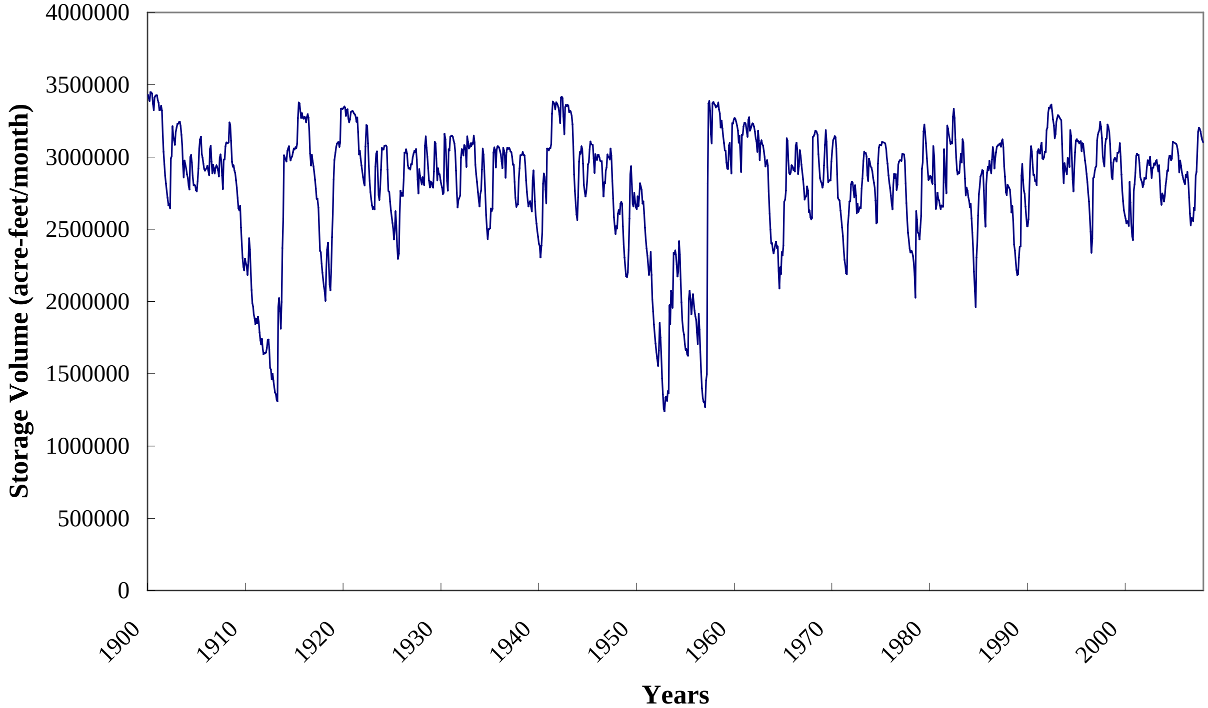

Figure D.29 Bwam3 Total Storage Volume of 14 Reservoirs

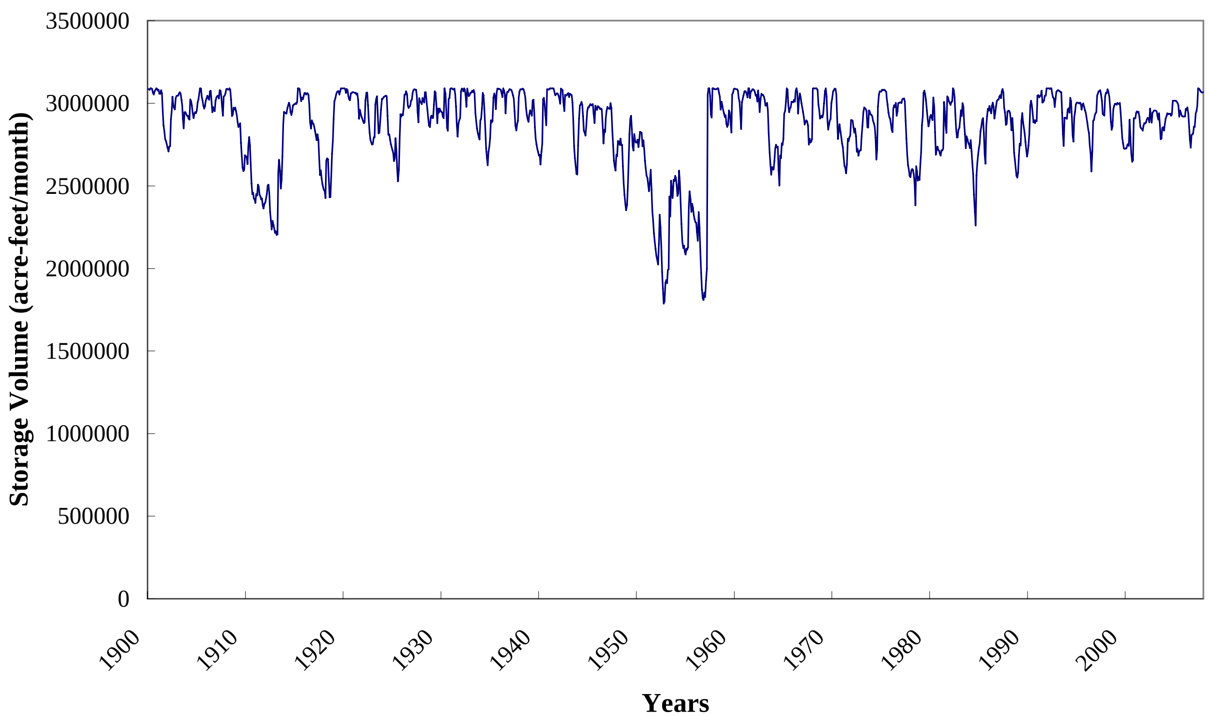

Figure D.30 Bwam8 Total Storage Volume of 14 Reservoirs

Appendix E

Plots of 1900-2007 BRAC Inflows at 48 Control Points

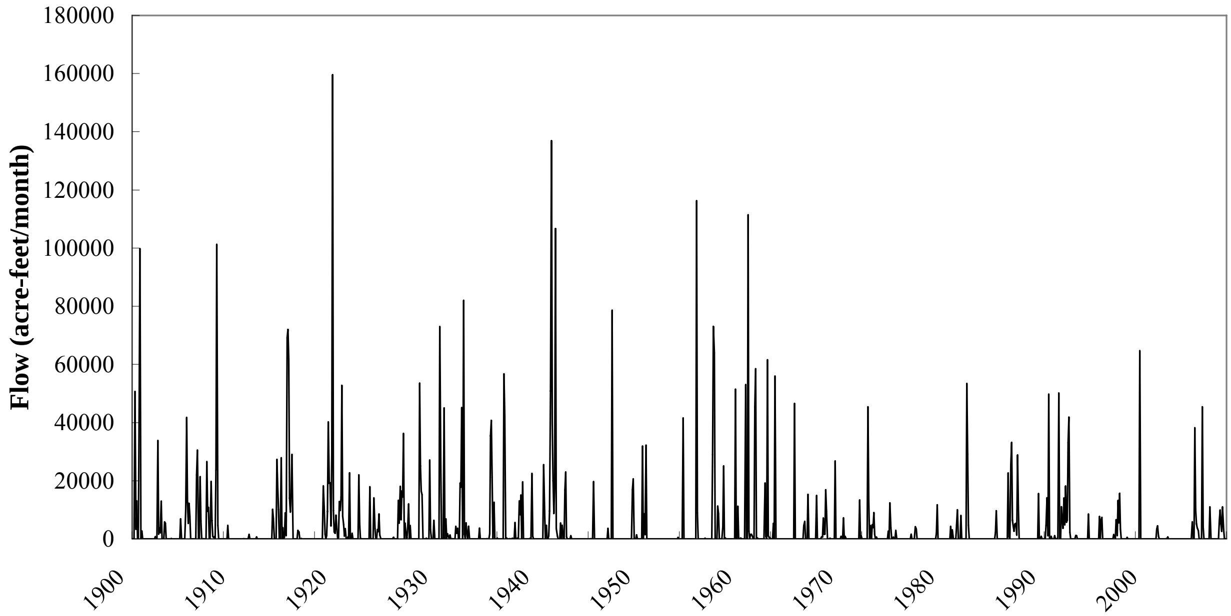

Figure E.1 Monthly BRAC3 Inflows at DMAS09 − Double Mountain Fork at Aspermont Gage

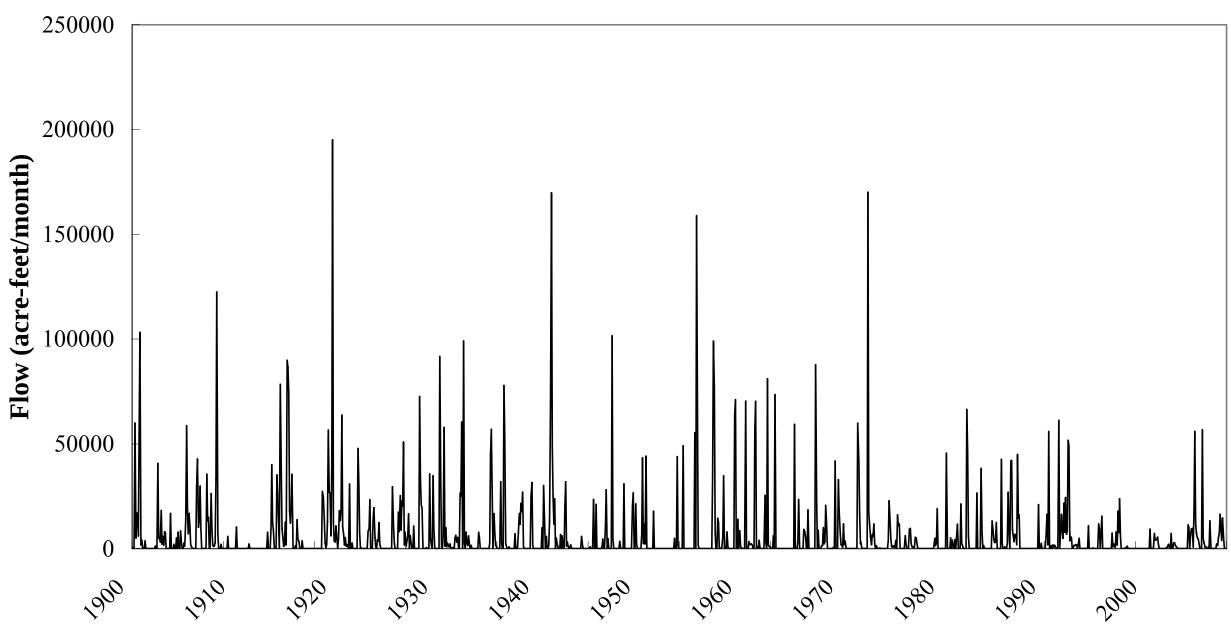

Figure E.2 Monthly BRAC8 Inflows at DMAS09 − Double Mountain Fork at Aspermont Gage

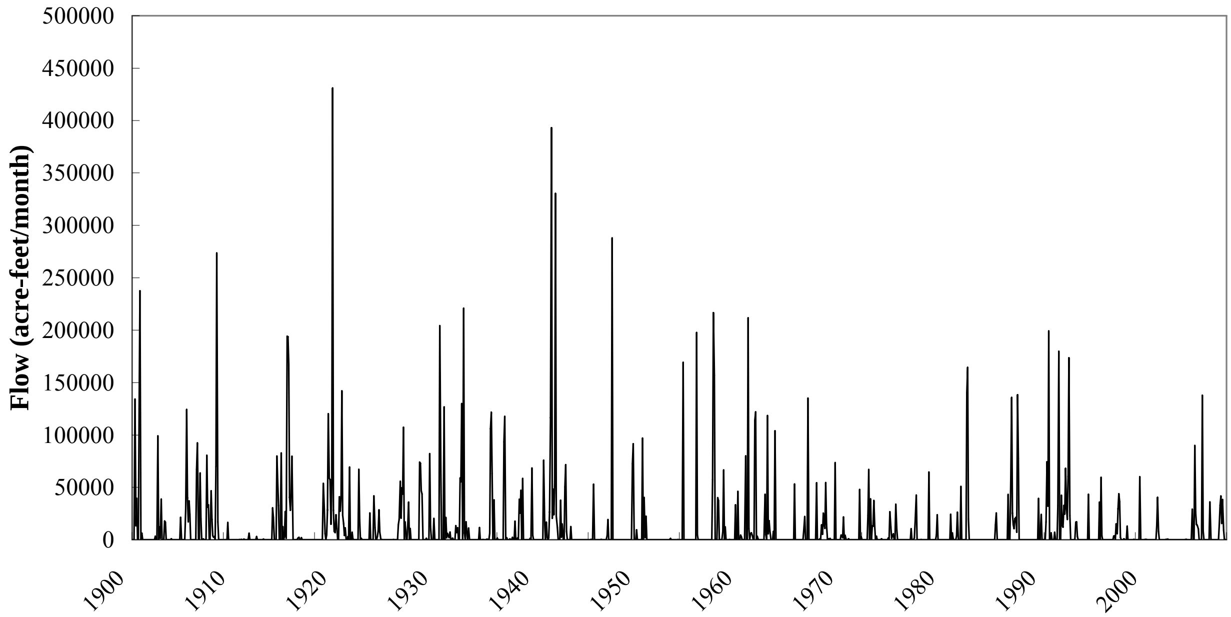

Figure E.3 Monthly BRAC3 Inflows at BRSE11 − Brazos River at Seymour Gage

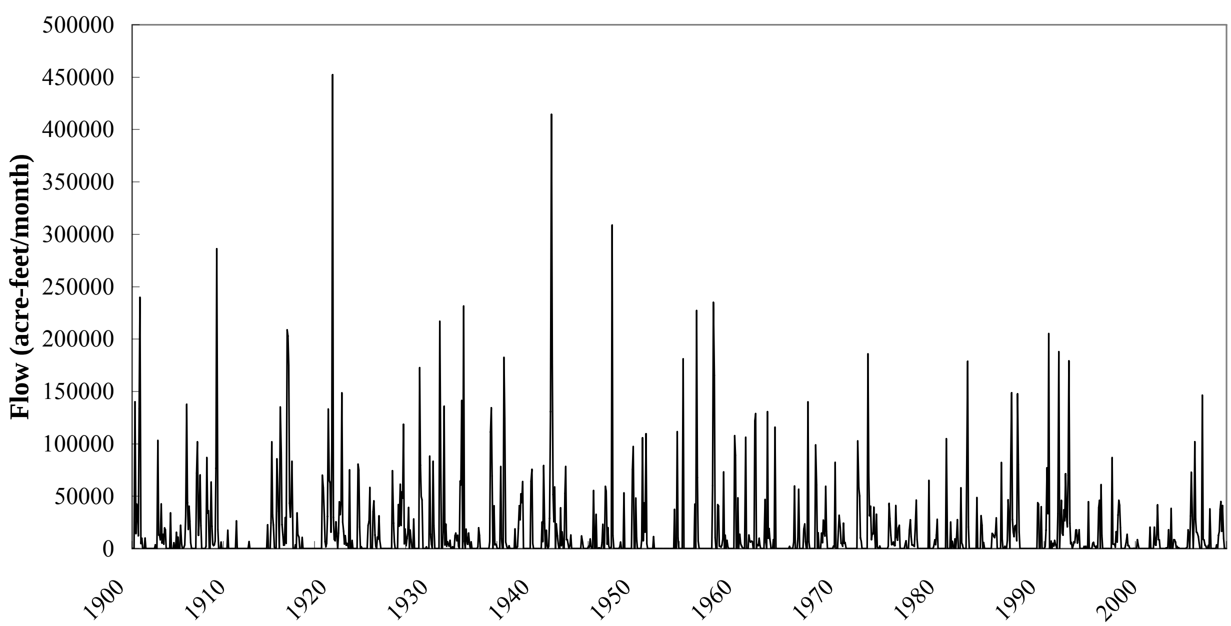

Figure E.4 Monthly BRAC8 Inflows at BRSE11 − Brazos River at Seymour Gage

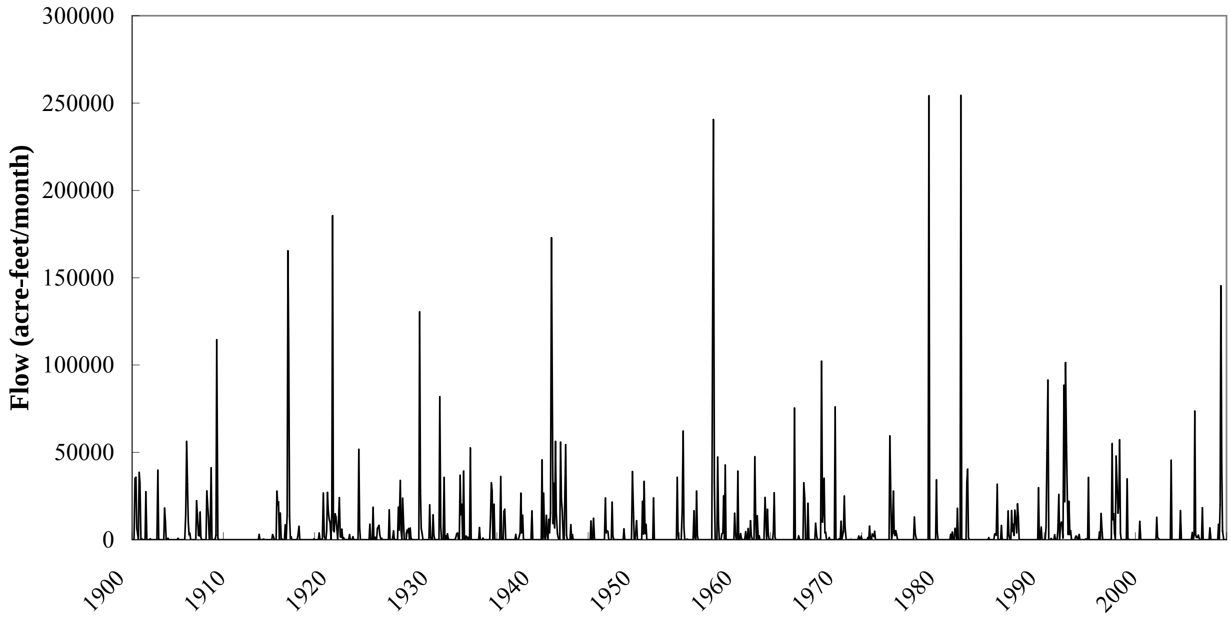

Figure E.5 Monthly BRAC3 Inflows at 421331 − Hubbard Creek Reservoir

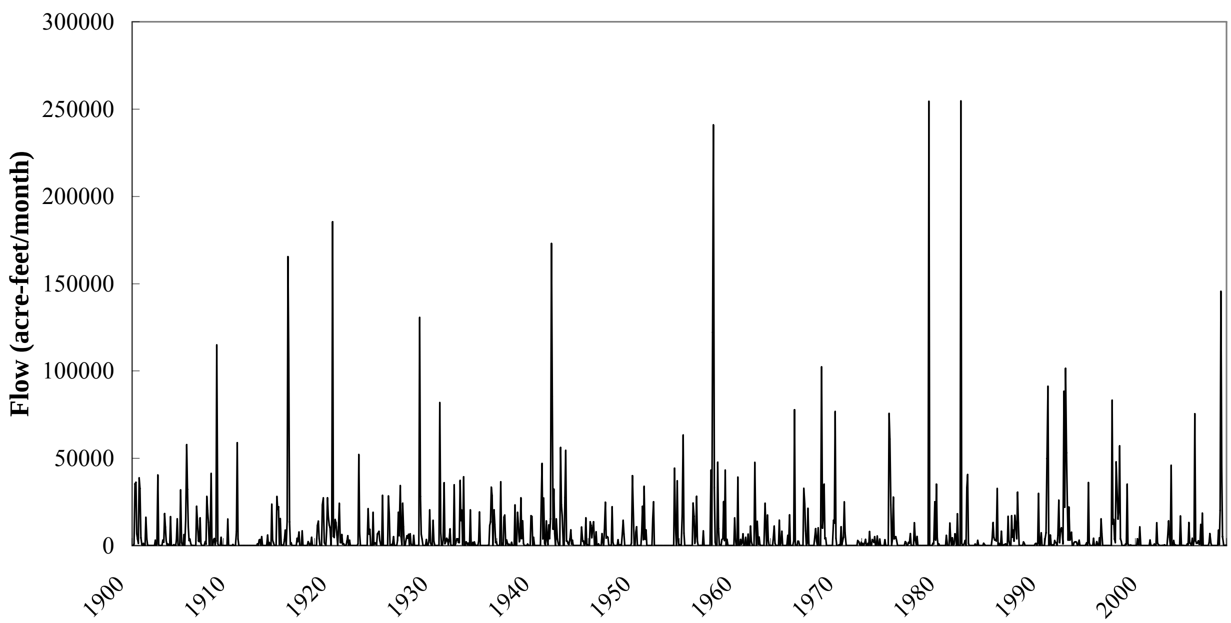

Figure E.6 Monthly BRAC8 Inflows at 421331 − Hubbard Creek Reservoir

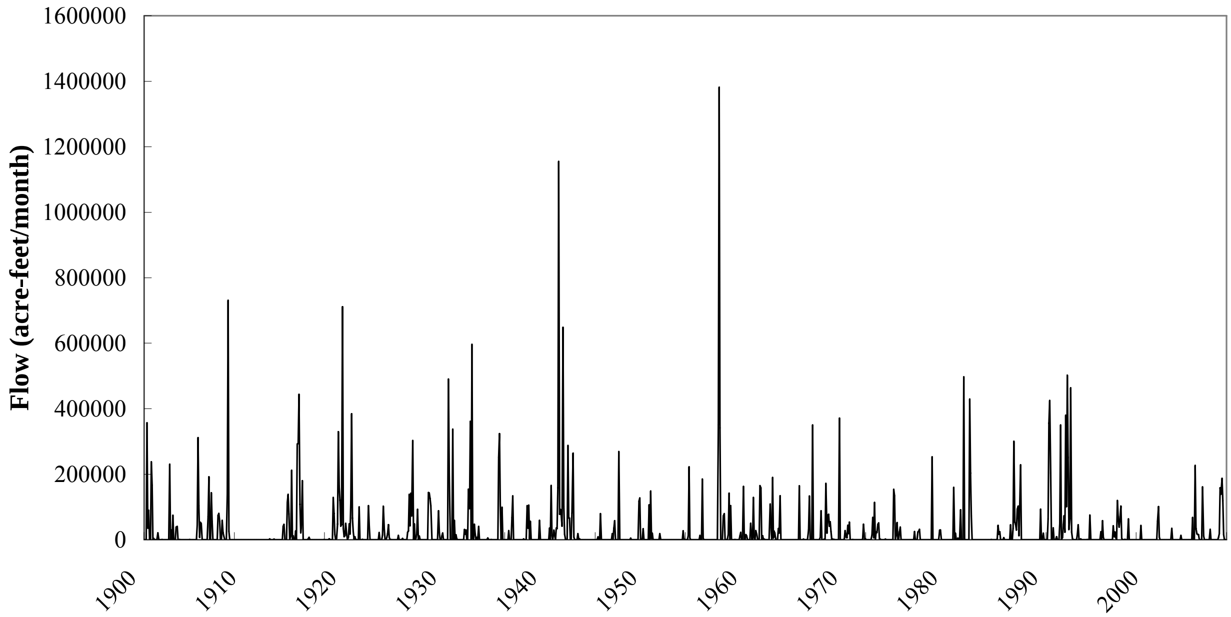

Figure E.7 Monthly BRAC3 Inflows and Bwam3 Naturalized Flows at CON036
Confluence of Hubbard Creek and Brazos River

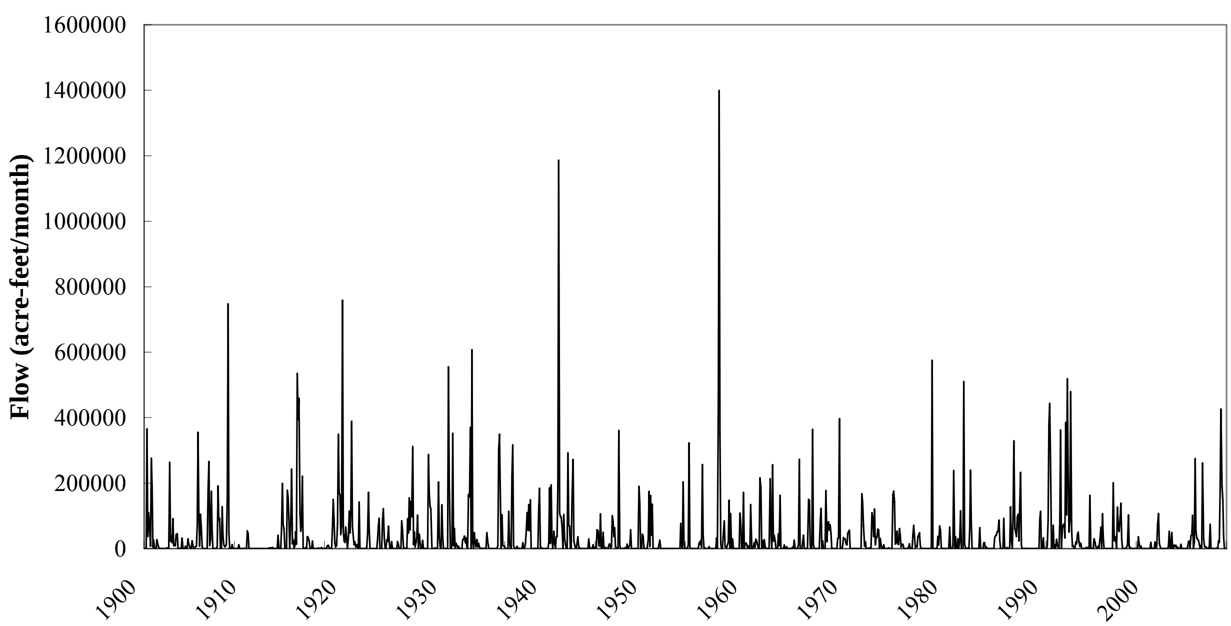

Figure B.8 Monthly BRAC8 Inflows at CON036
Confluence of Hubbard Creek and Brazos River

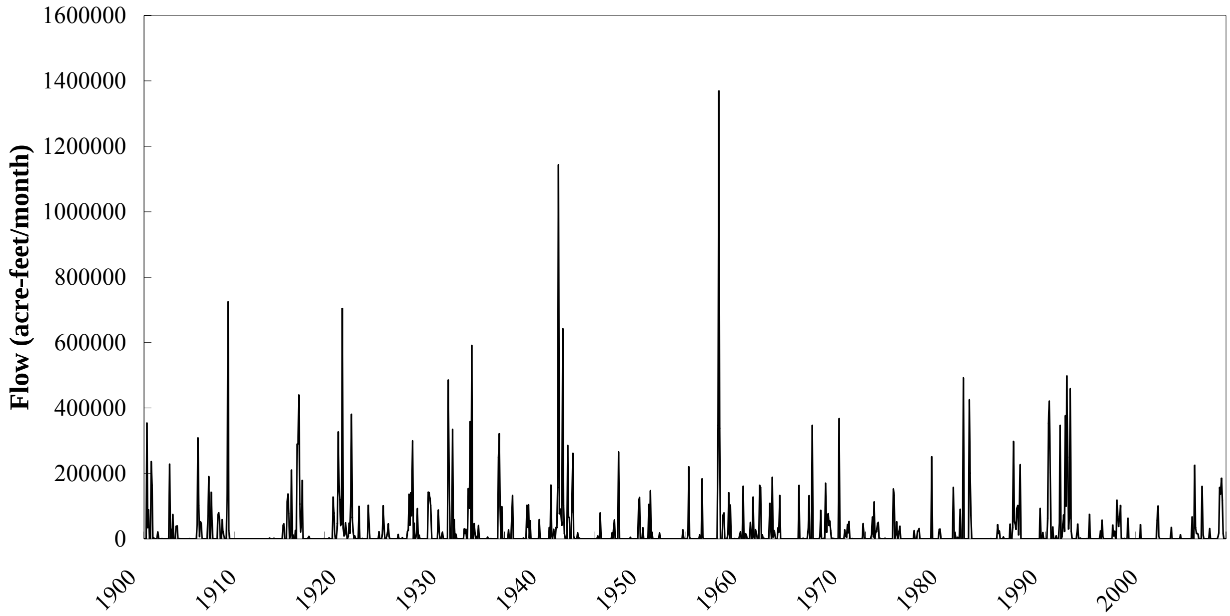

Figure E.9 Monthly BRAC3 Inflows at BRSB23 − Brazos River at South Bend Gage

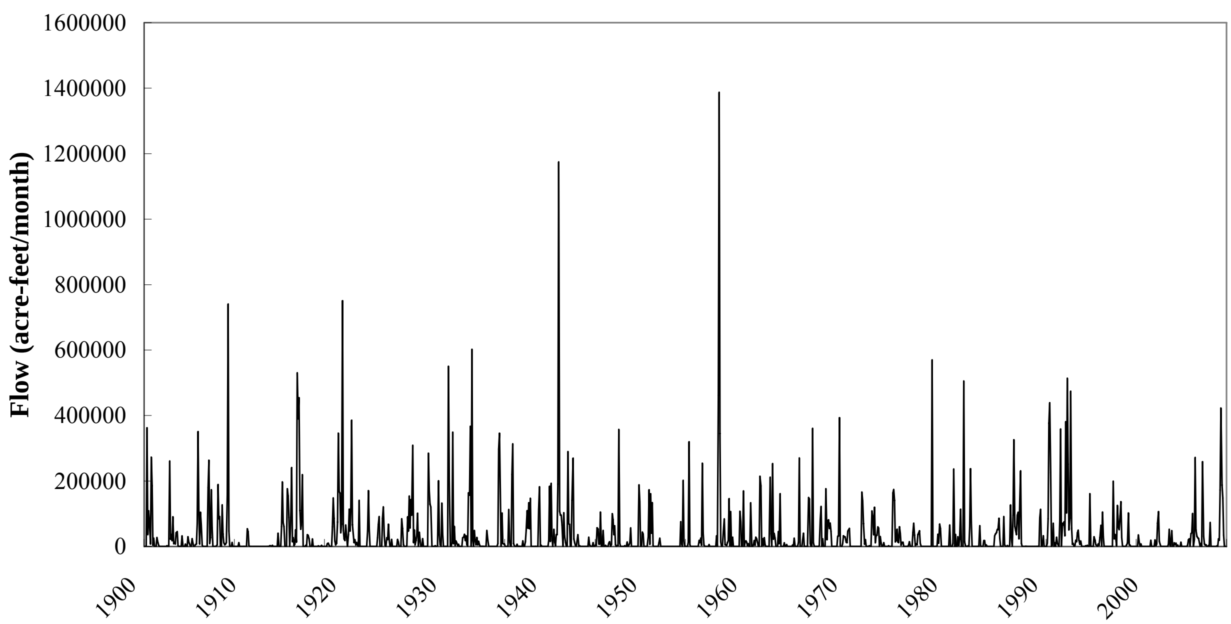

Figure E.10 Monthly BRAC8 Inflows at BRSB23 − Brazos River at South Bend Gage

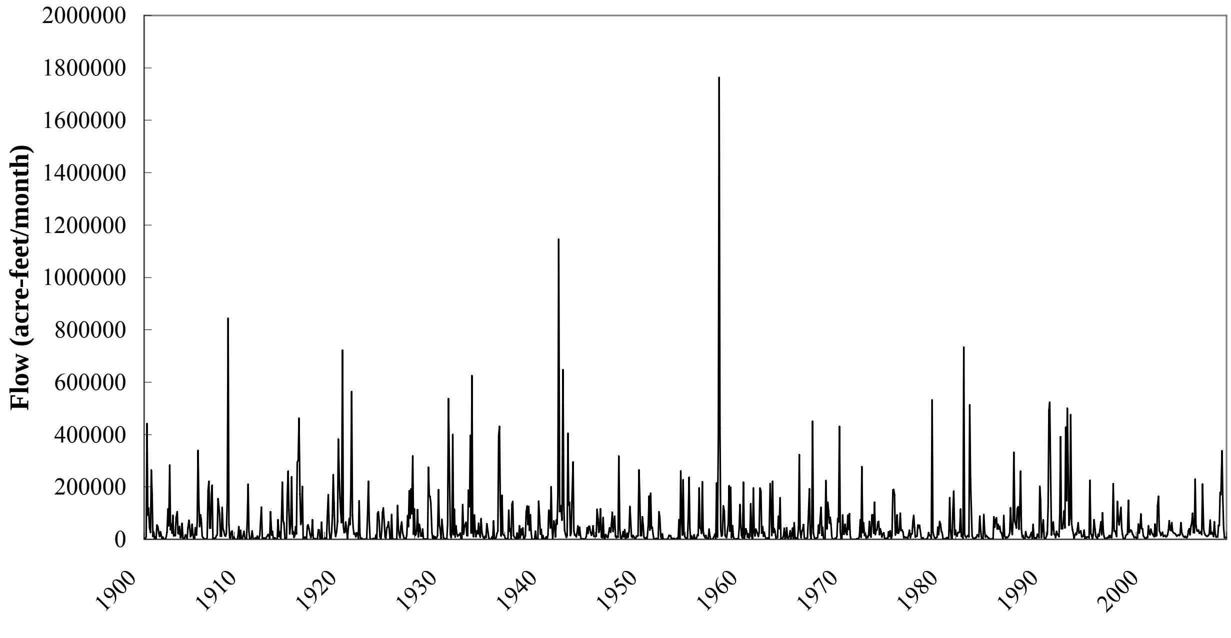

Figure E.11 Monthly BRAC3 Inflows at 515531 − Possum Kingdom Reservoir

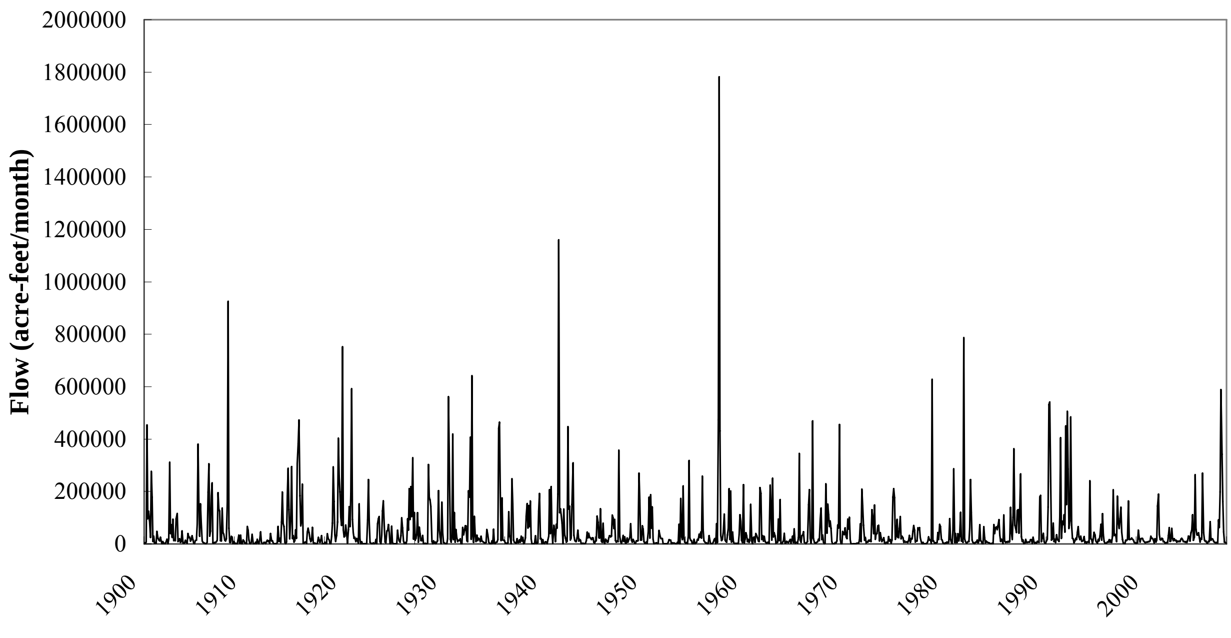

Figure E.12 Monthly BRAC8 Inflows at 515531 − Possum Kingdom Reservoir

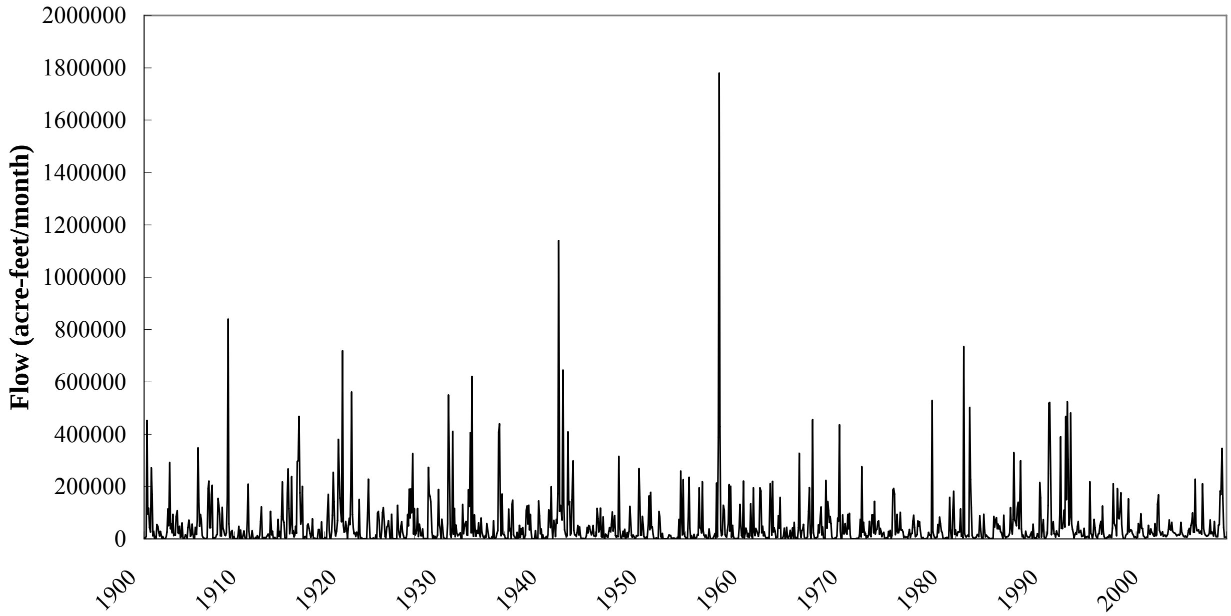

Figure E.13 Monthly BRAC3 Inflows at BRPP27 − Brazos River at Palo Pinto Gage

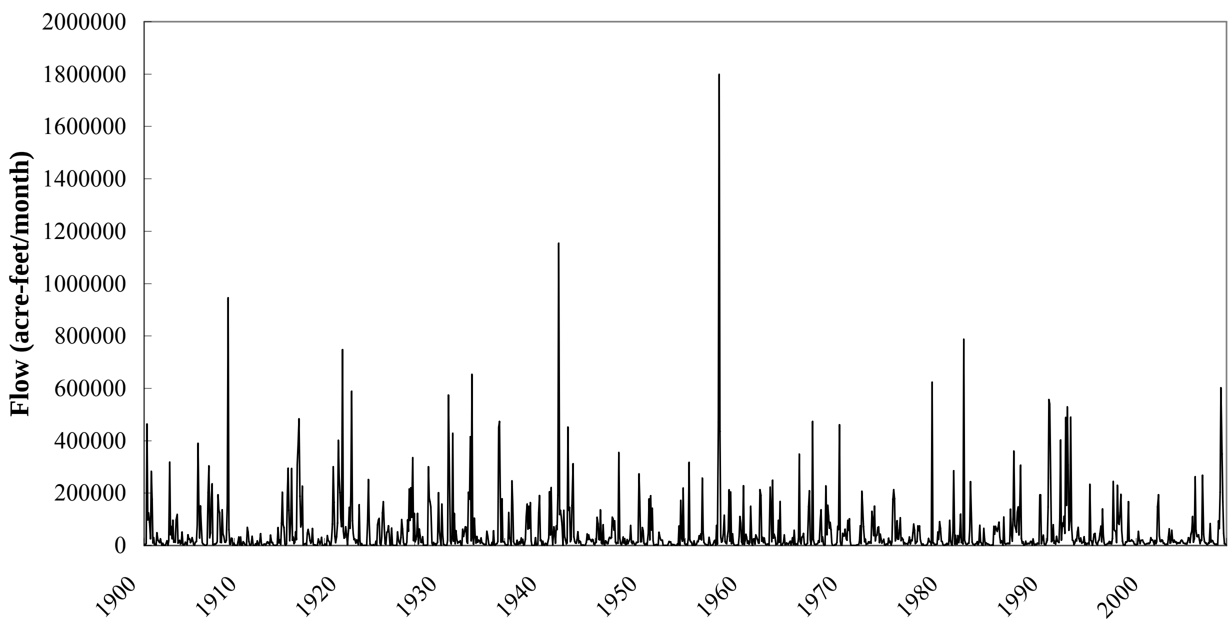

Figure E.14 Monthly BRAC8 Inflows at BRPP27 − Brazos River at Palo Pinto Gage

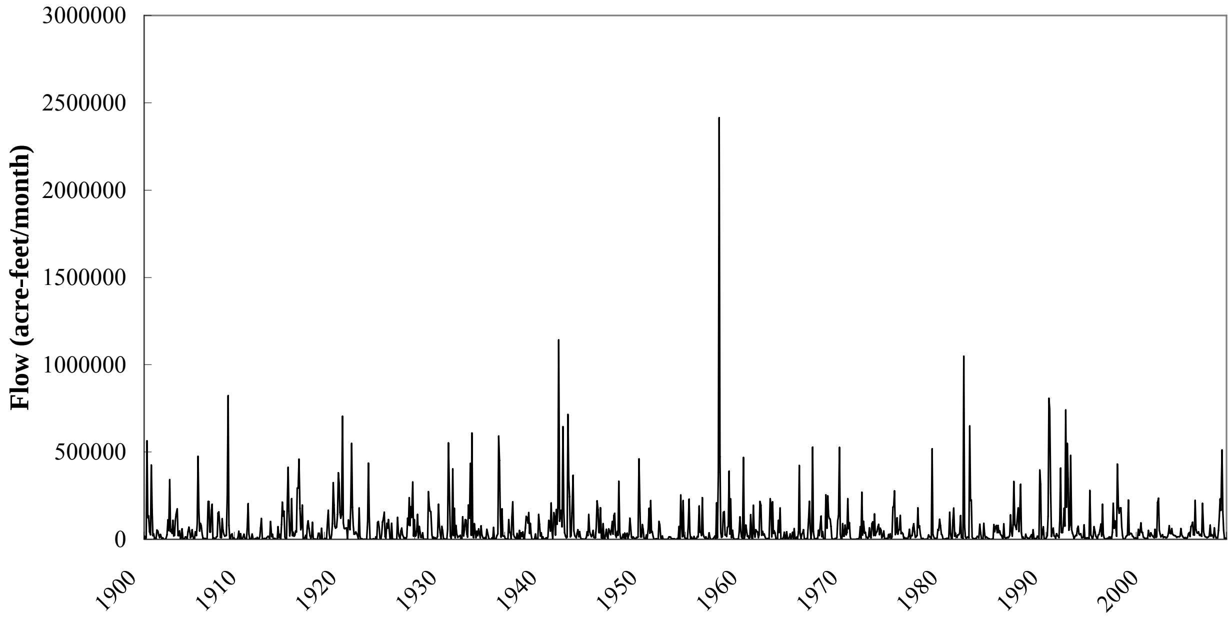

Figure E.15 Monthly BRAC3 Inflows at BRDE29 − Brazos River at Dennis Gage

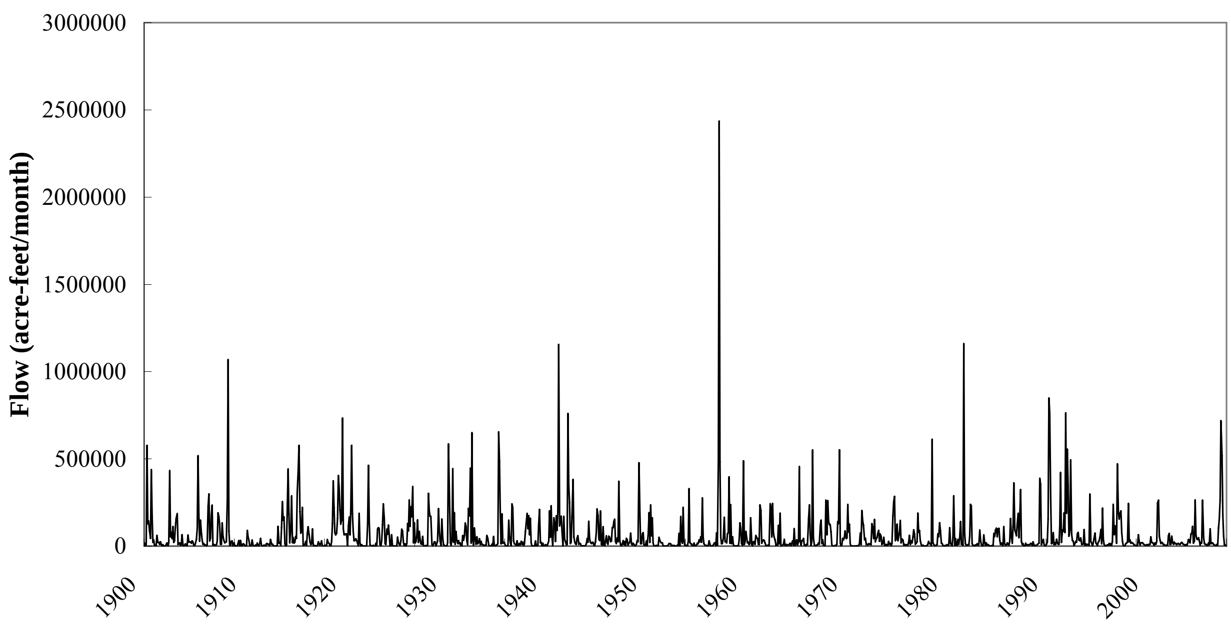

Figure E.16 Monthly BRAC8 Inflows at BRDE29 − Brazos River at Dennis Gage

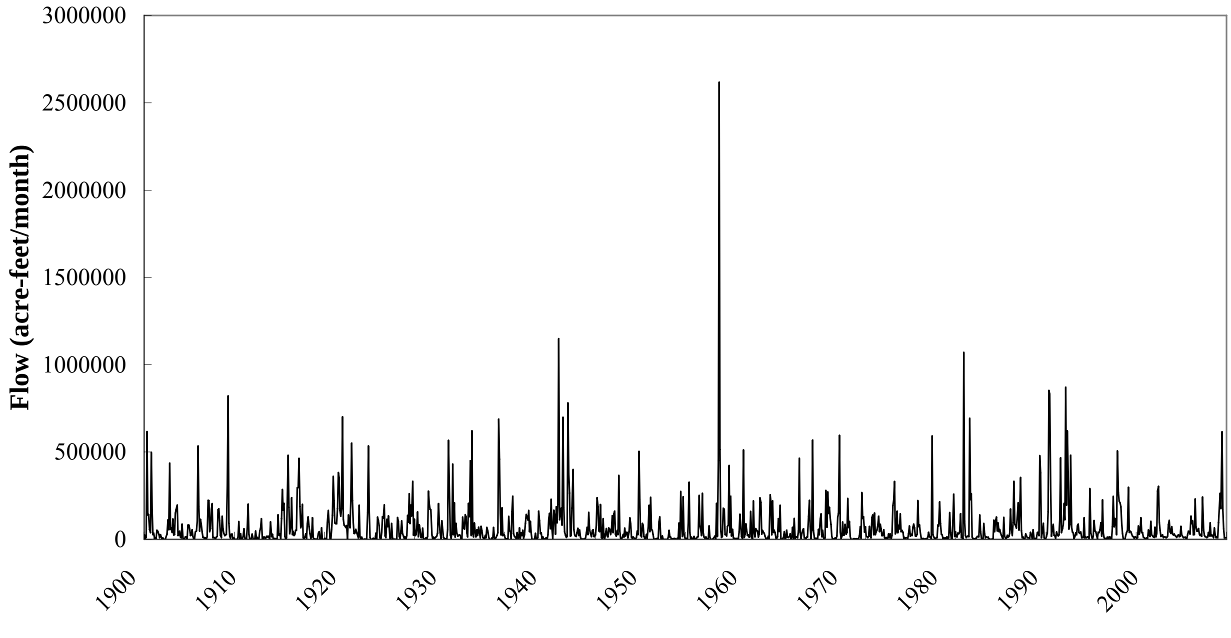

Figure E.17 Monthly BRAC3 Inflows at 515631 − Granbury Reservoir

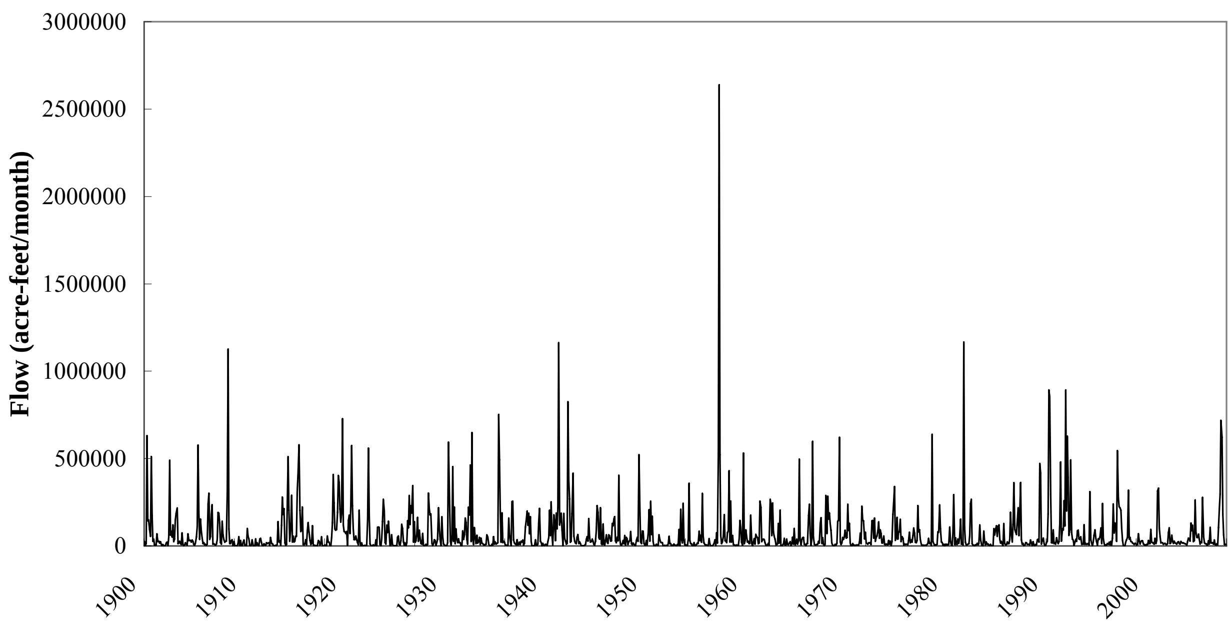

Figure E.18 Monthly BRAC8 Inflows at 515631 − Granbury Reservoir

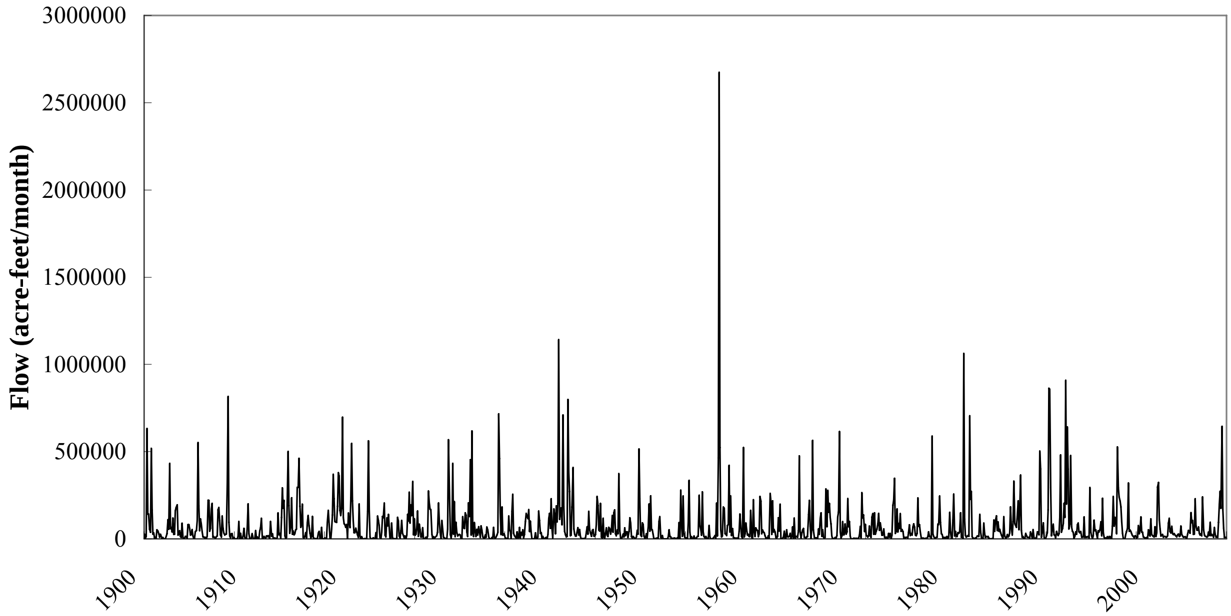

Figure E.19 Monthly BRAC3 Inflows at BRGR30 − Brazos River at Glen Rose

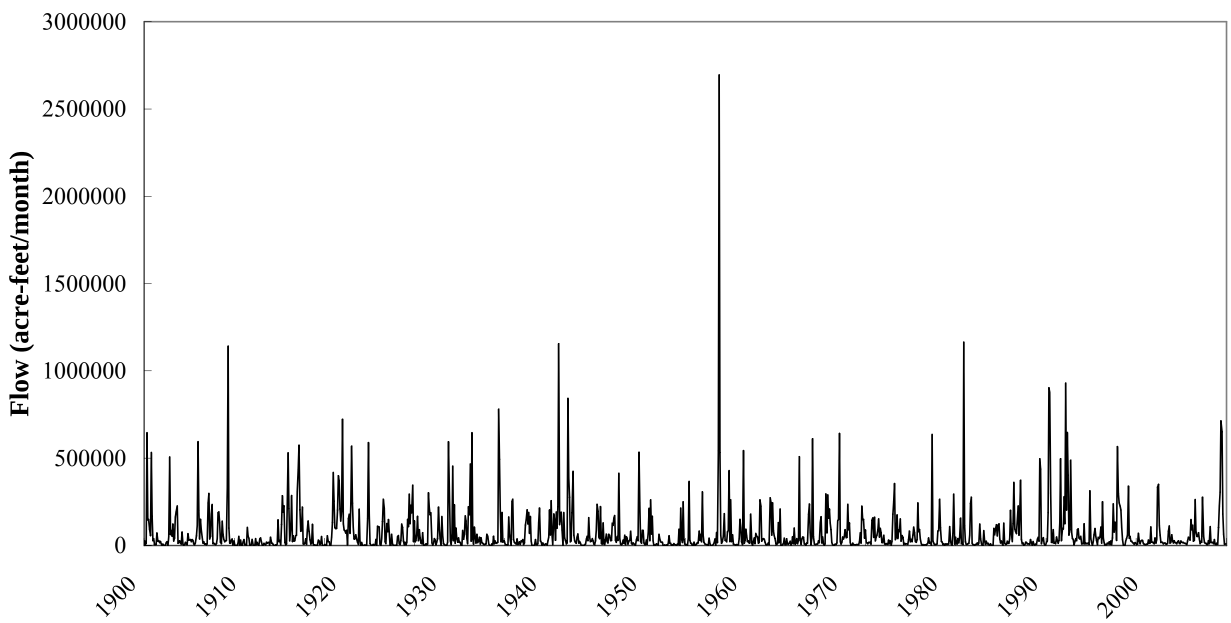

Figure E.20 Monthly BRAC8 Inflows at BRGR30 − Brazos River at Glen Rose

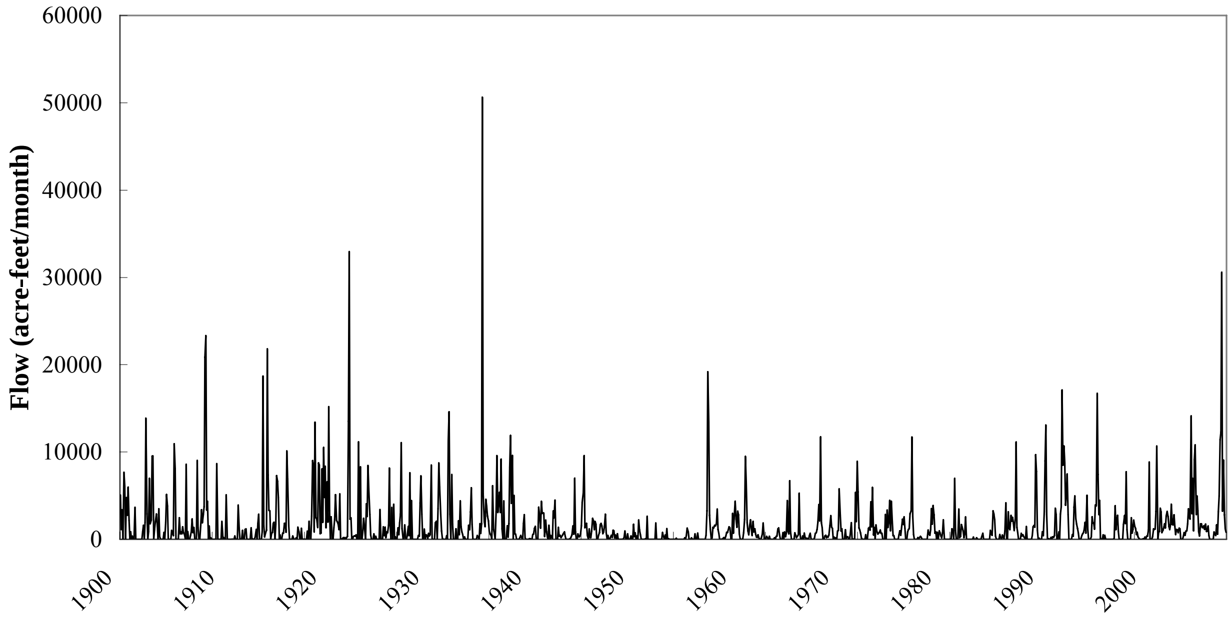

Figure E.21 Monthly BRAC3 Inflows at 409732 − Squaw Creek Reservoir

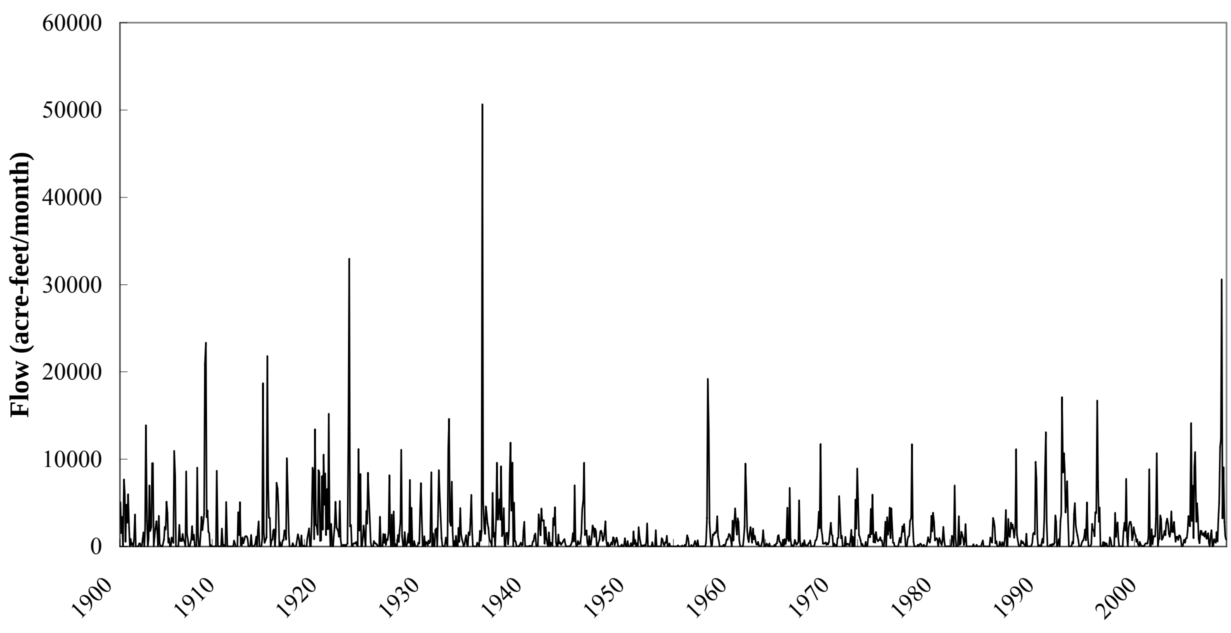

Figure E.22 Monthly BRAC8 Inflows at 409732 − Squaw Creek Reservoir

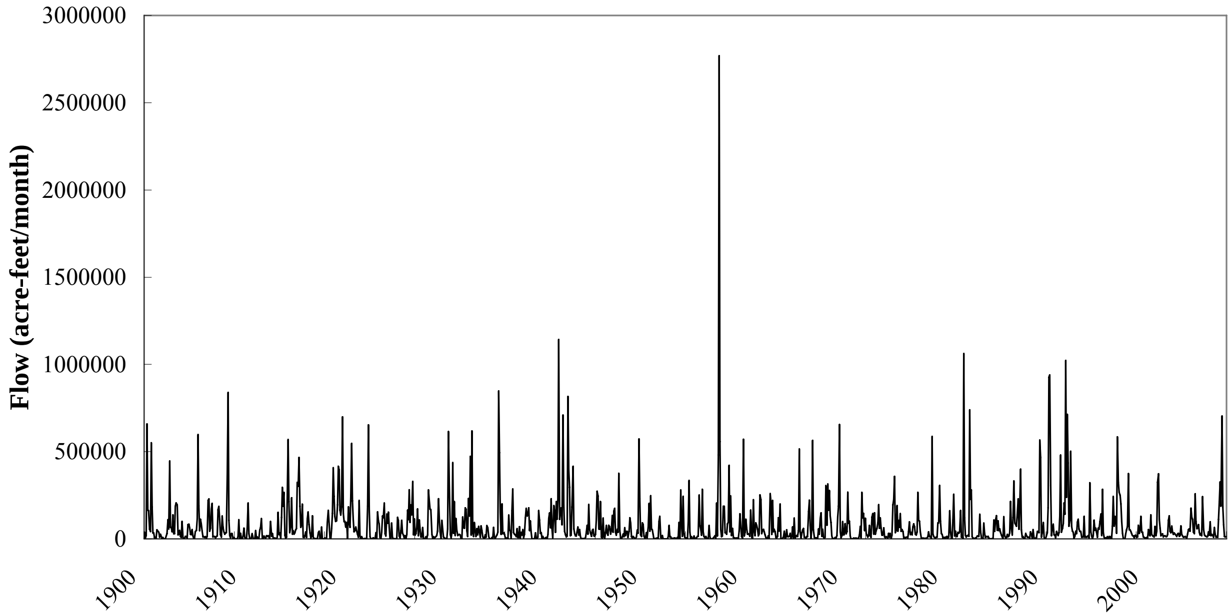

Figure E.23 Monthly BRAC3 Inflows at CON063 − Confluence of Squaw Creek and Brazos River

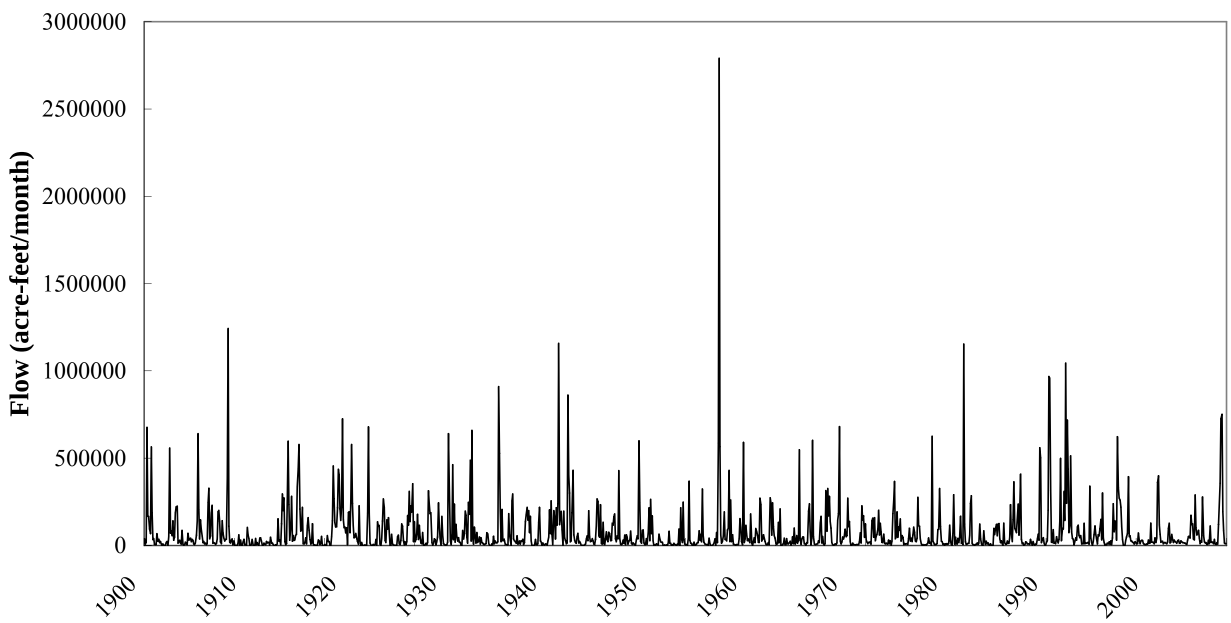

Figure E.24 Monthly BRAC8 Inflows at CON063 − Confluence of Squaw Creek and Brazos River

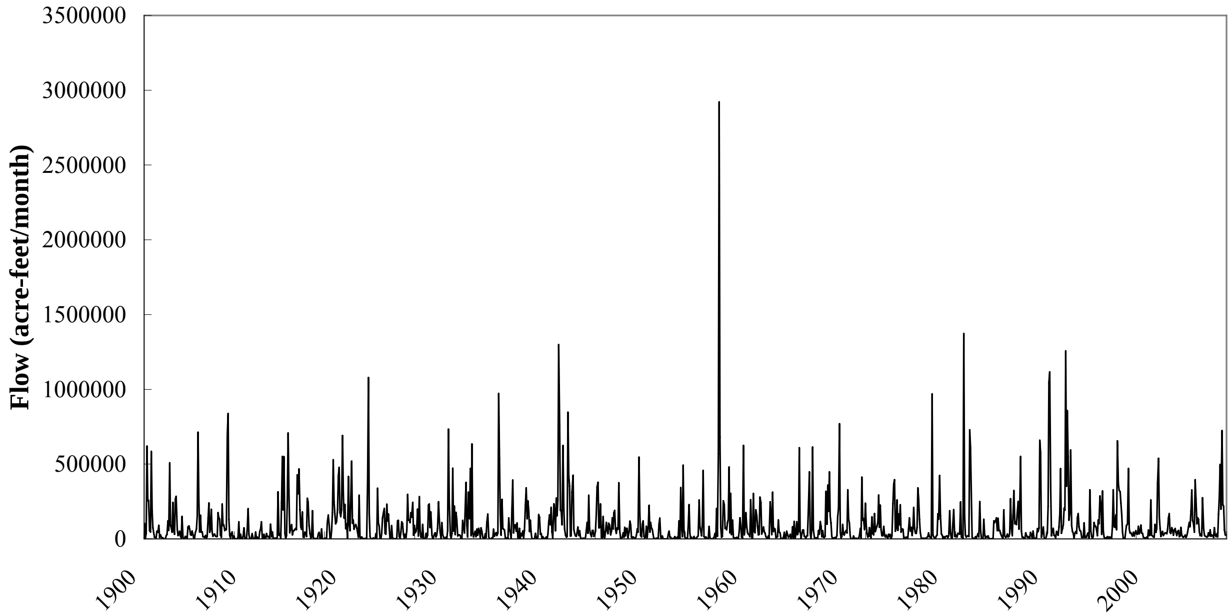

Figure E.25 Monthly BRAC3 Inflows at 515731 − Whitney Reservoir

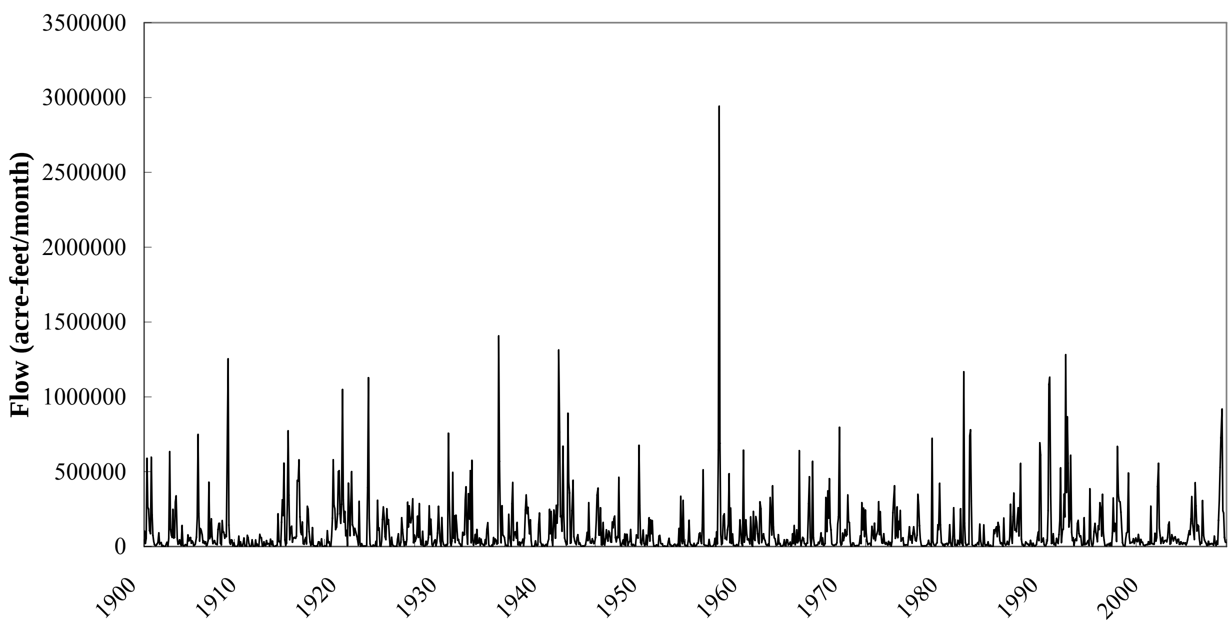

Figure E.26 Monthly BRAC8 Inflows at 515731 − Whitney Reservoir

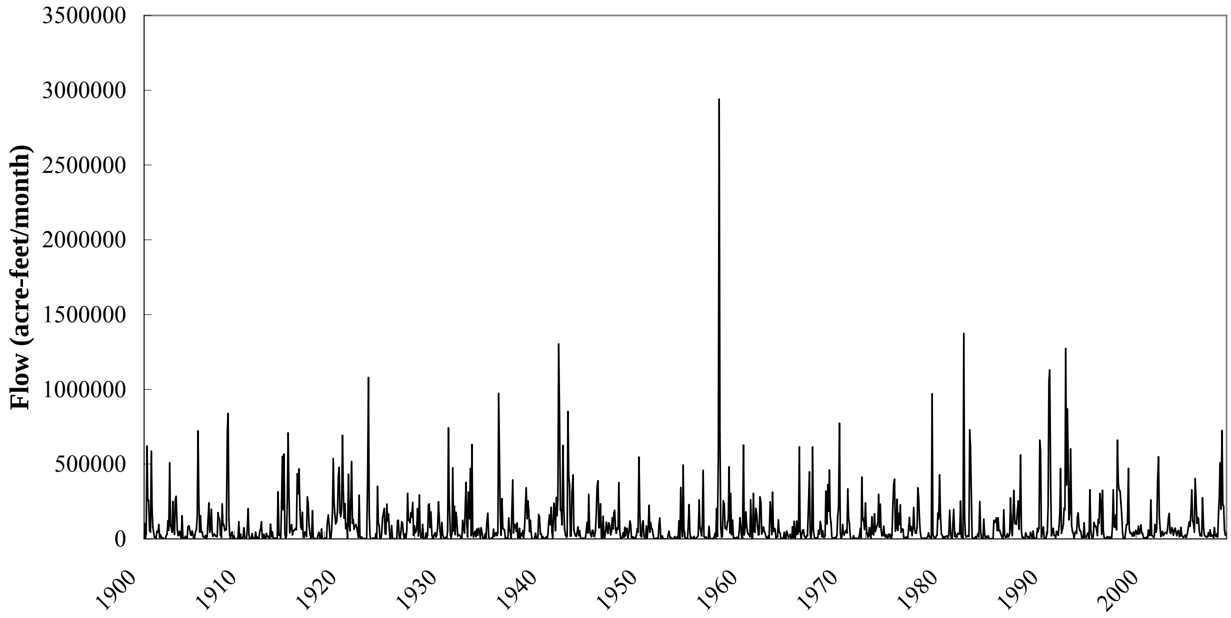

Figure E.27 Monthly BRAC3 Inflows at BRAQ33 − Brazos River at Aquilla Gage

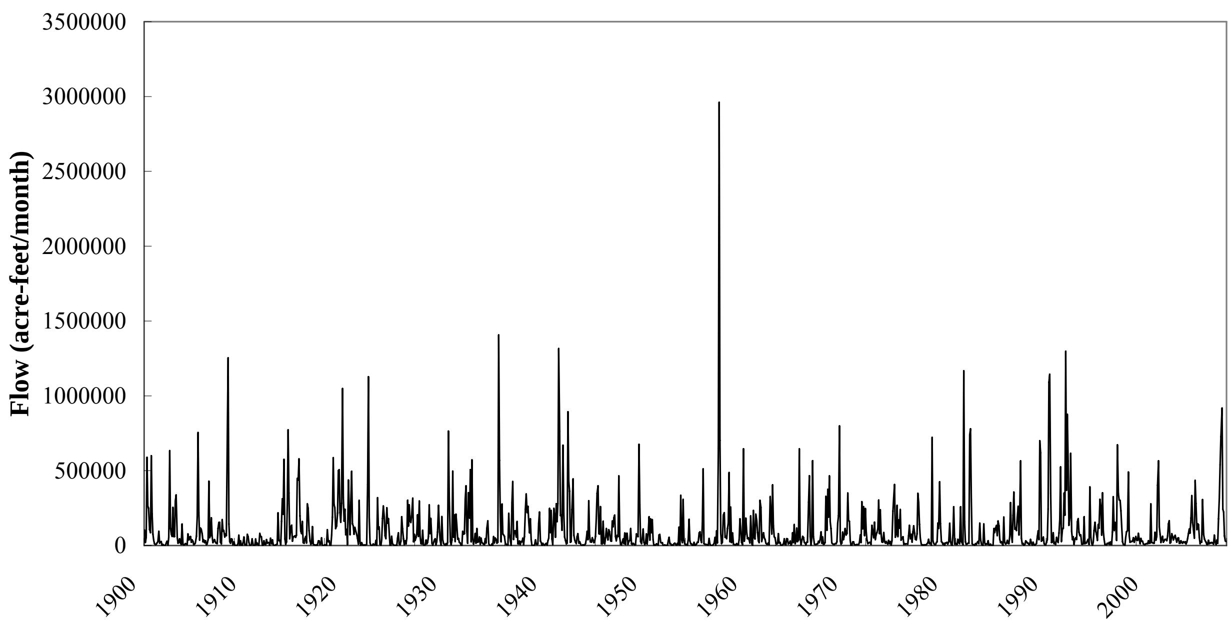

Figure E.28 Monthly BRAC8 Inflows at BRAQ33 − Brazos River at Aquilla Gage

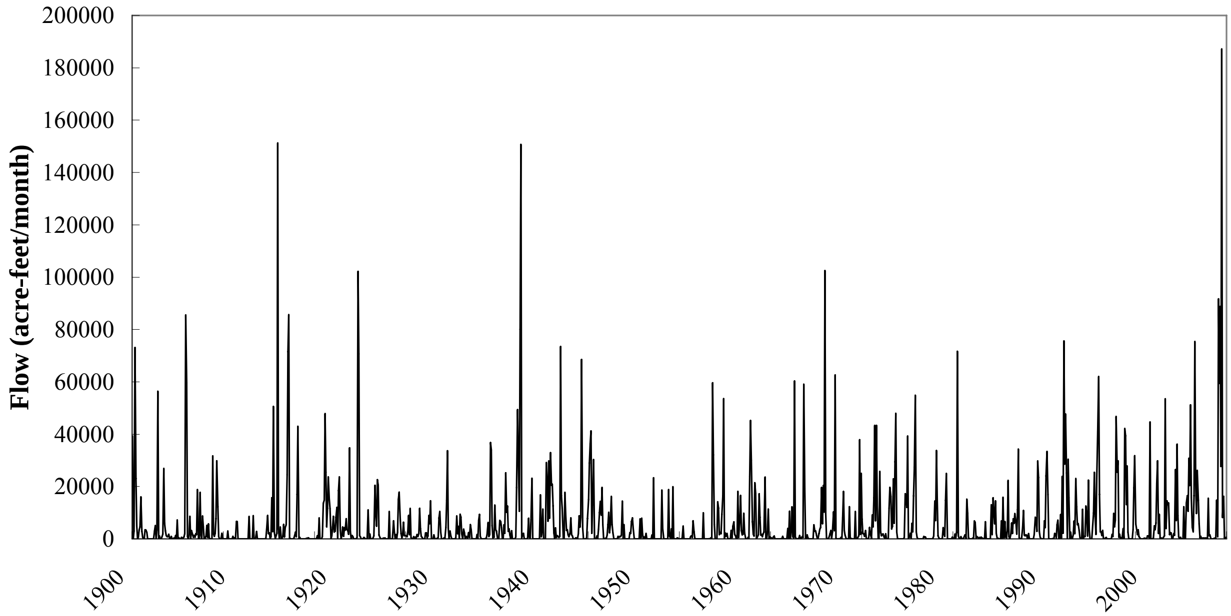

Figure E.29 Monthly BRAC3 Inflows at 515831 − Aquilla Reservoir

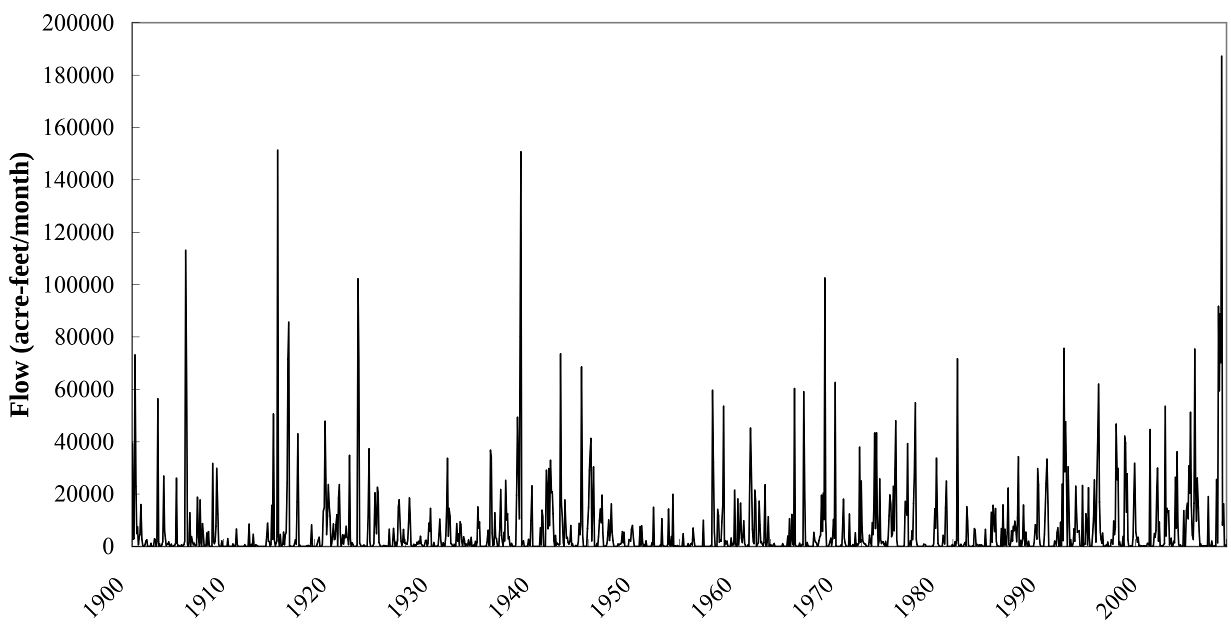

Figure E.30 Monthly BRAC8 Inflows at 515831 − Aquilla Reservoir

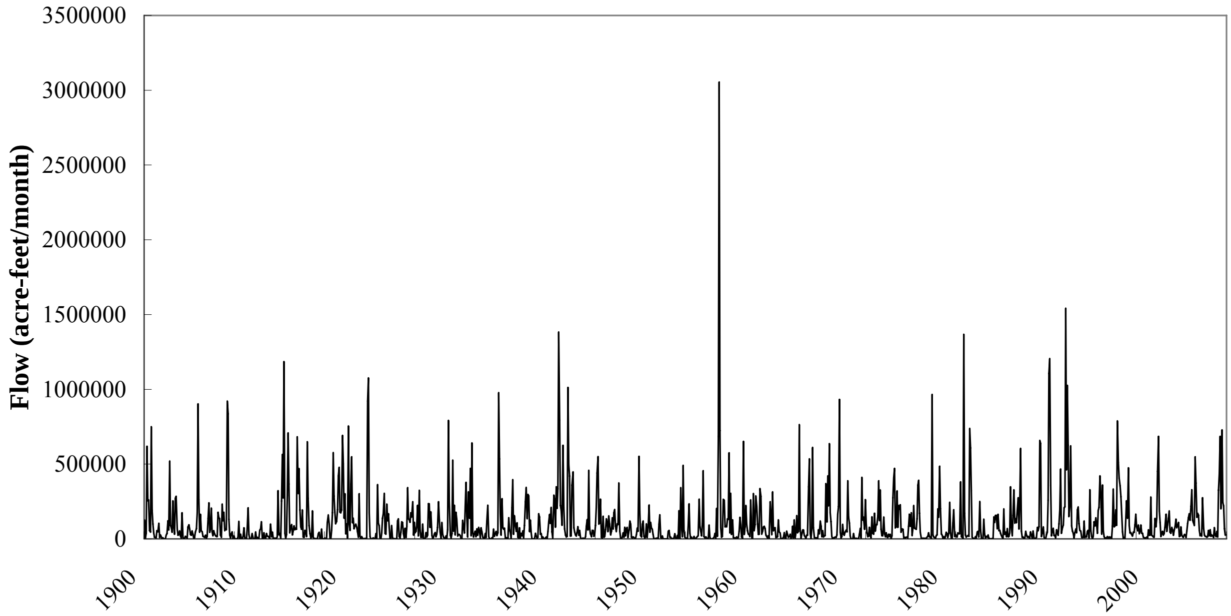

Figure E.31 Monthly BRAC3 Inflows at CON070 − Confluence of Aquilla Creek and Brazos River

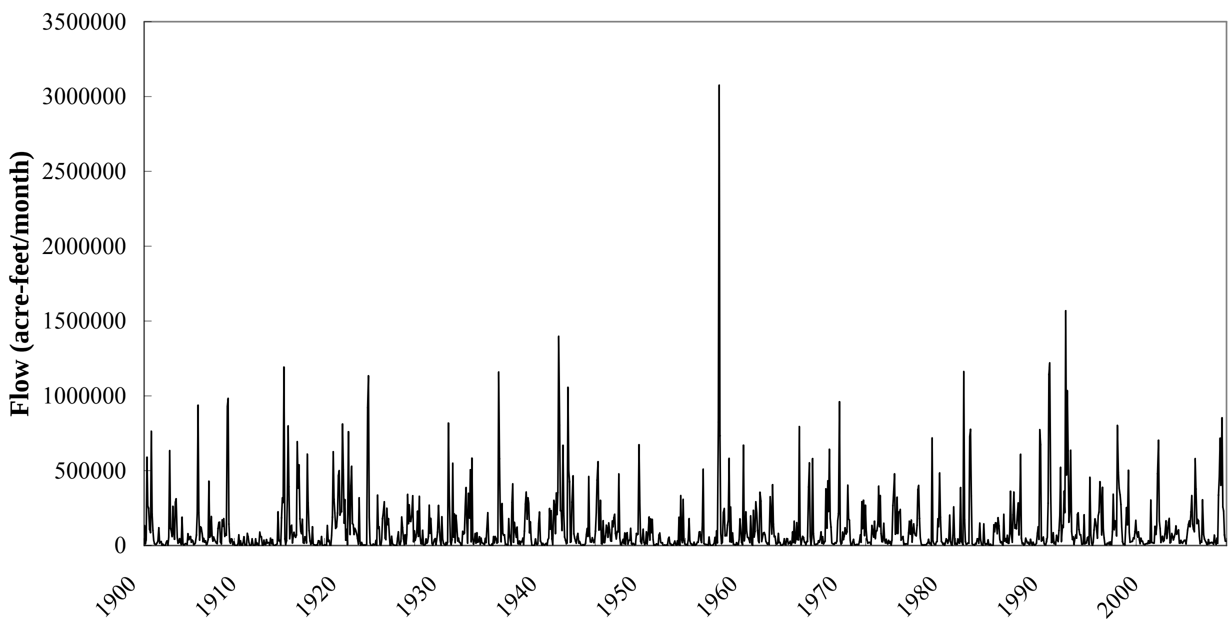

Figure E.32 Monthly BRAC8 Inflows at CON070 − Confluence of Aquilla Creek and Brazos River

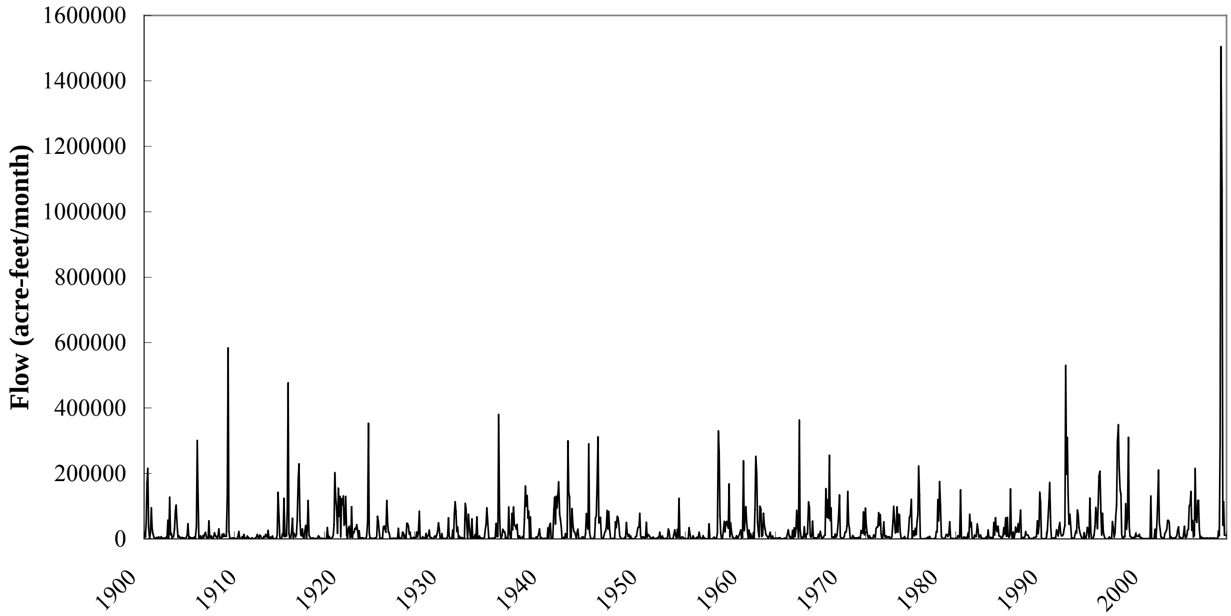

Figure E.33 Monthly BRAC3 Inflows at 509431 − Waco Reservoir

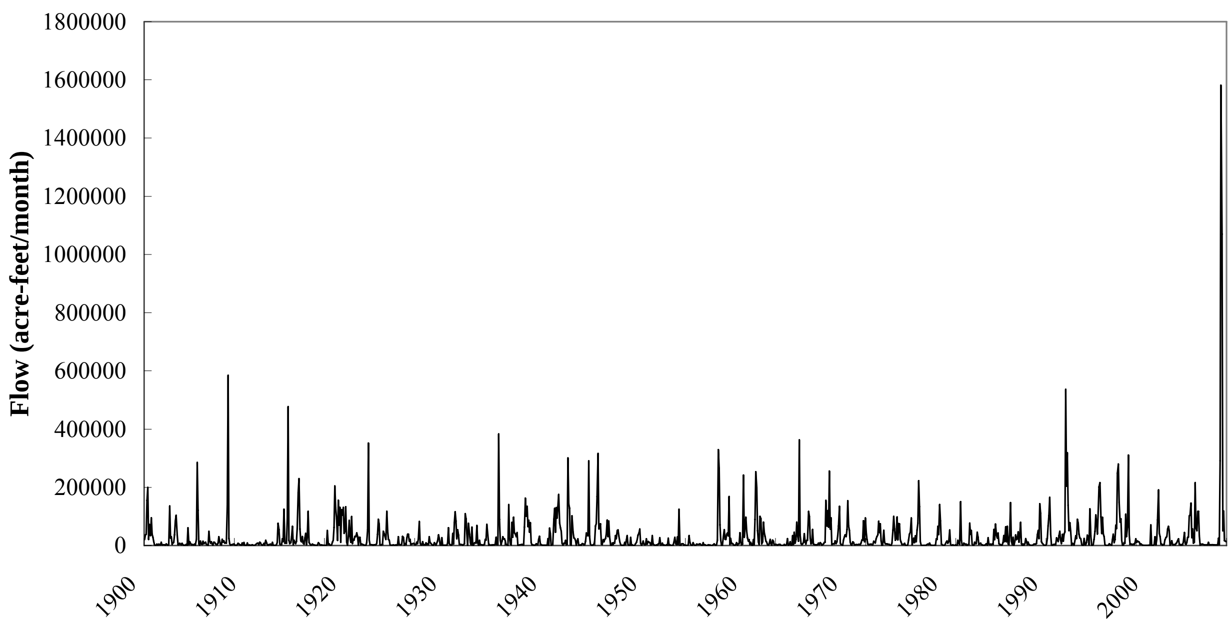

Figure E.34 Monthly BRAC8 Inflows at 509431 − Waco Reservoir

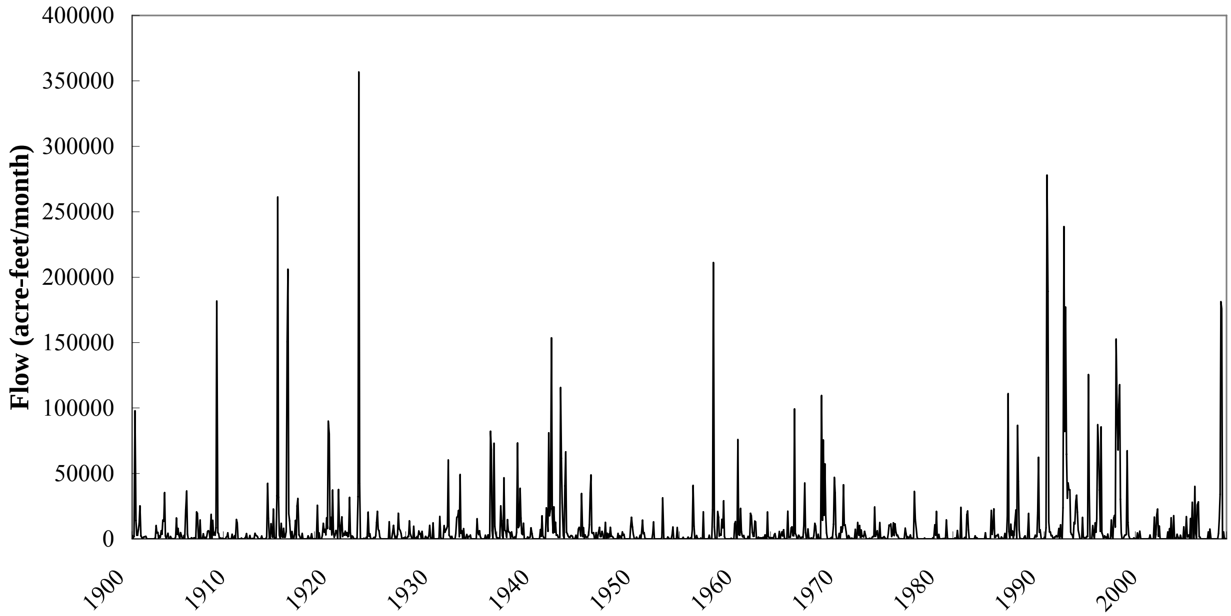

Figure E.35 Monthly BRAC3 Inflows at 515931 − Proctor Reservoir

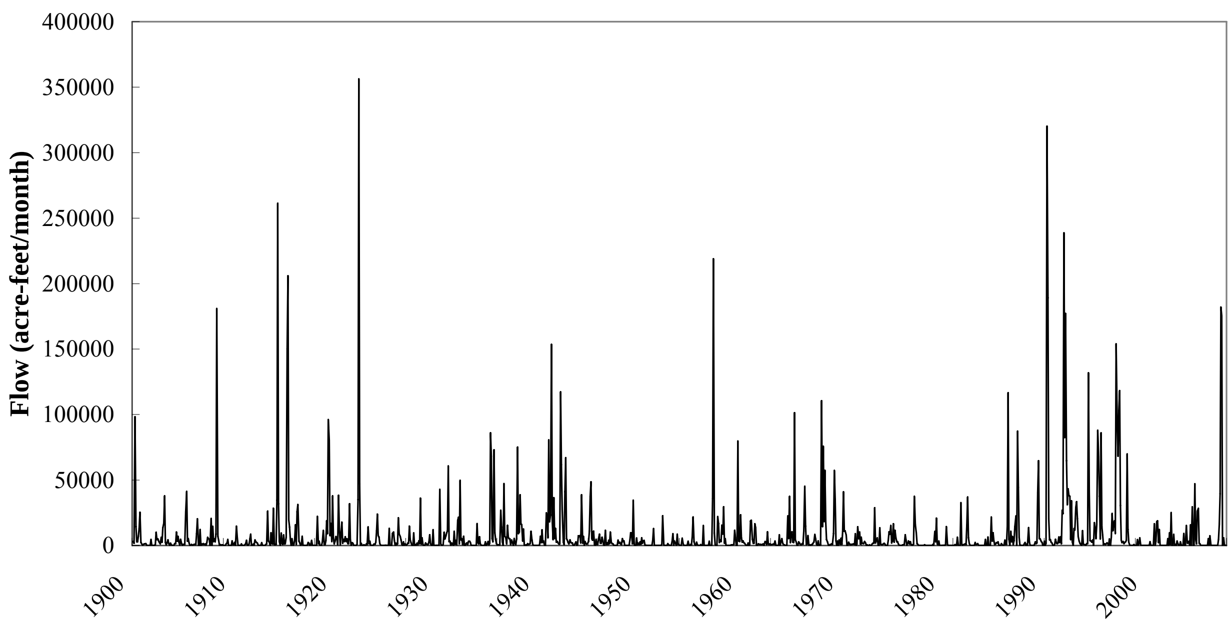

Figure E.36 Monthly BRAC8 Inflows at 515931 − Proctor Reservoir

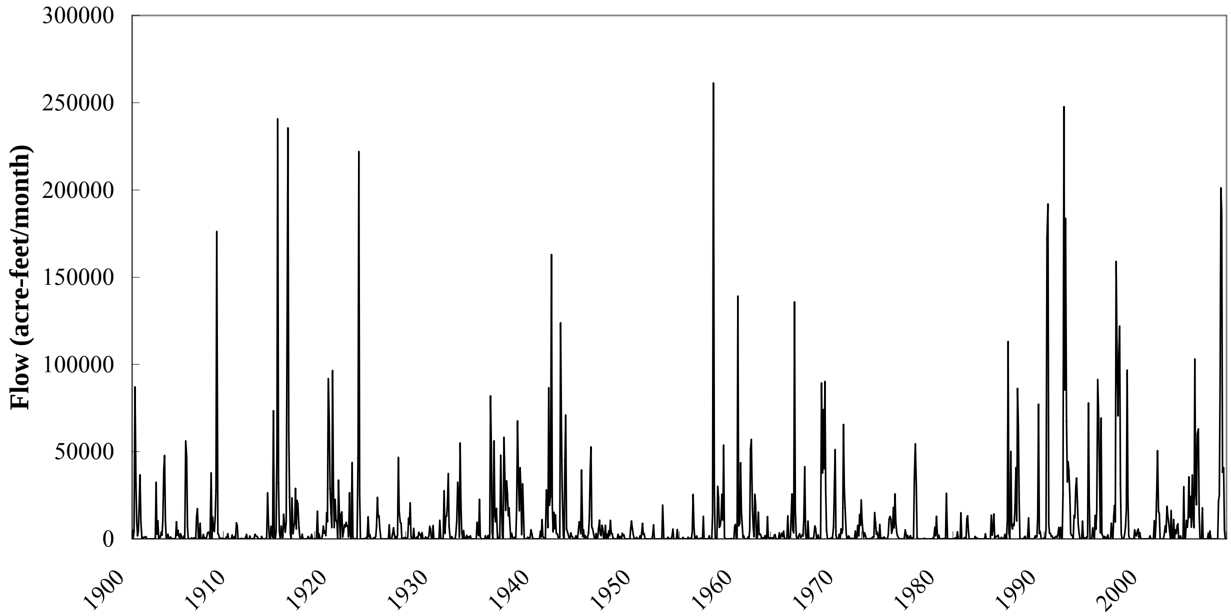

Figure E.37 Monthly BRAC3 Inflows at LEHM46 − Leon River at Hamilton Gage

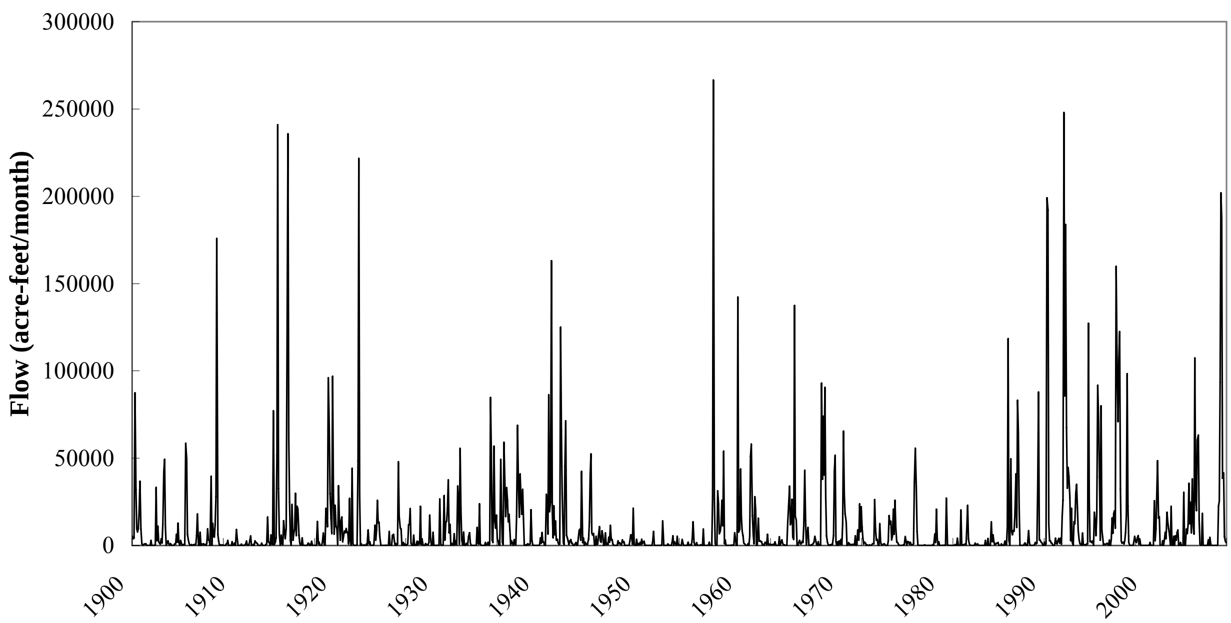

Figure B.38 Monthly BRAC8 Inflows at LEHM46 − Leon River at Hamilton Gage

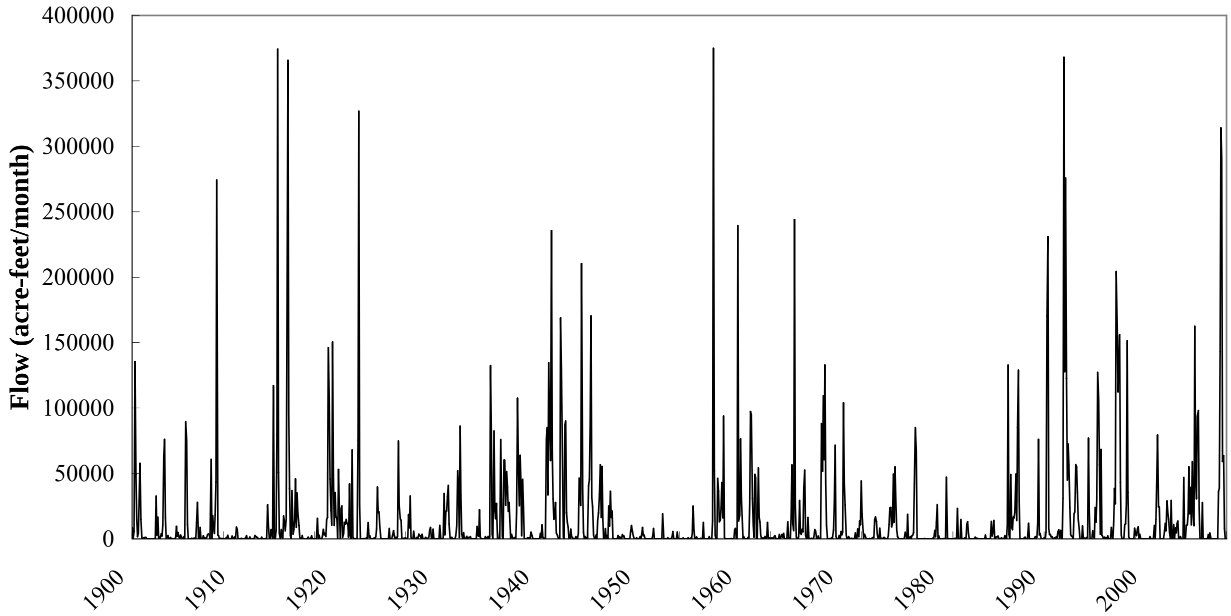

Figure E.39 Monthly BRAC3 Inflows at LEGT47 − Leon River at Gatesville Gage

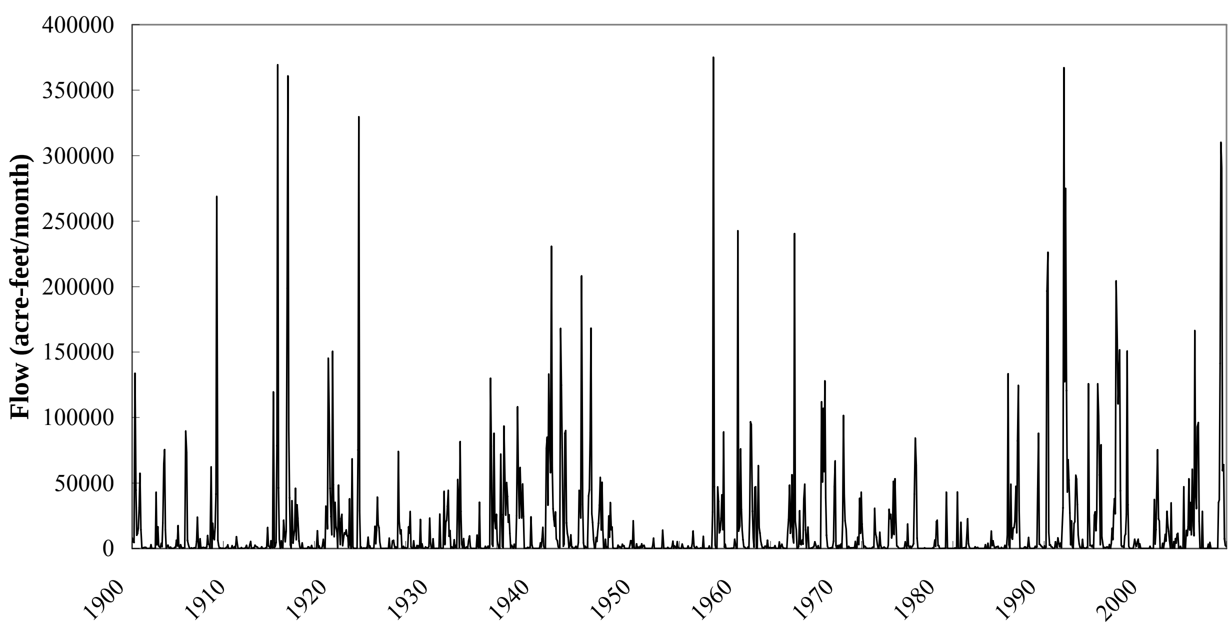

Figure E.40 Monthly BRAC8 Inflows at LEGT47 − Leon River at Gatesville Gage

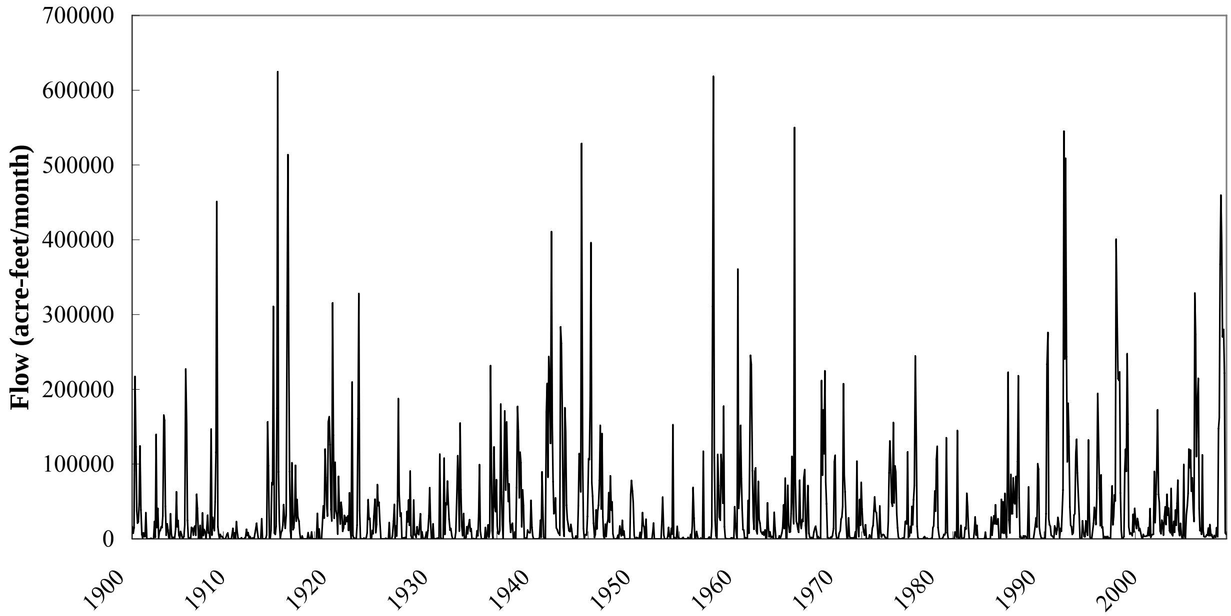

Figure E.41 Monthly BRAC3 Inflows at 516031 − Belton Reservoir

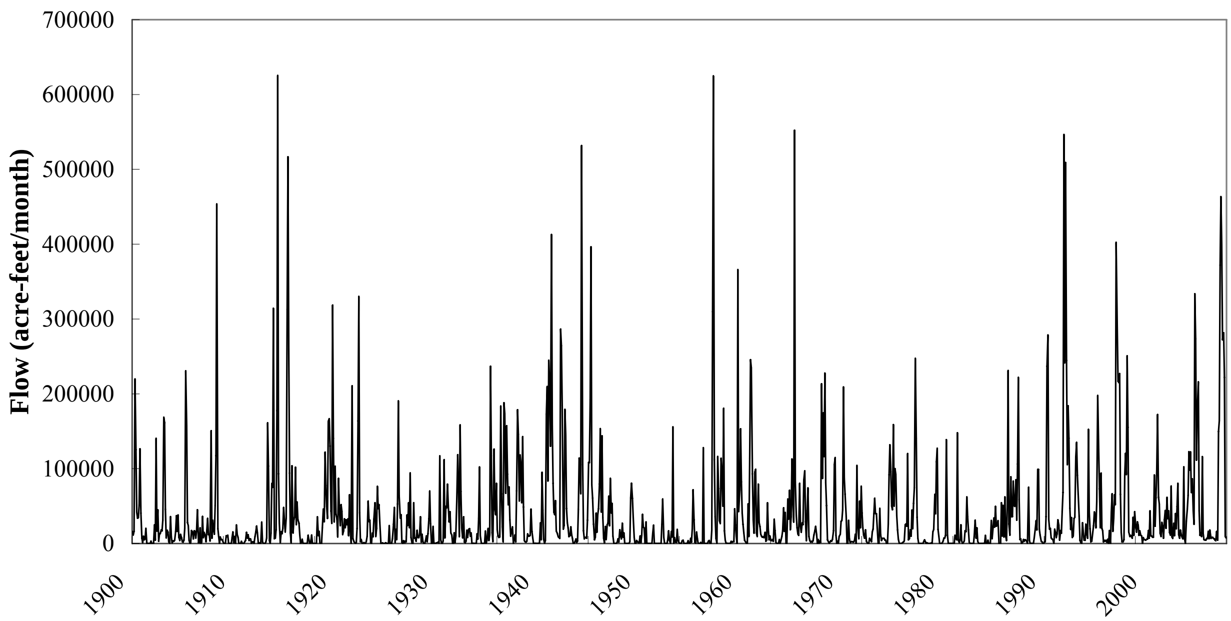

Figure E.42 Monthly BRAC8 Inflows at 516031 − Belton Reservoir

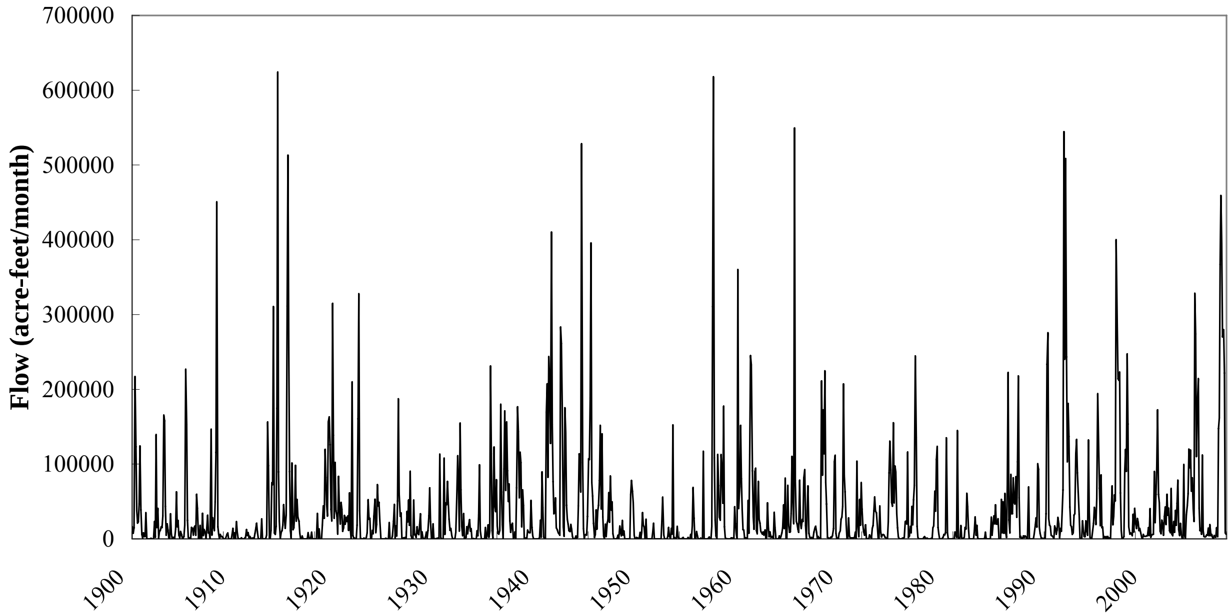

Figure E.43 Monthly BRAC3 Inflows at LEBE49 − Leon River at Belton

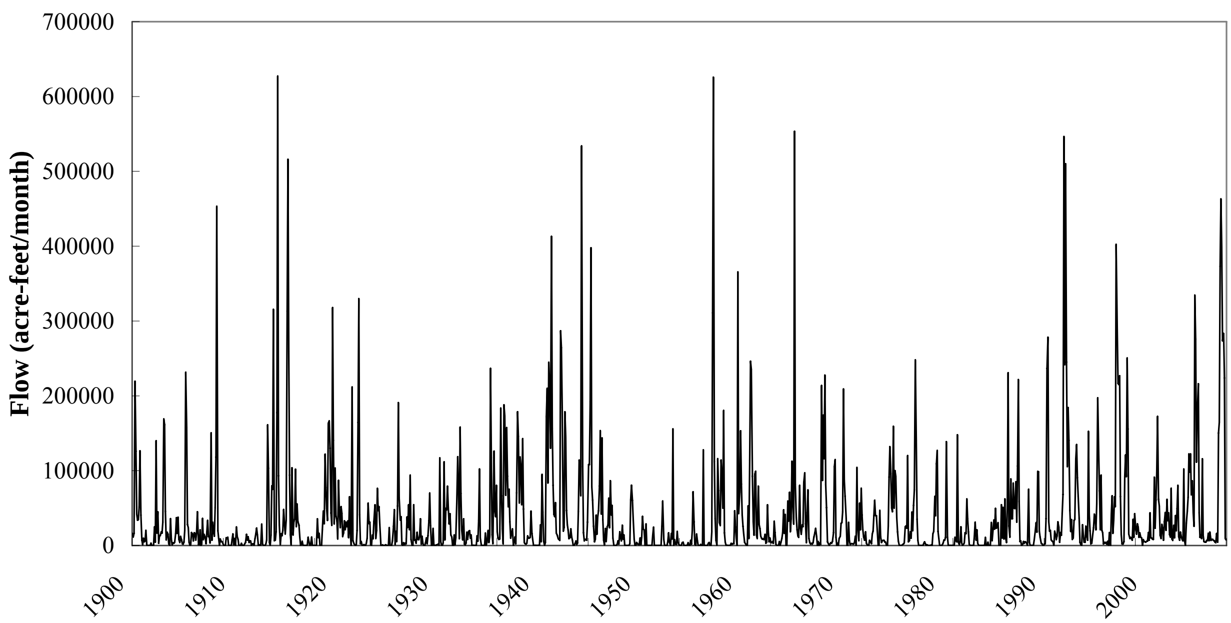

Figure E.44 Monthly BRAC8 Inflows at LEBE49 − Leon River at Belton

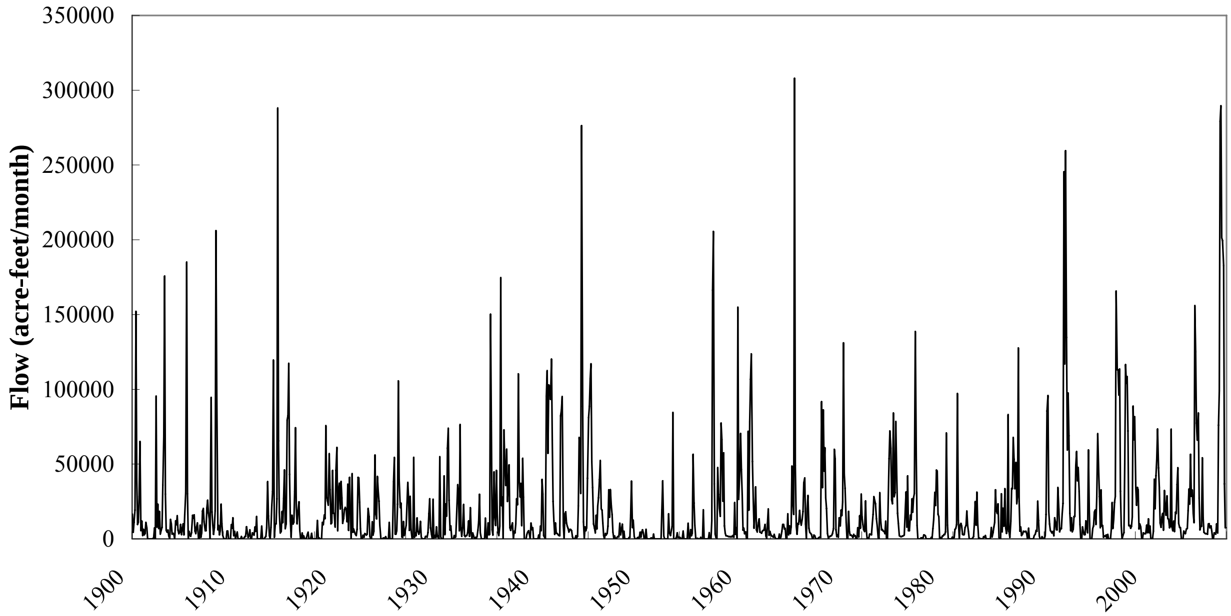

Figure E.45 Monthly BRAC3 Inflows at 516131 − Stillhouse Hollow Reservoir

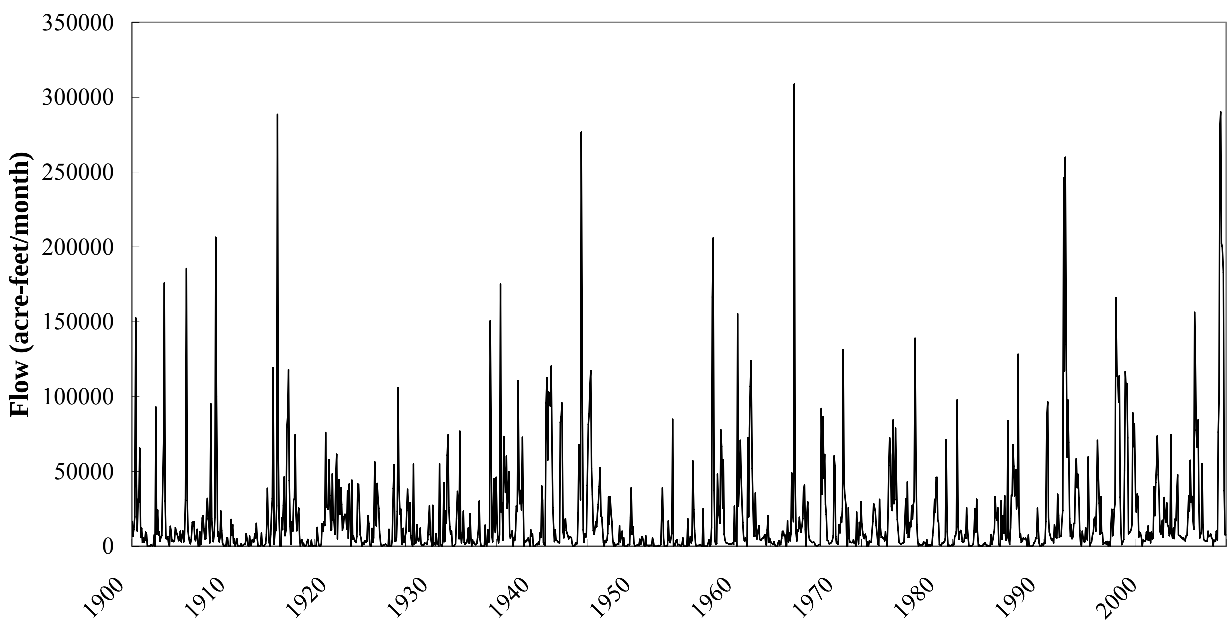

Figure E.46 Monthly BRAC8 Inflows at 516131 − Stillhouse Hollow Reservoir

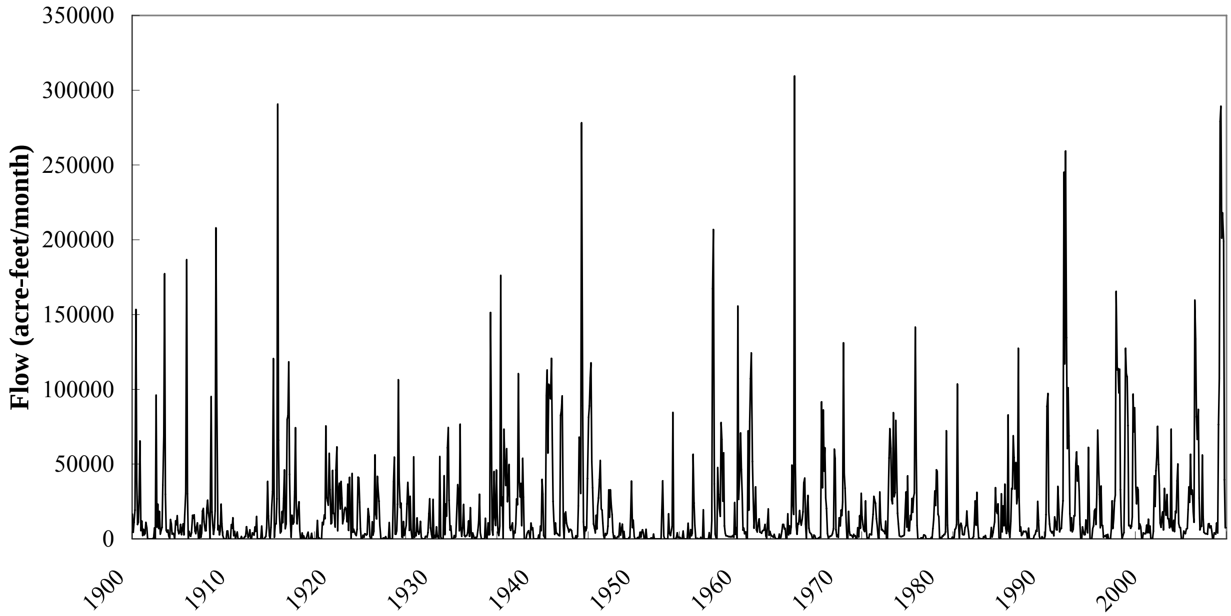

Figure E.47 Monthly BRAC3 Inflows at LABE52 − Lampasas River at Belton Gage

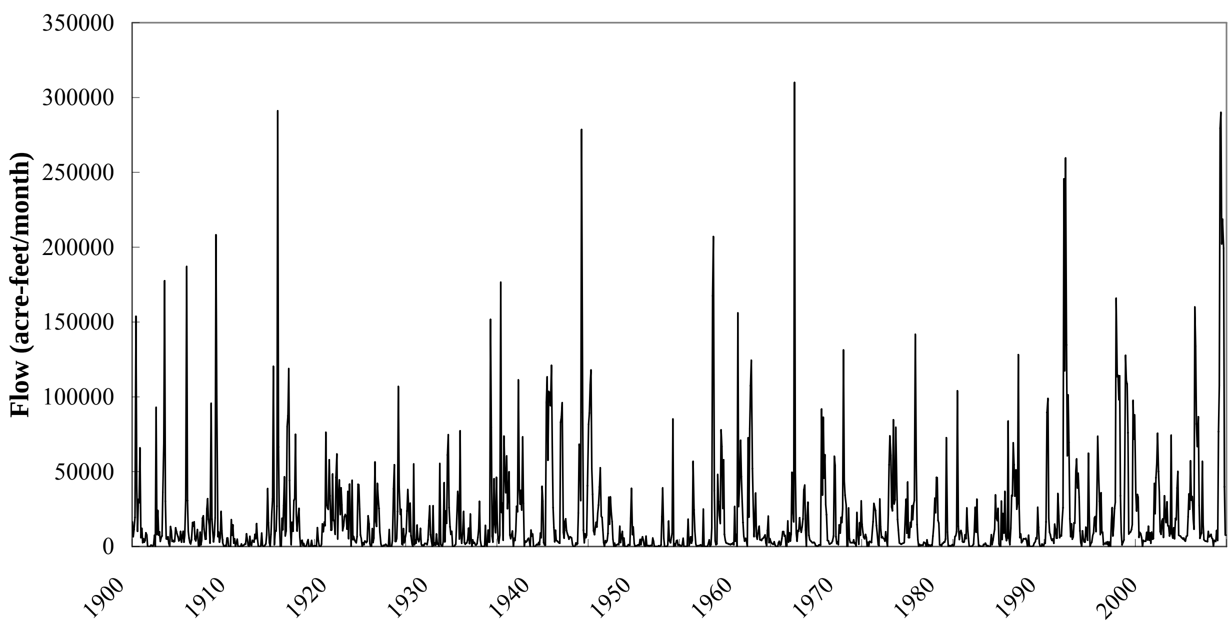

Figure E.48 Monthly BRAC8 Inflows at LABE52 − Lampasas River at Belton Gage

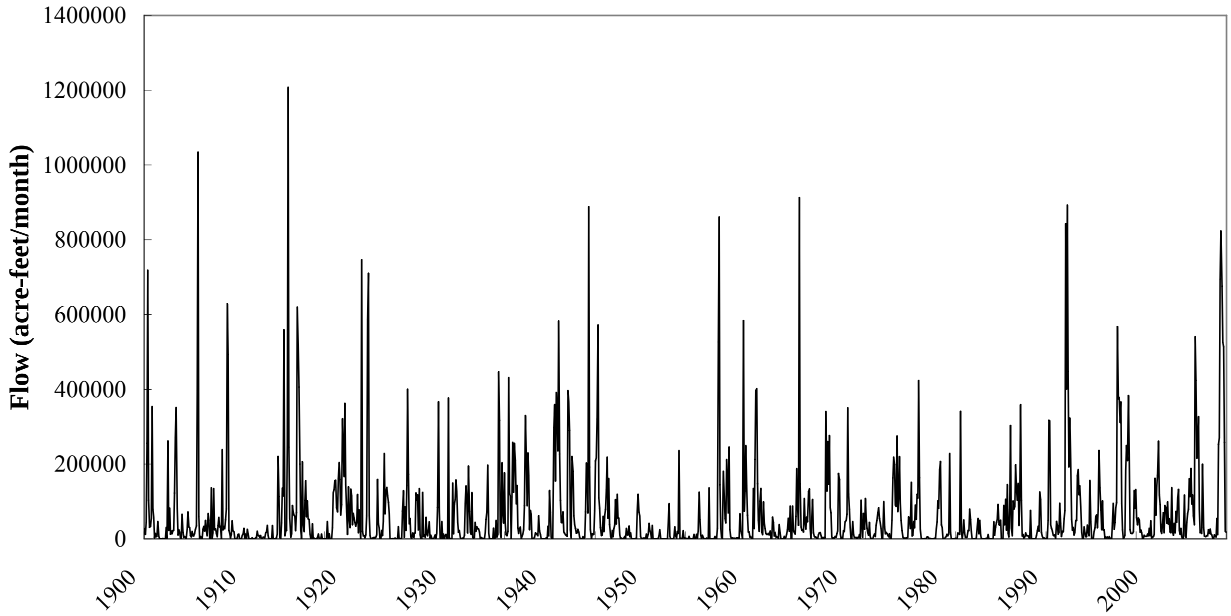

Figure E.49 Monthly BRAC3 Inflows at CON096 − Confluence of Lampasas and Little Rivers

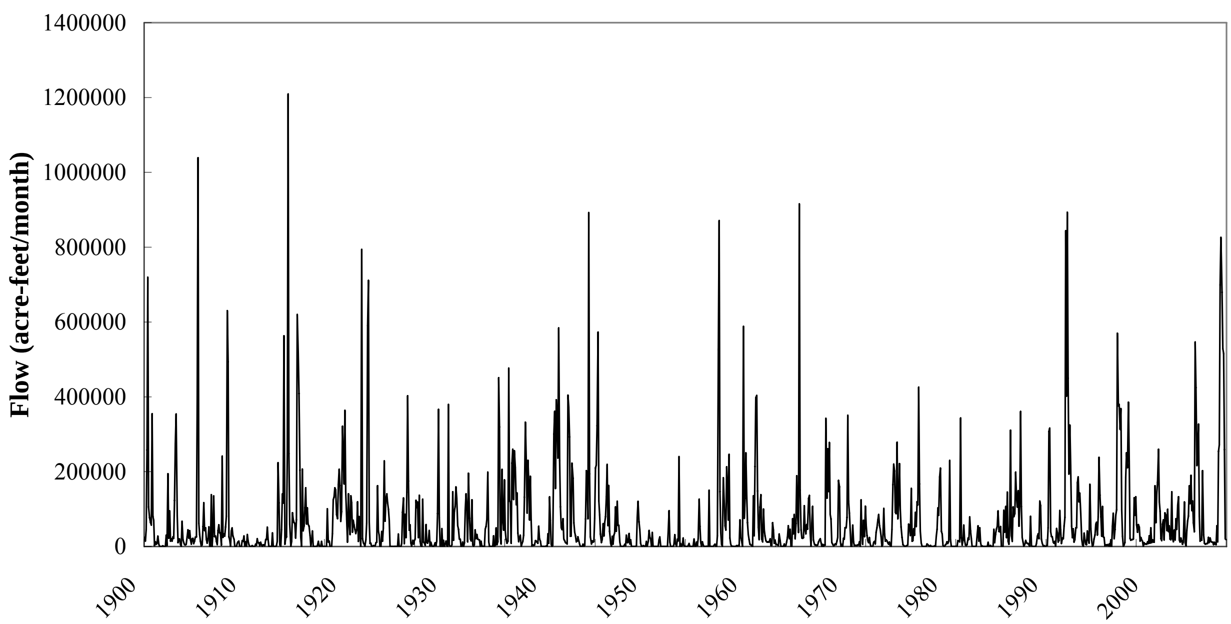

Figure E.50 Monthly BRAC8 Inflows at CON096 − Confluence of Lampasas and Little Rivers

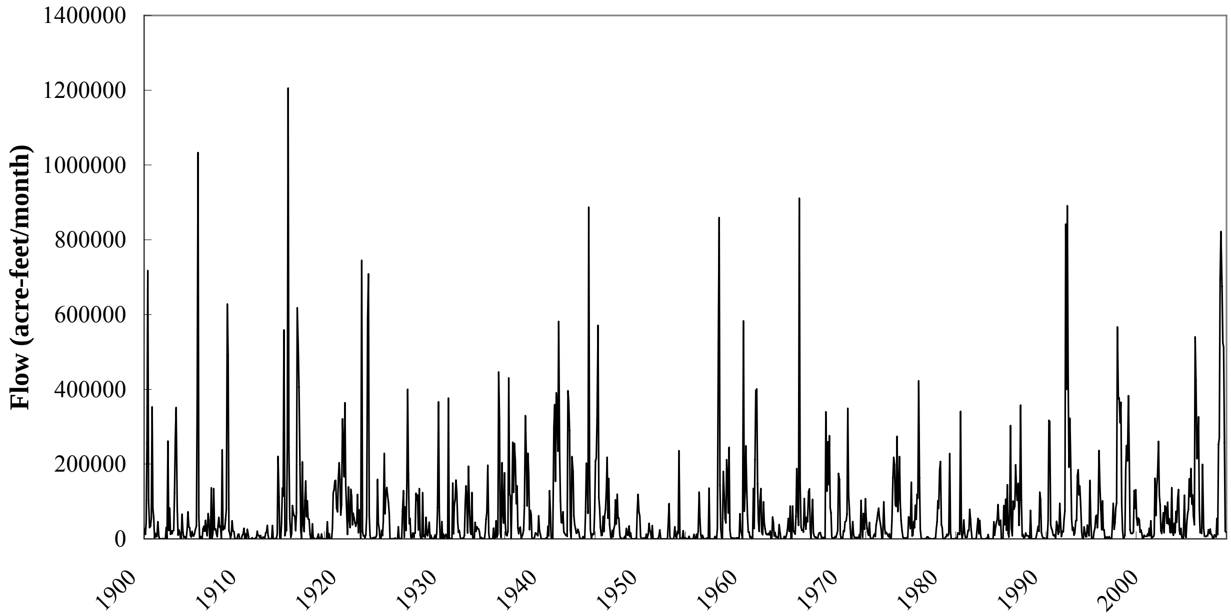

Figure E.51 Monthly BRAC3 Inflows at LRLR53 − Little River at Little River Gage

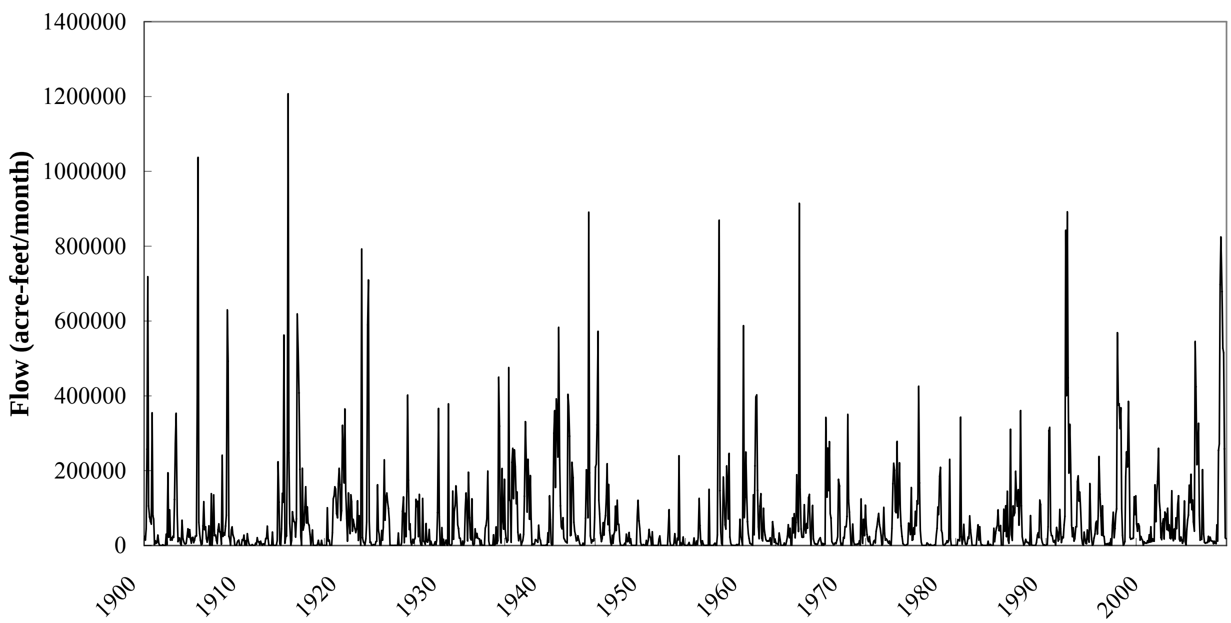

Figure E.52 Monthly BRAC8 Inflows at LRLR53 − Little River at Little River Gage

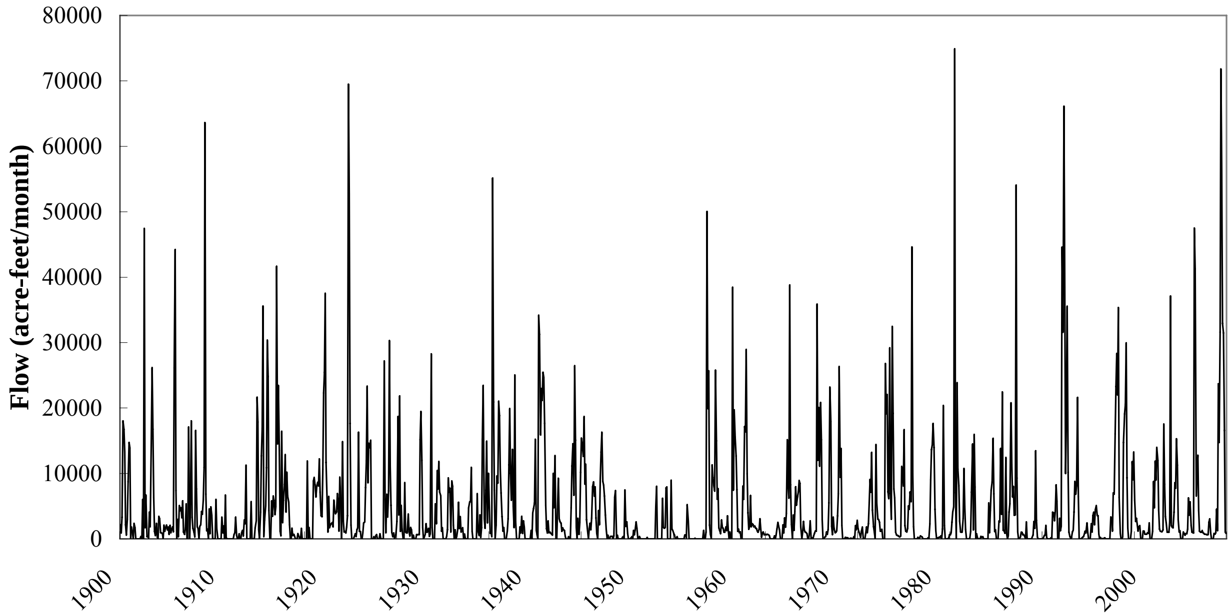

Figure E.53 Monthly BRAC3 Inflows at 516231 − Georgetown Reservoir

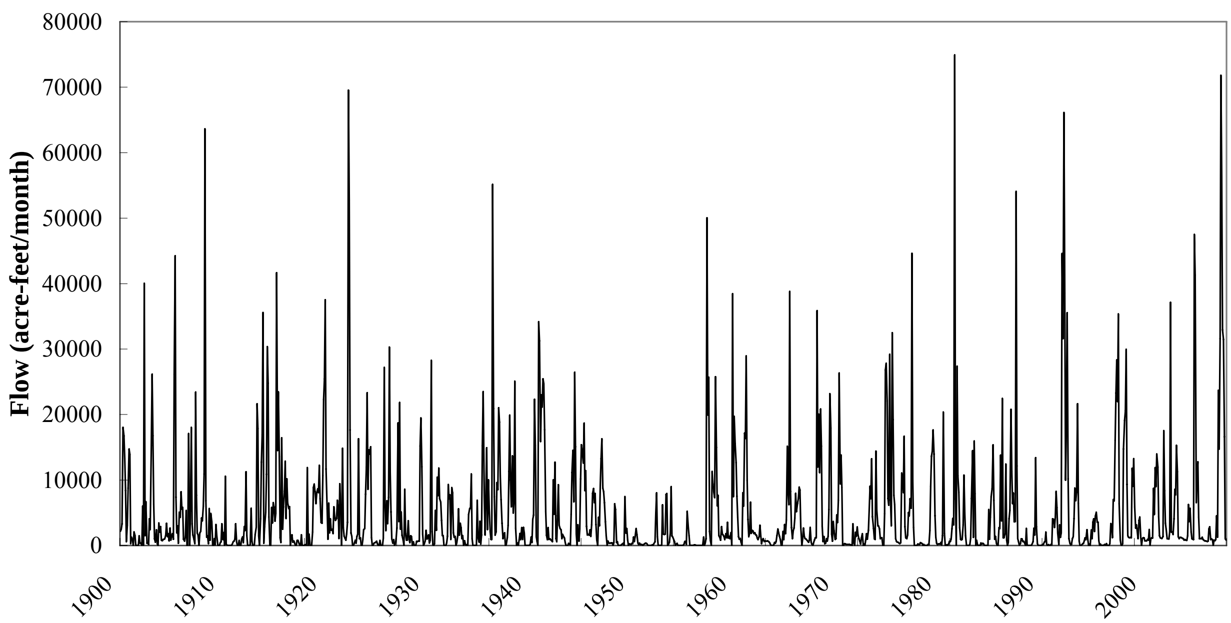

Figure E.54 Monthly BRAC8 Inflows at 516231 − Georgetown Reservoir

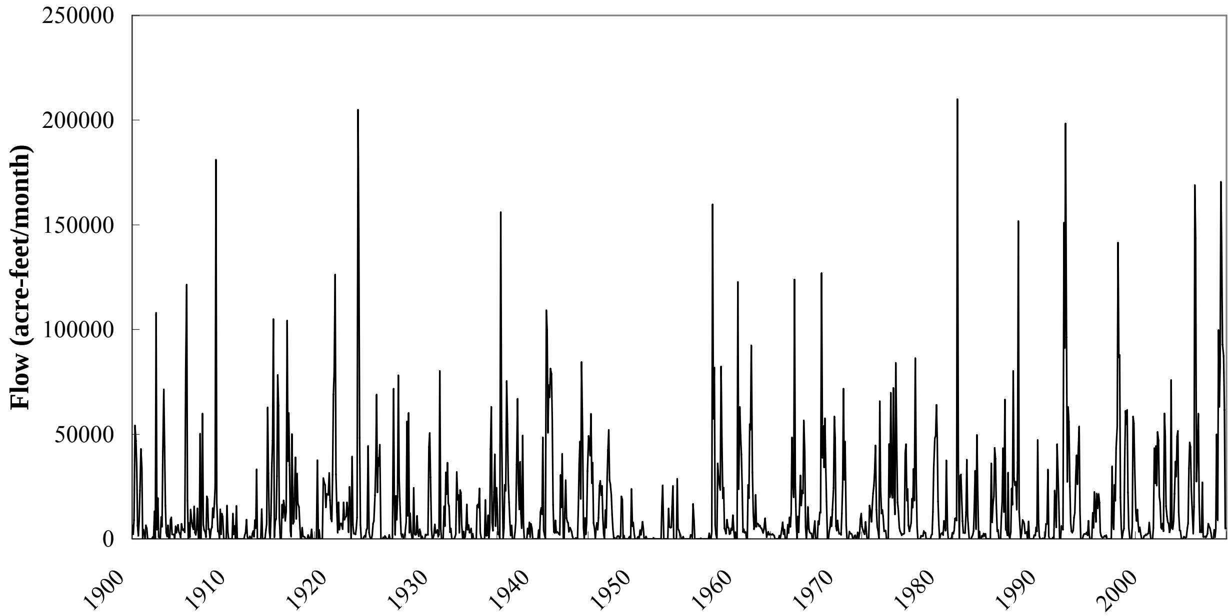

Figure E.55 Monthly BRAC3 Inflows at 516331 − Granger Reservoir

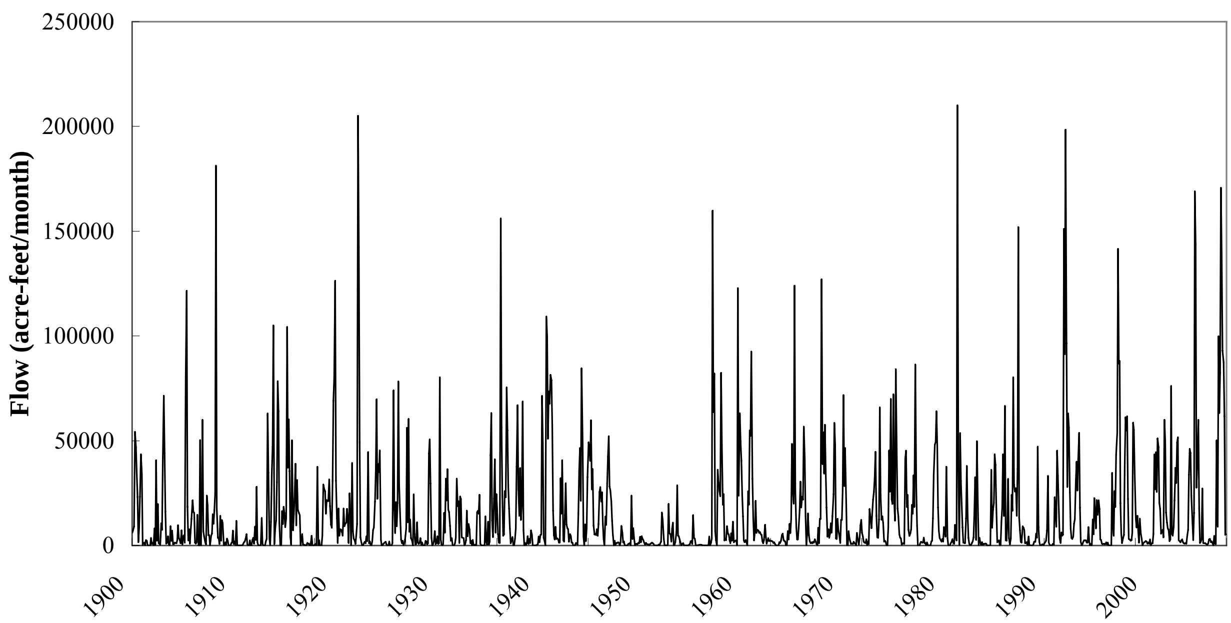

Figure E.56 Monthly BRAC8 Inflows at 516331 − Granger Reservoir

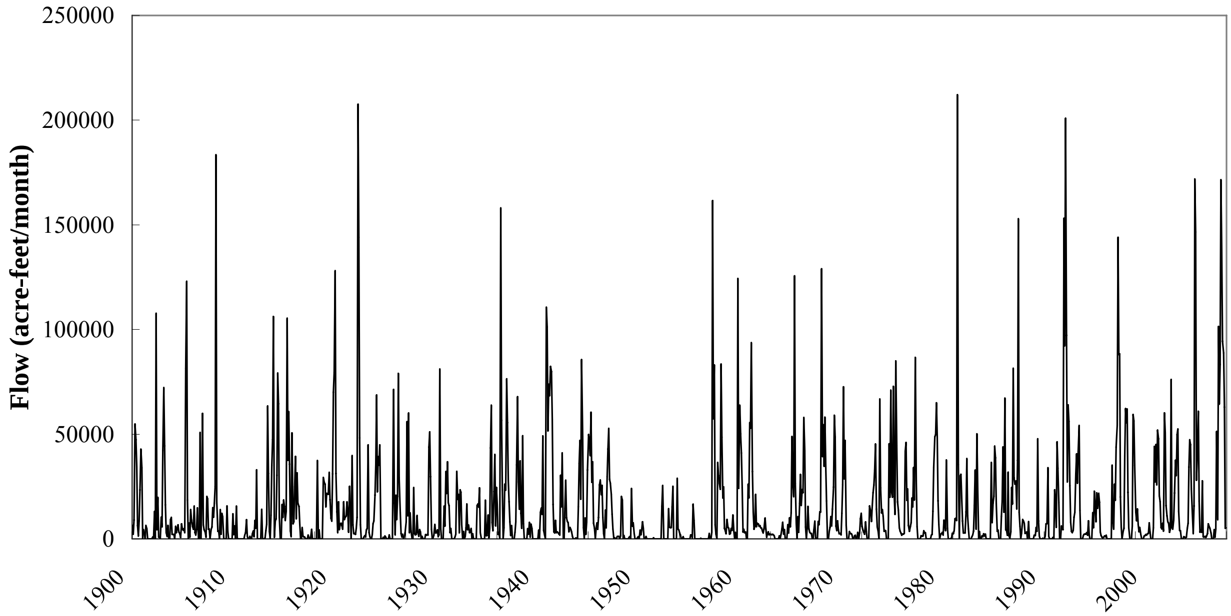

Figure E.57 Monthly BRAC3 Inflows at GALA57 − San Gabriel River at Laneport Gage

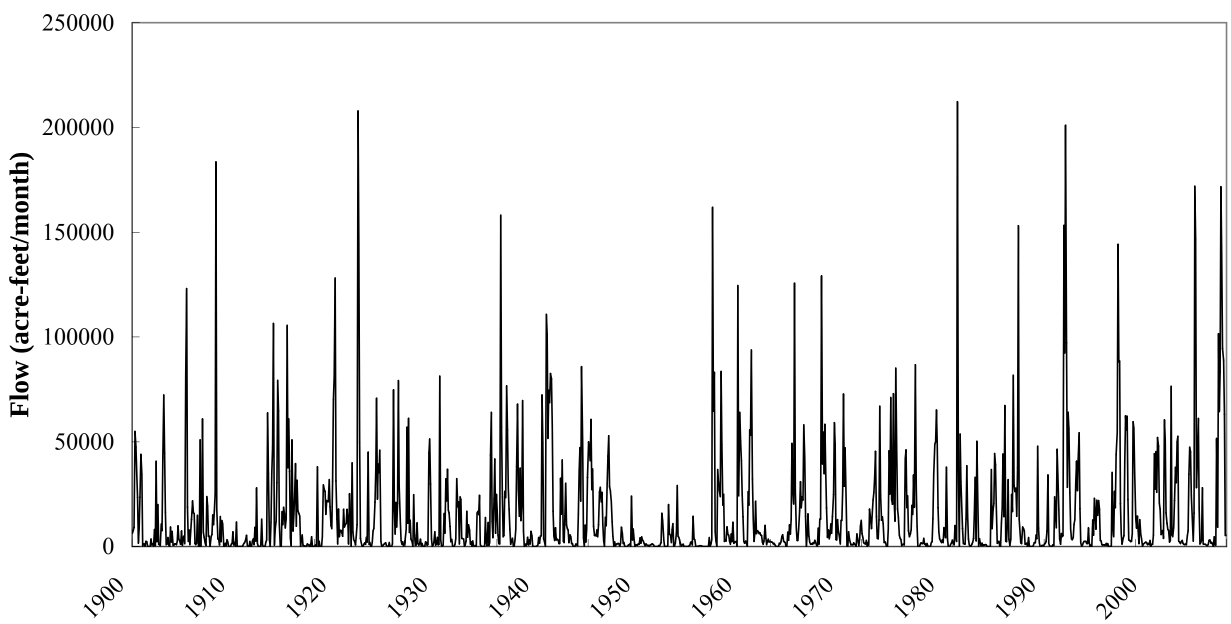

Figure E.58 Monthly BRAC8 Inflows at GALA57 − San Gabriel River at Laneport Gage

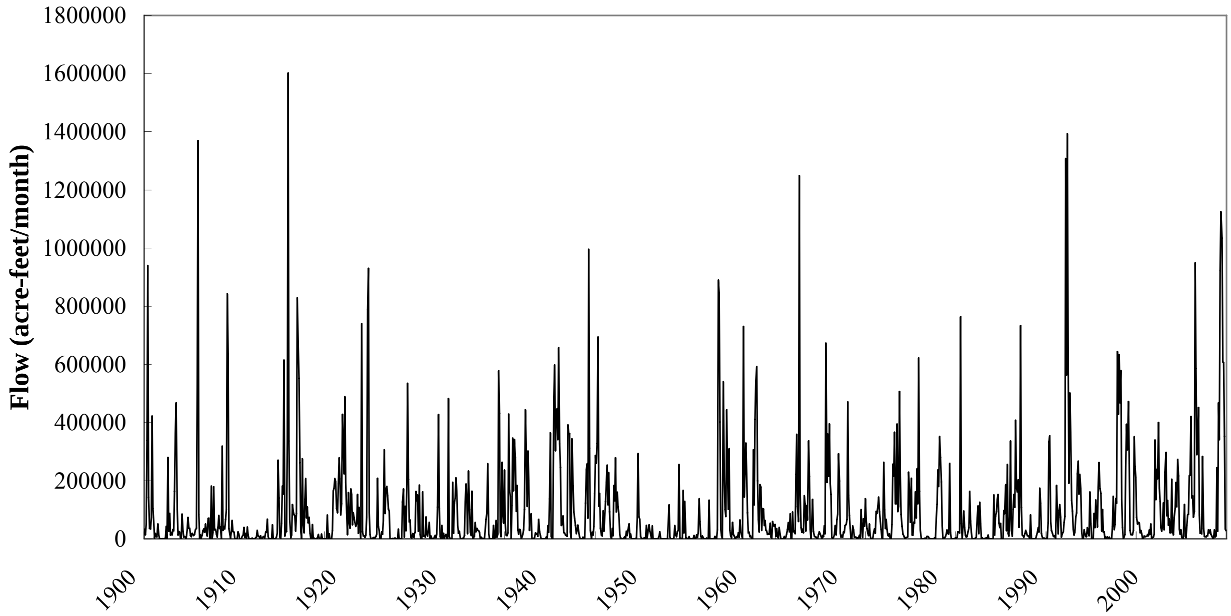

Figure E.59 Monthly BRAC3 Inflows at CON108 − Confluence of Little River and San Gabriel River

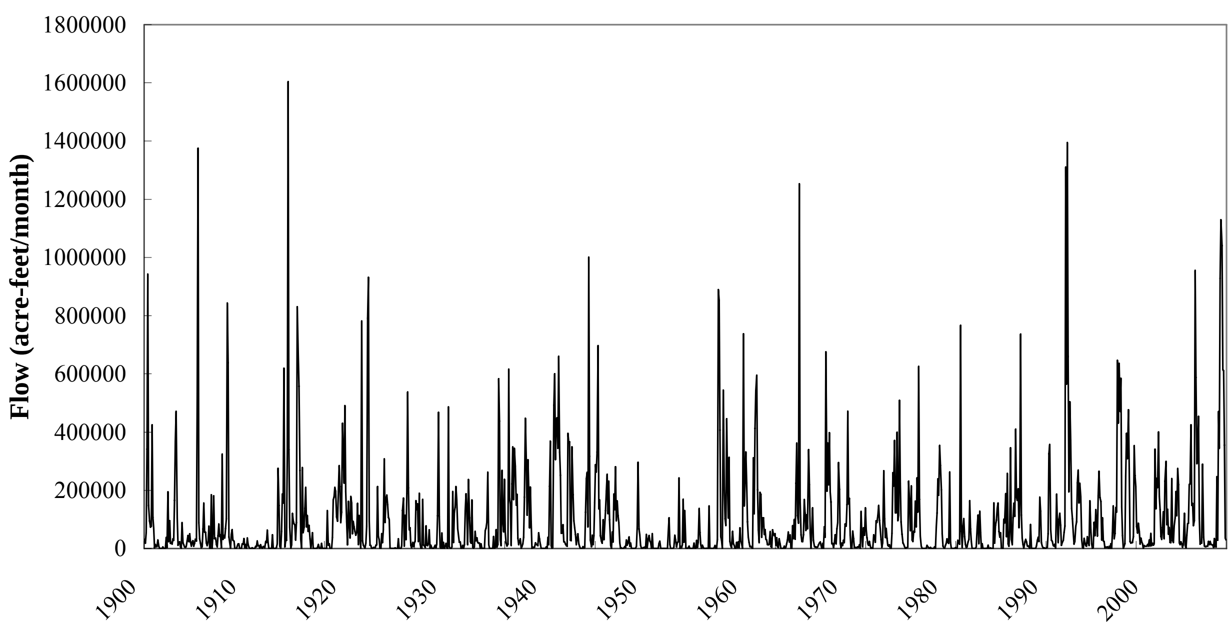

Figure E.60 Monthly BRAC8 Inflows at CON108 − Confluence of Little River and San Gabriel River

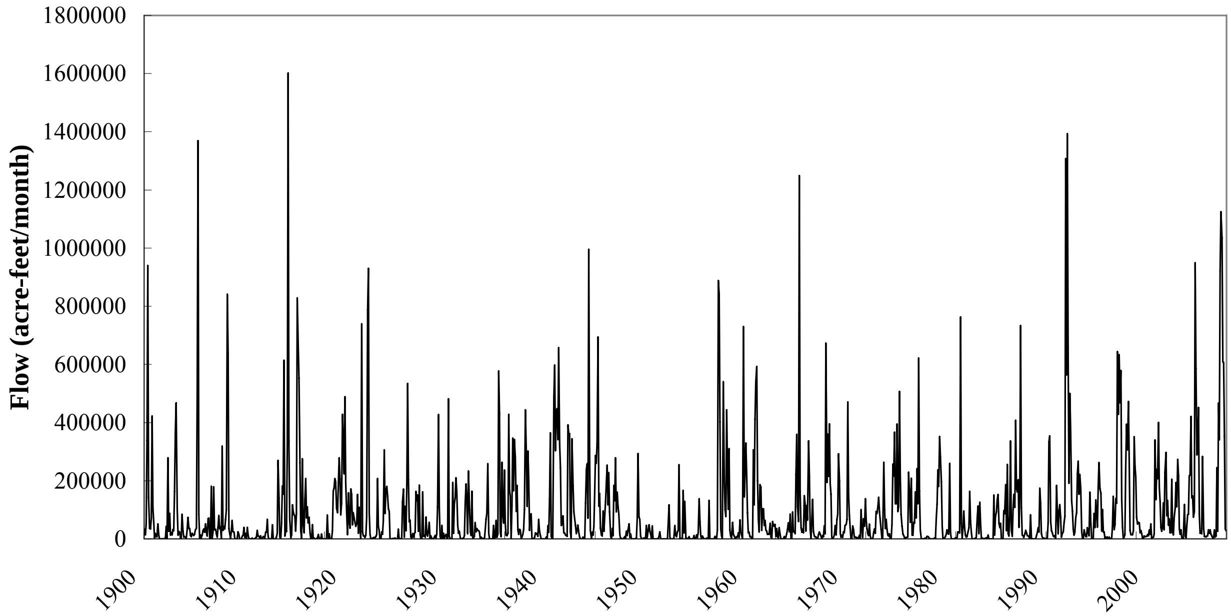

Figure E.61 Monthly BRAC3 Inflows at LRCA58 − Little River at Cameron Gage

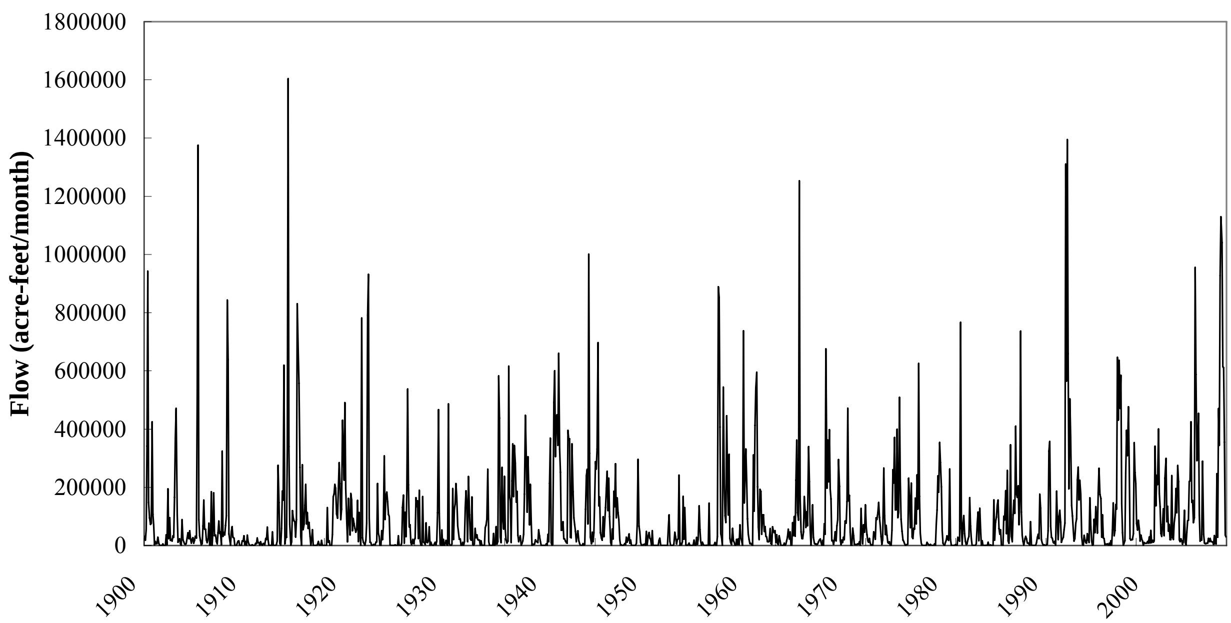

Figure E.62 Monthly BRAC8 Inflows at LRCA58 − Little River at Cameron Gage

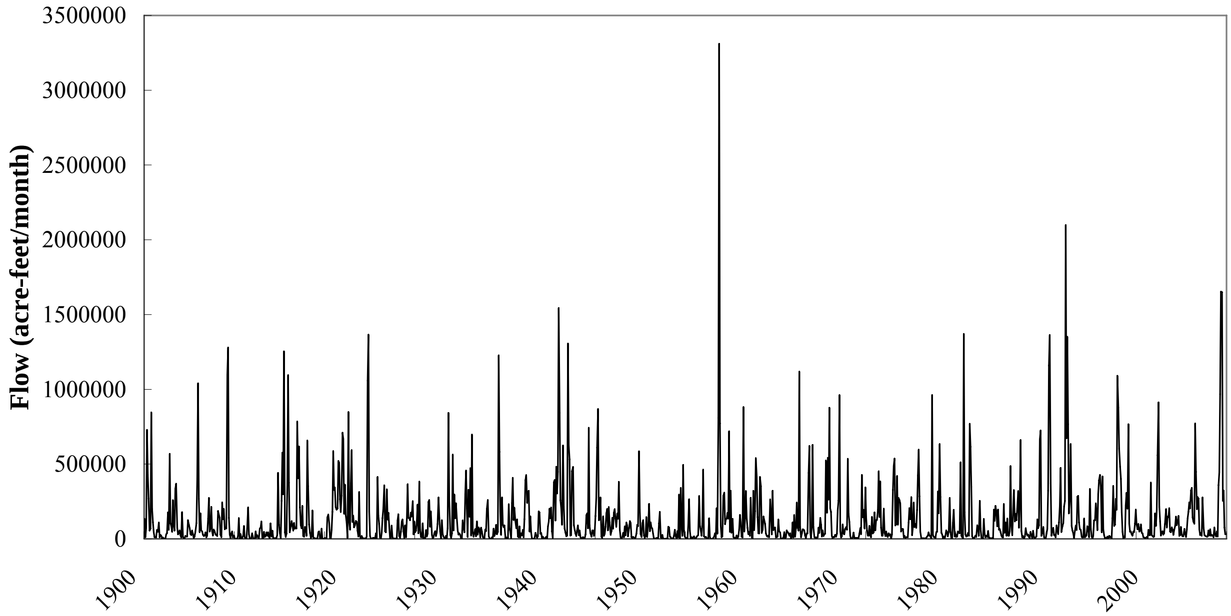

Figure E.63 Monthly BRAC3 Inflows at 433901 − Confluence of Bosque and Brazos River

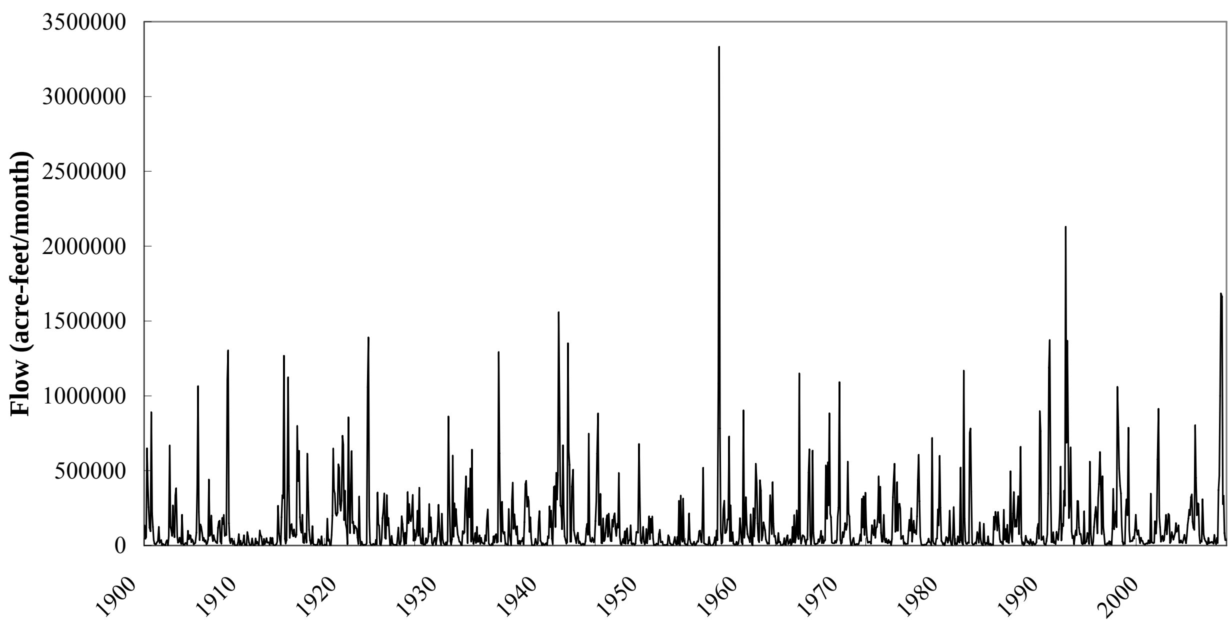

Figure E.64 Monthly BRAC8 Inflows at 433901 − Confluence of Bosque and Brazos River

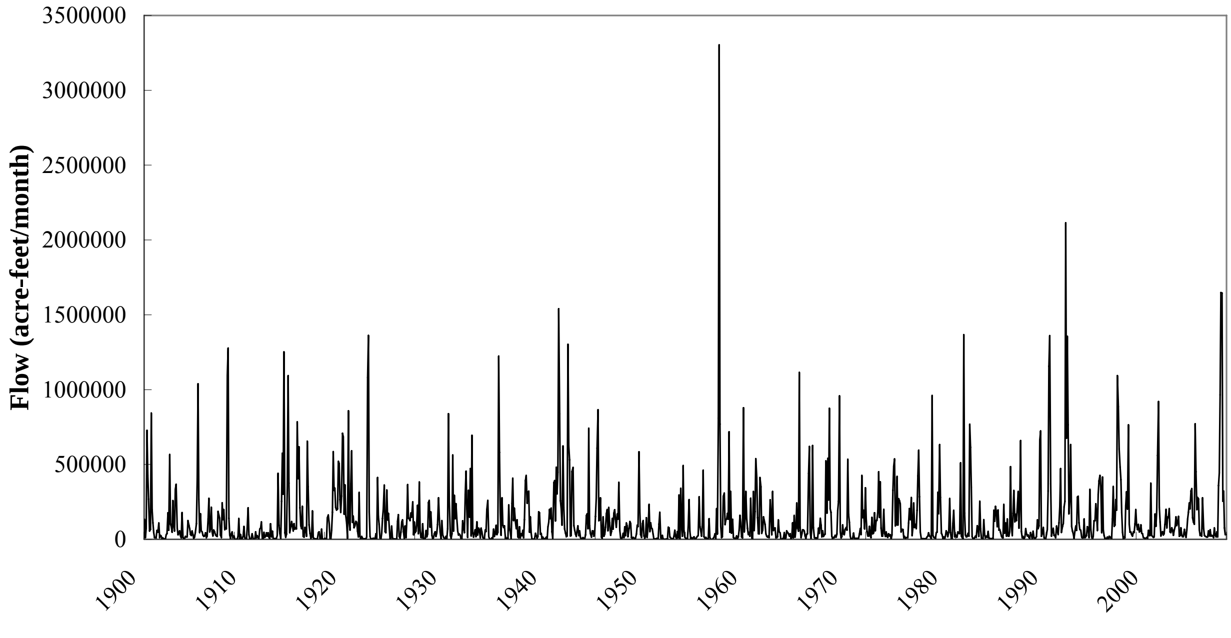

Figure E.65 Monthly BRAC3 Inflows at BRWA41 − Brazos River at Waco Gage

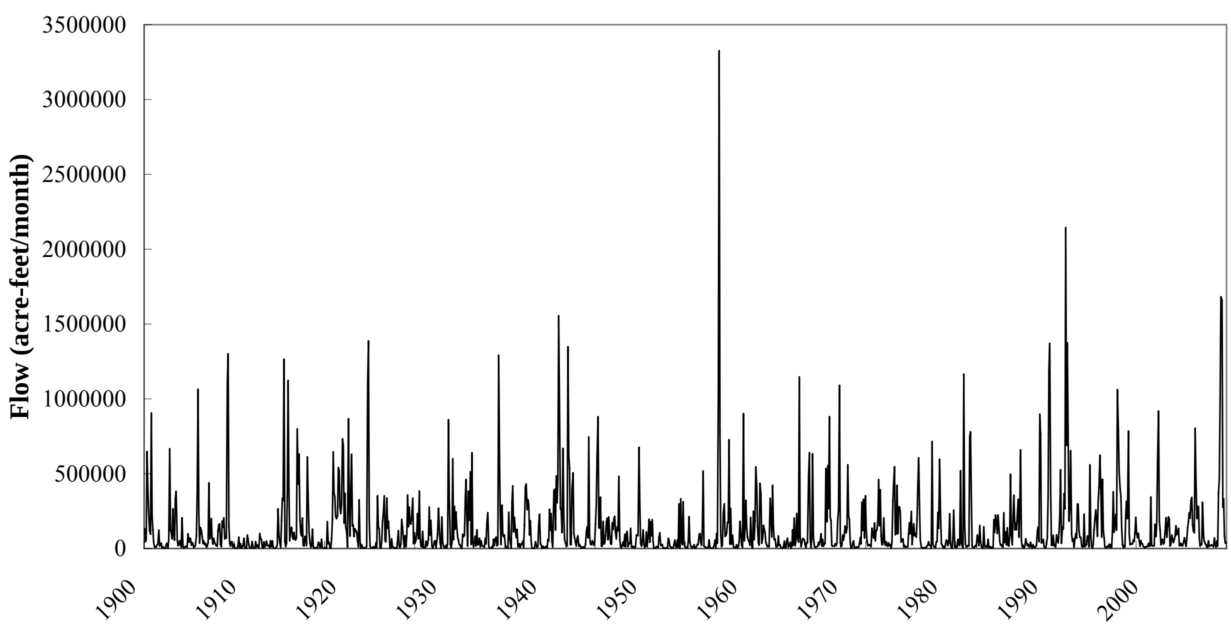

Figure E.66 Monthly BRAC8 Inflows at BRWA41 − Brazos River at Waco Gage

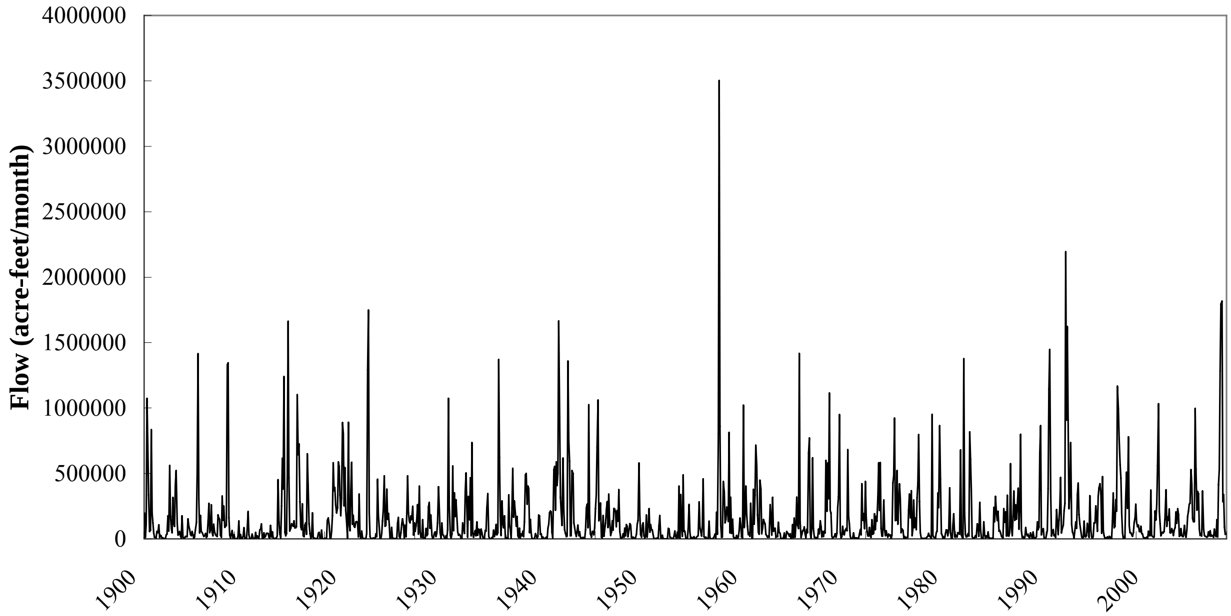

Figure E.67 Monthly BRAC3 Inflows at BRHB42 − Brazos River at Highbank Gage

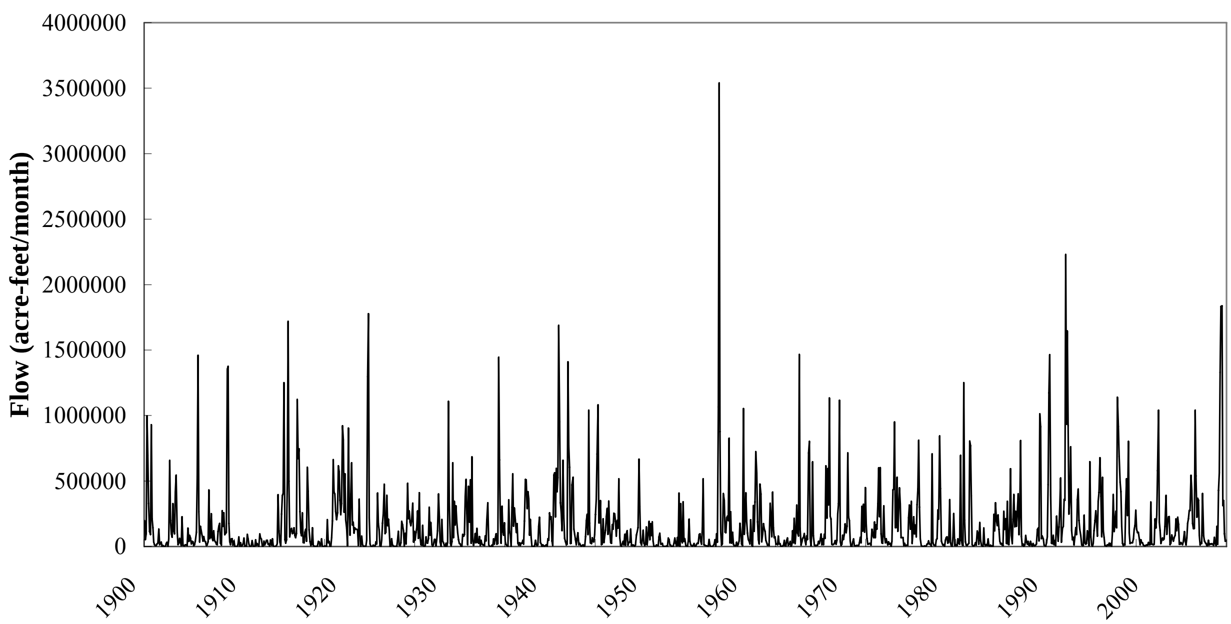

Figure E.68 Monthly BRAC8 Inflows at BRHB42 − Brazos River at Highbank Gage

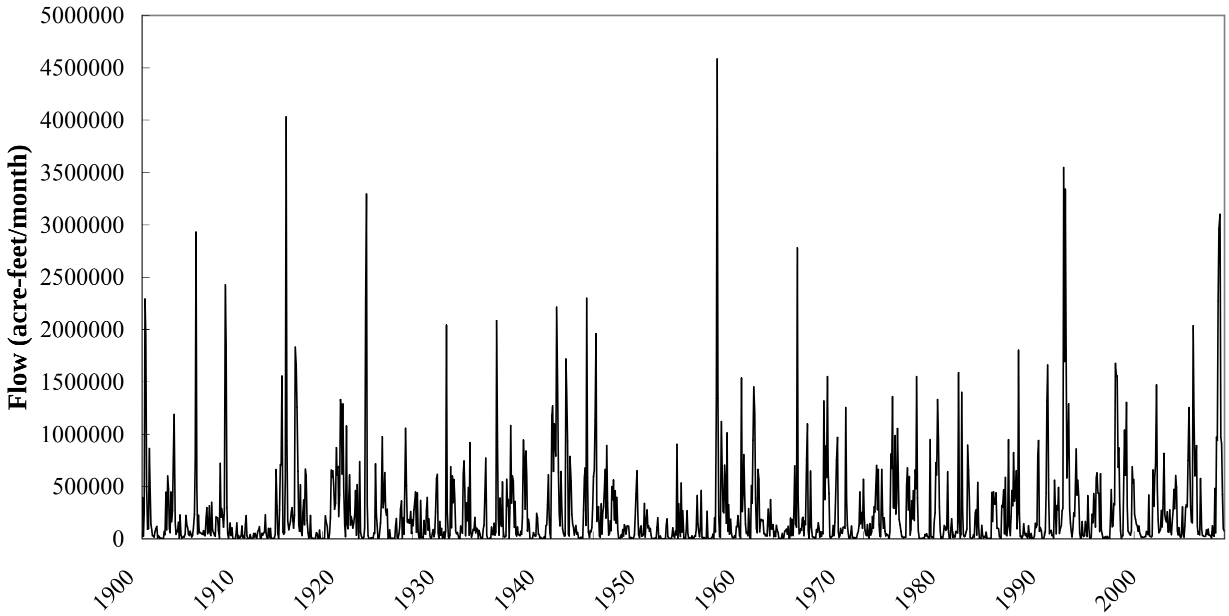

Figure E.69 Monthly BRAC3 Inflows at CON111 − Confluence of Little River and Brazos River

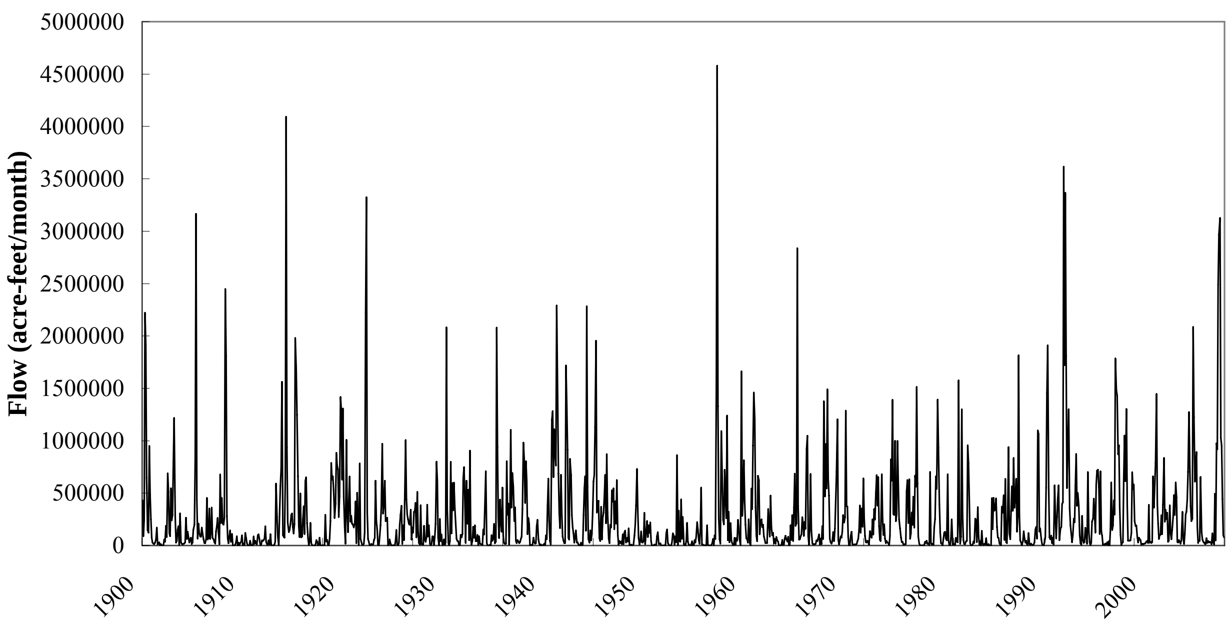

Figure E.70 Monthly BRAC8 Inflows at CON111 − Confluence of Little River and Brazos River

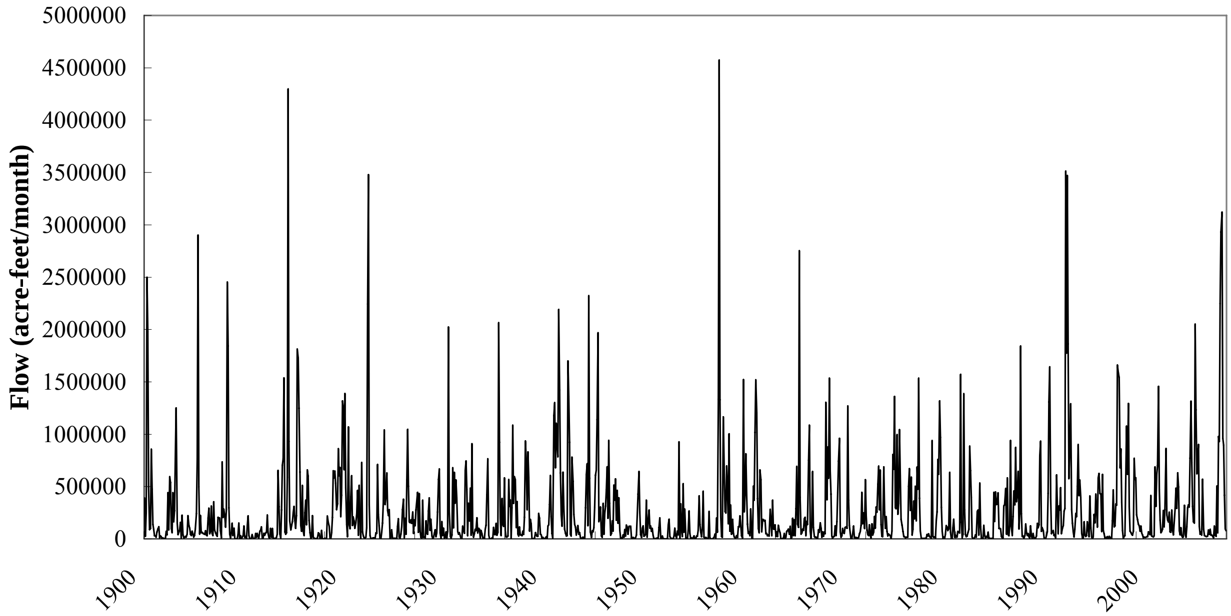

Figure E.71 Monthly BRAC3 Inflows at BRBR59 − Brazos River at Bryan Gage

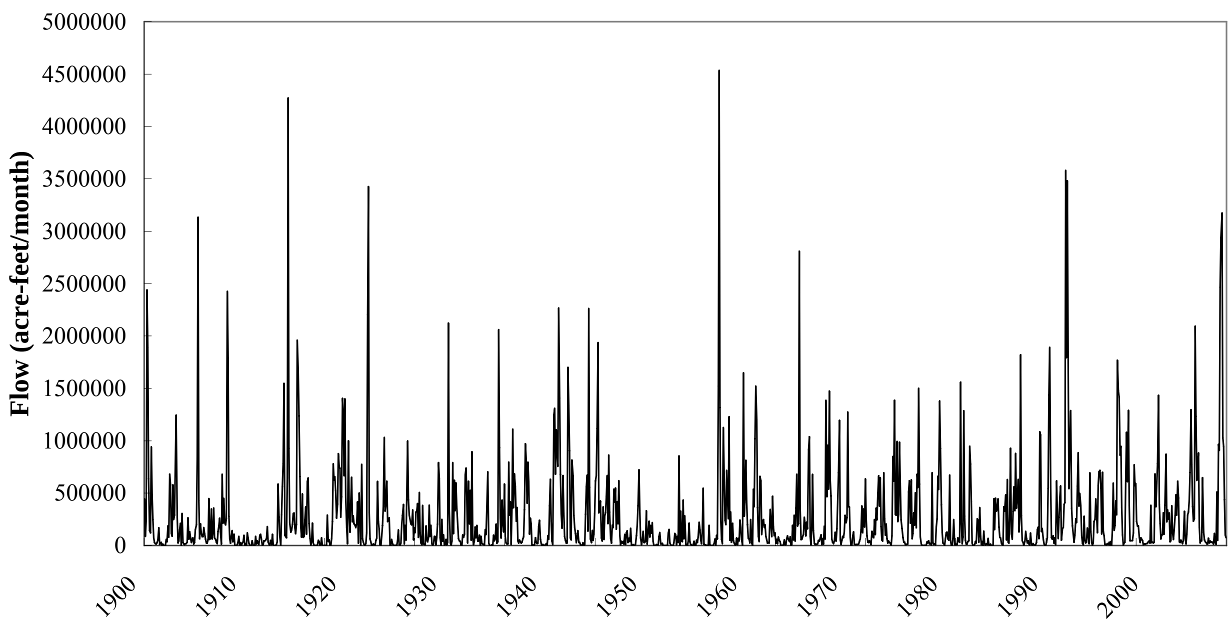

Figure E.72 Monthly BRAC8 Inflows at BRBR59 − Brazos River at Bryan Gage

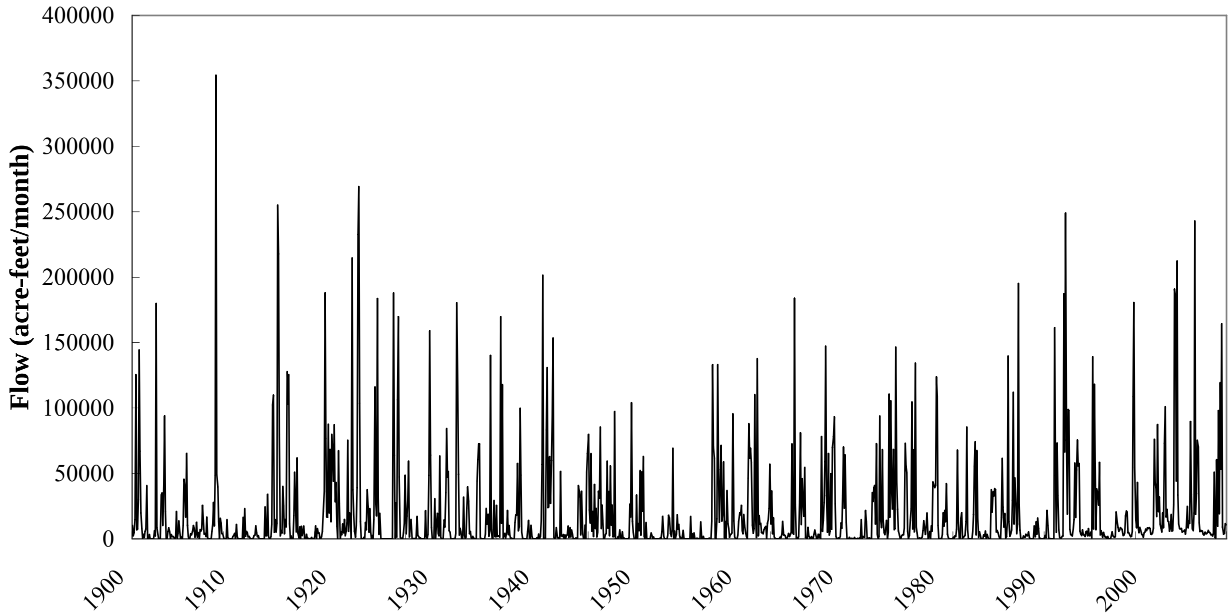

Figure E.73 Monthly BRAC3 Inflows at 516431 − Somerville Reservoir

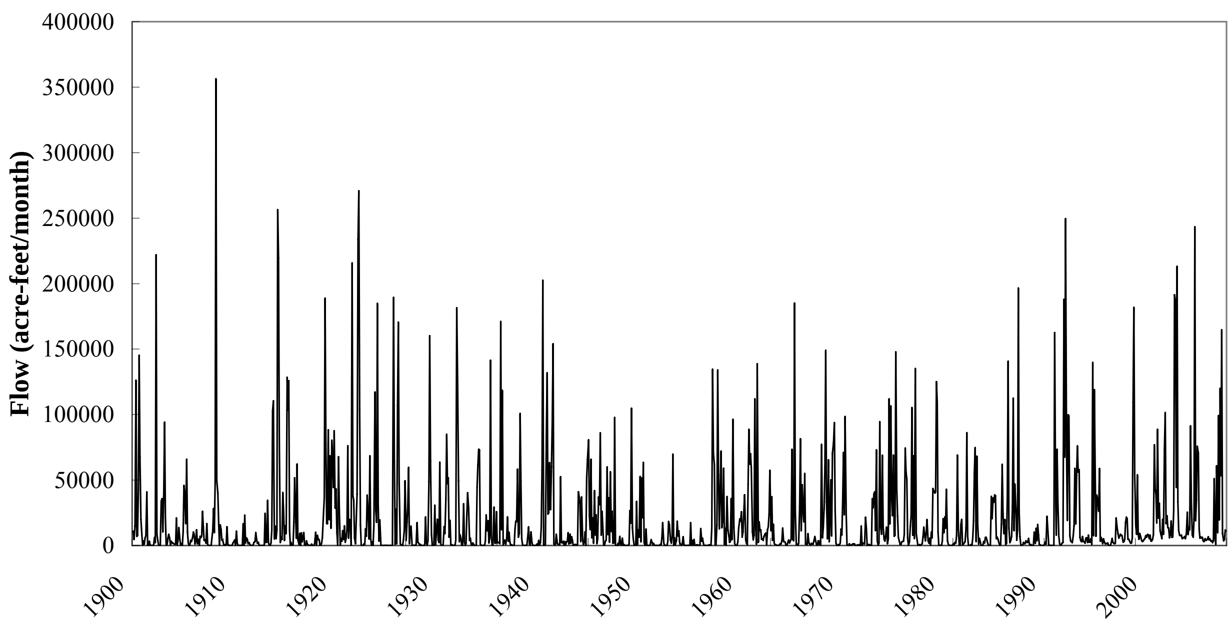

Figure E.74 Monthly BRAC8 Inflows at 516431 − Somerville Reservoir

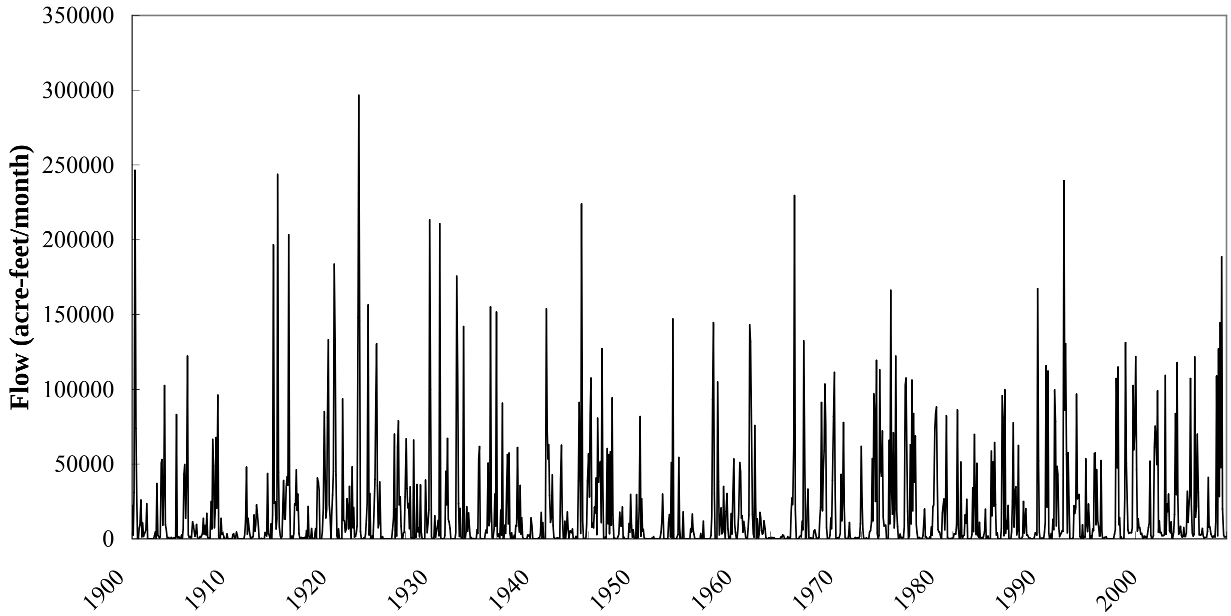

Figure E.75 Monthly BRAC3 Inflows at 516531 − Limestone Reservoir

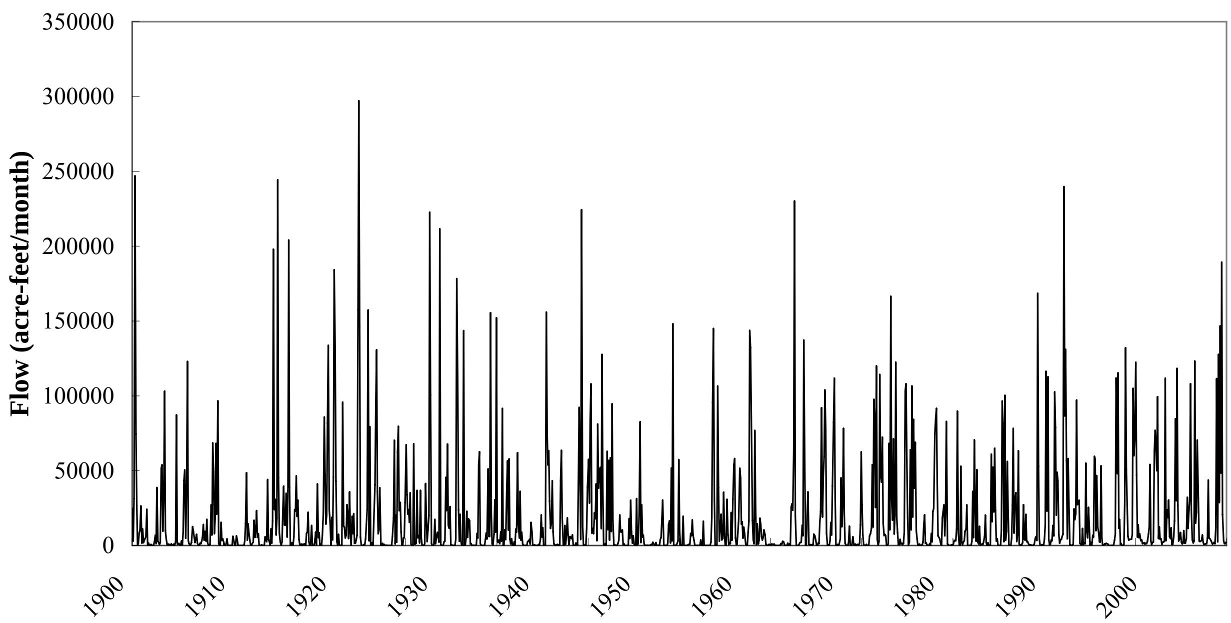

Figure E.76 Monthly BRAC8 Inflows at 516531 − Limestone Reservoir

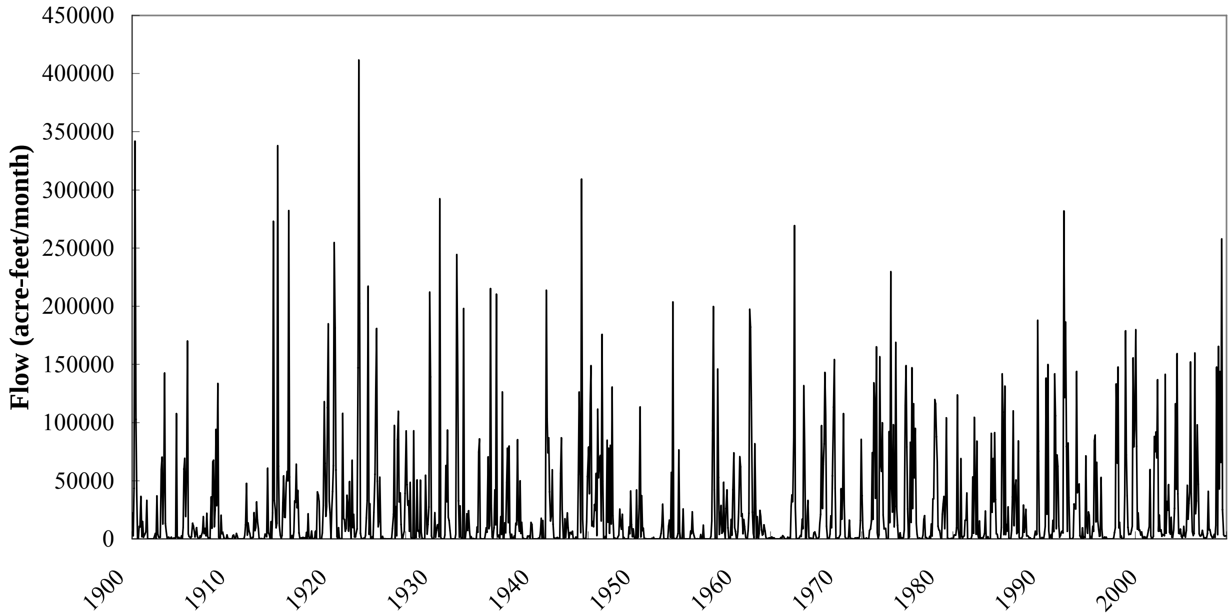

Figure E.77 Monthly BRAC3 Inflows at NAEA66 − Navasota River at Easterly Gage

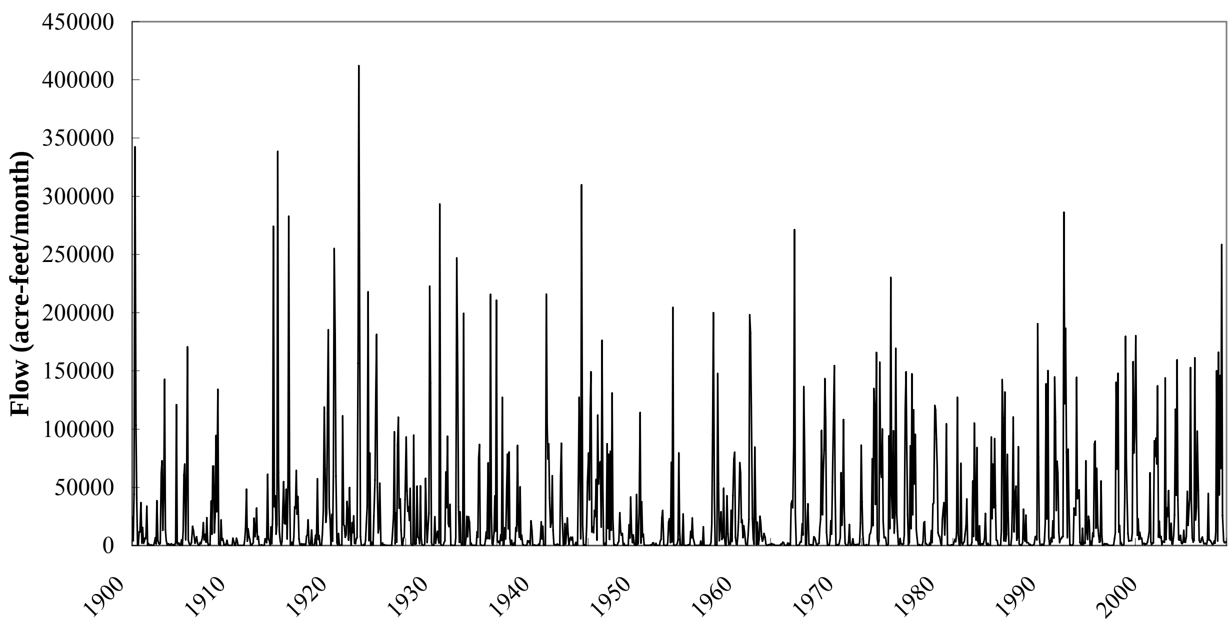

Figure E.78 Monthly BRAC8 Inflows at NAEA66 − Navasota River at Easterly Gage

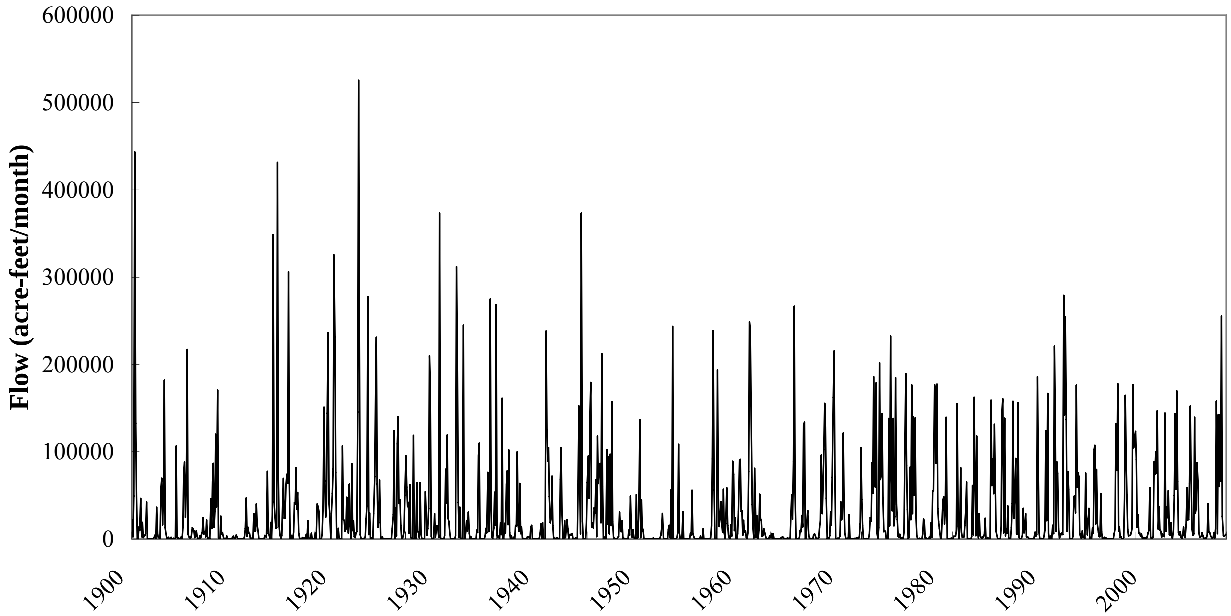

Figure E.79 Monthly BRAC3 Inflows at NABR67 − Navasota River at Bryan Gage

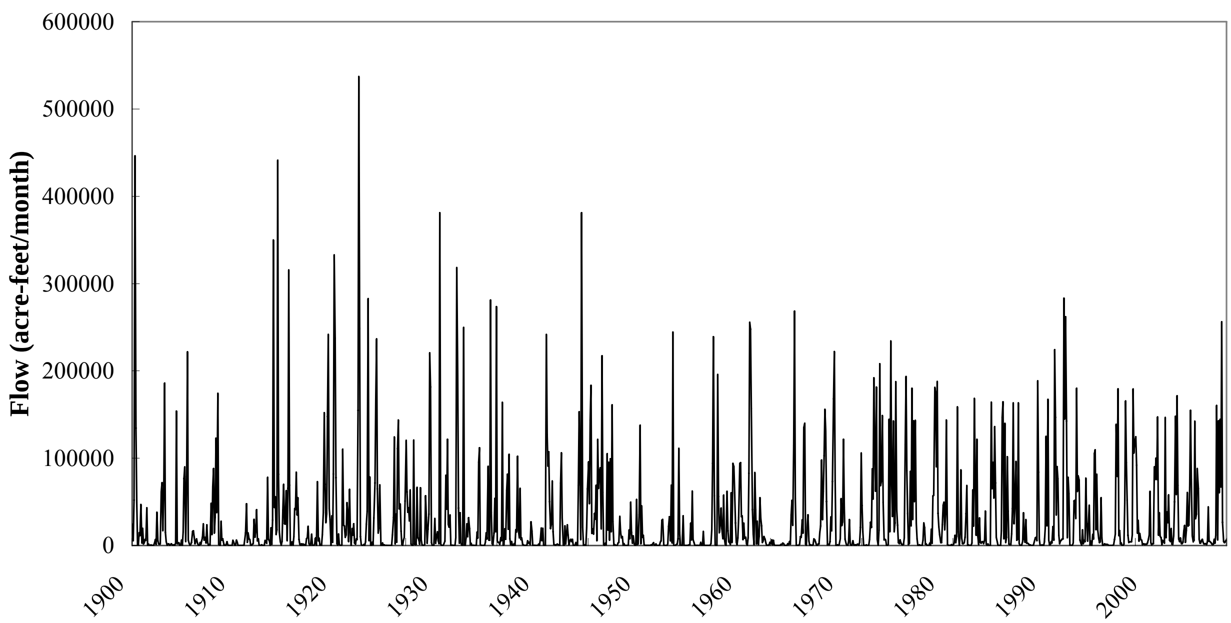

Figure E.80 Monthly BRAC8 Inflows at NABR67 − Navasota River at Bryan Gage

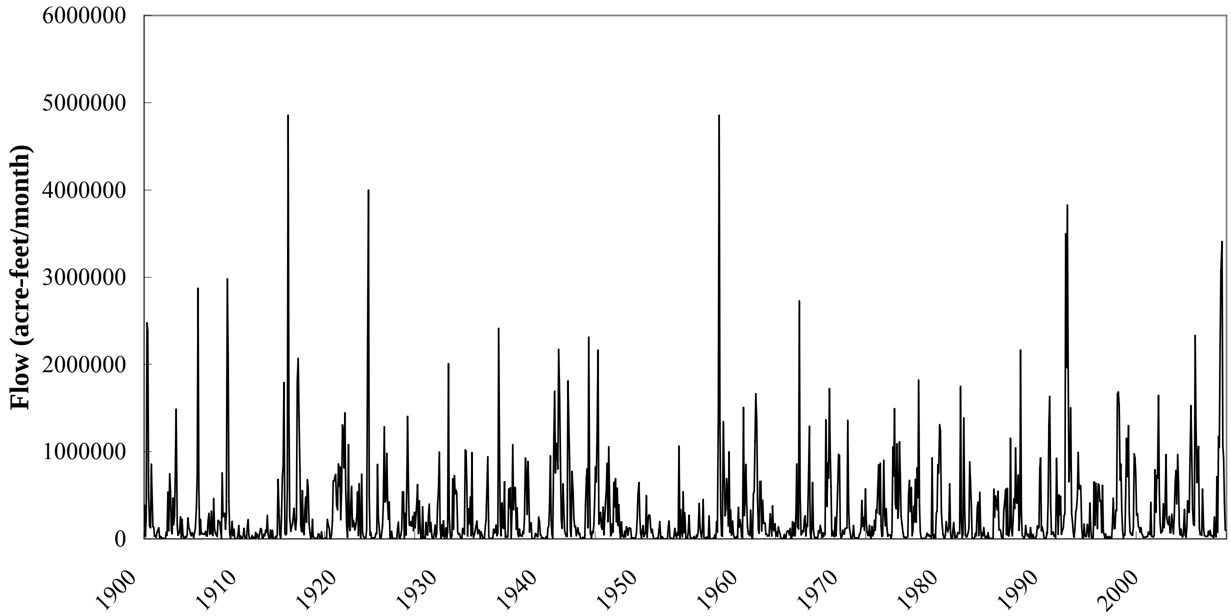

Figure E.81 Monthly BRAC3 Inflows at CON130 − Confluence of Yequa Creek and Brazos River

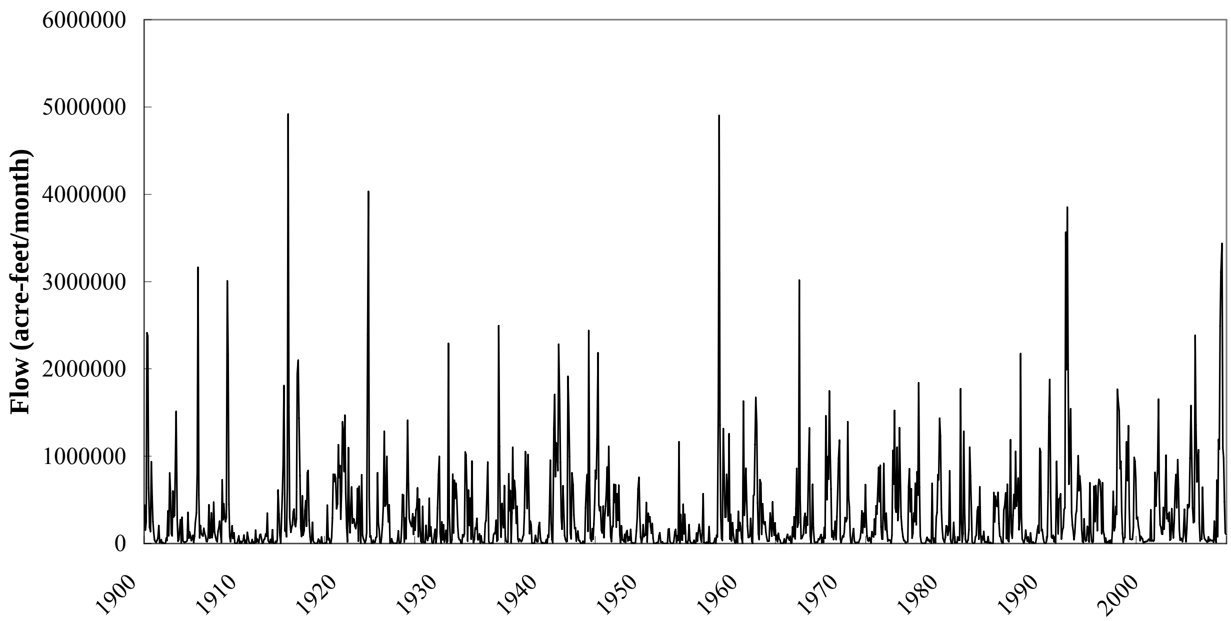

Figure E.82 Monthly BRAC8 Inflows at CON130 − Confluence of Yequa Creek and Brazos River

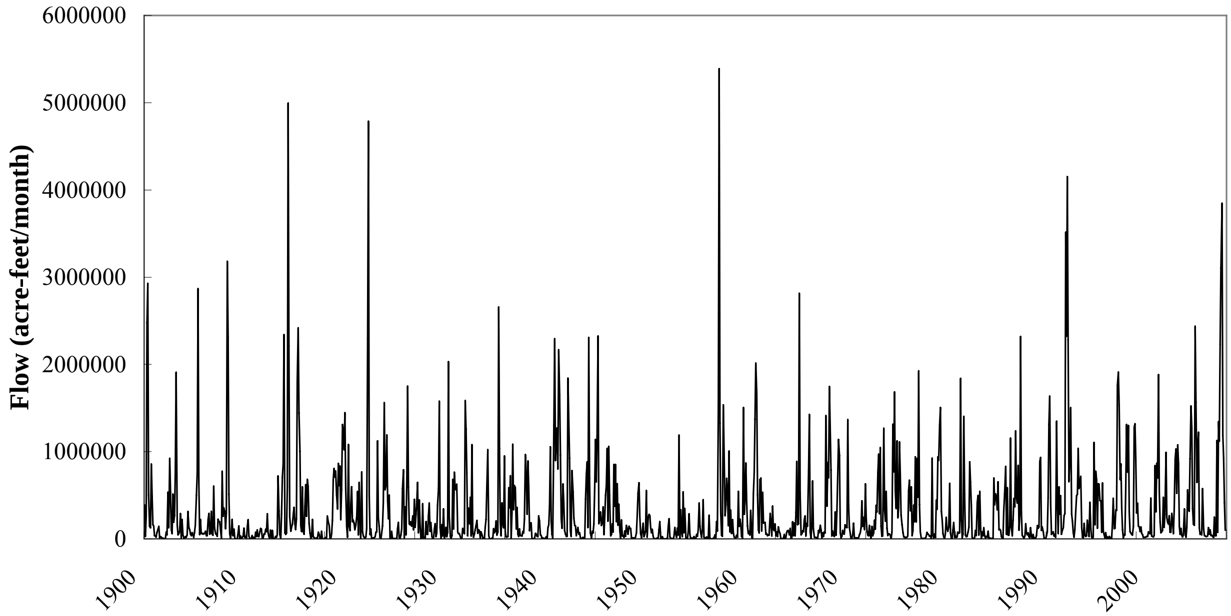

Figure E.83 Monthly BRAC3 Inflows at CON147 − Confluence of Navasota River and Brazos River

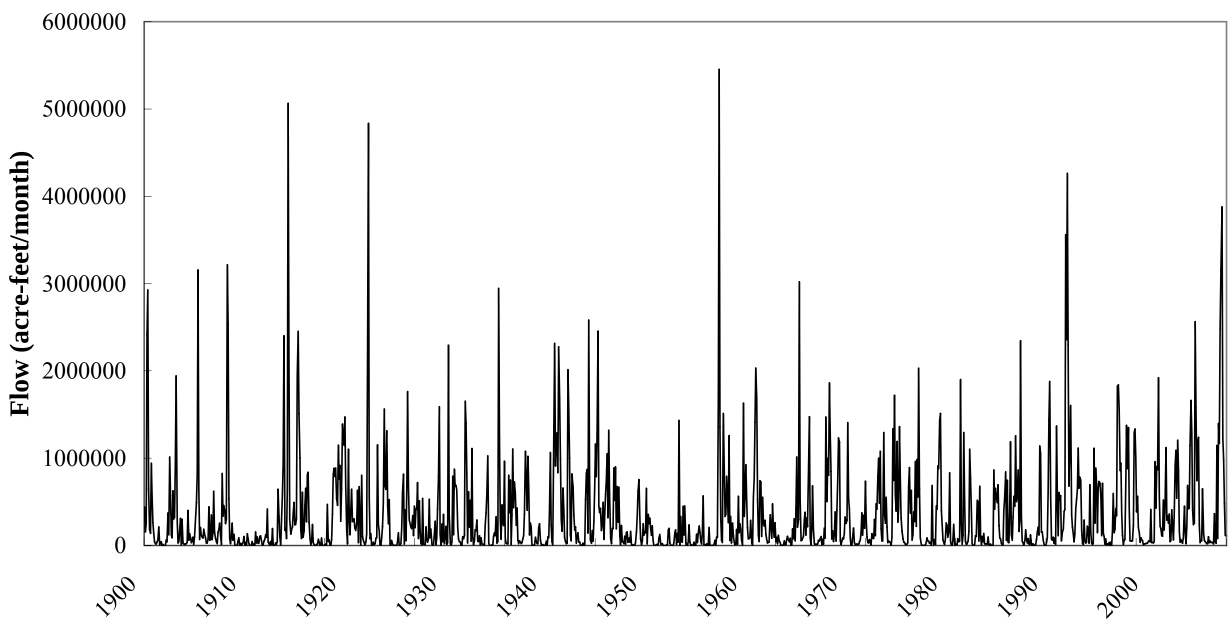

Figure E.84 Monthly BRAC8 Inflows at CON147 − Confluence of Navasota River and Brazos River

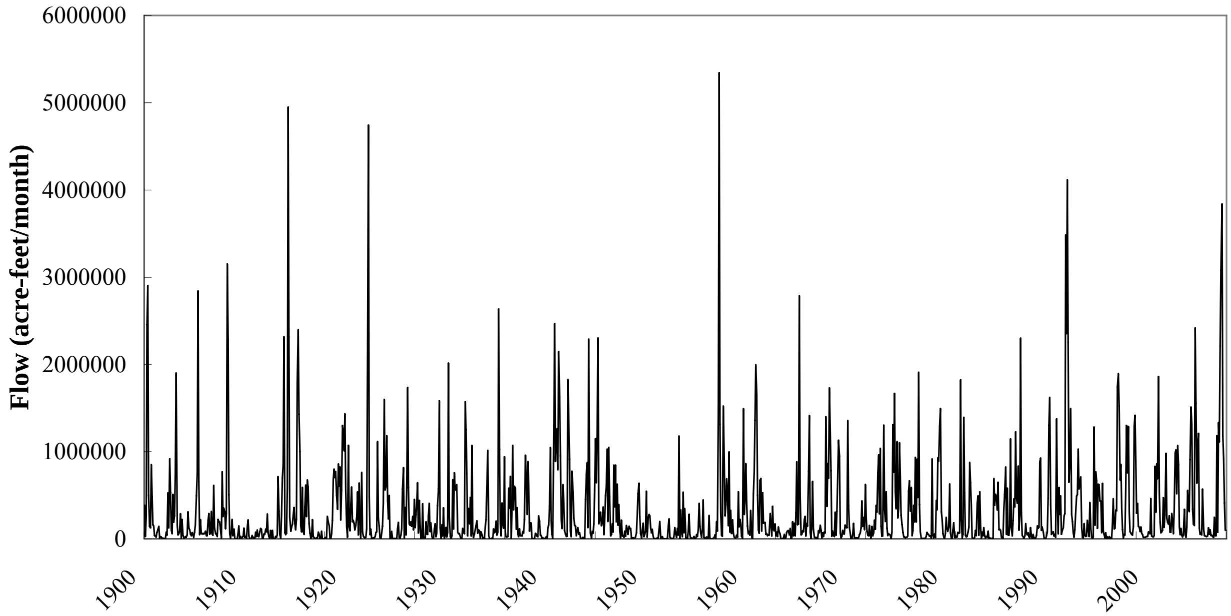

Figure E.85 Monthly BRAC3 Inflows at BRHE68 − Brazos River at Hempstead Gage

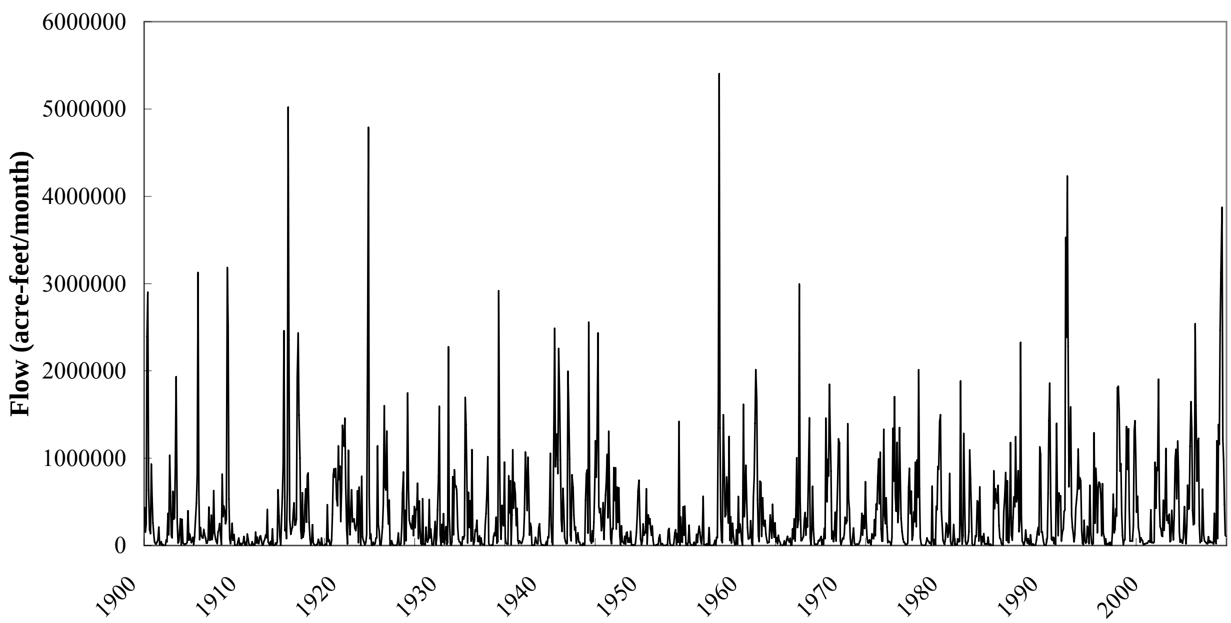

Figure E.86 Monthly BRAC8 Inflows at BRHE68 − Brazos River at Hempstead Gage

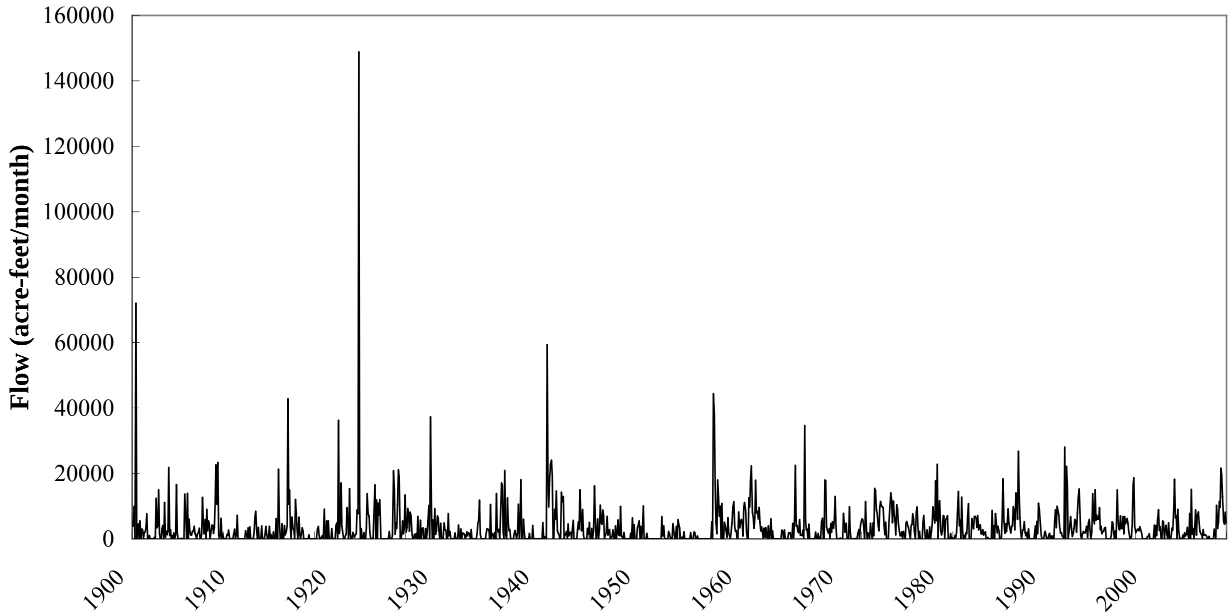

Figure E.87 Monthly BRAC3 Inflows at 292531 − Allens Creek Reservoir

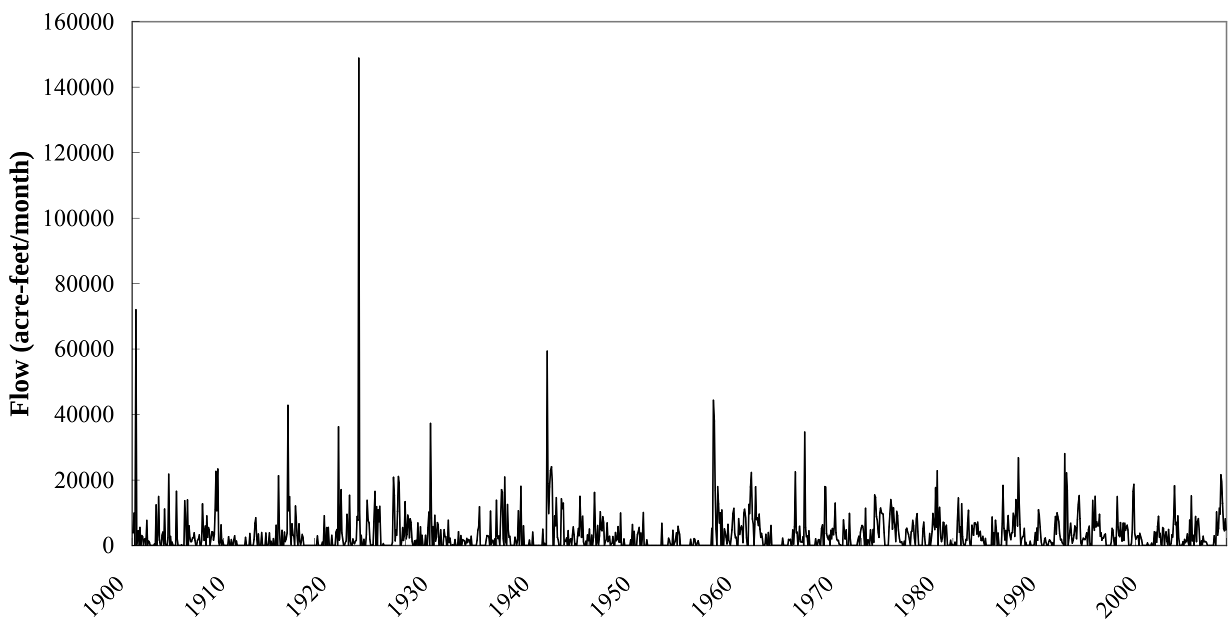

Figure E.88 Monthly BRAC8 Inflows at 292531 − Allens Creek Reservoir

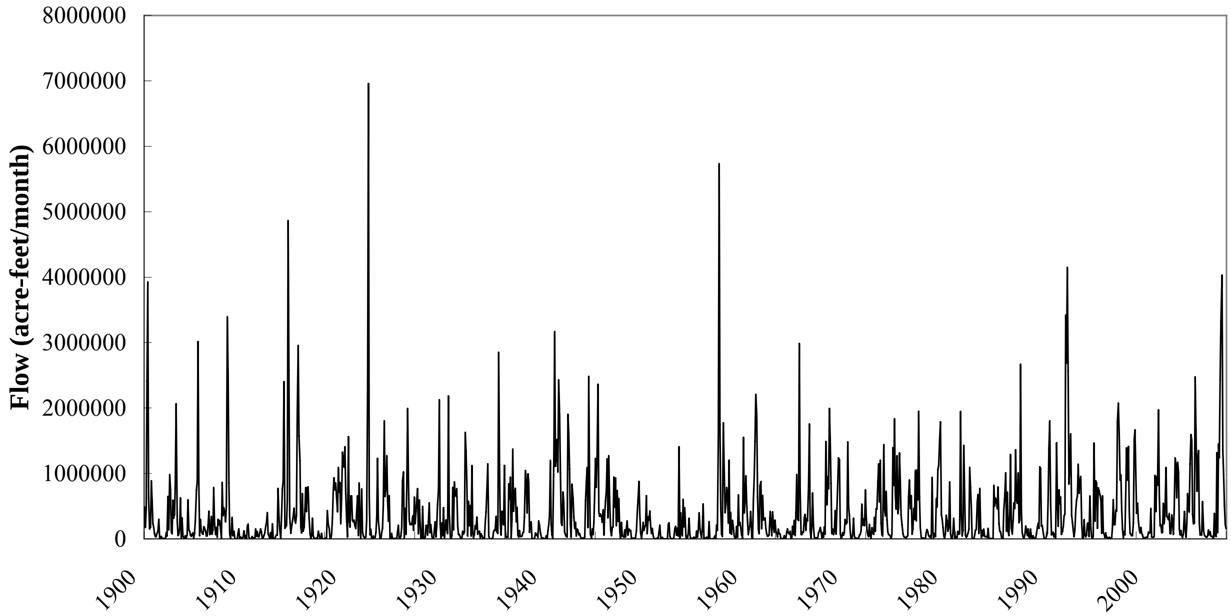

Figure E.89 Monthly BRAC3 Inflows at CON234 − Confluence of Allens Creek and Brazos River

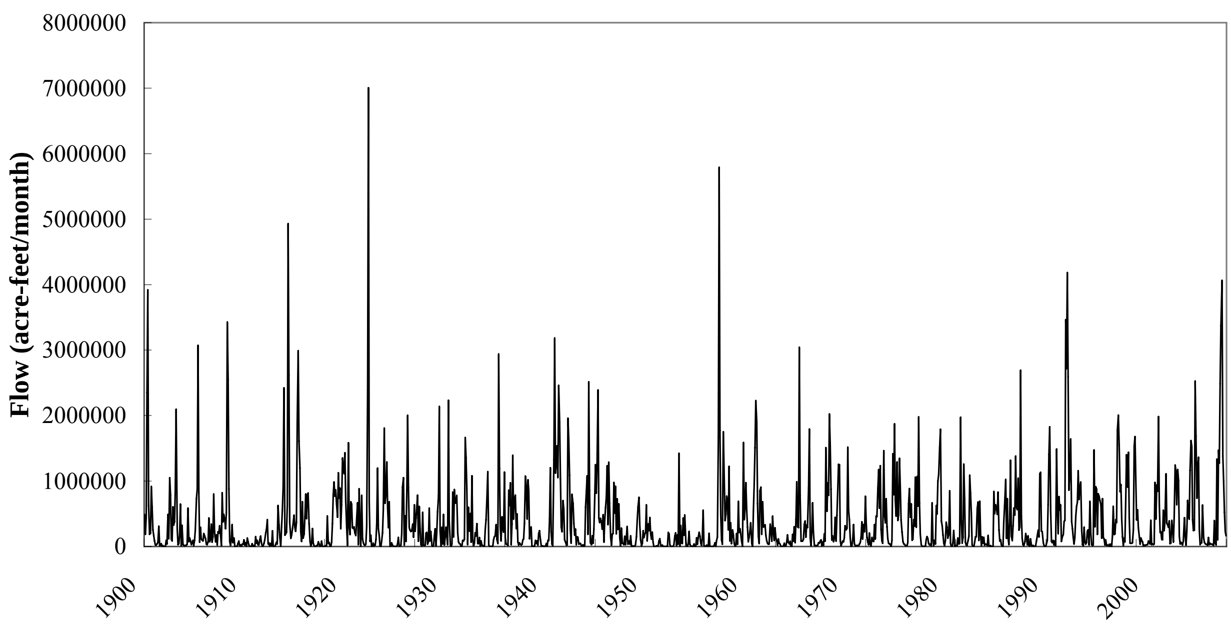

Figure E.90 Monthly BRAC8 Inflows at CON234 − Confluence of Allens Creek and Brazos River

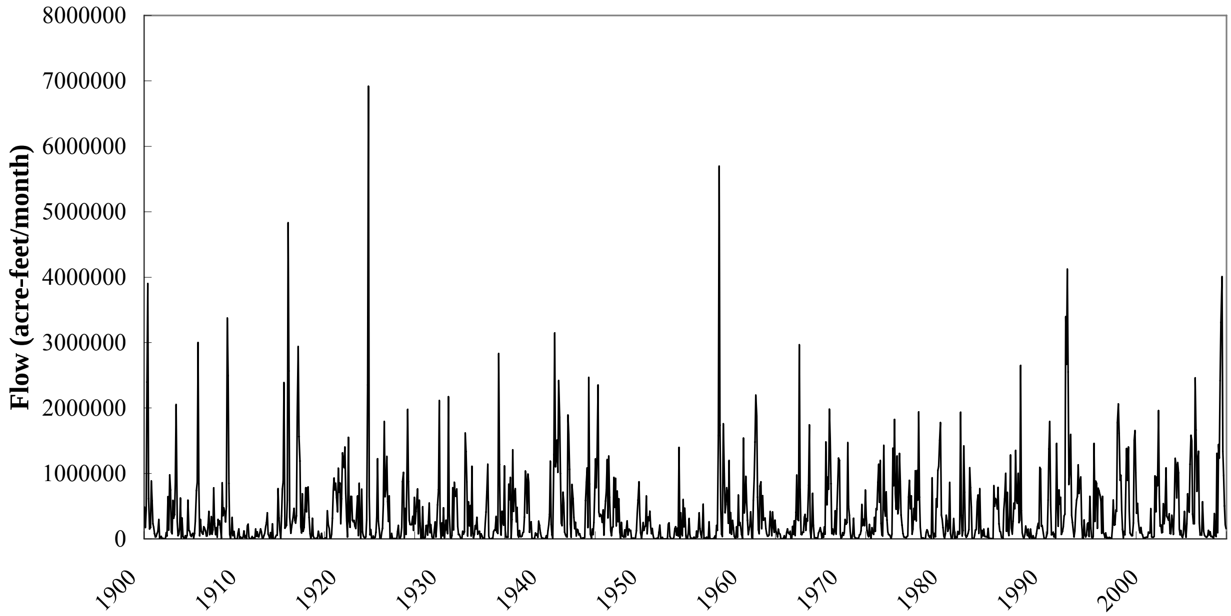

Figure E.91 Monthly BRAC3 Inflows at BRRI70 − Brazos River at Richmond Gage

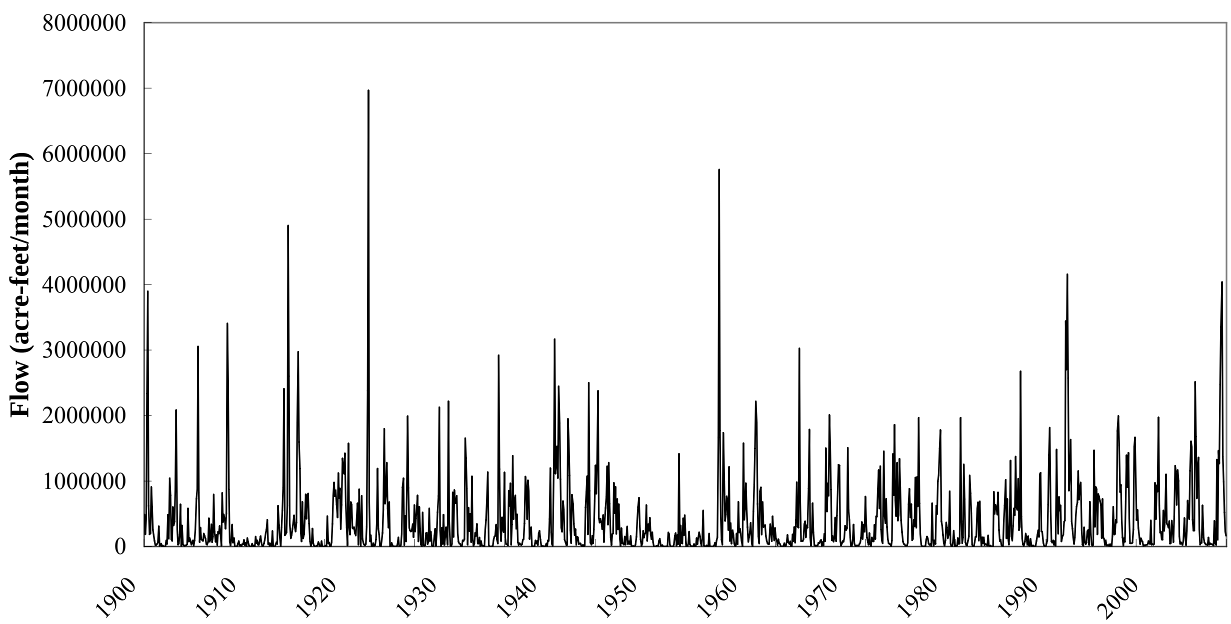

Figure E.92 Monthly BRAC8 Inflows at BRRI70 − Brazos River at Richmond Gage

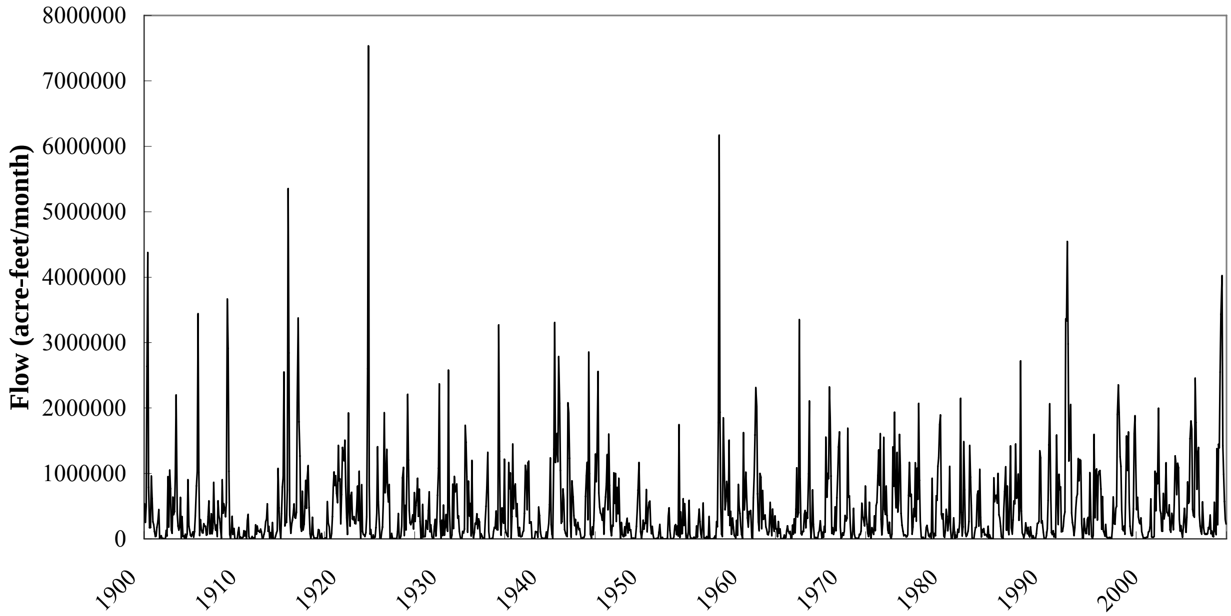

Figure E.93 Monthly BRAC3 Inflows at BRRO72 − Brazos River at Rosharon Gage

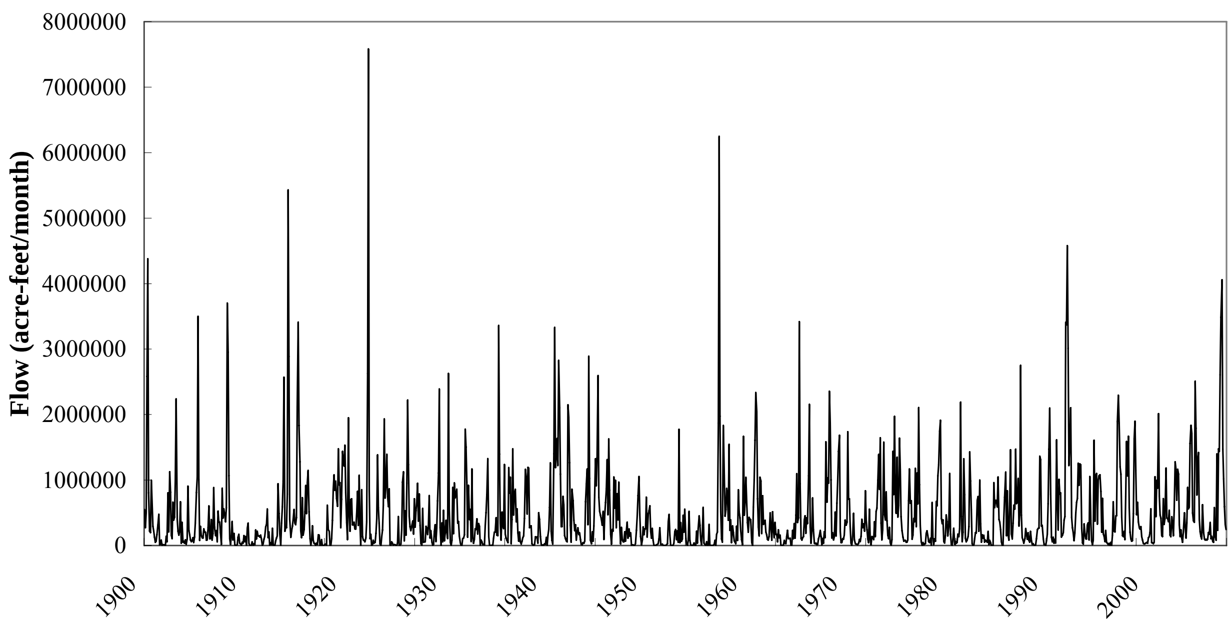

Figure E.94 Monthly BRAC8 Inflows at BRRO72 − Brazos River at Rosharon Gage

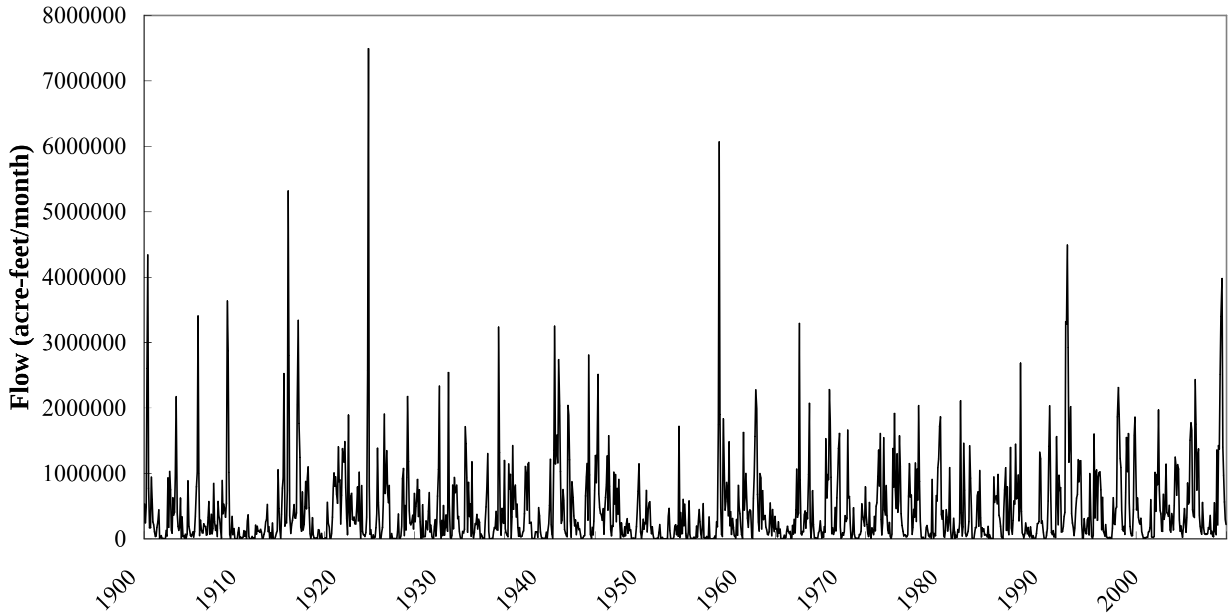

Figure E.95 Monthly BRAC3 Inflows at BRGM73 − Brazos River Outlet at Gulf of Mexico

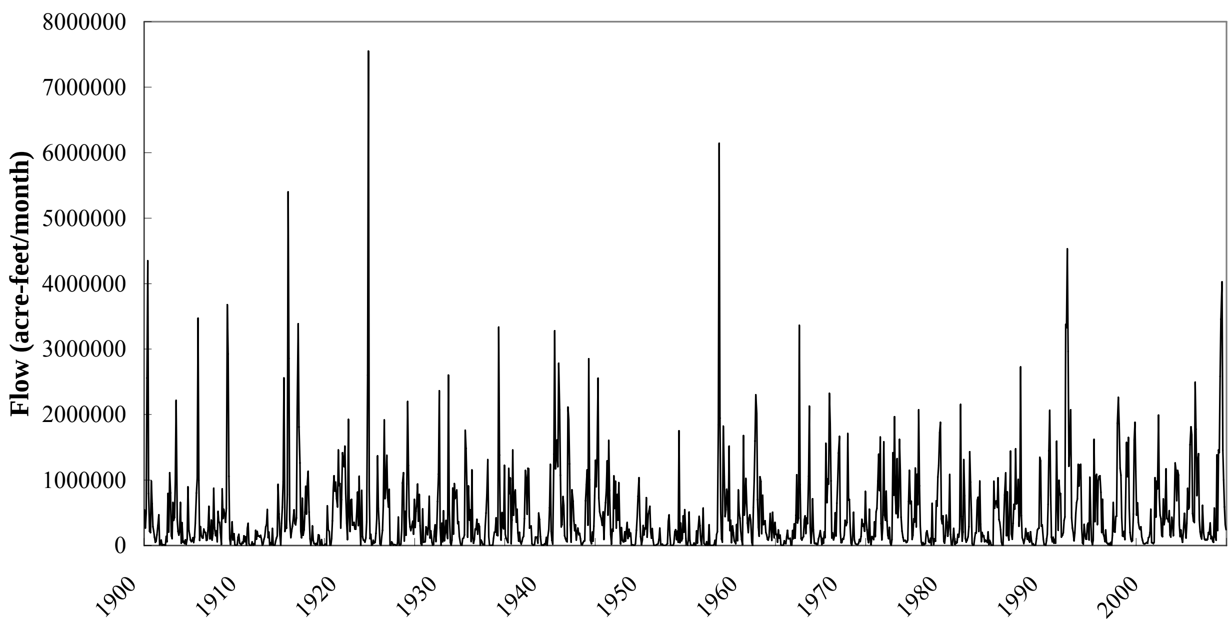

Figure E.96 Monthly BRAC8 Inflows at BRGM73 − Brazos River Outlet at Gulf of Mexico