WATER MANAGEMENT PLAN

FOR THE

LOWER COLORADO RIVER BASIN

EFFECTIVE SEPTEMBER 20, 1989

INCLUDING

AMENDMENTS APPROVED BY
TEXAS COMMISSION ON ENVIRONMENTAL QUALITY
THROUGH JANUARY 27, 2010

AND

DROUGHT CONTINGENCY PLAN CHANGES
APPROVED BY THE LCRA BOARD OF DIRECTORS
THROUGH JUNE 16, 2010

DEDICATION

This revision of LCRA's Water Management Plan
is dedicated to Dr. Quentin W. Martin (1946-2003).

TABLE OF CONTENTS

Chapter **Page**

Tables

Figures

Volume I Appendices

Volume II Appendices

VOLUME 1

WATER MANAGEMENT PLAN
FOR THE LOWER COLORADO RIVER BASIN

PREFACE

A. Background

The "business" of water resources management in Texas, and throughout the nation, is in the midst of transition and transformation. The transition is largely the result of ever increasing demands and competition for renewable but limited water supplies and a growing awareness of the limits of "traditional" water supply management strategies. Additionally, the spectra of long-range shifts in global climatic patterns have injected a new element of uncertainty in water resources planning and management. Clearly, the past may no longer be a valid guide to the future.

In response to new challenges and uncertainties, it is imperative that water management institutions, at all levels, adopt a balanced, flexible, and feasible approach that gives due weight to all the conflicting demands on the water, including the heavy economic dependence of the farmers on historic uses of irrigation water, rapidly emerging public interest in recreation, and environmental values. The challenge is to recognize both the historic uses and the forces of change, transform emerging problems into new opportunities, and guide the institutions of water resources management toward a new era where clean water in Central Texas is recognized as a scarce commodity.

On April 20, 1988 Judge J. F. Clawson of the 264th Judicial District of Bell County, Texas, signed the Final Judgment and Decree relating to LCRA's and the City of Austin's respective water rights. (See Appendix 1A, Volume II).[1] This settlement was the product of a long series of negotiations among LCRA, the City of Austin, and the Texas Water Commission (TWC), predecessor agency of the Texas Commission on Environmental Quality (TCEQ).

---

[1] The Appendices for Volume II of the Water Management Plan are also being updated at this time.

Under the Final Judgment and Decree, LCRA was granted the right to use 1,500,000 acre-feet annually from Lakes Buchanan and Travis. As part of this settlement LCRA was required to determine the Combined Firm Yield of both Lakes Buchanan and Travis. An interim level of Combined Firm Yield of 500,000 acre-feet was established by the Texas Water Commission (TWC) (predecessor to TCEQ) with an understanding that LCRA would establish the basis for the Combined Firm Yield calculation and submit it to the TWC. The amount of water available for use in excess of the Combined Firm Yield is considered interruptible water and may be sold only on an interruptible basis subject to annual availability and certain rules and conditions required by the TWC.

The purpose of this document, Water Management Plan for the Lower Colorado River Basin (WMP), is to define LCRA's water management programs and policies in accordance with these requirements.

The WMP is not a static document. As LCRA's blueprint for its operation of the Lakes Buchanan and Travis, the WMP is periodically revised to reflect changes in water demands. The last revision was completed by LCRA in February 1997 and approved by the Texas Natural Resources Conservation Commission (TNRCC) (predecessor to TCEQ) in 1999 (herein referred to as the 1999 WMP). The present revision was submitted to TCEQ in May 2003 and approved by TCEQ on January 27, 2010. The most notable changed condition over the last five years has been a significant increase in projected municipal and industrial (firm) water demands. With this large projected increase in firm water demand, the WMP must be adjusted to give a compensating reduction in the interruptible stored water supplies available since firm water demands take priority. This reduction will be achieved by revising the annual interruptible stored water supply curtailment policy adopted in this WMP. Revisions to the WMP require approval by LCRA's Board of Directors, followed by approval by the TCEQ. Such revisions become amendments to LCRA's water rights for Lakes Buchanan and Travis.

The allocation of water to various types of use in the WMP is also reviewed on an annual basis by LCRA. LCRA will continue to provide to the TCEQ an Annual Report on or before March 1.

B. Executive Summary

1. Legal Authority

The legal authority underlying the development of the WMP is derived from four principal sources:

(1) The Final Order of Adjudication of the water rights of the Lower Colorado River Authority;
(2) The Enabling Act of the Lower Colorado River Authority;
(3) General law of the State of Texas, particularly the Texas Water Code; and
(4) The water policies of the Lower Colorado River Authority Board of Directors.

In combination, the authorities establish and define LCRA's responsibility to develop and implement a WMP. In particular, the final adjudication of LCRA's water rights includes provisions relating to the manner in which LCRA will manage the Highland Lakes and the Colorado River above and below the Highland Lakes and directed LCRA to prepare and submit a proposed WMP to the Texas Water Commission, predecessor agency to the TCEQ. This document was initially developed and is periodically revised by LCRA pursuant to that directive.

2. Summary of Water Management Plan

a. Key Elements of the Water Management Plan

The key elements of the WMP include the following:

(1) Lakes Buchanan and Travis and the Colorado River will be managed together as a single system for water supply purposes.

(2) LCRA will manage the system to maximize the beneficial use of water derived from inflows below the Highland Lakes.

(3) LCRA will manage the system to stretch and conserve the waters stored in Lakes Buchanan and Travis.

(4) All demands for water from the Colorado River downstream of Lakes Buchanan and Travis should be satisfied to the extent possible by run-of-river flows of the Colorado River.

(5) Inflows should be passed through Lakes Buchanan and Travis to honor downstream senior water rights only when those rights cannot be satisfied by the flow in the river below the Highland Lakes.

(6) The firm, uninterruptible commitments of water from Lakes Buchanan and Travis should not exceed the Combined Firm Yield.

(7) The water from Lakes Buchanan and Travis will be available on an interruptible basis as long as LCRA's ability to meet the demand for firm water is not impaired.

(8) Water shall not be released through any dam solely for hydroelectric generation, except during emergency shortages of electricity, and during other times that such releases will be needed for another beneficial purpose.

(9) Competing demands on the system include water quality matters, flood control, water supply, recreation and tourism, hydroelectric power, instream flows and bays and estuaries.

(10) The Combined Firm Yield of Lakes Buchanan and Travis is determined to be 535, 812 acre-feet, including that portion allocated to O.H. Ivie Reservoir, which is owned and operated by the Colorado River Municipal Water District.

(11) To supply existing firm water commitments, including commitments to the environment as proposed herein and the allocation of firm water to O. H. Ivie Reservoir, during a repetition of the critical drought would require an average of 442,350 acre-feet per year to be released, diverted, or otherwise committed from storage in Lakes Buchanan and Travis.

(12) LCRA's Board of Directions has reserved 50,000 acre-feet of the remaining Combined Firm Yield of Lakes Buchanan and Travis for the future needs within LCRA's 35-county water service area, particularly those areas now using ground water supplies that are becoming depleted or are of poor water quality.

(13) The four downstream irrigation operations (Gulf Coast, Lakeside, Garwood and Pierce Ranch) will have first priority for all the interruptible stored water in the annual allocation process to the extent of their Conservation Base acreage or Priority Allocation acreage, whichever applies.

(14) In recognition of the importance of recreation and tourism demands, additional sales of interruptible stored water, other than for the four irrigation operations pursuant to a semiannual allocation, will be limited based on the volume of water in Lakes Buchanan and Travis. The supply of interruptible stored water available for the January through June period will be based on the January 1 storage levels in Lakes Buchanan and Travis taken separately. The supply for the July through December period will be based on the minimum of the maximum storage levels in April, May and June in Lakes Buchanan and Travis taken separately. No sales will occur if either lake is less than 94% of its maximum conservation capacity. If both lakes are at their maximum conservation capacity as calculated above for either six-month period then such interruptible stored water sales will be limited to a total of 30,000 acre-feet for that year. For projected lake volumes between 94% and 100% of conservation capacity, such interruptible stored water sales will be limited proportionately, based on the storage reservoir with the lowest percentage of capacity on January 1 as calculated above.

(15) Instream flow needs will be met by the release of stored water from Lakes Buchanan and Travis to maintain the daily river flows at no less than the critical instream flow needs in all years. Daily river flows will be maintained at the target instream flow needs in those years when the four major irrigation operations are not curtailed, to the extent of inflows each day to the Highland Lakes as measured at the upstream streamgages. Releases of stored water will be a combination of firm and interruptible water supplies. Firm stored water will be supplied in years when the four major

irrigation operations' interruptible stored water supplies are curtailed. Interruptible stored water will be supplied in all other years. Total commitments of the Combined Firm Yield from Lakes Buchanan and Travis for instream flow maintenance will be an <u>average</u> of 27,380 acre-feet per year, with a <u>maximum</u> of:

(a) 51,100 acre-feet in any one year;
(b) 85,700 acre-feet in any two consecutive years;
(c) 114,200 acre-feet in any three consecutive years;
(d) 147,700 acre-feet in any four consecutive years;
(e) 184,500 acre-feet in any five consecutive years;
(f) 212,200 acre-feet in any six consecutive years;
(g) 246,500 acre-feet in any seven consecutive years; and
(h) 273,800 acre-feet in any eight to ten consecutive years.

(16) Bays and estuary needs will be met by releasing monthly stored water from Lakes Buchanan and Travis to meet target inflow needs of 1.03 million acre-feet per year if January 1 storage level in Lakes Buchanan and Travis combined is greater than 1.7 million acre-feet. Critical inflow needs of 171,120 acre-feet per year will be met in all years with releases of stored water from Lakes Buchanan and Travis. In years when the January 1 combined storage in Lakes Buchanan and Travis is less than 1.7 million acre-feet but greater than 1.1 million acre-feet (*i.e.* 86% and 55% full, respectively), one hundred and fifty percent (150%) of critical inflow needs (256,680 acre-feet per year) will be met, subject to the available monthly storable inflows into Lakes Buchanan and Travis. Releases of stored water will be a combination of firm and interruptible water supplies. Firm stored water will be supplied in years when the four major irrigation operations' interruptible stored water supplies are curtailed. Interruptible stored water will be supplied in all other years. Total commitments of the Combined Firm Yield from Lakes Buchanan and Travis for bays and estuaries (estuarine inflows) will be an <u>average</u> of 6,060 acre-feet per year, with a <u>maximum</u> of:

(a) 20,660 acre-feet in any one year;
(b) 23,570 acre-feet in any two consecutive years;
(c) 23,680 acre-feet in any three consecutive years;
(d) 32,220 acre-feet in any four consecutive years;
(e) 40,800 acre-feet in any five consecutive years;
(f) 41,400 acre-feet in any six consecutive years;
(g) 47,800 acre-feet in any seven consecutive years; and
(h) 60,600 acre-feet in any eight to ten consecutive years.

(17) The total <u>firm</u> stored water commitment for both environmental purposes will be an average of 33,440 acre-feet per year. Estimated interruptible stored water supplied

during the critical drought for both purposes will be an additional 23,030 acre-feet per year.

b. Key Elements of the Drought Management and Drought Contingency Plans

The key elements of the Drought Management and Drought Contingency Plans (DMP/DCP) include the following:

(1) A 10-year time period from 2000-2010 is the time frame for the DMP/DCP.

(2) The DMP/DCP establishes criteria for the curtailment of stored water that is committed through contract or by LCRA Board resolution.

(3) Establishes a criteria for interruptible stored water supply curtailments that protects firm demands, establishes a Reserve Storage Pool, and provides for gradual curtailment in order to protect the full demand of first crop rice in all years of the critical drought.

(a) Open Supply - If the total January 1 storage in Lakes Travis and Buchanan combined is equal to or greater than 1,400,000 acre-feet, then LCRA will supply all interruptible stored water demands. This assumes 273,000 acre-feet of interruptible storage water is sufficient to irrigate a total of 83,700 acres within the four irrigation operations, with seventy percent (70%) of that acreage being irrigated for a ratoon, or second, crop of rice.

(b) Curtailment occurs in stages when the combined storage in Lakes Buchanan and Travis on January 1 is less than 1.4 million acre-feet and greater than 325,000 acre-feet. If combined storage on January 1 is between 1.4 million acre-feet and 1.15 million acre-feet, the interruptible stored water supply available will vary beginning at 273,000 acre-feet available at 1.4 million acre-feet of storage and decreasing at a rate of approximately 31,200 acre-feet for each 100,000 acre-foot decrease in combined storage until a value of 195,000 acre-feet available at a combined storage of 1.15 million acre-feet. When the combined storage in Lakes Buchanan and Travis on January 1 is less than 1,150,000 acre-feet, the interruptible stored water supply available will vary beginning at 195,000 acre-feet available at 1.15 million acre-feet of storage and decreasing at a rate of approximately 4,250 acre-feet for each 100,000 acre-foot decrease in combined storage until a value of 160,000 acre-feet available at a combined storage of 325,000 acre-feet.

(c) Cutoff of interruptible supply for the coming year occurs when combined storage in Lakes Buchanan and Travis on January 1 is less than or equal to 325,000 acre-feet.

(d) Review and cancel the curtailment of interruptible stored water for the irrigation operations at any time during the year prior to July 31, if the combined storage in Lakes Buchanan and Travis is projected to be equal to or greater than 1.4 million acre-feet anytime in July.

(e) Reserve Storage Pool - Cutoff of all interruptible supplies when combined storage in Lakes Buchanan and Travis is less than or equal to 200,000 acre-feet.

(f) Allow each irrigation operation the option of a fixed maximum amount of interruptible stored water or all the water necessary to cultivate a maximum acreage agreed upon by the operation and LCRA.

(g) LCRA encourages its firm water customers to implement long-term water conservation measures year-round to meet the goals included in their water conservation plans. LCRA will implement a public awareness campaign on water use and conservation.

(h) Whenever total storage in Lakes Buchanan and Travis is at or below 1.4 million acre-feet, LCRA requests its firm water customers implement the voluntary water use reduction measures contained in their drought contingency plans, with a target reduction goal of five percent.

(i) Whenever the total storage in Lakes Buchanan and Travis is at or below 900,000 acre-feet, LCRA will ask all its firm water customers to implement mandatory water use reduction measures in their drought contingency plans, with a target reduction goal of 10 - 20 percent. LCRA will also begin discussions with firm water customers to develop a specific stored water curtailment plan, to be approved by the LCRA Board and TCEQ.

(j) During a drought more severe than the Drought of Record, LCRA will implement a mandatory pro rata curtailment of a minimum of twenty percent among all of its firm water supply customers according to the amount of firm water to which they are legally entitled under the terms of their contract and consistent with the curtailment plan approved by the LCRA Board and TCEQ. If lake levels continue to drop below 600,000 acre-feet, the mandatory pro rata curtailment percentage may be increased as determined by the LCRA Board. All uses of interruptible stored water will be totally cutoff prior to and during any mandatory curtailment of firm stored water customers.

(k) Require legally enforceable local drought contingency plans for LCRA firm water customers and the four major irrigation operations.

TABLE P-1, below, summarizes these plan elements.

TABLE P-1. DROUGHT CONTINGENCY PLAN SUMMARY TABLE

	A	B	C	D	E	F	G	H
	Drought Response Levels and Stages	**Water Use Reduction Goals**	**Water in Storage (acre-feet)**	**Status (Date)**	**Actions Affecting Interruptible Supplies**	**Actions Affecting Firm Supplies**	**Actions Affecting Instream Flows**	**Actions Affecting Matagorda Bay Freshwater Inflows**
1			**Full**	January 1	Full Supply ↓	Full Supply **Voluntary Conservation; Public Awareness Campaign**	1. Full Supply for Critical Needs 2. Supply for Target Needs Limited to Storable Inflows	Supply for Critical and Target Needs Limited to Storable Inflows ↓
2			**N/A**	January 1 or July 1 – Other customers (either Lake Travis or Buchanan less than 94% full)	1. Interruptible Supplies Cease for All Customers Except Four Major Irrigation Operations 2. Full Supply for Four Major Irrigation Operations	↓	↓	↓
3			**Less than 1,700,000**	January 1	↓	↓	↓	1. Supply 150% of Critical Needs Limited to Storable Inflows 2. Cease Meeting Target Needs
5	**Firm Stage 1: Voluntary Conservation** **Interruptible Level 1: Initial Curtailment**	**5% of firm demand** ***0-30% of interruptible demand**	**Less than 1,400,000**	January 1 At Any Time – Conservation	Begin Curtailment for Four Major Irrigation Operations with interruptible stored water ranging from 273,000 acre-feet available at storage of 1.4 million acre-feet to 195,000 acre-feet at storage of 1.15 million acre-feet	Full Supply Begin Voluntary Drought Measures	1. Full Supply for Critical Needs Only 2. Cease Meeting Target Needs ↓	
6	**Interruptible Level 2: Steeper Curtailment**	***30-40% of interruptible demand**	**Less than 1,150,000**	January 1	Continued Curtailment for Four Major Irrigation Operations with interruptible stored water ranging from 195,000 acre-feet at storage of 1.15 million acre-feet available to 160,000 acre-feet at storage of 325,000 acre-feet		↓	
7	*NOTE: Interruptible water use reductions are built-in to the interruptible stored water curtailment schedule.							

TABLE P-1. DROUGHT CONTINGENCY PLAN SUMMARY TABLE

	A	B	C	D	E	F	G	H
	Drought Response Levels and Stages	**Water Use Reduction Goals**	**Water in Storage (acre-feet)**	**Status (Date)**	**Actions Affecting Interruptible Supplies**	**Actions Affecting Firm Supplies**	**Actions Affecting Instream Flows**	**Actions Affecting Matagorda Bay Freshwater Inflows**
8			**Less than 1,100,000**	January 1 - Environmental Flows At Any Time - Conservation	↓	↓		Supply Only for Critical Needs Limited to Storable Inflows
9	**Firm Stage 2: Requested Mandatory Conservation**	**10-20% of firm demand**	**Less than 900,000**	At Any Time During Year	↓	Full Supply Request Mandatory Drought Restrictions Meet with Firm Customers to Develop Curtailment Plan TCEQ and LCRA Board Approve Curtailment Plan		↓
10	**Firm Stage 3: Pro-Rata Curtailment**	**20% or more of firm demand**	**Less than 600,000** If Drought Worse Than Drought of Record*	At Any Time During Year	Interruptible Supplies Cease, Unless Drought Less than 36 Months in Duration, then Interruptible Supplies Cease No Earlier than Following July 31 or Jan. 1, which ever comes first	Curtail Firm Customers on Prorata Basis with Other Firm Users According to Approved Plan	Curtail on Prorata Basis with Other Firm Users	Curtail on Prorata Basis with Other Firm Users
11	**Interruptible Level 3: Cutoff Supplies**	**100% of interruptible demand**	**Less than 325,000**	January 1	Interruptible Supplies Cease	↓	↓	↓
12	**Interruptible Level 4: Cutoff Supplies**	**100% of interruptible demand**	**Less than 200,000**	At Any Time During Year	↓	↓	↓	↓
13	***NOTE:** Drought Worse than Drought of Record defined by all of the following conditions occurring simultaneously at any time: 1. Combined Storage in Lakes Travis and Buchanan being less than 600,000 acre-feet. 2. Drought duration of at least 24 months. 3. The cumulative inflow deficit of the current drought exceeding that of the drought of record by at least 5% for a minimum of six consecutive months. 4. Declaration of the LCRA Board based on all three of the above conditions occurring simultaneously.							

C. Definitions

To understand the WMP, it is important to know the definitions of the key legal and hydrologic terms used in this plan. The major terms are defined below and should be considered specific to LCRA.

adjudication - a court proceeding to determine all rights to the use of water on a particular stream system.

beneficial use of water - use of the amount of water that is economically necessary for a purpose authorized by law, when reasonable intelligence and reasonable diligence are used in applying the water to that purpose. Such uses include domestic use, municipal uses, industrial use, agricultural use, hydroelectric power, navigation, fish and wildlife, etc. The benefit may vary from one location to another and by custom. Beneficial uses are defined by statute in the Texas Water Code.

combined firm yield - a specific amount or quantity of water stated in acre-feet that represents the maximum average annual demand that can be met from a reservoir system during a simulation of a repetition of the system's Drought of Record, while honoring the full extent of upstream and downstream senior water rights.

conservation base acreage - the historical 10-year average acres irrigated at a total of 5.25 acre-feet of water per acre irrigated.

curtail - to reduce the supply of water being provided through a diversion by reducing the amount of water served under the contract for a specific period of time. Curtailment may occur during drought or other emergency conditions.

critical drought period - the period of time during which the reservoir system was last full and refilled, and the storage content was at its minimum value.

cutoff(water) - to discontinue, or to terminate completely, the supply of water provided under contracts for diversion for a certain period of time. Cutoff may occur during drought or other emergency conditions.

diversion demand - the water pumped from a water body for beneficial use.

domestic water use –use of water by an individual or a household to support domestic activity. Such use may include water for drinking, washing, or culinary purposes; for irrigation of lawns, or of a family garden and/or orchard; for watering of domestic animals; and for water recreation including aquatic and wildlife enjoyment, but does not include water used to support activities for which consideration is given or received or for which the product of the activity is sold.

drawdown - the lowering of the water level in a water body by diversion, pumping, or release.

drought - a prolonged period of dryness or lack of rainfall that has a significant effect on water or water-related uses.

drought of record - the drought that occurred during the critical drought period.

firm water - a supply of stored water that is drawn from the combined firm yield of the reservoir system. Such supplies are diverted or otherwise committed under a contract or resolution issued by the LCRA Board.

firm yield - the maximum average annual supply of water that can be supplied from a water source without shortages during a repetition of the critical drought period.

gaging station - particular site on a stream, canal, or lake where systematic observations of hydrological data are obtained.

instream flow - the specific amount of water needed to flow in a stream or river to support aquatic life, minimize pollution, or for recreational use, usually stated as a daily mean discharge values in cubic feet per second.

interruptible stored water - stored water supplied pursuant to contract or resolution, where the contract, resolution or special conditions defining the commitment specifically provides that such commitment is "subject to interruption or curtailment."

irrigation - The use of water for the irrigation of crops, trees, and pasture land, including, but not limited to, golf courses and parks, which do not receive water through a municipal distribution system.

reserve storage pool - a storage level that, when reached at any time during the year, would require the total cutoff of all water for interruptible use.

run-of-river flows - the natural flow in the river that is available under law at a given point on the river at a given instant in time to honor a right with a given priority date. This flow is determined by hydrologic studies that assume that all reservoirs and diversions under upstream junior rights do not exist. Rights to use run-of-river flows for beneficial uses, rights to store inflows in reservoirs, and pass-through of inflows and releases from reservoirs, are regulated by the TCEQ.

storable inflows - the actual daily inflows to the reservoir system minus the daily pass throughs from the reservoir system required to meet downstream senior water rights.

storage capacity - the quantity of water that can be contained in a reservoir.

streamflow - rate of flow of water that occurs in a natural channel.

water conservation - those practices, techniques, and technologies that will: (1) reduce the consumption, loss or waste of water, (2) improve the efficiency in the use of water, or (3) increase the recycling and reuse of water, so that a water supply is made available for future or alternative uses.

water right - a legally protected right, granted by law, to impound, divert, convey, or store state water and put it to one or more beneficial uses.

CHAPTER 1
INTRODUCTION TO THE WATER MANAGEMENT PLAN

A. Goals of the Water Management Plan

The 1988 Final Judgment and Decree adjudicating LCRA's Highland Lakes water rights required LCRA to submit a reservoir operations plan describing how LCRA would determine the amount of firm and interruptible stored waters and how LCRA would manage the waters in Lakes Buchanan and Travis and the Colorado River. The Water Management Plan for the Lower Colorado River Basin (WMP) was developed using the following goals and guidelines as provided in the Final Judgment and Decree:

1. Lakes Buchanan and Travis and the Colorado River will be managed together as a single system for water supply purposes.

2. LCRA will manage the system to maximize the beneficial use of water derived from inflows below the Highland Lakes.

3. LCRA will manage the system to stretch and conserve the waters stored in Lakes Buchanan and Travis.

To achieve the goals stated above, LCRA will manage the system according to the following guidelines:

1. All demands for water from the Colorado River downstream of Lakes Buchanan and Travis should be satisfied to the extent possible by run-of-river flows of the Colorado River;

2. Inflows should be passed through Lakes Buchanan and Travis to honor downstream senior water rights only when those rights cannot be satisfied by the flow in the Colorado River below the Highland Lakes;

3. The firm, uninterruptible commitments of water from Lakes Buchanan and Travis should not exceed the Combined Firm Yield;

4. The water from Lakes Buchanan and Travis will be available on an interruptible basis as long as LCRA's ability to meet the demand of its firm water customers is not impaired;

5. Water shall not be released through any dam solely for hydroelectric generation, except during emergency shortages of electricity and during other times that such releases will be needed for another beneficial purpose.

B. LCRA Act

Through the passage of the LCRA Act by the Texas Legislature in 1934, LCRA was established as a "conservation and reclamation district" consisting of ten counties that comprise the watershed of the lower Colorado River. Those ten counties are Blanco, Burnet, Fayette, Colorado, Llano, Travis, Bastrop, Wharton, San Saba, and Matagorda. The LCRA Act was amended in 1993 to expand LCRA's water service area to include all or part of an additional twenty-four counties. In 1999, the LCRA Act was amended to include Williamson County in LCRA's water service area and was again amended in 2001 to allow LCRA to enter into an agreement with the San Antonio Water System (SAWS) to provide water. LCRA's current water service area is depicted in Figure 1-1. The 1999 amendment contains specific restrictions on LCRA water sales to Williamson County. Similarly, the 2001 amendment contains very lengthy and detailed restrictions and study requirements prior to any transfer of water to SAWS. The Highland Lakes system is comprised of two water storage reservoirs, Lakes Buchanan and Travis, and three intermediate pass-through reservoirs, Lakes Inks, LBJ and Marble Falls. Lake Austin, the last of the lakes in the chain, is owned by the City of Austin but operated by LCRA under agreement and may be referred to as part of the system from time to time. Technical data on each of the dams and lakes is included in Appendix 2A of Volume II.

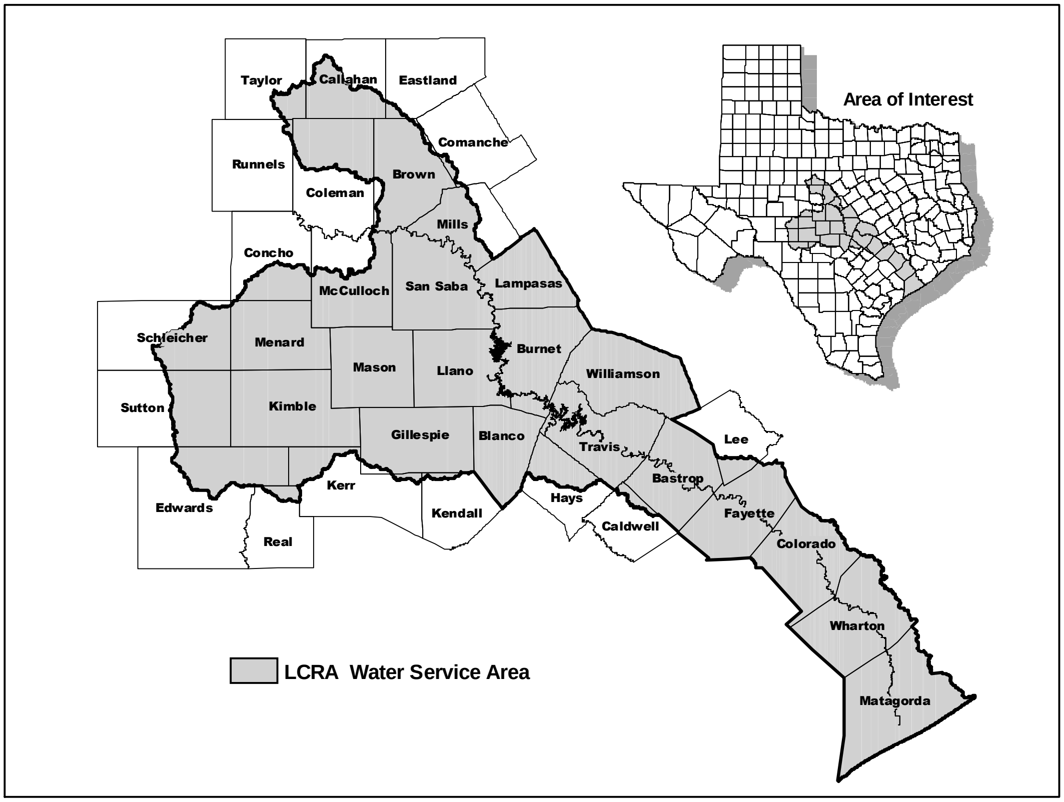


Figure 1-1. LCRA Water Service Area as of January 1, 2003.

LCRA has been delegated the responsibility of harnessing the Colorado River and its tributaries and making them productive for the people within LCRA's water service area.

The Act establishes LCRA's mission in four areas--water, electric energy, conservation and lands. In water, LCRA is empowered to control floods and control, store, sell, preserve and distribute the waters of the Colorado River and its tributaries. The waters are to be used for beneficial purposes including irrigation, generation of electric energy, reclamation of arid lands and the creation of lakes for water storage. LCRA is required to prevent flood damage to people and property by the Colorado River and to control the uses of the surface of the lakes it created.

Consistent with the control of the waters, LCRA is empowered to develop, distribute, and sell the energy created through hydroelectric generation both inside and outside the 10-county district. Later legislation allowed LCRA to expand its electric generation capabilities beyond hydropower through developing fossil fuel generation facilities.

As a conservation and reclamation district, LCRA is to conserve and develop the lands, forests and water of the district and to study and correct both artificial and natural sources of pollution that may affect the ground and surface waters within the district. LCRA is also empowered to provide water and wastewater treatment services within the district.

During the construction of the dams and development of the Highland Lakes system LCRA acquired large tracts of land that surround the reservoir system. The Act authorizes LCRA to develop, manage, and promote the use of these lands for parks, recreational facilities and natural science laboratories and to promote the preservation of fish and wildlife. LCRA must also provide public access to, and use of, its lakes and lands for recreation.

Each of the many purposes, functions, and uses of the elements of the river—the lakes, the lands, the ground and surface waters, the bays and estuaries—must be considered as parts of an integrated system.

The WMP describes the issues and conflicts that LCRA must recognize and, where possible, resolve.

C. LCRA Water Resources Management – History and Guiding Principles

It is important to consider the historical context in which this WMP has evolved. In the early years of LCRA's existence, the predominant priorities in water resources management were to moderate and control the floods and droughts in the Lower Colorado River Basin. This was accomplished through the construction of dams in the Hill Country west of Austin, which created the Highland Lakes.

The results have been impressive. The ravages of floodwaters have largely been controlled. These same dams have also provided a dependable source of water supply for municipal, industrial, agricultural, and mining uses. Additionally, the Highland Lakes provided the source of inexpensive, renewable electrical energy, and recreational opportunities for the citizens and communities of Central Texas. In sum, the work of LCRA in its early years provided the foundation on which much of the present day population and economy of Central Texas depend.

Notwithstanding the successes of the past, in developing a WMP for the river, LCRA today faces an array of water management issues and opportunities that were scarcely envisioned a half-century ago. Recreation has emerged as a major use, both on the lakes and the river. Maintaining the aquatic habitat in the river channel and in the bays and estuaries is a major use, as is water quality and the use of the river to sustain a growing population and economy. This intensified competition among the various users of the water resource is placing increasing stress on the ecological and environmental resources supported by the Colorado River. LCRA, in partnership with the State of Texas, local governments, and private interests, must confront these challenges as we develop a meaningful WMP.

LCRA's WMP is grounded in these key principles:

(1) LCRA recognizes the supremacy of the State of Texas, acting through the TCEQ, as the ultimate authority for water resources management and as the arbiter of disputes involving the allocation of water from the Colorado River and its tributaries. LCRA, within the intent and meaning of its legal authority, is the steward of the water rights granted to it by the State of Texas. Further, LCRA recognizes the responsibilities and prerogatives conferred upon local political subdivisions of the State and the rights of private citizens and corporations.

(2) Many water management issues and opportunities are regional in scope and effect. Solutions and strategies must be built upon regional consensus and action. LCRA considers its role as one of consensus-building among competing users of Colorado River water and among the public and private interests concerned with the management of the Colorado River.

(3) LCRA, in exercising its responsibilities as a steward of the water resources of the Colorado River and its tributaries, will strive to maximize the beneficial use of Colorado River water and achieve a sustainable balance among the competing demands on the system. In pursuing this objective, LCRA will implement management procedures and programs addressing:

(A) The efficient management of available water supplies as an integrated system;
(B) Water demand management measures including long-term conservation measures and short-term drought contingency measures;
(C) Protection and, where possible, enhancement of water-related environmental values; and
(D) Future water supply development and augmentation.

D. LCRA's Comprehensive Water Policy Review and Public Stakeholder Process

LCRA has approached the development of the WMP as much more than a set of complex engineering tools to serve as guidelines for operating the structures on the Colorado River system. The development of the WMP stimulated a comprehensive review of how LCRA has developed and operated the Highland Lakes and the lower Colorado River system for the past 60 years to meet the needs of the area it serves.

As a foundation for the prior versions of the WMP, LCRA conducted a comprehensive review of the policies and programs that guide and shape the way LCRA manages the river system. This review was conducted as a series of meetings held as joint public meetings of the LCRA Board's Planning and Public Policy and Natural Resources Committees. The meetings were designed to use staff expertise and information from outside experts to analyze the environmental, social, economic and legal factors that shape the issues that LCRA faces in managing the Colorado River system.

An important part of these public meetings was the involvement of the State agencies, environmental groups, business, industry and agricultural interests, wholesale electric customers and other constituencies whose interests are affected by LCRA policies. The process was designed to assure that participation was effective in informing LCRA of public views and also so that these constituencies would be better informed about the issues involved in the policy decisions. An issues inventory was developed and briefing papers were prepared for each of the meetings. Summaries of the meetings elements were developed and distributed to the LCRA Board and members of the public.

As a result of the Board and the public review, LCRA adopted a set of water and flood control policies to address many of the issues in water quality and water supply that face LCRA today and will continue to face the agency well into the future. These policies undergo periodic review and revision by the LCRA Board. (See Appendix A, Volume I for the most current versions of these policies).[1] These policies, read in conjunction with LCRA's Certificates of Adjudication for the Highland Lakes, have formed the foundation of LCRA's WMP.

In developing the initial WMP and all of its subsequent revisions, LCRA has sought broad public participation through the work of an Advisory Committee and a series of public information and input meetings in the LCRA district. The Advisory Committee included over two dozen representatives from varied interests in the river basin. Taking part in the process were State and local officials, rice farmers, representatives of tourism and recreation interests, coastal sports and commercial fishing interests, business and industry and economic development representatives and environmental interest group leaders. The other major water right holders on the Lower Colorado River were also active participants on the Advisory Committee.

The purpose of the Advisory Committee has been to provide information to LCRA on the attitudes and interests of the major organizations and groups concerned with the allocation and management of LCRA's water resources. LCRA management and staff appreciate the commitment of time and energy made by the Advisory Committee. The Advisory Committee has actively participated in the development of the technical studies and the analysis of the policy options during every revision of the WMP. In addition, they aided LCRA by providing information on the WMP to the public and the local news media. Many of the policy concepts and alternatives found in the WMP are the direct result of suggestions made by the Advisory Committee. However, neither the report as a whole, nor any portion thereof, necessarily reflects the views of the Advisory Committee or any member of the Advisory Committee.

E. Organization of the WMP

Volume I of the WMP is organized as follows:

(1) Chapters 1-3 of the WMP describe the issues and conflicts in the demands on the Colorado River system and lays out the policies and management actions LCRA will use to accommodate the variety of demands on the system.

(2) Chapter 4 of the WMP describes the issues and conflicts in the demands on the Colorado River system during drought periods and sets forth the policies and

[1] Since the WMP's last approval in 1999, the LCRA Board of Directors has amended or consolidated several of its policies related to water. Board Policy 502 "Interbasin Transfers" and Board Policy 504 "Water Resources Management" were repealed by the LCRA Board on June 21, 2000 and combined, with amendments, into Board Policy 501 "Water Resources Management," initially adopted on Aug. 18, 1999 and subsequently amended June 21, 2000, Sept. 18, 2002, and November 16, 2005. Board Policy 503 "Lowering of LCRA Operated Lakes" was amended on Oct. 20, 1999, Sept. 18, 2002, and October 20, 2004. Board Policy 507 "Water Quality Leadership" was amended on December 13, 2000. Board Policy 509 "Water Conservation" was last amended on June 21, 2000. Board Policy 508 "Water Pricing Policy" is included, but has not been amended since December 16, 1988, but a reformatted version of the policy is contained in this submission.

management actions LCRA will use to address the competing demands for water in times of shortage based on 2010 projected demands for water.

(3) Chapters 5-6 of the WMP describe the engineering and hydrological models and data sources and the process for the determination of the Combined Firm Yield of Lakes Buchanan and Travis.

Volume II of the WMP is a compilation of several technical appendices used to develop the WMP.

CHAPTER 2
MANAGING THE SYSTEM AMONG COMPETING DEMANDS

Demands on the Highland Lakes and the lower Colorado River system are many, varied, and often compete with one another. These demands are dynamic and will continue to evolve not only as the population grows throughout the region, but also as a result of changes in federal agricultural programs, the effectiveness of various conservation and reuse efforts, developments in our understanding of water needs for environmental purposes, and many other factors.

LCRA's reservoir system is designed to store waters from winter and spring rains and make that water available for use during the summer months for agricultural needs, water supply, and hydroelectric generation. During the summer months, these water demands cause a decline in the reservoir levels, thus providing storage for the next year's winter and spring rains. This type of operating pattern enables LCRA to serve a variety of functions with its reservoir system. It can also create conflicts among these functions. If the system's ability to meet all of these demands is to be maximized, compromises must be made among the competing demands.

LCRA must continually re-evaluate its WMP to assure that the competing demands are being met according to their priority within the framework of legal and financial constraints on the system. This chapter describes various demands on the system, the measures LCRA implements to address these various demands, and identifies those areas where further analysis is needed to adequately understand and address these various demands and the challenges they present.

A. Water Quality Issues and Demands

Everyone favors "clean water," but achieving an understanding of the value of water quality so that the necessary investments and efforts are made is a major challenge to LCRA's management responsibility. This is an issue in which every user of the river has an interest and responsibility. The problem areas are as follows:

1. Point Source Pollution

In managing the river system, LCRA must consider the impact of point sources of pollution entering the tributaries and the river, even though the TCEQ is the agency that establishes regulatory standards to control point sources of pollution. But even if a point source of pollution is lawful, the assimilation of sewage treatment plant wastes is a function and use of the lakes and the river for which no one pays in dollars and everyone pays in quality. During the low flow periods of the year, when LCRA is not releasing water for the agricultural operations downstream, the flows of the Colorado River below Austin are dominated by treated wastewater effluent discharged by the City of Austin, with such effluent sometimes comprising as much as 90 percent of the total flow. This condition is exacerbated during periods of low rainfall or drought that affect not only the quality of the river but also its aesthetic value. Downstream residents complain about the smell of the river and its loss of use for recreation, fishing, and as a water supply for grazing livestock.

During prior efforts to revise the WMP, many stakeholders raised concerns regarding LCRA's role in monitoring and reducing the volume and concentration of point source pollution. While water quality is an ongoing concern of LCRA, specific concerns regarding water quality impacts from point source discharges were not identified during the stakeholder process employed for the current revisions of the WMP. LCRA nonetheless actively monitors and, in some cases, actively participates in water quality permitting activities at the TCEQ that have the potential to affect the water quality in the lower Colorado River basin.

2. Nonpoint Source Pollution

Runoff from urban and agricultural areas, soil erosion, and leakages from faulty septic tank and waste dumps all represent nonpoint sources (NPS) of pollution. The EPA estimates that approximately 73 percent of the pollution in the nation's rivers is caused by nonpoint sources.

Due to the high quality of water in the Highland Lakes chain, there is great concern for preventing NPS pollution and maintaining this high quality of water for the future. The lakes serve as a source of drinking water for over a million citizens of the Austin-Travis County metropolitan area and all of its uses are enhanced by maintaining a high degree of purity.

While LCRA is encouraging and supporting economic development, tourism, and recreation activities in the Highland Lakes and the Colorado River downstream, there is the awareness that increased usage and development will result in more nonpoint source pollution unless effective controls are put in place.

The causes and sources of NPS pollution are dispersed and difficult to manage without broad public awareness and support. LCRA's Water Quality Leadership Policy requires effective implementation to control NPS pollution through research, monitoring, education, and the use of LCRA's ordinance making powers to prevent and control sources of nonpoint pollution within the 10-county district.

During this revision of the WMP, the nonpoint source pollution of the Colorado River was not identified as an issue of concern among the stakeholders. In past years, however, LCRA has received comments and letters of support regarding its efforts in nonpoint source pollution abatement from various interest groups. Although this issue was not specifically identified for attention in the WMP revision process, LCRA has continued its efforts to ensure that the Colorado River is not adversely affected by nonpoint source pollution through the enforcement of its own Nonpoint Source Ordinance and rules and through active participation in the TCEQ's Total Maximum Daily Load (TMDL) efforts in the Colorado River basin.

3. Soil Erosion and Sedimentation

Soil erosion and the resulting sedimentation in the Highland Lakes, the Colorado River, and its streams and tributaries is a cross cutting issue in water quality and water supply. The sedimentation in the lakes causes problems for boating and fishing. The build up of silt also reduces the storage capacity of the lakes for water supply and for holding floodwaters. Siltation downstream of the Highland Lakes in the river channel reduces the capacity of the river for holding flood releases. Both in the lakes and in the river, the silt in the water causes problems of turbidity or cloudiness, thus reducing the aesthetics of the water and may cause higher water treatment costs. This factor often shows up in LCRA's Water Quality Index and triggers lower ratings for many areas. Beyond increased turbidity, soil erosion can contribute to water quality problems by carrying pesticides, herbicides, and other pollutants into the water along with the soil particles.

4. Dissolved Oxygen Problems

The dissolved oxygen content of LCRA's releases of stored water through the hydroelectric turbines in the dams has caused water quality problems in the summer months. The deep lakes stratify during the warmer months of the year, which prevents replenishment of oxygen at the levels from which the turbines draw water. The passage of water with low levels of dissolved oxygen from one reservoir into another or into the river system can cause fish kills and reduce the assimilative capacity of the river system. In 2000, to address particular concerns below Mansfield Dam (Lake Travis), LCRA modified its hydroelectric turbines with a water aeration system that significantly enhances the levels of dissolved oxygen in the river below the dam.

5. Upstream Pollutants

Pollutants from the watershed upstream of the Highland Lakes and outside of LCRA's district can also affect the resources for which LCRA is responsible. An example of this is the inflows of high concentrations of salts in the water from seepage from natural springs and highly concentrated bodies of salty water in the upper watershed combined with high rainfall in the "salt water" basin. Abandoned unplugged oil wells may also be a cause of this problem. Remedial action has been taken by the Colorado River Municipal Water District (CRMWD), but the problem persists.

B. Flood Control Responsibilities

Flood control is one of the primary reasons for LCRA's existence. The series of dams and reservoirs from Buchanan through Mansfield contribute to the control of the lower Colorado River and the protection of lands and communities within the lower Colorado River basin. While all the dams and reservoirs aid in controlling and storing the waters of the Colorado, Mansfield Dam is the only designated flood control structure. Mansfield Dam flood storage space is between the elevation of 681 feet mean sea level (msl) and the spillway crest elevation of 714 feet msl, providing approximately 800,000 acre-feet of dedicated flood control storage. During flood control operations, Mansfield Dam is operated in accordance with regulations specifically developed for that facility by the U.S. Corps of Engineers, the U.S. Bureau of Reclamation, and LCRA and published in the Code of Federal Regulations (see Appendix B, Volume 1; 33 C.F.R.§ 208.19).

Over the years, as floods no longer ravaged the river basin washing out riverbanks and clearing away vegetation, the capacity of the channel to contain water releases, especially during flood conditions, has been reduced. U.S. Corps of Engineers rules require LCRA to limit the rates of releases during flood events in an attempt to minimize downstream flood damage. These limitations on allowed outflow from Lake Travis can result in increased water levels upstream of Mansfield Dam, which, in turn, may result in damage to properties around Lake Travis. This balancing problem is compounded by encroachments on the floodplains both upstream and downstream. Lake and river residents have built boathouses and structures into the floodplain and suffer property losses during flood occurrences. LCRA's management requires renewed efforts to remove encroachments and put people on clear notice that they are at risk.

The schedule by which floodwaters must be released from the flood control storage space between the elevations of 681 feet msl and 714 feet msl in Lake Travis is governed by the U. S. Army Corps of Engineers' Water Control Manual for Mansfield Dam. This release schedule was designed to minimize damages both downstream and upstream of the dam without endangering the safety of the dam. A brief description of this schedule is as follows:

RESERVOIR ELEVATIONS feet msl	RELEASE cfs
681 to 683	3,000
683 to 685	5,000
685 to 691	5,000 during Jan/Feb/Mar/ Apr/July/Aug/Nov/Dec 30,000 during May/June/Sept/Oct
691 to 710	30,000
710 to 714	50,000
714 to 722	90,000

LCRA maintains an active and continuous program to educate those members of the public who may be adversely affected by flooding along the lower Colorado River and the Highland Lakes. Moreover, during specific flood events, LCRA notifies individuals who may be affected and the general public about the flood and projected lake levels, gate operations, downstream flood stage projections, and other impacts.

LCRA believes that the existing policy of delicately balancing the adverse impacts of rising flood waters in the reservoir against the damages resulting from downstream flood releases is the best option.

C. Water Supply

Under the constraints specified in the Final Judgment and Decree, LCRA determined as part of its 1989 WMP that the Combined Firm Yield of Lakes Buchanan and Travis was 535,812 acre-feet per year. Of that amount, 90,546 acre-feet are allocated to O. H. Ivie Reservoir. The remaining 445,266 acre-feet are available to supply LCRA's current and future contractual commitments and agreements for firm water supply. The development of this Combined Firm Yield estimate is discussed in more detail in Chapter 5 of this document.

Currently, LCRA estimates that 368,364 acre-feet of firm stored water is already under contract or held in reserve to back up existing or new contracts for firm water, such as those held by the City of Austin and the STP Nuclear Operating Company. This comprises approximately 83 percent of the total 445,266 acre-feet of the Combined Firm Yield that is available for commitment (excluding that portion allocated to O. H. Ivie Reservoir).

With the exception of the City of Pflugerville, all of the municipalities downstream of Austin currently draw their water supplies from ground water sources. Ground water also supplies 40 percent of the agricultural irrigation in LCRA's service area. Upstream of Austin, the municipalities use a mixture of ground and surface waters.

As economic and industrial development increases, the demand for water increases. As other demands are more accurately determined, such as the fresh water needs in the bays and estuaries, the demands on the system are also likely to increase. LCRA is thus faced with the conflict between near-term demands and holding some remaining amount of the firm water in reserve for future users. The LCRA Board has attempted to address this conflict by reserving 50,000 acre-feet of firm water for future uses authorized under LCRA's certificates of adjudication within LCRA's water service area.

D. Water Demand

LCRA supplies water to two general categories of water demands: firm and interruptible. Firm demands presently include the water for municipal, domestic, industrial, steam-electric power generation, some irrigation, and instream flow and estuarine flow maintenance. Currently, interruptible stored water is used almost entirely for agricultural irrigation, specifically rice irrigation, and environmental flow maintenance. Detailed projected demands for 2010 are described in Chapter 4.

Year 2000 surface water demands within the lower Colorado River basin totaled approximately 675,800 acre-feet annually, including stored water released from Lakes Buchanan and Travis to maintain instream flows and freshwater inflows to the bay and estuary in the lower Colorado River (see Tables 4-2 and 4-3, *infra*). About 56 percent of surface water diversions are used for rice irrigation in the four major irrigation operations located in Colorado, Wharton, and Matagorda Counties. The next largest demand for surface water is the City of Austin, which in year 2000, used approximately 163,700 acre-feet for municipal use and steam-electric power generation under its own run-of-river rights and contracts for stored water from Lakes Buchanan and Travis.

1. Municipal and Domestic Water Demands

a. Municipal Demand

Municipal use includes water used by private residences, commercial establishments, public offices, industries, and institutions to the extent that such uses are included in the definition of municipal use as provided by the rules of the TCEQ. Eighty percent of the municipal use in LCRA's service area is in Travis County. The Austin area experienced rapid population growth during the early and mid 1980's and again in the 1990's. The Austin area is expected to show a steady growth over the long-term with the normal cycles of advances and pauses associated with economic growth.

The City of Austin's total diversion from Lake Austin and Lady Bird Lake for 2000 was 153,300 acre-feet. In 2000, approximately 65 percent of this demand was met through the City's own senior water rights. While much of the City of Austin's water is currently obtained from the Colorado River under the City's own water rights, especially during wet years, LCRA provides stored water from the Lakes Buchanan and Travis to back-up Austin's water rights under a series of contractual agreements. Also, some portion of the growth in the Austin area has occurred in areas served by municipal utility districts, LCRA's water utility, or other communities in Travis and Williamson Counties that purchase stored water from the lakes.

Over the long-term, Hays, Bastrop and Burnet Counties are forecasted to be the other three counties with the greatest gains in municipal use. This is due to their proximity to Travis County and the associated spillover of population growth and related services.

LCRA currently supplies water to about 50 water utilities, communities, and cities within LCRA's 10-county district, exclusive of Austin. The current annual demand of all these contracts is approximately 80,748 acre-feet per year.

At present, the City of Pflugerville is the only community downstream of Austin that is supplied water from the Combined Firm Yield of Lakes Buchanan and Travis for potable water use.

LCRA currently requires an approved conservation plan of its new water customers through its water contracts.

b. Domestic Water Use Demand

In August 2000, LCRA estimated that total diversions from the Highland Lakes for domestic water use (not including domestic water demands satisfied through a municipal water supplier) to be 4,536 acre-feet of water. Of this total, approximately 4,362 acre-feet (96%) is believed to be used for landscape irrigation. The remainder is believed to be used for cooking and washing (approx. 129 acre-feet), watering of domestic livestock (approx. 45 acre-feet), and recreational use.

2. Industrial Demands

Industrial demands include both water for manufacturing use and cooling water for electric power production other than hydroelectric generation.

a. Manufacturing Use

LCRA supplies water for various industrial uses within its 10-county statutory district. The water supply for these industrial uses is considered a firm demand on the system.

The largest current and projected manufacturing water users are located in Travis and Matagorda counties and account for slightly more than 80 percent of total manufacturing water use. Most of the manufacturing in Travis County is served by treated water from the City of Austin, which is considered to be municipal use under TCEQ rules. Growth in demand in this sector increased in the last decade, particularly in microelectronic manufacturing--a high water demand industry. Downstream, demand for industrial use has experienced modest increases in Matagorda County in the petrochemical industry.

LCRA has established programs for industrial water conservation and encourages existing and new industrial users to consider efficiency and direct re-use strategies for industrial processes.

b. Steam Electric Use

Much of the demand for steam electric use is from electric generating plants in Bastrop, Fayette, Llano, Matagorda, and Travis Counties. LCRA's own system of power plants makes up the largest demand for this sector at a current demand of about 22,000 acre-feet per year. Uses include total evaporative use, plant use and the addition of a reservoir at the Fayette Power Project (FPP). The second largest user, the South Texas Project (STP), is served by LCRA pursuant to a contract that provides the facility with water under a run-of-river water right jointly owned by LCRA and the STP Nuclear Operating Company, backed-up by firm stored water from Lakes Buchanan and Travis. The City of Austin's generating plants are served under the City's own water rights, and are backed up with stored water from Lakes Buchanan and Travis under a series of contracts with LCRA.

Most of the current industrial users are located downstream of the Highland Lakes, thus allowing a portion of their demand to be supplied from the run-of-river water originating below Lake Travis. LCRA's system under the WMP allows for full utilization of the water in the river before calling for releases from storage in the reservoirs.

3. Demands for Interruptible Stored Water

Under the Final Judgment and Decree, LCRA is permitted to develop contractual commitments with water users whose demands do not have to be met 100 percent of the time. LCRA's WMP allows such demands for interruptible stored water to be met to the extent water is available each year after firm demands are satisfied. At the present time, the contracts for the Combined Firm Yield of Lakes Buchanan and Travis are not using their full commitment. By applying an "overdraft" concept, the portion of the Combined Firm Yield that is not yet committed and the water that is committed but not yet being used determines the interruptible stored water that is available each year. The water that is captured and stored during flood events also adds to the amount of interruptible stored water that is available. Over time, as the current firm contracts draw fully on their commitments and the remainder of the Combined Firm Yield is contracted for, there will be less interruptible stored water available on an annual basis.

a. Irrigation Demands

Currently the vast majority of LCRA's commitments for interruptible stored water are for irrigation downstream. Most of the irrigation is for rice farming, although row crops, pecans, turf grass, and golf courses also use interruptible stored water for irrigation. As the irrigation operations have historically used the waters that are now considered part of LCRA's interruptible stored water supply, one way of mitigating the potential future conflicts is to assure the irrigation operations a priority call to a portion of the interruptible stored waters that are made available on an annual basis.

In good years with adequate rainfall, there is an abundance of interruptible stored water compared to the current demand, which is largely for growing rice. These four operations (Garwood, Gulf Coast, Lakeside, and Pierce Ranch) are primarily concerned with the growing of rice, although there are some turf and row crops grown within these operations. The real conflict would occur during a drought in the years ahead as other demands compete.

Irrigation water represents the largest demand of any user on the lower Colorado River system with rice irrigation in the lower basin constituting about 56 percent of the total annual use. The demand for water to irrigate rice varies greatly from year to year based upon the number of acres irrigated and weather conditions throughout the irrigation season. The number of acres irrigated is highly dependent upon federal agricultural programs affecting rice as well as the world market for rice.

Most of the rice irrigated by water from the Colorado River is concentrated in four irrigation operations whose annual demand on the system is projected to be 436,200 acre-feet of water in the year 2010 (see Table 4-3). These include the Lakeside, Gulf Coast, and Garwood Irrigation Operations, which are owned and operated by LCRA, and Pierce Ranch. These irrigation operations represent about 60 percent of total irrigated agriculture for water use in the three counties. The remaining 40 percent comes from pumped ground water.

LCRA owns run-of-river water rights associated with each of its irrigation operations as well as Pierce Ranch. These water rights have very early priority dates to divert surface water from the Colorado River, and LCRA has relied on these rights to the extent water is available, to satisfy irrigation customers' needs up to their permitted rights. These water rights allow the operations to pump water from the river as it is available without LCRA having to release water from storage. However, often in the height of the irrigation season, rainfall inflows are insufficient to supply these needs. During these periods, LCRA releases water from storage to make up the deficit. The demand on Lakes Buchanan and Travis for the release of interruptible stored water for the rice irrigation season varies greatly from year to year. During an average year, about 30 percent of the total water needed for irrigation comes from interruptible stored water released from storage in Lakes Buchanan and Travis.

Because a very large percentage of the overall demand on the system is related to irrigated agriculture, that demand must be met in the most efficient way possible. LCRA's ability to constantly monitor the amount of water in the river available to meet these demands through the Hydromet System allows full utilization of the flows originating below Lake Travis prior to making any releases from storage. The operational goal for the system is to ensure that the amount of flow passing the last diversion point meets the instream flow needs and requirements for the bays and estuaries as required by this WMP.

As discussed fully in Chapter 4, the four downstream irrigation operations (Gulf Coast, Lakeside, Garwood, and Pierce Ranch) have first priority for the interruptible stored water in the annual allocation process. This priority is set by establishing a Conservation Base for LCRA's Lakeside and Gulf Coast irrigation operations. The Conservation Base acreage will be the historical 10-year average acres irrigated (see Table 3-2) at a total of 5.25 acre-feet of water per acre irrigated. In 1999, LCRA purchased the Pierce Ranch water right of 55,000 acre-feet. In return, LCRA agreed to supply Pierce Ranch with interruptible stored water from Lakes Buchanan and Travis at an annual rate of 20,000 acre-feet based on a five year rolling average with a 30,000 acre-feet one year maximum in any calendar year, and subject to curtailment as set out in the Water Management Plan. The Garwood acreage is based upon a priority allocation as set forth in contractual agreements with LCRA.

b. Agriculture Conservation

As the largest user of water from the lower Colorado River system, irrigated agriculture also provides the best opportunity for reduction of the overall demand through conservation programs. LCRA currently has underway a water conservation program within the Lakeside and Gulf Coast irrigation operations. These conservation activities are directed at improving the efficiency of the water delivery systems and improving water use efficiency on the individual farms served by the operations. Formerly, LCRA provided water to individual customers of the irrigation operations on a per acre of rice irrigated basis. Since 1993, LCRA has sold water on a per acre-foot basis in the Gulf Coast and Lakeside Divisions. LCRA's sale of interruptible stored water for rice irrigation on a volumetric basis, as opposed to a per acre of rice basis, should encourage conservation among rice farmers.

Historical data shows that as much as seven (7) acre-feet of water had to be pumped from the river to irrigate one acre of rice. The TCEQ, in its Final Adjudication order of all of the irrigation rights in the lower Colorado River basin, stated that the use of more than 5.25 acre-feet of water for the irrigation of one acre of rice constituted a waste of water. This goal can be achieved and, in fact, recent results indicate that the overall irrigation demand can be reduced by as much as 25 to 30 percent, thus bringing water use per acre to well within the TCEQ's required 5.25 acre-feet per acre. A reduction of this magnitude could have a major impact on the reservoir system's ability to meet other competing demands.

4. Recreation and Tourism Demands

The use of water for recreation and tourism is closely linked to the population of an area, nearness of the recreation, and the value of the resource to recreational users. Recreational users are interested in qualities including: full lakes, flowing rivers, clean water, and aesthetics.

In many areas, recreational uses of the waterways are increasing steadily. The entire Highland Lakes area, from Lake Austin to Lake Buchanan, receives a great deal of recreational use from boaters, park visitors, and swimmers from all over Texas and the Southwestern United States.

Recreation and tourism demands in the Highland Lakes area are an important contributor to the local area economies. Recreation is not just fun, it is a critical economic factor in the life of citizens of the Hill Country.

a. Managing Lake Levels for Recreation and Tourism

The recreation industry associated with the Highland Lakes has experienced phenomenal growth over the past decade and is currently the major economic stability factor in many of the counties surrounding the Highland Lakes. The viability of this recreational industry is strongly tied to the level of water in the reservoirs. In the pass through lakes--Inks, LBJ, Marble Falls, and Austin--little impact is felt from variations in the levels of Lake Buchanan and Travis.

The original purposes of flood control and water supply for the rice farmers and others for which Lake Travis and Buchanan were constructed dictate that the lake levels will follow an annual cycle--that of filling the conservation storage space in the winter and spring months of the year to be drawn down by water uses during the summer months. The recreational users of these reservoirs are accustomed to a certain amount of variation in the lake levels. However, two or more consecutive years of below normal inflows into the reservoirs results in some extreme variations that can have an adverse impact on recreational interests.

Because these multiple purpose reservoirs were not constructed to maximize the recreational use of the reservoirs, the demands for stability in the reservoir levels by these incidental beneficiaries (the recreation interests) present conflicts that are extremely difficult to accommodate. If limits were placed on how far down the reservoirs' water levels are allowed to decline, a corresponding limitation on the amount of water that is available to supply the other demands on the reservoir system would also be required.

It is neither practical, nor in the public interest, to limit drawdown from demands for municipal, industrial, agricultural, or critical instream and bay and estuary uses. To the extent that the annual analysis of the amount of water in storage reveals that there are interruptible stored water supplies available after meeting the demands of the irrigation operations, interruptible stored water may be held in the reservoirs to maintain lake levels to the extent that such waters are not required to be released to meet critical instream flows requirements.

LCRA recognizes the importance of the recreational economy of the region by limiting additional sales of interruptible stored water, other than for the four irrigation operations' Conservation Base acreage or Priority Allocation acreage, based on the volume of water in Lakes Buchanan and Travis. The supply of interruptible stored water available for the January through June period will be based on the January 1 storage levels in Lakes Buchanan and Travis taken separately. The supply for the July through December period will be based on the minimum of the maximum storage levels in April, May, and June in Lakes Buchanan and Travis taken separately. No such sales may occur if either lake is less than 94% of its maximum conservation capacity. If both lakes are at their maximum conservation capacity as calculated above for either six-month period, then such interruptible stored water sales would be limited to a total of 30,000 acre-feet for that year. For lake volumes between 94% and 100% of conservation capacity, interruptible stored water sales would be limited proportionately, based on the storage reservoir with the lowest percentage of capacity as calculated above.

The current operation of the Lakes Buchanan and Travis contemplated water releases from Lakes Buchanan and Travis to meet downstream water demands, primarily for irrigation. The operation takes approximately equal amounts of water from both lakes, with the water from Lake Travis being released first, followed by water releases from Lake Buchanan. In general, the result of this operation is that Lake Travis water levels are reduced during the spring and early summer while Lake Buchanan levels are stable or increasing during that period. Starting in mid- or late July, Lake Buchanan levels begin to fall while the level of Lake Travis remains generally stable, but at a lower elevation than at the beginning of the irrigation season. During the WMP revision process, members of the WMP Advisory Committee representing Lake Travis recreation interests proposed changing the current operation of the Highland Lakes to increase the level of water storage in Lake Travis during the summer by proposing that releases from each lake be equal (the "equal draw proposal").

Study of this recommendation during the WMP revision showed that LCRA did not have sufficient economic impact information to assess the impact of such an operational change on recreation and tourism on Lake Travis. Additionally, the potential impact of the operational change on flooding and flood damages was not assessed due to insufficient information. LCRA committed to continue to study this issue and to examine alternative operational policies that may be mutually beneficial to both lakes' interests. Additionally, LCRA will evaluate requests for additional studies of physical improvements to the lakes to encourage recreation and tourism. The study may be enlarged to include proposed improvements, such as extending boat ramps.

The study is intended to determine if recommendations will be made to change the current operational policies for Lakes Travis and Buchanan to improve recreational benefits. The study would include:

- economic analyses of impacts on local economies resulting from potential changes in water levels in Lakes Buchanan and Travis on seasonal recreation and tourism and the local economies;
- impacts on water supply, hydropower generation, and other uses due to operational changes; and
- evaluation of tradeoffs in water use benefits between alternative operational policies.

Alternative operating policies for Lakes Buchanan and Travis will be evaluated, including but not limited to the "equal draw" proposal that was made during the WMP revision process. In addition to the lake operations issue, several lake interest representatives raised other issues related to encouragement of recreation and tourism activities. The need for such changes to encourage recreation will occur during dry periods regardless of modest operational changes as envisioned in the “equal draw” proposal. These “non-operations” related activities or programs that can be pursued will be analyzed and included in the economic evaluations.

b. Downstream Recreation

The river downstream of the Highland Lakes is a potential source of recreation of vast importance to the people who live along its shores. Water levels are very low and water quality deteriorates in the winter months when the river below Austin primarily consists of treated wastewater discharged by the City of Austin. LCRA’s commitment to maintain instream flows may partially ameliorate this condition. However, as with many rivers, the Colorado has many broad low areas where the flow is not sufficient for boating.

The more fundamental conflict is between people who want LCRA to keep the Highland Lakes full for recreation upstream and people who live along the river who want LCRA to release water to improve the downstream recreation potential. As with demands for stability in reservoir elevations to accommodate recreational use of the reservoirs, demands for stability in downstream river flows are extremely difficult to address because the reservoirs were not constructed to maximize recreational use of the river downstream. Crucial to improving downstream recreation are better controls on wastewater treatment plants and nonpoint pollution from Austin, the downstream communities, and other users.

Gaining access to the river downstream of Austin is often difficult because there are few boat ramps and riverside parks. LCRA has developed additional boat launches and recreation areas along the river throughout the 10-county district to give the public better access to the Colorado River.

5. Hydroelectric Power Demand

Hydroelectric power plants located in each of the dams owned and operated by LCRA total approximately 281 megawatts of capacity. Until the 1960s, the hydro plants represented LCRA’s total capability for generating electric energy. These plants still represent the cheapest power produced. The Final Judgment and Decree recognizes the competing needs for the stored water in the reservoirs, and as a result hydropower has been subordinated to be a by-product of the release of water for other purposes or when hydropower generation will not impair LCRA’s ability to satisfy all stored water demands. To the maximum extent possible, releases of water through all of the structures are made to take maximum advantage of the energy produced by those releases. LCRA retains the right to make releases solely for hydropower production in times of emergency as part of the WMP operating policies.

6. Mining Demand

There is presently very little demand for water for mining purposes, and LCRA does not anticipate any major increases in this demand.

7. Instream Flow & Estuarine Freshwater Inflow Requirements

As described in more detail below, both firm and interruptible supplies are used to meet the water demands for instream flow and estuarine freshwater inflows. The amount of water flowing within the river channel supports the strengths and diversity of the aquatic life in the system. As flows decrease, the river ecosystem can be depleted and some species destroyed.

In 1992, LCRA completed an instream flow needs study. The results of that study are two sets of instream flow needs: critical flows and target flows. The following schedule of flows takes into consideration the water quality and physical habitat requirements of the fish community native to the Colorado River.

a. Critical Flows

Since all City of Austin wastewater plants discharge into the Colorado River downstream of Highway 183, return flows of treated effluent bypass the Austin gage, effectively de-watering parts of the river immediately downstream of Longhorn Dam when no releases are being made from the dam. Flows of less than ten (10) cfs were historically common at this gage during the non-irrigation season, although flows substantially increased immediately downstream. Although this segment does not have the capacity to support a balanced, natural community due to its proximity to the dam, it is nevertheless appropriate to maintain a minimum flow in this reach. A review of historical flow records indicate that flow seldom fell below 50 cfs during dry periods before impoundment by the Highland Lakes. Therefore, LCRA's 1992 study of instream flow needs recommended an instantaneous flow of at least 46 cfs be maintained at the Austin gage at all times. A flow of 46 cfs represents the 7Q10 (the seven-day average low flow expected to occur every ten years) for the Austin gage based on the period of record prior to impoundment by the Highland Lakes (1898 to 1940). Maintenance of these flows at the Austin gage requires close coordination with the City of Austin employees operating Longhorn Dam to avoid pulsed discharges from the dam's automatic gates. At times, LCRA may not be able to guarantee this instantaneous minimum due to actions by the City of Austin, which LCRA cannot control.

In addition, if the critical flow of 46 cfs should occur for an extended period of time, then operational releases are made by LCRA to temporarily alleviate the critical flow conditions. Specifically, should the flow at the Austin gage be below a 65 cfs daily average for a period of 21 consecutive days, LCRA will make operational releases from storage sufficient to maintain daily average flow at the Austin gage of at least 200 cfs for two consecutive days. If this operational release condition persists for three consecutive cycles (69 days), then a minimum average daily flow of at least 75 cfs will be maintained for the next 30 days.

A mean daily discharge of greater than 120 cubic feet per second as measured at the Bastrop Gage should be maintained at all times except March, April, and May (critical flow months) in order to provide adequate water quality conditions in the Colorado River. This is a minimum flow based on the TCEQ's standard of a daily average of greater than five milligrams per liter dissolved oxygen and meets the criteria for the high quality aquatic habitat designation in segment 1402 and 1428. Model simulations indicate that this discharge will provide a minimum daily average of greater than six mg/l dissolved oxygen throughout most of segment 1428. This recommendation is based on the assumption that the City of Austin will maintain effluent quality at or above current levels. Minimum flow recommendations should be considered subject to revision as predictive capabilities are improved.

The seasonally adjusted target flow recommendations given below are largely adequate to meet the critical flow requirements for the target species during the spawning season. However, until more information on the flow requirements of the Blue Sucker (Cycleptus elongatus) during critical periods are available, LCRA has agreed to maintain an instantaneous flow at or above **500 cfs** from Bastrop to Eagle Lake for a continuous period of not less than six weeks during the months of March, April, and May. Further studies on the life history of the Blue Sucker in the Colorado River are needed.

b. Target Flows

A schedule of flows that provides an optimal range of habitat complexity to support a well balanced, native aquatic community was determined for each study reach. These flow regimes are considered an optimal range and should be maintained whenever water resources are adequate but should be classified as an interruptible demand subject to curtailment when water resources become limited during drought periods. Since native fish species are adapted to normal seasonal variations in flow regimes, target flows were adjusted monthly to emulate the annual cycle. It is interesting to note that the composite optimal flows are roughly equivalent to the historic median flows prior to impoundment. The following recommended target flows are based on the Bastrop study reach since this segment contains suitable habitat for the Blue Sucker (Cycleptus elongatus), listed as a threatened (protected non-game) species by the Texas Parks and Wildlife Department (TPWD). Since diversions for irrigation have the potential to reduce flows significantly in the lower reaches, flow monitoring at Eagle Lake and Egypt should continue to assure that target flows for those reaches are also met.

c. Maintenance Flows

While there have been no macrophyte studies performed on the Colorado River below Longhorn Dam, it is believed that periodic spates of high flows are needed to prevent siltation and dense macrophyte growth. It is presumed that these flows would be provided by natural high rainfall events.

These recommendations for critical and target instream flows, as shown on Table 2-1 below, represent a balanced, long-term approach to satisfying instream flow requirements that take into account both natural flow regimes and water quality conditions needed to support a healthy, diverse native fish community downstream of Austin. The recommended flows are based on a technically sound, scientific instream flow study. As described in more detail in Chapter 4, LCRA supplies both firm and interruptible stored water to meet the instream flow needs. With every WMP update, LCRA's commitment towards instream flows is determined after carefully balancing the impact on the environment and irrigation needs with increases in the demand for firm water.

TABLE 2-1
SCHEDULE OF CRITICAL AND TARGET FLOWS FOR THE COLORADO RIVER DOWNSTREAM OF AUSTIN

Month	Critical Flows (cfs)		Target Flows (cfs)		
	Austin	Bastrop to Eagle Lake	Bastrop	Eagle Lake	Egypt
January	46[c]	120	370	300	240
February	46[c]	120	430	340	280
March	46[c]	500[b]	560	500[a]	360
April	46[c]	500[b]	600	500[a]	390
May	46[c]	500[b]	1030	820	670
June	46[c]	120	830	660	540
July	46[c]	120	370	300	240
August	46[c]	120	240	200	160
September	46[c]	120	400	320	260
October	46[c]	120	470	380	310
November	46[c]	120	370	290	240
December	46[c]	120	340	270	220

[a] **Since target flows at Eagle Lake (based on overall community habitat availability) were insufficient to meet Blue Sucker (Cycleptus elongatus) spawning requirements during March and April, target flows were superseded by critical flow recommendations for this reach.**

[b] **This flow should be maintained for a continuous period of not less than six weeks during these months. A flow of 120 cfs will be maintained on all days not within the six week period.**

[c] **LCRA will maintain a mean daily flow of 100 cfs at the Austin gage, to the extent of inflows each day to the Highland Lakes as measured by upstream gages, until the combined storage in Lakes Buchanan and Travis reaches 1.4 million acre-feet of water. A mean daily flow of 75 cfs, will then be maintained until the combined storage in Lakes Buchanan and Travis reaches 1.0 million acre-feet of water, then a critical flow of 46 cfs will be maintained at all times, regardless of inflows.**

In addition, if the critical flow of 46 cfs should occur for an extended period of time, then operational releases will be made by LCRA to temporarily alleviate the critical flow conditions. Specifically, should the flow at the Austin gage be below a 65 cfs daily average for a period of 21 consecutive days, LCRA will make operational releases from storage sufficient to maintain daily average flow at the Austin gage of at least 200 cfs for two consecutive days. If this operational release conditions persists for three consecutive cycles (69 days), then a minimum average daily flow of at least 75 cfs will be maintained for the next 30 days.

8. Bay and Estuary Requirements

LCRA recognizes the importance of freshwater inflows to the productivity of the Matagorda Bay system to which the Colorado River contributes. The Matagorda Bay system is the second largest estuary on the Texas Gulf Coast. This estuary, also known as the Lavaca-Colorado estuary, covers approximately 352 square miles, and its largest single body of water is Matagorda Bay. Other major bays in the estuary are Lavaca, East Matagorda, Keller, Carancahua, and Tres Palacios (Figure 2-1). The abundant production of fin fish and shellfish make this environmentally sensitive area important not only as an ecological resource, but also as a source of economically significant commercial and sports fisheries. Many factors contribute to this high natural productivity, but one of the most significant is an ample source of freshwater. Freshwater inflows are vital to the continued health of the natural ecosystems in and around the Matagorda Bay system.

In 1991, the U.S. Corps of Engineers re-routed the Colorado River into West Matagorda Bay to increase biological productivity by increasing the amount of freshwater entering the estuary. However, a storm blocked the new route until its channel could be dredged in 1992, when it became fully functional.

The Colorado River contributes freshwater to the estuary directly from the river and indirectly through return flows from rice fields irrigated from the river. Prior to the 1991 change, an average of 1.3 million acre-feet annually from the Colorado River entered the estuary at the mouth of the river, with about 150,000 acre-feet contributed through irrigation return flows. With the change in the Colorado River delta in 1991, the full average of 1.8 million acre-feet of annual flow of the Colorado River now enters Matagorda Bay.

It is relatively easy to quantify the water needs for municipal, industrial, agricultural and other human uses of water. However, the influence of water on the complex interactions in aquatic ecologies found in streams, lakes and estuaries are not well quantified. To more fully understand the implications of changes in freshwater inflows to estuarine ecosystems, state and federal agencies began studies of the Texas estuaries in the 1960s.

In 1985, the Texas Legislature directed the Texas Parks and Wildlife Department (TPWD) and Texas Water Development Board (TWDB) to continue studies of the estuaries and determine sufficient information so that the need for freshwater inflows to the estuaries could be considered in the allocation of the state’s water resources. These studies were to be completed by December 31, 1989. However, due to funding reductions, changes in priorities and other factors, they were significantly delayed.

LCRA was directly affected by the delay in completing these studies. The TWC's Order, dated September 20, 1989, approving the WMP (see Appendix C) required that LCRA return to the TWC in 1993 with recommendations to modify the plan based on the results of the state’s studies. Until the studies were completed, a schedule of interim minimum freshwater inflows was specified. This schedule called for a minimum monthly mean flow of 200 cfs, a minimum seasonal mean flow of

375 cfs, and a minimum annual flow of 272,000 acre-feet measured at the USGS stream gage at Bay City.

To expedite the state's freshwater inflow needs study of the Matagorda Bay system, LCRA entered into a cooperative agreement with TPWD, TWDB and TCEQ in 1993. LCRA agreed to adapt or modify existing methods used by the TPWD and TWDB and apply those methods to compute alternative freshwater inflow needs for the estuary. The participating state agencies would provide timely technical assistance to LCRA from the other participating parties. LCRA would also prepare a report on the methodology, data and results of the computation of alternative freshwater inflow needs.

Emphasis in the study was to be on the estuary west of the Colorado River in determining freshwater inflows from the Colorado and Lavaca Rivers and coastal basins. To the extent possible, the impact of freshwater inflows on the environmental conditions in East Matagorda Bay would be evaluated. Full analysis of East Matagorda Bay would be contingent on adequate external funding to allow LCRA to contract for an evaluation of the hydrologic, salinity and biological data collected to date on the conditions in this bay.

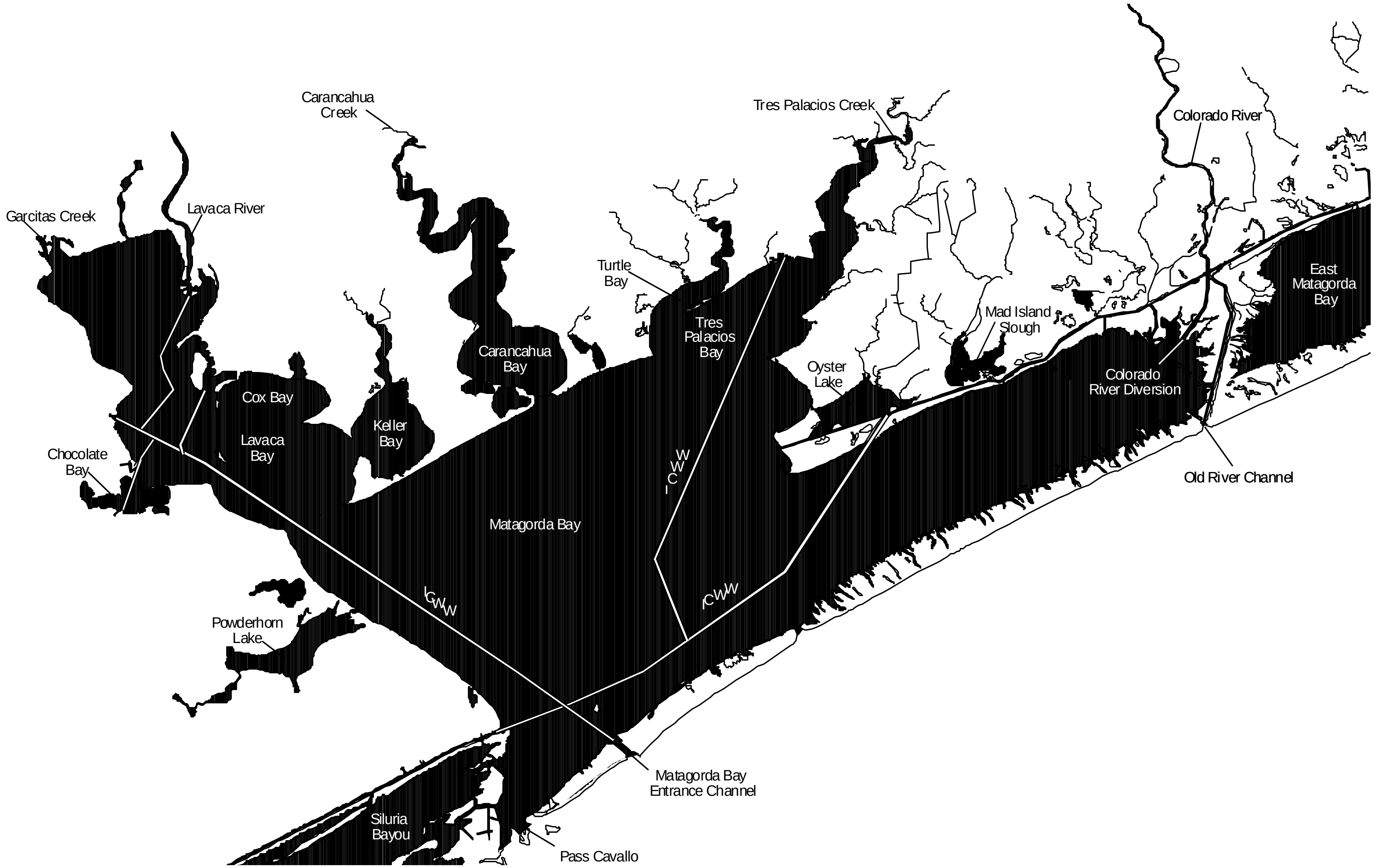


Figure 2-1. Major Tributary Streams, Passes and Bays in the Lavaca-Colorado Estuary

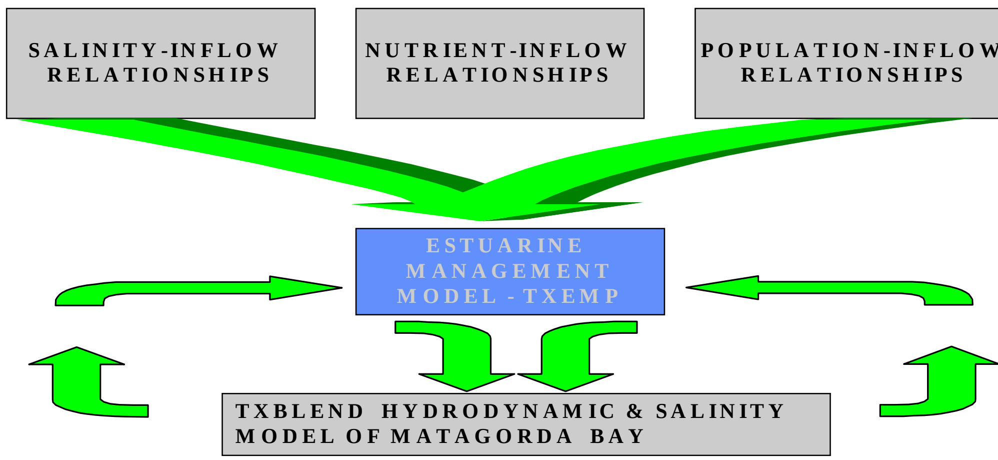
a. Methodology for Determining Freshwater Inflow Needs

In 1997, LCRA worked with TPWD, TWDB and TCEQ to estimate the freshwater inflow needs for Matagorda Bay, following as closely as possible the process developed by the TWDB and TPWD in their study of the Guadalupe Estuary (Longley, W.L., ed., TPWD AND TWDB 1994). This process involved a number of separate functions (Figure 2-2). The monthly river inflows from the Colorado and Lavaca Rivers were considered to be controllable variables. Of course, this is only partially true since large portions of the watersheds are not controlled by large reservoirs and, even where large impoundments exist, they have a limited storage capability to control floods. The salinity, productivity and nutrients are related to the river and total freshwater inflows by statistical equations. The unregulated inflows in the coastal basins contributing flow to the estuary are considered to be uncontrollable. However, these flows are affected by man's actions particularly in terms of return flows from irrigation. For this analysis, the inflows from the coastal basins were assumed to be in the same proportion to the inflows from the two major river basins as has occurred historically. The first major element is the development of statistical relationships for the varied and complex interactions between freshwater inflows and important indicators of estuarine ecosystem conditions. The key estuarine indicators considered are: salinity, species productivity, and nutrient inflows.

The second essential process involved using the statistical functions to compute optimal monthly and seasonal freshwater inflow needs. This was accomplished using the TWDB's Texas Estuarine Mathematical Programming (TXEMP) Model (Longley, W. L., ed., 1994). The TXEMP model estimates the long-term freshwater inflow needs of an estuary by representing mathematically the varied and complex interactions between freshwater inflows and salinity, species productivity, and nutrient inflows. Sediment inflows are excluded due to a lack of data concerning the volume of sediment needed to balance erosion and subsidence in the Colorado and Lavaca River delta.

The third major component of the process of developing inflow needs was the simulation of the salinity conditions throughout the estuary using the TXBLEND model developed by TWDB and modified by LCRA. The simulated salinity was then compared to desired salinity rangers over broad areas of the estuary. Where salinity was not within those ranges, then constraints in TXEMP were modified to achieve the desired salinity.

FIGURE 2-2. PROCESS FOR DETERMINING FRESHWATER INFLOW NEEDS



The application of the TWBD methodology and the resulting estimates of freshwater inflow needs are documented in Freshwater Inflow Needs of the Matagorda Bay System (LCRA: Martin, Q., Mosier, D., Patek, J., and Gorham-Test, C., 1997)

b. Freshwater Inflow Needs

The 1997 study estimated the freshwater inflow needs for the estuarine ecosystem associated with Matagorda Bay system for two levels of inflow needs: Target and Critical. The Target inflow needs are the long-term monthly and seasonal inflows that produced 98% of the maximum normalized population biomass for nine key estuarine fin fish and shellfish species while maintaining certain salinity, population density, and nutrient inflow conditions.

The salinity condition requires that estimated salinity fall within a predetermined range preferred by most species. The population density of any species has to be greater than 80% of its historical average. Finally, the total inflow of nutrients is at least equal to the natural nutrient losses from the ecosystem.

The Critical inflow needs were determined by finding the minimum the total annual inflow needed to keep salinity near the mouths of the Colorado and Lavaca Rivers at no more than 25 parts per thousand. These inflow needs were termed "critical" since they are believed sufficient to provide a fishery sanctuary habitat during droughts. From this sanctuary, the fin fish and shellfish species, particularly oysters, could be expected to recover and repopulate the bay when more normal weather conditions returned.

The Target inflow needs from all sources was calculated to be 2.0 million acre-feet per year. Inflow needs from the Lavaca and Colorado Rivers were estimated at 346,200 and 1,033,100 acre-feet annually, respectively. The remaining contributing areas are estimated to provide an additional 620,700 acre-feet annually.

A total annual freshwater inflow of about 287,400 thousand acre-feet was found to meet the Critical inflow need. Approximately 27,100 and 171,100 acre-feet annually would be provided from the Lavaca and Colorado River basins, respectively, with the remaining annual inflow of 89,200 acre-feet coming from the other contributing drainage basins.

The target and critical monthly freshwater inflow needs from the Colorado River are indicated in Table 2-2.

TABLE 2-2. TARGET AND CRITICAL FRESHWATER INFLOW NEEDS FOR THE MATAGORDA BAY SYSTEM FROM THE COLORADO RIVER

Month	Target Needs (1000 Acre-Feet)	Critical Needs (1000 Acre-Feet)
January	44.1	14.26
February	45.3	14.26
March	129.1	14.26
April	150.7	14.26
May	162.2	14.26
June	159.3	14.26
July	107.0	14.26
August	59.4	14.26
September	38.8	14.26
October	47.4	14.26
November	44.4	14.26
December	45.2	14.26

Month	Target Needs (1000 Acre-Feet)	Critical Needs (1000 Acre-Feet)
Total	**1033.1**	**171.1**

c. Revision of Freshwater Inflow Need from the Colorado River from Matagorda Bay

Based on additional data collection in Matagorda Bay since 1997, the statistical relationship between Colorado River flows and Matagorda Bay salinity has changed from what was developed and used in the 1997 study. The revised inflow-salinity relationship suggests that additional monthly inflows may be needed to maintain a salinity level of 25 ppt. However, because siltation and vegetation at the point where salinity is measured may have changed the morphology and stratification of sea water and freshwater at that location, additional study is warranted before further revisions are incorporated into the WMP.

Revising the critical FIN is not as simple as inserting the new salinity-inflow relationship. Indeed, there are a significant number of issues that must be considered in addition to the salinity threshold. The original FIN study used a very preliminary salinity limit of 25 ppt as the critical threshold value based solely on limited information about oyster impacts. It was never recognized as being a rigorous biological criterion for achieving conditions that would be truly critical for all the key plant and animal species in the bay near the mouth of the river.

At the time of the 1997 freshwater inflow needs (FIN) study, there was a clear intent to develop a much more complete set of criterion when the study was revised in the future. In light of these considerations, LCRA, TWDB, TPWD, and TCEQ entered into a Memorandum of Agreement in September 2002 to conduct a comprehensive study to revise all freshwater inflow need estimates for the Matagorda Bay system. Development of appropriate criteria for critical FIN will be considered in this study. Upon completion of this study, LCRA may propose changes to the WMP.

CHAPTER 3
DEVELOPMENT OF THE WATER MANAGEMENT PLAN

A. Introduction – The Significance of the Combined Firm Yield of Lakes Buchanan and Travis

One of the primary variables affecting the development of the WMP and allocation of water from Lakes Buchanan and Travis to various users is the Combined Firm Yield for Lakes Buchanan and Travis. This amount was determined in accordance with the Final Judgment and Decree, as explained more fully in Chapter 5 of this WMP, and is 535,812 acre-feet per year.

An essential criteria specified in the Final Judgment and Decree for the determination of the Combined Firm Yield was that all senior downstream water rights must be honored by LCRA by passing through inflows necessary to meet those senior water rights to their fullest extent. The senior water rights include those belonging to the City of Austin, Pierce Ranch[1] Irrigation Company, and the Garwood,[2]Lakeside, and Gulf Coast Irrigation operations owned by LCRA.

A full description of those water rights, the method used to determine their demand on a daily pass through basis, and the determination of Combined Firm Yield are found in Chapter 5. Honoring these senior water rights at their fully authorized diversion rate and annual demand has a major impact on the firm yield determination of Lakes Buchanan and Travis. The upstream reservoir demand for O. H. Ivie Reservoir of 90,546 acre-feet per year is considered in the calculation of the Combined Firm Yield based on the commitment for these upstream inflows to be withdrawn from the inflows prior to such flows going into Lake Buchanan.

B. Commitments Against Combined Firm Yield of Lakes Buchanan and Travis

The Combined Firm Yield of Lakes Buchanan and Travis represents the maximum average annual demand that could be met by these two lakes during a repetition of the most critical drought of record on the lower Colorado River. That drought period was from 1947 to 1957, an eleven-year period that was identified as the most severe drought occurring during the 105 years since data collection began in February 1898. The Combined Firm Yield was calculated while honoring all senior water rights to their fullest extent granted by the TCEQ.

A question of primary interest is how much of this firm supply of 535,812 acre-feet per year has LCRA committed to supply, and how much is remaining that can be devoted to future needs for firm water. The majority of the lakes' Combined Firm Yield has been committed to various users and purposes through contracts and Board resolutions. As of April 2003, 60,952 acre-feet of the lakes' Combined Firm Yield is not committed or held in reserve by the Board. This number excludes the increase in commitment of firm water for instream flows and freshwater inflows proposed by this filing. If this proposal is accepted, then the remaining Combined Firm Yield available for commitment would be reduced to 43,462 acre-feet. Agreements with the City of Austin and the Brazos River Authority (BRA) give LCRA the flexibility to meet its annual Combined Firm Yield allotments – 187,524 acre-feet for the City of Austin and 25,000 acre-feet for BRA – from any combination of sources. Currently, firm supply from Lakes Buchanan and

---

[1] LCRA now owns this water right.

[2] LCRA now owns 133,000 acre-feet of this right and the City of Corpus Christi owns the remaining 35,000 acre-feet of this right.

Travis are used as the source of the City of Austin and BRA firm water supplies through 2020. The remaining commitments that are expected to be needed beyond 2020 could be met from any source, including the Garwood water right, which is used primarily for irrigation at this time. Currently, the Garwood water right is not committed to any firm water user. The sources for the City of Austin and BRA water supplies may change periodically as LCRA determines the best method of filling all water commitments in LCRA's water service area at any given time.

Currently, there are seven groups of commitments that are considered as firm demands:

1. O. H. Ivie Reservoir

Permit No. 3676 authorizes O. H. Ivie Reservoir. Operation of the reservoir is under an operating agreement between LCRA and the Colorado River Municipal Water District (CRMWD) that called for a gradual filling of O. H. Ivie Reservoir. (See Appendix 1B, Volume II) This allows an incremental increase in O. H. Ivie Reservoir's firm demand as CRMWD's contractual commitments increase. The maximum impact of O. H. Ivie Reservoir on the Combined Firm Yield of Lakes Buchanan and Travis is 90,546 acre-feet per year.

2. City of Austin

Under the 1987 Comprehensive Water Settlement Agreement between the City of Austin and the Lower Colorado River Authority, LCRA agreed to make available to the City of Austin stored water from Lakes Buchanan and Travis as may be required from time to time to firm up or supplement the City's independent water rights to the extent of 290,156 acre-feet per year. Under the 1999 Amendment to the 1987 Agreement, the total amount of reserved water for the City was increased to 325,000 acre-feet. To fulfill this agreement, studies by LCRA show that a commitment of approximately 187,524 acre-feet per year from the Combined Firm Yield of Lakes Buchanan and Travis will be required. As stated above, at present the firm supply from Lakes Buchanan and Travis are used as the source of City of Austin firm water supplies through 2020, estimated as 122,084 acre-feet per year. The amount of water committed from Lakes Buchanan and Travis is less than in prior versions of the WMP because LCRA's 1999 Agreement with the City of Austin allows LCRA to meet the City's demands from any source. LCRA currently expects to meet the remaining committed supplies of 65,440 acre-feet that are estimated to be needed by the City of Austin beyond 2020 from other sources, including the Garwood water right, which is used primarily for irrigation at this time. The sources for the City of Austin water supplies may change periodically as LCRA determines the best method of filling all water commitments in LCRA's water service area at any given time.

3. Contracts for Use from Lakes Buchanan and Travis

As of April 2003, LCRA has committed through contracts for the diversion of water either directly from the Lakes Buchanan and Travis or releases to downstream customers a total of 119,838 acre-feet per year. These contracts are for municipal, industrial, and firm irrigation purposes and, because they call for a designated quantity of water each and every year with no other independent water rights available, they are considered to be a firm commitment for the supply of water. This estimate excludes commitments to LCRA utilities, facilities, and power plants, which are discussed below. As stated above, at present the firm supply from Lakes

Buchanan and Travis are used as the source of firm water supplies for the Brazos River Authority (BRA) through 2020, estimated as 10,000 acre-feet per year.[3] The remaining committed supplies of 15,000 acre-feet that are estimated to be needed by BRA beyond 2020 could be met from any source, including the Garwood water right, which is used primarily for irrigation at this time. The sources for BRA's water supplies may change periodically as LCRA determines the best method of filling all water commitments in LCRA's water service area at any given time.

4. LCRA Water Utilities and Facilities

As of April 2003, LCRA had committed through LCRA Board Resolution a total of 5,438 acre-feet per year for the diversion of water directly from the Lakes Buchanan and Travis for LCRA-owned utilities that provide potable water on a wholesale or retail basis. In addition, 1,473 acre-feet per year were reserved by the LCRA Board for purposes of landscape irrigation and cooling purposes at LCRA's office facilities in Austin and on Lake Buchanan. These commitments are subject to substantially the same terms and conditions of LCRA's standard contracts with other firm municipal customers.

5. Cooling Water for LCRA Power Plants

LCRA's power plants have a demand for cooling water and other plant uses that is considered to be a commitment against the Combined Firm Yield. By LCRA Board Resolution on January 22, 1987, the following commitments were made to each of the power plants:

Ferguson	15,000
Sim Gideon	10,750
Fayette	38,101
TOTAL	63,851 acre-feet per year

6. South Texas Project (STP)

LCRA currently has a contract in effect with Texas Genco, LP[4] to serve the South Texas Project (STP). STP Nuclear Operating Company[5] as project manager of STP, acts on behalf of, and for the benefit of, the participants in STP, which presently are: 1) the City Public Service Board of the City of San Antonio; 2) Central Power and Light Company; 3) the City of Austin; and 4) Texas Genco, LP, to supply cooling water for the South Texas Project in an amount up to 102,000 acre-feet per year. This water is to be made up of run-of-river water available and back-up stored water from Lakes Buchanan and Travis. To the extent that stored water is required to fulfill this commitment, it is considered a commitment against the Combined Firm Yield of Lakes Buchanan and Travis.

To determine what impact this commitment would have on the commitment of Combined Firm

[3] In October 2000, LCRA and BRA entered into a fifty (50) year contract wherein BRA agreed to purchase up to 25,000 acre-feet of water per annum from LCRA for use within designated areas within Williamson County.
[4] Texas Genco, LP has succeeded to the ownership interest formerly held by Houston Lighting and Power.
[5] STP Nuclear Operating Company succeeded Houston Lighting Power Company as operator of the South Texas Project.

Yield water, a simulated operation was conducted during the development of the initial WMP in 1989 that evaluated the critical drought period with a demand for cooling water generated by four units at the STP with a combined generating capacity of approximately 5,000 megawatts. This simulation showed that the STP would not require any water from storage as authorized under the LCRA/Texas Genco, LP contract to be released during most of the critical drought period.

However, the simulation through the critical drought period indicated a demand for stored water in one year of 51,700 acre-feet per year. Thus, an average of 5,680 acre-feet per year was included as the accumulated demand over the eleven year critical period to provide for this larger annual demand.[6]

7. Instream Flows and Bays and Estuaries

To honor the commitment towards environmental flow needs, both firm water supplies and interruptible stored water supplies are used. The classification of water allocated for environmental needs as firm or interruptible is based upon whether the interruptible stored water supplies are curtailed or not in the simulation for the four major irrigation operations.

Results of simulations conducted for the current revisions to the WMP showed that the total commitments of the Combined Firm Yield from Lakes Buchanan and Travis for instream flow maintenance will be an average of 27,380 acre-feet per year, with a maximum of:

- 51,100 acre-feet in any one year;
- 85,700 acre-feet in any two consecutive years;
- 114,200 acre-feet in any three consecutive years;
- 147,700 acre-feet in any four consecutive years;
- 184,500 acre-feet in any five consecutive years;
- 212,200 acre-feet in any six consecutive years;
- 245,600 acre-feet in any seven consecutive years; and
- 273,800 acre-feet in any eight to ten consecutive years.

Total commitments of the Combined Firm Yield from Lakes Buchanan and Travis for bays and estuaries (estuarine inflows) will be an average of 6,060 acre-feet per year, with a maximum of:

- 20,660 acre-feet in any one year;
- 23,570 in any two consecutive years;
- 23,680 acre-feet in any three consecutive years;
- 32,220 acre-feet in any four (4) consecutive years;

[6] LCRA is currently reevaluating the adequacy of this firm commitment. Initial indications are that this commitment should be revised upwards, perhaps significantly. When this analysis in complete, should a revision to the commitment be required, LCRA will submit an updated commitment for inclusion in this proposed revision of the WMP. Any revised number for the firm commitment to STP will have the effect of changing the amount of uncommitted water available for sale by LCRA, as discussed in this Chapter. It will not, however, affect any of the Drought Contingency Plan elements of this WMP contained in Chapter 4 of this WMP nor will it require any further revisions to Chapters 5 or 6 of this WMP.

- 40,800 acre-feet in any five consecutive years;
- 41,400 acre-feet in any six consecutive years;
- 47,800 acre-feet in any seven consecutive years; and
- 60,600 acre-feet in any eight to ten consecutive years.

The total firm stored water commitment for both purposes will be an average of 33,440 acre-feet per year. Estimated interruptible stored water supplied during the critical drought for both purposes will be an additional 23,030 acre-feet per year.

8. Summary

To supply the demands of the preceding commitments for firm water existing during a repetition of the critical drought would require an average of 442,350 acre-feet per year to be released or diverted from storage in Lakes Buchanan and Travis, assuming the proposed changes to firm commitments to instream flows and freshwater inflows to the bays and estuaries are accepted. This commitment is summarized below in Table 3-1.

Table 3-1. Existing Firm Water Commitments as of April 2003

O.H. Ivie Reservoir	90,546
City of Austin	122,084
Contracts from Lakes Buchanan and Travis	119,838
LCRA Water Utilities and Facilities	6,911
LCRA Power Plants	63,851
South Texas Project	5,680
Instream Flows/	27,380 (annual average)
Bays and Estuaries	6,060 (annual average)
TOTAL	442,350 acre-feet/year

Out of concern for the future needs of the many areas in LCRA's 35-county water service area, including areas now using ground water supplies that are becoming depleted or are of poor water quality, the LCRA Board committed to reserving 50,000 acre-feet of the remaining Combined Firm Yield.

This leaves an uncommitted balance of the Combined Firm Yield of 60,952 acre-feet per year with the commitments of firm supply to instream flows and freshwater inflows to the bays and estuaries as adopted by the TCEQ in 1999. Or, as indicated in Table 3-1, if the proposed changes to these commitments are accepted, the uncommitted balance of the Combined Firm Yield will drop to 43,462 acre-feet per year.

C. Annual Allocation of Firm and Interruptible Stored Water

Each year, LCRA will determine the amount of water that is available for interruptible commitments to supply the uses authorized under LCRA's Certificates of Adjudication.

No interruptible stored water will be supplied to cities or other industries that should be served on a firm basis. Interruptible stored water will be limited to irrigation or other similar uses where the value of water is well below firm water rates and the purchase is for one year only. New contracts for firm and interruptible stored water are subject to the Water Contract Rules as specified in Appendix 3 of Volume II.

In November of each year, LCRA determines the amount of water that is available in the following year to meet firm and interruptible demands in the system. LCRA manages the conservation storage of the reservoirs by using the interruptible stored waters to increase the average yield of the system.

Should an emergency occur that causes a demand for additional allocations of water to either firm or interruptible stored water contract holders, any interested party may petition the LCRA Board for such additional purchases.

1. Allocation of Firm Water

The amount of water required to meet the firm demand within the system for the preceding year will be calculated in early October. This amount will be compared to the projections for that year, and any variations will be noted and documented. LCRA will solicit information and projections of use from all of its firm supply contract holders and other firm uses provided for by resolution of the LCRA Board. This information will be used to develop a projection of firm demands for the coming year.

LCRA will assess the contents of Lakes Buchanan and Travis as of November 1 to project the storage levels for January 1 of the next year. Inflows into Lakes Buchanan and Travis from the upstream tributaries will be added to this preliminary storage level based on the minimum annual inflow from the period of drought.

This process will allow LCRA to reserve sufficient water in the system to meet all firm demands for one year beyond the year being considered for allocation.

Estimates for firm demand commitments for the next year will be subtracted from the total water supply available. The amount of water remaining will then be available for interruptible allocation for that year.

2. Allocation of Interruptible Stored Water

As part of the overall allocation process, every November LCRA will determine the amount of water that is available in the following year for interruptible contracts. LCRA may make commitments for interruptible stored water for terms in excess of one year. However, the allocation of interruptible stored water to be supplied under such commitments will be determined on an annual basis. All interruptible commitments are subject to full or partial curtailment.

3. Priority Uses in the Allocation of Interruptible Stored Water

In the allocation process, priority will be given to the irrigation operations (Lakeside, Gulf Coast, Garwood, and Pierce Ranch) to firm-up run-of-river water rights associated with individual irrigation operations. The LCRA Board will establish, by resolution, a Conservation Base number of acres determined by the historical (10-year) average acres that have been irrigated by Lakeside and Gulf Coast irrigation operations. The amount of surface water to be used for irrigation under this Conservation Base is based upon a limit of 5.25 acre-feet of water per acre irrigated (see Table 3-2). The priority allocation for Garwood irrigation operation is based on a contract that defines LCRA's commitment to supply interruptible stored water to the Garwood irrigation operation to the extent necessary to firm up the 133,000 acre-foot-per-year run-of-river water right associated with the Garwood irrigation operation. The priority allocation for Pierce Ranch is based on a contract that defines LCRA's commitment to supply interruptible stored water to Pierce Ranch. These contractual commitments to Garwood and Pierce Ranch are not based on a "Conservation Base acreage" calculation, but the 5.25 acre-foot-per-acre duty will apply to the acreage irrigated.

The Conservation Base acreage for the Lakeside and Gulf Coast irrigation operations will be served without charge for the amount of water designated under each operation's run-of-river rights. In years when the amount of run-of-river water is projected to be insufficient to serve the Conservation Base and the priority allocations for Garwood and Pierce Ranch, the annual allocation of interruptible stored water will provide back-up for those rights. The charge for the allocation of interruptible stored water shall be at the prevailing interruptible stored water rate set by the LCRA Board or, in the case of Garwood and Pierce Ranch, in accordance with their respective contracts with LCRA.

TABLE 3-2
CONSERVATION BASE ACREAGE OR OTHER PRIORITY ALLOCATION
OF INTERRUPTIBLE STORED WATER

	LAKESIDE	**GULF COAST**	**GARWOOD[1]**	**PIERCE[3]**
Acres x Duty[2]=Ac. Ft.	26,000 x 5.25 = 136,500 acre-feet	24,300 x 5.25 = 127,575 acre-feet	32,000 with 100,000 acre-feet.	25,000 with 20,000 ac. ft. (Max. 30,000 ac. ft.)
Conservation Base[6] Or other Priority Allocation	see above	see above	see above	see above
% R-O-R Rts.[4]	44.6%	58.6%[7]	93.1%	0%[8]
% Stored Int.[5]	55.4%	41.4%[7]	6.9%	100%[8]

[1] Garwood Irrigation Company and LCRA entered into a contract dated December 10, 1987, which defines LCRA's commitment to supply interruptible stored water to Garwood and the terms for curtailment during periods of shortages. This contractual commitment to Garwood is not based on a "Conservation Base Acreage" calculation, but the 5.25 acre-foot-per-acre duty will apply to the acreage irrigated. In 1998, LCRA purchased the assets of Garwood Irrigation Company, including its water rights. Under the terms of the 1998 agreement, LCRA has committed to supply up to 100,000 acre-feet annually consisting of run-of-river under the LCRA-owned Garwood water rights and LCRA interruptible stored water.

[2] Duty set by TCEQ (5.25 Ac.Ft./Ac.) for rice irrigation.

[3] LCRA has entered into a contract with Pierce Ranch regarding LCRA's commitment to supply interruptible stored water to Pierce Ranch and the terms for curtailment during periods of shortage. This contractual commitment to Pierce Ranch of 20,000 acre-feet annually based on a rolling five-year average with a 30,000 acre-feet maximum in any calendar year is not based on a "Conservation Base Average" calculation, but the 5.25 acre-foot-per-acre duty will apply to the acreage irrigated. The Pierce Ranch operation needs may also still be met through exercise of Certificate of Adjudication No. 14-5477D.

[4] % of Conservation Base or other Priority Allocation likely to be supplied by run-of-river rights (*i.e.* estimated reliability of the water right)

[5] % of Conservation Base or other Priority Allocation expected to be supplied by Interruptible Stored Water based on reliability of run-of-river rights.

[6] LCRA purchased 55,000 acre-feet of water rights from Pierce Ranch and transferred these water rights for diversion and use within the Lakeside service area, which is currently 28,300 acres

[7] % based on water used for 37,000 acres (194,250 acre-feet)

[8] % based on water use for 7,200 acres (37,800 acre-feet)

4. Use of Interruptible Stored Water for Recreation

Interest groups around the Highland Lakes, such as marina owners and other tourist and recreation industry members represented by the Highland Lakes Tourist Association expressed the need for recreation to be given some priority in the allocation of interruptible stored water.

In developing the annual interruptible allocation process, LCRA has considered the needs of the recreation industry around the lakes and proposes establishing some use of the interruptible stored waters to maintain lake levels in Lakes Buchanan and Travis. These levels would be above the possible minimal drawdowns of the lakes under the operating rule curve and would be established in recognition of LCRA's public interest responsibilities.

The conflict between supplies of interruptible stored water being held in the lakes for recreation or being released and sent downstream for agricultural irrigation and public recreation is one of the most difficult issues for LCRA to balance. The rice farmers have a historic claim to a "first call" on the water used for rice farming as shown in Table 3-2. However, LCRA believes that the needs and interests of the recreation industry that has developed around the Highland Lakes must be heard and given due consideration.

Once the first priority allocation of interruptible stored water has been made to supply the Conservation Base of the Lakeside and Gulf Coast irrigation operations and LCRA's contractual commitments to the Garwood and Pierce Ranch irrigation operations, LCRA staff will make recommendations to the LCRA Board for the remainder of the interruptible stored water available for supplying other authorized uses under LCRA's water rights. In recognition of the economic benefits to the recreation industry in the Highland Lakes region, the WMP establishes a process to consider the levels of Lakes Buchanan and Travis.

LCRA will limit additional sales of interruptible stored water, other than for the four irrigation operations' Conservation Base or Priority Allocation acreages, based on the combined volume of water in Lakes Buchanan and Travis at certain times of the year. To provide for more flexibility to supply interruptible stored water in normal and wet years, the supply allocation formula is based on a semi-annual allocation process using the following policies:

1. Interruptible stored water supply available (other than to the four major irrigation operations) for January through June in any year is based on the minimum of the separate storage levels, as percent of maximum water conservation capacity) in Lakes Buchanan and Travis on January 1 of that year according to the schedule provided in Table 3-3.

2. Interruptible stored water supply available (other than to the four major irrigation operations) for July through December in any year would be based on the minimum for Lakes Buchanan and Travis of their separate maximum storage levels (as percentage of capacity) in April, May and June of that year. That is, the maximum percent full for each lake over April through June would be compared and the lower

of the two percentages selected. The water supply allocation for July through December is also given in Table 3-3.

3. Maximum supply available in any year is 30,000 acre-feet, with the semi-annual allocation based on a typical municipal monthly demand distribution.

TABLE 3-3. MAXIMUM INTERRUPTIBLE STORED WATER AVAILABLE FOR SALE, EXCLUSIVE OF SALES FOR THE CONSERVATION BASE OR PRIORITY ALLOCATION ACREAGE OF THE FOUR IRRIGATION OPERATIONS

Minimum of the Maximum Reservoir Storage for Either Lakes Travis or Buchanan Either on January 1 or over the months of April, May and June (As Percentage of Full Water Conservation Capacity)	Maximum Additional Interruptible Stored Water Available for Sale in January Through June (Acre-feet)	Maximum Additional Interruptible Stored Water Available for Sale in July Through December (Acre-feet)
≤94	0	0
95	2,170	2,830
96	4,330	5,670
97	6,500	8,500
98	8,670	11,330
99	10,830	14,170
100	13,000	17,000

No maintenance, except for emergencies that would require the lowering of Lakes LBJ, Marble Falls, and Inks, will be permitted if the refilling of those lakes would result in substantial loss of hydropower generation benefits or other costs. Periodic lowering and refilling of Lake Austin will be done when requested by the City of Austin and consistent with LCRA Board Policy 503-Lowering LCRA-Operated Lakes.

5. Publication of Allocation of Firm and Interruptible Stored Water

LCRA will publish the results of the allocation process and notify the LCRA Board, the firm supply contract holders, and any existing or potential interruptible contract holders of the results.

6. Monthly and Quarterly Operations

The operational rule curve will be applied to the system on a monthly basis to determine how the system is responding to current conditions as compared to historical operations. This will allow LCRA to optimize reservoir operations on a real time basis and to determine if adjustments to the amount of interruptible stored water should be considered. The monthly allocation model serves to continually evaluate inflows into the system, to evaluate risks, and to assess system reliability. The monthly analysis would detect early signs of drought and allow LCRA to develop and implement contingency measures in a timely fashion.

At minimum, a quarterly system operations report showing inflows to the system, monthly releases for firm and interruptible commitments, and important operating characteristics will be provided to the LCRA Board.

D. Summary of LCRA's Water Conservation Plan and Programs

Although LCRA has had extensive water conservation programs since the late 1980s, it did not formally adopt a water conservation plan until 1998. This plan was updated to reflect water conservation and drought contingency planning requirements under Senate Bill 1 and approved by the LCRA Board of Directors in April 2000. In March 2009, the LCRA Board of Directors approved water conservation goals and strategies that will be phased in over several years to reduce overall water use in the basin. The 2009 LCRA Raw Water Conservation Plan meets the requirements of Chapter 288 of the TCEQ rules as a wholesale water supplier for municipal, irrigation and industrial customers, as a retail supplier of water to irrigation operations, and as an industrial user of water at LCRA power plants. The Plan discusses separate water conservation strategies for municipal wholesale water customers, LCRA irrigation divisions, LCRA power plants, and other nonagricultural and agricultural irrigation, recreation and industrial uses. The following provides a summary of LCRA's plan.

1. Wholesale Municipal, Industrial and Other Firm Water Supply Strategies

Water conservation and reuse are viewed as important strategies for mitigating the effects of urban growth on the region's water resources, particularly in the Austin and surrounding areas. In addition to reducing future municipal water demands, municipal water conservation and reuse can make important contributions toward satisfying the water and wastewater service requirements of growing urban populations and economics.

LCRA's municipal water conservation programs are predicated on the fact that the implementation of conservation measures must occur in partnership with customers and stakeholders. Many water utilities have limited or no programs for water conservation, while the City of Austin (accounting for more than 70 percent of all municipal water use in LCRA's water service area) has one of the most aggressive conservation programs in Texas. As such, the focus of LCRA's programs is to increase water-use efficiency to reduce the waste of water throughout the water service area Strategies are listed below.

a. Water Measurement and Accounting

The LCRA Water Contract Rules impose requirements on LCRA's water customers to properly measure water diversions. One of the provisions specifically requires all meters to be accurate within +/- 5 percent of the indicated flow over the possible flow range. LCRA personnel read these meters on a monthly basis. Each customer is required to provide third-party verification of meter testing and calibration to LCRA staff each year. LCRA-owned and-operated water utilities must also follow these rules.

b. Monitoring and Records Management

LCRA maintains records of water distribution and sales through several monitoring and billing systems. A Windows-based system provides a central location for water billing information and an automated way to compile and present that information.

c. Conservation-Oriented Rates

LCRA's wholesale raw water rates were designed to encourage water conservation. The water rate is 42 cents per 1,000 gallons or $138 per acre-foot. However, any water used above the contracted amount increases to $262.20 per acre-foot. Customers also are allotted a reservation charge of $69 per acre-foot for water reserved but not used.

LCRA has also developed increasing block rates for all retail water utilities.

d. Contractual Requirements

According to LCRA Board Policy 509 - Water Conservation, all future water sales contracts and water utility agreements shall contain "appropriate conditions requiring conservation measures that are economically feasible." LCRA's Rules for Water Conservation are updated periodically to meet the requirements of Chapter 288 of TCEQ's rules for water conservation and drought contingency plans.

All plans must be reviewed and approved by LCRA staff before contracts are signed. Each customer agrees that, in the event that it furnishes water or water services to a third party that in turn will furnish the water or services to the ultimate consumer, the water conservation requirements shall be met through contractual agreements between it and the third party.

In April 2007, the LCRA Water Contract Rules were amended to clarify that LCRA will determine the reasonableness of the quantity of any raw water contract request. The reasonableness of the quantity requested is evaluated based on many factors, including the applicant's water conservation plan, delivery or system losses, and other factors. Agency and industry standards are used in LCRA's assessment, including but not limited to the TWDB Water Conservation Task Force Best Management Practices Guidebook. To the extent the applicant requests a water supply based on standards other than those commonly used, the applicant must submit a written justification describing the reasons these standards were not employed and how the water supply needs were calculated.

e. Technical Assistance

LCRA has worked with communities and cities in its water service area for the past two decades to demonstrate the effectiveness of water conservation in reducing water consumption and wastewater flows. This effort ranges from providing sample water conservation programs, to developing conservation and drought contingency plans and landscape ordinances, to providing planning and equipment for plumbing retrofit programs.

f. Public Education and Outreach

LCRA began implementing the Water IQ program in Central Texas in 2006. The program uses a diverse set of tools to reach the public with water-saving tips and information, including television, radio, and print ads; billboards; electronic advertising; and community outreach with key audiences. In 2008, the City of Austin, LCRA, and the City of Cedar Park collaborated on the Water IQ: Know your Water campaign. Recognizing that water conservation outreach programs can be costly and consumers may become confused hearing mixed messages from water suppliers, LCRA and two cities pooled their resources on a shared outdoor water efficiency campaign. By reaching a consensus on a few key outdoor watering recommendations, the three entities were able to transmit a valuable regional message that reached a broad range of customers throughout the 10-county area.

Additional LCRA outreach and education efforts include the promotion of the Texas Hill Country Landscape Option to promote landscape best management practices, continued involvement in the Major Rivers education program, natural science education programs at LCRA nature parks, and the use of video tutorials and other water efficiency tips on the LCRA Web site. In 2008, TWDB and LCRA jointly updated the Major Rivers curriculum to correlate with the latest education standards and to add additional "hands-on" activities such as a new outdoor water use and conservation activity.

g. Future Conservation Strategies

In January 2009 LCRA staff proposed a comprehensive strategic plan for municipal, industrial and non-agricultural irrigation water conservation — based on results of the research and considering input from stakeholders and customers — to the LCRA Board. This comprehensive program will include a variety of strategies to save water, including incentive programs through which LCRA will partner with its customers to offer water-saving fixtures such as high-efficiency toilets; requirements that new construction meet standards for soil depth and irrigation systems; and expansion of LCRA's education outreach efforts to provide useful information to consumers. Elements of the program will be phased in over the next several years.

2. Irrigated Agriculture Conservation Strategies

As the largest user of water from the lower Colorado River system, irrigated agriculture provides the best opportunity for reducing the overall demand through conservation programs. Beginning in 1986, LCRA initiated a major program to increase irrigation water use efficiency in rice irrigation systems. Rice cultivation accounts for more than 90 percent of all irrigation in LCRA's water service area.

LCRA's efforts in irrigation water conservation have been and continue to be focused on promoting water conservation at its irrigation operations: Lakeside, Gulf Coast and Garwood. These systems, along with one other privately owned major irrigation company, account for approximately 65 percent of the surface water irrigation in Colorado, Wharton, and Matagorda counties. The LCRA irrigation operations do not provide water for other wholesale customers or public water suppliers.

Substantial water savings resulted from irrigation conservation programs implemented in the Lakeside and Gulf Coast Irrigation Operations. Combined between the two operations, LCRA saved about 41,500 acre-feet annually from 1989 to 1996. This savings is approximately 13 percent of the projected water use that would have occurred without conservation practices in place. Conservation strategies implemented in the operations include the following:

a. Water Measurement

From 1989 to 1997, LCRA invested about $1.3 million for improvements in the water delivery system, structure standardization, purchase of electronic measurement devices for daily measurements, and customer education. Starting in 1993, LCRA began selling irrigation water in the Lakeside and Gulf Coast systems at a price based on a mix of acreage and water use. Formerly, LCRA provided water to individual customers of the irrigation operations only on the basis of acreage irrigated. In 2009, the LCRA Board approved a project to complete similar improvements to the Garwood system to enable on-farm water measurement which include the purchase of in-canal check structures to improve water distribution as well as structure standardization. Initial funding of $250,000 was approved recently from HB1437 funds. This project began in the fall of 2009 and is anticipated to be complete by 2012. This strategy is anticipated to save at least 3,400 acre-feet per year and possibly as much as 10,000 acre-feet per year.

b. Canal Maintenance (Water Loss) Program

In 1987, LCRA initiated an irrigation canal rehabilitation project for improving canal conveyance efficiency, reducing power consumption, and improving canal system management. In this project, from 1987 to 1996, LCRA invested about $1.5 million for regrading and selectively removing high water-consuming trees and vegetation from about 210 miles of canal; replacing about 300 water control structures, and modifying pump utilization schedules. The large majority of effort was in the Gulf Coast system. Prior to the implementation of this project, canal water loss in the Gulf Coast system was about 55 percent and in the Lakeside system was about 25 percent. Following the implementation, based on recent analysis, this loss has come down to about 30 percent in the Gulf Coast system and about 20 percent in the Lakeside system.

With the completion of the canal rehabilitation project, LCRA has implemented a routine preventive maintenance program. This effort is expected to maintain existing canal operation efficiencies within the Lakeside and Gulf Coast systems. The Garwood canal system is in relatively good shape, with losses running at about 20 percent, similar to that found in the Lakeside system.

c. Customer Outreach

To facilitate communication with irrigation customers, LCRA created the Lakeside and Gulf Coast Farmer Advisory Committees in 1984. Garwood Irrigation Operation customers formed a farmer advisory committee in 1999, shortly after LCRA acquired the system. These committees represent the interests of customers of the irrigation systems. They also provide forums for LCRA to inform the farming community on LCRA’s water conservation programs and to stimulate discussion on potential farming practices that can reduce water use. The HB1437 program also has an advisory committee, as required by the legislation. This committee was reappointed in 2009 and is actively involved in reviewing HB1437 activities.

LCRA initiated agricultural water conservation efforts in the mid 1980s through funding $90,000 to the Texas A&M University Agricultural Research and Experiment Station for developing the “Less Water, More Rice” program. The emphasis of this program was to deliver water conservation messages to rice irrigators. Based on the preliminary results of "Less Water, More Rice," improved cultivation and management practices (e.g., precision land leveling, multiple inlet systems, etc.) can reduce on-farm water use by 25 to 30 percent.

d. House Bill 1437

In May 1999, the Texas Legislature passed House Bill 1437, which allows LCRA to sell up to 25,000 acre-feet of water from the Colorado River to public water suppliers in Williamson County. The HB 1437 legislation requires "no net loss" of water in the Colorado River watershed and authorizes an additional charge to be added to the base water rate to fund strategies to ensure that an equal amount of water is conserved, replaced or offset. Funds collected from the additional charges are to be used for the development of water resources or other water use strategies to replace or offset the amount of surface water transferred. In 2000, LCRA entered into a water supply contract with the Brazos River Authority to provide water to Williamson County communities. A 25 percent surcharge is applied to the standard water rate to provide income to the Agricultural Water Conservation (Ag) Fund. In 2004, the LCRA Board authorized an engineering study and public meetings to develop a plan for implementing the HB 1437 program. The results of this study lead to the revised LCRA Board Policy 501, which defined the term “no net loss,” and the development of a short-term plan to implement conservation projects that would allow the water transfer to occur under the provisions of the HB 1437 legislation. This short-term implementation plan has been updated recently and was finalized in October 2009.

The HB 1437 Agricultural Water Conservation Program was developed in 2005 in order to provide grants from the fund to eligible producers to construct on-farm water conservation projects. From 2006-2009, this program has provided grant funding to precision level a little over 19,000 acres, saving an estimated 4,750 acre-feet of water each year, mostly in the Lakeside and Garwood Irrigation Divisions. An annual report is prepared yearly showing details of current demand projects, current planning efforts, program results (including volume conserved and available for transfer), financial details about the Ag Fund, and a program outlook for the next year. To date, approximately $1.875 million has been spent on this program. Recently, the LCRA Board authorized an additional $200,000 to fund precision land leveling cost-share projects in 2010 and $250,000 to begin the Garwood measurement project. In 2009, LCRA contracted with a PhD student at the University of Texas' LBJ School to complete a statistical model to verify water savings from the precision land leveling grant program. This work is expected to be completed in 2010.

3. Industrial Water Conservation Strategies

a. Fayette Power Project

The Fayette Power Project (FPP) has an extensive conservation and reuse program. The power plant conserves and reduces the amount of water diverted from the river. This helps maintain the integrity of the cooling reservoir dam by properly controlling the water level. FPP developed a plant water balance that indicates water usage. It was found that unique opportunities existed at FPP that do not exist at other plants, mainly because of its size and the reuse design from the no-discharge ponds. Highlights of reused water and wastewater include:

- Water reuse from the reclaim pond in the Unit 3 Flue Gas Desulfurization (FGD).
- Reverse osmosis reject water reused in the FGD or returned to the lake.
- Reuse of ash pond water for Units 1 & 2 bottom ash and economizer fly ash removal.
- Reuse of wastewater treatment plant effluent in the ash pond or reclaim pond.
- Reuse of the fly ash runoff pond water in the reclaim pond.
- Reuse of the coal runoff water in the ash pond in times of drought.

Additional conservation measures for FPP include converting the bottom ash system on Units 1 and 2 to a dry system, using reclaimed pond water in place of raw water for dust suppression, recycling stormwater from the coal pile runoff pond back to the reservoir, recycling stormwater from the reclaimed water pond to the reservoir, distributing information and training about water conservation and leak detection to employees, and revising the irrigation system to use wastewater or alternative water sources.

b. Lost Pines Power Park (includes Sim Gideon and Lost Pines 1 Power Plants)

The largest water conservation and cost reduction measure at the facility is the implementation of a Lake Bastrop elevation level management policy, whereby the lake level is managed to an elevation that is eight to 14 inches below the spillway for multiple reasons. By maintaining an average 12-inch drop in elevation, there is a reduction in the surface area of Lake Bastrop from 915 surface acres to 875 acres. This is a 4.4 percent reduction in the natural evaporation loss rate. Another benefit is the opportunity this level provides to capture rainfall runoff and never incur any loss by overflowing the spillway. Additionally, all the water used at Sim Gideon in the production of high purity boiler water, such as blowdown, backwash, and reverse osmosis reject waters, are returned to Lake Bastrop for reuse, which reduces the power plant's water consumption from Lake Bastrop. Additional conservation strategies include seasonally managing the lake level to optimize rainfall capture and further minimize natural evaporation rates, converting old plumbing fixtures to high efficiency models, distributing of information and training about water conservation and leak detection to staff, and revising the irrigation system to use wastewater or an alternative water source such as rainfall.

c. Thomas C. Ferguson Power Plant

The Thomas C. Ferguson Power Plant currently reuses approximately 450,000 gallons of water from its demineralization process. The water is reused by mixing it with Lake LBJ water and using it as clarifier makeup. Reusing this water has eliminated a discharge outfall to the Colorado River. Additional conservation strategies include converting old plumbing fixtures to high efficiency models, distributing information and training about water conservation and leak detection to staff, and revising the irrigation system to use wastewater or an alternative water source such as rainfall.

CHAPTER 4
DROUGHT MANAGEMENT PLAN AND DROUGHT CONTINGENCY PLAN

A. Introduction

1. Background

On September 20, 1989, the Texas Water Commission, the predecessor agency to the TCEQ, issued its Order approving LCRA's Water Management Plan (see Appendix C, Volume I) for the Highland Lakes and the lower Colorado River. The Commission's Order included a requirement for LCRA to submit, within one year, a Drought Management Plan (DMP) with the Commission for its review and approval. On December 23, 1991, the Texas Water Commission issued its Order approving the DMP. (See Appendix D, Volume I). TCEQ subsequently adopted specific rules requiring water suppliers, such as LCRA, to develop a Drought Contingency Plan (DCP). LCRA's initial DCP was modeled after the most recent DMP approved by the Commission in 1999. As part of this WMP revision, LCRA proposes to fully incorporate into the WMP the LCRA's DCP, with modifications.

Chapter 4 describes the Lower Colorado River Authority's DMP, as required by the water rights granted to LCRA, as well as LCRA's DCP, as required by Commission rules (collectively DMP/DCP). Although the water resources available in the lower Colorado River are considered as a system, only waters used under LCRA's water rights are addressed by this DMP/DCP.

LCRA recognizes that its responsibility and authority under this DMP/DCP is subject to and shall not conflict with the authority of any Watermaster operation the TCEQ may establish on the Colorado River. Moreover, LCRA recognizes that the Commission has jurisdiction to resolve any and all disputes regarding the allocation of stored water from Lakes Buchanan and Travis, not withstanding the procedures and guidelines set forth in this DMP/DCP.

2. The Lower Colorado River System

The lower Colorado River is considered to be the lower portion of the drainage basin of Colorado River beginning in San Saba County and continuing to Matagorda County on the Texas Gulf Coast (see Figure 1-1). The river flows through nine of the ten counties that make up LCRA's statutory water district.

The upper portion of LCRA's district is part of the Texas Hill Country. In the Hill Country, the river is largely controlled by a series of five dams and their reservoirs--Buchanan, Inks, Wirtz, Starcke, and Mansfield. Marked by steep slopes and shallow rocky soils with outcroppings of granite and limestone, the Hill Country ends abruptly in the Balcones Fault region near the edges of Austin. At Austin is the Tom Miller Dam that creates Lake Austin. From the eastern edges of Austin the river broadens out, snaking through the dark rich Blackland Prairie soils and then rolls gently downstream through the sand and shale of the coastal plains.

Water from the Colorado River and its tributaries is used for a variety of purposes to support the citizens and economy in the LCRA district. These uses include public water supply, manufacturing, cooling water for electric generating plants, irrigation, agriculture and mining. The water to supply these uses comes largely from the natural runoff into the Colorado River. However, the Colorado River Basin is subject to recurrent, severe droughts and devastating floods resulting in wide ranges of river flows. To provide an assured water supply and to relieve flooding, the LCRA, with the help of the Federal government, constructed the Highland Lakes reservoir system.

The development of LCRA's dams and reservoirs on the Colorado River, accomplished in the years from 1939 through 1951, changed Central Texas in many ways. Beginning by controlling the devastating floods on the river, using the river's power to generate electricity, and creating a secure and reliable water supply, LCRA has helped to stimulate the growth and development of the region. The lower Colorado River's water resources satisfy a wide variety of uses, many of which have changed and will continue to change in concert with the changes in the environment and the growth and development of the region.

3. Major Water Rights Holders

The largest water right holders in LCRA's water district also use the majority of the water (Table 4-1). LCRA holds the largest rights, with rights to use up to 1.5 million acre-feet per year from

Lakes Buchanan and Travis. Some of the other large water right holders downstream of Lakes Buchanan and Travis have priority dates earlier than that of LCRA's Highland Lakes permits. These rights belong to the City of Austin, Corpus Christi (portion of Garwood), LCRA for Pierce Ranch, and the LCRA's Garwood, Lakeside and Gulf Coast Irrigation Operations. These rights are considered as senior in time and superior to LCRA's right to store water in the Highland Lakes. Hence, any inflows to the Highland Lakes that need to be diverted for use under these rights must be passed through the Lakes for use downstream. There are also some large water rights downstream of Lakes Buchanan and Travis that have junior priority dates.

TABLE 4-1 MAJOR WATER RIGHTS AND AUTHORIZED RIGHTS IN THE LOWER COLORADO RIVER BASIN, LISTED IN ORDER OF PRIORITY (Acre-Feet/Year)

LCRA (GARWOOD)	133,000
CORPUS CHRISTI (GARWOOD)	35,000
CITY OF AUSTIN (LAKE AUSTIN)	250,150
LCRA (GULF COAST)	228,570
LCRA (LAKESIDE)	107,500
LCRA (PIERCE RANCH)	55,000
CITY OF AUSTIN (Remainder of Certificate of Adjudication No. 5471)	46,403
LCRA (Lakes Buchanan and Travis)	1,500,000
CITY OF AUSTIN (Certificate of Adjudication No. 5489)	35,456
STP NUCLEAR OPERATING COMPANY and LCRA	102,000
LCRA (Gulf Coast junior portion)	33,930
LCRA (Lakeside junior portion)	78,750
TOTAL	2,606,759

4. <u>Historic Operation of the Highland Lakes</u>

Lakes Buchanan and Travis serve as the water supply and flood control reservoirs in the Highland Lakes system. Since their construction in the late 1930s and early 1940s, the water storage in these lakes has fluctuated dramatically in response to extreme floods and droughts. The lakes were at their lowest levels in 1952 when Lake Buchanan was at 983 feet mean sea level (msl) and Lake Travis was at 614 feet msl. The highest water surface elevations were in 1991 for Lake Travis (710.4 feet msl) and in 1991 for Buchanan (1021.37 feet msl).

Operational management of the lakes has also changed over time. A major use of the dams in the 1940s and 1950s was for hydroelectric power generation. That use became secondary to water supply purposes when LCRA developed its fossil fuel electric generation stations. As a result of the Final Judgment and Decree for LCRA's water rights, the use of water for hydroelectric generation was formally subordinated to higher uses except during emergency shortages of electricity, and during other times to the extent that such releases will not impair

LCRA's ability to satisfy all existing and projected demands for water from Lakes Buchanan and Travis pursuant to all firm commitments and all non-firm, interruptible stored water commitments.

5. Purpose and Legal Considerations

The purpose of the DMP/DCP is to specify how LCRA will contract and supply firm and interruptible stored water supplies during a repetition of the critical Drought of Record. In managing the stored water from Lakes Buchanan and Travis, LCRA must

- Define the conditions under which water shortages exist, and
- Specify the actions to be taken by LCRA to mitigate the adverse effects of such shortages.

The overall goals of the DMP/DCP are to:

- Extend available water supplies.
- Preserve essential uses of water and protect public health and safety during extreme shortages of supplies.
- Equitably distribute among LCRA's water customers any adverse economic, social and environmental impacts associated with drought-induced water shortages.

The scope of the DMP/DCP must adhere to the findings of the State District Court's Final Judgment and Decree, adjudicating LCRA's water rights, as well as the 1989 Water Commission's Order approving the WMP and TCEQ rules concerning drought contingency plans. The scope of the DMP is limited to the curtailment of LCRA's interruptible stored water supplies to insure that there is sufficient firm water available to meet projected demands for such water through a repetition of the Drought of Record and also addresses how LCRA will provide water for environmental flow needs. Firm water is subject to curtailment only if it is determined that the drought in effect is worse than the Drought of Record. The DCP also addresses water use reduction goals required by TCEQ's Chapter 288 rules and establishes more detailed procedures for pro rata allocation of interruptible stored water during periods of curtailment.

In times of shortage of supply caused by drought or emergency, LCRA, in accordance with Section 11.039 of the Texas Water Code, will first curtail and distribute the available supply of interruptible stored water among all of its interruptible stored water supply customers on a pro rata basis, so that preference is given to no one and all interruptible stored water supply customers suffer alike. Although projected firm demands for stored water for the next ten years are significantly greater than demands included in the last revision to WMP, these projected needs are still significantly less than the total firm water supplies available.

If the shortage of supply caused by the drought is worse than the Drought of Record, then LCRA must curtail and distribute the available supply of firm water among all of its firm water supply customers on a pro rata basis, so that preference is given to no one and all firm water supply customers suffer alike.

In the annual allocation of interruptible stored water supplies, LCRA follows the priority order of water use as specified in Section 11.024 of the Texas Water Code and the WMP.

Similarly, in making additional commitments of firm water supplies, LCRA must also follow the priority order of uses given in Section 11.024 of the Texas Water Code.

As noted above, a goal of the DMP/DCP is to determine how to allocate available water supplies when there is not sufficient supplies to meet projected water demands even after reasonable, cost-effective water conservation efforts have reduced the water demands. Therefore, the DMP/DCP does not emphasize water conservation practices that should occur all the time, not just in drought conditions. LCRA has major programs to encourage conservation in water use. These programs are summarized in Chapter 3 of this WMP.

As discussed previously, the WMP, and the DMP/DCP, require periodic revision to reflect changes in water demands. The last revision was completed by LCRA in February 1997 and approved by TCEQ in March 1999. Significant changes in demand, as discussed below, have necessitated the present revision.

The most noticeable changed condition over the last five years has been a significant increased projection of municipal and industrial (firm) water demands. The WMP approved in 1999 projected the ten-year future firm demands within LCRA's service area at about 280,000 acre-feet annually for 2005. Based on the analyses for Regional Plans pursuant to the Senate Bill 1, the ten-year projected demands are now projected to be about 360,100 acre-feet per year for 2010 (see Table 4-2). The primary reason for this increase is additional water needs to meet population and economic growth in the Austin area, including domestic water use around the Highland Lakes.

With this large projected increase in firm water demand, the WMP must be adjusted to give a compensating reduction in the interruptible stored water supplies available since firm needs take priority. This reduction can be achieved by revising the annual interruptible stored water supply curtailment policy adopted in the WMP.

B. Water Users and Interest Groups

1. LCRA Firm Water Customers

LCRA manages the Highland Lakes for the benefit of all users. LCRA supplies water under its water rights for the Highland Lakes to numerous municipal water supply systems, manufacturers, and power generating plants. As of May 2003, LCRA had over 110 contracts for firm water supplies. The total contractual commitments and reservations of firm water from Lakes Travis and Buchanan at the time was about 318,364 acre-feet per year. This number does not include any commitment to instream flows or freshwater inflows to the bays and estuaries or the amount allocated to O. H. Ivie Reservoir. Annual use of firm stored water was about 35-36 percent of the 318,364 acre-foot amount.

The major concern of firm water customers is that sufficient supplies be allocated to insure that their demands for water are fully satisfied even during severe drought conditions. An additional concern for those customers pumping water directly from Lakes Buchanan and Travis is that the lake levels remain sufficiently high for them to continue to use their existing water intake structures. Extending intake facilities further into the lake to follow retreating shorelines can be very expensive. Most of the intakes can accommodate water levels at the historical low lake levels of 614 feet msl on Lake Travis and 983 feet msl on Lake Buchanan.

2. Agricultural Interests

a. Historic Claims to the Waters of the Colorado River

The waters of the Colorado River have served the rice farming industry of the Texas Gulf Coast counties of Colorado, Wharton and Matagorda counties since 1885 when the first rice crops were planted near Eagle Lake, Texas. When legislation creating LCRA was first proposed in the Texas Legislature in 1933, promises were given to the rice producers and other farmers that the waters stored behind the dams proposed for the LCRA system would be available to serve their needs when the natural flow of the river diminishes in dry years.

Rice is the major crop irrigated in the most downstream three counties in the LCRA water district. While some rice producers in the region irrigate their crops with pumped groundwater, the major source of water for irrigation is from the waters of the Colorado River, either under run-of-river water rights, or from releases of interruptible stored water from Lakes Buchanan and Travis. Approximately 40% of the water used to irrigate in the three counties comes from groundwater. The majority, 60%, is supplied from surface water. Approximately 379,300 acre-feet, which is about 56% of the annual water use of the Colorado River and the Highland Lakes, is used for rice farming. During an average year, about 30% of the total surface water used for irrigation comes from the interruptible stored water in Lakes Buchanan and Travis.

When LCRA has purchased irrigation operations (Gulf Coast in 1959, Lakeside in 1983, and Garwood in 1998) and their associated senior water rights from private firms, LCRA made certain commitments to the farmers to provide water from Lakes Buchanan and Travis as back-up to the run-of-river rights.

b. Concerns of the Agricultural Interests

The primary concern of the agricultural interests is how LCRA will curtail the interruptible stored water during times of shortage. The producers understand the interruptible concept because, in essence, the waters were always interruptible. The WMP formalizes the understanding of how the water supply--both run-of-river and stored water--is managed.

3. Recreation and Tourism Interests

The waters of the Colorado River and the Highland Lakes serve a variety of recreational and tourism interests in Central Texas. In the WMP, LCRA recognizes the economic interests of the tourism and recreation industry around the Highland Lakes through a commitment to limit its sales or commitments of interruptible stored water, other than to satisfy the four irrigation operations' Conservation Base acreage or Priority Allocation acreage, based on the volume of water in Lakes Buchanan and Travis, as described later in this Chapter.

While the WMP sets minimum projected reservoir storage levels for Lake Travis and for Lake Buchanan, the lakes will most likely have fallen below these levels during even a brief drought period. Economic hardship on the owners of the many marinas, small recreation businesses (bait stores, fishing camps, restaurants, campgrounds), and larger businesses, such as motels, could last much longer than the drought conditions. Many of the marinas on Lake Travis have the ability to move boat docks further out into deeper water and are willing to bear the added operational costs of such moves to stay in business. On Lake Buchanan, the shallow nature of the shoreline allows little flexibility in moving docks and other facilities. Some residents and other lake users have expressed concerns about the lack of access to the lakes during low elevations. Most of LCRA's boat ramp facilities and private boat ramps and launches become unusable when Lake Travis falls below 640 feet msl and Lake Buchanan falls below 1000 feet msl. Additionally, water hazards such as tree stumps and rock areas increase as reservoir levels recede, restricting more of the lake surface available for sail and power boating.

Lake area Chambers of Commerce, residents, and representatives of the tourism industry are also concerned about the elevation of the lakes area during low water periods even when a true drought is not in effect. There is a concern that first time visitors will not return to the area having once experienced low water levels in the reservoirs, thus dampening potential future economic growth.

River recreation interests downstream of the Highland Lakes are also concerned that drought conditions will leave stretches of almost dry riverbed and that water quality will deteriorate severely during drought periods.

4. Concerns for Instream Flows and Freshwater Inflows for the Bays and Estuaries

The Colorado River is the largest single source of freshwater flowing into the Lavaca-Tres Palacios estuary through channels in the Colorado River Delta. The Lavaca-Tres Palacios estuary is one of the largest of the seven major and three minor estuaries along the 370 miles of Texas Gulf shoreline. The bays and estuaries of this system provide a rich environment for wildlife, commercial seafood harvest, recreation, and aesthetic opportunities.

Average inflow to the bay has been 2.9 million acre-feet per year. Of that inflow, about 34 percent came from the Coastal Basins, 22 percent from the Lavaca River Basin, and 44 percent from the Colorado River. Freshwater inflows influence estuarine biological productivity by lowering salinity, increasing nutrients, and providing sediments. In 1991, the U.S. Corps of Engineers re-routed the Colorado River into West Matagorda Bay to increase biological productivity by increasing the amount of freshwater entering the estuary. However, a storm blocked the new route until its channel could be dredged in 1992, when it became fully functional.

The Colorado River contributes freshwater to the estuary directly from the river and indirectly through return flows from rice fields irrigated from the river. Prior to the 1991 change, an average of 1.3 million acre-feet annually from the Colorado River entered the estuary at the mouth of the river, with about 150,000 acre-feet contributed through irrigation return flows. With the change in the Colorado River delta in 1991, the full average of 1.8 million acre-feet of annual flow of the Colorado River now enters Matagorda Bay.

Estuaries and their associated wetlands are a transition zone between the fresh water and marine environments and serve as the nurseries for over 97% of the fishery species in the Gulf of Mexico. Thus, the levels of salinity, nutrients, and sediments determined by freshwater inflows is critical for high estuarine production. Fluctuation of estuarine conditions from severe droughts, floods, and hurricanes results in a shift of the biological elements of the system and can directly affect the production and survival of many plant and animal species.

During the rice irrigation season, even under drought conditions, the instream flow needs should be satisfied as a result of natural inflows and return flows downstream of the Highland Lakes, pass-throughs of inflows to the Highland Lakes required to honor downstream senior water rights, and releases of interruptible stored water flowing downstream to the irrigation operations. Under current water demand conditions, it is in the winter months, when the portions of inflows required to be passed through the reservoirs to honor downstream senior rights are low and when downstream demands for stored water are also low, that it is most likely that instream flows will need to be supplemented with firm stored water releases. However, should interruptible stored water for irrigation be curtailed or cut off, the periods of low flow in the river would be extended and additional water would be demanded to serve these needs for periods of time.

While it is difficult to estimate the full effect of inadequate instream flows or inadequate inflow to the bays and estuaries, it is clear that many plant and animal species in the food chains would be severely stressed and that productivity would be lessened if the condition persisted for an extended period of time.

C. Projected 2010 Surface Water Demands During Droughts

1. Introduction

To properly allocate available water supplies in the DMP/DCP, LCRA must project the future water demand on those supplies. The DMP/DCP is based on conditions that may occur in the next decade. This ten year planning period was chosen because the critical drought period used to determine the Combined Firm Yield of Lakes Buchanan and Travis lasted approximately a decade. Further, the estimates of future water demands are most accurate in the near future. If the critical drought were to repeat itself beginning now, the maximum demands during the drought period would be those in year 2010. Thus, a ten year planning period was used for the development of the DMP/DCP.

Total estimated surface water use in LCRA's 35 county water service area (Figure 1-1) in 2000 was approximately 675,800 acre-feet annually, including water released to maintain instream flows in the lower Colorado River. About 56% of water diverted was used for rice irrigation in the four major irrigation operations located in Colorado, Wharton and Matagorda Counties. The next largest demand for surface water is the City of Austin, with approximately 134,000 acre-feet yearly averaged over the last ten years for municipal use and steam-electric power generation. In general, City of Austin's use has been increasing steadily, with a use of 163,800 acre-feet for the year 2000.

LCRA supplies water to two general categories of water demands: firm and interruptible. Firm demands presently include the water for municipal, domestic, industrial, steam-electric power generation, some irrigation, and instream flow maintenance purposes. Currently, interruptible stored water is used almost entirely for agricultural irrigation, specifically rice irrigation, and for environmental needs. As noted earlier, the most noticeable changed condition over the last five years has been a significant increased projection of municipal and industrial water (firm) demands. With the large projected increase in firm water demand, the DMP/DCP must be adjusted to give a compensating reduction in the interruptible stored water supplies available since firm needs take priority.

Surface water demands in LCRA's water district over the next decade have been projected by LCRA staff based on drought-condition weather, population growth, water use patterns, and economic development, as outlined in the Senate Bill 1 regional water plan for Region K. The assumptions used in projecting 2010 demands are described in the following sections.

2. Projected Firm Water Demands

a. Municipal, Manufacturing, Steam-Electric, and Domestic Water Demand Projections

LCRA staff allocated Senate Bill 1 2010 projected demands using a 1996 water use distribution. Actual water use in 2000 and projected water demands for 2010 are shown in Table 4-2.

The water demand for STP and the Austin power plants may be met by using unregulated run-of-river flows under separate water rights associated with those facilities, supplemented as necessary with stored water. The arrangements for satisfying these demands at STP and at LCRA power plants are described in more detail in Finding 58 of the September 7, 1989 Order of the Texas Water Commission approving LCRA's WMP. The 2010 demands included in this WMP for these facilities reflect those provided to the Senate Bill 1 Regional Planning Group (Region K) by the City of Austin and the South Texas Project Nuclear Operating Company.

Today, LCRA has only a handful of firm water contracts for domestic water use. Unfortunately, most of this water is taken from the Highland Lakes by landowners that do not have contracts with LCRA. Absent a contract, most if not all of these diverters have no legal claim to the water they are diverting. At some point, LCRA may choose to pursue enforcement of its water rights to curtail these unauthorized diversions. Total domestic water use is projected to increase to 6,273 acre-feet by 2010. As water supplies become more and more scarce, many landowners are likely to realize the benefit of a firm water contract that better protects their water supply during drought conditions. Thus, for purposes of this WMP, LCRA has estimated that approximately 5,000 acre-feet of domestic water use will come under contract with LCRA over the next ten years.

TABLE 4-2. REPORTED 2000 AND PROJECTED 2010 ANNUAL FIRM SURFACE WATER DEMANDS UNDER DROUGHT CONDITIONS

Water Demand Category	2000 Reported Water Use (Acre-Feet)	Projected 2010 Water Demand (Acre-Feet)
Highland Lakes Municipal	23,100	37,200
Manufacturing (Excluding Austin)	8,500	11,500
City of Austin Municipal and Manufacturing	153,300	187,931
City of Austin Power Plants*	10,400	13,500
LCRA Power Plants	22,000	29,500
South Texas Project (STP)*	64,800	47,000
Instream Flow Maintenance & Estuarine Inflows	14,500	**33,440
Total	296,600	**360,071

*Firm water demands for STP and the City of Austin may be met from run-of-river flows, if they are available, under their existing water rights.

**Based on the 2003 revision resulting from the effect of the new trigger for curtailment of interruptible stored water supplies from Lakes Buchanan and Travis and freshwater inflow needs of the Matagorda Bay, as described in this Chapter.

.

b.Instream Flow Demands

LCRA completed the initial instream flow needs study in 1992. The study identified two sets of instream flow needs: critical flows and target flows. The recommended instream flows for the Colorado River downstream of Austin are in Table 2-1.

LCRA will continue with the reservoir operation procedure to release stored water from Lakes Buchanan and Travis to maintain daily river flows as follows:

1. LCRA will release stored water and pass storable inflows to maintain no less than the critical instream flow needs in all years as set forth in Table 2-1, including maintaining, on an instantaneous basis, instream flows of 46 cfs and 500 cfs critical flows as set forth in Table 2-1 during the times those respective flow values are in effect, and

2. In those years when the four major irrigation operations are not curtailed, LCRA will schedule the passage of inflows to lakes Buchanan and Travis that are legally available for storage, as measured at the upstream stream gages, to maintain the target flows as set forth in Table 2-1 as a daily average. Furthermore, during those times when target instream flow requirements are in effect and when such inflows are sufficient to allow LCRA to satisfy the daily target flow requirement at the Bastrop gage, LCRA will also schedule the passage of these inflows to maintain the following minimum flows, as measured at any time at the Bastrop gage:

Month	**Minimum Flow (cfs) 100% of the time**	**Minimum Flow (cfs) 95% of the time**
January	266	
February	269	
March	233	
April	244	287
May	492	579
June	355	418
July	295	347
August	165	
September	201	
October	208	

November	241	
December	264	

In rare instances, LCRA's ability to meet the instream flow requirements set forth in this WMP may be impaired by certain unavoidable constraints such as the capacity of its hydro-generation units and hydro-generation scheduling mandates as well as unforeseen diversions, unforeseen changes in flow conditions downstream, and adjustments to the ratings of the applicable gages.

This recommendation fully meets the most important instream flow needs at all times and meets the target flows during periods of normal or above normal streamflow conditions.

To fully honor this commitment, LCRA will use both firm water and interruptible stored water. Firm water is only supplied in years when the interruptible stored water supply is curtailed for the four major irrigation operations. The actual annual releases of stored water will vary from year to year depending on hydrologic conditions.

For the 2003 update, it is estimated that an annual average of about 27,380 acre-feet of firm water is needed to meet these instream flow commitments, with the remainder coming from interruptible stored water supplies. Therefore, the present annual commitment for instream flows of 12,860 acre-feet of firm water is recommended to be increased to 27,380 acre-feet per year. In addition to firm water, interruptible stored water will be provided to meet instream flow needs. The estimated interruptible stored water to be supplied during the critical drought will be an additional 8,590 acre-feet/year**.** Demands for both firm and interruptible stored water for instream flow needs were estimated from the simulated results of the water supply alternative that was recommended for the 2003 update of the WMP. The recommended water supply alternative represents a careful balance of environmental and irrigation impacts based on results from various scenarios that were considered.

The releases for instream flows generally, but not always, contribute to meeting the Critical or Target freshwater inflow needs of Matagorda Bay. However, the timing for these instream flow releases is independent of the monthly freshwater inflow needs for the bay.

c. Freshwater Inflow Demands

The water demands for maintaining the ecological balance of coastal bays and estuaries have been determined in 1997 by LCRA, in cooperation with TPWD, TWDB and TNRCC (predecessor to TCEQ). As indicated in Table 2-4, estimates of freshwater inflow needs (FIN) from the Colorado River at Bay City are 1.03 million acre-feet annually for the target needs and 171,000 acre-feet yearly to meet critical needs. Historically, an average of approximately 1,800,000 acre-feet flows annually in the Colorado River at Bay City.

For the 2003 WMP update, LCRA has recommended a change in the reservoir operation procedure for releasing stored water from Lakes Buchanan and Travis for estuarine needs after a careful balance of environmental and irrigation impacts from the results of various scenarios that were considered. LCRA will release stored water from Lakes Buchanan and Travis to maintain monthly estuarine inflows at:

1. the target inflow needs in those years when the combined storage in Lakes Buchanan and Travis on January 1 is greater than or equal to 1.7 million acre-feet, to the extent of storable inflows each month to Lakes Buchanan and Travis, as measured at the upstream stream gages;

2. one hundred and fifty percent of the critical inflow needs in all years when the combined storage in Lakes Buchanan and Travis on January 1 is less than 1.7 million acre-feet and greater than 1.1 million acre-feet, to the extent of storable inflows each month to Lakes Buchanan and Travis, as measured at the upstream stream gages; and

3. the critical inflow needs in all years when the combined storage in Lakes Buchanan and Travis on January 1 is less than 1.1 million acre-feet, to the extent of storable inflows each month to the Highland Lakes, as measured at the upstream stream gages.

With the recommended intermediate estuarine inflow reservoir operation procedure of increasing the release of stored water from Lakes Buchanan and Travis in years when the combined storage is between 1.1 and 1.7 million acre-feet, the estuarine ecosystem will receive more freshwater inflows during moderate droughts than it would have under the WMP as approved in 1999. For any given month, LCRA will compensate for any deficit in releasing stored water to meet freshwater inflow needs during the following month by releasing additional stored water from the Lakes Buchanan and Travis. LCRA will not account for the inflow in the following month in making such release to make up for the previous month's deficits.

The reservoir operation procedure of releasing stored water for the freshwater inflow needs are based on the following:

- both Target and Critical FIN are provided with stored water;

- Target FIN are used as the estuarine inflow demands during years of plentiful water;

- water supply needs for the four major irrigation operations from the interruptible stored water supply were balanced carefully with the environmental needs while assessing the impacts from the results of various scenarios that were considered;

- the frequency and duration of high salinity conditions in Matagorda Bay are kept relatively low; and

- the Critical FIN are met about 80 percent of the months during the critical drought.

This recommendation will require an estimated 205,060 acre-feet of stored water during the ten-year critical drought for estuarine inflows. However, not all of this is from the Combined Firm

Yield of Lakes Buchanan and Travis. Similar to the instream flow demands, both firm water and interruptible stored water are used to meet the freshwater inflow needs. Firm water is only supplied in years when the interruptible stored water supply is curtailed for the four major irrigation operations. An annual average of about 6,060 acre-feet of firm water should be allocated, with the remainder coming from interruptible stored water supplies to meet freshwater inflow needs. The estimated annual interruptible stored water supplied during the critical drought will be an additional 14,450 acre-feet/year**.** The recommended changes are based on the alternative that was selected for the 2003 update based on a careful balance of environmental and irrigation impacts from the results of various scenarios that were considered.

For purposes of estimating required releases of water from Lakes Buchanan and Travis to meet the instream flow or freshwater inflow requirements of this WMP, LCRA will rely on stage data obtained from the gaging system jointly maintained and operated by the U.S. Geological Survey and LCRA for determining these requirements. If the ratings used to convert stage to flow published by LCRA and the USGS are not identical at the time required releases are estimated, LCRA will exercise its discretion to rely on the latest updated rating of the gage.

3. Projected Interruptible Stored Water Demands

a. Interruptible Stored Water Customers

LCRA presently supplies interruptible stored water to four major irrigation operations. These operations are: Pierce Ranch Irrigation Company, and LCRA's Garwood, Lakeside and Gulf Coast Irrigation Operations. These operations have associated with them very early run-of-river rights to divert surface water from the Colorado River, to the extent it is available, to satisfy customer needs up to their permitted amounts. These run-of-river rights are all senior to LCRA's water rights in the Highland Lakes. Thus, LCRA may impound only that portion of the inflows to the Highland Lakes remaining after passing through inflows to the extent needed to honor these and any other downstream senior water rights.

These four operations are primarily concerned with the growing of rice although there are some turf and row-crops grown within these operations. Virtually all irrigation water is pumped from the Colorado River. Only the Lakeside Irrigation Division has the use of a small amount of groundwater for irrigation purposes.

b. Projected Rice Irrigation Water Demands

The projected average annual irrigation water demand for 2010 is about 438,200 acre-feet annually (Table 4-3). Water to supply that need will come from both interruptible stored water and run-of-river sources. Statistical analysis by LCRA staff indicates that agricultural water diversions at these operations are influenced by the number of acres planted, rainfall, and evaporation. Planted acreage is the strongest statistical predictor of agricultural water use, but is also the most difficult to forecast since annual acreage varies greatly. Rice acreage is largely governed by the federal farm support program, which is currently undergoing changes. It is premature to forecast the ultimate impact of these changes on the rice industry in LCRA's water district.

Because of the many variables that impact total water diversions at the irrigation operations, a conservative projection was made of future rice irrigation water acreage. First crop acreage for each operation was projected to be equal to the largest acreage cultivated over the last ten years. The projected first crop acreage, as well as 2000 actual first crop acreage, is given in Table 4-3. The Lakeside Irrigation Division has cultivated more acreage in the last ten years, but has used groundwater to meet the excess water needs.

The projections of second crop acreage are based on a fraction of the first crop acreage. The fraction used is the ratio of the second crop to first crop acreage in the year of greatest first crop acreage over the past ten years. These fractions are 0.44, 0.83, and 0.96, respectively, for Gulf Coast, Lakeside and Garwood. Second crop acreage for Pierce Ranch is taken as 6% of the total second crop acreage for Gulf Coast, Lakeside and Garwood.

The actual use of water for irrigation is highly variable, with relatively large differences from year to year. Water diversions projected for each irrigation operation, except Pierce Ranch, are calculated from predictive equations that consider rainfall and evaporation conditions, as well as acreage, during each irrigation season (Martin, 1990). These projected demands are based on rainfall and evaporation conditions expected during the duration of a repetition of the critical drought period experience from 1947 through 1956. The projected demands from Pierce Ranch are taken as 9% of the total projected demands of the other three major irrigation systems. This percentage reflects Pierce Ranch's historical proportion of total diversions over the past ten years adjusted for the major water reductions through water conservation.

TABLE 4-3. REPORTED YEAR 2000 AND PROJECTED ACREAGE AND SURFACE WATER DEMANDS FOR IRRIGATION				
Irrigation System	**Reported 2000 First Crop Acreage (Acres)**	**Reported 2000 Water Use (Acre-Feet)**	**Projected Year 2010 First Crop Acreage (Acres)**	**Projected Year 2010 Water Use (Acre-Feet)**
Gulf Coast	18,800	152,200	30,300	155,600
Lakeside	23,500*	117,800	27,500	135,600
Garwood	15,000**	83,200	21,200	109,000
Pierce Ranch	4,500**	26,100	4,740	36,000
Other Senior Rights	0	0	1,000	2,000
Total	61,800	379,300	84,740	438,200
* Includes acreage supplied from groundwater.				
** Estimated				

Adjustments are also made to the water demand estimates developed from the equations to reflect ongoing water use efficiency improvement programs. Aggressive water conservation efforts are projected to reduce the water diversions at the Gulf Coast Division by over 25% by 2010, from historical 1968-1986 period usage levels. The water demands for the other three major irrigation operations are expected to decline as well due to water conservation efforts, with 5% total cumulative reductions by 2010, from patterns of historical usage.

To estimate the demand for interruptible stored water supply for irrigation needs, a table of acreage was developed for the irrigation operations that included the likely allocation of various amounts of interruptible stored water between first and second rice crop. Such table was developed based on several assumptions.

Allocation of interruptible stored water supply to the individual irrigation operations was according to the following formula:

> Interruptible Stored Water Supply = 0.5*Average annual interruptible stored water usage over past 10 years + 0.5*Highest year of interruptible stored water usage within past 10 years.

Using the last ten years of interruptible stored water usage, it was found that each irrigation operation is entitled to the following percentages of interruptible stored water supplies available:

Gulf Coast	.425
Lakeside	.425
Garwood	.063
Pierce Ranch	.088

Pierce Ranch was not included in the acreage table since there is not a reasonably accurate predictive equation for water use at Pierce Ranch. To represent Pierce Ranch's needs, water use and acreage were assumed at 9 % and 6 %, respectively, of the combined water use and acreage, respectively, of the other three operations.

In developing the table of acreage, it was assumed that the hydrologic and meteorological conditions reflected a 1 in 5 dry year, or stated differently, the dry conditions that would be expected only 20% of the time.

The maximum annual demand for the interruptible stored water acreage projected for 2010, under a 1 in 5 dry year condition, was 273,000 acre-feet. Using that as the greatest interruptible stored water demand, a set of smaller interruptible stored water supplies were assumed to generate a set of first and second crop acreages expected to be cultivated by the three major operations. These acreages were assumed to be the maximum planting acreage that could be supported by the limited water supplies, both run-of-river and interruptible stored water. The allocation of the available interruptible stored water supplies for irrigation was based on the assumption that the demand for projected first crop acreage for rice (83,700 acres) will be fully met, with any acreage curtailments occurring in second crop.

The acreage level was set for each level of interruptible stored water supply using the following process:

1. The total interruptible stored water supply available was allocated to each of the three major operations according to the percentages given above.

2. The available interruptible stored water for each irrigation operation was used first to meet the needs of first crop rice.

3. The remaining interruptible stored water supply, after first crop, was used for second crop needs. If there was insufficient interruptible stored water supplies, then the maximum allowed second crop acreage was reduced in the same proportion as the ratio of the available to the maximum needed interruptible stored water supplies. For example, if there is only 50% of the interruptible stored water needed to meet the needs of the maximum second crop acreage allowed, the second crop acreage is set to 50% of the maximum second crop.

The table of acreage thus developed for the irrigation operations was used in simulations conducted with the RESPONSE model for this WMP update to define the planning decisions of allocating available interruptible stored water when curtailments were instituted. As noted before, Pierce Ranch acreage and water demand were treated in the RESPONSE model as percentages of the combined acreage and water demand of the three other irrigation operations.

In addition to the senior water right holders and major irrigation operations, there are additional demands for surface water along the Colorado River. These demands, and their water rights, are junior in time to December 1, 1900 but senior to November 1, 1987. Consistent with LCRA's water rights for Lakes Buchanan and Travis, the WMP provides that LCRA will treat any of these rights junior to the water rights for Lakes Buchanan and Travis in the same manner as the users of interruptible stored water. The maximum amount of interruptible stored water to meet the demand of such junior water rights is about 4,700 acre-feet annually, however these demands are not likely to take place each and every year.

c. Instream Flow and Estuarine Freshwater Inflow Water Demands

As noted in the section on firm water demands, interruptible stored water is used to meet part of the environmental water demands for instream flow and estuarine freshwater inflows. During the critical drought, the average annual demand on interruptible stored water is estimated to be 23,030 acre-feet per year, with 8,600 acre-feet per year of that amount provided for instream flow maintenance.

4. Summary

Projected surface water demands in LCRA's ten-county water district during severe droughts total about 798,300 acre-feet annually in 2010. Firm water demands are projected to be approximately 360,100 acre-feet annually in 2010 (See Table 4-2). Surface water demands for irrigated agriculture under drought conditions are estimated to be 438,200 acre-feet annually. The projected irrigation demands, as well as reported use in 2000, are indicated in Table 4-3.

REFERENCES

Tex. Water Dev. Bd., WATER FOR TEXAS – 2002 VOLUME III (2002) (Region K Plan) (available online at http://www.twdb.state.tx.us/rwp/k/PDFs/).

Martin, Q. W. (1990). "Economic Evaluation of Alternative Rice Cropping Decisions," Open File Report, Water and Wastewater Utilities Program, Lower Colorado River Authority, Austin, TX.

D. Projected Water Supplies

1. Water Supply Management Procedure

a. Systems Operation Concept

A fundamental concept of the WMP is that Lakes Buchanan and Travis and the lower Colorado River are operated as a combined water supply system. Unregulated inflows entering the

Colorado River from drainage areas downstream of the Highland Lakes must be used to the maximum extent possible before inflows to the Lakes Buchanan and Travis are passed through or stored and subsequently released to satisfy downstream water needs.

Such a system concept requires a careful and extensive analysis of the interconnection of hydrologic conditions, water demands, and priority of water rights and uses. The WMP uses the following general guidelines for the storage and use of water in the Highland Lakes and the lower Colorado River.

b. Critical Drought Period Concept

A basic assumption in assessing water availability for the DMP/DCP is that all operational procedures must be evaluated as if the worst drought ever recorded for the lower Colorado River were to reoccur. This Drought of Record for the Highland Lakes was the 1947-1957 period, a period that was identified as the most severe occurring during the 105 years since data collection started in February 1898.

c. Procedures For Evaluating Water Availability

LCRA staff developed a computer program for evaluating water availability under a variety of management policies. This program is called "RESPONSE - Lower Colorado River Authority Reservoir System Simulation Computer Program." The evaluation of water availability proceeds on an annual basis. For each year, a three-stage process is executed:

1. water demands are estimated for each user or usage category for the coming year;
2. the daily flows are allocated among users based on legal priority or seniority; and
3. the operation of Lakes Buchanan and Travis is simulated on a monthly basis to reflect the storage of unused inflows, evaporation, and potential spills.

The demands for water in the next year are specified as either fixed annual amounts or demands that vary depending on water in storage. The firm demands are all held constant in each year of simulated hydrologic conditions. The irrigation demands change from year to year depending on: (1) the acres cultivated in each irrigation operation for first and second crop rice; (2) weather conditions (rainfall and evaporation) in that year; and (3) water held in storage in Lakes Buchanan and Travis at the beginning of the year. The water demand for first crop rice occurs only in the months of March through July, while second crop demands are in August through October. All annual water demands are distributed on a daily basis using historical water usage information.

The simulated allocation of inflows into Lakes Buchanan and Travis in the DMP/DCP among downstream senior water rights holders follows the same procedure used in developing the Combined Firm Yield of Lakes Buchanan and Travis for the WMP. It is important to note, however, that these simulated monthly operations do not necessarily reflect the actual day-to-day operations of the reservoir system, which often requires the exercise of best professional judgment.

2. Supplies for Firm Demands

The annual dependable water supply that can be supplied from Lakes Buchanan and Travis during a repetition of the Drought of Record is referred to as the Combined Firm Yield. Based on the studies available to LCRA, the Combined Firm Yield has been calculated by LCRA to be 445,266 acre-feet per year, exclusive of the amount allocated to O.H. Ivie Reservoir. In addition to this Combined Firm Yield, water supplies are also available from the natural flow of the river downstream of the Highland Lakes to meet a major part of the City of Austin's and the South Texas Project's firm water demands.

Adding the other firm water demands to those of the City of Austin gives a projected drought-condition demand in the year 2010 of approximately 360,100 acre-feet annually, as described in Table 4-2. Portions of the demands of the City of Austin and of STP can be supplied from run-of-river flows under separate water rights, reducing the projected drought-condition demand for stored water in year 2010 to about 184,000 acre-feet annually. The estimate of drought-condition firm demand for stored water in 2005 is about 134,000 acre-feet annually. The firm demands for stored water over the next ten years are low relative to the firm supplies from the Combined Firm Yield. Thus, curtailment of firm demands is not likely in the next decade, even under a recurrence of extreme drought conditions. A large surplus in firm stored water supplies is therefore available to meet interruptible stored water needs without placing at risk the stored water needed for firm water users in the next decade.

3. Supplies for Interruptible Stored Water Demands

As specified by the WMP, the amount of interruptible stored water available for the next irrigation season is projected by LCRA staff in November of each year. The projected supply depends upon the amount expected to be in the combined storage in Lakes Buchanan and Travis on January 1, anticipated inflows for the subsequent months through the irrigation season, and the current demands for firm water.

Several procedures were evaluated to predict the likely supplies available, during a repetition of the Drought of Record, in the next year for interruptible stored water demand. Historical records of streamflow were examined, but were found to be highly variable and hence not accurate in estimating water availability for the next year. The most accurate indicator of water availability is the combined storage in Lakes Buchanan and Travis at the beginning of the year. Thus, for the DMP/DCP, the allocation of stored water supplies to meet interruptible stored water demands is based solely on the combined reservoir storage in Lakes Buchanan and Travis at the beginning of each year, and decisions to curtail interruptible stored water supplies in annual contracts are keyed to particular total January 1 storage levels.

At relatively full storage levels on January 1, the supply of interruptible stored water is sufficient to meet all projected firm and interruptible stored water demands. However, at or below some storage levels, there are not sufficient supplies and the annual contracts for interruptible stored water must be reduced. At lower and lower January 1 storage levels, less and less interruptible stored water is available for allocation through the annual contracts. At some relatively low storage, there will be a total cutoff of water for interruptible stored water use in the coming year. Provisions will be made to revise the water supply estimates during the year to respond to significant changes in projected streamflow and storage due to rainfall in the basin.

The evaluation of expected hydrologic and water demand conditions during a repetition of the Drought of Record can only be simulated based on projected information. This projected information is subject to some uncertainty. LCRA has determined it prudent to designate some minimum storage level serving as a safety factor to insure that all firm demands are fully met during the critical drought. Under this conceptual operating plan, there would be a storage level which, when reached at any time during the year, would require the total cutoff of all water for interruptible stored water use. That storage level defines a Reserve Storage Pool for the system.

With the increase in projected firm water needs of about 50,000 acre-feet annually from Lakes Buchanan and Travis for 2010, there is less water for interruptible stored water supply from Lakes Buchanan and Travis since firm water needs take priority over interruptible stored water uses. To avoid shortages to firm water users, it is recommended that interruptible stored water supplies from Lakes Buchanan and Travis be reduced during the critical drought years from what is available under the WMP approved in 1999 by revising the annual interruptible stored water supply curtailment policy, as discussed below. This reduction in supplies impacts irrigation primarily since irrigation has the highest priority for use of interruptible stored water.

E. Water Curtailment Policies

1. Triggering Conditions

The DMP/DCP contains distinct triggering levels, as well as several associated cancellation measures, that are associated with the amount of water available in Lakes Buchanan and Travis. These responses range from voluntary conservation by firm water customers to total cutoff of interruptible stored water customers. This DMP/DCP fully meets the critical instream flow needs at all times and meets the target flows during periods of normal or above normal stream flow conditions.

2. Curtailment of Interruptible Stored Water Demands within Irrigation Operations and for Instream and Bay and Estuary Freshwater Inflows

Given the large demand for interruptible stored water for rice production, there will likely be a shortage of interruptible stored water at some time during the next decade. The curtailment policies considered in the DMP/DCP focus primarily on the reduction in interruptible stored water supplies through the annual contracting process. The impact of reducing supplies in the annual contracts is far less than forcing a curtailment or total cutoff during the year after the rice farmers have made economic commitments based on the assumed availability of the water.

a. Recommendation for Interruptible Stored Water Demand Curtailment for Irrigation and Environmental Needs

To examine possible alternative policies for the 2003 update, LCRA staff reviewed with the Water Management Plan Revision Advisory Committee over thirty options for allocating water supply between irrigation and environmental needs.

In determining available interruptible stored water supplies, it is essential that firm water demands be fully protected during a repetition of the Drought of Record (DOR). This drought is the worst ever recorded on the lower Colorado River and occurred from 1947 through 1956. As noted earlier, projected firm water demands from Lakes Buchanan and Travis over the next ten years (to 2010) are estimated to increase by 50,000 acre-feet annually (24 percent) from the ten-year projections used in the 1999 version of the WMP (to 2005). Meeting those increased demands may only be achieved by decreasing the interruptible stored water supplies presently provided from Lakes Buchanan and Travis. This reduction in supplies impacts irrigation primarily since irrigation has the highest priority for use of interruptible stored water. The second factor affecting interruptible stored water supplies available for irrigation is the allocation of interruptible stored water supplies between irrigation and environmental protection. This allocation is always a delicate balancing between benefits and adverse impacts.

After examining the alternatives, LCRA recommends that interruptible stored water supplies be reduced from present levels and that additional water be provided for estuarine freshwater inflows. As more specifically described below, LCRA recommends that interruptible stored water supplies be reduced from the current levels with the initial storage curtailment threshold raised from the current value of 1.1 to 1.4 million acre-feet. The annual interruptible stored water supplies are determined based on beginning-of-year storage. As storage declines, there is a decline in annual interruptible stored water supplies available. For storage levels less than 1.4 million acre-feet, there would be progressive reductions in annual interruptible stored water supplies.

Further, LCRA recommends that an intermediate release schedule be provided for estuarine freshwater inflows that allows a slightly more gradual reduction of inflows to Matagorda Bay during low flow years. The recommended changes are deemed by LCRA as a balance between a modest incremental decrease in irrigation water supplies during drought conditions and modest increased inflow to Matagorda Bay during non-drought years to help maintain the ecological health of the Bay. Based on a balance of environmental and irrigation impacts, the recommended WMP changes include an increase of stored water released for estuarine freshwater inflow. This increase would be provided in years when the January 1 storage level in Lakes Buchanan and Travis is between 1.1 to 1.7 million acre-feet (55 and 86 percent full).

The recommendations for the current update are as follows:

1) Open Supply - If the total January 1 storage in Lakes Travis and Buchanan combined is equal to or greater than 1,400,000 acre-feet, then LCRA will supply all interruptible stored water demands. This assumes 273,000 acre-feet of interruptible storage water is sufficient to irrigate a total of 83,700 acres within the four irrigation operations, with seventy percent (70%) of that acreage being irrigated for a ratoon, or second, crop of rice.

2) Curtailment will begin if the total January 1 storage is less than 1,400,000 acre-feet and greater than 325,000 acre-feet. The available interruptible stored water supply when combined storage on January 1 is less than 1,400,000 acre-feet is shown in Figure 4-1. If combined storage on January 1 is between 1.4 million acre-feet and 1.15 million acre-feet, the interruptible stored water supply available will vary beginning at 273,000 acre-feet available at 1.4 million acre-feet of storage and decreasing at a rate of approximately 31,200 acre-feet for each 100,000 acre-foot decrease in combined storage until a value of 195,000 acre-feet available at a combined storage of 1.15 million acre-feet. When the combined storage in Lakes Buchanan and Travis on January 1 is less than 1,150,000 acre-feet, the interruptible stored water supply available will vary beginning at 195,000 acre-feet available at 1.15 million acre-feet of storage and decreasing at a rate of approximately 4,250 acre-feet for each 100,000 acre-foot decrease in combined storage until a value of 160,000 acre-feet available at a combined storage of 325,000 acre-feet.

3) Cutoff of the interruptible stored water supply for the coming year will occur when the combined storage in Lakes Buchanan and Travis on January 1 is less than or equal to 325,000 acre-feet.

4) Reserve Storage Pool - If at any time during the year the total storage in Lakes Buchanan and Travis, combined, is less than or equal to 200,000 acre-feet then all use of interruptible stored water will be stopped.

5) During periods of curtailment or cutoff instituted on January 1, LCRA will cancel the curtailment of interruptible stored water for the irrigation operations at any time during the year prior to July 31, if the combined storage in Lakes Buchanan and Travis is projected to be equal to or greater than 1.4 million acre-feet anytime in July. Further, the remaining available interruptible stored water supplies for the year may be reallocated, at this time, between irrigation operations if such allocations do not adversely affect any irrigation operation.

6) During periods of curtailments, LCRA will allow each irrigation operation the option of either: (1) using up to a maximum authorized volume of interruptible stored water allocated to that operation, or (2) using sufficient water to cultivate a level of acreage agreed upon among the customers within each particular irrigation operation and LCRA.

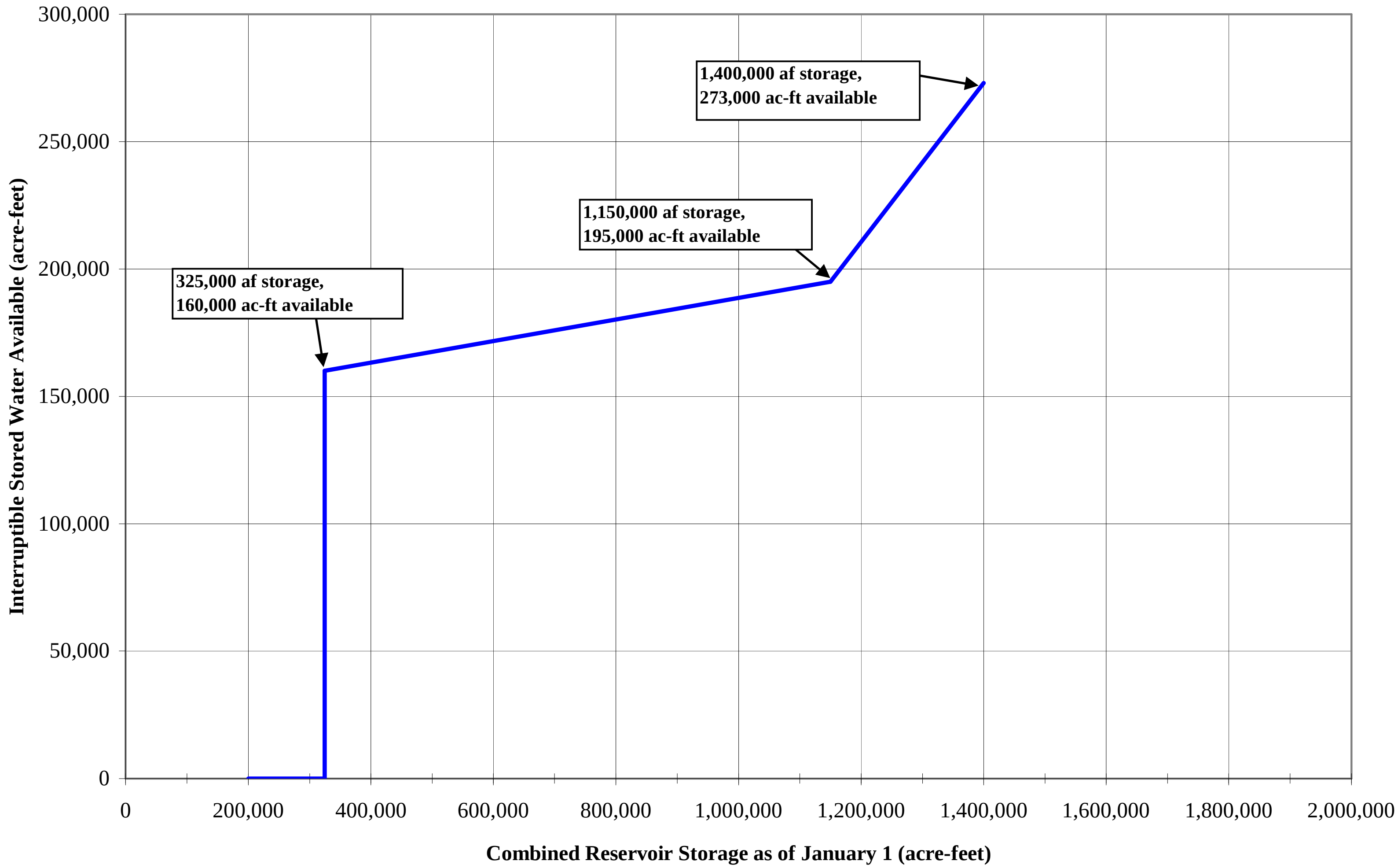
Since the curtailment begins at a storage level more than one half full, curtailment of irrigation water supplies may occur during some relatively mild droughts, however such curtailment would be limited in scope and duration. Further, it is likely that the rice producers will only be tentatively required to curtail second crop rice, which is cultivated after first crop rice is harvested in July and August. Thus, the curtailment plan has the added advantage that spring rains and runoff may increase water supplies and reduce demand and thereby allow an increase in the estimate of interruptible stored water available for second crop rice. Rice producers could relatively easily increase their second crop acres if they were aware of any increased water supply by June 15.

To achieve the estimated benefits of the management policy, it is necessary for the irrigation operations to reduce their water demands to correspond to reductions in the estimated interruptible stored water supplies, in accordance with the procedures in this WMP or the terms and conditions of contracts between LCRA and stored water users. Close coordination between LCRA and the operations will be needed. Should an operation choose not to reduce the acreage cultivated in response to the projected shortage of interruptible stored water supply, LCRA will only supply that operation with its estimated portion of the reduced interruptible stored water supply. No additional interruptible stored water will be released in that year for that irrigation operation once the diversion limit has been reached.

In addition to the above features, and consistent with state law, LCRA's customers must prepare and adopt a legally enforceable local drought contingency plan, which should include specifics concerning the actions to be taken to comply with LCRA's DMP/DCP regarding the curtailment of interruptible stored water supplies. LCRA staff is available to provide technical assistance with the preparation of required local plans.

FIGURE 4-1

Interruptible Stored Water Available During Curtailment
Based On January 1 Combined Storage in Lakes Buchanan and Travis



b.Irrigation Allocation Among the Irrigation Operations

As provided in Finding 25 of the September 7, 1989 Order of the Texas Water Commission approving LCRA's WMP, "the priority allocation and terms governing the interruption of supply of stored water for Garwood are based upon a contract between Garwood and LCRA."

LCRA has negotiated a contract with Pierce Ranch governing the interruption of the supply of stored water to Pierce Ranch. Interruption of the supply of stored water for other commitments similarly would be governed by contract or LCRA Board resolution.

There are many ways in which interruptible stored water demands may be curtailed through the annual contracts. The two most likely are a gradual curtailment with reductions indexed against beginning of year storage in Lakes Buchanan and Travis; or an abrupt total cutoff policy where the full demands are supplied if the beginning of year storage level in Lakes Buchanan and Travis was above a specific level, otherwise totally stop interruptible stored water sales for the next year.

The largest use for interruptible stored water is rice production. Rice producers must plan their crops for the next season based upon the projected interruptible stored water supply, even though more supply may actually be available in future months. The advantages of the gradual approach of curtailment are that the rice industry could use the water allocated to achieve the greatest benefit. Water could be used in first crop on the hope that conditions in the spring would refill the river and lakes. The disadvantage is that some curtailment would occur when it was not really necessary in years when the critical drought was not repeated. Lakes Buchanan and Travis would refill and spill because the drought ends before conditions become as severe as the critical Drought of Record.

The advantages of the "all or nothing" approach are that there would be more years when the full demands would be met and minor droughts would not affect available supplies. Disadvantages would be that in some years there would be no interruptible stored water and most rice producers would risk substantial or total loss of their crops if sufficient run-of-river water was not available throughout the growing season.

In years when there is not sufficient projected interruptible stored water available to meet all irrigation needs, the interruptible stored water will be allocated to the irrigation operations so that all operations have the same percentage shortage in their total interruptible stored water demand. The calculation of the annual demand of interruptible stored water will be based on a projection of relatively dry weather and low streamflow conditions in the next year.

The allocation of interruptible stored water supply to the individual irrigation operations is discussed above in Section C.3.b. Briefly, allocation of interruptible stored water supply to the individual irrigation operations for the 2003 update of the WMP is according to the following formula:

Interruptible Stored Water Supply = 0.5*Average annual interruptible stored water usage over past 10 years + 0.5*Highest year of interruptible stored water usage within past 10 years.

Using the last ten years of interruptible stored water usage, each irrigation operation was determined to be entitled to the following percentages of interruptible stored water supplies available:

Gulf Coast	.425
Lakeside	.425
Garwood	.063
Pierce Ranch	.088

Based on this allocation, a table of acreage was developed for the three major irrigation operations showing the likely allocation of various amounts of interruptible stored water between first and second rice crop. Pierce Ranch was not included in the table since there is not a reasonably accurate predictive equation for water use at Pierce Ranch. To represent Pierce Ranch's needs, water use and acreage were assumed at 9 and 6 %, respectively, of the combined water use and acreage, respectively, of the other three operations.

c. Irrigation Allocation Within the Irrigation Operations

Because Pierce Ranch has entered into a long-term interruptible stored water contract with LCRA, Pierce Ranch will determine how water will be allocated within its own operation. Within each LCRA irrigation operation, LCRA and its customers, through the advisory committees, will mutually determine which of the following allocation methods to follow:

<u>Volumetric method</u> – The total volume of water available to each operation will be divided by the operation's total recent base history to establish an amount available per acre, not to exceed 5.25 acre-feet. Each customer's actual first crop per acre usage for each landmass will then be subtracted from the per acre farm level availability and the balance, if any, will be made available to the customer for second crop production. Additional water made available due to any customers choosing not to irrigate either first or second crop will be equitably distributed to customers who irrigate other crops within the operation.

<u>Acreage Method</u> – The irrigation operation choosing this method would irrigate first crop acreage, but prior to the initial contracting process, would determine the maximum first crop acreage that could be irrigated with allocated water supplies. The first crop acreage for the particular irrigation operation would be determined by dividing the total water available to the particular irrigation operation by a first crop acre-foot per acre water use duty as agreed upon

between LCRA and the respective advisory committee. Contracted first crop acreage would be limited to this amount and would be made available to individual customers pro rata, based on their recent irrigation history as described below. For irrigation operations using volumetric measurement, any use of water in excess of the first crop acre-feet per acre duty would be subject to a surcharge. Prior to contracting for second crop water, the acreage available for second crop would be determined and contracted for on a pro rata basis, in a manner similar to that used for first crop, including a duty and surcharge. During a curtailment, water would be available for rice only, except at the Gulf Coast irrigation operation, where water would also be available for turf grass. Other supplemental agricultural interruptible demands within an operation would also be considered on a limited basis and only to the extent that water is available within the canal system which is not needed for rice irrigation.

Each customer's average base acreage history is to be determined based upon an averaging period agreed to by the farmer advisory committees. The averaging periods are as follows: Garwood – five (5) years; Gulf Coast – two (2) years; and Lakeside – six (6) years.

At the Lakeside and Garwood irrigation operations, the base acreage history shall be based upon the lands irrigated such that a customer shall not be entitled to irrigate lands in a curtailment year that were not previously irrigated by that customer, unless the current landowner of the land that contributed to the base acreage history grants express written consent, and such consent is provided to LCRA with customer's application. In the event that a customer no longer farms land which has a history of being farmed, that history shall be credited to the current landowner or a successor tenant farmer unless the landowner has granted consent for such base acreage to follow the customer to additional lands as described above.

At the Gulf Coast irrigation operation, the base acreage history shall follow the LCRA customer, and not be restricted to a particular landmass.

Allocation of curtailed interruptible stored water to the various users within the irrigation operation will be based on the amount of irrigated acreage on each landmass. This water use will be determined by accounting for established crop rotations during the defined averaging period and will include only those years during that same period that water was used on the landmass. Irrigation operations personnel will maintain this information for each irrigated landmass. Separate base acreage histories will be maintained for rice and turf grass. During periods of curtailment, irrigation customer contracts will be limited to the base acreage as determined by the method described above and any reductions necessary will be made from this base acreage.

d.Drought More Severe Than Drought of Record

In the event that the LCRA Board of Directors declares a drought to be more severe than the Drought of Record, limits would be placed on first crop production. If that occurred, the following key elements of limiting first crop would stand:

- On Jan. 1 of each consecutive critical drought year, the projected run-of-river flow and interruptible stored water would be calculated and the water volume available to each operation would be projected.

- Each irrigation operation would decide with LCRA which allocation method to use, either the maximum acreage plan or the maximum volume plan.

- The application and contracting process would have a final deadline of February 15th of each year of the drought period that is more critical than the Drought of Record.

e. Termination of Water Allocation Policy

The water allocation model and water allocation plan for agricultural irrigation will terminate when the combined stored volume of Lakes Buchanan and Travis exceeds 1.4 million acre-feet.

The first crop water allocation process described here would terminate when LCRA reallocates interruptible stored water to the irrigation operations after the Board declares the drought worse than the Drought of Record to be over.

f. Procedures for Water Use Accounting

LCRA will employ its ordinary and standard water measurement procedures to account for water used during curtailment periods. During the implementation of the water allocation policies, LCRA will notify each customer of the amount of acreage for which LCRA will provide water. LCRA staff will perform actual field surveys to verify that each customer was not planting more than the allocated acreage. Customers planting excess acreage will be required to prevent irrigation waters from entering excess acreage through construction of appropriate outside levees enclosing only permitted acreage.

g. Transfer of Water Among Individual Users

Water allocation among individual users within individual operations is not a property right and there are no procedures or policies for individual users to obtain that right. All waters available during the critical drought would be allocated on a pro-rata basis to the landmasses contracted to irrigate during that critical drought year and either the maximum volume or maximum acreage for that irrigation operation would be consistent with that plan.

h. Variances

Within each LCRA irrigation operation, the LCRA General Manager or his designee is authorized, after consultation with the operation's advisory committee, to move and adjust the averaging period for base acreages within farm service agency farms units to account for established field rotations and contemporary changes in management practices so long as such adjustments do not result in a net increase in acreage history.

i. Enforcement

All LCRA interruptible stored water contracts include a provision requiring that, in cases of a shortage of water resulting from drought, the water be distributed in accordance with LCRA's WMP and Texas Water Code section 11.039.

Interruptible stored water customers within the irrigation operations failing to comply with the pro-rata allocation requirements (curtailment plan) shall be subject to a civil action to enjoin the non-compliant customers for breach of contract. Additionally, the use of water in excess of the customer's per acre duty as described in section C.3.c above is subject to a surcharge.

3. Curtailment of Interruptible Stored Water Demands for Other than Irrigation Operations

LCRA will limit additional sales or commitments of interruptible stored water, other than for the four irrigation operations' Conservation Base acreage or other priority allocation, based on the combined volume of water in Lakes Buchanan and Travis at certain times of the year.

The supply of interruptible stored water made available outside the irrigation operations for the January through June period will be based on the January 1 storage levels in Lakes Buchanan and Travis taken separately. The supply for the July through December period for such sales will be based on the minimum of the maximum storage levels in April, May, and June in Lakes Buchanan and Travis, taken separately. No such sales will be allowed if either lake is less than 94% of its maximum conservation capacity. If both lakes are at their maximum conservation capacity as calculated above for either six-month period, then such interruptible stored water sales will be limited to a total of 30,000 acre-feet for that year. For projected lake volumes between 94% and 100% of conservation capacity, such interruptible stored water sales would be limited proportionately, based on the storage reservoir with the lowest percentage of capacity as calculated above.

4. Curtailment of Firm Water Demands

LCRA is required by TCEQ and the Texas Water Code to follow water supply allocation procedures to insure that there is no shortage or deficiency of stored water to meet firm demands during a repeat of the Drought of Record. Given the relatively small demand on firm water supplies at present, the possibility of a firm water shortage occurring is remote for the foreseeable future.

LCRA cannot determine with absolute certainty whether a particular drought event will be more or less severe than the Drought of Record. Therefore, LCRA will engage its customers in a public education campaign and seek voluntary reduction of firm demands from its firm customers in the early stages of a drought, as more specifically described below.

LCRA cannot invoke mandatory curtailments of firm water demand unless a particular drought event is determined to be more severe than the Drought of Record or some other water emergency that drastically reduces the available firm water supply. LCRA Water Supply Planning staff has developed a simplified "drought monitoring procedure" for identifying a drought worse than the Drought of Record for the Highland Lakes watershed. Historical inflow data for the contributing watershed of the Highland Lakes were used in the development of this procedure.

a. Policy Recommendation for Firm Water Demand Curtailment

1) <u>Recommendation 1</u>: LCRA encourages its firm water customers to implement long-term water conservation measures year-round to meet the goals included in their water conservation plans. LCRA will implement a public awareness campaign on water use and conservation.

2) <u>Recommendation 2</u>: Whenever total storage in Lakes Buchanan and Travis is at or below 1.4 million acre-feet, LCRA requests its firm water customers implement the voluntary drought restrictions contained in their drought contingency plans, with a target reduction goal of 5 percent (5%).

3) <u>Recommendation 3</u>: Whenever the total storage in Lakes Buchanan and Travis is at or below 900,000 acre-feet, LCRA will ask all its firm water customers to implement mandatory water use reduction measures in their Drought Contingency Plans, with a target reduction goal of ten to twenty percent (10 – 20%). LCRA will also begin discussions with firm water customers to develop a specific stored water curtailment plan, to be approved by the LCRA Board and TCEQ.

4) <u>Recommendation 4</u>: A mandatory pro rata curtailment of a minimum of twenty percent (20%) of LCRA's firm water customers' demands pursuant to Texas Water Code §11.039 will be implemented when the LCRA Board determines that the river system is experiencing a drought more severe than the Drought of Record. If lake levels continue to drop below 600,000 acre-feet, the mandatory pro rata curtailment percentage may be increased as determined by the LCRA Board LCRA will curtail and distribute the available supply of firm water among all of its firm water supply customers on a pro rata basis according to the amount of firm water to which they are legally entitled under the terms of their contract and consistent with the curtailment plan approved by the LCRA Board and TCEQ. All uses of interruptible stored water will be totally cutoff prior to and during any mandatory pro rata curtailment of firm stored water supplies.

In addition to the above features, this curtailment policy for firm water demands, LCRA will require each of its firm water customers to prepare and adopt a legally enforceable local drought contingency plan that specifies the actions to be taken to comply with this DMP/DCP regarding the curtailment of firm supplies. Such plans should be developed pursuant to LCRA guidelines and submitted for LCRA review and acceptance within a reasonable time.

b. Monitoring and Enforcement

LCRA will monitor customers' compliance with the required demand reduction goals and will take enforcement action as necessary against noncompliant customers. Monitoring and enforcement of water-use restrictions at the end-user level generally will be the customers' responsibility.

c. Variances

LCRA's General Manager or his designee may, in writing, grant a temporary variance to the pro rata water allocation requirement of this DMP/DCP if it is determined that failure to grant such a variance would cause an emergency condition adversely affecting the public health, welfare or safety and if one or more of the following conditions are met:

- Compliance with the plan cannot be technically accomplished during the duration of the water supply shortage or other condition for which the plan is in effect.

- Alternative methods can be implemented that will achieve the same level of reduction in water use.

Persons requesting an exemption from the provisions of the DMP/DCP shall file a petition for variance with the LCRA General Manager or his designee within five (5) days after pro rata allocation has been invoked. All petitions for variances shall be reviewed by the LCRA Board of Directors and shall include the following:

- Name and address of the petitioner(s).

- Detailed statement with supporting data and information as to how the pro rata allocation of water under the policies and procedures established in the LCRA DMP/DCP adversely affects the petitioner or what damage or harm will occur to the petitioner or others if the petitioner complies with the pro rata reduction requirements of the plan.

- Description of the relief requested.

- Period of time for which the variance is sought.

- Alternative measures the petitioner is taking or proposes to take to meet the intent of the plan and the compliance date.

- Other pertinent information.

Variances granted by the LCRA Board of Directors shall be subject to the following conditions, unless waived or modified by the LCRA Board of Directors:

- Variances shall include a timetable for compliance.
- Variances granted shall expire when pro-rata reduction requirements are no longer in effect, unless the petitioner has failed to meet specified requirements.

No variance shall be retroactive or otherwise justify any violation of the LCRA DMP/DCP occurring prior to the issuance of the variance(s).

d.Notification of TCEQ Executive Director

The LCRA General Manager or his designee will notify the TCEQ Executive Director within five (5) business days of implementation of any mandatory provisions in the DMP/DCP.

5. Declaration and Cancellation of a Drought More Severe Than the Drought of Record

The LCRA Board of Directors will declare a drought worse than the drought of record when the following three conditions are simultaneously met: (a) drought at least 24 consecutive months (24 months since both Lakes Buchanan and Travis were at their maximum allowable water conservation storage levels); and (b) the cumulative inflow deficit since the beginning of the drought exceeds the envelope curve for cumulative inflow deficits by at least 5% for six consecutive months; and (c) the combined storage in Lakes Buchanan and Travis is less than 600,000 acre-feet.

Curtailments of interruptible stored water due solely to the declaration of a drought worse than the drought of record of duration less than 36 months is only effective on the following January 1 or July 31, whichever occurs first following the declaration by the LCRA Board of Directors. Droughts more than 36 months in length have no restrictions as to when supply reductions can be implemented.

The LCRA Board of Directors will cancel such a declaration if any of the following conditions are met: (a) the cumulative inflow deficit since the beginning of the drought is less than the envelope curve for cumulative inflow deficits by at least 5% for six consecutive months; or (b) the combined storage in Lakes Buchanan and Travis is greater than 1.4 million acre-feet of water, which is simply the recommended threshold for curtailment of interruptible stored water during a repetition of the drought of record. Prior to declaring a drought worse than the drought of record, LCRA will re-evaluate this threshold level to determine if a more accurate conservation storage level in lieu of 1.4 million acre-feet can be determined.

6. Public Notice

LCRA will carry out a public information campaign that is appropriate to the particular curtailment contemplated. This could include some or all of the following efforts: (1) news releases, (2) news updates to area media, (3) interviews with local radio and television stations, (4) responses to requests for information, (5) distribution of water conservation education materials, (6) advertisements in local newspapers to inform the public about current water supply and usage and our water management planning strategies, (7) improvements to LCRA's automated telephone message system to provide information on lake levels, and (8) public service announcements on local radio stations.

7. Impacts of the Recommended Management Policy

a. Firm Water Demands and Supplies

All projected year 2010 demands for firm water are fully satisfied under these simulated critical drought conditions. The largest firm water demand is for the City of Austin. The majority of Austin's projected annual demand of 201,400 acre-feet is met from run-of-river flows diverted under its senior water rights.

Approximately 65% of the demand during the 1947-1956 critical drought years is estimated to be supplied by these flows with the remainder supplied by firm stored water.

b. Interruptible Stored Water Demands and Supplies

With the increase in projected firm water needs for 2010, there is less water for interruptible stored water supply from Lakes Buchanan and Travis since firm water needs take priority over interruptible stored water uses. To avoid shortages to firm water users, it is recommended that interruptible stored water supplies from Lakes Buchanan and Travis be reduced during the critical drought years from what is available under the WMP approved in 1999. This reduction in supplies primarily impacts irrigation.

Under the recommended management policy, all interruptible stored water available during a repetition of the Drought of Record is used by the four downstream irrigation operations, except for that portion committed to maintaining instream flows and estuarine freshwater inflows.

With the curtailment threshold raised from the current value of 1.1 to 1.4 million acre-feet, the projected first crop demand of 83,700 acres will be fully met under the proposed changes, as it is under the WMP approved in 1999. However, there will be a substantial reduction in the irrigation acreage supplied for second crop under the proposed curtailment policy. The WMP approved in 1999 provides sufficient water to irrigate an average of 56,500 acres of second crop each year during a repetition of the Drought of Record. The proposed plan would provide water only for an average of 32,700 acres of second crop under the same drought conditions. Approximately 92 percent (21,800 acres) of this decrease in acreage is due to the increased projected municipal demands, with the remainder (2,000 acres) due to the proposed change in environmental releases for estuarine inflows. In spite of this reduction, irrigators would use, during a repeat of the Drought of Record, an average of 168,400 acre-feet annually, or 75 percent of all interruptible stored water used for irrigation and environmental protection.

The simulated acreage cultivated in first and second crops are given for all four operations combined and individually in Figures 4-2 thru 4-6, at the end of this Chapter. As noted previously, however, the actual interruptible stored water curtailments may differ from the values reflected by the cultivated acreage as shown in this simulation, depending on the facts as they then exist and the terms and conditions of the contracts between LCRA and users.

The recommendation concerning instream flows reflects the philosophy adopted in the initial WMP and continuation in the amendments to the WMP that instream flows be curtailed whenever there is a curtailment of interruptible stored water to the four major irrigation operations. Since the curtailment threshold for irrigation supplies is recommended to rise from 1.1 to 1.4 million acre-feet, LCRA has proposed that the curtailment storage threshold for instream flows also be revised upwards the same amount. By synchronizing these curtailment trigger points, the WMP reflects reduced supplies available to maintain instream flows, including both supplies released for irrigation that simultaneously benefit instream flows as well supplies dedicated to maintain streamflows for ecological benefit.

The recommended intermediate estuarine inflow policy would provide for releases of stored water from Lakes Buchanan and Travis of up to 256,700 acre-feet (150 percent of Critical FIN) annually to Matagorda Bay in years whenever the combined storage in Lakes Buchanan and Travis on January 1 is between 1.1 and 1.7 million acre-feet. By increasing the releases of stored water from Lakes Buchanan and Travis in years when the January 1 storage is within this given range, the estuarine ecosystem receives more freshwater inflows during moderate droughts than it would be under the present WMP.

The WMP, with the proposed revisions herein, will have essentially the same total stored water commitments for environmental purposes as currently provided in the present WMP. During a repetition of the DOR, the present WMP would provide an annual average of 56,000 acre-feet for both instream flows and estuarine inflows. With the proposed changes, the WMP would provide about 56,500 acre-feet annually during the same period and for the same purposes.

The proposed increase in the firm water allocated for environmental purposes from about 16,000 to 33,400 acre-feet is required to properly account for the stored water dedicated for environmental purposes. Whenever irrigation interruptible stored water supplies are curtailed, stored water used for environmental protection has be accounted as firm water since irrigation has priority use of available interruptible stored water supplies. Since the proposed storage threshold for curtailment of irrigation supplies is significantly greater than the present threshold, there will be more years in the DOR when irrigation supplies are curtailed, hence increasing the environmental flows that have to be assigned to firm water supplies.

The proposed additional 17,400 acre-feet firm water commitment for environmental purposes would be provided from the presently uncommitted firm yield of 60,952 acre-feet. The remaining firm yield available after this allocation would be 43,462 acre-feet. This amount is in addition to 50,000 acre-feet reserved by the Board for future uses. The total proposed firm water allocation of 33,400 acre-feet for environmental purposes represents 8 percent of the total firm supply from Lakes Buchanan and Travis.

c. Lake Storage Levels

For the simulated repetition of the Drought of Record, the total combined storage of Lakes Buchanan and Travis was reduced to very low levels in the worst drought years (Figure 4-8), even with the partial curtailment of interruptible stored water supplies. Approximately 200,000 acre-feet of stored water remains in Lakes Travis and Buchanan combined at the lowest storage content. The simulated lake water surface elevations and storage levels are given in Figures 4-9 and 4-10, for Lakes Buchanan and Travis, respectively. The minimum lake water surface levels during the simulation period are about 960 feet msl on Lake Buchanan and 578 feet msl on Lake Travis. The average lake water surface elevations (for the repetition of the 1941-1965 period hydrology) are projected to be 1005 feet msl on Lake Buchanan, and 657 feet msl on Lake Travis.

The simulated minimum water levels in Lakes Travis and Buchanan are lower than the historical low levels of 614 feet and 983 feet, respectively. The greater drawdown on the lakes in the simulated operation is largely because of greater water demands and lower storable inflows than occurred historically. The projected year 2010 water demands are significantly greater than those that occurred historically in the 1941-1965 period. Firm water demands during the actual drought of record were only a small fraction of those projected by year 2010. Additionally, the rice producers only cultivated one crop of rice prior to about 1963. The current practice of producing two crops each year has increased the water demands of irrigation over those of the 1947-1956 critical drought period.

The second factor causing the simulated storage levels to be lower than historical levels is a difference in the storable inflows. The simulated operation uses historical inflows adjusted for any flow reductions caused by water diverted for upstream water rights, particularly major reservoirs including O. H. Ivie Reservoir. Most of the large reservoirs upstream of the Highland Lakes were not in operation during the critical drought period. During any repetition of the Drought of Record, these upstream reservoirs would likely significantly reduce storable inflows.

d. Flows in the Colorado River

For a repetition of the hydrologic conditions in the 1947-1956 critical drought years, the estimated average flow of the Colorado River at Bay City is about 471,000 acre-feet annually with the projected 2010 demands. For a repetition of the 1941-1965 period, the simulated annual flow at Bay City averages 1.22 million acre-feet. Of this total, a portion of the flow consists of dedicated releases of stored water from Lakes Buchanan and Travis to meet the Target and

Critical freshwater inflow needs and a portion consists of stored water released to meet critical instream flow needs at several upstream locations.

The dedicated firm and interruptible stored water releases for the 1947-1956 critical period amount to an average of 56,500 acre-feet per year of which 36,000 acre-feet is for maintaining instream flows.

F. Annual Implementation of Drought Management and Drought Contingency Plans

1. Annual Review and Revisions

As part of the WMP, the DMP/DCP is subject to review each year. The DMP/DCP may be revised at any time subject to approval by the LCRA Board and the TCEQ. Changing water supply and demand conditions on the lower Colorado River will be reflected as necessary in future amendments to the WMP.

2. Administration

The curtailment of interruptible stored water supply will occur through the annual contracting process in November through January of each year. The curtailment of firm water will depend on storage levels and will be monitored continuously. Curtailment of interruptible stored water supply for Garwood and other entities supplied pursuant to long-term contracts will be accomplished pursuant to the terms of those contracts.

LCRA will monitor customer compliance with the required demand reduction goals and take enforcement action as necessary against noncompliant customers. Monitoring and enforcement of water use restrictions at the end-user level generally will be the customer’s responsibility. At present, LCRA’s ability to enforce curtailments of firm water demands is uncertain and may be limited to taking civil action to enjoin a non-compliant customer for breach of contract.

Figure 4-2: Simulated Irrigated Acreage - 4 Irrigation Operations Combined

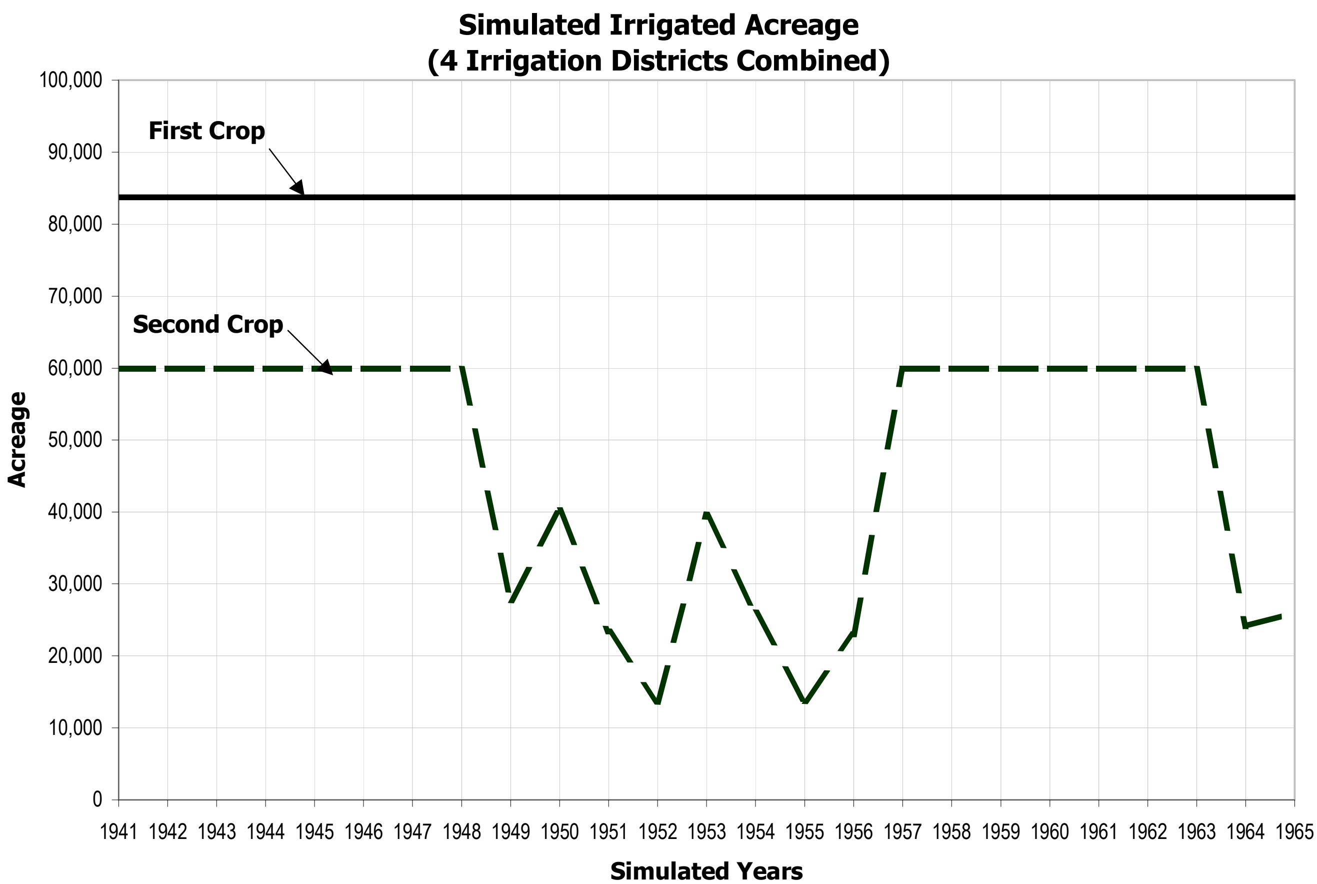


Figure 4-3: Simulated Irrigated Acreage - Gulf Coast

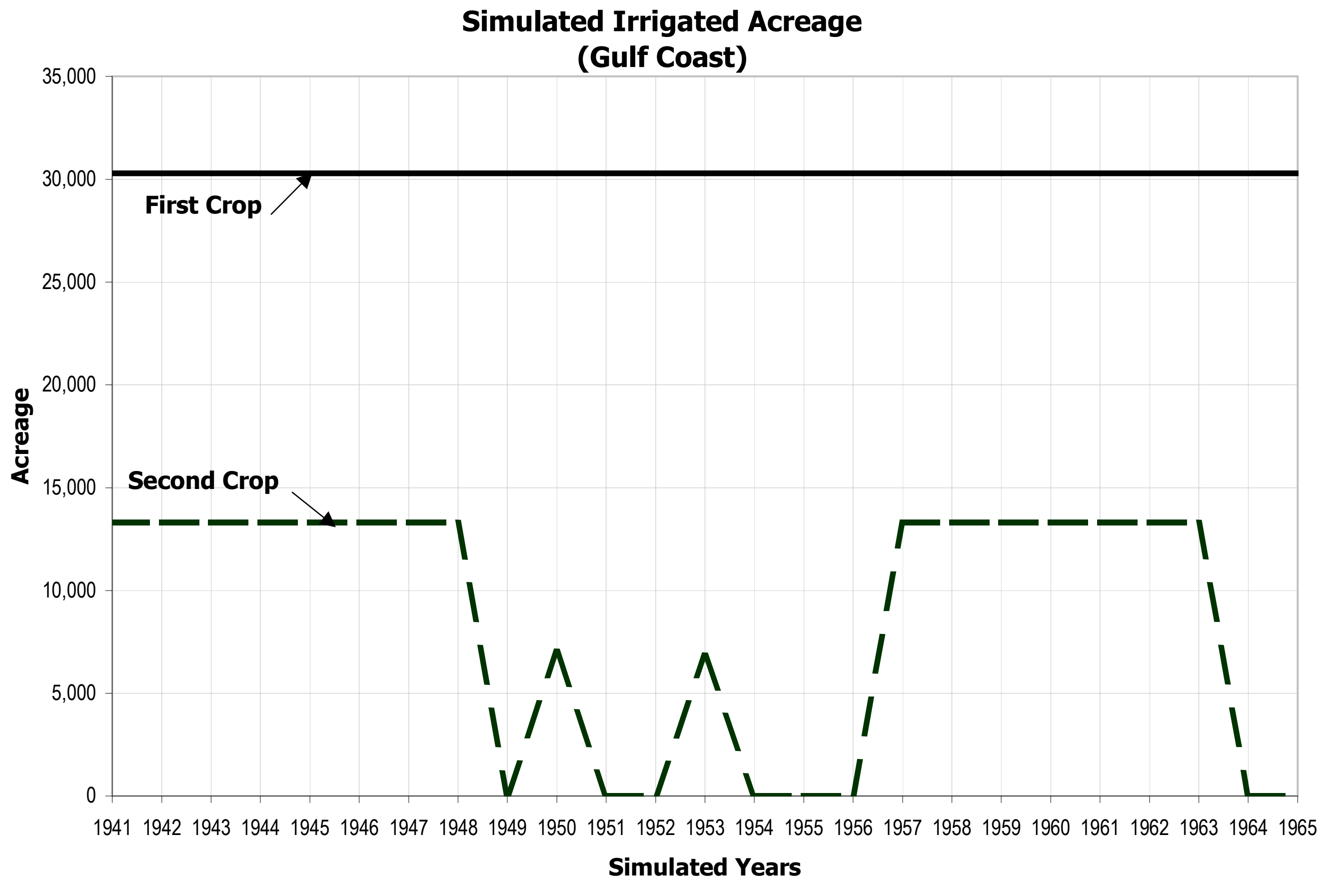


Figure 4-4: Simulated Irrigated Acreage - Lakeside

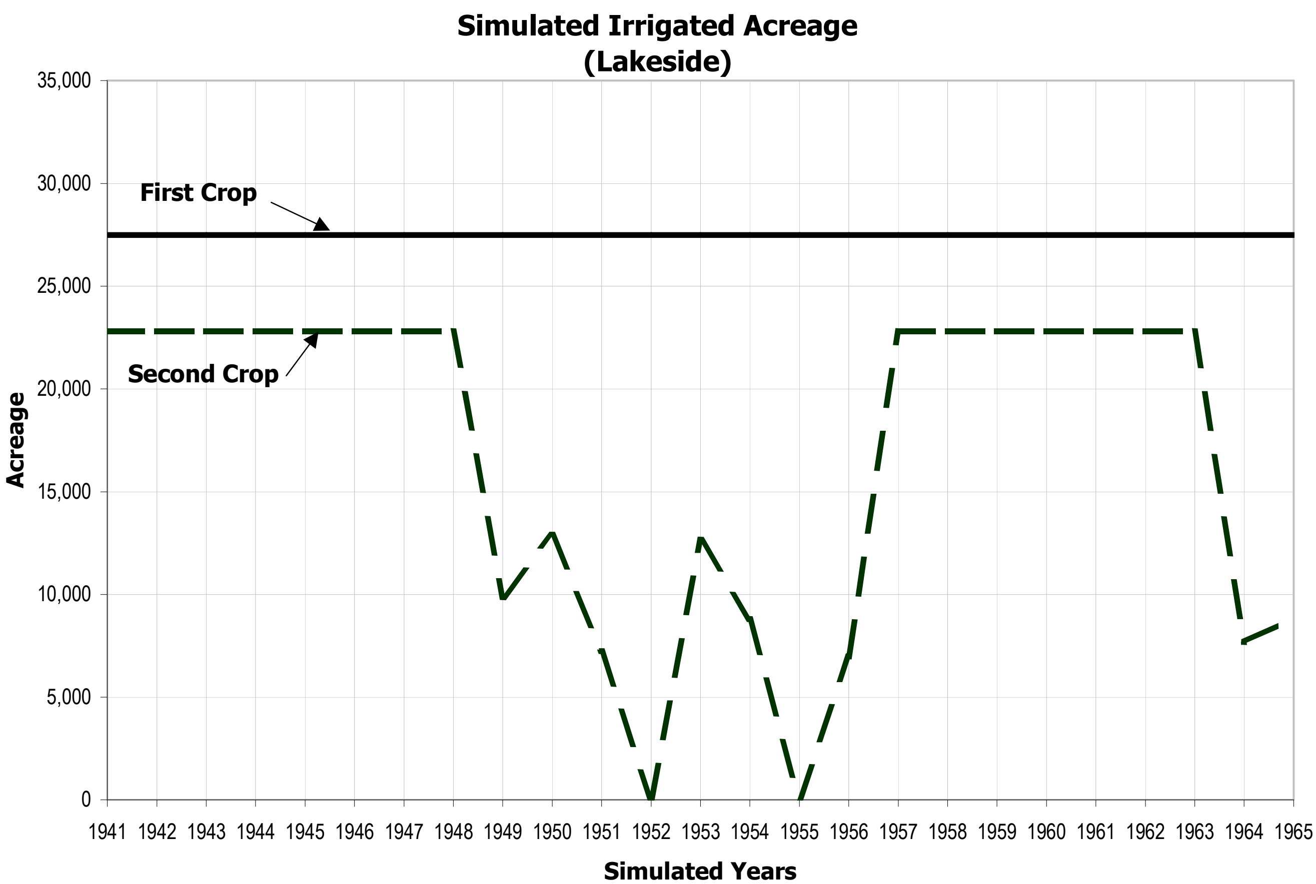


Figure 4-5: Simulated Irrigated Acreage - Garwood

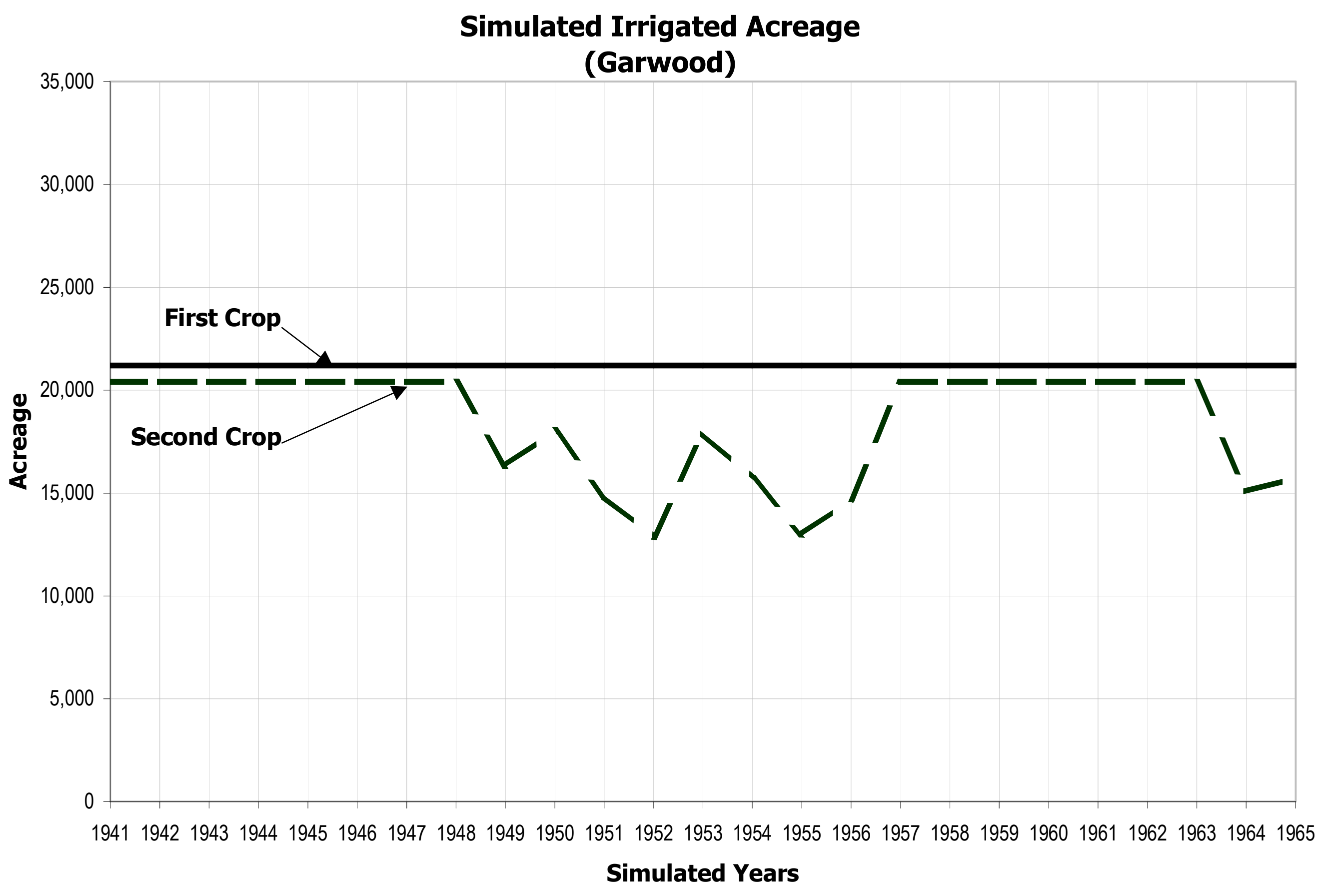


Figure 4-6: Simulated Irrigated Acreage - Pierce Ranch

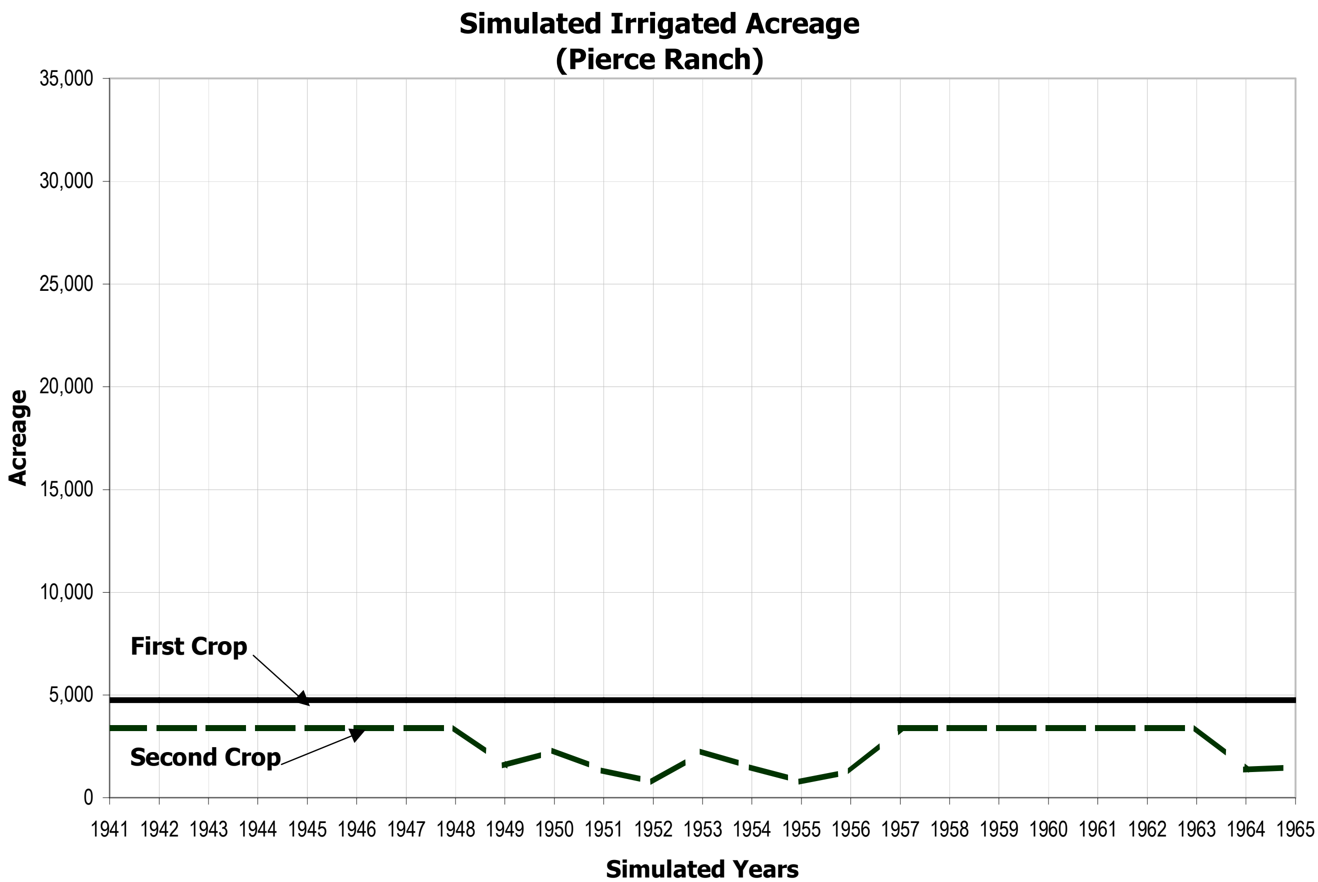


Figure 4-7: Simulated Travis and Buchanan Storage Condition

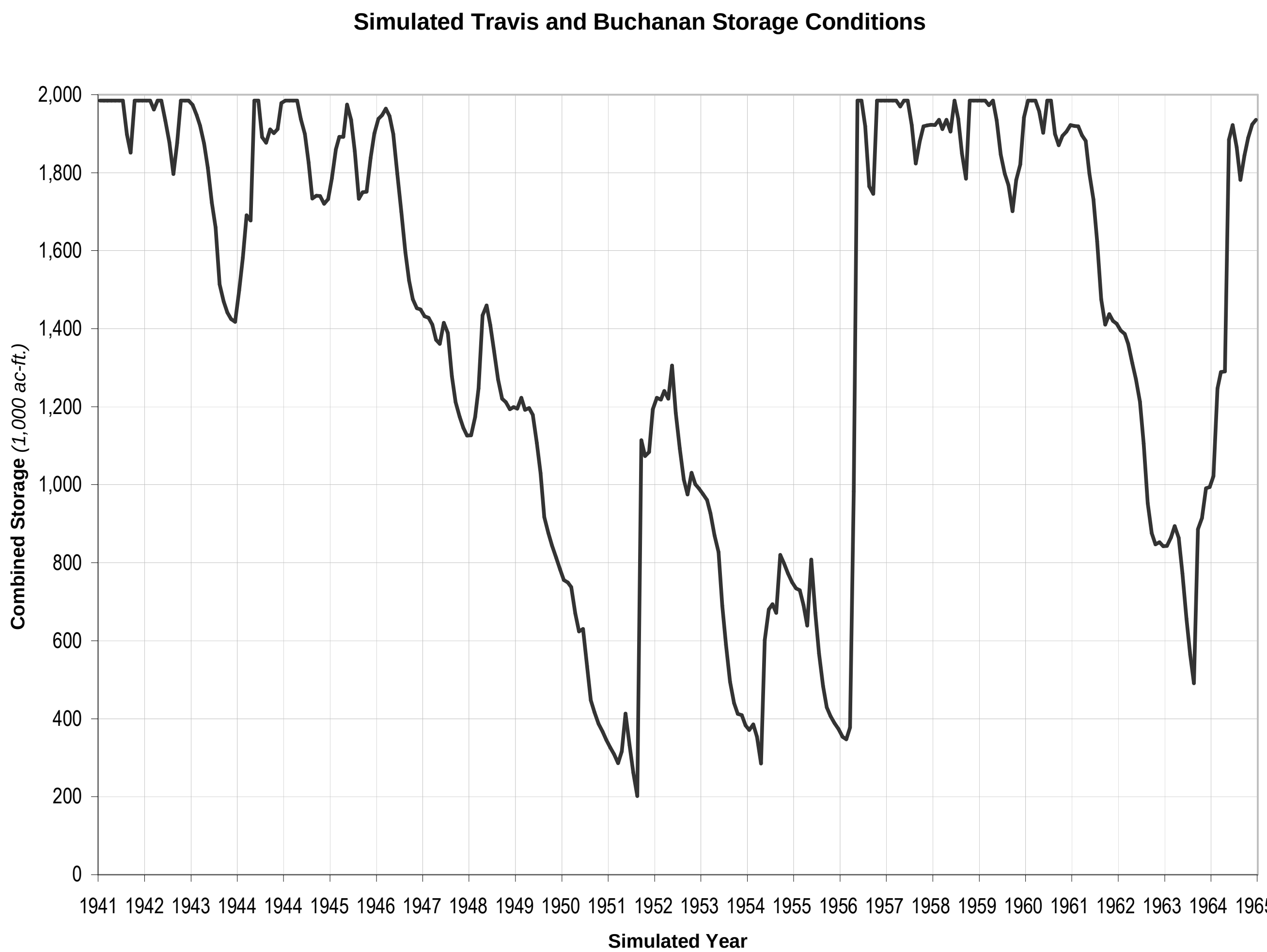


Figure 4-8: Lake Buchanan Simulated Elevation and Storage

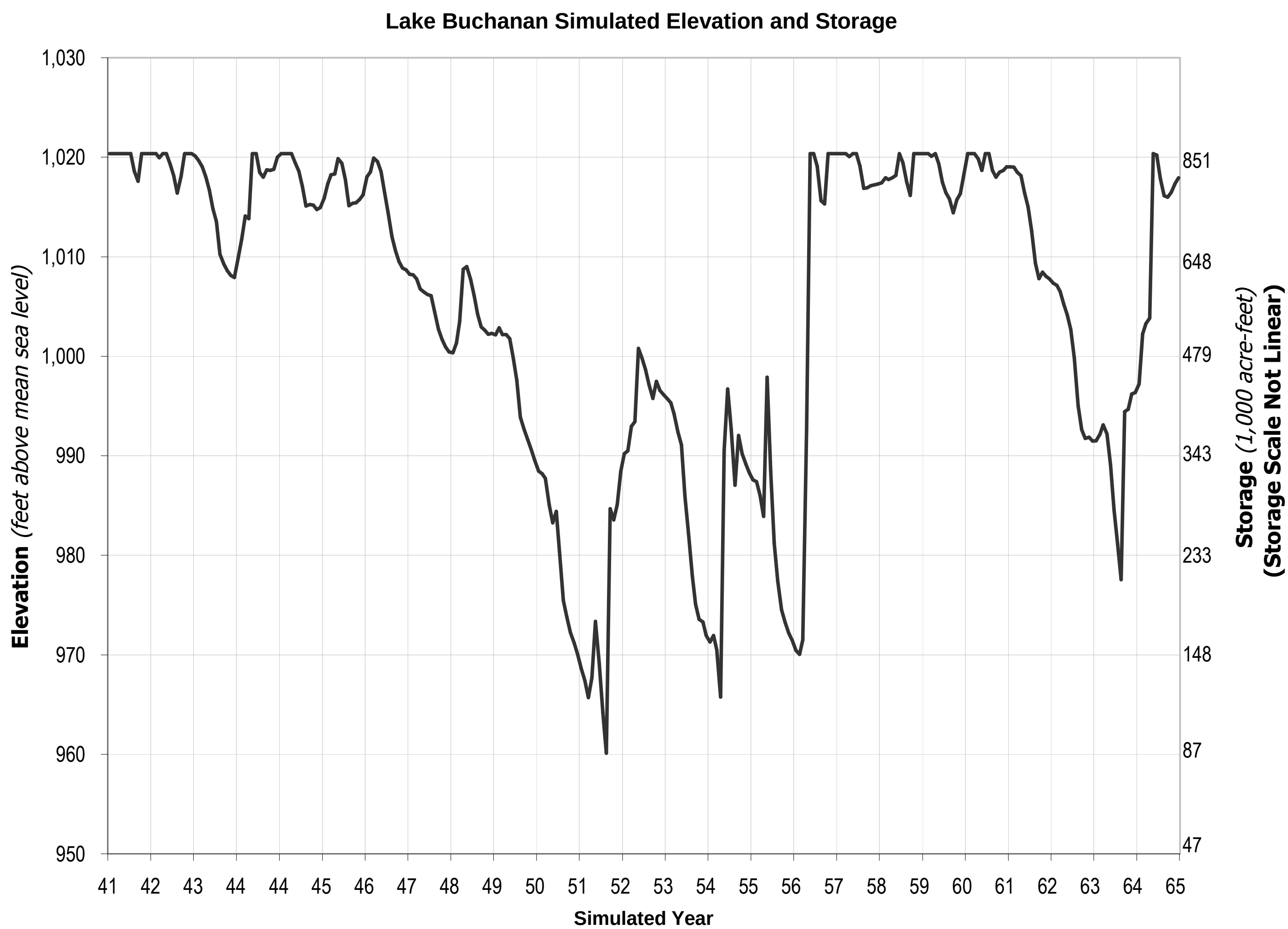
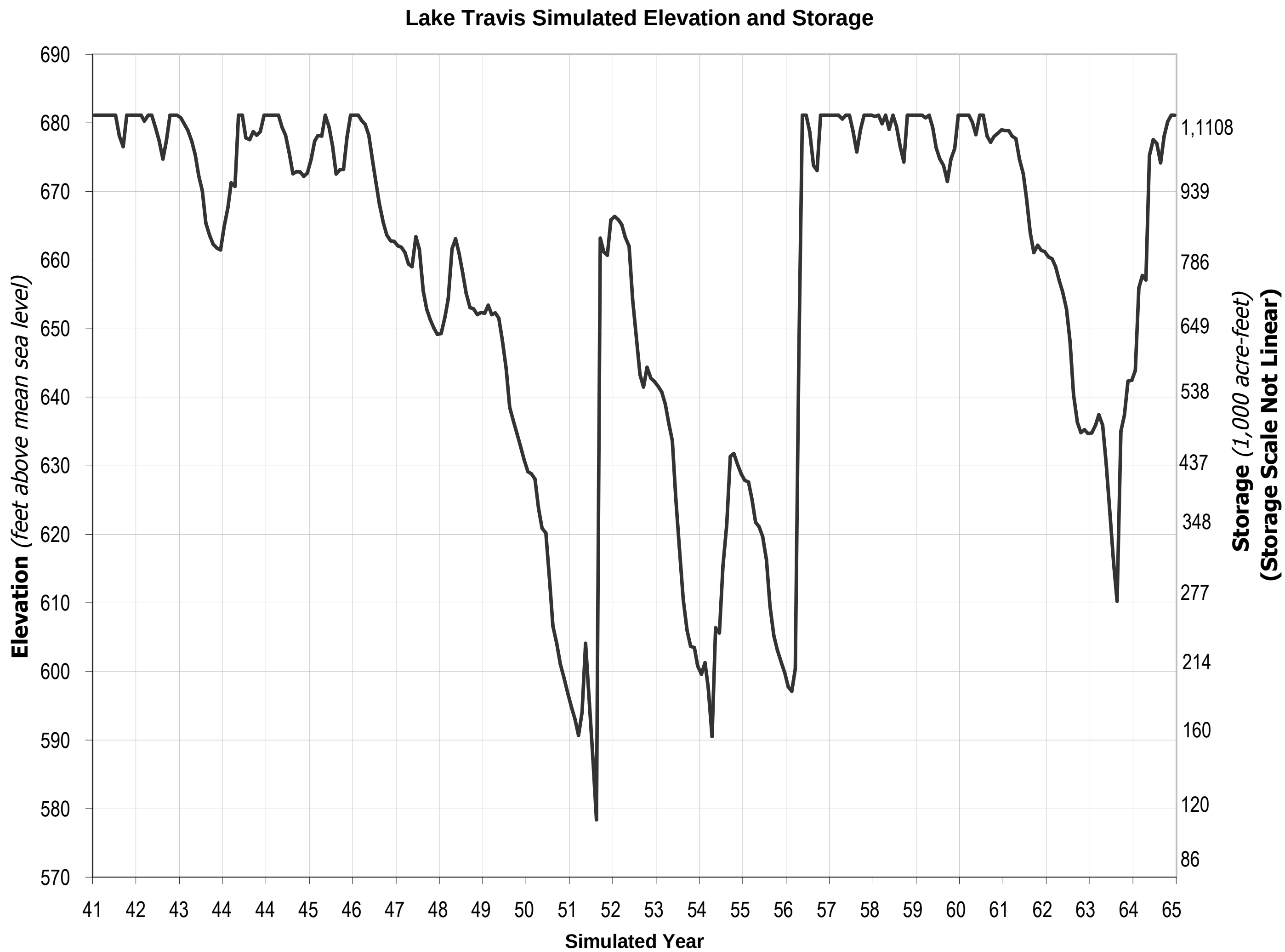


Figure 4-9: Lake Travis Simulated Elevation and Storage



CHAPTER 5
DETERMINATION OF THE COMBINED FIRM YIELD

A. Requirement of LCRA's Water Rights for the Lakes Buchanan and Travis

Two new reservoir yield terms and definitions were introduced in the Final Judgment and Decree. These terms, Combined Theoretical Yield, and Combined Firm Yield, each allowed Lakes Buchanan and Travis to be operated as a system. The Combined Theoretical Yield was defined as the yield of the lakes if no other impoundment occurred upstream, and no water had to be passed through for senior rights. The Combined Theoretical Yield has not been calculated within this study.

The Combined Firm Yield of Lakes Buchanan and Travis is that portion of the yield remaining after honoring the full extent of upstream and downstream senior water rights. An interim value of 500,000 acre-feet per year was specified, which was in effect until the Texas Water Commission (predecessor to TCEQ) approved the original Water Management Plan in 1989 and determined the Combined Firm Yield. The firm yield of O. H. Ivie Reservoir was calculated separately from the Combined Firm Yield of the Lakes Buchanan and Travis. The sum of the firm yield of O. H. Ivie Reservoir and the Combined Firm Yield of Lakes Buchanan and Travis is the total Combined Firm Yield for Lakes Buchanan and Travis. The determination of this value is required by Certificates of Adjudication 14-5478 and 14-5482 (previously Permits 1259 and 1260). This chapter describes the data, methodology, and models used to determine the Combined Firm Yield of Lakes Buchanan and Travis, including information on reservoir inflows, junior and senior water rights priorities and demands, reservoir evaporation data, return flows, and other critical information. In the Combined Firm Yield analysis, the three intermediate reservoirs (Inks Lake, Lake LBJ and Lake Marble Falls) are considered to remain at constant levels during the entire period of simulation. Lakes Buchanan and Travis are allowed to fluctuate down to empty.

B. Reservoir Operation Models

A reservoir operation model is used to determine the firm yield of a reservoir. It provides the ability to analyze a reservoir, or reservoir system, for its ability to supply water under numerous scenarios. Depending on the system in question, the model used can range from a simple, single reservoir operation to a complex, multiple reservoir operation. A reservoir operation model can also be used to determine the firm yield, or the maximum annual supply of water that can be supplied from the reservoir during a repetition of the critical drought period. To establish the firm yield of O. H. Ivie Reservoir and the Combined Firm Yield of Lakes Buchanan and Travis, two different models were required.

1. O. H. Ivie Reservoir Firm Yield Model

The firm yield of O. H. Ivie Reservoir was determined using a standard single reservoir operation model. The model is based on a simple mass balance. The required inputs include inflow, net evaporation, a monthly water demand distribution, and an area/capacity curve for the reservoir. Both the inflow and the evaporation will be discussed in later sections. The demand distribution was extracted from a Texas Department of Water Resources memo of March 21, 1978 concerning the Stacy Dam permit application. The area/capacity curve was taken from the Freese and Nichols, Inc. report titled Engineering Report on Stacy Dam, 1977. These data are presented in Appendix 2D, Volume II.

2. Lakes Buchanan and Travis Combined Firm Yield Model

The Combined Firm Yield of Lakes Buchanan and Travis was analyzed using a multiple reservoir operation model developed by the staff of LCRA. This complex model considers the Highland Lakes and the downstream portion of the Colorado River as a system (Figure 5-1). Computations for this system are conducted in three components within this model.

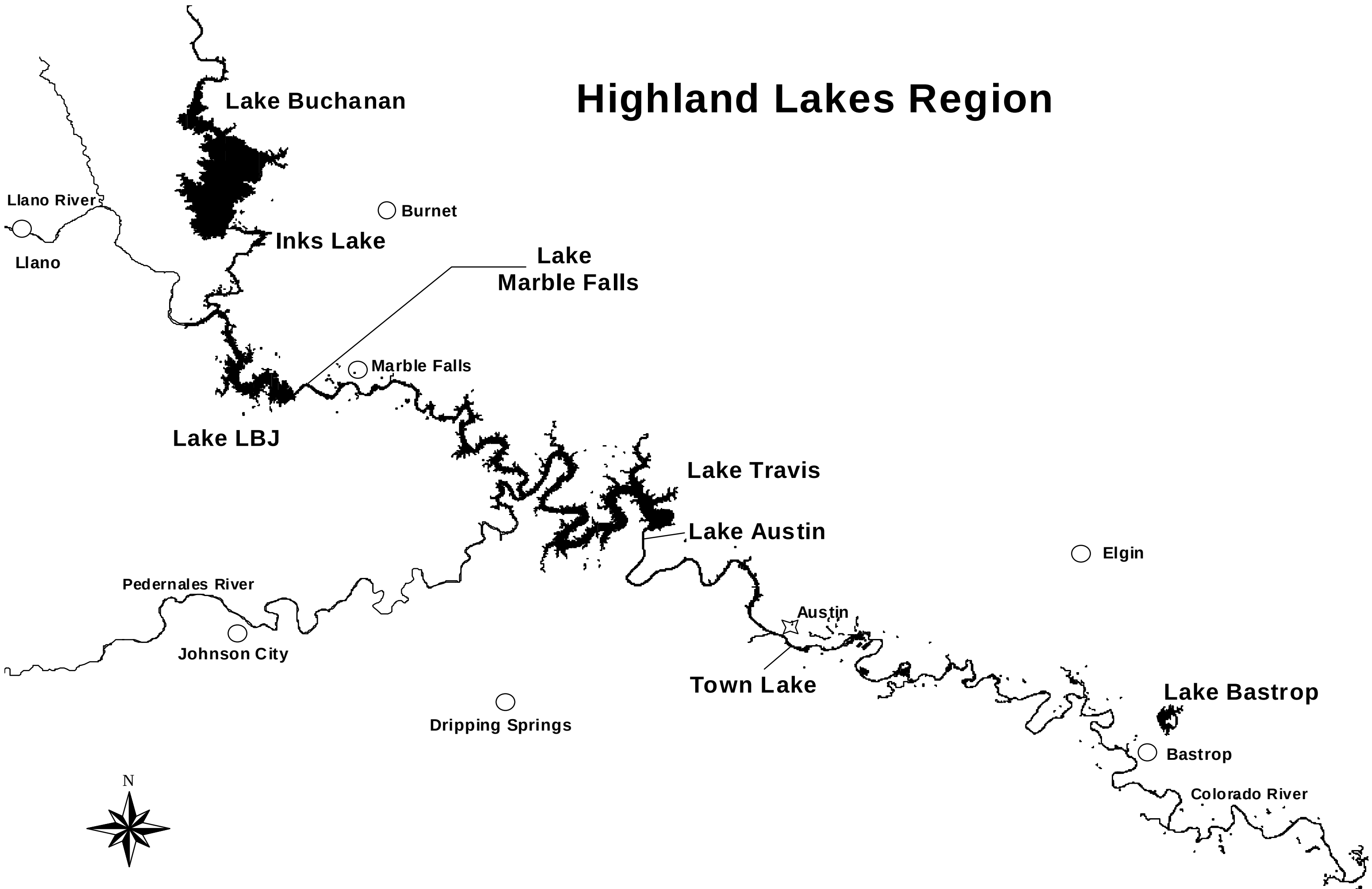


Figure 5-1.
(*In August 2007, Town Lake was renamed "Lady Bird Lake".)

a. Downstream Senior Water Rights

First, the Lakes Buchanan and Travis Combined Firm Yield model considers the senior water rights demands on the Colorado River downstream of Mansfield Dam (Lake Travis). On a daily basis, these demands are compared to the lateral inflow and return flow that enters the river downstream of Mansfield Dam. All unsatisfied demands are considered deficits that could require passage of daily reservoir inflow through the Highland Lakes system.

The information required for the first section of the Lakes Buchanan and Travis Combined Firm Yield model includes:

- daily lateral inflow entering the Colorado River from watersheds downstream of Mansfield Dam,
- appropriate return flow,
- coefficients for equations to describe the movement of water down the river, and
- daily water demands of senior water rights along the river.

b. Passage of Daily Reservoir Inflow

Second, the Lakes Buchanan and Travis Combined Firm Yield model uses an optimization procedure to calculate the minimum passage of daily reservoir inflow required to meet, to the extent possible, the deficits of the downstream senior water rights on the Colorado River. Additional information required for the second section is the daily reservoir inflow entering the Highland Lakes.

c. Operation of the Highland Lakes System

Third, the Lakes Buchanan and Travis Combined Firm Yield model addresses the operation of the Highland Lakes. Storable inflows are the daily reservoir inflows remaining after the calculated required amount passed to meet downstream senior water rights has been subtracted. The combined firm yield of Lakes Buchanan and Travis is calculated with a monthly mass balance using these storable inflows.

Inputs required for the third section, operation of the Highland Lakes system, include:

- storable portion of the reservoir inflows entering the Highland Lakes (storable inflows),
- monthly net evaporations,
- local annual water demands,
- monthly water demand distributions,
- minimum and maximum allowable contents, and
- area/capacity curves.

For a further description of the data requirements for each reservoir in the system, see Appendix 2C, Volume II.

In addition, an operations policy defining individual reservoir operation and a Lake Travis demand distribution for releases are required.

C. Downstream Senior Water Rights in the Lakes Buchanan and Travis Combined Firm Yield Model

1. Final Judgment and Decree

The Final Judgment and Decree requires that all water demands downstream of the Highland Lakes be satisfied to the maximum extent possible by inflows to the Colorado River downstream of those lakes. To determine the water available from these unregulated inflows, the flow conditions in the river must be determined on a daily basis.

2. Development of Model

This section first describes the mathematical procedure for routing streamflow down the Colorado River, and then estimates of the daily water demands are identified to fully satisfy the maximum authorized annual water diversion of each of the major senior water rights in the lower Colorado River Basin. Next, the daily flow conditions in the river from Mansfield Dam to Bay City are simulated using the daily unregulated inflows entering the river downstream of the Highland Lakes. Daily water demands at a specific location are satisfied to the extent that flow is available in the river at that point on that specific day. Daily water demands that are not satisfied by the unregulated runoff become deficits that could require passage of daily reservoir inflow through the Highland Lakes system.

a. Daily Flow Routing Procedure

The daily flow routing procedure is a simple mass balance. To properly analyze the downstream system, a multiple day flow routing relationship is required. This is due to the fact that flows routed between reaches attenuate as they move downstream. Part of the flow arrives at the next reach the very next day, while the rest arrives one or even two days later.

For each reach, a flow is computed that has two components. The first component is the flow being passed from the upstream reach and the second component is the incremental lateral inflow from within the reach. The following equation, which represents the first component, is the routing correlation of downstream to upstream discharges:

$$QD_t = [QU_t \times C_0] + [QU_{t-1} \times C_1] + [QU_{t-2} \times C_2] \qquad (1)$$

where:

QD and QU represent the downstream and the upstream discharges, respectively. The subscript t is the current day, t-1 is day prior to the current day, and t-2 is second day prior to the current day;

C = the routing coefficients for the reach, with subscript 0 corresponds to the current day, 1 corresponds to the day prior to the current day, and 2 corresponds to the second day prior to the current day.

The equation, which incorporates the second component, adds incremental lateral flow within the reach and subtracts diversions to meet demand at each diversion point within the reach:

$$QR_i = QR_{i-1} + (QL \times F_i) - D_i \qquad (2)$$

where:

QR_i = the flow remaining after the i^{th} diversion within the reach (the value of i ranges from 1 to the number of diversions within the given reach), if i=1, then QR_{i-1} is QD_t as defined in the first equation,

QL = the incremental lateral inflow within the reach,

$F_i = (DA_i - DA_{i-1}) / A$, or the ratio of additional drainage are for the i^{th} diversion within the reach,

DA_i = the drainage area at the current diversion point,

DA_{i-1} = the drainage area at the previous diversion point (zero if i=1),

A = the intervening drainage area between downstream and upstream ends of the reach., and

D = the demand for the i^{th} diversion.

To simplify computations, it was assumed that the daily streamflow reflected at the upstream end of a reach would be routed to the downstream end before any extractions were made for local water rights. This action usually imposes an increased amount of conservatism into the routing. By routing the flows to the downstream end, additional attenuation is incurred that may not have physically occurred at each diversion point. This assumption will shift the time of diversion with respect to the pass through discharges in addition to causing additional discharges to potentially be required.

As can be seen by the second equation, it is assumed that only a proportionate amount of the lateral flow is available at any diversion point within the reach. Also, that this proportionate amount is based on the drainage area of the reach to the diversion point. The upstream flow is available to all diverters in the reach.

A review of the lateral inflows defined in a study published in TDWR Report LP-60, entitled "Present and Future Surface-Water Availability in the Colorado River Basin, Texas" (1978) will show a considerable number of negative flows. Records of these negative flows were maintained in the routing model. These values were not routed from reach to reach - rather, they were stored for each reach as a reach loss for the system. The model kept summary records of the unsatisfied authorizations and the reach losses. These were then used in generating the required passage of reservoir inflow to assure that the downstream deficits were satisfied to the greatest extent possible.

The computation procedure of how much downstream deficit remains after accounting for local area flows is as follows:

(1) Compute the quantity of water available to the most upstream right. This requires that the daily lateral flows be adjusted by using a drainage area ratio and that the daily upstream flows be added to the result (note that the daily upstream flow has already been adjusted to reflect the attenuation that would result from passing it from the upstream to the downstream end of the reach);

(2) Extract the amount required to meet the noted water right. If the daily flow is insufficient, maintain a record of the reach deficit, otherwise make the remaining daily flow available to the next downstream water right;

(3) If all water rights in the reach have not been analyzed, return to step 1; otherwise, continue to step 4;

(4) Record reach daily water deficits for further analysis. Two values are maintained for this study. One is the amount of the daily unsatisfied right and the other is the daily stream flow loss that would need to be satisfied to allow flow to reach the additional reaches located downstream.

In this analysis, no distinction is made as to priority among the downstream water rights senior in priority to LCRA's Highland Lakes water rights. The purpose of this section is to describe the method used to estimate the deficits of all senior rights regardless of their relative priority.

b. Demands of Downstream Senior Water Rights

The Final Judgment and Decree found that water rights existed downstream of the Highland Lakes that are senior in priority to the water rights of the Highland Lakes. These downstream water rights, as adjudicated and amended, are summarized in Table 5-1.

TABLE 5-1
DOWNSTREAM WATER RIGHTS SENIOR TO THE HIGHLAND LAKES

OWNER (Certificate No.)	USES	DIVERSION (ac-ft/year)	PRIORITY DATE
Austin (14-5471B)	Municipal	250,000	6-30-1913[(a)]
	Irrigation	150	6-30-1913[(a)]
	Municipal	22,403	6-27-1914
	Industrial	24,000	6-27-1914
Several Smaller Rights[(d)]	various	1975	various
Lakeside [(b)] (14-5475A)	Irrigation	52,500[(c)]	01-04-1901
	Irrigation & Municipal	55,000	09-01-1907
Garwood [(b)] (14-5434C)	Municipal, Industrial, & Irrigation	133,000	11-01-1900
Corpus Christi (14-5434B)	Municipal, Industrial, & Irrigation	35,000	11-02-1900
Pierce Ranch [(b)] (14-5477D)	Municipal, Industrial, Irrigation, & Recreation	55,000	09-01-1907
Gulf Coast [(b)] (14-5476A)	Irrigation	228,570[(c)]	12-01-1900
TOTAL	All	857,598	

(a) Any water right owned by LCRA with a priority date junior to November 15, 1900 is specifically subordinated as to priority to this right.
(b) Water right owned by LCRA.
(c) Lakeside and Gulf Coast have additional authorized diversions for irrigation of 78,750 and 33,930 acre-feet/yr., respectively, with a junior priority date of November 1, 1987.
(d) Certificates 14-5379, 14-5382, 14-5384, 14-5396, and 14-5402.

Demands for these senior water rights were modeled on a daily time step. The main concern involved the development of a daily demand distribution that would be representative of those senior rights diversions. It was decided to define the required distributions using historical daily diversions. Two distributions were derived, one municipal and the other irrigation.

The municipal distribution (Figure 5-2) was derived using the historical City of Austin diversions recorded during the years 1976 through 1985. The same date diversions were totaled for all years (i.e. all January 1st diversions for all years), and then an average daily percentage was derived.

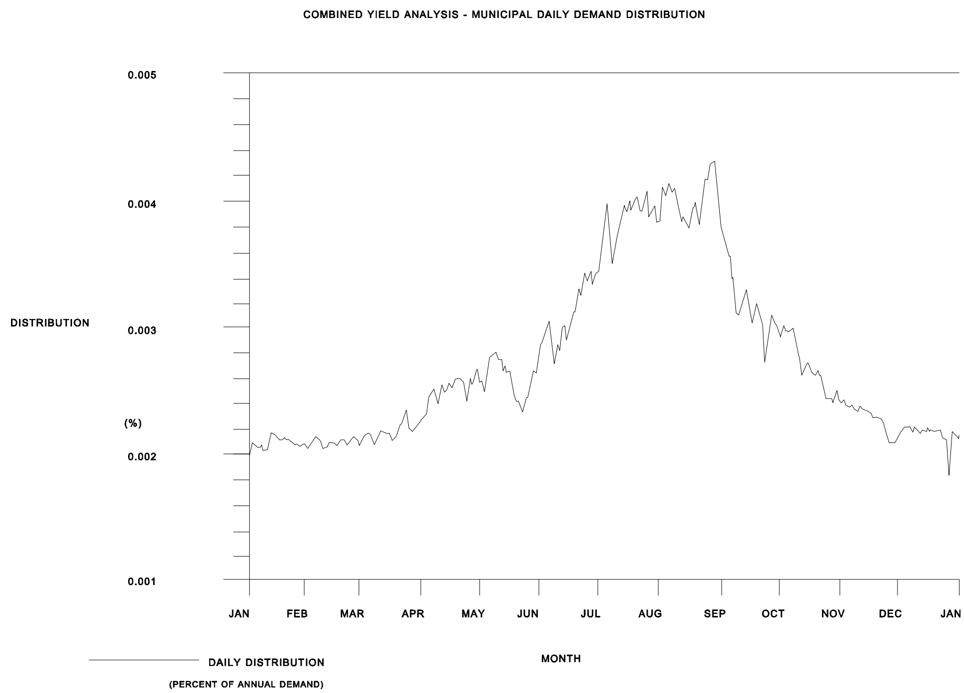


FIGURE 5-2
MUNICIPAL DAILY DEMAND DISTRIBUTION

The irrigation distribution (Figure 5-3) was derived similarly. The same period of record was used (1976-1985) as was the same date methodology for defining the daily percentages. The only difference was that the historical diversions for LCRA's Lakeside and Gulf Coast Irrigation Operations, Garwood Irrigation Company, and Pierce Ranch were totaled and used in lieu of the single City of Austin diversion. As a result, the distribution used for irrigation truly reflects the various irrigation practices of the largest downstream diverters. This distribution was used to simulate all irrigation diversions. The primary need for this assumption is that there were no daily diversion records available for the other simulated rights.

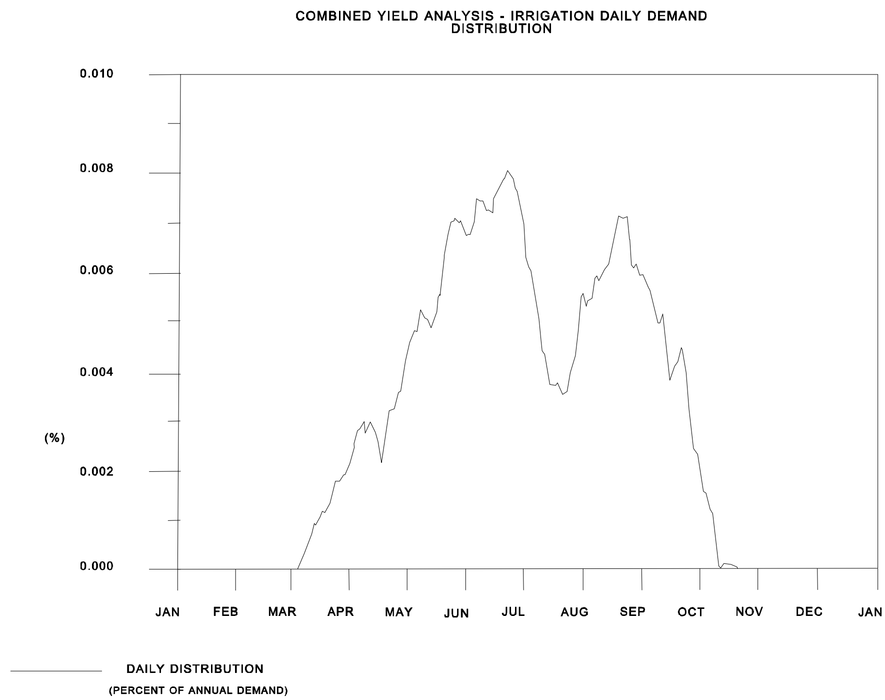


FIGURE 5-3
IRRIGATION DAILY DEMAND DISTRIBUTION

c. Intervening Inflows And Channel Losses From Mansfield Dam To Bay City

During years of average and high levels of rainfall, the Colorado River typically discharges large volumes of streamflow into the Gulf of Mexico and Matagorda Bay. On an annual average, this total flow is 1.7 million acre-feet, as measured at the Bay City gaging station. This average is for the period 1941-1984 and includes many years of drought, particularly the historic critical drought period of 1950-1957. While the Highland Lakes control most of the streamflow upstream of Mansfield Dam, the runoff in the lower Colorado River basin below Mansfield Dam is virtually uncontrolled.

The Colorado River downstream of Lake Travis has a drainage area of approximately 3,500 square miles.

Runoff from this area averages approximately 600 thousand acre-feet annually.

This water represents a significant water resource to the lower Colorado River basin and the adjacent coastal basins.

Since there is limited capacity to store runoff in the Colorado River basin below Austin, the dependability of this runoff is subject to the ability of users to divert and store the runoff when it does occur. Since the timing of this runoff is highly variable, it is important to consider its daily distribution.

(1) Natural Runoff and Springflow

The most extensive analysis of the daily runoff in the drainage basins of the Colorado River below Lake Travis was undertaken by the Texas Department of Water Resources (TDWR) as part of "Colorado Coastal Plains Study" of the U.S. Bureau of Reclamation, Department of the Interior. The results of the TDWR study were published in 1978 in TDWR Report LP-60, entitled "Present and Future Surface-Water Availability in the Colorado River Basin, Texas." The daily inflows to the Colorado River were analyzed in LP-60 for each of five stream segments: (1) Mansfield Dam to the Austin stream gage, (2) Austin to Smithville, (3) Smithville to Columbus, (4) Columbus to Wharton, and (5) Wharton to Bay City. Daily flow and diversion records, where available, were used to determine the incremental net daily inflow for the drainage areas for each of the five river segments for the period 1941-1965, inclusive. The net daily inflows represented the sum of the runoff from the drainage area contributing directly to the stream segment, spring flows, and any return flows, minus channel losses (seepage and evapotranspiration) and diversions by man.

Daily diversions for the major surface water irrigation users during the 1941-1965 period were not available. Thus, they were not used in the calculations of incremental net inflows in LP-60. Additionally, the City of Austin daily wastewater discharges for the same period were not available, and similarly were not used to adjust the gaged flow records. However, information is available on the annual Austin effluent discharges from 1949 to present. For the critical drought period of 1949-1957, the average annual return flow from the City of Austin was 12,500 acre-feet. This volume of return flow is thus included in the net daily inflows calculated in LP-60 for the Austin to Smithville river segment. Chapter 5 of LP-60 gives a complete description of the development of the incremental net daily inflows.

Not all the net daily inflows developed in LP-60 were used in this study. The net inflows from LP-60 for the three river segments from Mansfield Dam to Columbus were used without change. However, the net inflows for the Columbus to Bay City portion of the river were not used since they included the historical diversions for rice irrigation. Thus, they are not representative of the actual inflows and channel losses in the river. For the WMP analysis of the Combined Firm Yield of Lakes Buchanan and Travis, the net daily inflows from the drainage area between Columbus and Bay City are set to zero, which is a very conservative approach.

(2) City of Austin Treated Wastewater Effluent Discharges

Inflows to the Colorado River below the Highland Lakes include discharges of treated wastewater.

By far, the largest of these discharges is from the City of Austin wastewater treatment plants to the east and south of Austin. For the WMP Combined Firm Yield analysis, the City of Austin effluent discharges are projected to be 149,800 acre-feet per year. This projection is based upon Austin fully using its maximum authorized annual municipal use senior water right of 272,403 acre-feet and then returning all effluent derived from that water. The resulting wastewater flow is assumed to be equal to the historical percentage (55%) of municipal water diversions returning as wastewater. This estimate of return flow is 149,800 acre-feet per year. The water used under Austin's water rights for steam electric power cooling water is not included in the return flow estimates.

It is recognized that currently the City of Austin is not returning this amount of water to the river; however, the criteria established for determining the Combined Firm Yield dictates that all water right holders must be assumed to be using all the water to which they are entitled. For the City of Austin, this amounts to 272,403 acre-feet per year for municipal use under its senior water right. The assumption has also been made that wastewater from this use will return to the river at a rate equal to the historical percentage; however, Austin may find other uses or other methods of disposal of such wastewater, thereby reducing the percentage. Additionally, the percentage may be decreased by decreases in inflow and infiltration to the City's wastewater collection system.

The annual return flow is distributed on a monthly basis according to historical monthly discharge patterns for the years 1978 through 1987, inclusive (Table5-2). A uniform daily distribution is assumed for flow in any given month.

TABLE 5-2
MONTHLY DISTRIBUTION OF ANNUAL CITY OF AUSTIN RETURN FLOW, CALENDAR YEARS 1978 – 1987

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
%	8.06	7.52	8.47	8.09	9.00	9.14	8.30	8.07	8.10	9.09	7.60	8.56	100%

The net runoff data for the river segment between the Austin stream gage and the Smithville stream gage includes approximately 12,500 acre-feet of historical discharges for the City of Austin during the historical critical drought period. To avoid double accounting of this historical return flow, the volume of the City of Austin return flow added to the system for the purposes of flow simulation is considered to be 137,300 acre-feet annually (149,800 less 12,500 acre-feet). The monthly distribution of that return flow is given in Table 5-3.

TABLE 5-3
MONTHLY RETURN FLOWS FOR THE CITY OF AUSTIN ADJUSTED FOR HISTORICAL RETURN FLOWS
(1000 ACRE-FEET)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
11.1	10.3	11.6	11.1	12.4	12.5	11.4	11.1	11.1	12.5	10.4	11.8	137.3

Return flows from communities in the Colorado River Basin below Austin were not included as inflows to the river since the volume of projected inflows is very small compared to the natural inflows.

(3) Return Flows From Irrigation

Studies made by TDWR in the 1970s indicated that as much as 35 percent of the water applied for irrigation of rice returned to surface water streams and, eventually, to coastal bays and estuaries. This represents an important source of freshwater inflow to the estuaries. These inflows are estimated at about 150,000 acre-feet annually. Virtually none of this return flow reenters the Colorado River at or upstream of Bay City.

Because of the anticipated agricultural conservation measures, the estimated return flow percentage for the year 2030 will likely decrease from historical rates to a level of approximately 25 percent. These return flows must be considered in all estimates of total freshwater inflow to Texas bays and estuaries.

d. Flow Routing Coefficients

The downstream system was divided into five reaches (Table 5-4). To enable staff to utilize the incremental inflows developed by the Texas Department of Water Resources in their report LP-60, these reaches were defined using the same end point locations. Each reach required a set of routing coefficients. These coefficients were derived using the curve fitting program QFIT, which was developed by the Texas Water Development Board (Report VM-49).

TABLE 5-4
Downstream Reach Definition

REACH NUMBER	LOCATION
1	MANSFIELD DAM TO USGS AUSTIN GAGE
2	USGS AUSTIN GAGE TO OLD USGS SMITHVILLE GAGE
3	OLD USGS SMITHVILLE GAGE TO USGS COLUMBUS GAGE
4	USGS COLUMBUS GAGE TO USGS WHARTON GAGE
5	USGS WHARTON GAGE TO USGS BAY CITY GAGE

Historical daily gage station records were obtained for each of the selected sites to be used as input to QFIT. Hydrograph pairs were selected for each reach that represented discharges in the range of 500 to 3000 cfs (the typical flow regime encountered during the irrigation season). In addition, the hydrograph pairs selected each had to exhibit the classic hydrograph wave shape. The values in each hydrograph had to have enough change to allow discernment of the wave from the upstream to the downstream gage.

After the hydrograph pairs were selected, QFIT was run under a variety of equation forms to test for the most reasonable curve fitting method. The specific coefficient calculation method resulting used only variable inflow coefficients, with outflow coefficients set to zero, and with the summation of all inflow coefficients equal to one. While runs were also made that allowed variable outflow coefficients, these were used for cross-checking only, with runs actually being applied only when the resulting outflow coefficients equaled zero.

For each hydrograph pair, the number of prior days to be used in the flow equation was varied to test this factor's influence on the resulting coefficients. The predicted and observed outflow values were examined, and any large deviations were noted. The percentage difference between total predicted and observed outflows, or average daily deviation, was also checked, and only runs with an average daily deviation of less than one percent were further applied.

The resulting values were compared to known travel times for potential elimination. Those that appeared reasonable were maintained. The final coefficients were then generated by taking the average of the remaining sets of coefficients. The values used in the daily analyses are found in Table5-5.

TABLE 5-5
DAILY FLOW ROUTING COEFFICIENTS

REACH NUMBER	DAY T	DAY T-1	DAY T-2
1	1.000	0.000	0.000
2	0.000	0.528	0.472
3	0.000	0.556	0.444
4	0.055	0.716	0.229
5	0.290	0.710	0.000

e. Hydrologic Routing Relationships

Basic to determining the optimum reservoir releases is the hydrologic flow routing relationships. Figure 5-4 indicates the location of stream gages and water diversion demands used in the routing. The equations used to predict the daily flow at various points on the lower Colorado River have been developed by LCRA's Water Resources Management staff. The flow routing relationships and equations are discussed separately for each river segment. The flow routing equations used to simulate the passage of daily unregulated inflows below Lake Travis are identical to those used in the calculation of daily reservoir inflow releases.

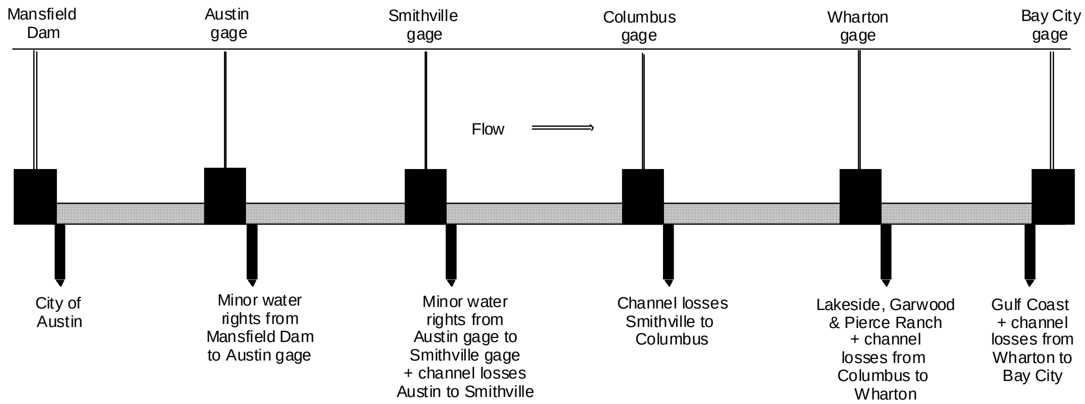


Figure 5-4.
Location of Stream Gages and Diversion Points for Routing of Reservoir Releases

(1) Mansfield to Austin Gage

This stream segment receives inflow on day t from releases and pass throughs from Lake Travis ($I_{1,t}$). The City of Austin has part of its diversion ($COA_{1,t}$) at the upstream end of the section (Lake Austin). The remainder of its diversion ($COA_{2,t}$) is at Lady Bird Lake. For this analysis, this downstream diversion is treated as if it occurs at the upstream end of the river section. Therefore, the net daily flow into the reach is

$$\text{Reach Net Inflow on day } t = I_{1,t} - COA_{1,t} - COA_{2,t} \geq 0 \qquad (3)$$

The flow travel time between Mansfield Dam and the Austin gage is only a few hours. Therefore, the daily outflow ($O_{1,t}$) at the Austin gage location is set equal to the inflow to the next downstream reach $I_{2,t}$.

The daily net incremental inflows for this reach are all non-negative.

Thus no channel loss will accumulate at the Austin gage.

(2) Austin Gage to Smithville Gage

This stream segment has minor daily water rights ($AS_{1,t}$) that are assumed to be withdrawn at the upstream end of the reach. Thus the net daily inflow to the reach is

$$\text{Reach Net Inflow on day } t = I_{2,t} = O_{1,t} - AS_{1,t} \geq 0 \qquad (4)$$

This inflow is then routed to give the outflow on day t ($O_{2,t}$) at the Smithville gage location using the following daily flow routing equation for that stream segment.

$O_{2,t} = .528*I_{2,t-1} + .472*I_{2,t-2}$ (5)

(3) Smithville Gage to Columbus Gage

This stream segment has minor water rights on day t ($AC_{1,t}$) that are assumed to be withdrawn at the upstream end of the reach. The daily net incremental inflows for the Austin to Smithville river segment may be negative during certain periods. Any negative net incremental inflows on day t at the Smithville gage ($CL_{2,t} \leq 0$) calculated during the routing of uncontrolled inflows must be added to the deficit water rights diversions in determining the net reach inflow. Thus,

Reach Net Inflow on day t = $I_{3,t} = O_{2,t} - AC_{1,t} + CL_{2,t} \geq 0$ (6)

This inflow is then routed to give the daily outflow (O_3,t) at the Columbus gage location using the following daily flow routing equation for that stream segment.

$O_{3,t} = .556*I_{3,t-1} + .444*I_{3,t-2}$ (7)

(4) Columbus Gage to Wharton Gage

This stream segment has major water rights demands on day t for the LCRA Lakeside Irrigation Operation (LK_t) and Garwood Irrigation Company (GW_t) that are assumed to be withdrawn at the upstream end of the Wharton to Bay City reach. The daily net incremental inflows for the Smithville to Columbus river segment may be negative during certain periods. Any negative net flows at the Columbus gage on day t ($CL_{3,t} \leq 0$) calculated during the routing of uncontrolled inflows must be added to the deficit water rights diversions in determining the net reach inflow. Thus,

Reach Net Inflow on day t = $I_{4,t} = O_{3,t} + CL_{3,t} \geq 0$ (8)

This inflow is then routed to give the daily outflow ($O_{4,t}$) at the Wharton gage location using the following daily flow routing equation for that stream segment.

$O_{4,t} = .055*I_{4,t} + .716*I_{4,t-1} + .229*I_{4,t-2}$ (9)

(5) Wharton Gage to Bay City Gage

This stream segment has major water rights diversions for day t for Pierce Ranch (PR_t) and the LCRA Gulf Coast Irrigation Operation (GC_t). Pierce Ranch diversions are assumed to be withdrawn at the upstream end of the reach. Diversions for Bay City are assumed to be withdrawn at the downstream end. In addition, the Garwood and Lakeside diversions are assumed to be withdrawn at the upstream end of this river segment.

The daily net incremental inflows for the Columbus to Wharton river segment are assumed to be zero. Thus,

$$\text{Reach Net Inflow on day t} = I_{5,t} = O_{4,t} - PR_t - LK_t - GW_t \geq 0 \qquad (10)$$

This inflow is then routed, using the following daily flow routing equation for this reach, to give the outflow in day t ($O_{5,t}$) of the reach prior to diversions for the Gulf Coast Operation.

$$O_{5,t} = .290 * I_{5,t} + .710 * I_{5,t-1} \qquad (11)$$

The diversions for the Gulf Coast Irrigation Operation are subtracted from the flow into the Bay City gage to obtain the resulting daily outflow. Thus,

$$\text{Reach Net Outflow on day t} = O_{6,t} = O_{5,t} - GC_t \geq 0 \qquad (12)$$

f. Resulting Downstream Deficit

The downstream area was divided into five reaches. The water demands associated with the full senior water rights in each reach are found in Table 5-6.

TABLE 5-6
MODELED REACH DEMANDS

REACH NUMBER	DIVERSION DEMAND (ACRE-FEET/YEAR)
1	296,403
2	2,192
3	0
4	330,500
5	228,570

The total modeled demand is 857,665 acre-feet per year. The first step in developing the pass-through values of the Highland Lakes inflow was to determine to what extent the downstream inflows could not satisfy the lower basin demands. The results of this analysis are as follows:

- Average annual unsatisfied demand was 520,657 acre-feet;
- Maximum annual unsatisfied demand was 674,095 acre-feet; and
- Minimum annual unsatisfied demand was 340,500 acre-feet.

These unsatisfied demands were then used as the input demands for determining the required pass through of inflows from the Highland Lakes.

D. Passage of Daily Reservoir Inflows in the Lakes Buchanan and Travis Combined Firm Yield Model

Under the terms of the Final Judgment and Decree and for the purposes of determining the Combined Firm Yield, daily inflows into the Highland Lakes must be passed through to the extent necessary to meet any downstream water rights senior to those of LCRA for the Highland Lakes. Not all inflows on a given day need to be passed through Mansfield Dam. Only that portion of the inflows needed to satisfy demands of the senior water right holders must be passed through.

All surface water diversions for senior downstream water rights must first be satisfied by inflows to the Colorado River from drainage areas downstream of Mansfield Dam. Only that portion of the senior water rights that cannot be meet from inflows to the Colorado River downstream of Mansfield Dam become the downstream demands for which inflows are passed through the Highland Lakes.

In this analysis, no distinction is made as to priority among the downstream water rights senior to LCRA's rights. The purpose of this section is to describe the method used to estimate the required passed through amounts of reservoir inflows to meet all senior rights regardless of their relative priority.

Determining the required passed through amounts of reservoir inflow depends upon the results of the routing of the unregulated, daily inflows below Mansfield Dam. Similarly, the results of the reservoir inflow passed through calculations are used in the reservoir firm yield calculations.

An optimization procedure is used to calculate the minimum required pass through of daily inflows to meet the remaining downstream water demands, to the extent possible. The daily reservoir inflows remaining, after the calculated pass through flows are subtracted, are treated as storable inflows available for storage in the Highland Lakes and are used in the estimation of the Combined Firm Yield of Lakes Buchanan and Travis.

1. Solution Procedure

The basic method proposed to determine the minimum reservoir inflows allowed to move downstream is to simulate, on a daily basis, the hydrologic conditions in all reaches of the river below Mansfield Dam.

Steps in the Solution Process

The sequence of steps in the determination of the optimal pass through amount of reservoir inflow is indicated below.

Step 1. Read daily data for period of simulation: reservoir inflows, deficits in senior water right diversions, and channel losses not fully satisfied.

Step 2. Begin on initial day of simulation.

Step 3. Subtract the City of Austin water demand for the current day from the reservoir inflows for that day. If the resulting number is less than or equal to zero then set the inflow available for reservoir storage to zero for that day and go to Step 7. If the resulting number is greater than zero then inflow is potentially available to meet any senior water right demand deficits downstream. Go to Step 4.

Step 4. Calculate total deficiencies in downstream senior water rights diversions for next eight days, including current day. If there are no deficiencies then go to Step 7. If there are deficiencies then go to Step 5.

Step 5. Determine the minimum amount of inflows to pass through to meet downstream senior water rights. This minimum pass through amount is calculated by solving the Linear Programming Flow Routing Problem (described below) for eight day period beginning on current day. Go to Step 6.

Step 6. Store optimal reservoir outflow for current day. Also, store any remaining unsatisfied channel losses and senior water right demands. Go to Step 7.

Step 7. Consider next day. If the end of the simulation period is reached then stop. Otherwise, go to Step 3.

2. Required Input Data

- Linear daily flow routing equations for each river segment between Mansfield Dam, Austin gage, Smithville gage, Columbus gage, Wharton gage, and Bay City gage.

- Diversion requirements (deficits) for senior water rights for each river segment that could not be met from routing inflows below Mansfield Dam.

- Net channel losses upstream of diversion deficits. These must be fully satisfied on each river segment before any senior right diversion deficit is computed on that river segment or any downstream segment.

- Combined daily inflows to Lakes Buchanan and Travis.

- All data are for the period January 1, 1941 through December 31, 1965, inclusive.

3. Time of Travel for Flows

A flow release from Lake Travis takes a number of days to pass Bay City. Based upon the flow routing equations noted above, all flows released on a given day would have reached Bay City in eight days, beginning on the day of release. Therefore, eight days is considered sufficiently long to allow the influence of any reservoir release on a given day to pass completely through all river segments.

The simulated change in flow rates as water moves downstream is illustrated in Figure 5-5. A 1,000 cfs flow is assumed at Austin on day 1, with no flow at Austin for the remaining seven days. The flows in the river downstream of Austin are assumed to be zero on day 1.

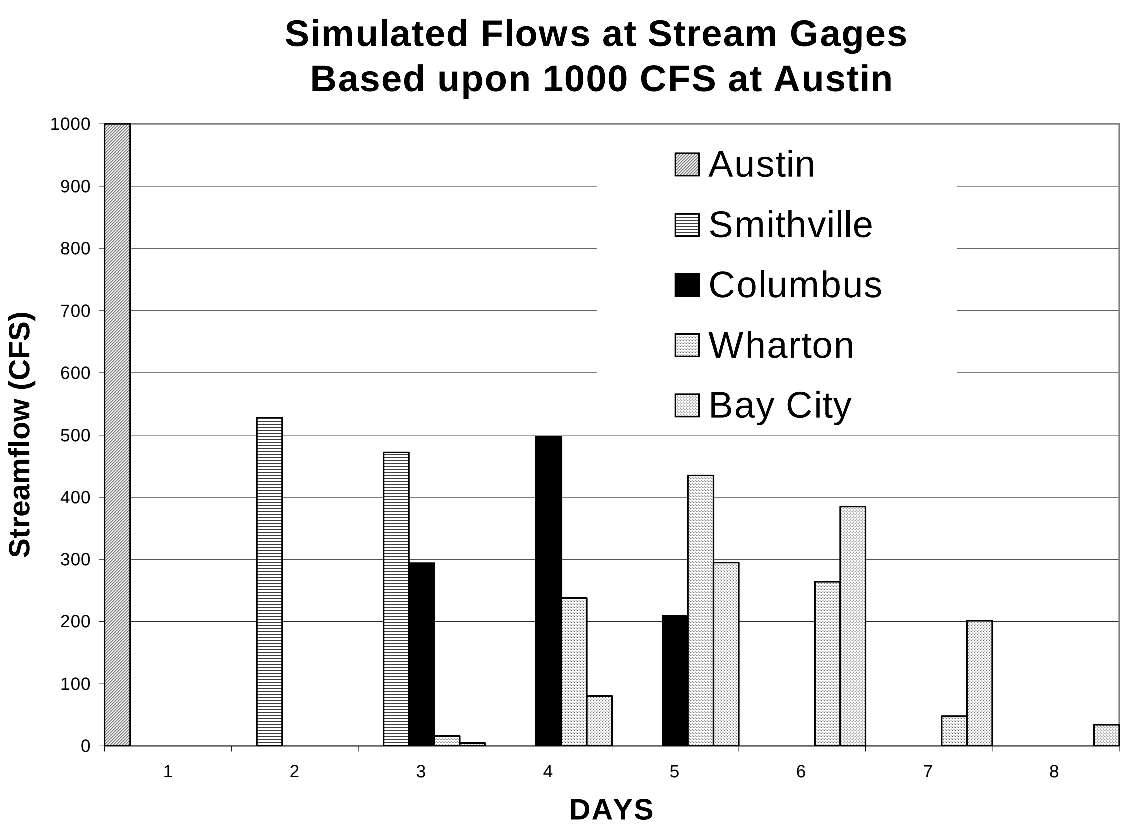


Figure 5-5. Simulation of Downstream Flow Rate Decreases

4. Channel Losses

Water flowing in the Colorado River is lost from plant evapotranspiration, surface evaporation and ground-water recharge. When these losses exceed the inflows from tributaries, ground-water seepage, and direct rainfall, then net channel losses occur.

The daily net incremental inflow data for the reaches below Lake Travis include many periods when channel losses (negative net incremental inflows) occur. In the flow routing of any reservoir releases, these negative inflows on a river segment act as "water demands" that must be fully satisfied before water can flow past that reach to a downstream senior water right holder. Therefore, to meet a downstream water right diversion demand requires the passage of reservoir inflows to the extent needed to fully satisfy the demand, up to the maximum amount of daily inflow to the reservoir. However, when there are no deficits in senior water rights diversions, then there is no need to pass through reservoir inflows just to satisfy channel losses below Lake Travis.

5. Flow Routing Optimization Problem

a. Problem Statement

Step 5 in the solution process determines the volume of reservoir inflows, on a given day, to pass downstream to meet the demands of senior water rights holders. This required passage of daily reservoir inflows is determined by finding the minimum reservoir pass throughs that satisfy, to the maximum extent possible, the water demands of senior water rights holders, while satisfying the following constraints:

The movement of water downstream in the lower Colorado River is governed by the set of linear flow routing equations (5), (7), (9) and (11).

The daily reservoir pass through cannot exceed the corresponding daily reservoir inflow.

Flow is conserved at all stream junctions as specified by equations (3), (4), (6), (8), (10) and (12).

Upstream channel flow losses must be satisfied fully before any downstream water rights diversion deficits can be satisfied.

All inflows to the Colorado River below Lake Travis have been used to the maximum extent possible to meet the maximum authorized diversion demands of downstream senior water rights holders.

All river flows and diversions are nonnegative.

b. Linear Programming Optimization Technique

The minimum daily pass through amounts may be found by solving a sequence of Linear Programming (LP) optimization problems, one for each day in the simulation period when inflows may satisfy diversion demands. Linear Programming is a mathematical solution technique that maximizes a linear function while satisfying a set of linear equality or inequality constraints. The Linear Programming formulation for the reservoir pass through problem is given as finding the value of $I_{1,t}$ that maximizes, over days t through t+7, the total water demands met plus the total channel losses minus a penalty cost for water passing the Bay City gage. The solution must satisfy equations 3 through 12 for all eight days and must pass through no more than the inflow on day t.

The penalty cost is given by *a* times the total flows past Bay City in the eight days, where *a* is a constant coefficient. The penalty factor is needed to keep from passing through more water than is absolutely necessary to meet the downstream demands. Without a penalty for flows past Bay City, the Linear Programming solution can give a pass through in excess of the minimum needed. Such a pass through would give the same benefits of meeting all the diversions as the minimum pass through.

For example, suppose that 5,000 acre-feet of inflow occurs on a given day and that only 1,000 acre-feet is needed as a pass through to satisfy all demands downstream. Thus, any pass through value from 1,000 to 5,000 acre-feet is an alternative solution to satisfying all downstream demands. Without a penalty term, the Linear Programming solution may be larger than 1,000 acre-feet of pass through.

The 25 year simulation period is evaluated with a given constant value of *a*. The value of *a* is varied between these simulation to determine the penalty factor that gives the least pass through of inflows while meeting the maximum downstream demands.

6. Simulation Results

The solution process described above was used to determine the inflows needed to be passed to downstream water rights holders on a daily basis for the period 1941 through 1965, inclusive. Table 5-7 gives a summary of the inflows, demands, channel losses, and spills for the period using a variety of spill penalty values. The use of different penalty values allows an assessment of the tradeoffs between inflows available for storage and for downstream water diversions.

As would be expected, as the penalty value increases, there is a decrease in the water spilled past Bay City. However, as the spill penalty increases, the downstream water diversions remain essentially constant. The maximum water diversions possible are given when the penalty factor is zero.

An important result of the simulations is that storing inflow in the upstream reservoirs, instead of releasing it downstream, does not necessarily cause appreciable decreases in water diversions for water rights downstream. Table 5-7 illustrates this condition. The amount of downstream water diversions remains within 1% of the maximum possible diversion until the penalty coefficient value is between 1.0 and 2.0. However, the inflows available for storage increases by 4.6 million acre-feet over the 25-year period: from 15.2 million acre-feet (for α=0.) to 19.8 million acre-feet (for α =2.0). Further, the 25-year total volume of pass through amounts of reservoir inflows passing Bay City decreases by 4.4 million acre-feet: from 4.52 million acre-feet (for α =0.) to 127 thousand acre-feet (for α =2.0). Thus, the additional water available for storage is actually water that would otherwise spill from the Colorado River basin.

An α value of 2.0 appears to provide a reasonable penalty for spilling water past Bay City without unduly reducing the inflows passed through and actually diverted for downstream senior water right holders. Using this penalty value, the simulated water diversions are reduced about four percent from the maximum possible diversion volume of 4.63 million acre-feet (for $\alpha = 0.$) to 4.47 million acre-feet. This is a reduction of 160 thousand acre-feet over the entire 25-years of simulation.

Table 5-7
SUMMARY OF DOWNSTREAM FLOW RATE SIMULATION

CATEGORY	SIMULATED TOTAL VOLUMES FOR PERIOD 1941-1965 (1,000,000 ACRE-FEET)					
	SPILL PENALTY COEFFICIENT (∀)					
	.00	.10	.40	1.0	2.0	3.0
Reservoir Inflow	22.445	24.445	24.445	24.445	24.445	24.445
Water Diversion Demands	13.012	13.012	13.012	13.012	13.012	13.012
Channel Losses Met	.121	.121	.119	.119	.119	.105
Diversion Demands Met from Pass Through Reservoir Inflows	4.631	4.615	4.591	4.553	4.466	4.440
Flow Past Bay City Resulting from Pass Throughs of Inflows	4.524	1.723	.670	.458	.127	.075
Total Pass Throughs of Reservoir Inflows	9.276	6.459	5.380	5.131	4.712	4.621
Storable Inflow	15.169	17.986	19.065	19.314	19.733	19.824

TABLE 5-8
TOTAL DIVERSION DEMANDS FOR SENIOR WATER RIGHTS BELOW MANSFIELD DAM TO BE MET FROM PASS THROUGHS OF RESERVOIR INFLOWS (ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**TOTAL**
1941	19136	16123	19308	20437	26966	28675	34930	93097	79584	25678	10499	5839	380272
1942	12203	7411	9216	17726	58917	129662	71108	118740	59903	23634	18107	17595	550631
1943	17028	15479	18059	48610	87445	123107	75828	121213	64930	17726	12226	13821	507337
1944	12671	6862	6388	27108	47579	93998	87352	109096	48771	23868	12968	8175	485791
1945	4920	6900	6249	2546	60811	79737	77785	93627	50375	20316	14580	10122	428923
1946	6894	4401	5081	19104	27426	48813	60609	117286	42117	13623	1253	4397	351004
1947	1543	10138	14495	20090	73121	121685	83304	97286	45027	19344	14737	13829	514599
1948	16998	17883	13851	46260	75126	127996	84074	108065	68127	18698	14196	14382	605656
1949	14797	13167	16133	26016	79475	109915	79046	114042	69862	21294	12518	11550	568265
1950	12387	9954	17131	26809	69392	90708	77347	120122	58375	21113	15080	17264	535682
1951	15770	13607	17317	53394	99812	94273	97135	124186	58629	20849	16510	16225	627707
1952	15608	14461	21944	44267	80395	120731	88605	126336	65124	20528	10848	13164	622011
1953	10910	12980	18146	42700	55623	129987	76589	119034	51908	19848	13101	9823	560649
1954	12853	11286	23554	51633	92017	136315	100538	117915	74303	20550	15695	17202	673861
1955	15870	13190	25066	50968	75132	104300	84950	115303	74433	21260	12371	16742	609585
1956	14928	12252	21805	52934	90904	127484	94716	122141	76736	20859	14951	16355	666065
1957	15749	13412	14513	22682	19489	17301	46306	112513	71377	5579	91	1349	340361
1958	1384	488	6929	15340	21331	76663	62610	109494	40788	8821	7619	11592	363059
1959	11390	8393	12534	15292	53033	97310	81716	108521	61249	4081	5041	7259	465819
1960	5807	3758	5916	15542	63609	108973	52900	94805	64404	13934	9741	3962	443351
1961	3770	4682	4464	18087	73739	56095	21766	92491	41013	14412	7320	8393	346232
1962	10763	13565	15128	32158	88929	100217	80167	119408	61303	16110	13589	12022	564314
1963	11608	11723	17514	43654	91983	127934	90779	127702	79320	20605	16365	15144	654331
1964	14418	13406	16189	58439	103577	117673	91947	125078	60585	18253	13692	13988	647245
1965	10703	3072	10200	26686	26420	48118	60676	114922	68319	15269	10162	4682	399229

TABLE 5-9
SIMULATED MONTHLY SENIOR WATER RIGHTS DIVERSIONS FROM RESERVOIR INFLOWS
(ACRE-FEET)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1941	19136	16123	19312	20248	27069	26901	33691	29562	57388	24456	10499	5839	290224
1942	12203	7411	9107	16094	56359	99307	15132	37088	50499	23008	18107	17595	361908
1943	17000	12213	17139	21097	30181	46863	16768	1402	16975	13373	10404	12439	215853
1944	12671	6862	6388	15982	31780	62900	14041	14503	36586	17637	12968	8175	240493
1945	4920	690	6249	2546	45088	45676	33822	12228	18799	18178	14440	10122	218968
1946	6894	4401	5081	12719	25985	19024	5824	2197	26086	12855	1253	4397	126715
1947	1543	10138	14495	16923	38123	19830	4140	2330	268	728	6439	8774	123731
1948	8103	10977	7436	18070	32328	31068	50841	26202	10808	3348	1890	6418	207489
1949	11122	12855	15685	17943	57066	49779	14941	6646	12535	8252	9093	11485	227401
1950	12139	9954	1253	9547	32767	12481	7258	4549	7641	1620	1424	1946	102579
1951	2388	8343	9533	964	28701	41215	1997	728	5226	3510	3169	2911	108685
1952	3052	1481	2703	19565	35615	26935	8946	12579	26012	2836	6856	13107	159687
1953	10910	10527	15732	14495	27291	2729	6291	21551	7226	14991	5295	2049	139087
1954	5408	4865	607	2421	49759	4035	1485	2009	1692	2352	6414	1015	82063
1955	6574	11114	940	2521	29359	68541	40926	33761	18375	13003	2336	2921	230370
1956	5367	8365	748	8309	52910	2963	839	6617	12930	3711	4315	4942	112015
1957	1741	6804	11691	10379	15474	14757	21648	2853	16819	5253	91	1349	108859
1958	138	488	6929	15207	21244	44929	37399	19352	21347	8821	7619	11592	196312
1959	11390	8393	11672	12072	31939	48072	56407	17802	5737	4081	5041	7259	219866
1960	5807	3758	5916	14786	28280	5571	22443	39613	11216	12827	9741	3962	163920
1960	3770	4682	4464	16183	29319	28589	21463	35438	12976	14412	7320	8393	187009
1962	10763	13565	9097	19690	14620	26689	232	1854	5180	14914	10935	11544	139084
1963	10989	11118	10622	6531	35915	63006	4053	1126	4224	8486	13375	11891	181336
1964	12679	13406	16046	19985	20030	4933	16	6186	21081	18255	13692	13988	160296
1965	10703	3072	10200	19565	14873	35117	20634	2392	15156	15269	10162	4682	161824

TABLE 5-10
SIMULATED MONTHLY CHANNEL LOSSES SATISFIED BY RESERVOIR PASS THROUGHS
(ACRE-FEET)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0	0	0	454	9184	4805	101	232	817	192	0	0	15786
1942	0	0	54	0	2	3461	420	1890	5020	1677	0	0	12523
1943	0	0	1039	2183	129	1982	71	0	167	0	0	0	5570
1944	0	0	0	73	1949	1130	0	62	1083	30	0	0	4328
1945	0	0	0	0	204	196	3709	0	375	0	0	0	4485
1946	0	0	0	125	0	0	0	0	119	0	0	0	244
1947	0	0	0	0	155	0	0	0	0	0	0	0	155
1948	0	0	0	145	83	133	2378	16	0	182	0	0	2936
1949	0	0	157	0	0	206	0	0	156	0	0	0	519
1950	0	0	0	0	0	0	0	0	0	0	0	0	0
1951	0	0	0	0	1015	1085	0	0	0	0	0	0	2100
1952	0	0	0	0	133	2519	0	0	4395	0	0	0	7046
1953	0	0	0	505	1359	0	0	0	0	0	0	0	1864
1954	0	0	0	0	2997	0	0	0	0	0	0	0	2997
1955	0	0	0	0	6905	8860	3498	3046	8135	2259	0	0	32704
1956	0	0	0	0	5093	0	0	0	0	0	0	0	5093
1957	0	0	0	0	7295	6118	0	0	245	0	0	0	13657
1958	0	0	0	0	0	266	0	0	0	0	0	0	266
1959	0	0	0	0	0	0	2118	111	0	315	0	0	2544
1960	0	0	0	0	0	178	0	0	0	0	0	0	178
1961	0	0	0	0	112	658	0	0	0	0	0	0	771
1962	0	0	0	0	2	1126	0	0	0	0	0	0	1128
1963	0	0	0	0	40	0	0	0	0	0	0	0	40
1964	0	0	0	1018	557	59	0	0	288	0	0	0	1920
1965	0	0	0	89	0	0	0	0	0	0	0	0	89

TABLE 5-11
SIMULATED MONTHLY FLOWS PAST BAY CITY FROM RESERVOIR PASS THROUGHS
(ACRE-FEET)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	0	0	0	775	2955	2862	1485	0	1187	251	0	0	9515
1942	0	0	203	491	3987	3406	142	2290	4202	585	0	0	15307
1943	0	0	4	561	79	2054	537	0	1000	0	0	0	4235
1944	0	0	0	303	2333	3429	0	0	1286	118	0	0	7469
1945	0	0	0	1	2406	913	1737	0	70	1	0	0	5128
1946	0	0	0	244	2612	739	34	0	474	0	0	0	4104
1947	0	0	0	610	2007	0	63	0	0	0	0	0	2679
1948	0	0	3	617	1372	689	2016	536	156	47	0	0	5436
1949	0	0	211	168	2171	1168	47	0	0	0	0	0	3765
1950	0	0	0	0	726	482	18	0	16	0	0	0	1243
1951	0	0	0	0	2224	1645	0	0	2	0	0	0	3871
1952	0	0	0	910	1318	1033	0	0	1364	0	0	0	4625
1953	0	0	4	117	913	0	0	266	382	0	0	0	1681
1954	0	0	0	0	1139	51	0	0	0	0	0	0	1190
1955	0	0	0	0	3817	7750	2022	0	3219	733	0	0	17540
1956	0	0	0	130	3298	0	0	0	0	0	0	0	3428
1957	0	0	0	27	4754	3267	267	0	0	0	0	0	8316
1958	0	0	0	0	1939	3461	1009	0	520	0	0	0	6929
1959	0	0	25	318	746	2777	2483	0	0	210	0	0	6558
1960	0	0	0	389	82	0	227	1662	0	0	0	0	2360
1961	0	0	0	738	202	1117	1101	449	464	0	0	0	4073
1962	0	0	0	453	70	140	0	0	0	0	0	0	663
1963	0	0	0	0	794	977	0	0	0	0	0	0	1770
1964	0	0	163	883	0	0	0	0	180	1	0	0	1227
1965	0	0	46	614	871	1954	95	0	0	0	0	0	3580

TABLE 5-12
SIMULATED MONTHLY STORABLE INFLOWS
(ACRE-FEET)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1941	78213	213250	264511	422194	747597	380518	117806	3917	12309	162238	41931	32705	2477189
1942	25242	19467	18382	248336	233338	37215	4264	40728	87478	290136	83511	30986	1119082
1943	6336	3727	6501	7308	0	69894	7593	0	10085	16100	1926	3407	132421
1944	77131	84752	113052	14811	393515	51694	0	87106	67216	20966	14822	89298	1014363
1945	150148	154941	184864	250246	24865	28559	37994	0	59314	22014	6467	21776	941188
1946	57182	81404	44527	76811	133121	11294	0	341	31451	21857	93950	70330	622268
1947	203837	52150	67619	26686	10707	0	0	0	0	0	607	9749	371356
1948	24	6552	6866	7820	25509	151761	39361	791	6544	879	0	54	246160
1949	2788	46669	78337	185329	44489	3732	0	0	0	12300	184	8659	382486
1950	3375	24280	0	17787	5966	3750	1462	0	1426	0	0	0	58011
1951	0	0	2493	0	19352	54342	0	0	1717	0	0	0	77904
1952	0	0	0	54242	120077	2058	0	0	919291	0	18007	106962	1220638
1953	44003	3274	36106	11440	128739	0	0	2350	2082	71960	149	75	300179
1954	274	0	0	0	2659	0	0	0	0	589	12681	0	16203
1955	1854	18156	0	51	349086	103974	63065	0	172229	7226	0	0	715642
1956	0	3675	0	11201	214530	0	0	0	0	3560	2057	1327	236349
1957	0	363	32041	616597	1129879	481621	0	0	38214	697493	196589	84010	3276807
1958	100382	356619	221545	71611	224697	202295	3534	0	67457	56519	50197	23796	1378652
1959	16704	32693	14624	48158	5643	233663	64422	0	1222	668260	46788	109411	1241589
1960	206798	153416	69775	45812	10420	0	13006	72451	2120	80121	42202	147195	843317
1961	159820	279671	97389	16756	0	346163	68337	0	4460	44941	15033	22033	1054603
1962	10065	14471	0	7114	0	9355	0	0	0	45229	1172	1696	89101
1963	875	3018	292	335	6553	11059	0	0	0	4	19394	48	41577
1964	4962	24951	34839	14985	0	28	0	0	406673	43958	79034	10223	619653
1965	30706	225311	43628	13929	596289	53847	263	0	102408	51222	51607	87439	1256649

a. Water Diversions

Table 5-8 gives the monthly demands for all senior water rights holders downstream of Mansfield Dam after using all available inflows to the Colorado River downstream of Lake Travis. The monthly inflows used directly to satisfy these diversion demands of senior water rights, using α =2.0, are shown in Table 5-9.

b. Channel Losses

The monthly inflows required to meet channel losses, using α=2.0 are, shown in Table 5-10.

c. Flows Past Bay City

The monthly inflows passing the Bay City stream gage, using α=2.0, are shown in Table 5-11.

d. Inflows Available for Storage

The monthly inflows available for storage in the Highland Lakes, using α=2.0, are shown in Table5-12.

E. Operation of the Reservoir System in the Lakes Buchanan and Travis Combined Firm Yield Model

The Combined Firm Yield of Lakes Buchanan and Travis was determined in accordance with the directives of the Final Judgment and is shown in Table 5-13.

TABLE 5-13
COMBINED FIRM YIELD
CERTIFICATES 14-5478 AND 14-5482
(ACRE-FEET/YEAR)

Highland Lakes	445,266
O. H. Ivie	90,546
Total	535,812

The essential criteria specified in the Final Judgment and Decree for the determination of the Combined Firm Yield was that all senior downstream water rights must be honored by LCRA by passing through inflows necessary to meet those senior water rights to their fullest extent. Those senior water rights include not only the City of Austin but also the water rights owned by LCRA – Pierce Ranch, Garwood, Lakeside, and Gulf Coast. Honoring these senior water rights at their fully authorized diversion rate and annual demand has a major impact on the Combined Firm Yield determination of Lakes Buchanan and Travis. In considering the Combined Firm Yield as calculated herein, it is important to recognize that current demands under the senior downstream water rights are about 65 percent of the authorized total. Whether future demands will approach the authorized quantities is uncertain. Future contractual relationships with the senior downstream water rights holders may also have significant impact on the Combined Firm Yield of Lakes Buchanan and Travis.

1. Description of Reservoir System

The LCRA Highland Lakes system is comprised of five reservoirs that receive inflow from the Colorado River and two major tributaries. Figure 5-1 shows the respective location of each lake and river. Lake Buchanan, one of the two water supply storage reservoirs, is the upstream-most reservoir and receives inflow from the Colorado River. Downstream are Inks Lake, Lake LBJ (which receives inflow from the Llano River), and Lake Marble Falls. Lake Travis, the other water supply storage reservoir, is the downstream-most reservoir and receives inflow from the Pedernales River and the Colorado River.

LCRA's water rights associated with the Highland Lakes, as adjudicated and amended, are summarized in Table 5-14. To reduce the many findings into a single table, some of the context may have been lost in the summarization. The reader should reference the Final Judgment and Decree, as well as the Certificates of Adjudication, for a more complete understanding of these rights and their complex history.

TABLE 5-14
SUMMARY OF LCRA'S HIGHLAND LAKE WATER RIGHTS

Certificate of Adjudication (No.)	TYPE RIGHT	PRIORITY DATE	AUTHORIZED AMOUNT	USES
Buchanan (14-5478)	Impound	3/29/1926	992,475 ac-ft	Recreation
	Consume	3/7/1938[a]	1,500,000[b] ac-ft/y	Livestock, Recharge, Recreation, Domestic, Municipal, Industrial, Irrigation, Instream Flow, Mining, Bay/Estuary Inflow
	Divert	n/a	3,630 CFS	Hydroelectric generation
Inks (14-5479)	Impound	3/29/1926	17,545 ac-ft	Recreation
	Divert	n/a	2,600 CFS	Hydroelectric generation
LBJ (14-5480)	Impound	3/29/1926	138,500 ac-ft	Recreation
	Consume	8/24/1970	15,700 af/yr	Industrial
	Divert	n/a	9,000 CFS	Hydroelectric generation
Marble Falls(14-5481)	Impound	3/29/1926	8,760 ac-ft	Recreation
	Divert	n/a	8,120 CFS	Hydroelectric generation
Travis (14-5482)	Impound	3/29/1926	1,170,752 ac-ft	Recreation
	Consume	3/7/1938[a]	1,500,000[b] ac-ft/y	Livestock, Recharge, Recreation, Domestic, Municipal, Industrial, Irrigation, Instream Flow, Mining, Bay/Estuary Inflow
	Divert	n/a	5,530 CFS	Hydroelectric generation

Note: AC-FT is acre-feet of storage capacity,
AF/YR is acre-feet per year of consumption,
CFS is cubic feet per second of diversion rate.

a. Priority may not be imposed against any junior permanent water right with a priority date senior to 11/1/87, except to the extent that LCRA's right to divert and use water from Lakes Buchanan and Travis is limited to the Combined Firm Yield.

b. This amount includes both Lake Buchanan and Travis. The bed and banks of the Colorado River may be used for conveyance.

2. Hydrologic Significance of Firm Yield

The Combined Firm Yield as determined and used herein is based on a drought period (1947-57) identified as the most severe occurring during the 105-year period since data collection started in February 1898. Although firm yield of reservoirs is usually expressed as the minimum supply available in any single year, the cumulative effect of the drought period is the most influencing factor. For example, the minimum annual streamflow since 1898, at the Austin gaging station has been 358,880 acre-feet in 1917; whereas, the minimum annual streamflow at the station during the 1947-57 drought period was 558,080 acre-feet.

Statistical inference in hydrology is based on being able to array annual events in normal distributions. Therefore, computing the recurrence interval for variable-duration drought periods is not practical with only a 105-year period of record. Moreover, the hydrologic considerations necessary in computing the Combined Firm Yield as defined herein, removes much of the natural hydrologic recurrence associated with drought periods.

3. <u>Reservoir Inflow</u>

LCRA is required to pass the water that flows into the Highland Lakes through the system of lakes to honor each of these rights up to the maximum authorized amount, if the water is needed and would have been available to those diverters had the dams not been built. The Final Judgment and Decree further ruled that LCRA could not include inflows passed through to honor these rights when calculating the Combined Firm Yield of Lakes Buchanan and Travis.

Because firm yield calculations for reservoirs are most always predicated upon the hydrologic recurrence of the most severe drought period for which data are available, the hydrologic setting for the time of recurrence has to be agreed upon. The most critical hydrologic factor in the calculations is the inflow to the reservoir(s). Ordinarily, it is agreed that the inflow that actually occurred during the drought period will be adjusted to simulate that for a future time period. For example: "Watershed conditions of 2030." Man's water-use activities in the watershed since the actual drought period occurred usually result in adjusted inflow values being considerably less than those that occurred.

a. Water Availability Model (pre-2003)

To aid in adjusting runoff to that expected if the drought period of record were to recur, the Texas Water Commission (predecessor agency of TCEQ) developed a computer model. The model basically takes monthly runoff data, adjusts it back to "virgin" runoff, then imposes demands on the runoff equal to the maximum water-use right authorized, or to the extent water is available. The resulting adjusted runoff becomes that available for appropriation under the Texas Water Code and usable in firm yield calculations. Adjusted monthly values of inflow to Lakes Buchanan and Travis for the period January 1940 to December 1972, were provided to LCRA by the Texas Water Commission for calculations of the Combined Firm Yield of the LCRA system. However, LCRA's analysis of daily flow conditions in the lower river considers the 25 year period from 1941 through 1965. This shorter period, which includes the worst drought of record in the lower Colorado River basin, was selected for this analysis. The reservoir inflow values are shown in Appendix 2C, Volume II.

b. Future Considerations

A new Water Availability Model (WAM) was being reviewed by Texas Commission on Environmental Quality (TCEQ) during the first half of 2002. Unlike the previous model, when water rights junior to a reservoir were encountered, the new WAM inflows should reflect that the upstream junior right was not allowed to divert any available flow unless the storage volume in the reservoir downstream is at or above maximum conservation storage. The reason for this is that by taking water, the junior right could be impairing the reservoir's ability to supply its authorization if the critical drought is repeated. Firm yield analysis of Lakes Buchanan and Travis with inflow from this new WAM has not yet been conducted. New monthly inflow values should be obtained from TCEQ when available. Then, a new analysis could be done and an amended value for the Combined Firm Yield of Lakes Buchanan and Travis might be submitted at some future date.

4. Reservoir Evaporation

Evaporation data was taken from the Texas Department of Water Resources LP-60 Report entitled Present and Future Surface-Water Availability in the Colorado River Basin, Texas, dated June 1978. The following excerpt is taken from page V-26, "Reservoir Evaporation Rates":

> The monthly net evaporation rates, for the period 1941 through 1965, were determined for each reservoir project considered in the study area. TWDB Report 64, Monthly Evaporation Rates for Texas, 1940 through 1965, provided net reservoir evaporation data by each one degree quadrangle within the State of Texas. These data are based on available evaporation pan data and appropriate evaporation pan coefficients. To convert these data to project areas, the data by quadrangle were weighted inversely proportional to the distance from the project area to the center of the four adjacent quadrangles. An established computer program was used to transfer the data to project areas. The latitude and longitude for each project was selected (generally about 1/3 the distance from the dam to the headwaters of the reservoir) and the center of each quadrangle was assumed to be the focal point of the data for that quadrangle, thereby a computer routine was used to compute the appropriate distances for the horizontal and vertical variations.

The tables in Appendix 2B, Volume II show the monthly net reservoir evaporation rates, in feet, for each reservoir.

5. Local and Downstream Demand Distributions

The only monthly demand distribution utilized is reflected as a release from Lake Travis. This distribution was generated using records of diversions by the City of Austin and by the four major irrigators downstream. The resulting distribution is found in Table 5-15.

TABLE 5-15
LAKE TRAVIS ANNUAL DEMAND DISTRIBUTION (%)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
6.4	6.1	6.8	7.6	8.1	9.5	12.0	12.4	9.4	8.2	6.8	6.7

6. Simulated Highland Lakes Operations

An operations simulation procedure defines how water would be released from each of the system's water supply storage reservoirs to meet the downstream demands. LCRA specifies the proportion of the demands to be satisfied from each reservoir based on current system storage contents and other hydrological conditions. The ultimate goal is the optimal use of the water supply from the system in accordance with LCRA Board Policy 501.

For the Combined Firm Yield analysis, an operations simulation procedure was developed to minimize the impacts of the losses due to evaporation and to spills. The two water supply storage reservoirs of the Highland Lakes are Buchanan and Travis. Lake Buchanan has a large surface area when it is at or near conservation storage capacity. This results in large losses due to evaporation. Lake Travis generally receives much more inflow than Lake Buchanan. As a result, it is more susceptible to spilling during normal operations.

The operations simulation procedure in the Combined Firm Yield analysis allows full utilization of Lake Travis until its storage drops below 850,000 acre-feet. At that point, the downstream demands are met at a rate of 65% directly from Lake Travis and 35% released from Lake Buchanan. When the storage in Lake Travis drops below 700,000 acre-feet, Lake Buchanan is called on to meet 90% of the downstream demand. When operations draw Lake Buchanan down to between 50,000 and 150,000 acre-feet, Lake Buchanan is then called on to meet only 35% of the demand. Finally, when the storage in Lake Buchanan drops below 50,000 acre-feet, Lake Travis is called on to meet all downstream demands. The process is shown in Table 5-16. This operation was derived through repetitive simulations and represents neither the optimal solution nor the actual operation that LCRA would follow when all hydrologic factors are considered.

TABLE 5-16
HIGHLAND LAKES OPERATIONS SIMULATION

LAKE TRAVIS END OF MONTH CONTENT (AF)	LAKE BUCHANAN RELEASE RATE (%)
GREATER THAN 850,000 (E1.= 662 ft)	0
LESS THAN 850,000 AND GREATER THAN 700,000	35
LESS THAN 700,000 (E1. = 651 ft)	90

LAKE BUCHANAN END OF MONTH CONTENT (AF)	LAKE BUCHANAN RELEASE RATE (%)
LESS THAN 150,000 AND (E1. = 966 ft) GREATER THAN 50,000	35
LESS THAN 50,000 (E1. = 948 ft)	0 [1]

[1] Releases made only for diverters from Lakes Inks, LBJ, and Marble Falls.

It should be noted that, during the entire period of operation, Lake Buchanan storage is used to meet any and all local area demands and evaporation losses from Inks Lake. Depending on inflows into Lake LBJ from the Llano River and into Lake Travis from the Pedernales River, Lake Buchanan storage may also be used to meet local area demands and evaporation losses from Lake LBJ, Lake Marble Falls, and Lake Travis. The ultimate purpose depends on the demands and the specified minimum allowable contents of the intermediate reservoirs (Inks, LBJ, and Marble Falls) (See Table 5-17).

TABLE 5-17
HIGHLAND LAKES ALLOWABLE OPERATIONS CONTENTS

	CONTENTS (AC-FT)	
RESERVOIR NAME	**MINIMUM**	**MAXIMUM**
BUCHANAN	0	918,000
INKS	17,540	17,540
LBJ	138,500	138,500
MARBLE FALLS	8,760	8,760
TRAVIS	0	1,170,069

7. Demand Alternatives

The Combined Firm Yield computed for Lakes Buchanan and Travis is based on passing through streamflow as required to satisfy downstream senior rights up to their maximum authorized annual amount. Actual operations under the WMP will see streamflow passed through to satisfy senior rights holder's actual demands. In many years the actual demands can be expected to be less than the maximum authorized rights. Of course, this is a major factor in being able to fulfill water supply demands in many years greater than the Combined Firm Yield.

CHAPTER 6
WATER OPERATIONS SYSTEM

A. Introduction

The Water Operations System is a network including remote data acquisition, central computers, and hydrologic models (Figure 6-1). It is being used on a daily basis to monitor the Colorado River and operate the Highland Lakes.

B. Hydrometeorological Data Acquisition System

LCRA has in operation a Hydrometerological Data Acquisition System (Hydromet) that allows remote interrogation of a networked system of one hundred self-reporting rainfall gages, fifty remotely monitored streamflow gages, and eleven reservoir elevation gages. All fifty of the streamflow gages also gather rainfall information, giving a total of one hundred fifty rainfall sites.

The Hydromet System is polled each hour, and all data is verified and stored in a real-time data base on the Central Computer System. Communications are a combination of microwave and LCRA's Trunked Radio System. The combination of a modernized Hydromet system and Trunked Radio will allow for future expansion necessary to improve streamflow forecasting, lake operations and public flood warning.

C. Hydrologic Models

Several specialized hydrologic models have been implemented to assist both routine daily allocation and emergency flood operations. Each of these models is further described below.

1. Daily Allocation Model

The Allocation model was developed to allocate daily inflows into the Colorado River in accordance with established priority water rights. This analysis enables LCRA to report the amount of stored water used from Lakes Buchanan and Travis by each major diverter. A provisional report is sent out once a week, allowing each diverter to be kept apprised of stored water usage. At the end of each year, all stream flows are reconciled and diversion data is verified. The model reports are then provided to all diverters, as well as the TCEQ as part of LCRA's Annual Water Use Reports.

2. National Weather Service River Forecast System

LCRA and the National Weather Service (NWS) have pursued a joint project to share information and implement a system to forecast flow conditions along the Colorado River. LCRA routinely reports river data to the NWS River Forecast Center in Fort Worth, Texas. This allows the NWS to produce much more timely and accurate public information forecasts utilizing their River Forecast System. LCRA also receives processed radar data on an hourly basis, and has implemented a flood forecast modeling system as an operational tool to aid flood operations on the Highland Lakes. This model processes doppler radar, raingage, and stream gage data to forecast flood inflows to the Highland Lakes and resulting lake elevations, providing improved information for operational decisions.

D. Standard Operating Procedures for Lakes Buchanan and Travis

There are currently three modes of Standard Operating Procedures for Lakes Buchanan and Travis. The first is the daily operations mode, in which daily demands for water are met by releases from Lakes Buchanan and Travis and the intermediate reservoirs are maintained within normal operating levels. The second is flood control, which primarily concerns Lake Travis since it is the only reservoir with a dedicated flood pool. Incorporation of the WMP has added a third mode for drought contingency.

1. Daily Operations

Hydrology staff in the River Operations Center (ROC) coordinate with the System Operations Control Center (SOCC) and the Hydro Operations Control Center (HOCC) to make decisions regarding the daily operations of the river and the Highland Lakes. The SOCC and the HOCC provide Hydrology staff with information about electrical system load requirements and operational considerations at the hydro plants. Hydrology staff in the ROC incorporate these considerations along with other water release requirements into daily operational decisions. When making these decisions, ROC staff must also assess changing water use demands downstream, minimum flow requirements for aquatic life and flow constraints for special functions held on or near the river.

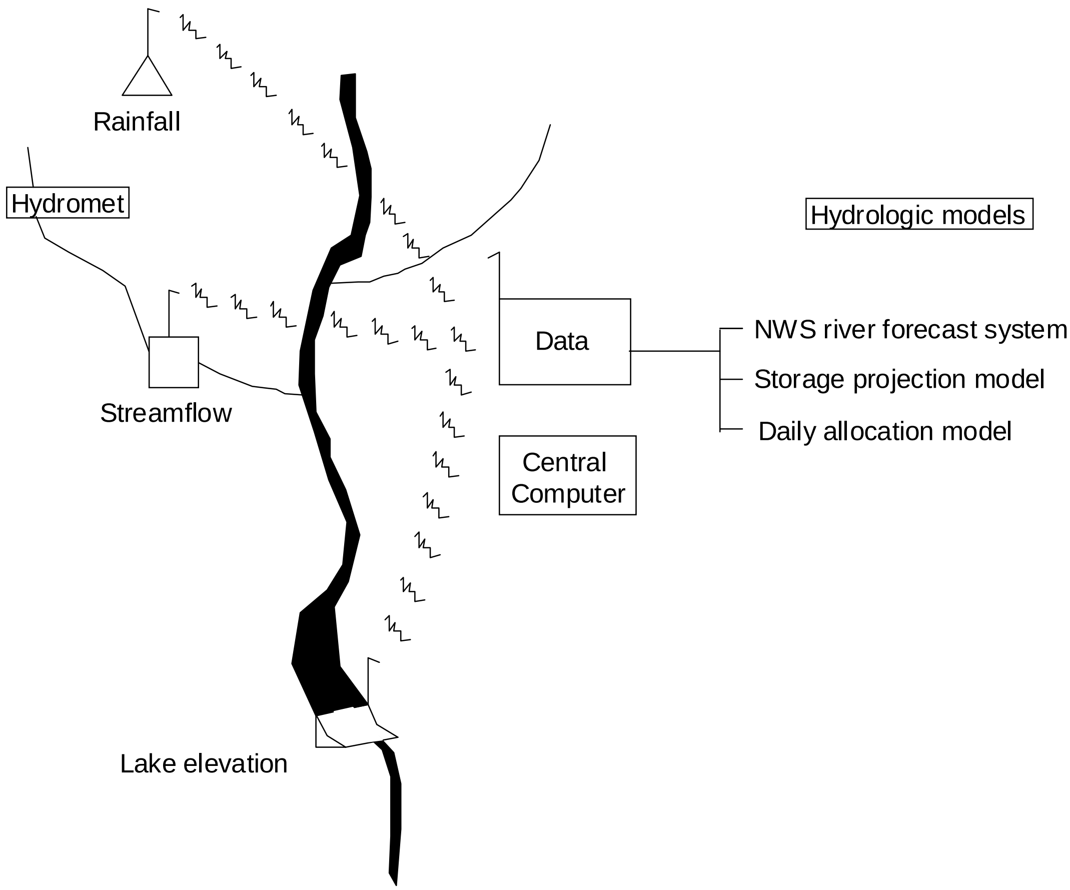


Figure 6-1.

a. Standard Operating Levels

Standard operating levels are as noted in Table 6-1.

TABLE 6-1
STANDARD OPERATING LEVELS FOR THE HIGHLAND LAKES

LAKE	TARGET ELEVATION RANGE (NGVD)
Lake Buchanan	1020.35 (1018 May - October)
Inks Lake	887.30 +/- 0.4
Lake LBJ	824.70 +/- 0.3
Lake Marble Falls	736.60 +/- 0.4
Lake Travis	681.00
Lake Austin	492.30 +/- 0.5

b. Variances on Daily Operations Procedure

From time to time, LCRA must deviate from normal operating procedures to perform necessary maintenance, or to honor the request of a public entity. Examples of this may be drawing down a lake preceding maintenance on a dam, in the interest of safety, or interrupting daily release operations for public events, such as the Austin Aqua Festival. LCRA retains the right to use its discretion in operating its reservoirs during such events, to protect its investments and the public safety, as a responsive public servant.

2. Flood Operations

The primary flood operations focus is on Lake Travis and the Army Corps of Engineers' *Plan of Regulation* for Lake Travis. The principal operating criteria in this manual are summarized in Appendix B2, Volume I.. During a flood event, any available storage in Lake Buchanan is used before releasing water to maintain the pool level. Following an operational agreement between LCRA and the Federal Emergency Management Agency (FEMA), Lake Buchanan is held two feet lower during the historically flood-prone months of May through October. (See Appendix B2, Volume I.)