

THE STATE OF THE PROTECTION OF FRESHWATER INFLOW
TO THE BAYS AND ESTUARIES OF TEXAS

By Tom Wassenich
Copyright, 2005

ACKNOWLEDGEMENTS

First I would like to thank my wife, Dianne, for her support and companionship during the completion of this project. I also want to thank my parents, Paul and Ruth Wassenich, for their continuing support and intellectual stimulation all these years.

I appreciate the expertise, patience, and endurance of my committee members Dr. Earl and Dr. Curran. Special thanks go to the committee chairman, Dr. Kimmel, who inspired me to undertake this project at this point in my life.

Many others who work and volunteer to conserve water resources in Texas provided expertise that assisted me in this project, starting with Dr. Jack Fairchild, longtime friend, scholar, and river advocate. Others providing expertise include, Dr. Norman Johns, Joe Trungale, and Stuart Henry.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	i
LIST OF FIGURES	xii
LIST OF TABLES	xv
LIST OF DOCUMENTS	xvi
ABBREVIATIONS	xvii
DEFINITIONS	xviii
ABSTRACT	xix

PART I

INTRODUCTION AND LITERATURE REVIEW

Chapter	Page
1. INTRODUCTION	1
2. PREVIOUS RESEARCH AND LITERATURE REVIEW	4

PART II

THE COMPONENTS OF FRESHWATER INFLOW PROTECTION

3. THE CONSTITUTION, STATUTES, CODES AND THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY	14
The Constitution and the Texas Water Code	14
The Texas Commission on Environmental Quality	15
The Texas Administrative Code	18
4 THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND THE WATER RIGHTS PROCESS	19
5. WATER RIGHTS AND ESTUARINE CONSIDERATIONS	26

Chapter	Page
Exempt Uses, Riparian Law and Prior Appropriation	30
Summary Discussion of Estuarine Protection and the Water Rights Process	32
6. FEDERAL AGENCIES AND LAWS AND FRESHWATER INFLOW	37
The United States Army Corps of Engineers	40
The United States Bureau of Reclamation	47
The Natural Resource Conservation Service	48
Summary of Federal Laws and Entities	50
7. THE TEXAS WATER DEVELOPMENT BOARD	52
The Texas Water Bank and Water Trust	54
8. THE TEXAS WATER DEVELOPMENT BOARD AND THE REGIONAL AND STATE WATER PLANS	56
The Regional Plans and the Administrative and Water Codes	56
Details and Results of the 2002 State Water Plan	59
Environmental Portion of the State Water Plan	62
Senate Bill 1639 and Plan Recommendations	64
Consensus Criteria	67
Summary Discussion of Estuary Inflow Protection and the Water Planning Process	75
Inland Regions and Region H	75
Region I and Saltwater Barrier Dams	76
Coastal Regions K, L, M, N, and P Environmental Flow Considerations	79

Chapter	Page
Criticism of the Plans and Planning Process Regarding Freshwater Inflows	81
Environmental Flow Problems to be Addressed by the Second Round of Water Planning	83
9. THE TEXAS PARKS AND WILDLIFE DEPARTMENT	88
Summary of the Texas Parks and Wildlife Department and Protection of Freshwater Inflow	91
10. THE BAY AND ESTUARY STUDIES	94
Methodology of the Studies	95
Harvest Data and Constraints	101
Inflow Data and Constraints	101
Biomass Ratios	103
Salinity Data and Constraints	103
Sediment Constraint	104
Nutrient Constraint	105
Model Output – MaxH and MinQ	105
The LCRA and the Matagorda Bay Study	108
The Coastal Bend Bay Area Studies	114
Summary Discussion of the Bay and Estuary Studies	117
Challenges to the Studies	117
Conclusion	119
11. THE WATER AVAILABILITY MODEL	121
WAM Modifications and Technical Issues	123

Chapter	Page
Problems of the WAM	128
The East Texas Region Plan	129
The Guadalupe/San Antonio River WAM	130
Proposed Changes to the WAM	134
Groundwater Issues, Modeling and Freshwater Inflow	135
12. THE ADMINISTRATIVE CONNECTIONS BETWEEN THE MAJOR COMPONENTS	140
Interagency Connections in the Water Appropriation Process	141
Interagency Connections in the Regional and State Water Plans	143
Interagency Connections in the Bay and Estuary Studies	145
PART III	
QUANTITATIVE ASPECTS OF THE COMPONENTS OF FRESHWATER INFLOW PROTECTION	
13. COMPARISON OF NATURALIZED AND UNAPPROPRIATED FLOWS TO RECOMMENDED FLOWS IN VARIOUS ESTUARIES	150
The Sabine River Available Flow	151
The Trinity River Available Flow	155
The Colorado River Available Flow	157
The Guadalupe and San Antonio Rivers Available Flow	159
The Nueces River Available Flow	159
Summary Analysis of Available Flows	161

Chapter	Page
Additional Analysis of the Guadalupe/San Antonio River Inflow	163
Conclusion	167
14. WATER PLANNING AND THE RECOMMENDED FLOWS OF THE BAY AND ESTUARY STUDIES	168
The Consensus Criteria	168
The 7Q2 Flow	168
MinQ and MaxH Meet the Consensus Criteria	170
Summary Discussion of the Planning Criteria and Recommended Freshwater Inflows	173
15. THE WATER RIGHTS PROCESS AND THE BAY AND ESTUARY STUDIES	176
Administrative Aspects of Water Appropriations and the Bay and Estuary Studies	176
MinQ and MaxH Meet the Water Rights Process	177
The Lyons Method	178
Comparison of the Methods of Water Right Analysis	179
Summary Discussion of Water Rights Analysis and Bay and Estuary Studies	185
16. AN ANALYSIS OF CANYON DAM FLOOD FLOW MANAGEMENT ...	189
Methodology of the Analysis	190
Analysis of Outflow Comparison	192
Conclusions	195

Chapter	Page
17. A TOUR OF FRESHWATER INFLOW PROTECTION THROUGH WATER RIGHTS PERMITS	198
Methodology of Permit Research	198
Pre-1985 Permits and Post-1985 Permits	201
Post-1985 Permits	203
Permit 5317, 1990 – Saltwater Barrier	203
Permit 5369, 1991 – Clear Creek	204
Permit 5430, 1992 – Houston Ship Channel	205
Permit 5446, 1993 – Cedar Lake Creek	205
Permit 5466, 1996 – City of Victoria	207
Permit 5696, 2000 – Clear Creek	210
The San Marcos River Foundation Application, 2000-2003	217
PART IV	
SUMMARY AND CONCLUSIONS	
18. CRITICAL ISSUES AND KEY ASPECTS	223
Information and Understanding Gained in this Study	223
No Central Authority or a Balance of Power	223
Is the TCEQ a Neutral Agency?	224
Environmental Representation in Water Planning	227
Incomplete Bay and Estuary Studies	227
Limitations of the Bay and Estuary Studies as Tools for Planning and Appropriation	228

Chapter	Page
Questions about the Basis of Data for the Studies and the LCRA Methodology	229
Questions about the Water Availability Model	230
Criticism of Freshwater Inflow Protection from Agencies, Planning Groups and Committees	230
Key Aspects of Freshwater Inflow Protection	231
Overview of the System	233
19. FUTURE RESEARCH	234
Analyses Proposed by the TWDB	234
Suggested Research	239
Benefits of This Research	241
20. 2004 UPDATE	242
SECTION A: THE SCIENTIFIC ADVISORY COMMITTEE REPORT ON WATER FOR ENVIRONMENTAL FLOWS	242
The SAC Charge and Scope of Work	242
Economic Considerations	244
Non-Use Values	245
Water Demand and Water Use	246
Environmental Flow Assessment Tools for Rivers and Streams	248
Texas Instream Flow Studies Program	248
Critique of State Analytical Procedures for Rivers and Streams ...	249
Instream Flow Methods Used Outside Texas	251
Environmental Flow Assessment Tools for Bays and Estuaries	251

Chapter	Page
Bay and Estuary Methods Used Outside Texas	253
Implementation Strategies for Environmental Flows	254
Regulatory Environmental Flow Strategies	254
Market-Based Environmental Flow Strategies	255
Adaptive Management	255
The SAC Summary of Findings	256
Author's Comments on the SAC Report	257
Economic Analysis	257
Environmental Flow Assessment Tools	258
Market-Based Environmental Flow Strategies	259
Quality and Accomplishments of the Report	261
SECTION B: MAJOR PENDING WATER RIGHT APPLICATIONS	261
The Near-Term Forecast for Freshwater Inflow	263
21. 2005 UPDATE	265
The 2005 Legislature and SB3	265
Commission Rule Changes	266
Pending Court Cases on Environmental Flows	267
Pending Water Right and Reuse Applications	267
Summary	271
Appendix	
A. MAPS	273
B. WATER RIGHTS AND RESERVOIRS	277

Appendix (cont.)

C. BAY AND ESTUARY MODEL OUTPUT	279
D. COPIES OF WATER PERMITS	282
WORKS CITED	307

LIST OF FIGURES

Figure		Page
6.1	USACE divisions and districts	41
6.2	Location of Canyon Lake	44
6.3	Bureau of Reclamation reservoirs	47
8.1	Water planning regions	59
8.2	Blair biotic provinces	61
8.3	Consensus criteria – reservoirs	70
8.4	Consensus criteria – diversions	70
10.1	Galveston Bay TXEMP	98
10.2	Lower Guadalupe River Diversion	100
10.3	Guadalupe Estuary TXEMP	106
10.4	Dams on Colorado River	109
10.5	Matagorda Bay system	113
10.6	Nueces Estuary TXEMP	117
11.1	Guadalupe Estuary flow	131
11.2	Edwards Aquifer	132
11.3	Major Texas aquifers	137
11.4	Aquifers showing decline	138

Figure		Page
12.1	Interagency connections in water rights	144
12.2	Interagency connections in water planning	146
12.3	Interagency connections in the bay and estuary studies	148
12.4	Interagency connections in protection of freshwater inflow	149
13.1	Sabine River flow	153
13.2	Trinity River flow	156
13.3	Colorado River flow	158
13.4	Guadalupe/San Antonio Rivers flow	160
13.5	Nueces River flow	162
13.6	Guadalupe Estuary inflow 1934-1989	165
13.7	Guadalupe Estuary inflow for 1954	166
14.1	Victoria USGS gauge	170
14.2	Guadalupe Estuary and consensus criteria	172
15.1	Guadalupe River recommended flows 1954	180
15.2	Texas water rights timeline	183
15.3	Guadalupe River recommended flows 1934-1989	184
16.1	Spring Branch USGS gauge	191
16.2	Sattler, TX USGS gauge	192
16.3	Canyon Lake inflow/outflow	194
19.1	TWDB sample graph	236
A-1	Texas boundaries	273
A-2	Major Texas estuaries	273

Figure		Page
A-3	Water availability in Texas	274
A-4	Texas rivers, basins, and rainfall	275
A-5	Texas cities and roads	276
B-2	Number of reservoirs	278
C-1	TXEMP for Sabine–Neches	279
C-2	TXEMP for Lavaca–Colorado	280
C-3	TXEMP for Mission–Aransas	280
C-4	TXEMP for Upper Laguna Madre	281
C-5	TXEMP for Lower Laguna Madre	281

LIST OF TABLES

Table		Page
4.1	Beneficial uses	21
5.1	Timeline of surface water law	31
10.1	Target species	97
10.2	Upper and lower bounds	102
10.3	Monthly inflow needs	107
10.4	Predicted species harvest	107
10.5	Target FIN for Matagorda Bay	111
10.6	Critical FIN for Matagorda Bay	112
11.1	WAM model runs.....	128
11.2	Texas groundwater and surface water use	135
14.1	7Q2 flows	169
15.1	Guadalupe Lyons Method	178
16.1	Canyon Lake flow data	195
17.1	Sample water rights data base	199
17.2	Special conditions of Victoria permit	208
17.3	Median flow for Clear Creek	212
20.1	Pending water right applications	262
B-1	Water rights by basin	277

LIST OF DOCUMENTS

Document		Page
D-1	Water Permit 12-5366 and Amendment 1964C	283
	
D-2	Draft Permit 5724 – San Marcos River Foundation with staff analysis	289

ABBREVIATIONS

cfs	cubic feet per second
FIN	Freshwater Inflow Needs
FWI	Freshwater Inflow
GAM	Groundwater Availability Model
GBRA	Guadalupe-Blanco River Authority
LCRA	Lower Colorado River Authority
LGWSP	Lower Guadalupe Water Supply Project
LNVA	Lower Neches Valley Authority
MaxH	Maximum Harvest – TXEMP modeled flow producing maximum harvest
MaxQ	Maximum Flow satisfying all TXEMP model constraints
MinQ	Minimum Flow satisfying all TXEMP model constraints
MinQ-50	Minimum Flow satisfying all TXEMP model constraints at 50% harvest
MinQ-sal	Minimum Flow satisfying only TXEMP model salinity constraint
n.d.	no date
NEP	National Estuary Program
NOAA	National Oceanographic and Atmospheric Agency
ppt	parts per thousand
NRCS	National Resource Conservation Service
SARA	San Antonio River Authority
SAWS	San Antonio Water Supply
7Q2	Statistic for lowest average streamflow for seven consecutive days with a recurrence interval of two years
SMRF	San Marcos River Foundation
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TCMP	Texas Coastal Management Program
TNRCC	Texas Natural Resource Conservation Commission
TPWD	Texas Parks and Wildlife Department
TRA	Trinity River Authority
TWC	Texas Water Commission
TXEMP	Texas Estuarine Mathematical Programming or Optimization Model
TXRR	A calibrated rainfall runoff model
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAM	Water Availability Model
WRAP	Water Rights Analysis Package

DEFINITIONS

Acre foot – The amount of water to cover an acre of land one foot deep = 325,851 gallons.

Bay – "An indentation of a shoreline larger than a cove but smaller than a gulf" (Cognitive Science Laboratory 2004).

Estuary – "A partially enclosed body of water formed where freshwater from rivers and streams flows into the ocean, mixing with the salty sea water" (USEPA 2003).

Freshwater Inflow – "Freshwater flows needed to maintain acceptable salinity levels and supply nutrients and sediments for the estuarine areas that support marine life and other species" (Texas Living Waters Project 2003).

Instream Flow – "This is the amount of water needed in rivers and streams to support fish and wildlife in and along our waterways" (Texas Living Waters Project 2003).

Naturalized Streamflows or Flows – Historical gauged flows adjusted to remove the effects of human water management and use (Wurbs 2000).

Unappropriated Flows – A general term referring to the amount of water available after all existing water rights have been fully utilized. This number can vary according to the amount of return flows assumed.

ABSTRACT

THE STATE OF THE PROTECTION OF FRESHWATER INFLOW TO THE BAYS AND ESTUARIES OF TEXAS

By

Tom Wassenich, M.A.G.

Texas State University–San Marcos

Freshwater inflow to the bays and estuaries of Texas is considered essential to maintain their biological productivity. The reduced salinity of the estuaries is necessary for the juvenile stage of many marine species. More than 90 percent of fish harvested along the coast are dependent on estuaries for some part of their life cycle.

Anthropogenic changes such as diversions and reservoirs increasingly affect the quantity and timing of freshwater entering the bays and estuaries.

The protection of freshwater inflows in Texas is a complex process with many components. Lawmakers, citizens, water planners, water administrators and commissioners of state agencies need a better understanding of all aspects of this complex subject. A thorough examination of the current state of protection will facilitate an analysis of the effectiveness of protection of the state's estuaries. This document examines the major components of protection at the state and federal levels including laws, agencies, water rights, water plans, and bay and estuary studies, both from an

administrative and a quantitative perspective. From this analysis it is possible to determine the amount, if any, of freshwater inflow that is protected by the system.

The system of protection is fragmented and not well-defined. Three state agencies share partial responsibilities for inflow protection with no real central authority. Rivers are managed with little emphasis on estuaries, water rights are granted without well-defined freshwater inflow protection formulas, and water plans are made using different protection criteria than those used for appropriations of water or the bay and estuary studies. The water planning and appropriation areas are dominated by the water users with little input from conservationists and others concerned about adequate inflows for healthy bays and estuaries. Currently the state does not have a complete set of tools to deal with all of the aspects of inflow protection even were there a will to do so. This document recommends several specific research projects to improve the system of protection:

- Comparative examination of the water planning criteria with the recommended flows of the bay and estuary studies.
- Analysis of the amount of freshwater inflows protected since the 1985 requirements for protection were instigated.
- Determination of the effects of reservoir management on freshwater inflow timing.
- Review of the Water Availability Model and its assumptions related to groundwater and pre-anthropogenic flows.
- Analysis of the effects of maximum permitted and proposed water use on estuarine productivity repeated with every five year planning cycle.

- Establishment of a minimum freshwater inflow protection system that applies to low-flow situations while protecting the productivity of the estuaries.

The original document covered the period through the end of the 2003 Legislature.

Updates for 2004 and 2005 were added to analyze and comment on the Scientific Advisory Committee's Report to the 2005 Texas Legislature, which began its session in January 2005. The 2005 update also covers the 2005 Legislature and special sessions that were unsuccessful in implementing new environmental flow legislation. It is hoped that this document will provide a platform for continuing scrutiny of the freshwater inflow protection system in Texas, leading to ongoing positive adaptive management of sustainable environmental flows for the bays and estuaries.

CHAPTER 1

INTRODUCTION

Texas bays are extremely important to the quality of life and the economy of the state. Responsibility to protect these important resources is spread among a number of different governmental agencies. Even more complex is the responsibility to maintain sufficient freshwater inflow to ensure the ecological survival of these bays and estuary ecosystems. This study is the first attempt to perform a comprehensive assessment of the policies, regulations, and procedures relevant to maintenance of freshwater inflow into Texas bays.

Seven major and three minor bays cover 2.6 million acres along 370 miles of the Texas coast and contribute \$3.5 billion per year (1994 dollars) from commercial fishing, sport fishing and other recreation alone (TWDB 2004). The Texas Water Development Board states:

... the real value of the bays and estuaries is many times this amount and may be fully comprehended only by considering how much it would cost to replace all the goods and services provided by these valuable coastal systems (TWDB 2004, 1).

Other uses of estuaries include navigation, mineral resources, and natural waste treatment of pollutants (TWDB 2004). There appears to be wide spread agreement on the importance of estuaries as productive areas (Coastal Bend Bays and Estuary Programs 2001; Costanza et al. 1997; Duxbury, Duxbury and Sverdrup 2000; Odum H. 1971) and the United States Environmental Protection Agency estimates that estuaries provide habitat for over 75 percent of the United States commercial fish catch (USEPA 2003).

Freshwater inflow from rivers, streams, and runoff is an essential element required to maintain estuarine productivity (USEPA 2003; Oregon Dept. of Land Conservation and Development 2003; Odum 1971).

Freshwater inflow is a major determinant of the physical, chemical, and biological characteristics of most estuaries. It affects the concentration and retention of pollutants, the distribution of salinity, and the stratification of fresh and salt water within an estuary (NOAA 1999, 1).

Activities including diversions of water and construction of reservoirs reduce the amount of freshwater inflow or alter the timing of the flows reaching the estuary, either of which can be detrimental to the productivity of the estuary system (Alber and Flory 2002; Chen 2002; Duxbury, Duxbury, and Sverdrup 2000; Coastal Bend Bays and Estuaries Program 1998).

Protection of freshwater inflows to bays and estuaries is an area of growing concern around the world to scientists as well as citizens and governments (United Nations 2003; U.S. Dept. of State 2003; Turek et al.1987). The protection of freshwater inflow to the bays and estuaries of Texas is a complex process with many components (USEPA 2003). There seems to be little understanding of all the aspects of protection in Texas, either by lawmakers, citizens, water planners, or administrators and commissioners of state agencies (Texas Water Matters 2003; TCEQ 2003c). To solve this problem of a lack of understanding, a comprehensive analysis and synthesis of the various aspects of the protection of freshwater inflow are needed to enable participants in the process to determine its overall effectiveness.

Purposes of the Study

- 1) Define and examine the various components of protection of freshwater inflows in Texas. The term “components” here includes any law-making entity, agency, commission, planning process, program, law, or scientific studies.
- 2) Identify or derive the quantitative targeted flows, if any, deemed necessary to protect by each component.
- 3) Examine the consistency and interaction or communication between the components relative to protection of freshwater inflows.

Subsidiary Questions

- 1) How do the flows recommended in the bay and estuary studies compare quantitatively to the naturalized (prior to diversions) flows and the unappropriated flows shown in the Water Availability Model?
- 2) How do the bay and estuary studies compare quantitatively and administratively to the state's regional water plans?
- 3) How do the bay and estuary studies compare quantitatively and administratively to the water rights granting process?
- 4) What are the administrative connections between the state water laws and codes, the water rights granting process, the bay and estuary studies, and the state's regional water plans?
- 5) What are the consistencies and inconsistencies between the state water laws and codes, the water rights granting process, the bay and estuary studies, the state's regional water planning process, and any other related federal or state program or agency regarding the recommended quantitative protection of freshwater inflow?

CHAPTER 2

PREVIOUS RESEARCH AND LITERATURE REVIEW

There have been studies of individual components of freshwater inflow (FWI) protection in Texas, as well as studies of multiple components and their interactions. Gerston (1995) mentions a multitude of components in Texas freshwater inflow management resulting in uncoordinated efforts. (Note: NEP refers to the National Estuary Program).

Before the National Estuary Program, 19 federal, state, and local agencies monitored Texas' estuaries, but in patchwork fashion. This scattershot approach resulted in unexpected side-effects, as actions taken on any ecosystem do not occur in isolation. By taking an ecosystem, rather than resource approach, NEP's consider interrelated processes (Gerston 1995, 3).

Probably more important information than the consolidation of monitoring by the National Estuary Program is the fact that only two of the eight major bays in Texas are under that program (See appendix figure A-3 for map of Texas estuaries). This means by deduction, the other six major bays have approximately nineteen agencies still monitoring them, depending on changes in laws and programs since 1995. Gerston (1995) does not attempt to analyze the nineteen components, only to discuss the new federal-state partnership for the two designated bays, Galveston Bay and Corpus Christi Bay. This apparent multitude of entities involved in estuaries in Texas indicates the need to define and examine the components of the protection process to assist in determining the state of FWI protection.

Howard J. Saxion's 1990 dissertation, "Environmental Decisions in the Public Policy Arena: Protection of Texas Bays and Estuaries and the Freshwater Inflow Issue" is a thorough analysis of various elements of freshwater inflow protection in Texas. Saxion

(1990) concentrates on the debate leading up to the passage of House Bill 2 in the 1985 legislature that addressed among other things freshwater inflow. He concludes:

The enactment of House Bill 2 provided additional guidance to the Texas Water Commission to address the effect of impoundments and upstream diversions of water on coastal bays and estuaries. However, several significant omissions resulted in the issue not being adequately resolved (Saxion 1990, 187).

Saxion (1990) further examines the questionable delegation of evaluation of FWI needs to the Texas Water Development Board (TWDB) instead of the Texas Parks and Wildlife Department (TPWD). He also discusses the various roles of these two departments and the potential conflicts of interest involving the TWDB. Although this is a thorough coverage of FWI protection and its various components, it pre-dates some critical laws, processes, scientific studies and programs related to FWI protection in 2003. Among these later developments are the establishment of instream flow as a beneficial use, completion of the Water Availability Models for all major river basins except the Rio Grande, completion of the recent bay needs studies for four of the eight major bays, and the completion of the first five-year round of the 1997 Texas State Water Plan.

Regarding the lack of current applicability by the previously discussed studies, this is an appropriate place to discuss the timing of this document. One hesitates to undertake such time-sensitive issues as freshwater inflow protection as a topic; however, it can be argued that this is a crucial point in the protection process in Texas and an analysis is not only justified but needed at this time. Several critical elements related to freshwater inflow are now available that previously did not exist – the WAM, the bay and estuary studies, and instream use defined in the Water Code. Several environmental groups have recently applied for unprecedented instream flow water rights totaling

millions of acre feet to protect freshwater inflows to bays and estuaries, and these are currently being either litigated in court or debated at the TCEQ.

Judith Clarkson in her 1987 thesis titled "Policy Options for Protecting Freshwater Inflows to Bays and Estuaries in Texas," examined instream flow protection in various other states and used some of those concepts to recommend protection measures for Texas. She covers the history and development of the existing relevant laws in Texas and how they define the role of various agencies. In her executive summary she states: "The most direct approach for protecting instream needs would be for Texas Parks and Wildlife Department to quantify the needs of each estuary and file an appropriation with the Texas Water Commission" (Clarkson 1987, 2). (Note: The Texas Water Commission was the forerunner of the Texas Commission on Environmental Quality). Again we see the problem of agency responsibility. Clarkson stresses mainly the legal aspect and does a thorough job, but as in Saxion's (1990) work, there are missing elements due to the date of her research.

A third study of freshwater inflow protection in Texas was published in 1986 as a master's thesis by Sharon Marie Kelly titled "An Evaluation of Legal Strategies for Protecting Freshwater Inflows Into Texas Estuaries" (Kelly 1986). As evidenced by the title, Kelly is primarily analyzing the law and possible uses of it to protect FWI, plus suggesting revisions to make it more effective. Again the date of the work limits the applicability to current protection issues.

The current complexities of protection are briefly discussed in a 2003 article in *Texas Parks and Wildlife Magazine* containing interviews with the chairman of the TPWD, a board member of the TWDB and a commissioner of the TCEQ (Harvey 2003).

Freshwater inflow protection, instream flow protection, the bay needs studies and the roles of the three agencies are covered, but due to the individual interview format there is no real synthesis.

In the "Background" section of the LCRA's 1997 study of the FWI needs of Matagorda Bay on the Colorado River, Quentin Martin et al. briefly summarize the structure of Texas' FWI protection. As for the legal aspect they bluntly state: "Presently, Texas law does not mandate specific freshwater inflow needs" (Martin et al. 1997, I-1 – I-4). They proceed to explain the bay studies and roles of the various agencies.

Probably the most current and overall in-depth analysis of FWI protection is provided by a coalition of three nationally-based environmental groups; the National Wildlife Federation, Environmental Defense, and the Lone Star Chapter of the Sierra Club. Functioning as the Texas Living Waters Project, they produce the Texas Water Matters website (<http://www.texaswatermatters.org>) that maintains frequent updates of Texas water law, agency actions, water permit applications, bay and estuary studies, the Water Availability Model and the Texas Water Plan. Dr. Norman Johns, Water Resources Scientist for the National Wildlife Federation, generates numerous statistical analyses of the various aspects of water issues in Texas including FWI issues.

Due to the temporal aspect of this document, one would not expect an abundance of current analytical literature, as the dynamics change almost daily as new laws are passed, court decisions interpret existing law, scientific studies are completed or modified, the water plans proceed, and water rights for diversion continue to be granted. Peer-reviewed scientific literature that involves extensive research and documentation plus review by members of the academic community, can have difficulty maintaining

current analyses of ongoing policy related processes. This is often the role of the non-profit advocacy groups and their web-based information process. By avoiding the rigor of the scientific disciplines and using easily updateable web media, advocacy groups can more readily keep abreast of ever-changing issues. Proper care should be taken in the use of this information, and knowledge of both the organization and the personnel involved are essential.

Now that all the river basins in Texas except the Rio Grande have been modeled in the Water Availability Model (WAM), the data for each basin are available online at the Texas Commission on Environmental Quality (TCEQ) website (<http://www.tnrcc.state.tx.us>). The Groundwater Availability Model (GAM) is just being initialized, therefore only the place-holding values for groundwater inputs and outputs are incorporated into the WAM, which could be problematic. The studies of three of the major bays and estuaries of Texas have been completed by TPWD and TWDB and preliminary model runs of seven of the major bays and estuaries are available online at <http://www.twdb.state.tx.us>. In addition LCRA's study of Matagorda Bay is available from its website at <http://www.lcra.org>.

There are seven Senate Bill 1 planning regions containing coastal areas (TWDB 2002b). Some of these regions have targeted flows while others do not. Region K, which includes the Colorado River Basin, used the target flows from the LCRA Matagorda Bay Study. Unfortunately they used different methods than those modeled with the TWDB/TPW criteria (Martin et al. 1997). The Galveston Bay Region H Planning Group specified target levels of FWI in their plan (Galveston Bay Estuary Program 2001, 104). Since only four bay and estuary studies are totally complete and four more only have the

model results without the final analysis, it is difficult to determine the recommended flows for each planning region without further analysis.

Presently there is no composite compilation of the different quantitative flows either targeted for protection or actually protected. The previously mentioned Living Waters Project has compiled various reports using state data, some of which compare actual permitted flows with the planning process and the bay studies (Living Waters Project 2003). Perhaps due to spatial limitations of web-based media and intended-audiences' reading time, there appears to be no extensive compilation of the quantitative data on their website. However Johns with the National Wildlife Federation has generated more complete data that may be useful (National Wildlife Federation 2003-2004). Note: As this publication was going through final editing in December, 2004, the National Wildlife Federation issued its report "Bays in Peril" (NWF 2004). This report contains thorough analyses of the forecasts for freshwater inflows for each of the major estuaries in Texas along with a ranking of the future freshwater availability for each estuary.

I have not yet found a comprehensive analysis in any state documents of the relationships between the components of FWI protection. There are laws, rules and some discussions about the interaction between various elements and departments, but most of these only deal with two or three agencies at a time

As part of House Bill 2 passed by the Texas Legislature in 1985, Chapter 16 of the Water Code calls for interagency action on studies of bays and estuary needs (The "Board" refers to the Texas Water Development Board):

The Parks and Wildlife Department and the board shall have joint responsibility, in cooperation with other appropriate governmental agencies, to establish and

maintain on a continuous basis a bay and estuary data collection and evaluation program and conduct studies and analyses to determine bay conditions necessary to determine bay conditions necessary to support a sound ecological environment (Tex. Water Code § 16.058).

Also as a result of Texas House Bill 2, 1985, Chapter 11 of the Water Code describes the utilization of the studies (Note: the "commission" refers to the Texas Commission on Environmental Quality):

The Parks and Wildlife Department and the commission shall have joint responsibility to review the studies prepared under Section 16.058 of this code, to determine inflow conditions necessary for the bays and estuaries, and to provide information necessary for water resource management (Tex. Water Code § 11.1491[a]).

In subsection (b) the Code recommends further agency interaction:

For purposes of guiding data collection and studies specified under Subsection (a) of this section, an advisory council may be established by the executive directors of the commission and the Parks and Wildlife Department and the executive administrator of the Water Development Board for each principal bay and estuary. . . . The advisory councils may develop recommendations to the executive directors and to entities and organizations having operational responsibilities or holding major water rights in the contributing watersheds regarding alternative water management methods that may be used in maintaining the sound environment of the bays and estuaries (Tex. Water Code § 11.1491[b]).

It should be mentioned that the code also mandates the advisory council to include other specific agencies and representatives from various groups including one fishermen and one conservationist. At this point in the search for connectivity between the studies and the agencies and their administrative practices, it is still not clear how or if the quantitative results are actually utilized in protection of freshwater inflow. Therefore, some data will have to be compiled to examine the quantitative aspects of freshwater inflow protection.

In the Draft Region L Scope of Work proposal, HDR Engineering lists as one of its tasks to describe the consistency of the Regional Water Plan with protection of

instream flows and freshwater inflows to bays and estuaries (HDR Engineering 2002). Perhaps in doing this HDR will compare the recommendations of the bay and estuary studies to various WAM output although it is not clear if the studies will be considered. Unfortunately this report is not scheduled for completion until March 31, 2005.

The lack of quantitative comparisons of various aspects of freshwater inflow is impeded by the ever-changing data of the Water Availability Model (WAM). This could be one reason for the apparent absence of state agency or any planning group-generated comparisons. The data and output of the WAM provide the actual and modeled annual and monthly flows for each river basin under various scenarios including:

- 1) Historical (actual gauged) flows.
- 2) Modeled naturalized flows assuming no anthropogenic activities or infrastructure.
- 3) Modeled unappropriated flows if all current water rights were utilized and no wastewater was returned to the stream (Wurbs 2000).

The WAM data is obviously necessary to perform these comparisons and although all river basin WAMs except the Rio Grande are initially complete, there are unresolved issues in the data and output. For example the HDR Draft Scope of Work for Region L, proposes to modify the Guadalupe and Nueces River WAMs to reflect recent amendments to the Canyon Lake and Choke Canyon reservoir permits (HDR Engineering 2002). These same factors affect this study, but since 2003 is the time frame of this document, I will use data available through the end of the 2003 year.

Judging from the literature, there appear to be communication and/or management problems among at least some of the elements of FWI protection. The United States Environmental Protection Agency manages the previously mentioned National Estuary Program (NEP). Its literature discusses issues faced by the twenty eight designated

United States bays, including individual state management systems and laws. Regarding protection of FWI in Corpus Christi Bay the USEPA states: "The current decision-making framework is politically and emotionally charged, and more 'crisis management' than proactive in nature" (USEPA 2003). Regarding Galveston Bay, the other national estuary in Texas, the USEPA says: ". . . there is no statutory mechanism in Texas to provide for the necessary freshwater or circulation. Inflow to Galveston Bay is dealt with on a case by case basis advocacy process with the state environmental agency" (USEPA 2003, 2). These comments from the current USEPA website indicate federal recognition of problems with the Texas system of protection.

The relevant parts of the Texas Water Code and Texas Administrative Code do not appear to contain language mandating a specific quantity to be protected or a mechanism to establish one (Tex. Water Code 2003 & Tex. Admin. Code 2003). There are mandates for TPW and TWDB to prepare and review estuary needs studies (TX Water Code § 16.058 and §12.0011), but no mention of the studies' quantitative results or description of a framework for their utilization.

The previously mentioned EPA comments refer to the state environmental agency which is the TCEQ, dealing with FWI on a case by case basis and there being no statutory mechanism to preserve necessary freshwater inflows (USEPA 2003). This would imply a lack of quantitative agreement between Texas laws and codes, the TCEQ, and the definition of necessary flows. It is not clear what EPA meant quantitatively by "necessary flows," but disagreement between the components is obvious.

Other federal or state programs or agencies that may be involved in freshwater inflow issues will be researched in this document. For example the USEPA National

Estuary Program already mentioned is involved in at least two Texas bays, but it is not evident as to their administrative authority or if they recommend or mandate specific quantitative flow values. The Sierra Club used the Federal Endangered Species Act of 1973 to preserve springflows for a segment of the San Marcos River in Texas (Eckhardt 2003), but to this point in the research, no information has been found on the Act being applied to preservation of freshwater inflow to any Texas estuaries.

CHAPTER 3

THE CONSTITUTION, STATUTES, CODES, AND THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

The Constitution and the Texas Water Code

The terms "bay," "estuary," and "freshwater inflow" do not appear in the Texas Constitution; however, there is mention of "water" and "natural resources." Article 16, Section 59(a) describes the duties of the State to include "The conservation and development of all of the natural resources of this State, . . . including . . . *preservation* and distribution of its storm and flood waters, *the waters of its rivers and streams* . . ." (Texas Constitution). (Note: The previous words in italics and those from here forward in italics except as otherwise noted, are italicized by the author to emphasize words and phrases relevant to the issue of freshwater inflow protection). There is also a declaration for state policy to

". . . *encourage* the optimum development of the limited number of feasible sites available for the *construction or enlargement of dams and reservoirs* for *conservation of the public waters of the state*, which waters are held in trust for the use and benefit of the public . . ." (Texas Constitution, Article 3, Section 49-d[a]).

The legislature is designated to pass the laws necessary to carry out these duties (Texas Constitution, Article 16, Section 59[a]).

The Texas Water Code is the statute containing the water laws of Texas and establishing the agencies and defining their general duties in administering the water resources of the state. Section 1.003 states that the public policy of the state includes ". . . the *maintenance of a proper ecological environment of the bays and estuaries of Texas and the health of related living marine resources*" (Tex. Water Code).

The Texas Commission on Environmental Quality

Chapter 5 of the Water Code establishes and defines the Texas Commission on Environmental Quality (TCEQ), formerly the Texas Natural Resource Conservation Commission (TNRCC):

The commission is the agency of the state given primary responsibility for implementing the constitution and laws of this state relating to *the conservation of natural resources and the protection of the environment* (Tex. Water Code § 5.012).

It is notable that "protection of the environment" appears here as an expansion of the constitutional duties. The TECQ is given "general jurisdiction " over, among other areas, water and water right permits and water quality rules and standards" (Tex. Water Code § 5.013). Section 5.120 requires the commission to ". . . administer the law so as to promote the judicious use and maximum conservation and protection of the quality of the environment and the natural resources of the state" (Tex. Water Code).

Also in Chapter 5 the commission is designated as the lead state agency for implementing the National Estuary Program (NEP) in Texas (§5.604). The NEP is a cooperative estuary management program administered by the United States Environmental Protection Agency (USEPA) to develop comprehensive conservation and management plans for estuaries designated as nationally significant (Federal Water

Pollution Control Act 33 U.S.C. Section 1330). Section 5.603 of the Water Code,

Finding of Benefit and Public Purpose states:

The state recognizes the importance of implementing estuary management plans protecting and improving water quality and restoring estuarine habitat that makes the bays and estuaries productive, protecting the economies of those areas, and continuing the involvement of the public and the many interests who use and appreciate the estuarine resources of Texas (Tex. Water Code).

This is followed with a mention of local control and property rights.

The state and the implementing agencies recognize the prerogatives of local governments and the sanctity of private property rights. No action by an estuary program is intended to usurp the authority of any local government. A local government's participation in or withdrawal from an estuary program is at the sole discretion of the local government and is subject only to the local government's obligation to complete any financial commitment it has made (Tex. Water Code § 5.603).

Other state agencies are mentioned as participants in the estuary programs including the General Land Office, the Texas Parks and Wildlife Department, and the Texas Water Development Board (TWDB). The TCEQ will administer the state's share of the funds for this program and make grants to assist the plans. This program will be further discussed in chapter 9 which covers federal programs.

Chapter 7 of the Water Code deals with enforcement powers of TECQ including certain administrative penalties related to water permits. Section 7.053 lists factors to be considered in determining the penalty amount including the impact of the violation on: a receiving stream or underground water reservoir and instream uses, water quality, aquatic and wildlife habitat or beneficial freshwater inflows to bays and estuaries.

The commission along with the TWDB and the TPWD is included in the 13 member Texas Water Advisory Council which expires in 2005 unless renewed by the legislature (Tex. Water Code § 9.002). This non-regulatory council has no paid staff and

its duties are advisory only. The council is instructed to make recommendations on state water issues including:

. . . encouraging commonality of technical data and information such as joint agency studies, *freshwater inflow recommendations*, surface water and groundwater availability models, *and bay and estuary and instream flow recommendations developed by the Parks and Wildlife Department*, the commission, and the Texas Water Development Board (Tex. Water Code § 9.008).

The TCEQ is given the power and duty to administer and act on all water right applications and amendments and permits for impoundment or transfer of public water (Tex. Water Code § 12.011). Chapter 11 of the Water Code is titled "Water Rights" and will be discussed in later chapters.

Chapter 16 of the Water Code is titled "Provisions Generally Applicable to Water Development." Principally the Texas Water Development Board is discussed, however the TCEQ's role in providing water supply and groundwater availability models is defined in § 16.012 (Tex. Water Code). The TECQ in coordination with TPWD is given 90 days after completion of a basin's water supply model to determine the potential impact of reuse of municipal and industrial effluent on existing water rights, instream uses, and freshwater inflows to bays and estuaries. This information goes to the regional water planning group of the particular basin as well as TWDB. Groundwater models for major aquifers are to be completed by Oct.1, 2004.

In the discussion to this point, the TCEQ's responsibility for protection of FWI to bays and estuaries is principally advisory with the exception of its supervision of the water availability models.

The Texas Administrative Code

The Texas Administrative Code (TAC) is a compilation of all the state agency rules in Texas and to some extent the TAC mirrors parts of the Texas Water Code. The Administrative Code rules are made by the respective agencies (Tex. Government Code § 2001.004) and the legislature can send the agency a statement of support or opposition to a rule (Tex. Government Code § 2001.032). The rules have to be cross-indexed to the statute with which they are associated (Tex. Government Code § 2001.04). When analyzing agency rules versus the Water Code, one should be aware that the rules can be changed by an agency, but the Water Code can only be changed by the legislature.

Title 30 Environmental Quality, Part 1 of the Administrative Code is titled the "Texas Commission on Environmental Quality." Chapters 295 and 297 of the Administrative Code regarding water rights, address issues of the TCEQ's duties that relate to FWI protection that will be discussed further in chapters 7 and 8 on the water rights process.

CHAPTER 4

THE TEXAS COMMISSION ON ENVIRONMENTAL QUALITY AND THE WATER RIGHTS PROCESS

In Texas all surface water in defined waterways is owned by the state and held in trust for every citizen (TWDB 1997). Anyone wanting to use this water must apply to the Texas Commission on Environmental Quality for the right to use surface water. A permit can only be granted if several criteria are met including having a beneficial use as defined by the Water Code, and the availability of unappropriated water (TWDB 1997). Water rights are based on seniority or "the first in time is the first in right" (Tex. Water Code §11.027). It is important to note that a similar system of permitting groundwater does not exist in Texas except where groundwater districts have been formed and given the authority to control groundwater use (TWDB 1997). This right to pump unlimited amounts of water from underneath your land is called the rule of capture and Texas is the only Western State that still adheres to this rule (Boisseau 2003).

Several definitions in Title 30 Chapter 297 of the Administrative Code are needed to understand the water right granting process and freshwater inflow protection. (Italics added for emphasis).

Beneficial inflows – Freshwater inflows providing for a salinity, nutrient, and sediment loading regime adequate *to maintain an ecologically sound environment in the receiving bay and estuary* that is necessary for the maintenance of productivity of economically important and ecologically characteristic sport or commercial fish and shellfish species and estuarine life upon which such fish and shellfish are dependent (30 Tex. Admin. Code § 297.1).

Beneficial Use – Use of the amount of water which is economically necessary for a purpose authorized by law, when reasonable intelligence and reasonable diligence are used in applying the water to that purpose . . . (Tex. Admin. Code § 297.1).

Instream Use – The beneficial use of instream flows for such purposes including, but not limited to, navigation, hydropower, fisheries, game preserves, stock raising, park purposes, aesthetics, water quality protection, aquatic and riparian wildlife habitat, *freshwater inflows for bays and estuaries*, and any other instream use recognized by law. An instream use is a beneficial use of water. Water necessary to protect instream uses for water quality, aquatic and riparian wildlife habitat, recreation, navigation, *bays and estuaries*, and other public purposes *may be reserved from appropriation by the commission* (Tex. Admin. Code § 297.1)

State water – The water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and of every bay or arm of the Gulf of Mexico, and the stormwater, floodwater, and rainwater of every river, natural stream and watercourse in the state. . . State water does not include groundwater, nor does it include diffuse surface rainfall runoff, groundwater seepage, or springwater before it reaches a watercourse (Tex. Admin. Code § 297.1).

The amount of water applied for must be available as stated in § 297.42 (c) for a water right to be granted. If there is no off-channel storage, *approximately 75 percent* of the water requested must be available 75 percent of the time on a monthly basis based on *the available historic stream flow record*. Note the reference to the historic streamflow record. The TCEQ now has models that show the projected availability if all rights were used which would mean much less water than was historically available.

The Administrative Code also states that a *new water right* may have conditions to protect instream uses, water quality, aquatic and wildlife habitat and freshwater inflows to bays and estuaries (Tex. Water Code §§ 11.147, 11.150, 11.152 and 16.059). In chapter 5 is a further discussion of the statutes and codes related to water rights and freshwater inflow.

A water right must also have a beneficial use. There are two lists of beneficial uses that have some important variances. In table 4.1 the Texas Water Code list is compared to the Texas Administrative Code list. Note that the lists are similar except in the area of instream use which is specified in the Administrative Code, but not in the

Water Code. There will be more discussion on instream flow as a beneficial use in chapter 15.

Table 4.1 - Beneficial uses for water permits

Note: The Water Code does not list the specific instream uses that are in the Administrative Code.

Texas Water Code § 11.023	Texas Administrative Code § 297.43
Domestic and Municipal	Domestic and Municipal
Industrial	Industrial
Agricultural	Agricultural
Mining	Mining
Hydroelectric power	Hydroelectric power
Navigation	Navigation
Recreation and pleasure	Recreation and pleasure
Public parks	Public parks
Game preserves	Game preserves
State water also may be appropriated, stored, or diverted for any other beneficial use.	Other beneficial purposes of use recognized by law.
(Intentionally left blank)	<i>Instream uses, water quality, aquatic and wildlife habitat, or freshwater inflows to bays and estuaries.</i>

The Water Code also defines the *preferences* of the listed beneficial uses (§ 11.024) and the order of preference is the same as in table 4.1. "In order to conserve and properly utilize state water, the public welfare requires not only recognition of beneficial uses but also a constructive public policy regarding the preferences between these

uses . . ." (Tex. Water Code § 11.024). The Administrative Code adds that these preferences do not alter the principle of seniority in water rights, but will be used in determining which new uses will be granted water rights as per § 11.123 in the Water Code which states:

The commission shall give preference to applications in the order declared in Section 11.024 of this code and to applications which will effectuate the maximum utilization of water and are calculated to prevent the escape of water without contribution to a beneficial public service (Tex. Water Code § 11.123).

There is no definition of "beneficial public service." In addition to the principle of preference, the state and any of its agencies and political subdivisions can also exercise eminent domain over water rights.

The right to take water necessary for domestic and municipal supply purposes is primary and fundamental, and *the right to recover from other uses* water which is essential to domestic and municipal supply purposes is paramount and unquestioned in the policy of the state (Tex. Water Code § 11.033).

The Water Code further states that water for manufacturing uses and other uses defined in the code including water for "irrigation of land for all requirements of agricultural employment" (Tex. Water Code § 11.033) is subject to eminent domain.

Most likely looking to the future and the possibility of removing salt from seawater to create more freshwater, there is a provision allowing diversion of water from a bay or the Gulf of Mexico to be changed to freshwater and used for any authorized purpose (Tex. Admin. Code § 297.43).

Even though groundwater in Texas is generally unregulated (Block and Richardson n.d.), the administrative code allows the commission to deny a water right if it is determined that the diversion is from a stream that subsequently recharges an aquifer and could significantly impair springflow upon which aquatic and wildlife habitat or bays

and estuaries depend (Tex. Admin. Code § 297.47). The commission *may* also consider in determining permit restrictions, instream losses that occur because of recharge in the bed of the stream that might reduce environmental flows. Here we see attempts at dealing with the connection between surface and groundwater that is complicated by the rule of capture.

Effects of a new permit on water quality shall be assessed by the commission (Tex. Admin. Code § 297.54). The minimum flows for rivers and streams to maintain water quality are calculated in the Texas Surface Water Quality Standards as covered in Chapter 307 of the Administrative Code. However § 297.54 only requires that the commission "*consider*" the maintenance of the standards.

If all or part of a water appropriation goes unused for ten years it is subject to cancellation in whole or in part as defined in the Texas Water Code § 11.173. According to the Texas Center for Policy Studies (2002) only on rare occasion have water rights been cancelled.

Surplus water is defined as "... water in excess of the initial or continued beneficial use of the appropriator" (Tex. Water Code § 11.11.002[10]). If there is surplus water from a permit for authorized use taken from a stream, that water shall be returned to the stream if it can be returned by gravity flow and it is reasonably practicable to do so (Tex. Water Code § 11.046[a]). The Commission *may* include conditions on the water right requiring a certain percentage or amount of the surplus water be returned to a watercourse for downstream senior permits or flows for bays and estuaries (Tex. Water Code § 11.046[b]). Before appropriated water is released into a watercourse it can be beneficially used and reused by the permit holder for the use specified in the permit (Tex.

Water Code § 11.046[c]). Once water has been diverted and then returned to a watercourse it is considered available for others to appropriate (Tex. Water Code § 11.046[c]).

There is a method of maintaining control of surplus water after it is discharged back into the watercourse, called a Bed and Banks Permit. A Bed and Banks Permit allows the user of water to return it to the watercourse and withdraw the equivalent amount downstream, less carriage losses (Tex. Water Code § 11.042[c]). This is another form of reuse of water, only in the case of a Bed and Banks Permit the water is combined with stream water and transported downstream. The discharge can be of lesser quality than the receiving stream although there is a stipulation that the water discharged cannot lower the stream section's classification (see chapter 15). Using the bed and banks of a stream to transport surplus water, which is often treated wastewater, was only recently allowed by Senate Bill 1 in 1997, but several applications have been made since then. Although reuse has been allowed previously, this expanded method of reuse via a bed and banks permit will most likely facilitate the reuse of what was previously return flows that provided instream flow and freshwater inflow to the bays and estuaries.

Summarizing the basics of the water right process that affect environmental flows in some manner, there are provisions that for a new water right to be issued:

- 1) Water must be available, though not definite on how often, for new permits.
- 2) There has to be a beneficial use which includes freshwater inflow, but that use has the lowest preference rating compared to all the other beneficial uses (table 4.1).
- 3) Water is subject to eminent domain for domestic and municipal purposes.
- 4) Groundwater is unregulated except in areas with a groundwater district.

- 5) New permits or amendments *may* be denied if they affect springflow that affects a bay and estuary.
- 6) Unused (surplus) water has to be returned to the stream, but may be reused before discharge. Additionally the bed and banks of a river may be used to transport reused water downstream before it is rediverted, although this requires a special permit.
- 7) For new permits and amendments, effects on water quality shall be assessed and there are standards set by the commission that *can* be applied.

CHAPTER 5

WATER RIGHTS AND ESTUARINE CONSIDERATIONS

In considering water rights applications *or amendments* the commission *shall assess* the effects of that application on the bays and estuaries as provided by Texas Administrative Code § 297.55 that is titled "Estuarine Considerations." Note that amendments to water rights are mentioned here, which is the process of existing right-holders applying to change the amount of use, place of use, diversion point or rate, acreage to be irrigated or other alterations (Tex. Water Code § 11.122). The bay and estuary consideration stipulation implies consideration of all new and amended permits, no matter how far from the coast. However, on permits within 200 river miles of the coast, the commission " . . . shall include in the water right, *to the extent practicable when considering all public interests*, those conditions *considered necessary to maintain beneficial inflows* to any affected bay and estuary system" (Tex. Admin. Code § 297.55[a]). The matters the commission shall consider are listed in § 297.55(b):

- 1) the need for periodic freshwater inflows to supply nutrients, sediments, and modify salinity to preserve the sound environment of the bay and estuary, using any available information, including *the studies and plans specified in Texas Water Code § 11.1491* [TPWD and TWDB bay and estuary needs studies] and other studies considered by the commission to be reliable; together with existing circumstances, natural or otherwise, that may prevent the conditions imposed from producing benefits.
- 2) the ecology and productivity of the affected bay and estuary system.
- 3) the expected effects on the public welfare of not including in the water right some or all of the conditions considered necessary to maintain the beneficial inflows to the affected bay or estuary system;
- 4) the quantity of water requested and the proposed use of the water by the applicant, as well as the needs of those who would be served by the applicant;

5) the expected effects on the public welfare of the failure to issue all or part of the water right being considered; and

6) the declarations as to preferences for competing uses of water as found in Texas Water Code §§ 11.023 and 11.024 as well as the policy statement in Texas Water Code § 11.003.

The studies and plans referred to in Tex. Admin. Code § 297.55(b)(1) are generally defined in Tex. Water Code § 11.1491. It states that the Texas Parks and Wildlife Department and the Commission shall have joint responsibility to *review studies* by the TPWD and the TWDB called for in Tex. Water Code § 16.058. The purpose of these studies is to determine the freshwater inflow needs for the bays and estuaries. There is also the expressed opportunity to establish an *advisory council* of the three main agencies and other representatives that *may develop recommendations* ". . . regarding alternative water management methods that *may* be used in maintaining the sound environment of the bays and estuaries" (Tex. Water Code § 11.1491[b]).

Rule § 297.55(c) further states that at least 5 percent of the annual firm yield (theoretical yield during the drought of record as per Tex. Admin. Code § 297.1[20]) of any reservoir started since 1985 within 200 river miles of the coast is appropriated to the Texas Parks and Wildlife Department to use for bay and estuary flow and adds:

This five percent figure may not be indicative of the full instream needs or the freshwater inflow needs of the affected bay or estuary system and the commission may impose additional water right conditions to provide a greater amount of water for this purpose, if necessary and appropriate after considering all the factors provided by subsection (b) of this section (Tex. Admin. Code § 297.55[b]). [Subsection (b) is the preceding list of conditions]. Also in this section is a provision that unallocated water and other water permitted to the TWDB that is stored in a TWDB facility *may* be released during an emergency for relief of ". . . insufficient flows for existing instream uses and beneficial inflows for the

maintenance of bays and estuaries" (Tex. Admin. Code § 297.55[d]). *These releases for instream flow and freshwater inflow cannot impair water that TWDB has already promised through contract* and the request can be made by the TCEQ only after establishing that there is an emergency. It further states that Texas Parks and Wildlife may petition the commission for releases from a TWDB facility for maintaining existing instream uses and beneficial inflows to bays and estuaries (Tex. Admin. Code § 297.55[d]).

Rule § 297.55(e) of the Administrative Code mandates that the conditions placed on a proposed amendment to a water right are limited by the "No Injury" Rule that is the title of Rule § 297.45. Rule § 297.45(b) says an *amendment* to a water right, except for one to increase the amount or rate of diversion, *shall be approved* if the change will not adversely affect other water right holders or *the stream environment any more than if the original water right had been fully exercised prior to the amendment*. This rule is cross-indexed to the Water Code § 11.122(b). An example of this type of application for an amendment would be an older, senior irrigation right that was never fully used and only seasonally, but now the owner was seeking to convert it to a municipal right that would eventually be utilized fully in all months. This amendment if granted would change the streamflow compared to historical use, but since it would not change streamflow compared to its original permit potential if fully utilized, it would be granted by this rule. The fact that historically more water was left in the stream for the environment due to underutilization of the water right than will be in the stream after the amendment is fully utilized would be irrelevant in the consideration for approval.

When considering new or amended water rights the commission shall consider the effect on existing instream uses (Tex. Admin. Code § 297.56). Flows that are necessary

to protect a federally endangered species, or a state-listed endangered species or ". . . self-sustaining wild populations that are endemic to the affected stream or have significant scientific or commercial value" (Tex. Admin. Code § 297.56[a]) shall be protected. The Water Code also requires the commission to *assess the effects of an application. on fish and wildlife habitats* if the permit is for more than 5000 acre feet per year (§ 11.152). The commission may require the applicant to mitigate the effects (Tex. Water Code § 11.152).

As discussed in chapter 6, the commission may place conditions on the amount of water that has to be returned to the stream by a new water right holder to provide flows for bays and estuaries (Tex. Water Code § 11.046[a]). If a permit holder wishes to use the bed and banks of the stream to convey its return flows downstream and then redirect those flows for reuse, it must apply for a bed and banks permit. A bed and banks permit being a new appropriation of water, is subject to restrictions to provide water for bays and estuaries if the Commission deems it necessary.

In the event of an emergency such as a drought, declared by the commission, permit conditions to protect inflows to bays and estuaries can be suspended under § 11.149 of the Water Code. In addition, a water right holder can petition for such a suspension as described in rule §297.57 of the Administrative Code.

Dams shall have outlets sized to allow the passage of flows necessary for instream flow and estuarine flow requirements (Tex. Admin. Code § 297.59). If a water right holder returns water to the stream after using it, it is subject to the maintenance of instream uses and beneficial inflows to bays and estuaries (Tex. Admin. Code § 297.49). The water right holder can use and reuse the water, but must return surplus water to the

stream unless specified in the permit (Tex. Admin. Code § 297.49). The Commission may specify an amount of water to be returned to the stream to protect instream uses and bay and estuary flows (Tex. Admin. Code § 297.49).

A permit to move water from one river basin to another is called an interbasin transfer (Tex. Water Code § 11.085). There are many restrictions on these permits, but probably the most restrictive is § 11.085(s) that declares the water transferred becomes junior in priority to all water rights granted before the application to transfer was filed. The commission shall also consider the effects of the transfer on instream use, water quality, aquatic and riparian habitat and bays and estuaries of the basin of origin (Tex. Water Code § 11.085[k][2][F]).

Exempt Uses, Riparian Law and Prior Appropriation

Texas water law contains influences from Spanish, Mexican, and English legal systems (Kaiser 1998). For a timeline of Texas water law influences see table 5.1. Some water use is exempt from the permitting process and dates back to an era before there was an appropriation system for water in Texas. The system of appropriation where water rights have a "first in time, first in right" priority began with the 1889 Irrigation Act when the existing system of riparian law proved incapable of handling a drought and the growing agricultural economy (Kaiser 1998). When the state of Texas was established in 1845, the English system of riparian law was adopted that tied the right to use water to the ownership of land adjacent to the stream (Kaiser 1998). These two systems coexisted in various proportions until 1967 when the Water Right Adjudication Act merged the riparian system into the prior appropriation system that exists today (Kaiser 1998).

Table 5.1 – Timeline of surface water law in Texas (based on Kaiser 1998).

Sovereign	Date	Water Rights Regime
Spain	1600–1821	Spanish Civil Law
Mexico	1821–1835	Mexican Civil Law
Republic of Texas	1836–1840	Presumably Riparian
	1840–1845	Riparian Law
State of Texas	1845–1888	Riparian Law
	1889–1912	Limited Prior Appropriation and Riparian Law
	1913–1966	Mixed Prior Appropriation and Riparian Law
	1967–Present	Unified to Prior Appropriation

As a holdover from the riparian system, landowners along streams and rivers still have the right to divert and use water for domestic and livestock purposes in an amount up to 200 acre–feet a year without a permit (Tex. Admin. Code § 297.21), regardless of how much land they own. In addition, this exempt water can be stored in a stock tank or behind a dam on a non-navigable stream that is also exempt from a permit (Tex. Admin. Code § 297.21). This riparian right is *superior to all other appropriative rights* (Tex. Admin. Code § 297.21) and has no permit restrictions since it is exempt from the permitting process.

Since these riparian rights are not registered, there is not information available on the total amount of water used by these permits either state–wide or on a given river, and it obviously varies with the weather patterns. These types of rights are the most senior in

priority and are not required to go through the permit process; therefore, they do not have restrictions on them for instream flow for bays and estuaries.

Summary Discussion of Estuarine Protection and the Water Rights Process

The water rights system administered by the TCEQ contains many elements related to the protection of freshwater inflow to bays and estuaries, including some that are beneficial to the estuaries and others that could limit beneficial flows. The 200 mile rule requiring protection for estuaries on permits within 200 river miles of the coast, and reserving 5 percent of new reservoirs' firm yield within 200 river miles of the coast for estuarine flow, does provide an amount of water for freshwater inflow (Tex. Admin. Code § 297.55). The firm yield refers to the theoretical yield during the drought of record, meaning that none of the reservoir capacity higher than the record lowest yield is required to be preserved for the estuary. The same section of the Administrative Code (§ 297.55[c]) goes on to say that the five percent figure may not be enough for freshwater inflow needs and the commission *may* impose more conditions. Other limitations on the 200 mile rule include the requirement that the commission include conditions to maintain beneficial inflows to bays and estuaries ". . . to the extent practicable when considering all public interests" (Tex. Admin. Code § 297.55[a]). The inflows that are mandated to be preserved are described as necessary to preserve the "sound environment of the bay and estuary" (Tex. Admin. Code § 297.55[b][1]), but there is no further definition of "sound environment." The studies on bay and estuary needs called for by the Water Code are listed as one of the *possible* sources to be considered in determining the freshwater inflow needs, but are not mandated as the only source. There is also mentioned the need to consider ". . . existing circumstances, natural

or otherwise, that may prevent the conditions imposed from producing benefits" (Tex. Admin. Code § 297.55 [b][1]). Probably the most important aspect of the 200 mile rule is the fact that it was passed into law in 1985. Since then only two major reservoirs have been completed and they were begun before the 200 mile rule applied (Texas Parks and Wildlife 2001). In addition, more than 90 percent of the water permitted by 2002 was granted before 1985, meaning that the effects of those permits on bay and estuary flow were not considered (Texas Center for Policy Studies 2002).

The studies defined in the water code *may* be used by the commission and the TPWD to establish an *advisory council* that *may* develop recommendations that *may* be used in maintaining a sound environment of the bays and estuaries (Tex. Admin. Code § 297.55 [b][1] and Texas Water Code § 11.491). In summary there is not a mandate that the commission use the studies when considering an appropriation.

Applying the "No Injury" Rule to amendments of existing permits allows the holder to utilize previously unused water with no further conditions added to the permit to protect bays and estuaries (Tex. Admin. Code § 297.55[e]). There is protection of existing instream uses, as in an existing flow requirement for an endangered species, when considering new permits or amendments (Tex. Admin. Code § 297.56). However, there is also the power to suspend permit conditions to protect bays and estuaries in the event of a declared drought by the commission (Tex. Water Code § 11.149).

Dam outlets have to be sized to provide freshwater inflows (Tex. Admin. Code § 297.59). Wastewater must be returned to the stream unless specified in the permit, and the commission *may* also specify that a certain amount of water has to be returned to the stream for estuarine protection (Tex. Admin. Code § 297.49). Interbasin transfers are

junior to the basin of origin and the commission must consider the estuaries before granting a transfer (Tex. Water Code § 11.085).

The Water Code calls for the completion of regional water plans (§ 16.053) and requires those plans to include consideration of ". . . provision for environmental water needs and for the effect of upstream development on the bays, estuaries, and arms of the Gulf of Mexico . . ." (Tex. Water Code § 16.053[5][F]). The link between the state and regional water plans that are the responsibility of the Texas Water Development Board and the water rights process over which the TCEQ presides is covered in Texas

Administrative Code § 295.16:

An application shall contain information describing how it addresses a water supply need in a manner that is consistent with the state water plan or the applicable approved regional water plan for any area in which the proposed appropriation is located or, in the alternative, describe conditions that warrant a waiver of this requirement.

Rule 297.41 basically reiterates this requirement and adds that a municipal water right will not be issued in a region that does not have an approved regional water plan. The commission is required to consider the projected impacts on instream uses, water quality, aquatic and riparian habitat and bays and estuaries that are expected to occur as outlined in the regional water plan of the basin of origin before considering an interbasin transfer (Tex. Water Code § 11.085[k][2][F]).

Does the water rights system in Texas preserve the necessary freshwater inflows for bays and estuaries in its appropriation process? When one considers the volume of the rights granted before 1985, at least some river basins are over appropriated, meaning more water rights were granted than there is water in the stream (Robbins 2002). See Appendix A-4 for map showing percentage of Texas rivers appropriated). The Interim

Report of the Legislative Joint Committee on Water Resources for the 2003 Legislative

Session declares:

"... the burden for protecting the state's fish and wildlife populations may fall disproportionately on new permit holders. In addition, the system does not provide for correcting problems on over appropriated rivers and streams since new permits are unlikely to be issued under these conditions (Texas Joint Committee on Water Resources 2002, 49).

The Lower Colorado River Authority states in their *Freshwater Inflow Needs of the Matagorda Bay System* that "Presently, Texas law does not mandate specific freshwater inflow needs" (Martin et al. 1997, I-3). The Galveston Bay Plan by the Galveston Bay National Estuary Program claims "... no statutory assurance exists to provide for freshwater resources and circulation necessary to maintain estuarine health and productivity" (1995, 93). The Texas Living Waters Project in referring to the estuary inflow protection rules initiated in 1985 says:

"This method addresses the matter of environmental flow and freshwater inflow on a piece by piece basis – it only minimizes damage, and does not provide any guarantee that the water needed for minimum productivity at the bays will reach them" (2003).

The 2002 State Water Plan discusses the Texas water right system and bay and estuary protection:

Where additional water rights are sought, the full burden of environmental protection may fall on the last applicants, while prior applicants have *no requirements* applied to them (Texas Water Development Board 2002b, 9).

The Texas Parks and Wildlife Department comments on the water right system:

Maintaining stable base flow is difficult since, of the approximately 6500 existing water rights issued by the state, the majority do not contain provisions **for instream flows and freshwater inflow maintenance**. [Bold type in original]. Today, most river basins in Texas are fully or over-appropriated (Texas Parks and Wildlife Department 1999, 5).

The Texas Commission on Environmental Quality in their publication *Water Rights and Instream Uses* lists their current areas of concern including: ". . . no current framework or regulatory authority to review existing permits that contain *no provisions* for instream flows or bay and estuary freshwater inflows" (2002, 6-9). The TCEQ provides a table of the active water rights by river basin (Appendix B-1) with a discussion of possible flow restrictions on active water rights to minimize potential impacts (TCEQ 2002).

There appears to be agreement even among the state agencies that the water rights process is not providing adequate protection for freshwater inflows to bays and estuaries, especially considering the amount of water rights granted before environmental restrictions began in 1985.

CHAPTER 6

FEDERAL AGENCIES AND LAWS AND FRESHWATER INFLOW

Several federal agencies, cooperatives and laws deal with coastal issues in all coastal states including Texas. Already mentioned was the National Estuary Program (NEP) administered by the USEPA as part of Section 320 of the Clean Water Act (USEPA 2003). The two NEP designated estuaries in Texas, Galveston Bay and Corpus Christi Bay or the Nueces Estuary, receive federal funding to assist in the creation of management plans for the designated estuaries, concentrating on water quality issues. Detailed studies and analyses of the associated estuary are performed by the programs administered in cooperation with the TCEQ and managed by the paid staff of each estuary program (Coastal Bend Bays and Estuary Program 1998; Galveston Bay National Estuary Program 1995). Any act of the particular bay programs and the plans they create cannot usurp local government powers and the local governments have the right to withdraw from the program (Texas Water Code § 5.603); therefore, the National Estuary Program has limited powers over estuarine issues in general.

The Texas Coastal Management Program (TCMP) provides a network for federal and state agencies to cooperatively manage coastal resources through the Coastal Coordination Council (TWDB 1997). The TWDB, TCEQ, and TPWD as well as the General Land Office sit on this council whose basic function is to review major coastal projects including the granting of water rights within the boundary of the Management Plan defined as normally one mile inland of the mean high tide line (TWDB 1997). Through this federally authorized program approximately \$2.2 million in federal Coastal

Zone Management Act funds are distributed annually to state and local entities in Texas to implement projects and program activities (Nipper, Chavez, and Tunnell 2004).

Program purposes fall under the following categories: Coastal Natural, Hazards Response, Critical Areas Enhancement, Shoreline Access, Waterfront Revitalization and Ecotourism Development, Permit Streamlining/Assistance and Governmental Coordination, Information and Data Availability, Public Education and Outreach, and Water Quality Improvement.

Although the program ultimately has the power to file a lawsuit against the state for inconsistencies with its goals of ". . . protecting, preserving, restoring, and enhancing coastal natural resource areas" (TWDB 1997, 2-6), it normally functions through consistency determinations of individual actions recommended by the state water plan including new water right appropriations of greater than 5000 acre-feet. The Council meets at least four times a year, but its actions do not appear in the water planning literature except to mention the existence of the Council; therefore, the Council does not appear to have a major role in freshwater inflow protection in Texas.

The United States Geological Survey (USGS) administers the stream flow gauge system that is the basis of all modeling data used in studies of freshwater inflow. The USGS is a scientific agency with no regulatory powers and is under the Department of the Interior. As a fact-finding agency it collects, monitors, and analyzes natural resource conditions, issues and problems (USGS 2004).

Numerous water rights and smaller reservoirs (< 5000 acre-feet) in Texas are owned by federal agencies, including the United States Fish and Wildlife Service and the United States Department of Agriculture's Forest Service. The beneficial uses for these

water rights generally involve fish and wildlife habitat or operations of facilities at the associated visitor centers.

The Endangered Species Act (ESA) passed in 1973 is the one legal doctrine with the potential to intervene in freshwater inflow issues in Texas. The Act can affect water management activities such as requiring certain streamflows to protect listed endangered species or critical habitat (United States General Accounting Office 2003). The USFWS and the NOAA share responsibility for the administration of the act. An example of its usage was the 1991 lawsuit by the Sierra Club against the USFWS for failure to enforce the Act by not adequately protecting spring flow of the Edwards Aquifer in Central Texas that was home to several endangered species (Eckhardt 2003). The court ruled that the state of Texas had to manage the aquifer to provide sufficient flow for the species even in the drought of record. Although this action only provides flow for the first few miles of the San Marcos River that flows from the aquifer and originates 260 river miles from the coast, it demonstrates the potential power of the act. The reality is unless there were an endangered species in the estuaries, the ESA could not be used to provide freshwater inflow. There are no federally listed endangered coastal fishes in Texas (TPWD 2003a); however, the Whooping Crane is a listed endangered species that spends half of the year on the wetlands around the Guadalupe Estuary and its principal diet, the blue crab, depends on adequate freshwater inflow (Stehn 2001). No actions are underway involving the Endangered Species Act and freshwater inflows in Texas.

The United States Constitution contains the Commerce Clause (art.I, § 8, cl. 3) that gives the federal government authority to regulate water that may be involved in interstate commerce including preservation of the navigability of waterways (United

States Government Accounting Office 2003). There is no information about the use of this act in protecting freshwater inflow in Texas. Other constitutional federal powers involving water resources are the Property Clause (U.S. Const. art. IV, § 3, cl.s) which permits federal regulation of water for the use of federal property and the Compact Clause that requires states entering into compacts including management of state waters to obtain consent of Congress (U.S. Const. art. I, § 10, cl.3).

The United States Army Corps of Engineers

A significant amount of water in Texas is impounded in reservoirs built and managed to varying degrees by the United States Army Corps of Engineers (USACE); the Bureau of Reclamation, which is under the Department of the Interior; and the Natural Resource Conservation Service under the Department of Agriculture. It is not in the scope of this study to analyze in detail all of the projects in Texas under these three agencies' domains, but I will summarize the role of each as it relates to freshwater inflow.

The United States Army Corps of Engineers was created in 1775 as an engineering unit of the United States Army. Still under the directorship of the U. S. Army, USACE employs approximately 34,600 civilians and 650 military personnel including biologists, engineers, geologists, hydrologists, and natural resource managers (Nipper, Sanchez, and Tunnell 2004). Its mission includes planning, designing, building, and operating water resources and other civil works projects, including projects for navigation, flood control, environmental protection, and disaster response. Designing and managing the construction of military facilities is also an important function of the USACE.

The principal role of the USACE affecting both instream and freshwater environmental flows in Texas is in the operations of its many reservoirs. Texas falls into two of the eight divisions of the USACE. The Southwestern Division that includes all of Texas east of the Pecos River has three districts that are either all or part in Texas, the Galveston District, the Ft. Worth District, and the Tulsa District (fig. 6.1). West Texas is in the Albuquerque District of the South Pacific Division. The divisions of the USACE are generally designed according to the major watersheds of the United States (USACE 2004c).

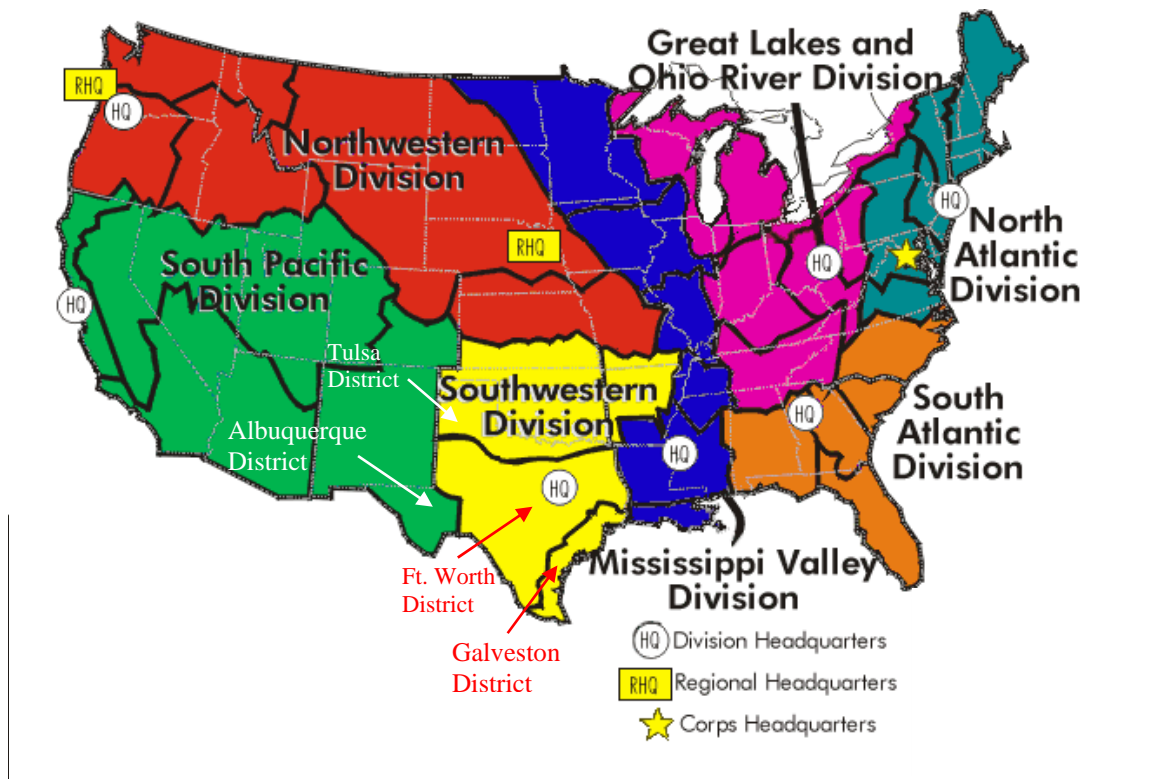


Figure 6.1 – USACE national divisions and Texas districts (USACE 2004c).
Note: Labels with arrows indicate districts contained all or part in Texas.

The Galveston District includes the entire Texas coast and extends about 100 miles inland, but does not include any major reservoirs that the USACE manages. Much

of its work involves navigation including harbor and Intercoastal Canal maintenance and improvements, and hurricane flood protection such as jetty maintenance (USACE 2004b). The management of the Intercoastal Canal has varying effects on bay and estuary salinity in Matagorda Bay (Martin et al. 1997), Corpus Christi Bay and the Upper and Lower Laguna Madre (Coastal Bend Bays and Estuaries Program 2001). In an effort to improve salinity regimes in Matagorda Bay in the early 1990's the USACE opened up the channel of the Colorado River to allow freshwater to flow into west Matagorda Bay (see fig. 10.5 for map). One of its upcoming projects is the saltwater barrier project on the Neches River which will be discussed in chapter 8. The affect of this saltwater barrier on estuary salinity is considered minimal, but I have concerns about the scope of that analysis.

The Ft. Worth District manages 23 reservoirs, including Sam Rayburn Reservoir which is the largest body of water within the boundaries of the state of Texas (USACE 2004a). This 1,145,000 acre-foot reservoir on the Angelina and Neches Rivers was authorized in 1955 and completed in 1965 for flood control, hydroelectric power, and conservation of water for municipal, industrial, agricultural, and recreational uses. As discussed in chapter 8, new reservoir projects were not required to provide any significant instream or freshwater inflow protection until 1985. No major reservoirs in Texas have been completed under the post-1985 rules (TPWD 2001).

The process for construction and operation of a USACE reservoir usually involves the USACE designing and constructing the reservoir in cooperation with a local entity such as the Guadalupe Blanco River Authority for Canyon Lake (USACE 2004a). The reservoirs serve multiple purposes with flood control often the primary goal. The

federal government through the USACE assumes the cost and continued management of the flood control aspect and recreation use aspect of the project. It then contracts with a local or state entity such as a river authority that will pay for water storage for municipal, industrial or agricultural use.

The reservoirs are divided volumetrically into a conservation pool and a flood pool. In its management of the flood pool, the USACE's management goal is to keep the lower (in elevation) conservation pool full while leaving the flood pool volume empty to provide room for the containment of the next flood. Importantly, *the USACE does not own any consumptive rights to the water in the reservoir*. It can only manage the flows in the flood pool. The cooperating local entity such as the GBRA for Canyon Lake (fig. 6.2) has a permit from the TCEQ for the rights to sell a certain amount of water out of the conservation pool. The local entity manages the conservation pool and controls the releases from it. The USACE releases flows when the level of the reservoir is above the conservation pool. Flow releases from the flood pool may vary according to upstream and downstream hydrological and climatological conditions. In the case of Canyon Lake specific releases are also mandated seasonally under certain conditions for the year round survival of the rainbow trout fishery below the lake (USACE 2004a).

Although the USACE itself does not have any consumptive rights, there are reductions in the volume of downstream flow as a result of increased evaporation due to the larger surface area of its reservoirs compared to the surface area of the river that existed before construction. For an example of evaporation potential, the Nueces River

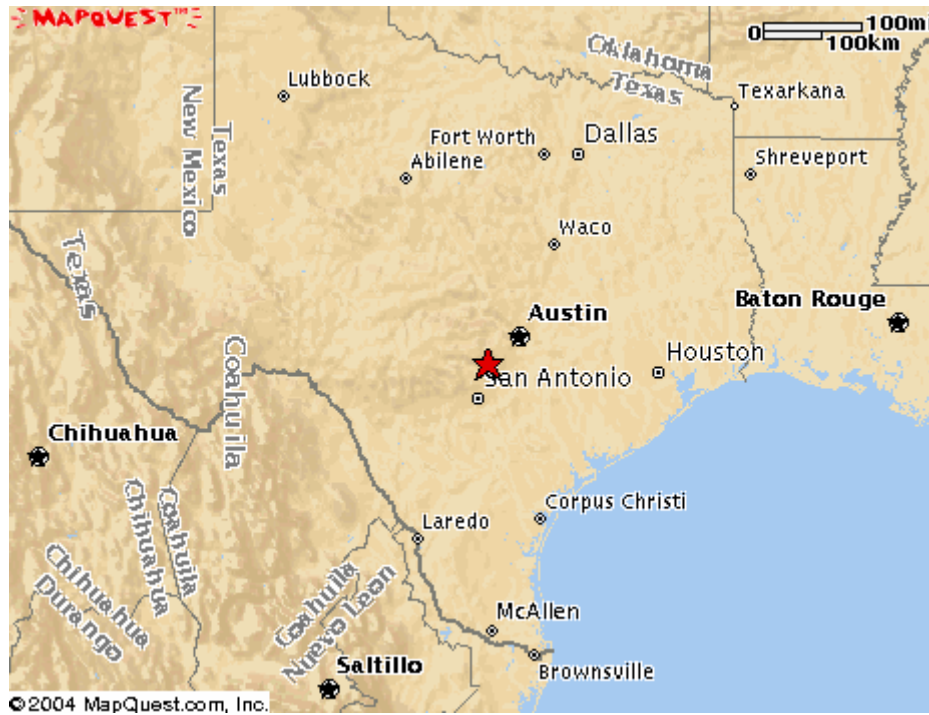


Figure 6.2 – Location of Canyon Lake shown by red star (MapQuest 2004)

Authority (2004) reported that on June 1, 2004 the daily evaporation from Choke Canyon Reservoir was 543 acre–feet. This is equal to a daily flow of 273 cfs (1cfs = 1.9835 acre–feet per day). There is also reduction of freshwater inflow as the result of the diversions by state and local entities for municipal and other uses from the conservation pools of the USACE's reservoirs. Administrators, planners, and scientists need to be aware of the complex issues of jointly managed USACE/state reservoirs and the effects, both actual and potential, on the volume of freshwater inflow

The management of the flood pool of the USACE reservoirs obviously affects the timing of flows to the bays and estuaries which can have negative effects on the estuarine productivity (TPWD 1998). Generally these flood pool releases occur during periods of more rainfall as the USACE is constantly concerned with maintaining available flood pool capacity. However, at lower flows as the USACE strives to fill the pool up to the

conservation level, there can be even more effects on the timing of flows as little or no flow is released until the reservoir refills depending on various factors. There are provisions in each reservoir agreement regarding varying requirements for the pass-through of the incoming flows from the river. These pass-through flow requirements are obviously not direct one-to-one ratios of inflow to outflow; otherwise, the reservoir could not be effectively managed for flood control and storage.

Reservoirs in Texas controlled by the USACE provide flood control for millions of people, saving lives and dollars (USACE 2004c). These reservoirs also provide means for storing water year round for beneficial uses such as municipal, agricultural, and industrial. By control of the timing of the flows, the management of these reservoirs enables users of the water to have adequate supply throughout the year in most droughts while protecting those living downstream from major flooding during peak rain events (USACE 2004c). The trade-off for this dependable supply of water for consumptive use and protection from flooding is the alteration in timing and volume of flows to the bays and estuaries. In the case of reservoirs under control of the USACE, the issues of managing for environmental flow releases are made more complex by the shared management roles of federal and state or local entities.

Another function of the USACE that affects freshwater inflow is its duty under Section 404 of the Clean Water Act to issue permits for any dredging or filling of waters of the United States including wetlands and water habitat for migratory birds or endangered species (Texas Environmental Profiles 2004). Although permits are granted for dredge and fill, the USACE or the state can require artificial wetlands to be created to offset any loss of existing wetlands. The USACE and the USEPA have agreed that

restoring wetlands should be the first option considered before creation of new wetlands (USACE 2004d). In research on water rights I found several permits for diversions of water by municipalities to create artificial wetlands for mitigation purposes. Although Section 404 permits are not directly related to freshwater inflow, they can be used to preserve wetlands that are part of an estuary.

The USACE assumes many roles in projects other than Section 404 Permits, including a major part in the restoration of the Everglades in Florida. The USACE along with other federal agencies and many Florida entities is working on a multi-billion dollar plan to restore the Everglades. Although not located in Texas, this USACE project is relevant to the purpose of this paper as an example of the changing role of the agency. These extensive marshlands have suffered from reduction and redirection of freshwater that historically passed through the marshes to the estuaries (Comprehensive Everglades Restoration Plan 2004). The reduction in flow was caused by numerous projects over time that were built to control flooding and divert water for agriculture. The intent of the project is to restore the natural movement of freshwater through what is called the River of Grass, and subsequently to the estuaries that depend on this freshwater inflow. Water supplies for people and farms will also be improved. The restoration is expected to take 20 years and is the largest such project undertaken by the United States (Comprehensive Restoration Plan 2004). To this point the USACE has not been active in freshwater inflow protection in Texas, although its actions certainly affect the timing and amount of environmental flows to the estuaries.

The United States Bureau of Reclamation

Another federal entity controlling reservoirs in Texas is the United States Bureau of Reclamation which is part of the Department of the Interior. Established in 1902 to provide irrigation projects for 16 western states including Texas, the Bureau is most well-known for the Hoover Dam project on the Colorado River. Hydroelectric generation has also been an important aspect of the Bureau's activities, although the Bureau has no hydroelectric facilities at its Texas projects (U.S. Dept. of the Interior 2004). Today the Bureau's mission has broadened to ". . . manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public" (U.S. Department of the Interior 2004, 1). The Bureau constructed and is currently responsible for five facilities in Texas shown in figure 6.3.

Two of the facilities, Choke Canyon and Palmetto Bend, are within 200 river miles of the coast, but were begun before the 1985 requirements for environmental flows



Figure 6.3 – Bureau of Reclamation reservoirs in Texas (from U.S. Bureau of Reclamation 2004)

were passed by the Texas Legislature. The Bureau constructed and continues to own the Choke Canyon Reservoir, but the reservoir is operated by the City of Corpus Christi. Reductions and alterations in timing of environmental flows have occurred as the result of Choke Canyon Reservoir (Coastal Bend Bays and Estuaries Program 2001). Palmetto Bend Reservoir was conveyed to the state in 2001 and has been operated by the Lavaca–Navidad River Authority (LNRA) since 1985 (U.S. Bureau of Reclamation 2004). Beyond design and construction of the aforementioned reservoirs, there does not appear to be a major role played by the Bureau in freshwater inflow protection in Texas.

The Natural Resource Conservation Service

The Natural Resource Conservation Service (NRCS) (formerly the Soil Conservation Service) under the United States Department of Agriculture was authorized in 1944 by Public Law 78–534 Flood Control Act to build upstream flood control dams (NRCS 1998). These types of dams are the first national effort that assists local organizations in planning and installing watershed–based projects on private property (Sells ca. 2000).

The function of these dams, built on small tributaries to major streams, is to hold back water during heavy rainfall and slowly release it through pipes in the dams (Buckley, Young, and Thralls 1998). Local sponsors secure the land rights and easements required for dam construction and the area of containment upstream. The NRCS provides technical expertise, watershed planning and financial assistance. The facilities are owned and managed by locally created entities which in the words of the NRCS "... provides a process to solve local natural resource problems and avoid unnecessary regulation" (Sells ca. 2000).

Since 1948, the NRCS has helped local sponsors build more than 10,400 small watershed dams across the U.S., with over half of them 30 or more years old (Sells ca. 2000). Nearly 2000 of these dams have been built in Texas alone, and 91 percent were built before 1979 (NRCS 2004).

As mentioned earlier, these dams contain pipes that slowly disseminate impounded high flows and thus are not actively managed like major reservoirs that operate adjustable gates to control their levels. Water is only temporarily held behind these dams. The resulting effect is that peak outflow rates are reduced from pre-dam rates (Earl and Wood 2002). Some water evaporates while being temporarily impounded, or in varying amounts soaks into the ground and recharges various aquifers. These dams can affect instream flow and thereby freshwater inflow in locations close enough to the estuaries to have provided flow historically. These effects include:

- 1) Alteration of the timing of flows.
- 2) Reduction of peak amounts.
- 3) Loss of flow through evaporation from temporary impoundment.
- 4) Loss of flow to the soil beneath the impoundment.
- 5) Reduction of flow through aquifer recharge with possible delayed recovery of freshwater inflow as subsequent springflow.

Earl and Wood (2002) analyzed the reduction in peak flows in the October, 1998 flood due to the existence of the recharge dams on the Upper San Marcos River Watershed, a portion of the Guadalupe Basin. They concluded that had the dams not existed, instead of being the fourth largest flood event on the San Marcos River, the event would have surpassed the historic record flood by a considerable margin (Earl and Wood 2002).

While these dams provided protection of property and possibly lives, there was a reduction in the amount and timing of flows reaching the Guadalupe Estuary.

The water temporarily impounded in these small watershed dams in Texas is not owned by the NRCS and remains state water. This water is only temporarily impounded and the sponsoring local entity does not need a water right permit. Since there is no permit, there are also no restrictions placed on this water regarding freshwater inflow amounts or timing. As the NRCS states, this system of small watershed dams provides a process to "... avoid unnecessary regulation" (Sells ca. 2000).

Summary of Federal Laws and Entities

In general the federal government recognizes the states' authority to appropriate and use water in their own jurisdictions and has traditionally deferred to the states in management and allocation of water resources (United States Government Accounting Office 2003). The Water Supply Act of 1958 (Water Supply Act) states that the federal government should recognize the primary responsibility of the states in developing water supplies and should cooperate with states and local interests in projects such as navigation, irrigation and flood control (United States General Accounting Office 2003).

In conclusion, there is substantial presence of the federal government in the various aspects of water planning and management in Texas. These include funding bay and estuary management plans, actual ownership of water rights for federal facilities, management and ownership of major reservoirs, jurisdiction over wetland dredging and fill operations, and maintenance of the Intercoastal Canal. Laws and powers do exist to enable the federal government to intervene in some state water issues; however, the

general tendency is to defer to the state. The Endangered Species Act probably gives the federal government more potential power than other federal laws over issues related to freshwater inflow protection even though the Act has not been utilized in Texas for that purpose. From an operational viewpoint, the management of the flood pool of numerous reservoirs by the U.S. Army Corps of Engineers has the most effect of any federal activity on the timing of freshwater inflows in Texas. The small watershed dams of the NRCS also affect freshwater inflow timing. Federal operations also affect the salinity of various estuaries as a result of the maintenance and construction of the Intercoastal Canal.

CHAPTER 7

THE TEXAS WATER DEVELOPMENT BOARD

Chapter 6 of the Water Code is titled "Texas Water Development Board" (called the "board") and lists its duties and powers. After the drought of the 1950's the Texas Legislature saw the need for water planning and created the board in 1957 (McKinney 2002). The board is the agency responsible for water planning and administering water financing (Tex. Water Code § 6.011) and has general jurisdiction over the development of a state water plan (Tex. Water Code § 6.012).

The State Water Plan incorporates the regional water plans as outlined in § 16.052 of the Water Code. Subchapter C of the Water Code is devoted to the water planning process that will provide for:

. . . the conservation of water resources and preparation for and response to drought conditions, in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of the entire state (§ 16.051[a])

The state water plan is described as ". . . a guide to state water policy" (§ 16.059[b]) and the TCEQ is instructed *to take the plan into consideration in matters* coming before it. The TWDB is to coordinate the guidance principles for the water plan with TPWD, TCEQ and the Department of Agriculture (§ 16.051). More details of the water planning process will be in separate chapters 8 and 14.

The TWDB is named a member of the Texas Water Advisory Council. Chapter 16 contains more details on TWDB responsibilities including "monitoring the effects of freshwater inflows upon the bays and estuaries of Texas" (Tex. Water Code § 16.012[b][6]) and monitoring instream flows. There are also instructions to lead and coordinate federal,

state and local government data networks to assess ambient water conditions (Tex. Water Code § 16.012).

The Drought Preparedness Council is set up to manage the drought response part of the state water plan and consists of TWDB, TPWD, TCEQ and several other agencies including the State Soil and Water Conservation Board, the Texas Department of Housing and Community Affairs, the Texas Forest Service, the Texas Department of Transportation, and the Texas Department of Economic Development (§ 16.055). The council shall consider the potential impacts of the drought on natural resources among other things, and develop the state drought preparedness plan.

The board and TPWD shall have joint responsibility to create and maintain data and conduct studies to determine ". . . bay conditions necessary to support a sound ecological environment" (§ 16.058[a]). The bay studies will be discussed in more detail in chapter 10. The board, TPWD and TCEQ shall cooperate on collecting data on instream flow and completing the studies on the flows necessary to support a "sound ecological environment" (§ 16.059[a]) by 2010. The results of these studies *"shall be considered by the commission in its review of any management plan, water right, or interbasin transfer"* (§ 16.059[e]).

Subchapter E of Section 16 the Water Code allows the TWDB to acquire or construct projects to develop water. The TWDB may release any unappropriated water stored in any of its facilities in the event of a drought or water shortage if TCEQ determines an emergency (Tex. Water Code § 16.195). Five percent of the firm yield of any reservoir built with state funds after 1985 shall be conveyed to Texas Parks and Wildlife for bays and estuaries and instream flow (§ 16.1331).

In summary, the Texas Water Development Board is the principal water financing and planning arm of the state government. The management of the state's regional water plans and cooperation with the TPWD in bay and estuary studies are the principle areas of the board's involvement in the administrative protection of freshwater inflow.

The Texas Water Bank and Water Trust

To prevent unused water rights from being cancelled (Tex. Water Code § 11.173) the Texas Water Bank was created to provide a place that water rights can be stored by the owner for up to ten years and not be cancelled (Tex. Admin. Code § 359.1). As the administrator of the Texas Water Bank, the TWDB can accept transfers to the Bank of water rights through purchases, leases or gifts. With the water rights in the Bank, the TWDB can facilitate transactions between the depositors of the water rights and water users, or the TWDB can make transfers out of the Bank for future beneficial use in Texas. Water rights deposited in the Bank may also be dedicated to ". . . environmental needs, including instream flows, water quality, fish and wildlife habitat, or bay and estuary inflows" (Tex. Admin. Code § 359.15[a]). The segment of the Water Bank for holding environmental water rights is called the Texas Water Trust and was created by Senate Bill 1 in 1997.

The donations to the Water Trust are voluntary and there is no state funding for the purchase of water rights for environmental purposes. (Texas Center for Policy Studies 2002). Another major drawback of donating water for environmental purposes is the fact that the increased streamflow from the donated water right is only effective to the point where the water was previously diverted. In other words, below the original diversion point the donated water could be reappropriated by the state to another applicant and diverted from the stream – there is no guarantee of the downstream protection of the donated water including

for flow to the bays and estuaries. For water to be donated to freshwater inflow, the water right would have to either be the last one on the river before the coast or else the diversion point would have to be moved downstream to the coast which could be politically and administratively difficult due to the potential effects on senior water right holders. (Note: The preceding comments are based on the author's knowledge of the water right system and are not in the literature.) Perhaps because of these limitations on the Water Trust and the rights donated to it, there has only been one donation for environmental flows. In September 2003, a West Texas rancher made the first donation to the Water Trust, six years after its inception (Texas Parks and Wildlife 2003b). This donation of 1236 acre feet of water on the Rio Grande, although widely publicized and appreciated will provide only 1.7 cubic feet per second of flow over a year's time (1cfs for one year = 723.97 acre feet), and only to the point of previous diversion which for this donation was upstream of Big Bend National Park several hundred river miles from the coast. In addition, if this permit had previously not been utilized and this portion of the river was already overappropriated, this donation may only be on paper and not provide an actual guarantee of streamflow (Author's observation). For comparison of this flow, a small river such as the San Marcos River in Central Texas averages 150 cubic feet per second (City of San Marcos 2004).

In summary the Texas Water Trust provides a potential vehicle for preservation of instream flows and freshwater inflows, but due to several limitations, the Trust may not prove an effective element for protection of environmental flows, especially freshwater inflows to bays and estuaries.

CHAPTER 8

THE TEXAS WATER DEVELOPMENT BOARD AND THE REGIONAL AND STATE WATER PLANS

The Regional Plans and the Administrative and Water Codes

The Texas Water Development Board was designated the lead agency for development of regional and state water plans as a result of Senate Bill 1, 1997 and the Administrative Code gave the TWDB guidelines for creating planning regions and appointing members of the planning group for each region (Tex. Admin. Code § 357.3; § 357.4). The state water plan is developed from the various regional plans (TWDB 2002). Each planning group consists of a minimum of eleven voting members, each representing an area of interest in the region including: the public, counties, municipalities, industry, agricultural, environmental, small business, electrical generation, river authorities, water districts (including groundwater), and water utilities (Tex. Admin. Code § 357.4[a]). A non-voting staff member from the TWDB, the TPWD and the Texas Agriculture Department is also part of each region planning group (Tex. Admin. Code § 357.4[g]).

The goals of the plan include protection of natural resources in drought conditions and the plan is to be redone at least every five years (Tex. Admin. Code § 357.5). The regional plans shall:

- (1) Ensure that water management strategies are adjusted to provide for appropriate environmental water needs, including instream flows and bays and estuaries inflows. Evaluation shall use environmental information resulting from existing site-specific studies, or, in the absence of such information, shall use state environmental planning criteria adopted by the board for inclusion in the state water plan after coordinating with staff of Texas Natural Resource Conservation Commission and Texas Parks and Wildlife Department (Tex. Admin. Code § 357.5[e][1]).

The mention of "environmental planning criteria" refers to the consensus criteria that will be discussed separately.

In this same section of the Administrative Code, what could possibly be a very important consideration for the planning groups begins with the instruction to protect existing water rights, but then adds that the groups: ". . . may consider potential amendments of water rights . . ." (Tex. Admin. Code § 357.5[e][3]) as a method of securing environmental flows. However, they follow this with: "Any amendments will require the eventual consent of the owner" (Tex. Admin. Code § 357.5[e][3]). Amendments to water rights could open the door to placing some of the burden of providing for environmental flows on the holders of pre-1985 water rights as discussed in the TCEQ document *Water Rights and Instream Uses* (2002). However, the necessary owner consent would probably make this an ineffective system for spreading the burden of freshwater inflow to pre-1985 water rights making it basically a voluntary program.

The cost-effectiveness and environmental sensitivity of potentially feasible water management strategy recommendations are to be determined in order to make selections that incorporate both qualities (Tex. Admin. Code § 357.5[e][4]). The process of determining the cost-effectiveness considers the reliability of the water (§ 357.7) and the environmental sensitivity determination considers ". . . effects on environmental water needs, wildlife habitat, cultural resources, and effect of upstream development on bays, estuaries, and arms of the Gulf of Mexico" (Tex. Admin. Code § 357.7[a][8][A][ii]).

Although not directly addressing freshwater inflow but certainly related to it, is the system for designation of ecologically unique river and stream segments (Tex. Admin. Code § 357.8). Each region can recommend unique segments preferably with an evaluation by the

TPWD, but the actual designation has to be approved by the legislature. The designation of a stream segment of unique ecological value *solely means that a state agency or political subdivision may not finance or construct a reservoir in the designated segment* (Tex. Water Code § 16.051[e]). Biodiversity, riparian relationships to recharge areas and flood control, wetland habitat, exceptional aquatic life, endangered species, and high aesthetic values are some of the criteria for unique segment designation (Tex. Admin. Code § 357.8). Each regional planning group shall assess the quantitative impact of their corresponding water plan on the designated segments (Tex. Admin. Code § 357.8). Region H (Galveston Bay) was the only planning group to recommend unique stream segments, choosing six sites that the TWDB also recommended to the legislature. Most of the other planning groups asked for more clarification on this process in order to address it in the next five year planning cycle (Texas Water Development Board 2002b).

As mentioned above, the unique stream segment designation *solely* means the state cannot build or finance a reservoir on that segment. There is no mention of freshwater inflows to bays and estuaries in the discussions of unique stream segments. The corresponding regional planning group has to *assess* the quantitative impact of their regional plan on the designated segment(s). There is no provision that a certain amount of environmental flows be preserved for that segment. There is also no discussion or provision for environmental flows below the unique segment. If there were any water preserved for the unique segment that water would not automatically be available for environmental flows downstream of that segment. In the case of freshwater inflows, unless the unique segment was the last segment on the river upstream of the estuary, no preserved flows in the unique segment would necessarily reach the estuary.

Details and Results of the 2002 State Water Plan

With the completion of the first five year cycle of the state water plan, the results and recommendations were published in *Water for Texas – 2002* (TWDB). The process of regional planning for the next fifty years consisted of sixteen planning regions (fig.8.1) with

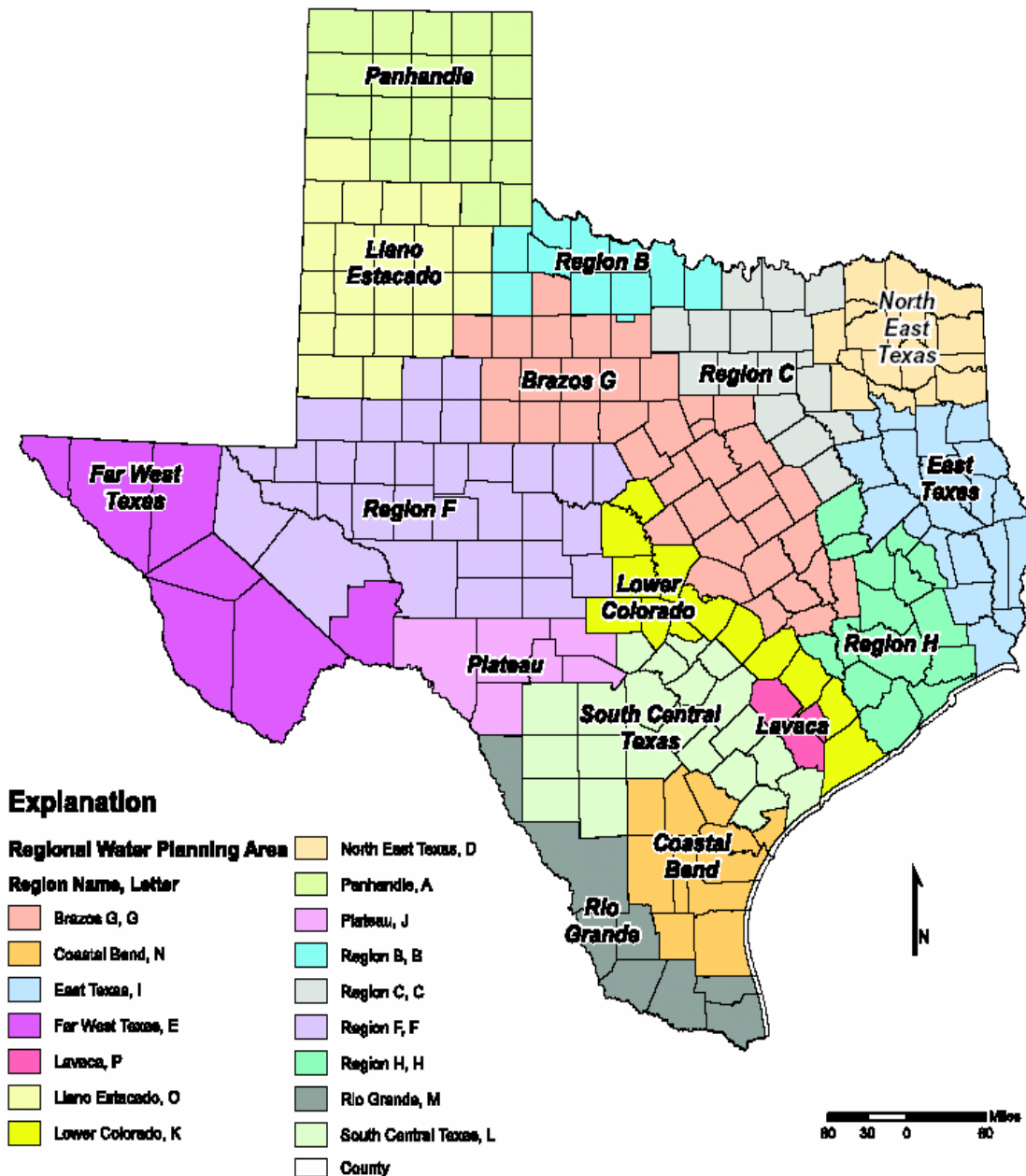


Figure 8.1 – Map of planning regions (TWDB 2002)

a total of 450 planning group members holding almost 900 meetings across the state (TWDB 2002). Additionally 83 individuals comprised a stakeholder group that provided input to the TWDB. The sixteen planning regions were designated by the TWDB based on multiple factors including: river basin and aquifer delineations, patterns of water utility development, socioeconomic characteristics, political subdivisions, public comments, and climatic zones (TWDB 2002). Hays County in Central Texas for instance, was divided into two regions, K and L, based on the Colorado and Guadalupe watersheds. Seven of the regions are located on the coast of Texas. The region boundaries are required to be reviewed at least every five years. In the preliminary 1997 state water plan, *Water for Texas* (TWDB) is a discussion of the method of selecting the geographic area of the planning regions as related to determinations of instream flow needs criteria. A team of scientists (described in more detail in the "consensus criteria" section) listed several considerations as a framework for determining instream flow needs including "regionalization" (TWDB 1997, 2-25), referring to the process of establishing planning regions. They recommended the use of biotic provinces as described by Blair (1950) when determining planning regions. A map based on Blair's work is shown in figure 8.2. Blair used the definition of a biotic province based on the work of Dice who wrote that a biotic province is:

... a considerable and continuous geographic area and is characterized by the occurrence of one or more ecologic associations that differ; at least in proportional area covered, from the associations of adjacent provinces (1943)

It is interesting to compare the biotic provinces shown in Fig. 8.2 to the actual regions defined by TWDB as shown in Fig.8.1. There is no discussion in the plan about the subsequent relation between the two maps, but by inspection some similarity is evident.

Forecast statistics for a repeat of the drought of record (generally the early 1950's for

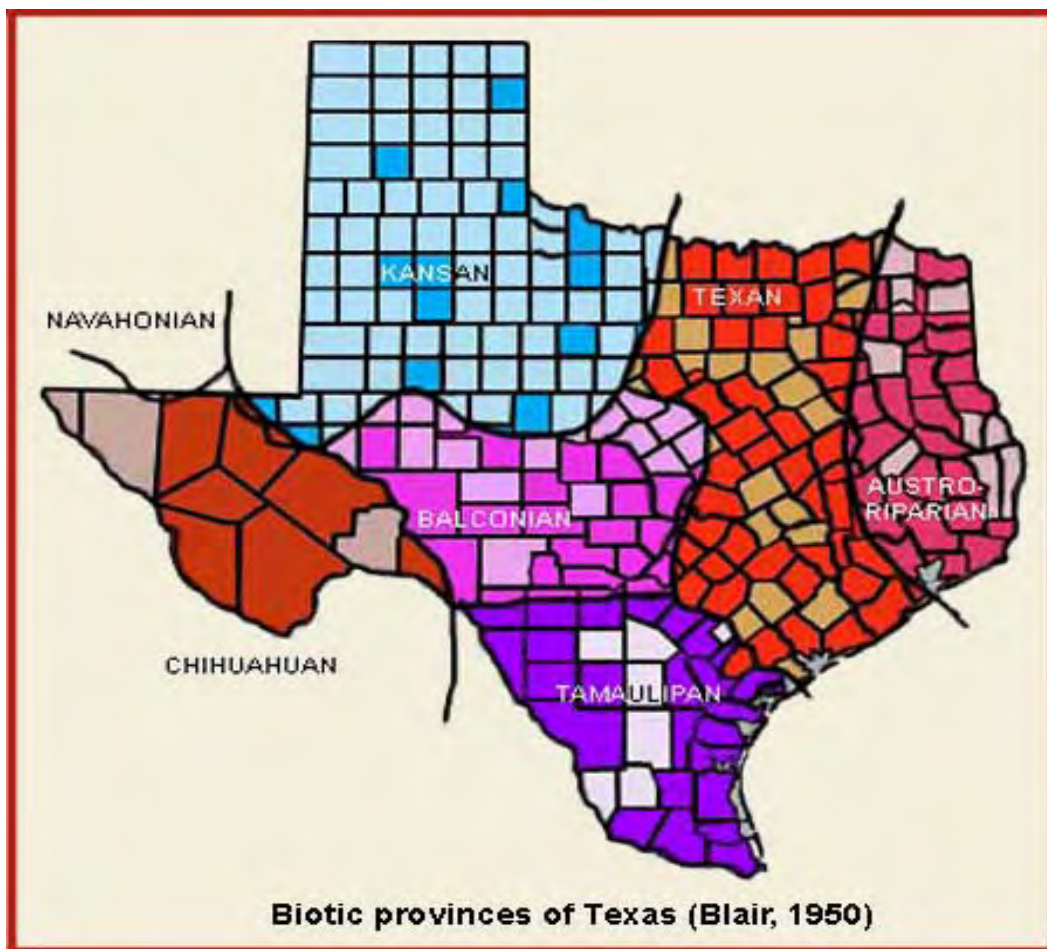


Figure 8.2 – Blair biotic provinces (Blair 1950, courtesy of TAMU, Stephenville, TX)

most of the state) show that with current use, 20 percent of irrigation and 7 percent of municipal water rights could not be met resulting in a shortfall of 2.4 million acre feet (TWDB 2002b). During the five-year planning process, some regions experienced a new drought of record that had to be recalculated for the plan (TWDB 2002b). In 2050 with projected increases in use, 43 percent of municipal rights would not be met in the conditions of a drought of record, resulting in a shortfall of 7.5 million acre feet. There is no mention of environmental flows in this discussion.

The 2002 Plan struggles with groundwater issues and recognizes the problems of unregulated groundwater and environmental impacts in general (TWDB 2002b). Freshwater inflow is not mentioned in the groundwater discussion, but there is mention of the Edwards Aquifer pumping limits driven by the Endangered Species Act reducing the withdrawals from the aquifer (TWDB 2002b). The effect of the Edwards Aquifer pumping limits on instream flow is not discussed. One of the major threats to depletion of groundwater is its immunity from the inter-basin transfer restrictions of surface water (Tex. Water Code § 11.085); therefore, it is an attractive mechanism for major water users wanting additional water from another area (TWDB 2002b). The plan recommends that a policy be considered allowing TCEQ and TWDB to jointly develop a process linking surface water availability models and groundwater availability models.

Eight new reservoirs of more than 5000 acre feet of storage are called for in the plan in addition to the 211 existing reservoirs. (See appendix table B-2 for a graph of reservoir construction). If completed these reservoirs would add 1.1 million acre feet or 16 percent of the projected 2050 shortfall (TWDB 2002b). These reservoirs would affect the volume and timing of freshwater inflows to the corresponding bays, but the effects of reservoirs on bays and estuaries are addressed by the "consensus criteria" formulas of the water plan that are consistent state-wide and will be discussed later in this chapter.

Environmental Portion of the State Water Plan

"Texas needs to ensure adequate freshwater flows in streams and rivers and into bays and estuaries" (TWDB 2002b, 9). This is the lead statement in the "Environmental" section of the plan highlights. The regional plans recognized this need by evaluating *new* projects to ensure environmental flows are passed through (consensus criteria) and one region (H),

recommended that Galveston Bay inflow needs be met (TWDB 2002b). The planning groups varied in the amount of detail regarding environmental impacts, with some groups providing comprehensive analyses and other groups presenting more limited analyses (TWDB 2002b).

The plan makes several requests for assistance in determining and managing instream flows and freshwater inflows. Stating that under current Texas law new management strategy impacts on instream flows and freshwater inflows must be evaluated, the plan requests: "**Additional clarity on what is considered an adequate environmental flow is needed**" (TWDB 2002b, 9, bold type in original). The list of requests and problems also includes:

- 1) More policy directives defining environmental flow, which species to protect, and how to balance these needs with the public welfare.
- 2) More clarity needed on environmental flows and their duration, frequency and location.
- 3) Since the "vast majority of Texas water rights were appropriated before the provision in law of these environmental assessments . . . **many river reaches and estuaries may not be managed with due consideration of the impacts of water use on these ecosystems**" (TWDB 2002b, 9, bold type in original).
- 4) The full burden of protection of the environment may fall on the newest applicants because prior applications had no restrictions on them.
- 5) Prior applicants invested and made decisions based on the law at the time of they received their rights.

This is the essence of the environmental flow debate in Texas: how to provide for current environmental needs while recognizing our past

practices and current law (bold in original). This dilemma is exacerbated because data on what a healthy ecosystem needs in many specific locations have not yet been derived (TWDB 2002b, 9).

To accomplish these needs the TWDB recommends that the 78th Texas Legislature that ended its first session in May 2003 consider several policy issues:

- 1) Establish evaluation criteria to measure a "sound ecological environment" (TWDB 2002b, 9) and identify methodologies for protection of environmental flows. *Also consider establishing these criteria by statute.*
- 2) Fund instream flow studies.
- 3) Fund a voluntary conservation program to use conserved water for environmental needs.
- 4) TCEQ, in coordination with TWDB and TPWD evaluate each river basin using the proposed statutory evaluation criteria.
- 5) Facilitate voluntary donations of environmental flows.

Since the time frame of this document is the end of the main legislative session in May 2003, I will address the legislative results of these recommendations. Some of these region plan /TWDB recommendations resulted in legislation that may or may not fully address the issue.

Senate Bill 1639 and Plan Recommendations

Senate Bill 1639 of the 2003 Texas Legislature dealt with some of the issues of instream flow and freshwater inflow requested by the state plan, by establishing a study commission on environmental flows that shall report to the next legislature and may draft proposed legislation to modify the current water right permitting statutes. Defining the current state of water permitting, the bill adds section 11.0235 to the Texas Water Code that states that the legislature *has*:

. . . expressly required the commission [TCEQ] while balancing all other interests to consider and provide for freshwater inflows necessary to maintain the viability of the state's bay and estuary systems in the commission's regular granting of permits . . . (SB 1639 Sect. 2 and Tex. Water Code § 11.0235[c]).

Then the bill adds language to the Water Code that explains that the legislature *has not* expressly authorized the TCEQ to grant water rights exclusively for: ". . . instream flows dedicated to environmental needs, inflows to the state's bay and estuary systems; or other beneficial uses" (SB 1639 Sect. 2 and Tex. Water Code § 11.0235[d]). This portion of the bill was apparently written to address recent applications by environmental groups for new water rights for instream flow and freshwater inflow that will be discussed in another section.

SB 1639 goes on to explain the need for improvement of the water rights system:

The fact that greater pressures and demands are being placed on the water resources of the state makes it *of paramount importance to reexamine* the process ensuring that these important priorities are effectively addressed in clear delegations of authority to the commission (SB 1639 Section 2 and Tex. Water Code § 11.0135[e]).

The bill creates the "Study Commission on Water for Environmental Flows" (SB 1639 Sect. 2 and Tex. Water Code § 11.0236) in order to:

. . . study policy implications for balancing the demands on the water resources of the state resulting from a growing population with the requirements of the riverine, bay, and estuary systems including granting permits for instream flows dedicated to environmental needs or bay and estuary inflows . . . (SB 1639 Sect. 2, and Tex. Water Code § 11.1236[j]).

Apparently to address the first recommendation of the water plan, the bill instructs the new study commission to ". . . specifically address ways that the ecological soundness of these systems [referring to previously mentioned ecosystems] will be ensured in the water allocation process" (SB 1639, Sect. 2 and Tex. Water Code § 11.1236[j]). There is no direct mention of the water plan's request of possible statutory criteria for measuring the ecological

soundness. The Study Commission will consist of various appointed Senators and Representatives, resource agency representatives, and other appointed members and will also appoint a scientific advisory committee (SB 1639, Sect. 2 and Tex. Water Code § 11.0236).

SB 1639 also added to the Water Code Section 11.0237 that prohibits TCEQ from issuing a *new* permit for instream flows for environmental needs or inflow to bays and estuaries. This statute does *not prohibit an amendment to an existing permit* that changes the beneficial use or adds a use for environmental instream flows or bay and estuary flows. This section 11.0237 of the Water Code expires September 1, 2005 and basically places a moratorium on the type of applications made by environmental groups for instream flow and freshwater inflow mentioned earlier (Kelly and Taylor 2003).

Section 3 of SB 1639 adds stronger language to the Water Code regarding environmental flow considerations for new water rights issued by TCEQ (Kelly and Taylor 2003). The wording of Section 11.147(d) regarding the commission's (TCEQ) responsibility in considering a water right application, formerly read:

. . . shall consider the effect, if any, of the issuance of the permit on [italics for replaced words] existing instream uses and water quality of the stream or river to which the application applies.

The new wording from SB 1639 reads:

. . . shall include in the permit, to the extent practicable when considering all public interests, those conditions considered by the commission necessary to maintain [italics for new words] existing instream uses and water quality of the stream or river to which the application applies (Tex. Water Code § 11.147[d]).

With the new wording, the TCEQ *has* to include conditions to maintain instream uses and quality in new permits. There is the caveat of this inclusion being only to the extent practicable when public interests are considered. But this new wording is stronger than the previous wording which only asked the TCEQ to consider the effect of the permit on existing

instream uses and quality. Section 11.147(e) addressing fish and wildlife habitat received similar word changes.

Except for the stronger language on instream flow and freshwater inflow (Kelly and Taylor 2003) and the study commission on environmental flows there does not appear to be significant change in the protection of freshwater inflows as a result of SB 1639. With the studies taking place and the stronger language, there is the *possibility* for improvement in the system. However, any potential improvements could be offset by the placing of a moratorium on new instream flow and freshwater inflow water rights, while at the same time, allowing consumptive rights to still be granted under the existing rules.

Consensus Criteria

The state and regional water planning process requires the use of consensus criteria to assess the environmental flow needs of *new* diversions and reservoirs when there are not site-specific studies available (TWDB 2002b). These criteria were the result of collaboration among the three natural resource agencies (TWDB, TPWD, and TCEQ) along with academics, consultants and informed citizens, and were agreed upon prior to the current water planning process, begun in 1997. The 1997 state water plan *Water for Texas* preceded the regional plans and outlined the consensus process in more detail than the 2002 plan.

The criteria consist of multi-stage operational rules for new reservoirs and diversions to protect environmental flows in three stages: above normal streamflow, below normal streamflow and drought conditions. According to the State Water Plan 2002, "The criteria provide balance by sharing the adverse impacts of drought so that neither human nor environmental needs prevail over the other" (2002b, 59). State and federal permitting processes may require different criteria based on field studies or other considerations (TWDB

2002b). The 1997 plan stated that when more detailed studies on environmental flows were completed, the criteria from those studies would be used instead of the generalized (consensus) values. The 1997 plan that provided guidance for the first five year regional planning cycle listed the status of the bay and estuary studies at that time (TWDB 1997). The Guadalupe estuary study was the most complete and was in draft review, Galveston Bay would be complete in 1997, Sabine estuary in 1998, Corpus Christi Bay and Mission-Aransas Bay in 1999, and Laguna Madre in 2002. The LCRA's Matagorda Bay and Lavaca Bay studies were also in the draft review stage. Perhaps because all of the studies were incomplete at the start of the five year planning process, they were not used in the regional plans started in 1997 and published in 2002. In actuality only three of the eight studies were completed before 2002, including the Matagorda, Galveston, and Guadalupe Estuaries – at least as far as the TPWD analysis. The TWDB preliminary model results for all seven estuaries were available. In chapter 13 the differences between the TPWD and the TWDB analyses will be discussed.

The Three Zones and Instream Flow

The structure of the consensus criteria is based on three zones that define the amount of water that has to be passed through a new reservoir or allowed to by-pass a new diversion with some differences between the two. See figure 8.3 for a reservoir criteria chart and figure 8.4 for a diversion criteria chart. The following discussion is based on the description of the criteria in the document *Environmental Target Flows* (TPWD n.d.).

Zone 1

For new reservoirs, Zone 1 or the above normal stage applies when the reservoir water levels are greater than 80 percent of conservation storage capacity. At this level, all flows into the reservoir up to the monthly median value based on naturalized streamflows will be passed downstream for instream flows and bay and estuary inflows. This also means, although not stated, that all flows above the median may be held in the reservoir. As a possible alternative basis, other central tendency flows other than the median, such as the mean, *could* be used as the benchmark depending on basin hydrology.

A reservoir permitted to capture all flows above the median in Zone 1 could reduce the periodic flushing flows needed for river channel and habitat maintenance. The report states however that "Flooding events appear to occur naturally with enough frequency that planning criteria requiring them may be unnecessary" (TPWD n.d., Appendix A). There is mention that the ". . . feasibility of providing flushing flows should be explored during site-specific investigations, and may be required as a condition of obtaining State or Federal permits" (TPWD n.d., Appendix A). There is no mention of the effects of flood flows on estuaries in the criteria. However *Freshwater Inflows to Texas Bays and Estuaries* (Longley 1994) presents methodology for determining freshwater inflow needs for Texas including analyses of sediment transport. This report served as the basic methodology of the bay and estuary studies that will be discussed in more detail. While not concentrating on flushing flows, Longley (1994) discusses the effects of the transport of sediment on the bays and estuaries, citing dams as one of the major causes of sediment reduction. Lake Corpus Christi on the Nueces River is downstream of 95 percent of the drainage area and Liebbrand (1987) showed that 97 percent of the sediment entering the lake was retained. Lake Livingston on

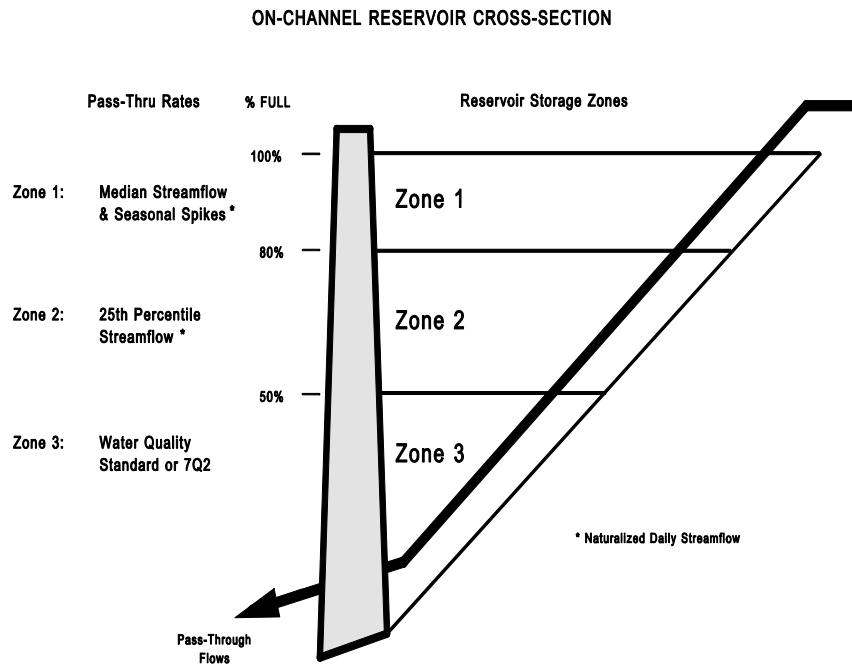


Figure 8.3 – Consensus criteria zones for new reservoirs (from TWDB 2001)

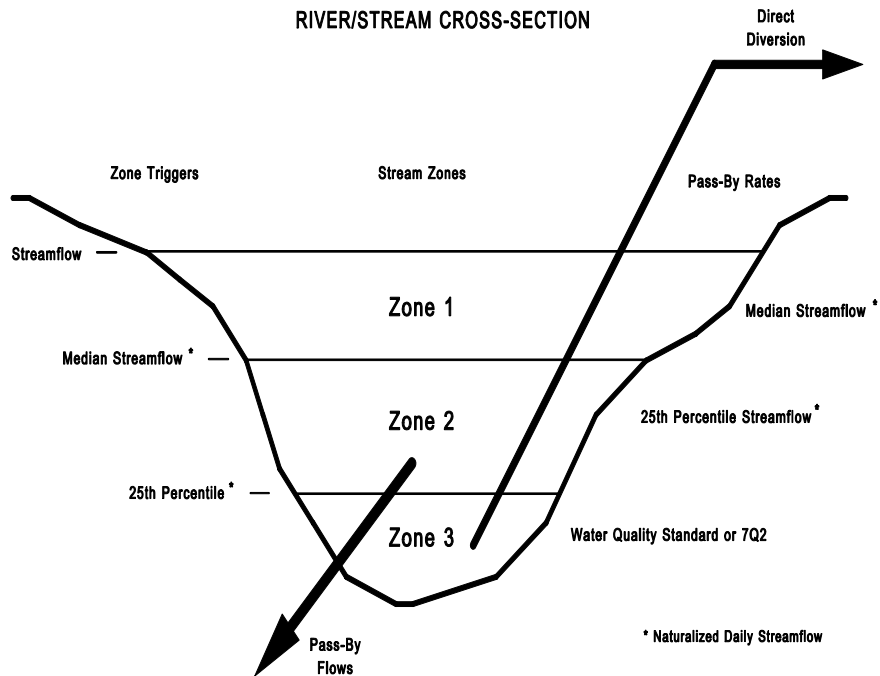


Figure 8.4 – Consensus criteria zones for new diversions (from TWDB 2001)

the Trinity River 100 miles upstream from the coast retained all but 2 percent of the sediment that entered the reservoir between 1974 and 1988. In addition the sediment load to the Trinity estuary decreased by 75 percent (Longley 1994). The amount of sediment that stays suspended and is carried past a reservoir varies with the proportion of sand or silt in the river, with sand falling out more quickly as the flow slows (Longley 1994). Sediments are an important part of the formation of deltas at the mouths of rivers and Longley (1994, 71) concludes: "Recent studies have documented reductions in the Nueces and Trinity delta areas that are most likely related to reservoir construction." Longley's analysis of sediment transport shows the possible effects of a new reservoir operating under Zone 1 on bays and estuaries besides the reduction and timing change of flow. There is instruction in the Texas Parks and Wildlife Code for the TPWD to evaluate the feasibility and effect of allowing sediment to bypass the reservoir and be transported to the estuary (Tex. Parks and Wildlife Code § 14.022) although only referring to state-owned coastal wetlands.

The criteria when applied to new diversions recommended in the water plan are based on streamflow conditions just upstream of the diversion point. Zone 1 applies when flows are higher than the monthly median flow, but when applied to a diversion the excess flows above the median may be diverted, and the flows less than median have to be allowed to bypass the project. The Zone 1 flows required to pass through new reservoirs or by-pass new diversions are available for bay and estuary use if the new project is within 200 river miles of the coast. There will be more discussion related to freshwater inflow at the end of this section.

Zone 2

Zone 2 seeks to provide flows for ". . . minimum ecological maintenance where the aquatic species are impacted by lower flows, but can survive for a short period" (TPWD n.d., 3). For reservoirs, Zone 2 is again triggered by the percentage of storage capacity in the reservoir. When the level of stored water in the reservoir is between 50 percent and 80 percent of capacity, the inflows, if any, required to be passed through would be reduced to the monthly naturalized 25th percentile flows. Though not stated, this means that any flows above the 25th percentile could be held in the reservoir– even flows that exceeded the median. The basis for pass through flows is the level of the reservoir—not the state of the incoming flows at that time. It should be noted that if the reservoir is in Zone 2 there could possibly be: (1) no incoming flows or (2) flow less than the 25th percentile. In case (1) no flows would be required to be passed through and in case (2) only the amount of incoming flows up to the 25th percentile would be passed through.

Zone 2 for new diversions occurs when the streamflow above the diversion is less than or equal to the median, but greater than the monthly 25th percentile naturalized flows. In Zone 2 conditions, only the 25th percentile naturalized flow has to be passed downstream, meaning all flows above the 25th percentile up to and including the median naturalized flow may be diverted. For instream use and bay and estuary inflow only those flows equal to the 25th percentile would have to flow downstream.

Zone 3

Zone 3 or drought conditions occur when new reservoirs hold less than 50 percent of their storage capacity. The inflows required to be passed through the reservoir would be at a ". . . level determined adequate for the protection of water quality in the downstream

segment" (TPWD 2002, 7). There is no mention of bay and estuary needs. The concern is water quality of the affected stream.

If there are no site-specific data, the pass-through amount will be the 7Q2 low-flow value published in the TCEQ's *State Water Quality Standards* (Tex. Admin. Code § 307.1[2]). The 7Q2 value varies for each river and stream in Texas and does not uniformly compare to a percent of flow. A quantitative analysis of the 7Q2 and other flow standards will be in chapter 17 including comparisons of the 7Q2 to the bay and estuary studies' target flows. The 7Q2 flows are minimum flows set by the TCEQ to protect the designated uses of a stream segment including recreation, aquatic life, and domestic water supply (Tex. Admin. Code § 307.10). The parameters considered include dissolved oxygen, pH, total dissolved solids, and temperature. An additional provision is made for Zones 1 and 2 that in the event the flows needed to maintain downstream water quality exceed the relevant statistic, either the median or 25th percentile, then the necessary amount for water quality preservation will be the target flow. As in Zone 2, if there are: (1) no inflows or (2) the inflows are less than the criteria, then (1) no water will be passed through or (2) only the amount flowing into the reservoir will be passed. The pass through never has to exceed the incoming flow and ". . . no water will be released from storage to meet environmental targets when inflows are below these limits" (TPWD 2002 n.d., 7)

Zone 3 applies to new diversions when actual streamflow is less than or equal to monthly 25th percentiles. The minimum flows to be allowed to pass will be the greater of the amount needed to maintain downstream water quality or a continuous-flow threshold (e.g. 15th percentile) to be determined by the consensus planning staff that ". . . will not allow the diversion by itself, to dry up the stream" (TPWD 2002 n.d., 8).

All Zones

The environmental flow amounts for each zone vary widely from the median in Zone 1 to the 25th percentile in Zone 2 to the 7Q2 in Zone 3. The transition between these flows is not a smooth process for diversion projects, and the TPWD suggests improvements to the procedure to facilitate changes in flow management.

The three zones and bay and estuary considerations

According to the discussion in *Environmental Target Flows*, Zone1 reservoir pass-through flows or direct diversion by-passes are a ". . . planning place-holder value" (TPWD n.d., 11), but will also provide freshwater inflow to bays and estuaries. However, if the project is within 200 river miles ". . . where inflow values adequate to meet the beneficial inflow needs as described in Texas Water Code § 11.147 have been established, those inflow volumes will be used for projects . . . as the basis for calculating the relative contributions of fresh water from the associated rivers and coastal basins during times of Zone 1 conditions" (TPWD n.d., 9).

Since there are no established inflow needs as per § 11.147, it appears that *the bay and estuary studies' results do not directly apply to the amount of pass-through or by-pass flows in Zone 1*. In addition, for Zone 2 and 3: "No other special provisions would be made for B&E [bay and estuary] purposes . . ." (TPWD n.d., 9). In chapter 17 the quantitative results of these policies will be analyzed.

For all reservoir zones:

In all zones, it is the intent of the planning criteria that flows passed for instream purposes also contribute to meeting the ecological needs of the associated bay and estuary system. In addition to passage of environmental flows, adequate flows will be passed through for protection of downstream water rights (TPWD n.d., 7).

In another passage they add ". . . all downstream water right needs will be honored at all times" (TPWD n.d., 2). Also for all zones, water in excess of the pass-through amounts can be captured, and ". . . *no water will be released from storage to meet environmental targets* when inflows are below these limits" (TPWD n.d., 7). Once the target amount of flow reaches the estuary in a given month, no extra flows have to be provided that month. The flows required for the remainder of the month will revert to instream criteria. However, they further add that since *most* future reservoir projects and direct diversions *are expected* to be solely for water supply rather than flood control, they will not be capable of capturing flood flows and therefore will allow excess water to pass downstream. As a result, these high flow events will increase the amount of water available for instream flow and freshwater inflow beyond the amounts provided by the consensus criteria alone.

Summary Discussion of Estuary Inflow Protection and the Water Planning Process

Inland Regions and Region H

The TWDB provides environmental information for each planning region in *Environmental Information for Senate Bill 1 Regional Water Planning Areas* ca. 1998). By examining the summaries for each coastal planning region's "Inflows to Bays and Estuaries" (TWDB ca. 1998, 1) both the general direction and individual differences of the regional plans and freshwater inflow protection are revealed. For all regions more than 200 river miles from the coast the TWDB states their freshwater inflow considerations similarly to Region C:

All water resources in Region C are greater than 200 river miles from any estuary, and therefore may not need to consider freshwater inflow needs to bays and estuaries (TWDB ca. 1998, 2).

Region C includes Dallas and Ft. Worth and is the most populous region in the state (TWDB 2002), has the highest per capita water use (Texas Water Matters 2003), and comprises the upper portion of the Trinity River Basin that eventually flows to Galveston Bay. According to the TCEQ, the current water rights on the Trinity River if fully utilized, will reduce the availability of minimum flows as determined by TPWD and TWDB by over 40 percent (Chenoweth 2003).

Region H, including the City of Houston, the Lower Trinity River basin and Galveston Bay, was the only region group to recommend freshwater inflows based on the TPWD and TWDB bay and estuary studies. In this early planning document, the TWDB discusses the fact that the TPWD staff recommends the MaxH flow for the Galveston Estuary.

Region I and Saltwater Barrier Dams

For Region I, the Sabine and Neches Rivers and the inland estuary Sabine Lake, the TWDB quotes the consensus criteria for its instream flow considerations. The Sabine River discharges the largest volume of water (more than 6 million acre feet) of all Texas rivers (NOAA n.d.) and of the four major reservoirs on the Sabine-Neches system that comprise 95 percent of the storage capacity in the region, only Lake Palestine has a requirement to release water for the environment at a minimum of five cubic feet per second (equivalent to a small creek).

Another factor besides upstream reservoirs potentially affecting the Neches River portion of the estuary is the recommendation for a salt water barrier dam in the Region I

Plan. Salt water barriers are facilities designed to prevent the intrusion of salt water into a body of fresh water (North American Lake Management Society n.d.) such as in this case from the estuary into the Neches River. Although there is little discussion in Texas state water literature on the subject of salt water barrier dams, they appear to have potential impacts on estuaries in ways related to freshwater inflows, such as increasing salinity and reducing sediment transfer (Dukes ca. 1998). Various types of barrier dams already exist on the Guadalupe, Nueces and Colorado Rivers. Region I states that currently, temporary sheet piling is installed in the river to protect the upstream freshwater intakes of the Lower Neches Valley Authority (LNVA) from saltwater intrusion. At other times freshwater is released from Sam Rayburn Reservoir upstream to force the salt water away from the intakes (TWDB 2003c). The interference of fish migration and increased upstream erosion caused by the temporary dams are cited as reasons for construction of a new permanent structure (Lower Neches Valley Authority [LNVA] 2002). The new structure will result in only a slight vertical differential between upstream and downstream elevations with most water passing through the project and provisions for navigational bypasses. By using pivoting gates called "tainter gates," at low flows, saltwater intrusion will be prevented from moving upstream while a minimum average daily discharge of 400 cubic feet per second will be maintained for downstream water quality (LNVA 2002). Although the new design will reduce environmental impacts (LNVA 2002) and there is no expected effect on the endangered paddlefish (Wilde 2000), TPWD wrote "The barrier project alone could provide an environmental challenge because it will affect nutrient loads and sediments reaching Sabine Lake's marshes" (Dukes ca. 1998, 2). However due to the complexity of the interaction between the river, estuary, reservoir, and diversions, the TPWD goes on to state that when all

aspects are examined the TPWD may not oppose the barrier idea (Dukes ca. 1998). At the time of this article, Sabine Lake was having low salinity problems so TPWD said it might not oppose the dam since the salinity had room to be raised. The agencies signed off on the project and the barrier dam is reported to be almost complete as of November, 2003 (Golden Triangle Audubon Society 2003).

The issues brought up by this barrier dam project on the Trinity River are not simply about the dam itself, but the overlapping anthropogenic effects on a river and estuary system that seem to create problems in a feedback loop that is difficult to resolve and may not be solvable by our current water rights and estuary management systems. In Charles Dukes' paper, *Sam Rayburn, Water, Fish and Rice* (TPWD n.d.), there is a discussion of these effects related to the Neches barrier dam. To sum up the feedback loop in the Neches case; a large reservoir, Sam Rayburn, was constructed in the late 1960's before there were estuarine concerns in Texas water law. Water intakes were constructed at a point between the reservoir and the estuary that were threatened by saltwater intrusion, causing stored water to have to be released from the reservoir to push the salt water downstream from the intakes. During droughts the reservoir was too low to spare this water for saltwater reduction, in part because increasingly more water was granted and/or used over time out of the reservoir and the river above it. Temporary gates were installed that limited flow and fish movement and a permanent replacement saltwater barrier dam was sought. Apparently TPWD had second thoughts about the new structure because it would raise salinities downstream. However, the downstream inland estuary, Sabine Lake, is having low-salinity problems that are not explained by Dukes, so the potential increased salinity caused by the new barrier dam is permissible by TPWD. Duke states that TPWD could change its mind if the amount of flow

from Toledo Bend Reservoir on the Sabine River that joins the Neches below the proposed saltwater barrier to Sabine Lake is reduced by future interbasin transfers. If the transfers are large enough, the reduced flow into Sabine Lake will cause salinities to be then *too high* which would be exacerbated by the barrier dam. The general manager of the LNVA believes the barrier would help restore the river to a more natural state as existed before the Beaumont Ship Channel brought saline water into Sabine Lake (Dukes ca. 1998). Also a large effluent discharge will have to be moved downstream of the barrier for water quality purposes. Although there will be more water in Sam Rayburn Reservoir after the barrier is built, some of the saved water that formerly was released downstream to push the saltwater back may be sold to pay for the barrier dam, a fact that concerns the recreation industry around the Sam Rayburn Reservoir. Rice farmers who depend on LNVA water also worry that with the new saltwater barrier, more water will be sold to Austin and Houston. Dukes' article on the barrier dam covers a wide range of issues that affect Sabine Lake. What is most interesting is that saltwater barrier dams are not addressed as a major factor in the legal or administrative protection of freshwater inflows in Texas.

Coastal Regions K, L, M, N, and P Environmental Flow Considerations

For Region K also called the Lower Colorado Regional Water Planning Group (Note: groups were allowed to choose a name other than the letter designation) the TWDB stated that an intensive freshwater inflow study has been conducted for Matagorda Bay and it is awaiting TPWD's recommendation in the near future (TWDB n.d.). This study, performed in conjunction with the Lower Colorado River Authority, used different methods in some cases than the other TPWD/TWDB studies and will be further discussed in chapter 13. The

TWDB states that for Region K the consensus criteria is suitable for planning purposes until the decision is made on this study.

Region L, the South Central Texas Regional Water Planning Group, includes the Guadalupe and San Antonio River Basins. There is extensive discussion, compared to the other regions, regarding freshwater inflows to the Guadalupe Estuary with the TPWD stepping in and recommending the larger MaxH flow rather than their MinQ or minimum flow (Note: These terms will be explained in chapter 13). The TPWD adds statistics of the historical distribution of these flows and recommends that even in reduced flow management periods that the frequency of reduced flows not be changed to occur more often.

Watershed management programs should provide target and lower flows at almost the same frequency at which they occurred in the past and retain as much historical variability at higher flows as possible (TWDB n.d., 12).

Region M includes the lower Rio Grande that has stopped flowing to the Gulf of Mexico on at least one occasion in 2002 (National Public Radio [NPR] 2002). In its estuary considerations TWDB recommends a new channel dam called the Rio Grande Weir downstream of Brownsville and near the river's mouth to "... capture available U.S. flows in the lower basin that normally would discharge to the Gulf of Mexico . . ." (TWDB n.d., 13). The TWDB mentions that freshwater inflows will have to be evaluated in the permitting process. It also includes the standard language of the consensus criteria:

For most environmental planning purposes, the Zone 1 instream flow requirements will also provide a "fair-share" of the total targeted freshwater inflows to the bays and estuaries, for new reservoirs or direct diversions located within 200 river miles of the coast. No other special provisions are made for Zones 2 and 3 regarding freshwater inflows, except that instream flows be allowed to pass all the way down to the receiving bay and estuary system (TWDB 2003c, 13).

There has been no TWDB/TPWD bay and estuary study for the Rio Grande since it was not on the list of major estuaries studied in the first round of seven estuaries just being completed. Since the Rio Grande has stopped flowing (NPR 2002), empirical evidence indicates the availability of flows for the estuary is zero even with current pumping and discharge levels. (Note: There are many more complex issues in the Rio Grande Basin than other Texas river basins due to the international sharing of water with Mexico, and the fact that the river originates in Colorado and flows through New Mexico.)

For the Coastal Bend Regional Water Planning Group, Region N, the TWDB cites the Agreed Order that established operating procedures for the Choke Canyon and Lake Corpus Christi Reservoir System as the basis for inflow requirements to the Nueces Estuary. These dams were started before 1985 so HB 2, 1985 that established the 200 mile rule did not apply (TPWD 2001). The report states that beneficial inflows for the other estuary in Region N, the Mission-Aransas, have not been scientifically determined, therefore the three zone system will provide a "fair-share of freshwater inflow" (TWDB 1998 n.d., 14).

Region P includes the Lavaca River and recommends the new Palmetto Bend II Reservoir (TWDB ca. 1998). They state the operational plan has not been finalized, but was agreed to in principal with the TPWD and would have ". . . triggers for various contents of the reservoir. . . " (TWDB ca. 1998, 15) that will be the basis for freshwater inflow.

Criticism of the Plans and Planning Process Regarding Freshwater Inflows

The state water plan, *Water for Texas – 2002* (TWDB 2002b) requests assistance in determining and managing instream flows and freshwater inflows: ". . . additional clarity on what is considered an adequate environmental flow is needed" (TWDB 2002b, 9). As

discussed earlier, there is concern among the planners that much of Texas water has been allocated in permits with no environmental provisions (TWDB 2002b). The plan states: "This dilemma is exacerbated because data on what a healthy ecosystem needs in many specific locations have not yet been found" (TWDB 2002b, 9). Warning that the answers are not easy, the plan says: "No clear consensus exists on these issues beyond the recognition of a problem regarding the provision of environmental flows" (TWDB 2002b, 9).

The fundamental theory of the place-holding consensus criteria is described by TPWD:

To acknowledge the priority of human needs during dry periods and drought, the relative *share of water provided for the environment will be successively reduced* to protect water supplies (TPWD n.d., 2).

A statement in a review draft by the engineering group contracted to assist Region I in round one of the water plans simply states:

The results of the TWDB-TPWD study of the Sabine-Neches Estuary will not be available until 2001. Therefore, this current Regional Plan can neither make provision for, nor assess whether there are, potential impacts on water supply availability from proposed projects as a result of providing inflows to bays and estuaries. These components of the plan should be addressed in the first update to the Regional Plan (Alan Plummer and Associates 2001, 31).

A statement by the Lower Colorado River Authority verifies the lack of provisions in historical permits for protection of freshwater inflow that becomes evident when analyzing the impact of its proposed projects in the plans. The LCRA is showing that the management of its agreed upon freshwater inflows only applies to the Highland Lakes that it controls.

These operational criteria apply only to the water rights for the Highland Lakes. *No other water right in the Colorado River basin is subject to any requirements maintaining the Target or Critical estuarine freshwater inflow* (Martin 2001).

The Clear Lake Field Office of the United States Fish and Wildlife Service (USFWS) submitted comments on the regional plans:

Each plan addresses the need for freshwater inflows to varying degrees, but *none of the plans provide a strategy or a recommendation to guarantee that adequate inflows will be available once water supplies are fully developed* (USFWS 2001).

The Living Water Project, a coalition of environmental groups monitoring the water plan listed shortcomings of the 2002 state plan: "The plan fails to guarantee freshwater inflows to sustain the productivity of our bays and estuaries" (Texas Living Waters Project 2003, 3).

There appears to be agreement among several entities, including the TWDB water plan itself, that there are problems in the water planning process related to the protection of freshwater inflow including:

- 1) Lack of defined targets of freshwater inflow for each estuary.
- 2) Methods to deal with the historical granting of water rights with no environmental restrictions and having them assume some of the burden of providing inflows to estuaries.

The TWDB and the regional planning groups addressed some of these problems in their scope of work for the second round of planning to be completed in 2007 (TWDB 2003c).

Environmental Flow Problems to be Addressed by the Second Round of Water Planning

The Texas Water Development Board lists actions to be taken by the regional groups in the next round of planning that are either responses to changes in conditions or recommendations of water management strategies (TWDB 2003c). Consistent with the recommendations to the legislature in the 2002 plan, the TWDB list includes: "Considering

and possibly recommending changes to current water policy and water law in Texas that may serve to better manage the State's water resources" (TWDB 2003c, 2). Due in part to requests from the planning groups and interested citizens and environmental groups, SB 1639, 2003 established the "Study Commission on Water for Environmental Flows" (Texas Water Code § 11.0236), discussed previously, that will address some of the changes that need to be made to Texas water policy, possibly in time for use in the next water plan.

Each region also submitted a scope of work to be accomplished during the next planning cycle. A few recommendations are relevant to the freshwater inflow issue. Region H (Region H 2002) of the Trinity-San Jacinto River Basin and Galveston Bay, asks for updates of the Water Availability Model to address any new water projects that the Dallas-Ft. Worth Region C is contemplating that would affect inflow into Lake Livingston in Region H. It also requests that reduced capacity due to sediment loading to major reservoirs be calculated in availability models including current loading and projected 2060 loading irregardless of the original permitted storage volumes (Region H 2002). Another task to be completed is the evaluation of the effects of inflow to Galveston Bay by various proposed interbasin transfers. The region also asks for analysis of the possible interbasin transfer of water from Toledo Bend Reservoir in Region I to Region H including possible effects of reduced inflows on Sabine Lake discussed earlier. The scope of work also requests an assessment of a new saltwater barrier on the Brazos River including effects on the estuary and upstream portions both quantitatively and qualitatively (Region H 2002).

Region I in the Sabine-Neches Basin requests an alternate model to the Water Availability Model, claiming it does not accurately represent the complexities of the Sam

Rayburn Reservoir. It claims that the Neches WAM does not recognize the water released from Sam Rayburn to push saltwater downstream away from freshwater intake structures (Region I 2002).

Region K on the Lower Colorado River Basin asks for ". . . action by the State to augment the standard planning process by developing predictions of what this region's growth limit is, assuming current technologies" (LCRA 2002c, 38). They further describe the growth limit as addressing how many people, industries, and agricultural systems can be supported by the regional plan whether they use water from this region or just obtain it from this region. With this growth limit the region asks the state to set a ". . . minimum standard of maintaining healthy riparian, riverine, estuarine, and hardwood bottomland ecosystem viability" (LCRA 2002c, 38). Note: The LCRA is the entity that Region K chose to develop their scope of work. Consideration of the conservation of cultural resources, regional economics, agriculture, and the preservation of rural communities are also to be considered in the analysis. Realizing the magnitude and uniqueness of this sustainability analysis, Region K adds: "The concept of sustainability of water resources is fairly new, and as such, will require more groundwork than the other prioritized tasks" (LCRA 2002c, 39).

The stakeholder group of the water planning process also made policy recommendations to improve the next planning cycle. Notable recommendations involving freshwater inflow include continued funding of the interagency bay and estuary studies, using water saved through conservation for environment flows, facilitating use of the Water Trust (see next chapter) for environmental flows, and more public education on the need for environmental flows for rivers and estuaries. Most significant was the recommendation that:

The legislature should consider establishing criteria and directing the natural resource agencies to develop procedures for reserving water in the river basins as environmental flows to protect and maintain the living natural resources of the State [This recommendation had one dissenting opinion] (TWDB 2002b, 145).

Some of the recommendations in the scope of work for the second phase of planning are necessary housekeeping and data management issues, but the requests for improvements to preservation mechanisms for freshwater inflow will not be accomplished simply by their existence in the individual region plans, the state plan and the stakeholder recommendations. Even though we are discussing the planning rules, their interrelation to the other elements of Texas water law and administration are apparent. The planning process appears to have problems due to shortcomings in the water law and the agency rules that do not seem to provide adequate restrictions on current permits for environmental flows for bays and estuaries. In addition, prior to 1985, there were virtually no restrictions on permits that make up 90 percent of the current appropriated water (Texas Center for Policy Studies 2002), and no mechanism exists to encourage or require holders of older permits to share the burden of the over-appropriation of rivers (TWDB 2002b) .

The water planning process alone cannot preserve adequate freshwater inflows to bays and estuaries until the state water laws and administrative practices are effectively changed. However, until effective changes are made, the planning placeholder values of the consensus criteria either have operational problems as in Region I or do not adequately protect freshwater inflow as indicated by the additional inflow requested by Region H and the TPWD recommendations in Region L. In different ways, most of the coastal regions have shown dissatisfaction with the process of planning and freshwater inflow protection, and to change the process the concerned members of the planning groups will have to

monitor and influence the interim Study Commission on Water for Environmental Flows established by SB 1639, 2003, and due to report to the next legislature.

CHAPTER 9

TEXAS PARKS AND WILDLIFE DEPARTMENT

The Texas Parks and Wildlife Department (TPWD or the "department") was established in § 11.011 of the Texas Parks and Wildlife Code (hereafter referred to in this chapter as the Code) and its general duties are administering laws related to game, fish, oysters, and marine life (Tex. Parks and Wildlife Code § 12.001). Besides powers and duties related to game and fish licensing and stocking, § 12.0011, Resource Protection (a) states: "The department is the state agency with primary responsibility for protecting the state's fish and wildlife resources." Other resource protection activities include:

. . . providing recommendations to the Texas Department of Water Resources [now the TCEQ] on scheduling of in-stream flows and freshwater inflows to Texas estuaries for the management of fish and wildlife resources (Tex. Parks and Wildlife Code § 12.0011[b][4]).

Section 1.011(d) of the Code enables the TPWD to regulate the taking and conservation of ". . . fish, oysters, shrimp, crabs, turtles, terrapins, mussels, lobsters, and all other kinds and forms of marine life . . ."

Under Chapter 12, *Powers and Duties Concerning Wildlife*, the TCEQ is *instructed to furnish the TPWD with a copy of all water permit applications*. The department ". . . *shall make recommendations to the Texas Department of Water Resources (TCEQ) to protect fish and wildlife resources, including permit conditions, mitigation, and schedules of flow or releases*" (Tex. Parks and Wildlife Code § 12.024[b]). The department can be a full party to any hearing on a water right application. These rights of the TPWD to participate and make recommendations in the water rights process are also covered in § 11.147 of the Texas Water Code.

For state-owned coastal wetlands, Chapter 14 of the Code instructs the department to develop conservation plans that include an evaluation of freshwater inflow requirements to estuaries that affect these wetlands. Another requirement of the plans is an evaluation of the feasibility and effects of allowing sediment to bypass a reservoir and be allowed to be transported to the bays and estuaries (Tex. Parks and Wildlife Code § 14.022).

As the licensing agency for the shrimp fishery, the TPWD is required to monitor environmental factors affecting shrimp supply and reproduction. Specifically the department is told to conduct continuous research on: ". . . environmental parameters in the bay and estuary areas that may serve as limiting factors of shrimp population abundance" (Tex. Parks and Wildlife Code § 77.004[a][6]).

State compliance with federal laws relating to fish restoration, commercial fish research and wildlife restoration projects is required in Chapter 83 of the Code titled *Federal-State Agreements*, but no real jurisdiction over freshwater inflows is provided by these cooperative efforts. The executive director of the TPWD also serves on the Gulf States Marine Fisheries Commission that makes recommendations to the five member states to control depletion and waste in the fishing industry. The department is also to provide assistance to the state components of the National Estuary Program to implement conservation and management plans (Tex. Water Code § 5.605).

Many of the department's responsibilities are in cooperative support roles principally with the TWDB and the TCEQ that were discussed in the sections on those agencies. These support roles involve both the responsibility to give recommendations on other agencies' actions and the sharing of resources when various studies are

performed. Previously mentioned was the requirement to make comments to the TCEQ on water right permits regarding protection of fish and wildlife (Tex. Parks and Wildlife Code § 12.024). If the TCEQ by emergency suspends a permit condition relating to bay and estuary flows, they must first notify the TPWD which has 3 days to comment on the suspension (Tex. Water Code § 5.506). In cooperation with the TCEQ, the department is the recipient of the mandated 5 percent of the annual firm yield of new reservoirs (since 1985) built within 200 river miles of the coast (Tex. Water Code § 16.1331). The department will manage the release of these stored flows for instream use and bay and estuary flows in cooperation with the TCEQ. The TWDB is instructed to consult the TPWD and the TCEQ regarding the rules for holding water rights in the Texas Water Trust (Tex. Water Code § 17.031) and the dedication of any water rights to that trust. The Texas Water Code instructs the Texas Water Development Board to consider advice from the TPWD regarding reservoir sites and the monitoring of freshwater inflows and instream flows (Tex. Water Code § 16.012).

The role of the Texas Parks and Wildlife Department in the planning process includes a representative of the department serving as an ex officio member of each of the planning groups (Tex. Water Code § 16.053). The department along with TCEQ and TWDB collaborated along with academics, consultants and informed citizens to formulate the consensus criteria that were the mechanism for determining the minimum environmental flow restrictions for new projects in the regional plans (TWDB 2002).

The department along with the TWDB has joint responsibility to:

. . . establish and maintain on a continuous basis a bay and estuary data collection and evaluation program and conduct studies and analyses to determine bay conditions necessary to support a sound ecological environment (Tex. Water Code § 16.058[a]).

The TPWD and the TCEQ shall also have joint responsibility for the evaluation and review of the studies mandated in § 16.058 of the Water Code to: ". . . to determine inflow conditions necessary for the bays and estuaries, and to provide information necessary for water resources management (Tex. Water Code § 11.1491[a]).

Summary of the Texas Parks and Wildlife Department and Protection of Freshwater Inflow

Although the Texas Parks and Wildlife Department can comment to the TCEQ on freshwater inflow needs in water permits, the commission only has to *consider* their recommendation including the studies by TPWD and TWDB (Tex. Admin. Code § 297.55). The other role of TPWD in the water right process – to have full party status in any water permit hearing (Texas Parks and Wildlife Code § 12.024), has limitations. The fact that there is a hearing often means that there is opposition to the permit and the TCEQ often sides with the applicant who wants to develop the water. If the department objected to the permit, they would often be put in the position of opposing the applicant and the Texas Commission on Environmental Quality. This is not likely a role the department would be comfortable with and therefore the right to protest permits is not a widely used mechanism for freshwater inflow protection.

TPWD's role in the planning process is as an ex officio member of each planning region (Tex. Water Code § 16.0530), however, their participation was noticed in the plans for Region L on the Guadalupe Estuary (TWDB 2002b) in which the department asked for the optimum recommended flows to be part of the plan. TPWD also had a presence in the planning process early on as a member of the group that formulated the consensus criteria for calculating flow amounts to protect for freshwater inflow. As

previously discussed, the consensus criteria process does not seem to provide the necessary flows for estuary protection, but the actual formulation process for the criteria was not examined as to various roles played by the agencies involved.

The role of the department in protection of estuary inflow with the most potential for effect is its joint responsibility with the TWDB in the studies of the bay and estuary flow needs (Tex. Water Code § 16.058), and its joint responsibility with TCEQ to review the studies to ". . . determine inflow conditions necessary for the bays and estuaries" (Tex. Water Code § 11.1491[a]). The method of review of the studies and the recommendation process is complex and begins with the TPWD, TCEQ, and TWDB establishing an advisory council for each principal bay and estuary along with the Texas Department of Health, the General Land Office, representatives of hunting, fishing, and conservation, and river authorities (Tex. Water Code § 11.1491). The advisory councils *may develop recommendations* to the agencies and to major water right holders and organizations with water management responsibilities in the contributing basin of ". . . alternative water management methods that may be used in maintaining the sound environment of the bays and estuaries" (Tex. Water Code § 11.1491[b]). The advisory council process appears to bring in diverse stakeholders, but the mechanism does not seem geared for scientific analysis of the studies or a method of adopting a binding quantitative definition of freshwater inflow protection. There are currently two bays with advisory councils – Corpus Christi and Galveston Bays (Loeffler 2004).

Thirty years of research by universities, state and federal agencies, and private research organizations have gone into the development of the Texas bay and estuary studies (Longley 1994). Although the recommendations of the studies have not been

utilized as the legal or official administrative target flows in the water rights or planning processes, these studies are the only science the state has for reference as it approaches the inevitable decisions on establishing minimum and/or target flows for bays and estuaries.

CHAPTER 10

THE BAY AND ESTUARY STUDIES

The Texas Water Development Board and the Texas Parks and Wildlife Department share joint responsibility for maintaining data and performing analyses of freshwater inflow needs for the bays and estuaries as described in § 16.058 of the Water Code. House Bill 2 1985, Senate Bill 683 1987, and Senate Bill 1 1997 were instrumental in furthering this study program (TWDB 2004).

The original completion date for the studies was December 31, 1989, as designated by HB 2 1985, but this was determined to be insufficient time and the studies are only now coming to completion for the major bays. Some of the delay was to allow time to accumulate a minimum of thirty years of data which is recognized by national scientific consensus as necessary for significant analysis (TWDB 2004). According to the TWDB (2004) studies for the seven major bays are complete for:

- Trinity-San Jacinto Estuary (Galveston Bay)
- Guadalupe Estuary (San Antonio Bay)
- Lavaca-Colorado Estuary (Matagorda Bay)
- Mission-Aransas Estuary (Aransas Bay)
- Nueces Estuary (Corpus Christi Bay)
- Sabine-Neches Estuary (Sabine Lake) Upper Laguna Madre (Baffin Bay)
- Lower Laguna Madre (South Bay) (Note: The seven bay reference counts the Laguna Madre as one bay)

However, according to the TPWD (Loeffler 2004), only four bay studies have been completed. The TPWD does their own analysis of the model results from the TWDB

emphasizing the biological aspects of the study. The titles of the printed TPWD studies read "Freshwater Inflow Recommendation for the ____ Estuary." The TPWD is listed as the author of the printed version of the studies with an appendix by the TWDB. The TPWD (2004) study completion list reads:

- San Antonio Bay/Guadalupe Estuary
- Galveston Bay/Trinity & San Jacinto Estuaries
- Matagorda Bay (completed by the LCRA)
- Nueces Estuary

The reports linked to the TWDB website are only graphs and tables while the published TPWD reports for the Guadalupe, Trinity-San Jacinto and Nueces Estuaries contain discussion and analysis along with the graphs. The LCRA's *Freshwater Inflow Needs of the Matagorda System* published in 1997 also contains discussion and tables and graphs. According to the TWDB (2004) the studies of the minor bays and estuaries are scheduled for completion by 2006 with one bay due per year including:

- East Matagorda Bay and Estuary – August 2002
- Rio Grande Estuary – 2003
- Christmas Bay Coastal Preserve – 2004 Cedar Lakes and the San Bernard River Estuary – 2005
- Brazos River Estuary 2006

Methodology of the Studies

In 1994, the Texas Water Development Board and the Texas Parks and Wildlife Department jointly published *Freshwater Inflows to Texas Bays and Estuaries* (Longley) which presented the analytical methodology for determining freshwater inflow needs for

Texas estuaries (Longley 1994). The analytical technique utilizes hydrodynamic modeling, optimization programs and data from special studies, monitoring and historical records. It considers salinity, nutrients and sediment loading regimes that are topics the TCEQ must consider when determining beneficial inflows to maintain a sound environment (Longley 1994).

Throughout Longley's work are frequent associations of the analytical methods with the intent of the Texas Water Code. The biological organisms requiring beneficial flows in Texas Water Code § 11.147(a) are: "...economically important and ecologically characteristic sport or commercial fish and shellfish species and estuarine life upon which such fish and shellfish are dependent." The target species to be modeled for beneficial flows were selected for each estuary with some variance between the estuaries (see table 10.1 for target species of the four published studies).

The target species selected for the Guadalupe Estuary study are described as "... representative dominant fishery organisms or ecologically important prey species common in the Guadalupe Estuary" (TPWD 1998, 23). A survey of various methods for establishing target indicators for freshwater inflow management around the United States revealed a variety of selections including the use of salinity as a measure in San Francisco Bay (Kimmerer 2002), certain submerged aquatic vegetation in the Caloosahatchee Estuary in Florida (Doering and Chamberlain n.d.), the bald cypress in the freshwater upper reaches of the Loxahatchee River in Florida (Alber and Flory 2002), and again in Florida, an inflow-based approach that only allows a 10 percent maximum drop in daily flow (Flannery, Peebles, and Montgomery 2002).

Table 10.1 – Target species for bay studies (TPWD 1998, 2001, 2002; Martin et al. 1997)

Galveston Bay	Matagorda Bay	Guadalupe Estuary	Nueces Estuary
Blue crab	Blue Crab	Blue Crab	Blue Crab
Eastern Oyster	Eastern Oyster	Eastern Oyster	-----
Red Drum	Red Drum	Red Drum	Red Drum
Black Drum	Black Drum	Black Drum	Black Drum
Brown Shrimp	Brown Shrimp	Brown Shrimp	Brown Shrimp
White Shrimp	White Shrimp	White Shrimp	White Shrimp
Spotted Seatrout	Gulf Menhaden	Spotted Seatrout	Spotted Seatrout
Flounder	Southern Flounder	-----	Southern Flounder
-----	Striped Mullet	-----	-----

Inflows are based on historical data and modeled data where gauges are not present. Species production is measured by using historical commercial catch records since these types of records are more abundant (Longley 1994).

Separate models are used to determine nutrient budgets and constraints, and sedimentation constraints (Longley 1994). Results of models and analyses are entered into the Texas Estuarine Mathematical Programming (TXEMP) model that is an optimization model created specifically as a decision-making tool to determine freshwater inflow needs of Texas bays and estuaries (Longley 1994). The TXEMP solution curves (see example for Galveston Bay, fig 10.1) are then verified through the use of TXBLEND; another model developed for the bay and estuary studies described as: ". . . a depth-averaged, two dimensional finite element model that simulates water circulation and salinity patterns in

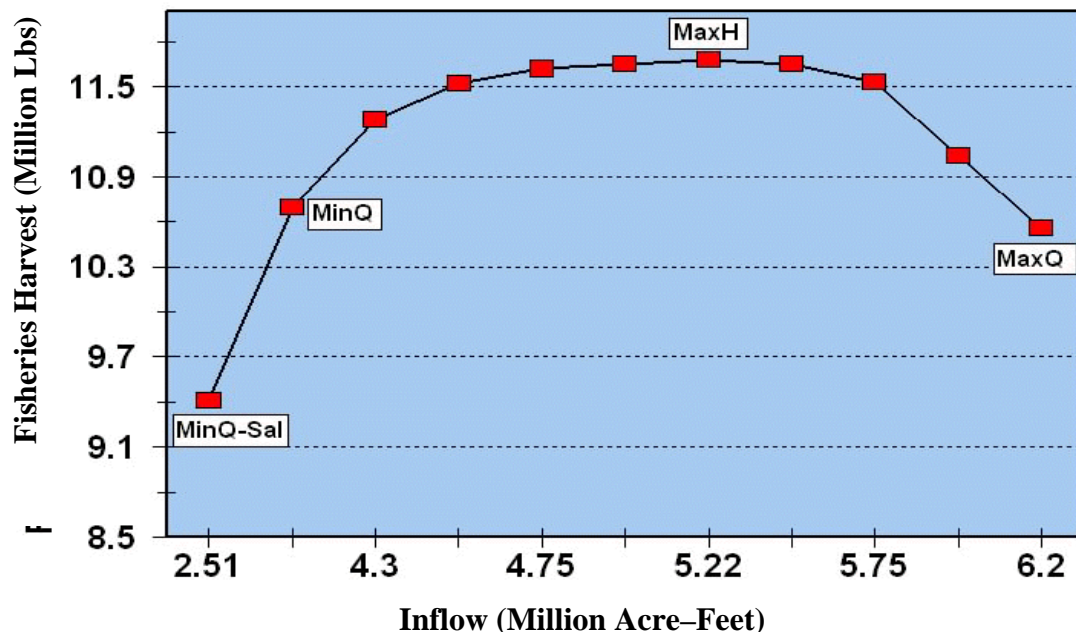


Figure 10.1 – Galveston Bay TXEMP (from TWDB 2003 website)

estuaries" (Longley 1994, 278). The recommended flows are entered into TXBLEND that in turn delivers monthly salinity distributions in the bay for given flow. If the salinity zones created by the modeled recommended flow compare favorably to salinity patterns that are considered optimum for maximum fish productivity in fresh, brackish, and marine habitats of the bay, then the model is considered verified (Longley 1994). In other words salinity is used as a "proxy" (TPWD 1998) to demonstrate the correlations between historical abundance of target species and freshwater inflow. (For TXEMP charts for bays not displayed in this chapter, see Appendix C).

Model Constraints

Several constraints are applied to TXEMP including harvest targets, monthly inflow, biomass ratios, salinity, sediment loading and nutrient loading. It is beyond the scope of this document to analyze all of the Texas estuary studies for consistency of constraints; however,

where constraint variations are found, they will be noted. TPWD (1998) states that the values and constraints used in the Guadalupe analysis generally follow the procedures described by Longley (1994). I chose the Guadalupe Estuary for this analysis as well as for other analyses for several reasons:

- The Guadalupe Estuary was the prototype estuary analyzed by Longley (1994) to design and test the methodology for all bay studies.
- The Guadalupe Estuary study was the first bay and estuary needs study to be completed by TWDB and TPWD (1998).
- The Guadalupe Basin is second only to the Rio Grande in total appropriated water (TNRCC 2002) (see appendix , table B-1 for list of all basins).
- The Guadalupe Estuary is the westernmost basin in a state with declining east to west rainfall totals that still has some unappropriated water (see Texas rainfall map in appendix, figure A-1 and TCEQ appropriation graphs in chapter 16).
- The Guadalupe Estuary only has one small community, Seadrift, population approximately 1000 (see fig. 11.2 to locate Seadrift), presumably making it relatively less locally impacted by humans than other estuaries.
- The Guadalupe River which is the principal tributary only has one major reservoir, Canyon Lake (Longley 1994). Several major reservoirs affect the flows of other basins including the Colorado, Trinity-San Jacinto, and Sabine-Neches Basins (TWDB 2002b). A major city, San Antonio, metro population 2,132,188, is considering a large diversion from just above the Guadalupe River mouth to return water to San Antonio via a pipeline (TWDB 2002). (See fig. 10.2 – Lower Guadalupe Diversion).

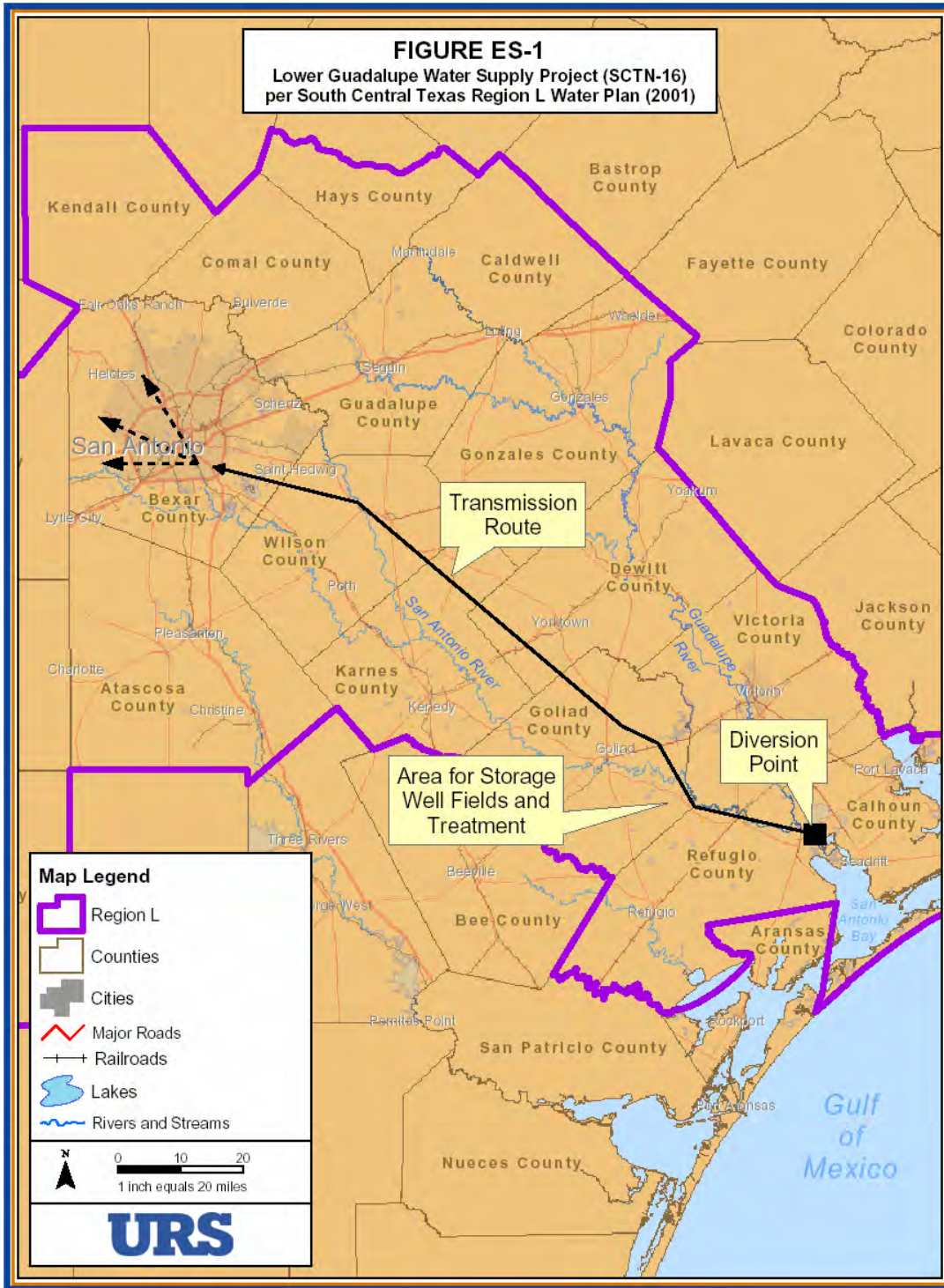


Figure 10.2 – Lower Guadalupe Diversion (Lower Guadalupe Water Supply Project 2004).

- A conservation group, the San Marcos River Foundation, has applied for an instream flow water right in the Guadalupe Basin in the amount equal to the recommended optimum flows for the Guadalupe Estuary (Texas Joint Committee on Water Resources 2002).

Harvest Data and Constraints

Data for historical commercial catch of target species in the Guadalupe Estuary came from several sources including the United States Department of the Interior, the United States Department of Commerce, National Marine Fisheries and the Texas Parks and Wildlife Department's own data especially in more recent years (TPWD 1998).

Harvest targets for each species were set for the model runs to be no less than 80 percent of the mean of the historical harvest of that species. The minimum probability that the calculated harvest meets or exceeds the harvest target, called the "harvest chance constraint," was set at 50 percent (TPWD 1998; 2001). An exception to the harvest target percentage was the Nueces Estuary with a harvest target of 70 percent of mean historic harvest while still having a harvest chance constraint of 50 percent (TPWD 2002). The TPWD (2002) discussed that a more statistically significant solution could theoretically be produced by a greater than 50 percent harvest chance constraint, but doing that would reduce the range of feasible inflow solutions.

Inflow Data and Constraints

Inflow data comes from historical USGS gauged data and modeled ungauged data from areas below the USGS gauges using TXRR, a calibrated rainfall-runoff model. Return flows are added back in to the ungauged area flows and diversions are subtracted out of the

ungauged flows with both of these data sets derived from TCEQ records (TPWD 1998). All of the flow sets together are called combined inflows. The gauged and modeled ungauged flows are in units of acre-ft/day while return flows and diversions are in acre-ft/month. The resulting combined flows are in acre-ft/day units that require converting the monthly return flow and diversion totals into daily flows by dividing by the number of days in a month assuming even distribution (TPWD 1998).

Inflow constraints were divided into three sets of flow bounds: monthly, seasonal (based on the use of 2-month seasons in the harvest equations), and annual (TPWD 1998). The monthly inflow lower bound was set at the 10th percentile and the upper bound was set at the median. In other words, in no month would TXEMP calculations exceed the median flow for that month based on the historical record, which for the Guadalupe was 1941-1987.

For seasonal (2-month) inflows on which the harvest equations are based, the bounds were set close to the sum of the two corresponding months. The lower bound was rounded to an even number slightly lower than the actual total and the upward bound was rounded slightly higher. This extension of the bounds was to allow the TXEMP model to have more maneuvering room to search for an optimal solution (TPWD 1998). An example of two seasons in table 13.2 shows the results of this process.

Table 10.2 - Upper and lower bounds in thousands of acre-ft/month for the Guadalupe Estuary (TPWD 1998).

Season Months	Sum of Lower Bounds	Sum of Upper Bounds	Seasonal Lower Bound	Seasonal Upper Bound
Jan-Feb	80.1	235.4	75.0	300.0
Mar-Apr	85.2	228.0	80.0	300.0

For annual upper and lower inflow bounds, the concern was false estimates of true maximum harvests (TPWD 1998). To avoid this, narrow ranges were run a number of times and the individual runs were combined into a single performance curve. For the Guadalupe, the smallest annual lower bound used was 200,000 acre-ft/year and the largest upper bound was 2.2 million acre-ft/year. Normally for a model run, the upper bound was set at the lower bound plus 200,000 acre-ft, then the model was run 10 or more times and combined into one performance curve (TPWD 1998).

Biomass Ratios

The biomass ratio is a model constraint based on harvest data from the estuary that assures that the relative harvests of the target species predicted by the model fall into ranges actually observed for the estuary (TPWD 1998). This prevents model results from providing abundant harvest for one or two species at the expense of the other target species.

Salinity Data and Constraints

Salinity data in parts per thousand (ppt) were taken from single measurements at various times of the year under a number of state programs prior to 1986. Since 1986 many one month continuous salinity data collection periods have been recorded by Hydrolab Datasondes left in the bay and taking hourly measurements. Since there are more new data points than pre-1986 ones, the data from the Hydrolab for seven day periods are averaged into a single value. The period of record is 1967-1994 and the numbers of data points for the three salinity zones of the model are: Seadrift (n=549), lower San Antonio Bay (n=266), and Espiritu Santo Bay (n=345). The three salinity zones were the result of work done by TWDB

In the model development stage in which all the major estuaries were generally divided into upper, mid-, and lower regions to establish salinity gradients (Longley 1994).

Salinity bounds were selected by the staff of the TPWD and TWDB by considering frequency distributions including the 25th and 75th percentiles, and the biotic salinity limits for major estuarine plants and animals (TPWD 1998). In most instances for the Guadalupe Estuary the monthly lower bound salinity was set below the 25th percentile or within 3ppt of the 25th and the upper bound was generally set above the 75th percentile.

Sediment Constraint

Sediment is required to maintain delta and shallow-water habitats in the upper areas of the Guadalupe Estuary. To enable TXEMP to satisfy the minimum flow necessary to transport these sediments, a sediment constraint was calculated by determining two major factors: the sea-level rise in that portion of the state and the percent of sediment that is deposited at the mouth of the river and not carried into the other portions of the bay and Gulf of Mexico (TPWD 1998). It was determined that 21 percent of the sediment entering the critical portion of the delta was actually deposited there to be used for delta construction. From previous data it is known the sea level rise at the Colorado River Delta (80 km east of the Guadalupe Delta) is measured at 8 mm/year. From this information it was determined that 439,375 acre-ft/year of inflow is required to maintain a healthy deltaic structure; therefore, this amount was set as the lower bound sediment constraint. Only the lower bound constraint was of interest to this analysis so the upper bound was set arbitrarily high (TPWD 1998).

Nutrient Constraint

Nitrogen was determined to be the nutrient most likely to limit primary production for the Guadalupe Estuary (TPWD 1998). Preliminary analysis determined that an annual inflow of 286,000 acre-ft/yr would provide a sustainable nutrient input; however, it was based on the assumption that current nutrient loading rates would continue into the future. Brock (1995) refined the nutrient flow demand by examining current nutrient loading rates, pre-modern loading of nitrogen and ongoing improvements to water quality. Current flow-weighted nitrogen loading is 2.33 mg/l while pre-modern levels are 0.9 mg/l; the difference being upstream anthropogenic activities (TPWD 1998). With these new considerations, an inflow of 860,000 acre feet/yr would be required to offset nutrient loss to the Gulf, lower estuaries, burial in the sediment, and harvest and migration of fish. As in the sediment constraint, only the lower bound is of concern for TXEMP operation; therefore, an arbitrarily high upper bound was set (TPWD 1998).

Model Output – MaxH and MinQ

The output from the TXEMP for the Guadalupe Estuary is shown in figure 10.3 - TXEMP model for the Guadalupe Estuary. The MinQ is the minimum flow that satisfies all of the model constraints. In between the inflow values satisfying all the model constraints is the MaxH which TPWD describes as "Optimal flow producing maximum fisheries harvest . . ." (TPWD 1998, 2). The MinQ-50, not often referred to in the literature, is the MinQ result at the 50 percent harvest target constraint as opposed to the MinQ at the 80 percent target constraint.

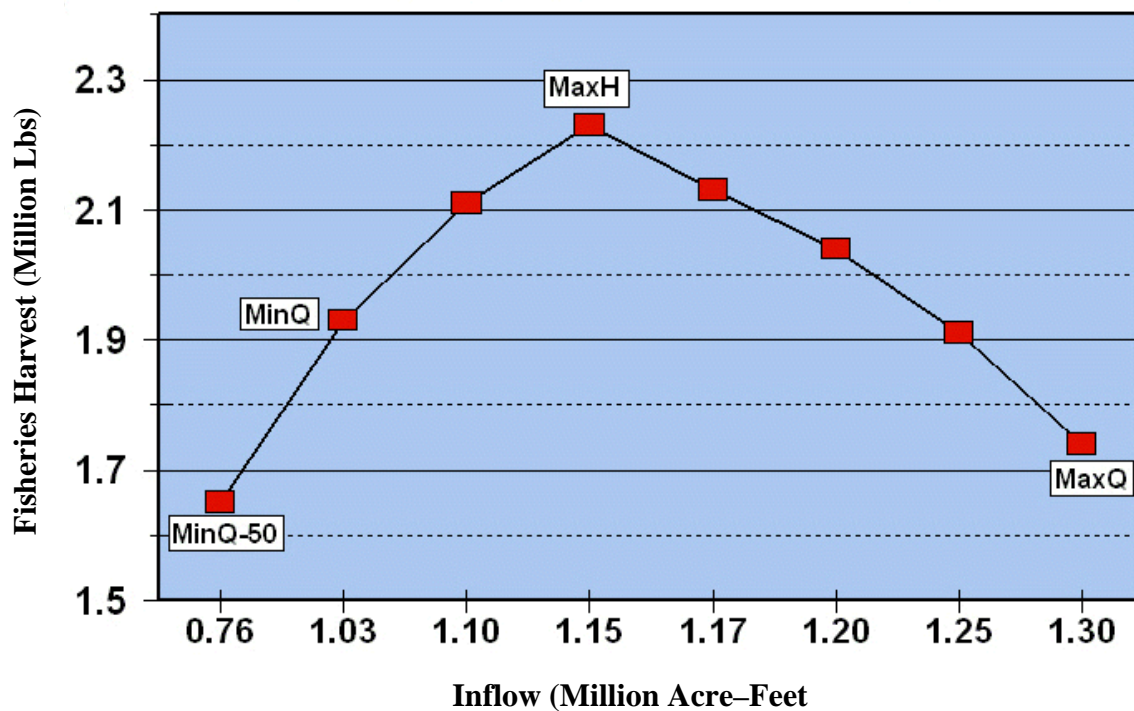


Figure 10.3 – TXEMP model for Guadalupe Estuary (from TWDB website 2004)

The statistical probability for the model is 50 percent meaning there is only a 50 percent probability that the MaxH or MinQ will achieve or maintain a certain salinity level (TPWD 1998). Because of the uncertainty with salinity-inflow relationships, the TPWD cautions that the results of the model be treated conservatively when applied to management systems. Since MinQ is at the lowest edge on the performance curve, they recommend using the more conservative MaxH flow which would allow some room for error (TPWD 1998).

Seasonal timing of freshwater inflow is also critical, therefore monthly flow recommendations for MaxH and MinQ are calculated (TPWD 1998) as shown in table 10.3.

Table 10.3 - Monthly inflow needs (in thousands of acre-feet) of Guadalupe Estuary for two simulations (from TPWD 1998)

Month	MinQ	MaxH
January	111.2	111.2
February	124.2	124.2
March	52.4	52.4
April	52.4	52.4
May	186.0	222.6
June	136.0	162.7
July	60.8	88.6
August	60.8	88.6
September	52.4	52.4
October	52.4	52.4
November	73.8	73.8
December	66.2	66.2
<i>Total Needs</i>	1028.8	1147.4

Table 10.4 shows estimated pounds of catch by target species for each month of MinQ or MaxH modeled flow. In addition to the seasonal variance needs there are occasional higher inflows that occur. The TPWD recommends that:

Table 10.4 - Predicted species harvest (in thousands of pounds) under two inflow simulations for Guadalupe Estuary (from TPWD 1998)

Species	MinQ	MaxH
Blue Crab	255.5	379.9
Oyster	609.7	702.7
Red Drum	63.8	84.0
Black Drum	32.4	32.4
Spotted Seatrout	113.0	114.8
Brown Shrimp	547.8	704.0
White Shrimp	918.2	910.3
<i>Total Harvest</i>	2540.4	2928.0

. . . water management programs retain these occasional higher inflows, particularly above the target level, because they are critical to maintaining the biological productivity and ecological health of this estuary (TPWD 1998, 40).

The TPWD recognizes that in drought conditions neither the MaxH nor MinQ flows could be met; however, they recommend that the frequency of these reduced flows should not increase beyond historical rates of occurrence (TPWD 1998). The main intent of the target flows created by the models is that when there are sufficient river flows that those total flows be allowed to reach the estuary before any new diversion is approved (TPWD 1998). At lower flows it is up to watershed management programs to maintain the frequency of those flows compared to historical events. Drought cannot be completely avoided, but:

What can be and should be avoided are the adverse environmental effects due to human-induced increases in the magnitude and duration of naturally occurring droughts (TPWD 1998, 44).

The LCRA and the Matagorda Bay Study

A separate section on the methodology of the Matagorda Bay inflow needs study is required because the Lower Colorado River Authority (LCRA) in cooperation with state agencies completed the study in the mid 1990's and used different methods in some cases than were used in the subsequent bay studies. The LCRA needed a quantitative inflow requirement to complete its management plan of the Colorado River which consists of six major reservoirs that control a significant amount of the flow of the Colorado River (fig. 10.4) that flows to Matagorda Bay (Martin et al. 1997). The Lavaca River is the second major tributary to Matagorda Bay and thus the term Lavaca–Colorado Estuary is used in various combinations with Matagorda to describe the area. A cooperative agreement with LCRA, TPWD, TWDB, and the then TNRCC (TCEQ) was signed in 1993 to determine the

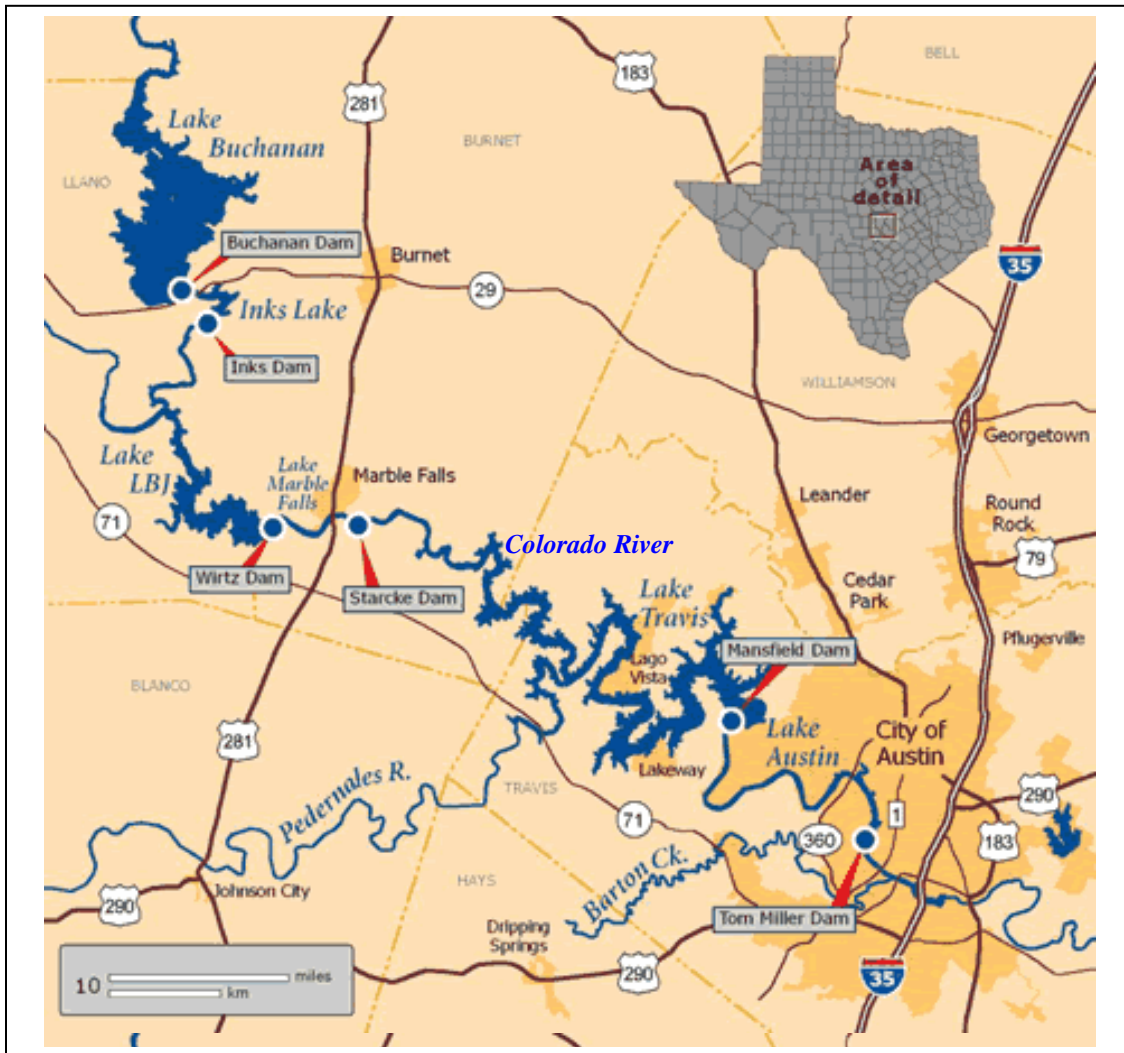


Figure 10.4 – Dams on Colorado River (from LCRA website 2003)

freshwater inflow needs of the Matagorda Bay system. In the words of the LCRA:

The LCRA agreed to adapt or modify existing methods for estimating freshwater inflow needs used by the TPWD and TWDB and apply those methods to compute alternative freshwater inflow needs for the estuary. The participating state agencies provided technical assistance and advice to the LCRA (Martin et al. 1997, i).

In the Memorandum of Agreement (1993) all parties are permitted to object to any or all of the final report and LCRA reserves the right to recommend revisions to their management plan "... as it considers appropriate based on the findings of the study"(LCRA 1993, 3).

Two of the major methodological departures from the procedures recommended in Longley (1994) involve sources of productivity data and the use of salinity for determining the lower flow requirement, replacing the more complex MinQ described in Longley's work and used in the other bay studies. According to the LCRA, although commercial harvest data (as used in the other bay studies) was available for a longer period of record than the TPWD monitoring data, the commercial harvest data contains many potential errors (Martin et al. 1997). Fishing effort, catch efficiency, consumer demand, harvest regulations, and economic factors could cause unexplained variances in the data set. Also some commercial operations fish in a larger area than one bay in a single voyage and the data assumes all landings reported in a bay are from that bay (Martin et al. 1997). Except for using commercial data for oysters and flounder that are difficult to collect by seining, the LCRA used the TPWD collected data set which only had 14 years of data as compared to the commercial records that spanned 30 years. Using the described data the Target Freshwater Inflow Needs (FIN) for the Colorado River was calculated at 1,033,100 acre-ft annually and 2,000,000 acre-ft. for the entire basin including the Lavaca River and other smaller rivers, streams and surface runoff. The term MaxH is not used in this study although much of its methodology was utilized in determining Target FIN. (See table 10.5 – Target FIN for Matagorda Bay).

For the minimum flow recommendations the LCRA chose to use flows necessary for maintaining tolerable salinities for oysters during the drought of record as the target minimum flow. Oysters being immobile unlike the other target species listed in Table 10.1, cannot tolerate salinities for an extended period above 25 ppt. The flow for the Colorado River required to keep the salinity under 25 ppt was determined to be 171,000 acre feet per year and is called the Critical Freshwater Inflow Needs (Martin et al. 1997) (table 10.6). For

Table 10.5 - Target FIN for Matagorda Bay (from Martin et al. 1997)

Month	Colorado River Inflows	Lavaca River Inflows	Other Contributing Basin Inflows
January	44.1	14.8	35.4
February	45.3	14.5	40.3
March	129.1	33.9	32.9
April	150.7	57.3	44.1
May	162.2	60.1	76.3
June	159.3	58.8	71.4
July	107.0	28.0	59.6
August	59.4	16.0	24.8
September	38.8	21.9	90.6
October	47.4	16.0	78.2
November	44.4	12.8	35.4
December	45.2	12.2	31.7
Basin Total Inflow	1033.1	346.2	620.7

the entire basin the Critical FIN was calculated to be 287,400 acre feet per year. The LCRA calls for a reexamination and correction if necessary, of inflow-salinity relationships in five years.

In *Recommended Revisions to the Water Management Plan* (2002c), the LCRA concludes that the critical FIN should remain the same. Although LCRA acknowledges that additional data indicate that about three times the monthly inflow is required, it expresses doubt that the original oyster-salinity relationship was ever 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” (LCRA 2002c, 14). LCRA further recommends that additional study be completed in cooperation with TCEQ,

Table 10.6 – Critical FIN for Matagorda Bay in thousands of acre–feet (Martin et al. 1997)

Month	Colorado River Inflows	Lavaca River Inflows	Other Contributing Basin Inflows
January	14.26	2.26	5.08
February	14.26	2.26	5.08
March	14.26	2.26	4.45
April	14.26	2.26	6.14
May	14.26	2.26	10.70
June	14.26	2.26	10.70
July	14.26	2.26	8.92
August	14.26	2.26	3.57
September	14.26	2.26	13.38
October	14.26	2.26	11.59
November	14.26	2.26	5.00
December	14.26	2.26	4.46
Basin Total Inflow	171.1	27.1	89.2

TWDB and TPWD as originally discussed, before considering changes to the inflow requirements.

Mention should be made of the numerous modifications that have occurred or been performed over the years to the Colorado River and especially the eastern arm of the bay and also to what is called East Matagorda Bay (fig. 10.5). Beginning with the removal of log jams over forty miles long in 1930, the Colorado River Channel was directed to the ocean and no longer provided inflow to the two portions of the bay (Martin et al. 1997). In 1991 the river was re-diverted to the eastern arm of Matagorda Bay and except for some mixed

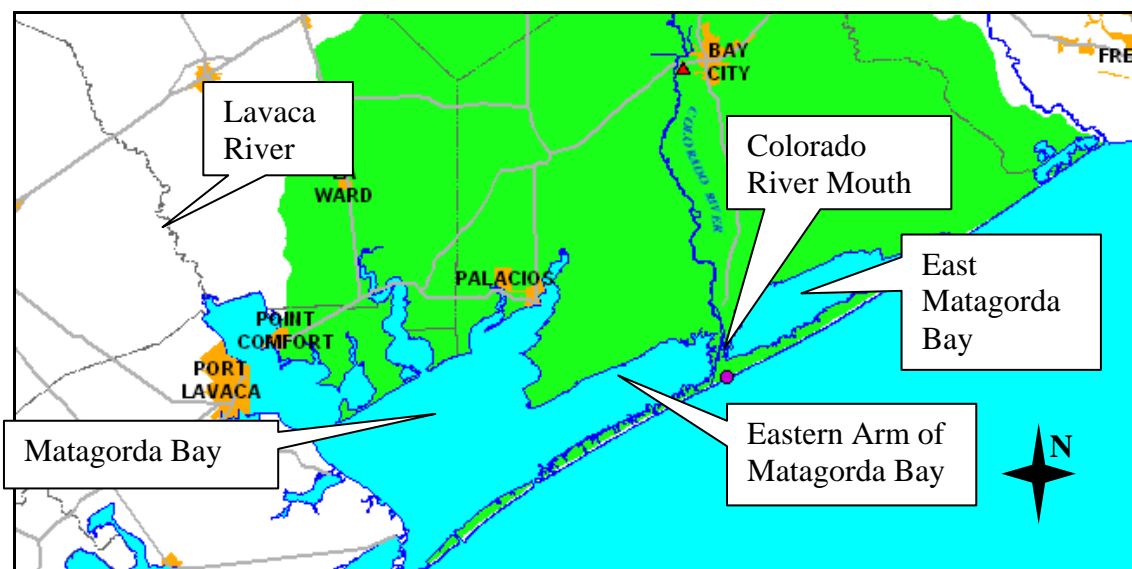


Figure 10.5 – Matagorda Bay system (base map from LCRA website 2004)

freshwater from the Intercoastal Canal, virtually no Colorado River water flows into East Matagorda Bay.

Until a new study of minimum flows is completed, the LCRA recommends a change in the management of stored water with more release of environmental flows for the bays (LCRA 2002c). This would be achieved by a complex altering of irrigation flows and trigger reservoir amounts at the beginning of each year that determine releases for the remainder of the year.

While the study and management discussions proceed, the water planning process also continues. In 2001 the LCRA assessed the water availability of four new off channel reservoirs including effects on freshwater inflow (Martin 2001). They concluded that the reservoirs would cause significant change in salinity conditions during critical drought of record periods, but it is not clear how much worse the environmental stress would be (Martin 2001). The four reservoirs were placed in the Region K and state water plan (TWDB 2002b), but Martin (2001) suggested further impact studies were needed before implementation,

including analysis of using some of the newly stored water to mitigate the increase in salinity.

The ongoing studies, planning and management decisions for the Colorado River are a microcosm of the process of freshwater inflow protection for the other major bays in Texas, admittedly complicated by the presence of the LCRA as another partner in the studies and by the use of different methods for the studies. On the Colorado River management of the reservoirs is changing in response to new studies showing more freshwater inflow need which could be considered an adaptive management action. At the same time the planning process is calling for new reservoirs with potential negative effects on the estuary (Martin 2001) which in a manner negates the adaptation. How the recommended projects in the water plans will comply with the freshwater inflow needs studies is still an unanswered question. The fact that the reservoirs are in the plans means that they have passed the consensus criteria tests, but whether the criteria preserve the needed flows for the estuaries is still under question (TPWD 2002; USFWS 2001; Texas Living Waters Project 2003).

The Coastal Bend Bay Area Studies

The Coastal Bend consists of a 12-county area containing three of the seven major estuaries in Texas – the Aransas Bay, Corpus Christi Bay and the upper Laguna Madre. The Corpus Christi Bay – Nueces Estuary study was completed in 2002. The bay and estuary studies for the Aransas Bay and the upper Laguna Madre are not complete and TPWD has not reviewed them; however, some of the model runs for those two bays are available from TWDB.

The Nueces Estuary presented a modeling challenge due to ". . . the almost complete lack of a typical estuarine salinity gradient in the system . . ." (TPWD 2002, 2). Reduced

inflows mainly as a result of Lake Corpus Christi and Choke Canyon Reservoir have resulted in a 55 percent decline in the annual flow of the Nueces over the past 60 years (Coastal Bend Bays and Estuaries Program 2001). The Nueces Basin has highly fluctuating rainfall patterns and the delta had historically adapted to receiving periodic flood flows that would overflow the channel and provide freshwater for the normally productive and low saline delta marshlands. The mean amount of freshwater flow from these higher flow events reaching this delta area has been reduced by 99 percent compared to before the construction of Choke Canyon Reservoir in 1982 (Irlbeck and Ward 2000). Note: The 1982 construction date preceded Texas Administrative Code § 297.1 requiring that 5 percent of the firm yield of a reservoir be released for freshwater inflow if the project was within 200 river miles of the coast. An additional factor causing higher salinities in Nueces Estuary than Texas estuaries to the east is a high evaporation rate (Coastal Bend Bays and Estuaries Program 2001).

The combination of these anthropogenic alterations and high evaporation rates creates a bay with inverse salinity – with fresher water near the Gulf and more saline water in the delta area near the river's mouth (Nature Conservancy 2002). Normal ocean salinity is around 35 parts per thousand (ppt) and most of the bay is > 30 ppt. As previously discussed 25 ppt was the maximum tolerable salinity in the Matagorda Bay model (Martin et al. 1997). As a response to this excessive salinity the Rincon Bayou project is underway to deliver more fresh water to the upper portions of the Nueces delta by providing an overflow channel and pipeline to the delta so flood waters will no longer be necessary to provide the needed freshwater (Nature Conservancy 2002).

Because of the salinity alterations to the Nueces Estuary, the normal modeling verification techniques using comparisons of production to salinity and inflows had to be altered; instead, direct correlations between freshwater inflow hydrology and fisheries were derived (TPWD 2002). TPWD Coastal Fisheries monitoring data from 1978-1997 were used for fishery data in this correlation.

It was found that instead of monthly recommended flows, a seasonal flow recommendation was needed for the Nueces Estuary due to the ecological adaptation of the bay species to the fluctuating low flow-high flow events or pulsed hydrology pattern (TPWD 2002). The monthly model results for Min Q and Max H are shown in figure 10.6. The MinQ-sal figure in the graph represents the result of running the model with only the salinity constraint. The TPWD recommends that from April through July the total cumulative monthly MaxH inflow (89,200 acre-feet) be delivered (TPWD 2002). The TPWD also specifies that the inflows be delivered to the upper delta area which is the most critical habitat and that the delivery could be in one or two pulsed events in April – July (TPWD 2002). If these April – July flows do not occur in a low flow year, then the TPWD calls for cumulative September through November MinQ flows (27,500 acre-feet) to be delivered to the upper bay near the delta to provide a refugium (TPWD 2002).

The Nueces Estuary and its accompanying freshwater inflow model are unique in many ways. Historical overall flow reductions, reduction in frequency of pulsing flood events, and a high evaporation rate create a highly saline bay with little variation, causing salinity to have to be abandoned as a factor in modeling inflow/productivity relationships (TPWD 2002). Also due to the alteration of pulsing flood events, the TPWD called for cumulative MaxH and MinQ releases in low flow years as pulse events (TPWD 2002).

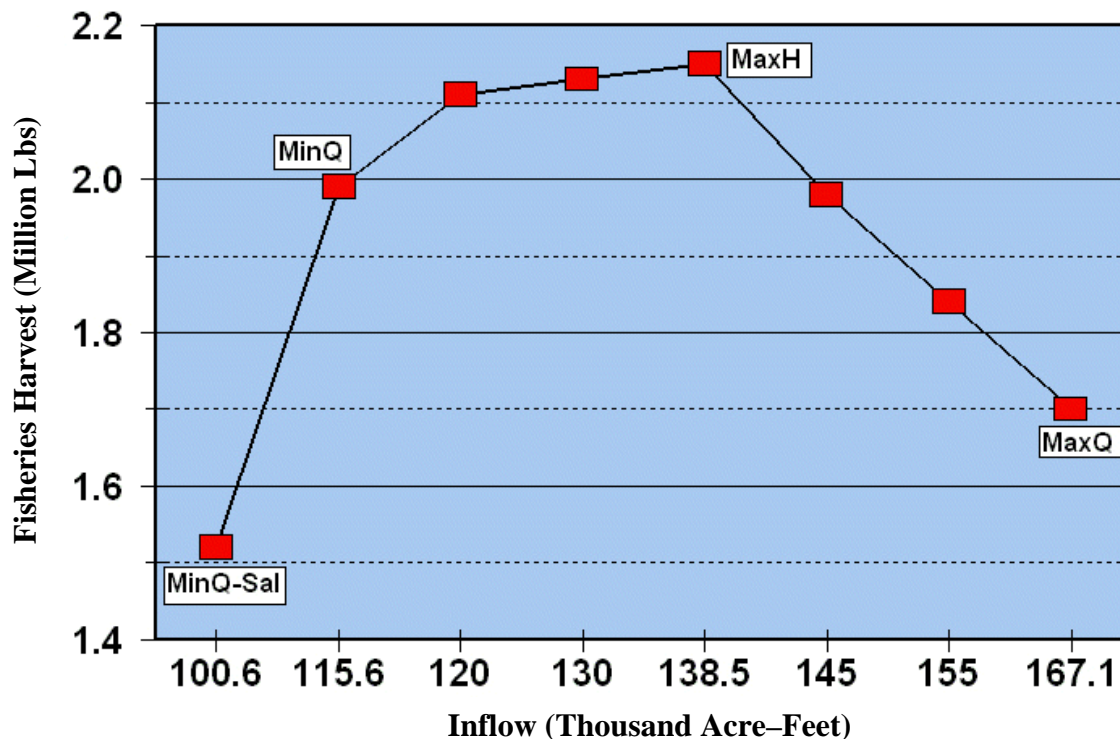


Figure 10.6 – Nueces Estuary TXEMP (from TPWD 2002)

Summary Discussion of the Bay and Estuary Studies

Challenges to the Studies

The Lower Colorado River Authority's previously described inflow study procedure could be considered a challenge to the methodology described by Longley (1994) and generally followed for the other published TPWD bay and estuary studies for the Trinity-San Jacinto, Guadalupe and Nueces basins. The LCRA also calls for reevaluation of their own methods for calculating critical freshwater inflow needs and described their objection to using commercial harvest as the baseline data for the target or upper range freshwater inflows (Martin et al. 1997).

The Galveston Bay inflow model is being reanalyzed by an engineering firm hired by a consortium of water interest groups including the Trinity River Authority (TRA), the City of Dallas, Tarrant Regional Water District (includes Ft. Worth), City of Houston, and North Texas Municipal Water District (TRA 2003). It is notable that the group consists of members of water planning regions C and H – Region C being the upstream portion of the Trinity basin encompassing Dallas and Ft. Worth, and Region H including the downstream portion of the Trinity basin and Houston and Galveston Bay. Part of the group's reason for wanting to revisit the issues in the study was the discovery that in a drought all of the Trinity reservoirs held only 2.1 million acre-feet of water per year and the MinQ for Galveston Bay was 4.2 million acre-feet with the Trinity River's share being 54 percent or 2.3 million acre-feet (TRA 2003). The group states that their primary concern is the use of commercial fisheries harvest data as an indicator of productivity as opposed to the TPWD's coastal fishery monitoring data. According to the TRA, commercial harvest data is influenced by such factors as the cost of fuel and the relative economic value of particular species in different years, neither of which is related to freshwater inflows (TRA 2003). They question the correlation between the commercial catch records and the TPWD sampling data. The TRA, speaking for the group, claims that these two data bases should correlate if one is trying to determine the health of the bay as a factor of the quantity of fish and shellfish in the bay. This lack of data correlation has been brought to the attention of the state agencies according to an October, 2003 article in the river authority's newsletter (TRA 2003).

More recently the partners in the Lower Guadalupe Water Supply Project (LGWSP) – the Guadalupe Blanco River Authority (GBRA), the San Antonio River Authority (SARA), and the San Antonio Water System (SAWS), have hired the same engineering firm studying

the Galveston Bay model to analyze the Guadalupe Estuary model (Bowen 2004). The partners felt there was a need to more accurately determine the necessary inflow requirements into the Guadalupe Estuary since their Lower Guadalupe Water Supply Project intends to direct river water from near the mouth of the Guadalupe River approximately 160 miles upstream to San Antonio. San Antonio, with a metro population of over two million, lies on the San Antonio River which joins the Guadalupe River less than 20 miles from the coast (fig. 13.2). The LGWSP partners and their engineers express concern over the statistical viability of the commercial catch data (Bowen 2004) for reasons similar to those cited by LCRA and the group reexamining the Galveston Bay model.

In three out of the four bays with completed TPWD/TWDB inflow studies, there are ongoing studies to re-analyze the methodology and possibly arrive at improved statistical recommendations; two of the reviews analyzing the use of commercial catch data. The TPWD and the TWDB say they welcome the reviews and realize this is a dynamic process (Bowen 2004). The groups challenging the studies to this point are all water-using entities, and except for the Matagorda Bay model, there have been no challenges to the models from environmental or conservation groups.

Conclusion

The cooperative studies by the Texas Water Development Board and the Texas Parks and Wildlife Department as mandated in § 16.058 of the Texas Water Code are the culmination of over twenty years of effort that includes an initial round of studies of the major estuaries in the early 1980's (Longley 1994) and now the near completion of the second set of freshwater inflow studies. After the first studies were completed it was decided

that the data were too unreliable to determine the quantities of freshwater inflow for management and regulatory purposes (Longley 1994).

According to the TWDB (2003-2004), the current estuary needs studies for all seven major estuaries are complete and the graphical output is available on their website; however, the published summaries with biological opinions from the TPWD are only available for four of the estuaries (TPWD 2003-2004). As the completion of this second generation of studies nears, various parties are hiring their own engineering firms to challenge the data and the process. With the four completed studies, two are being reviewed by outside entities – Galveston Bay and the Guadalupe Estuary, and the LCRA is requesting review of its data and processes on the third study.

With the second round of planning already underway (TWDB 2002b), the studies not quite officially complete (TPWD website 2003), the results of three of the four completed studies in question (Martin et al. 1994; TRA 2003; Bowen 2004), widespread agreement on the lack of state protection of freshwater inflow in the planning and water rights process (TWDB 2002b; USFWS 2001; LCRA 1997; Texas Living Waters Project 2003), and an interim legislative committee starting to meet in 2004 to reexamine environmental flow protection (SB 1639 2003), there are serious questions about the overall integration and consistency of the components of water rights, water planning and estuary studies.

Following a chapter about the Water Availability Model, the components of freshwater inflow protection will have been covered individually and this section will close with a comparative administrative analysis of the three principal agencies involved in protection of freshwater inflow. The following section will then quantitatively compare the various aspects of freshwater inflow protection.

CHAPTER 11

THE WATER AVAILABILITY MODEL

The fundamental component for analyzing the quantitative results of the water plans, the estuary studies, and the water rights system is the Water Availability Model (WAM) which estimates the resulting streamflow remaining under various scenarios of weather conditions and human-related water use. The WAM is a system with many components including water rights and related databases, database management software, a geographic information system, graphics programs, user interfaces and a simulation program set called the Water Rights Analysis Package or WRAP (Wurbs 2000). As discussed later in this chapter, the output of the WAM is not necessarily suited for analyses of all aspects of freshwater inflow in all basins. The principal use of the WRAP, which simulates management scenarios of the priority system, is to assess water availability and reliability for existing and proposed water rights (Wurbs 2000). As will be shown later, this availability function may not provide accurate results for examining the water plans and the estuary studies, at least in the Guadalupe Basin.

The WAM replaces older water availability models that had been developed for only eight of the twenty three river basins in Texas. These previous models were basin-specific and did not have the capability to handle all the data and calculations required to manage fully Texas water resources (TNRCC 1998). Following the brief but serious statewide drought in 1996 that caused lake levels and streamflows to drop to 11 to 50

percent of their historic levels, the Texas legislature as part of Senate Bill 1, 1997 funded the development of the water availability models for all 23 major rivers in Texas (TNRCC 1998). All of these availability models are complete as of the end of 2003 except for the Rio Grande model which is in the review process. The WAM project was managed by senior staff from the TCEQ, TWDB, and TPWD with input from a workgroup of water use interests including the Sierra Club, Galveston Bay Foundation, Coastal Bend Bays Foundation and water user groups such as the Texas Water Conservation Association or TWCA (TNRCC 1998). The project team with the assistance of various engineering firms selected an existing river basin model – the WRAP designed by Texas A&M University to be the principal hydrologic model software for the WAM.

The WRAP is a simulation model that can assess the capabilities of meeting certain management or use requirements during a hypothetical repetition of historical hydrology (Wurbs 2000). There are two basic requirements for a river basin model – data on streamflows and water demand data (TNRCC 1998). Developing the streamflow data is the most time-consuming portion of the project due to the necessity of calculating naturalized streamflows. Naturalized streamflows, or flows that would have historically occurred in a given year if there were no human impact (diversions, reservoirs, return flows, etc.), are the starting point for calculating the availability of water (TNRCC 1998). Historical gauged flows are frequently used to assist in developing modeled naturalized flows, but there are often gaps in the data. The missing data are derived by using regression techniques to extend flow data from other known months of the same gauge and data from other gauges (Wurbs 2000). For most of the basins the historical gauged

USGS data covers 1940 to the present and includes the 1950-1956 drought of record for most of Texas (Wurbs 2000).

Wurbs (2000) describes the WRAP as a river /reservoir model that has limited capabilities for simulating groundwater interaction with surface water. In rivers with dominant springflows such as the San Antonio, Guadalupe and Nueces River basins, the WRAP reflects springflows that are tied to management projections of the required spring output since the future flow of the river is the concern and the various management scenarios are not reflected in historical gauged flows (Wurbs 2000). As a result, the historical flow of the Guadalupe River for example, does not correlate with the naturalized flow and sometimes historical flow exceeds naturalized flow since the use of the associated aquifers may not have been maximized historically (See later discussion in this chapter). After naturalized flows are calculated, the WRAP model subtracts all existing water rights in order of their priority to determine the amount of flow, if any remaining, that is available for future permits or other purposes such as instream flow and bay and estuary freshwater inflow.

WAM Modifications and Technical Issues

Among the initial modifications required for the WRAP was the addition of the capability of calculating instream flow and freshwater inflow for bays and estuaries. Other initial modifications were in the areas of channel loss/gain, multiple use/multiple priority flows, and return flows from surface and groundwater sources (TNRCC 1998). The TNRCC (2001) discusses several technical issues that had to be resolved in the early stages of model development in order for the WAM to function properly and efficiently. This discussion reveals some of the principal conflicts between water users and

conservationists as they struggle to deal with issues of environmental flows that are not defined or not adequately defined in Texas laws, codes, and rules. The following discussion includes only those issues involved in instream flow or freshwater inflow.

The first technical issue involved flows released from a reservoir for a junior water right that have to flow past a senior water right location on their way to the junior water right. The question arose that if the senior water right had an instream flow requirement to meet, could these flows be counted as instream flow? To accomplish this would require extensive reprogramming of the WRAP requiring a delay in the project and more funds. It was decided to adopt a simplifying solution by assuming all releases for junior water rights in this case would be ignored by the model. When the WAM management team adopted this assumption they agreed to consider incorporating the capability of calculating this portion of the streamflow in a future version of the model (TNRCC 2001). From a water user perspective, it is easy to see why a user would want credit for this junior released water that flows past their diversion included in the model. From an environmental perspective, opinions might vary depending on the scope or "whole" as defined by Savory (1999). If the concern is the instream flow at the point of the senior diversion, the requirement could be numerically met. In a wider area of concern both spatially and temporally including both the portion of the river from the reservoir to the junior water right and comparing current to naturalized flows, it becomes a much more complex problem to decide how to treat in the model this released flow from a reservoir that did not historically exist. From an environmental perspective should this stored and released flow be credited as instream flow? Another part of this question is how this instream flow calculation affects the bays and estuaries. The assumption is

that instream flows are of concern only at the point of diversion. Once that flow requirement is satisfied there is not a continuum linking that point to the estuary, however far downstream it may be.

Another technical issue involving instream use dealt with reservations of instream flow that are not associated with permits; for example if the planning process wanted to establish a minimum target flow for a stream segment (TNRCC 2001). The question was whether to have the model treat these reserved flows in the same manner as a water right with a priority date or to establish some "observation points" which would indicate the frequency with which flow targets are met. The arguments on this issue are a microcosm of the freshwater inflow debate as evidenced from the TNRCC discussion: "The principle [sic] risk associated with this issue stems from potential controversy related to the priority of environmental flows" (TNRCC 2001). If these flows were modeled as a "right" someone would have to assign a priority date to that right for the model to function which the TNRCC states could be problematic:

Such assignment of priority dates would require more policy guidance regarding the priority of documented instream flow demands relative to existing permitted water rights (TNRCC 2001).

The resulting decision is a metaphor for the instream flow/freshwater inflow debate. It was decided to include environmental flows in the model as "observation points" only that would report the frequency and extent to which the flow needs were met, but not affect any of the diversions; however, the model will be flexible enough to also handle these flow needs as a "right" with a priority need that will affect junior rights in case it is decided to consider them with an associated priority date (TNRCC 2001). In conclusion,

the policy-makers have not made up their minds on the future structure of environmental flow protection; therefore, the model will remain flexible enough to handle which ever direction they take.

In a similar discussion the management team decided to treat streamflow requirements associated with permits with the same priority date as the permit when running the model. Essentially this treats streamflow restrictions in a permit as a ". . . priority immediately senior to the water right with which they are associated" (TNRCC 2001, #3). The reference shown here for the priority date for permit restrictions as compared to the lack of priority for reservations not associated with permits follows the apparent policy trend of maintaining the old priority system without fully addressing the priority of streamflow needs in a stream segment that could be continuous to the estuary.

A decision affecting the overall amount of water available according to the model involves the sedimentation of reservoirs over time. The issue was whether to use the "as built" dimensions of a reservoir or use the estimated reduced capacity due to sedimentation in year 2030 to determine the amount of stored water to use in the model runs. The first method would more accurately represent current available stored water supplies and the second method would understate current stored water while more accurately estimating water amounts in 2030 in keeping with planning analysis. The decision was to use the "as built" volume to determine perpetual permits and amendments while the pro-rated 2000 volume would be used for current use runs for temporary permits (TNRCC 2001).

The definition of the drought of record was proposed to either be based on the year in the record when the least amount of water *can* be diverted or the year in the record that the least amount of water *is* diverted (TNRCC 2001). The decision was made to use the year that the WAM computes to have the lowest *simulated diversion* amount as the drought year of record. Using this simulated amount would incorporate various complicating factors of water rights including type of use, demand distribution, and direct diversion versus on-channel reservoir diversion (TNRCC 2001).

Each engineering contractor for the WAM was required to develop nine modeling runs, which are outlined in table 11.1. RUN 3 was designated the official permitting run for use by the TCEQ when examining the availability of new perpetual (as opposed to temporary) water right applications. For temporary permits RUN 8 is utilized which considers the year 2000 reservoir capacity, assumes all return flows, and includes other term water rights (TNRCC 2001).

The decisions made on technical issues seem to parallel the trends in state water policy in general. An exception is the decision on future treatment of the capacity reduction of reservoirs due to sedimentation that varies somewhat from the state planning policy of projecting maximum use and accurate availability of water in 2030 as seen in the parameters of Run 3 (TNRCC 2001). However, when examined more closely, the intent might have been to protect the promised original amount of water stored in reservoirs that was defined in the original permit, and the preservation of this legal right was deemed more important than the accurate projection of available water in 2030.

Table 11.1 – Model runs of the WAM based on *WAM Resolved Technical Issues* (TNRCC 2001).

Run Name & Description	Amt. of Diversion	Reservoir Capacity	Return Flow Assumption	Term Water Rights
RE–USE RUNS (varied return flow amounts)				
RUN 1 – 0% re–use	All authorized Diversions	As built	<i>All return flows</i>	Not included
RUN 2 – 50% re–use	All authorized Diversions	As built	<i>50% return flows</i>	Not included
RUN 3 – 100% re–use	All authorized Diversions	As built	<i>No return flows</i>	Not included
CANCELLATION RUNS (varied diversions and return flows)				
RUN 4–Modified diversions	<i>All diversions used in past 10 yrs.</i>	As built	<i>All return flows</i>	Not included
RUN 5–Modified diversions	<i>Max. use in last 10 yrs.</i>	As built	<i>All return flows</i>	Not included
RUN 6–Modified diversions	<i>All diversions used in past 10 yrs.</i>	As built	<i>No return flows</i>	Not included
RUN 7–Modified diversions	<i>Max. use in last 10 yrs.</i>	As built	<i>No return flows</i>	Not included
CURRENT CONDITIONS RUN (term water availability)				
RUN 8–Modified diversions	Max. use in last 10 yrs.	<i>2000 capacity</i>	All return flows	<i>Included</i>
FIRM YIELD ANALYSIS				
Determine firm yield for all major reservoirs (A minimum of 10 acre–feet has to remain in the reservoir in the drought of record)				

Problems of the WAM

As evidenced by the technical issue discussion, the WAM is not simply a pure engineering tool that is immune to the influence of policy decisions. The WAM also is

required to accommodate all the river systems in Texas – a state with highly varied geography, climatology, and alterations by humans including reservoirs, saltwater barrier dams and groundwater management controls. As a result of this monumental task, there are the expected situations where the output of the WAM is being questioned.

The East Texas Region Plan

In the East Texas Region Water Plan Review Draft (Alan Plummer and Associates 2001) there were comments on the inability of the WAM to model accurately the flows of the Neches River due to the release of water from upstream reservoirs during normally low flow periods. The result is a higher historical flow (actual gauged flow with human effects) than a modeled naturalized flow (modeled flow without human effects) in the normally lower flow months. This reversal of expected values is the result of some historical flows (after reservoir construction) affected by the storage of water in higher flow periods and release of water in lower flow periods, while the naturalized flow assumes the absence of the reservoir. This incongruity becomes problematic especially because the trigger and target points of the consensus criteria covered earlier are a combination of naturalized and historical flows.

To demonstrate the WAM shortcomings, the contract engineering firm for the Region I East Texas Plan calculated that at a chosen point on the Neches River, Evadale, the 7Q2 flow (based on historical flow), that is the minimum flow required to pass through a project in Zone 3 drought scenario (see Chapter 8 discussion on the consensus criteria), is 1780 cfs. The WAM indicates that the median modeled naturalized flow which is the trigger for Zone 1, would be 679 cfs for the month of September. Applying these numbers to the consensus criteria, a new reservoir at this location would have to

pass 1780 cfs if it was 50 percent full (drought scenario) and only 679 cfs if it was 80 percent full (high flow scenario) which is the inverse of the intentions of the criteria (Alan Plummer and Associates 2001). The consensus criteria intend for pass-through flow requirements to decrease as the storage in the reservoir decreases. Region I also points out that the naturalized/historical flows below the Sam Rayburn Reservoir show similar incongruities (Alan Plummer and Associates 2001). Also regarding Sam Rayburn Reservoir, according to Region I the releases of freshwater from the reservoir to retard saltwater intrusion downstream (discussed in the water plans, chapter 8) are not recognized in Runs 1 through 8 of the WAM (Region I 2002).

The Guadalupe/San Antonio River WAM

The WAM naturalized flows for the Guadalupe Estuary were generally lower than the historical flows. This is contrary to what was expected since naturalized flows are a model of flows with all anthropogenic influences removed (TNRCC 1998); whereas historical flows are the actual flows which include human influences. Figure 11.1 displays the data for the worst year of the drought of record (1954) for the Guadalupe Estuary showing consistently higher historical flows compared to naturalized flows. An examination of the period of record at the estuary (1941-1989) shows 555 of the 588 months had naturalized values compared to historical values inversely related to expectations. Only 33 months had higher naturalized flows than historical flows, which would normally be expected for all 588 months. Starting with 1941 the first 17.5 years had historical values exceeding naturalized values with the first "normal" month being June 1958. In the 1960's only seven months had normal relative values, in the 1970's four months were normal, and in the 1980's twenty one months showed normal relative

values. For perspective on the relative size of this discrepancy, the average monthly flow for the period of record was 188,601 acre-feet while the average value by which historical flow exceeded naturalized flow was 19,242 acre-feet.

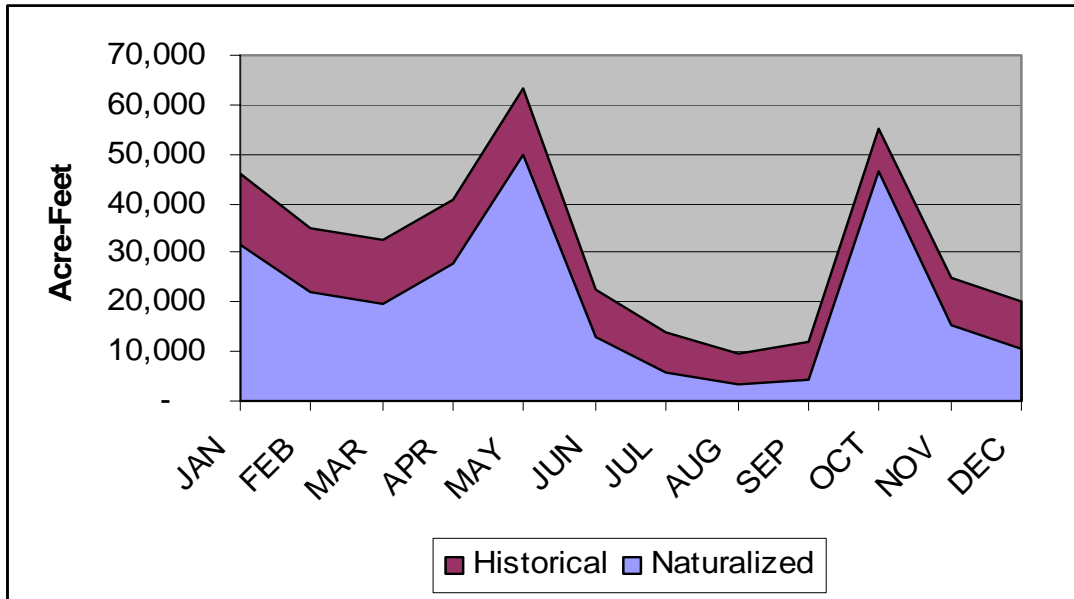


Figure 11.1- Guadalupe Estuary historical and naturalized flow comparison for 1954 (compiled from National Wildlife Federation data Oct. 7, 2003)

Norman Johns (2003-2004) of the National Wildlife Federation attributes this situation to WAM input decisions regarding Edwards Aquifer pumping limits which affect the modeled and historic flows of the Guadalupe and San Antonio Rivers (fig. 11.2). To model what is supposed to be pre-human influenced flow estimates, it was decided that the springflow from the Edwards Aquifer be calculated under the assumption that the Edwards Aquifer was pumped at a constant rate of 400,000 acre-feet per year (Johns 2003). The 400,000 acre-feet per year value is based on the legally mandated

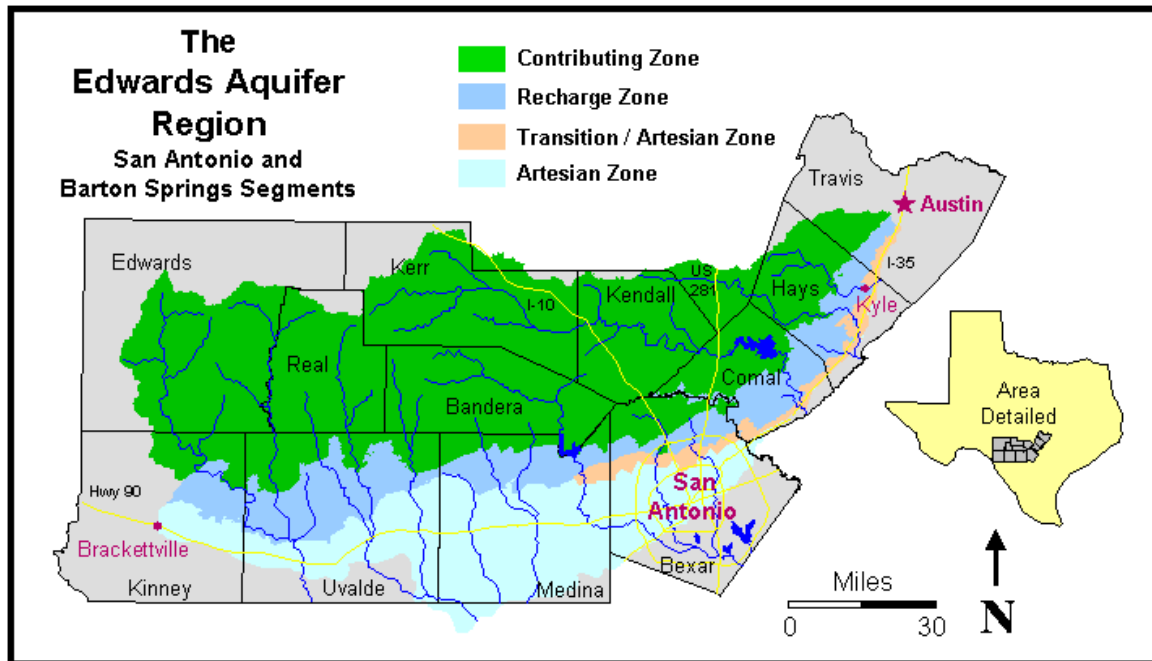


Figure 11.2 – Edwards Aquifer (Gregg Eckhardt 2004)

maximum annual pumping cap that under current rules is supposed to be met in 2008 (McCarl et al. 1999).

The relation between naturalized and historical flows in the WAM is described:

The naturalized flows downstream of Comal, San Marcos, Hueco, San Antonio, and San Pedro Springs include historical springflows, which reflect historical pumpage from the Edwards Aquifer (HDR 2.4.2 1999)

This pumping assumption appears to be a necessary modification due to limitations of the model to integrate groundwater and surface water. This interpretation of naturalized flows needs to be kept in mind when doing any analysis of the Guadalupe Basin, especially if it involves the consensus criteria.

Historical pumping was compared to the 400,000 acre-foot constant. In the earlier years of 1941-1958, there was not as much pumping from the aquifer as now, even though groundwater withdrawals were unregulated then. When the actual pumping is

less than the 400,000 acre-foot constant, the historical flow exceeds the naturalized flow; while when the actual pumping in a given year exceeds 400,000 acre-feet, the naturalized flows will be higher than historical as would be expected, although the naturalized flows will still be distorted by the use of the constant. Pumping from the Edwards has increased from approximately 100,000 acre-feet in 1934 to a peak of 542,400 acre-feet in 1989 (Eckhardt 2004) – a trend which is reflected in the increased number of months that naturalized flow exceeds historical flow in the 1980's (21 out of 108 months) as opposed to only 12 months in the previous 39 years. Although the most recent data from 2001 shows pumping from the Edwards Aquifer was 367,700 acre-feet for the year, since 1990 annual pumping of the aquifer has exceeded 400,000 acre-feet eight times (Eckhardt 2004), but there are not WAM runs for those years. To further complicate matters there are ongoing attempts to raise the aquifer pumping limits (Eckhardt 2004). The relationship between springflow and pumping amounts are complex with many factors, but when any pumping is assumed in an otherwise "natural" hypothesis, there will be distortion of the naturalized flows regardless of whether the historical flow is greater than the naturalized flow.

The effect of this alteration of modeled naturalized flows in the Guadalupe WAM will be evidenced in a similar manner as in the previously discussed Neches River WAM discrepancies in which the use of both historical and naturalized flows in the consensus criteria provide results contrary to the intent of the criteria. The consensus criteria intends for pass through requirements to decrease as reservoir capacity decreases, but as seen previously in the Region I-Neches River discussion, if historical flows exceed naturalized flows the result can be higher flow pass-through requirements when

reservoirs have less capacity which can obviously be problematic for water planning.

The reason for this discussion concerning pumping of the Edwards Aquifer and the Guadalupe WAM in a study of freshwater inflow is primarily related to the substantial percentage of freshwater inflow that was provided by the San Marcos and Comal Springs in the drought of record – almost 70 percent (McKinney 1997). Future reservoirs and diversions planned in the Guadalupe-San Antonio basin will be based on the consensus criteria which have been shown to provide results contrary to the original intent when historical flows exceed naturalized flows due to Edwards Aquifer pumping assumptions.

It is logical that the WAMs for the other basins will contain discrepancies in the naturalized/historical flow relationship to varying degrees depending on the influence of either reservoirs or springflows on the flow of the associated river; however, there is no discussion of this in the available state planning literature with the exception of the aforementioned Region I report. With the completion of the Rio Grande WAM in 2003, all river basins will have Water Availability Models for the first time in Texas. This could provide a window of opportunity for reevaluation of some of the processes. In chapter 22 there will be a discussion on the TWDB outline for using WAM data to analyze the next round of water plans.

Proposed Changes to the WAM

While many changes to the WAM were made initially, only a few modifications are proposed as of the end of 2003. There is mention that daily flow data or time step will be incorporated into the WAM in addition to the monthly time step of the current version (Wurbs 2003). This current lack of WAM output in daily format is of concern to

the TCEQ water rights division (Mosier 2003), since flow restrictions in water rights are expressed as instantaneous flows while WAM output is monthly. This is further complicated by the bay and estuary recommended flows being in monthly time step. In addition consensus criteria are a combination of 7Q2 flows which are expressed as instantaneous flows while naturalized flows are in monthly format. There is not a clear plan to unify these different time steps at this point, except to provide daily output from the WAM that could assist in integrating the different components of freshwater inflow – at least from a data perspective.

Groundwater Issues, Modeling and Freshwater Inflow

The effect of groundwater on the bay and estuaries of the Guadalupe has been discussed, but the importance of groundwater to all areas of Texas and all aspects of water planning and management in Texas is significant. Table 11.2 shows the 1997 types of water use totals and whether they were derived from groundwater or surface water.

Table 11.2 – Texas groundwater and surface water use in acre–feet for 1997 (TWDB 2004)

Source	Municipal	Mfg.	Power	Irrigation	Mining	Livestock	Total
Ground Water	1,352,866	251,922	59,965	7,395,067	144,112	153,340	9,357,272
Surface Water	2,076,526	1,269,414	265,925	2,134,741	102,561	184,664	6,033,831
Total	3,429,392	1,521,336	352,890	9,529,808	246,673	338,004	15,391,103

Groundwater provided almost 61 percent of all water used in 1997 with the major portion (79 percent) of groundwater use going to irrigation. The effects of groundwater via springflow on streams throughout Texas vary, but there is no doubt as to the link between springflow and streamflow (TCEQ 2002). As springflow decreases due to

groundwater shortage there will be even more pressure on surface water sources which are directly connected to bay and estuary inflow.

To assist water planning, the TWDB is overseeing the development of a Groundwater Availability Model (GAM) for each major and minor aquifer in Texas. The Texas Water Development Board is the lead agency for the development of the GAM and is primarily responsible for groundwater and water well data, groundwater planning and groundwater research (Texas Groundwater Protection Committee 2004). The GAMs for the major aquifers that supply 95 percent of the groundwater used in Texas should be complete by September, 2004 (TWDB 2003b). Output of the GAM will indicate how the aquifers respond to increased pumping and decreased recharge.

In the state water plan there is an estimated depletion of groundwater supply availability from 8.8 million acre-feet per year (AFY) in 2000 to 7.2 million AFY in 2050 or about 19 percent (TWDB 2002b). The largest reduction (1.2 million AFY) is from the Ogalla aquifer which has negligible recharge and supplies much of the irrigation needs in West Texas. (fig. 11.3). This 10 percent reduction in supply of the Ogalla was projected by the Llano Estacado Planning Region O. The Hueco-Mesilla Bolson Aquifer that supplies most of the city of El Paso's water is projected to decline 100 percent from 200,000 AFY in 2020 to zero in 2030 (TWDB 2002) although the TWDB graph shown in figure 11.4 only shows an approximate 80% decline. The Gulf Coast Aquifer that supplies much of the freshwater in drought periods for the Mission-Aransas Estuary (Blackburn 2003) is projected to be reduced by 140,000 AFY in 2050. (fig. 11.4). In the water plans between 2000 and 2050, 13 of the 30 aquifers show a decline in supply, five aquifers show an increase and 12 aquifers remain the same (TWDB 2002b).

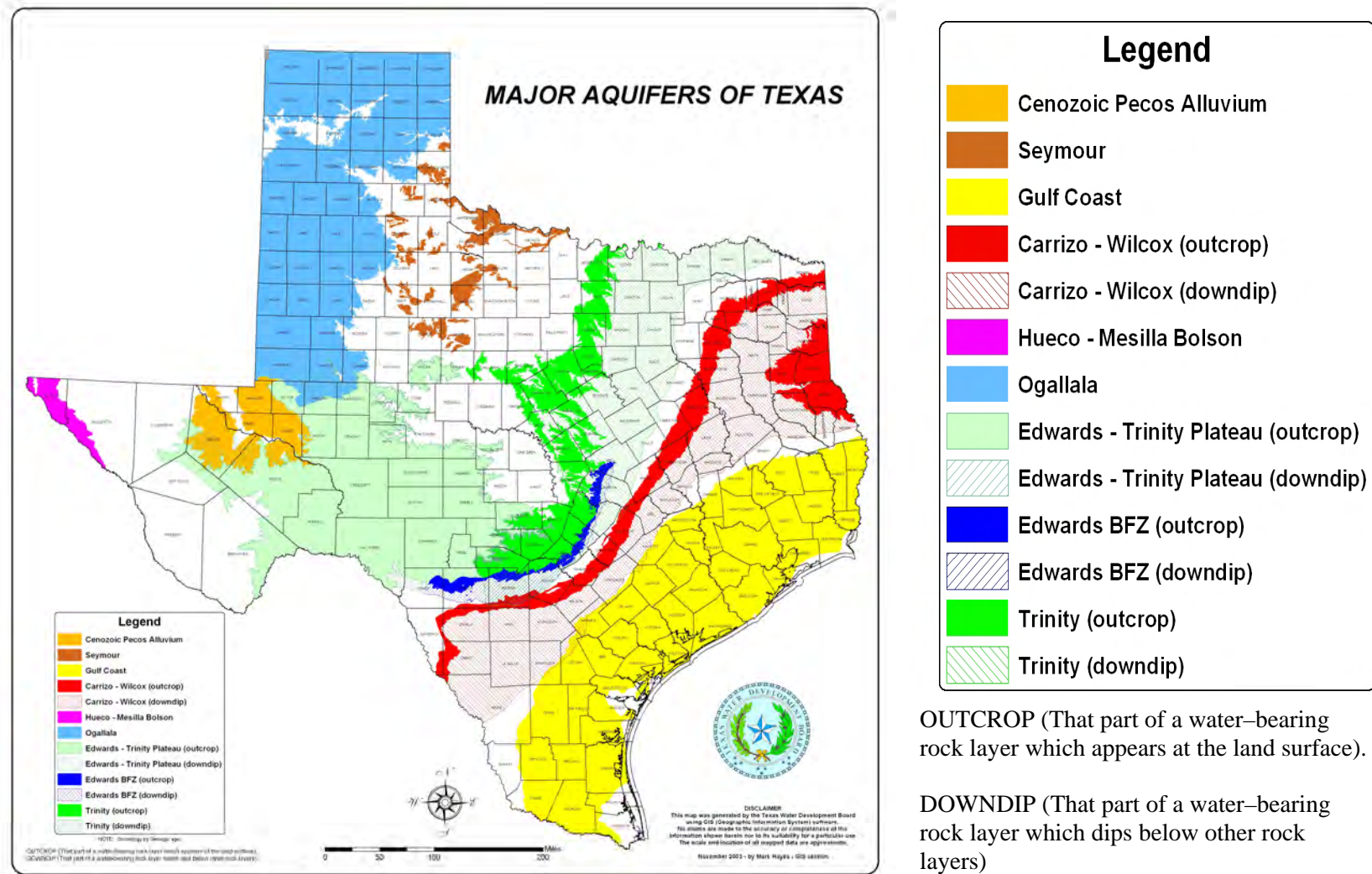


Figure 11.3 – Major Texas aquifers (from TWDB 2004)

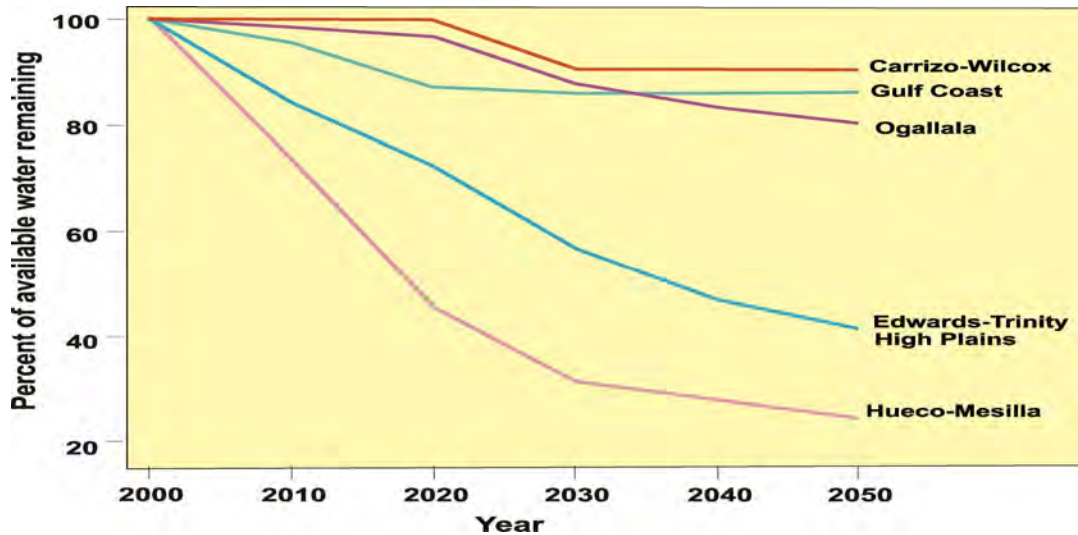


Figure 11.4 – Aquifers showing appreciable projected declines through 2050 (from TWDB 2002)

In the "Recommended Water Strategies" Chapter of the state water plan (TWDB 2002b) is a discussion of groundwater management strategies for the various planning regions. The most common strategy was to install new wells and two planning groups proposed transfers of groundwater over long distances through pipelines. Other plans recommended pumping more from existing wells while Region K and L in Central Texas recommended artificial recharge strategies that would increase aquifer supply in 2050. It is not mentioned what the effect of increased recharge would be on surface water availability, but it would seem the two are related as more runoff is diverted to the aquifer it would not necessarily be available as streamflow.

In the same manner as groundwater and surface water are not linked legally and administratively in Texas, neither are groundwater and surface water in the water planning process and the water availability analysis. The groundwater availability model may provide one of the tools needed for sustainable management – data; but without a well-defined legal and administrative connection between groundwater and

surface water, a viable plan for the preservation of freshwater inflows to the bays and estuaries may not be possible.

CHAPTER 12

THE ADMINISTRATIVE CONNECTIONS BETWEEN THE MAJOR COMPONENTS

Isolated connections between the three main state environmental agencies (TCEQ, TWDB, and TPWD) that apply to freshwater inflows have been discussed, but only as they relate to each individual agency. In this section an overview of the relationships of these components is presented as a means to understand the bigger picture of the state of the protection of freshwater inflow in Texas. The interrelatedness of the components is synthesized to demonstrate either the presence or lack of connectivity to facilitate the protection of freshwater inflow in Texas. Several previously discussed interagency entities such as the National Estuary Program, the Coastal Management Program and the advisory councils for individual bays are not included in this discussion because their capabilities to affect the actual protection of freshwater inflow are not considered significant – at least at this time. In a similar manner other state agencies that have advisory roles or consulting roles that do not significantly affect the current state of freshwater inflow protection are not covered in this analysis. Examples of some of these agencies are the General Land Office that is mainly involved in coastal land issues and the Department of Agriculture that is involved in the water planning process. With the exception of the potential of the Federal Endangered Species Act, none of the associated federal entities mentioned such as the USEPA, the USFWS, and the Corps of Engineers

are actively involved in the current state of freshwater inflow protection although they might have potential authority to varying degrees. The approach to this analysis of connectivity is separated into the three areas of state processes that most affect the protection of freshwater inflow:

- The appropriation of water.
- The regional and state water plans.
- The studies of recommended flows to the individual bays.

Interagency Connections in the Water Appropriation Process

The appropriation of surface water, meaning granting of new water rights or amendments, was discussed in detail in Chapter 7. The TCEQ obviously has the lead role in this process as defined in Chapter 5 of the Texas Water Code; however, in the Administrative Code the state and therefore its agency the TCEQ, is precluded from controlling groundwater (Tex. Admin. Code § 297.1). Although the TCEQ apparently has the primary role in the water appropriation process, there are areas where the TPWD and the TWDB can provide input or assist with information and studies related to freshwater inflow issues.

The TCEQ is required to furnish the TPWD a copy of all water permit applications and the department is required to make recommendations including restrictions on permits to protect fish and wildlife (Tex. Parks and Wildlife Code § 12.024). The department has the right to be a full party in any contested administrative hearing on a water right application (Tex. Parks and Wildlife Code § 12.024) although as discussed this may not often be utilized. For all reservoirs built within 200 river miles of the coast the TCEQ will convey to the TPWD five percent of the firm yield to manage for

instream flow and freshwater inflow (Tex. Water Code § 16.1331). The TPWD and TCEQ have joint responsibility for reviewing information to determine recommended freshwater inflow needs including review of the bay and estuary studies (Tex. Water Code § 11.149) although the specifics of these recommendations and their actual application to the water rights process is not outlined.

The role of the Texas Water Development Board in the water appropriation process is less direct than the role of the TPWD. The TWDB as the agency responsible for the state water plan has influence on the appropriation process of TCEQ in that any water right application must show consistency with the state water plan (Tex. Admin. Code § 295.16) although as discussed the water plan through its consensus criteria does not provide any well-defined protection for bay and estuary inflow (TWDB 2002b; TPWD 2002; Alan Plummer and Associates 2001; USFWS 2002; Texas Living Waters 2003).

Together the TPWD and the TWDB are jointly responsible for the development of the bay and estuary studies (Tex. Water Code § 16.058) and although the specific role of the studies' recommendations (Tex. Admin. Code § 297.55; Texas Water Code § 11.491) is not well-defined, the studies are on a list of sources that TCEQ may use as part of a process of determining freshwater inflow needs (Tex. Water Code § 11.149). According to the Director of the TWDB Hydrological and Environmental Monitoring Division, the bay and estuary studies are used by the TCEQ for permitting and by the TPWD in making recommendations on permit applications relative to freshwater inflow issues (Powell 2003). A discussion with TCEQ staff in the water right permitting division confirmed that they do look at the estuary studies when determining flow

restrictions for permits and amendments within 200 river miles of the coast; however, there were several unanswered questions such as: how to manage inflows when the flow of the river is below the Min Q and how to reconcile the fact that the studies are in monthly time step of acre-feet per month and the water permit restrictions are defined as instantaneous flow in cubic feet per second (Mosier 2003). The TCEQ staff also considers the 7Q2 and the Lyons method and generally uses whichever one calls for the most flow (the Lyons method will be addressed in an upcoming chapter).

The flow chart in figure 12.1 portrays the various roles of the TCEQ, TPWD and TWDB in the water appropriation process. As defined in Chapter 5 of the Water Code, the TCEQ is the lead agency in water appropriation, and this role is evident in the many commissioner meetings and hearings attended by the author.

Interagency Connections in the Regional and State Water Plans

The Texas Water Development Board is the agency responsible for the development of a state water plan (Tex. Water Code § 6.012) and in reality is the lead agency in coordinating the planning and publishing the results and updates of the regional and state plans. The Texas Parks and Wildlife Department and the Texas Commission on Environmental Quality serve various supporting and advisory roles in the planning process.

Generally the roles of the TCEQ and the TPWD in the planning process are parallel with two exceptions. First the TCEQ is instructed in the Water Code § 16.059 to take the plan into consideration in matters coming before it which we see in the requirement that all new applications and amendments must show consistency with the state water plan (Tex. Admin. Code § 295.16). Second the TPWD is declared an ex-

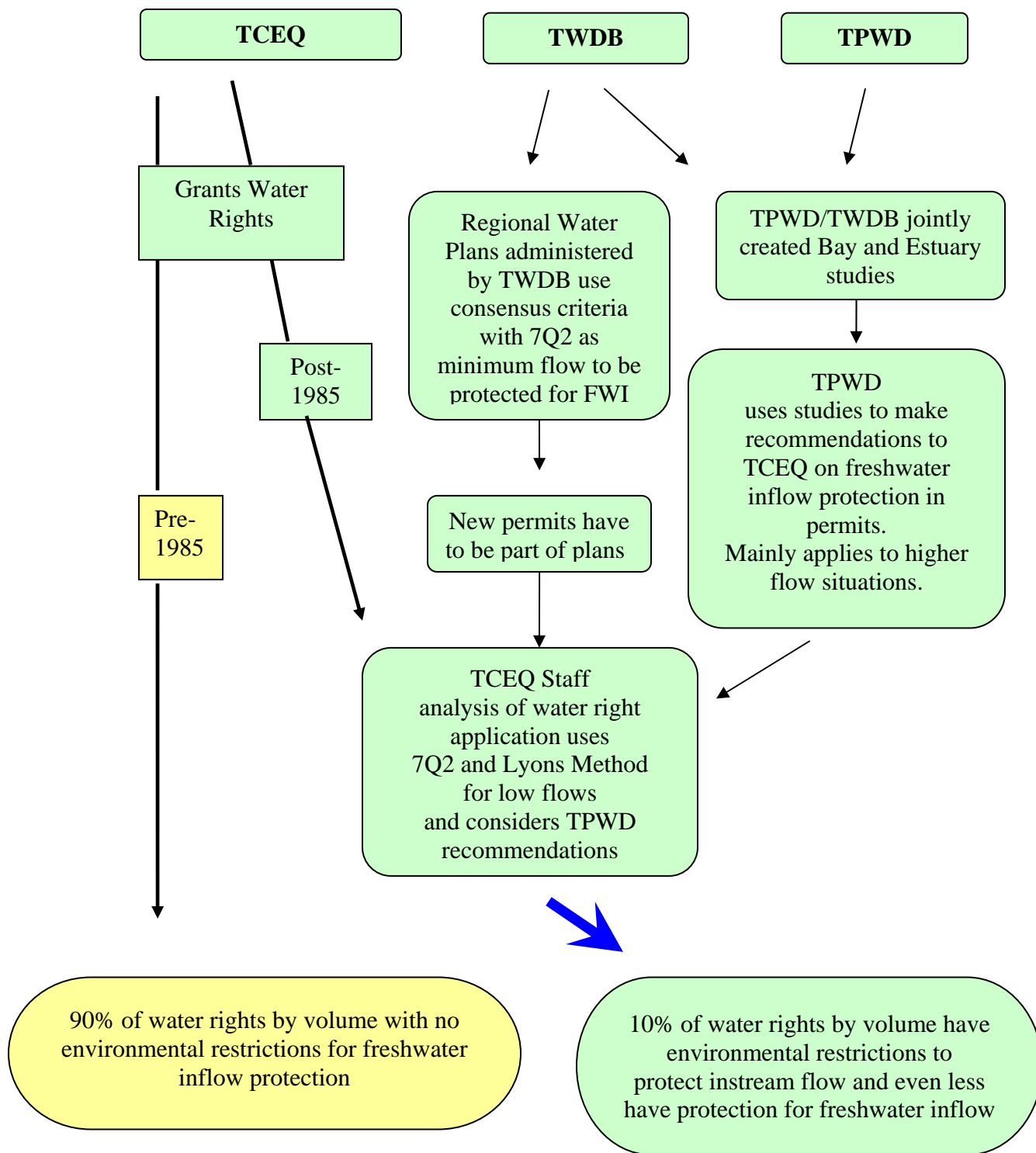


Figure 12.1 - Interagency connections in water rights permitting

officio member of each regional planning group throughout the process (Tex. Admin. Code § 357.4).

All three agencies (TCEQ, TPWD, and TWDB) were to be included in the coordination of the original principles of the plan as defined in the Texas Water Code § 16.051. The three agencies collaborated with scientists, consultants and citizens on the development of the consensus criteria for the planning process. The 83 member stakeholder group of the state water plan that made many recommendations for the next planning phase, had representatives of all three agencies as well as representatives of numerous other groups and will continue to advise the TWDB (TWDB 2002b).

Although the TWDB is the lead agency in the water planning process, the TPWD and the TCEQ have participated in both the design of the process and in the ongoing activities of planning. Figure 12.2 provides a flow chart showing the three agencies' roles in the water planning process.

Interagency Connections in the Bay and Estuary Studies

The bay and estuary studies are the only one of the three processes analyzed that has jointly shared responsibilities of management. The Texas Parks and Wildlife Department and the Texas Water Development Board have joint responsibility for maintaining data and performing analyses of freshwater inflows to bays and estuaries (Tex. Water Code § 16.058). Although it was discussed that the TWDB and TPWD appear to have different concepts of the state of completion of the studies, the final published reports show both agencies as the author.

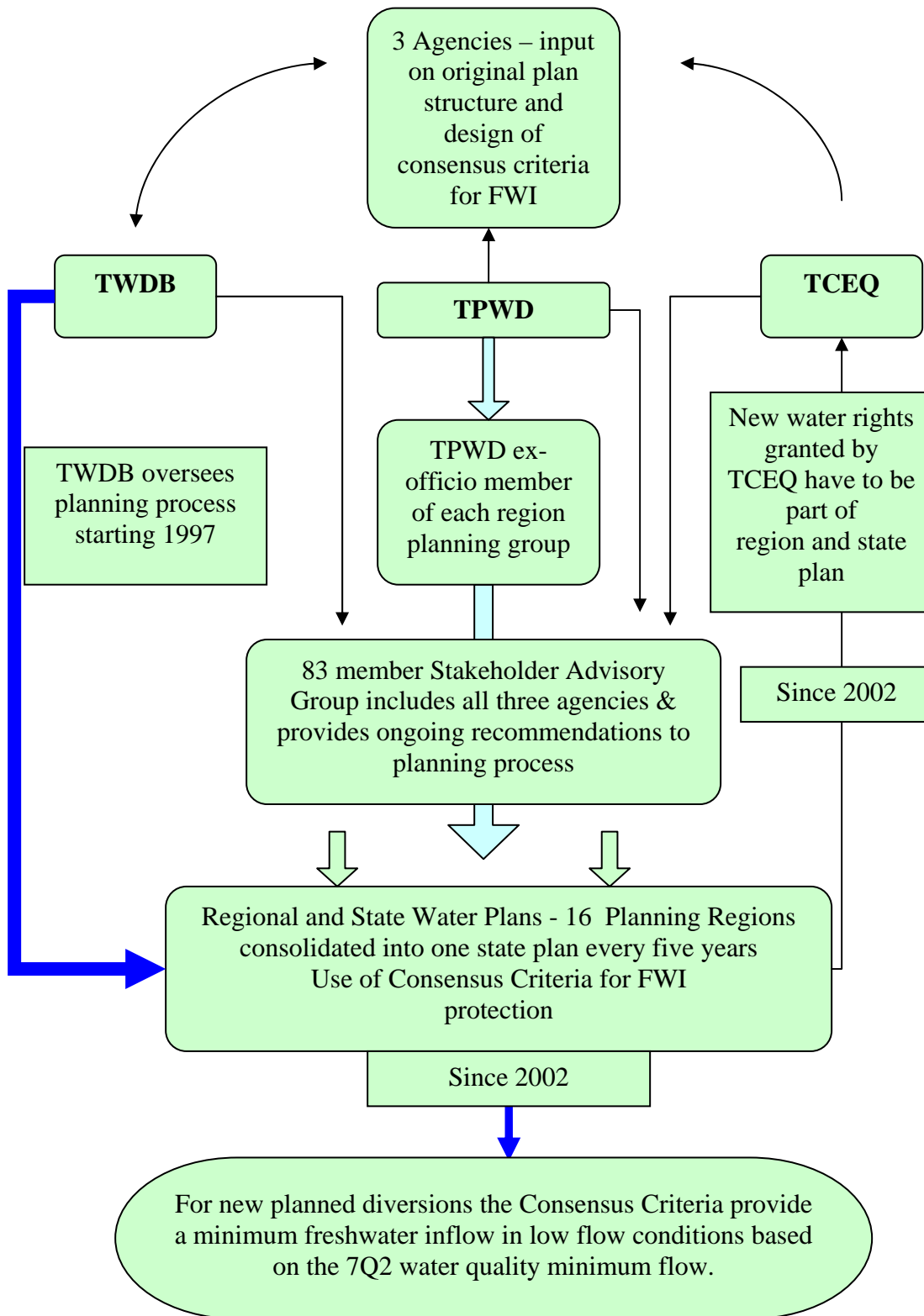


Figure 12.2 - Interagency connections in water planning. Note: Dark blue arrow represents TWDB major role in plans and light blue arrow shows TPWD lesser role.

The fourth completed report for the Matagorda Bay was done by the LCRA which entered into an agreement with the three agencies and established an Advisory Committee with representatives from each agency and with each department agreeing to assist in the transfer of technical data to the LCRA (Martin 1997).

The studies are referred to by the TCEQ in analysis of water right applications and by the TPWD in recommendations to the TCEQ on water right restrictions to protect freshwater inflow (Powell 2003). The studies are also part of a recommended list of sources for the TCEQ to consider in determining freshwater inflow needs (Tex. Water Code § 11.149). In figure 12.3 the relationships of the three entities in the bay and estuary studies are displayed in a flow chart.

All three agencies and the three analyzed processes are included in a master flow chart of freshwater inflow protection (fig. 12.4) that does not include as much detail as the individual agency flow charts due to space limitations. The intent of these graphic displays is to provide an alternate method of portraying the interagency responsibilities and roles in the protection of freshwater inflow. As the process of freshwater inflow protection inevitably evolves, flow charts can provide a vehicle for comparing the process over time.

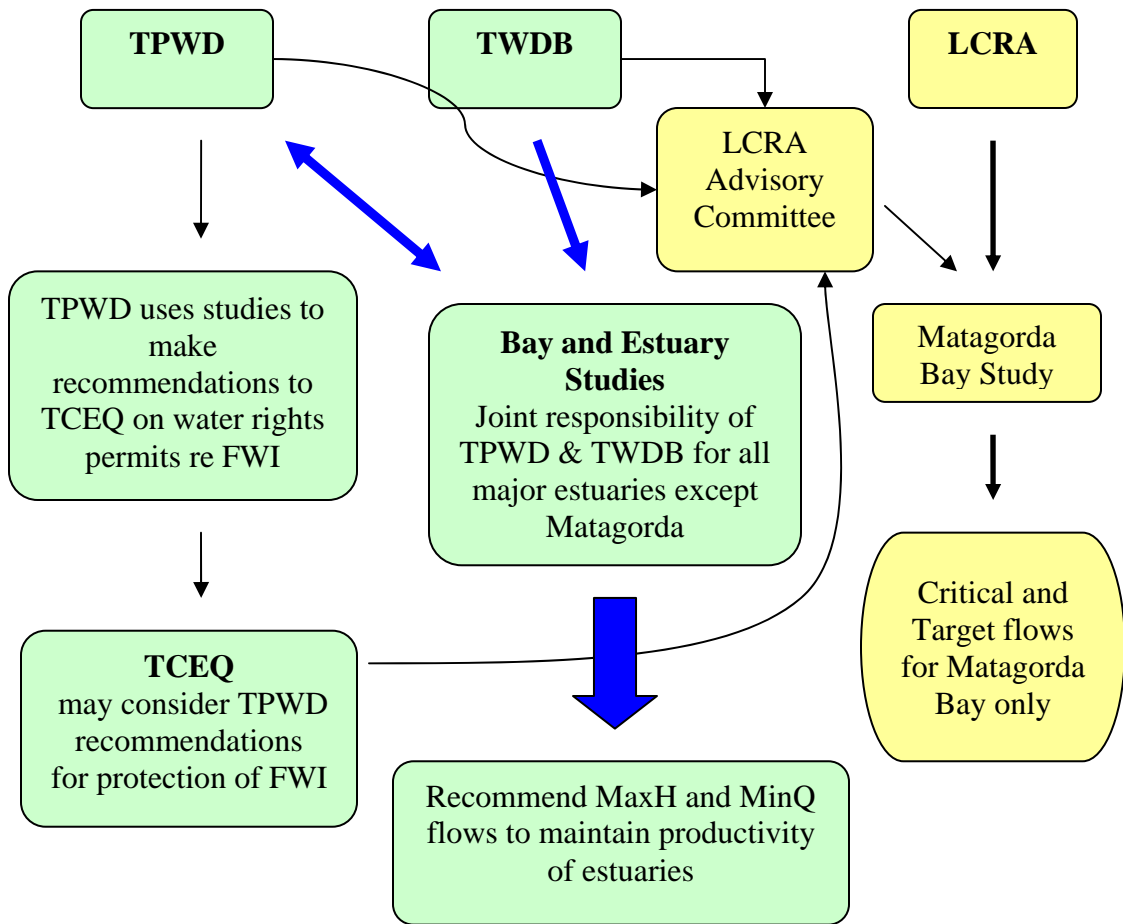
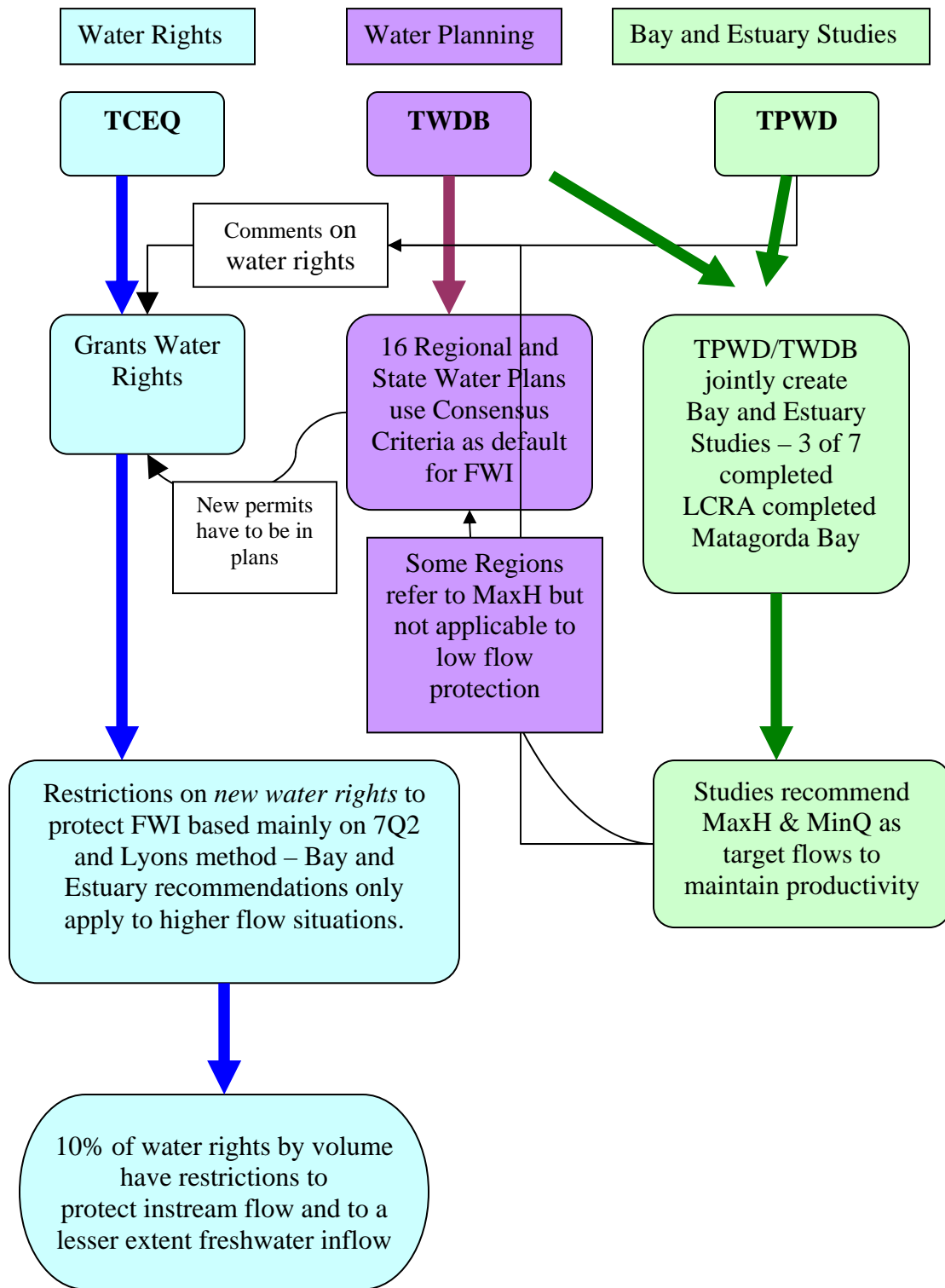


Figure 12.3 – Interagency connections in the bay and estuary studies. Note: Blue arrows represent major activities of the studies. Yellow areas are specific to LCRA.



12

.4 – Interagency connections in the protection of freshwater inflow. Note: The large colored arrows represent the major activities of each agency.

CHAPTER 13

COMPARISON OF NATURALIZED AND UNAPPROPRIATED FLOWS TO RECOMMENDED FLOWS IN VARIOUS ESTUARIES

At the request of the Commissioners of the Texas Commission on Environmental Quality a workshop was conducted by the TCEQ staff on environmental flow conditions in water rights permits (Chenoweth 2003). Several graphs were presented showing the naturalized and unappropriated flows (Run 3 of the WAM) of the rivers that feed the major estuaries along with the MaxH and MinQ values for the particular estuary. The naturalized flow is the modeled flow from the WAM assuming there were no human interferences such as diversions and reservoirs. Unappropriated flow which is the modeled result of Run 3 of the WAM is the flow that would remain in the river if all current water rights were fully utilized and no water was returned to the stream (the assumption being that all return water will someday be reused due to the increasing shortage of water). The resulting information provided by the series of graphs from TCEQ shows the percentage of time that a particular amount of naturalized or unappropriated flow is available at the estuary of each river.

For purposes of discussion the conditions of the estuaries will be compared to the Min Q which is the minimum flow satisfying all the constraints of the TXEMP model and is always less than the MaxH which is the "Optimal flow producing maximum fisheries harvest. . ." (TPWD 1998, 2). The selection of the MinQ as the comparative

recommended flow is in no way intended to imply that it is a satisfactory target. In fact the TPWD cautions that: "Since MinQ is by definition at the lowest allowable part of the performance curve for inflows, this value should be interpreted with caution in any management application" (1998, 39). The reasons for choosing the MinQ and not the MaxH for this analysis of all the bays were:

- 1) To analyze both the MinQ and MaxH for each bay would double the amount of data presented in this study without apparent benefits to justify the increase in data.
- 2) The spread between the MaxH and the MinQ for most bays, although in most cases biologically significant, would not be quantitatively significant and would simply overload the following descriptive analyses. If there is more interest in the MaxH, the information is displayed on the graph for further analysis.
- 3) Inasmuch as there are apparent problems with freshwater inflow protection in Texas (TWDB 2002b; USFWS 2001; Texas Living Waters Project 2003), the fact that this lower of the two recommended values is often not available makes a strong enough statement that would not be strengthened with more statistics about the availability of the MaxH flow.

The Sabine River Available Flow

Examining the graphs of basins in east to west order, figure 16.1 shows the available flow of the Sabine River at Sabine Lake which is the inland estuary previously discussed in the section on Region I planning. (fig. A-3) The Sabine River discharges more water (more than 6 million acre-feet) than any other Texas river (USGS 2004) and

has major reservoirs including Toledo Bend the largest reservoir in Texas with a capacity of 4,472,900 acre-feet in 1993 (USGS 2004).

In spite of this large existing flow, figure 13.1 shows the potential effect on flows at the river's mouth at Sabine Lake if all existing water rights are fully utilized. The solid black line descending from left to right represents the naturalized flow while the dotted black line descending from left to right represents the unappropriated (Run 3) flow. The solid blue horizontal line is the MaxH recommended flow which remains constant since the graph portrays annual data. The solid red horizontal line represents the MinQ flow constant which will be addressed in this discussion. The Sabine River and its estuary have two characteristics that warrant explanation – one peculiar to this basin and the other affecting only certain basins. The aspect peculiar to the Sabine Estuary as opposed to the other major Texas estuaries involves the apportionment of the flow of the Sabine River with the state of Louisiana which shares the river as the border between the two states. As explained at the TCEQ workshop, the flows displayed in the graph represent only the Texas portion of the flow which is equally divided between Louisiana and Texas (Chenoweth 2003). A second characteristic that also occurs in some other major Texas estuaries is the fact that multiple major rivers provide flows to the same estuary – in this case the Sabine and Neches Rivers. The Sabine River provides approximately 45 percent of the freshwater inflow while the Neches River contributes approximately 35 percent. (TNRCC 2002) The TCEQ graphs presented here as well as the bay and estuary studies treat these rivers proportionally as to their percentage of contributions (Chenoweth 2003).

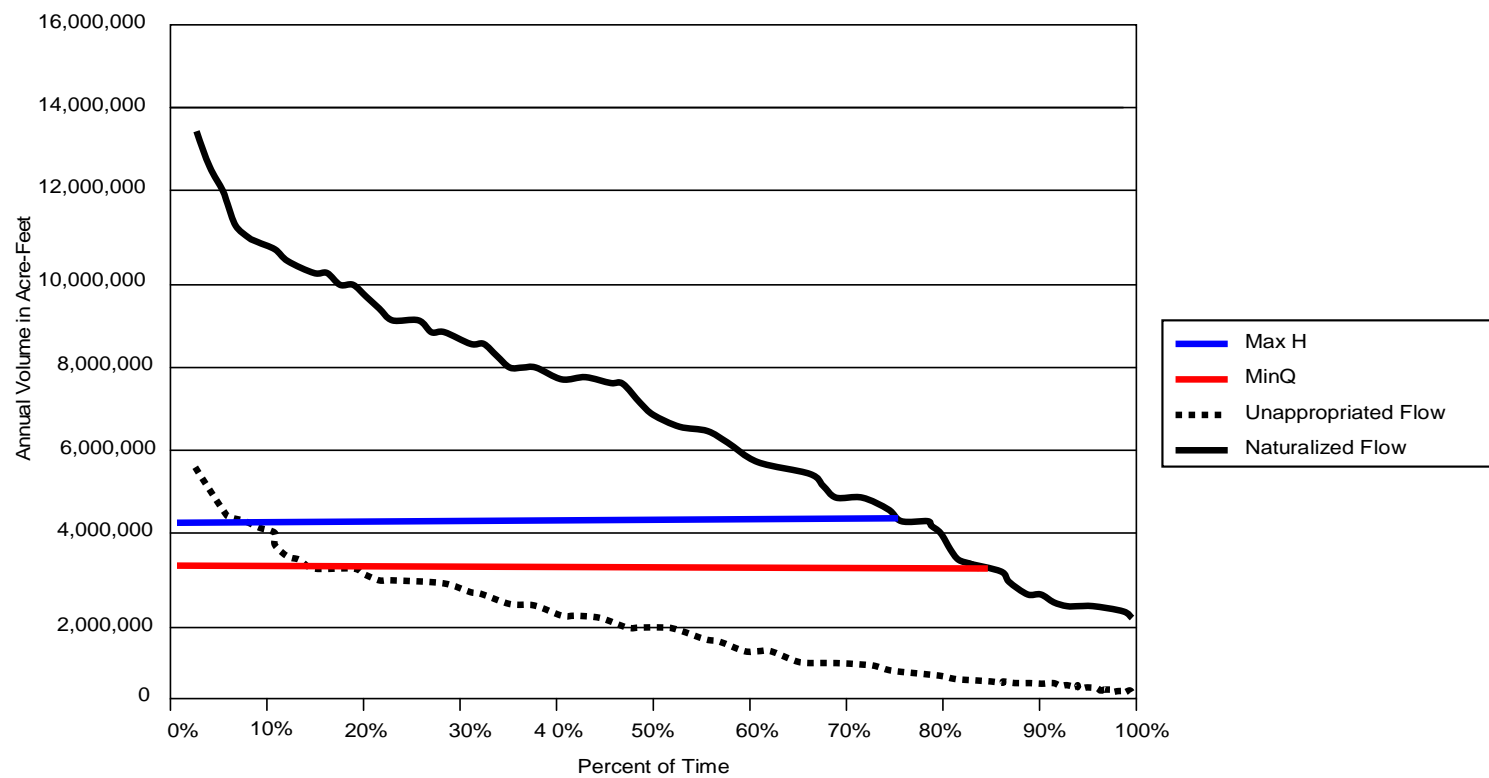


Figure 13.1 – Sabine River modeled flow (adapted from TCEQ 2003)

The graph in figure 13.1 reveals much information about the natural state of the estuary flow, the potential effect of existing water rights on estuary flow, and the availability of both the MinQ and MaxH under both scenarios. The associated data used to construct these charts were not available from the TCEQ (conversation with staff of the water rights division); therefore, the percentiles referred to in this discussion will be conservative visual estimates made from the graphical display. These estimates are sufficient to examine the variable availability of inflows to the major estuaries. One of the first items noticed is the percent of time the MaxH and MinQ are available. For this first graph the MaxH is mentioned in order to cover all aspects of the graphical display. The MaxH constant of approximately 4,300,000 acre-feet would be available only about 75 percent of the time if there were no human influences on the Sabine River, while under the same naturalized conditions the MinQ flow of approximately 3,155,000 would be available 85 percent of the time. Examining the unappropriated flow shows the availability of the MaxH will be reduced from 75 percent of the time to less than 10 percent, while the MinQ availability will decrease from 85 percent to about 20 percent if all existing water rights are fully utilized and no water is returned to the stream.

Another important statistic to derive from this series of graphs is the highest percentage availability of naturalized flow which for the Sabine River is approximately 2.3 million acre-feet, meaning in the period of record (typically 40 years for the estuaries analyzed by TCEQ in this workshop) the river did not dry up and 2.3 million acre-feet can be considered to be available 100 percent of the time. Only about 250,000 acre-feet per year of unappropriated flow is available with 100 percent probability. Another analysis of this availability is that the water appropriation system as of 2003 on the

Sabine River has reduced the 100 percent available flow from about 2.3 million acre-feet to about 250,000 acre-feet or almost a 90 percent reduction in the flow that would be available in all of the years of record.

Here we begin to see the quantitative results of the application of the various components of freshwater inflow protection to an actual river basin and estuary. Admittedly these are theoretical WAM models of future flow projections and there are questions at least in some of the planning regions concerning the accuracy of the naturalized flows (Alan Plummer and Associates 2001); however, in this river basin which contributes 45 percent of the freshwater inflow to the Sabine Estuary there appears to be a major potential impact of the water appropriation process on the availability of inflows with an approximate 65 percent reduction in availability of even the MinQ flow from 85 percent to 20 percent.

The Trinity River Available Flow

The Trinity River is the major contributor of freshwater inflow to the Galveston Bay providing 54 percent of the total volume of inflow (Galveston Bay National Estuary Program 1995). Figure 13.2 shows the effect of appropriations on the naturalized flow of the Trinity River, reducing the MinQ availability from approximately 88 percent to 65 percent. The total amount of water rights exceeds the available flow and the Trinity River could only provide any freshwater to the bay 90 percent of the time if all appropriations were utilized. It should be mentioned here that the sources of freshwater inflows to any bay are a combination of major and minor rivers, local runoff directly into the bay and rainfall on the bay. For Galveston Bay, in addition to the 54 percent

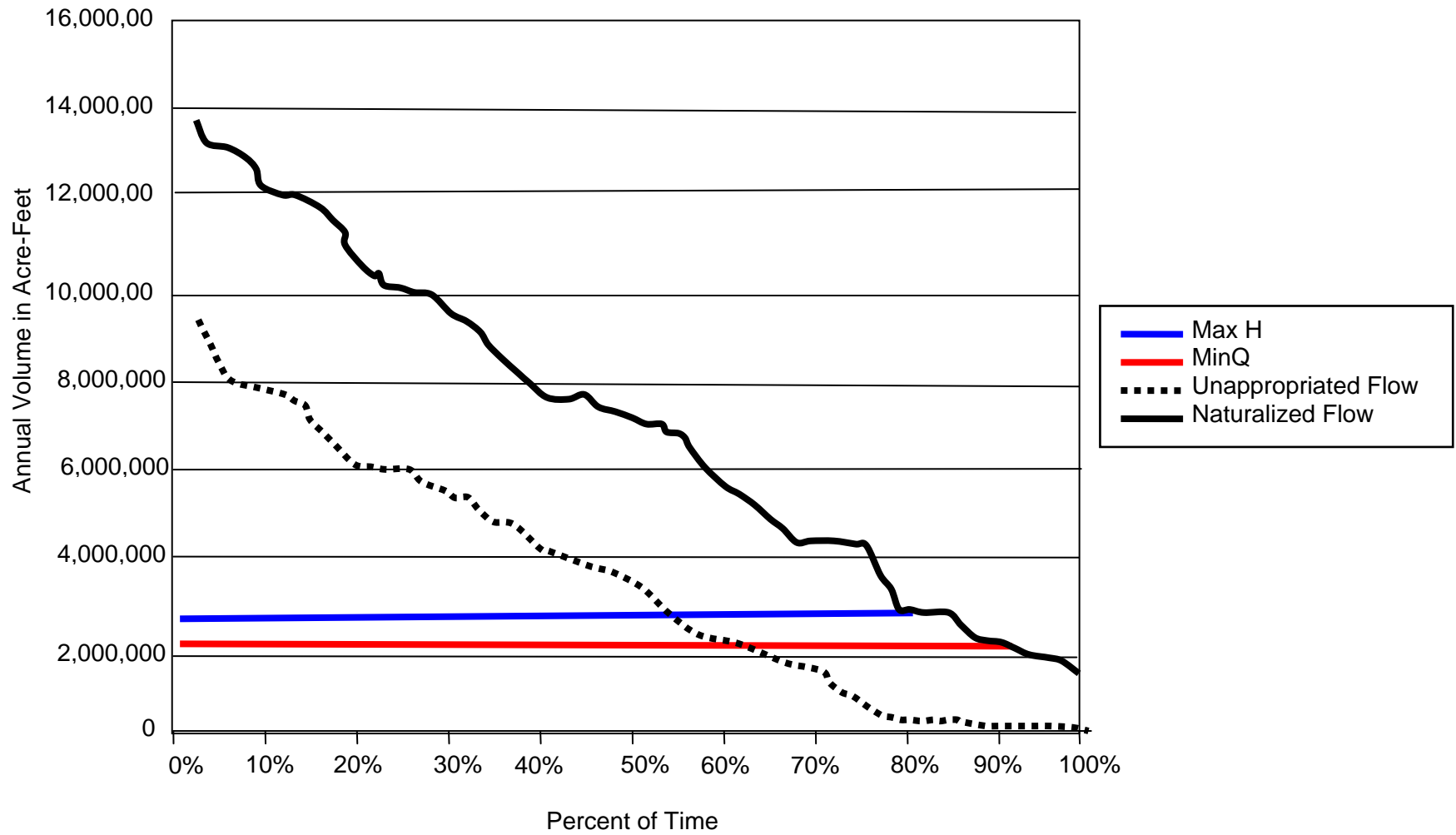


Figure 13.2 - Trinity River modeled flows (adapted from TCEQ 2003)

contribution from the Trinity River, the San Jacinto River provides 28 percent and the local watershed (runoff and creeks) contributes 18 percent of the freshwater inflow (Galveston Bay National Estuary Program 1995). Freshwater inflow calculation can be more complex in an urban area such as Galveston Bay which is surrounded by the City of Houston where runoff has increased due to impervious cover and increased return flows from wastewater plants. In an urban area a 30 percent increase in average annual rainfall results in about a 60 percent increase in runoff which can also cause pollution problems (Galveston Bay National Estuary Program 1995).

The Colorado River Available Flow

The Colorado and Lavaca Rivers are the major tributaries of the Matagorda Bay system with the Colorado River contributing about 60 percent of the Critical Freshwater Inflow Needs (Critical FIN) of 287,400 acre-feet per year. The Lavaca River provides about 10 percent of the freshwater needs with an additional approximate 30 percent coming from other contributing areas (Martin et al. 1997)

Figure 13.3 reveals a significant impact on the Colorado River due to appropriations of water. It should be pointed out that as shown in Chapter 11 the target and critical flows for the Matagorda Bay system were derived by the LCRA using a variation of the methods that the TWDB/TPWD used for the other major estuaries; therefore, this methodological difference should be kept in mind when comparing the Colorado graph to other estuary system graphs. The minimum critical flow (solid red line) is lower than all naturalized flows so would be available 100 percent of the time in a naturalized state. The total amount of recommended critical flow would only be available approximately 45 percent of the time if all appropriated water were used and the

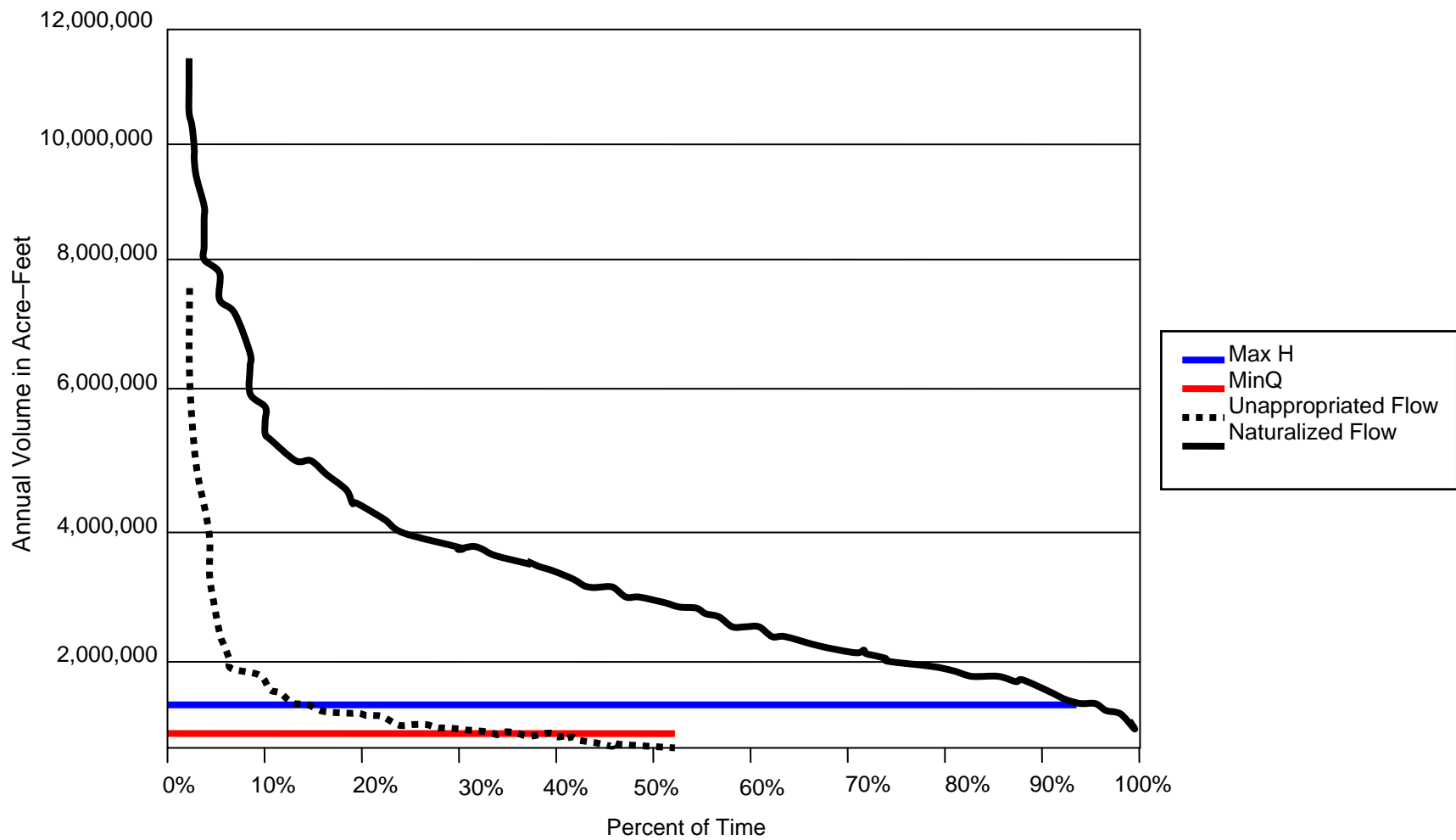


Figure 13.3 – Colorado River modeled flow (adapted from TCEQ 2003)

Colorado River would be dry 55 percent of the time in this scenario. In its naturalized state the Colorado does not dry up and is shown to have almost 900,000 acre-feet available 100 percent of the time. One could conclude from this disparity between the availability of naturalized flow compared to unappropriated flow that a significant percentage of the flow of the Colorado River has been appropriated.

The Guadalupe and San Antonio Rivers Available Flow

As shown in figure 13.4 the availability of the Min Q for the combined flow of the Guadalupe and San Antonio Rivers is approximately 73 percent in the naturalized model run and about 63 percent in the unappropriated flow model run (Note: the two rivers join less than 20 miles before reaching the estuary). The MinQ and Max H for the Guadalupe Estuary are relatively close compared to other estuaries with the MinQ at 1.03 million acre-feet per year and the MaxH at 1.15 million acre-feet (TPWD 1998). In its naturalized and unappropriated runs the Guadalupe/San Antonio rivers show at least some flow available 100 percent of the time although the unappropriated flow appears to be minimal. In the section on the WAM it was demonstrated that there are questions about the naturalized flow calculations for the Guadalupe River and the likelihood is that the values are too low (Johns 2003). An increase in naturalized flows would result in a more demonstrable impact of water rights on unappropriated flows by expanding the spread between the two scenarios.

The Nueces River Available Flow

The Nueces is the westernmost river basin examined in this series and therefore lies in an area of less rainfall than the other Texas basins (fig. A-5). The dry climate plus

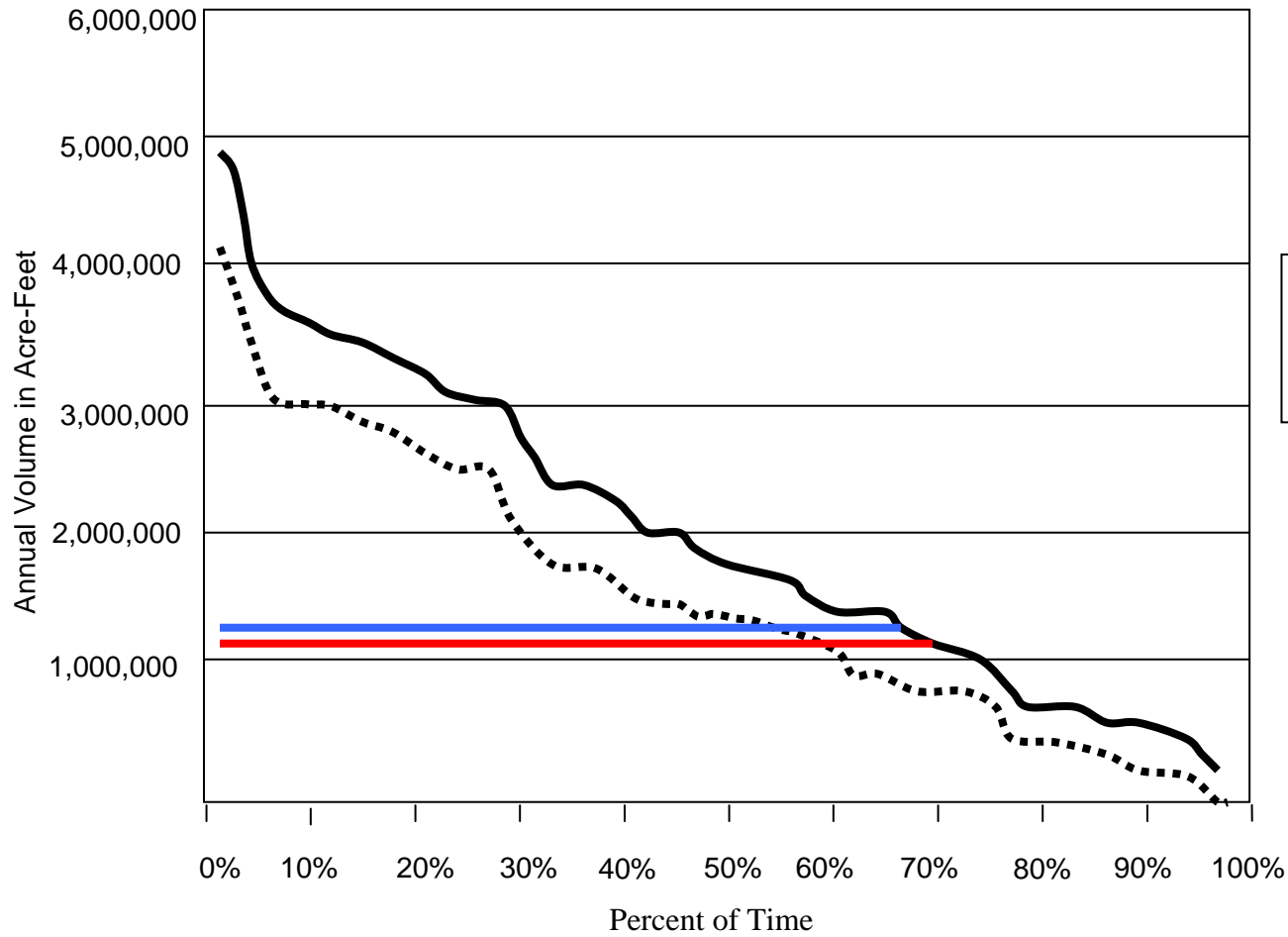


Figure 13.4 – Guadalupe/San Antonio River modeled flow (adapted from TCEQ 2003)

significant flow impacts from upstream reservoirs make freshwater inflow of critical concern (Coastal Bend Bays and Estuaries Program 1998). Figure 13.5 shows the effect of appropriations on this heavily impacted river basin. The MaxH is predicted to be 138,500 acre-feet per year and the MinQ is calculated at 115,600 acre-feet (TPWD 2002), and because of their proximity on the graph they are barely distinguishable.

Appropriation of water has reduced the availability of the MinQ flows from slightly above 90 percent to less than 20 percent and although the naturalized state of the river shows some flow 100 percent of the time, the unappropriated flow is calculated to only be available 30 percent of the time with no available flow 70 percent of the time.

Summary Analysis of Available Flows

The TCEQ graphs of available flow show varying impacts of the appropriation of water on the theoretical naturalized flow of the major contributing rivers with some questions about the naturalized flow data, particularly in the Sabine and Guadalupe basins (Alan Plummer and Associates 2001; Johns 2003). The Sabine River showed significant reduction of the availability of MinQ flows from 85 percent of the time in the naturalized state to 20 percent of the time after all appropriations were utilized. MinQ flow availability on the Trinity River was reduced from approximately 88 percent of the time to 65 percent of the time, but possibly more significant was the fact that the unappropriated flow was only available 90 percent of the time while the naturalized flow showed a 100 percent availability.

The Colorado River study notably used different methodology than the other estuary studies (Martin et al. 1997), but nonetheless the Critical FIN was only available

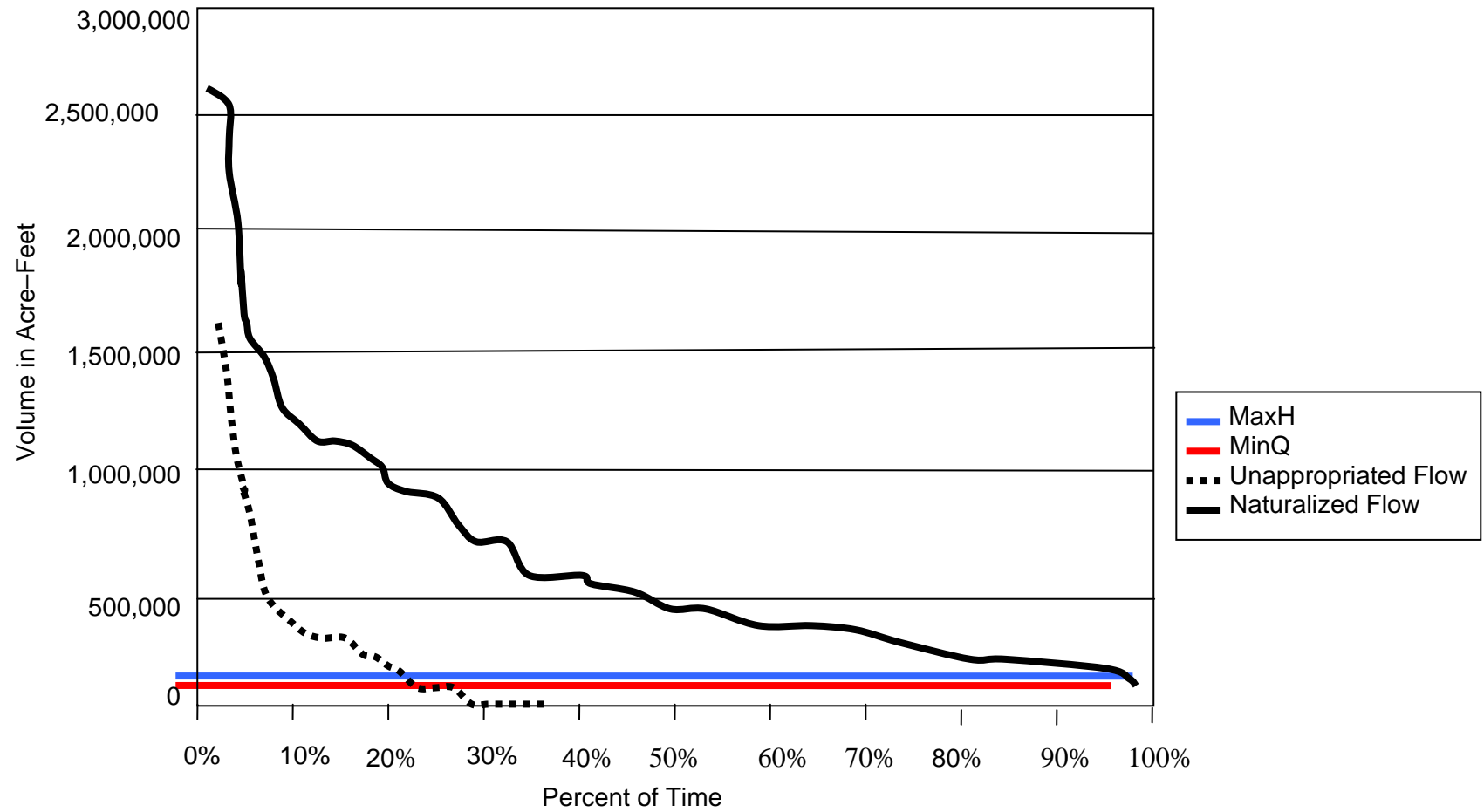


Figure 13.5 – Nueces River modeled flows (adapted from TCEQ 2003)

45 percent of the time with unappropriated flows – meaning that 55 percent of the time the Colorado River would not flow if all existing water rights were utilized.

The Nueces River graph has the MinQ availability decreasing from 90 percent with naturalized flows to only 20 percent with unappropriated flows. Only 30 percent of the time will there be any unappropriated flows meaning the Nueces will be dry 70 percent of the time if all water rights are utilized.

Notably the Mission-Aransas Estuary and the Upper and Lower Laguna Madre Estuaries were not covered in the referenced TCEQ workshop. Although these omissions were not explained, it is assumed the limited size of the Aransas and Mission Rivers (Corpus Christi Bay National Estuary Program 2003) and the lack of riverine input into Laguna Madre (GulfBase n.d.) made the analysis of unappropriated flows for these basins insignificant or irrelevant to the goal of the commissioner workshop at which these graphs were presented.

Additional Analysis of the Guadalupe/San Antonio River Inflow

The Guadalupe/San Antonio Rivers showed a drop in the availability of MinQ flows from 73 percent to 63 percent from the effect of appropriations, although there are questions about the naturalized flows being lower than actual (Johns 2003) which would increase this spread. Very minimal unappropriated flow is still available in the Guadalupe in a record drought. For the Guadalupe/San Antonio Basin a different graphic view seen in figure 13.6 compares the unappropriated (Run 3) flows to the naturalized flow for the period of record 1934-1989 along with the MaxH and MinQ constants. By analyzing the basin from the viewpoint of figure 13.6 compared to figure 13.4, different patterns become evident, including the *successive years* that the unappropriated flow

would either meet the MinQ recommendation (1965-1979) or not meet it (1950-1956).

The repeated sub-MinQ flows in the drought of record in the 1950's and the fact that the unappropriated flows would be lower than the naturalized flows or even the historical flows (fig 13.6), could mean the potential for serious ecological damage in a repeat of a drought of that severity.

A major concern of TPWD is that an increase in severity, frequency, or duration of drought flows will alter the ecosystem structure by either reducing overall fisheries production or by favoring one fisheries species production at the expense of others, thereby reducing biodiversity (TPWD 1998, 42).

For another perspective (fig. 13.7) the Guadalupe Estuary inflows were charted on a *monthly* basis for 1954 – the worst year of the drought, only this time adding historical flow data as well as naturalized and Run 3 data. Figure 13.7 compares the actual monthly historical flows to the recommended monthly MinQ and MaxH flows. Recalling the earlier discussion on the inversion of the historical and naturalized expected values, it was decided to include both sets of values in this chart to provide a better representation of the impact of appropriations in a severe drought. As pointed out previously the historical flows in pink are higher than the naturalized flows in blue. The modeled unappropriated flows are the lower line in red and the actual values are printed next to the data points to demonstrate that there are at least minimal flows in all months that due to the necessary scale of the graph, may appear to be zero. The lowest flow in June of 847 acre-feet would only amount to 14.24 cfs compared to the historical median flow of 1872 cfs (calculated by dividing volume in acre-feet by 59.5 acre-feet/cfs).

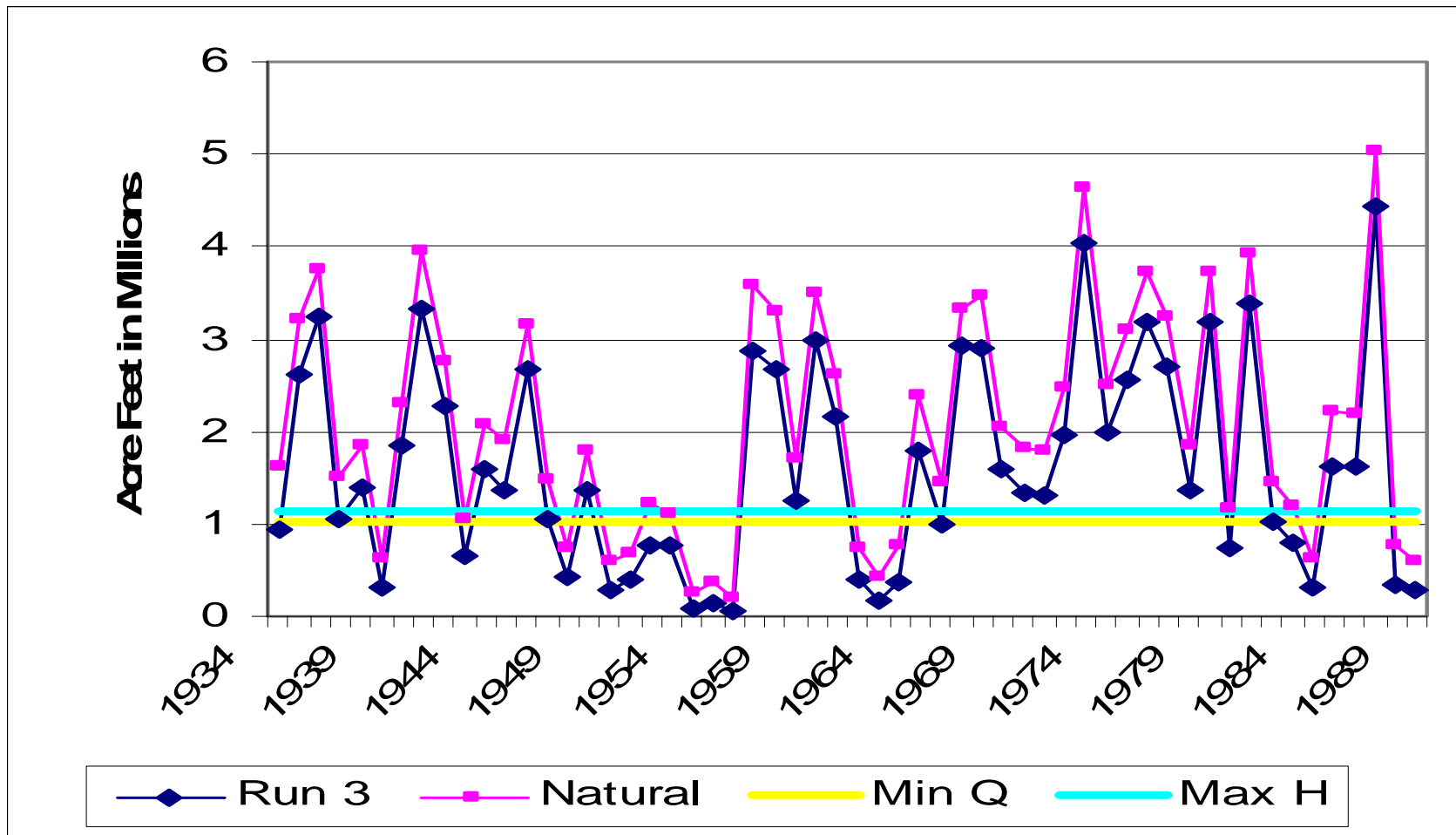


Figure 13.6 – Guadalupe Estuary inflow 1934-1989 (data from WAM December, 2003)

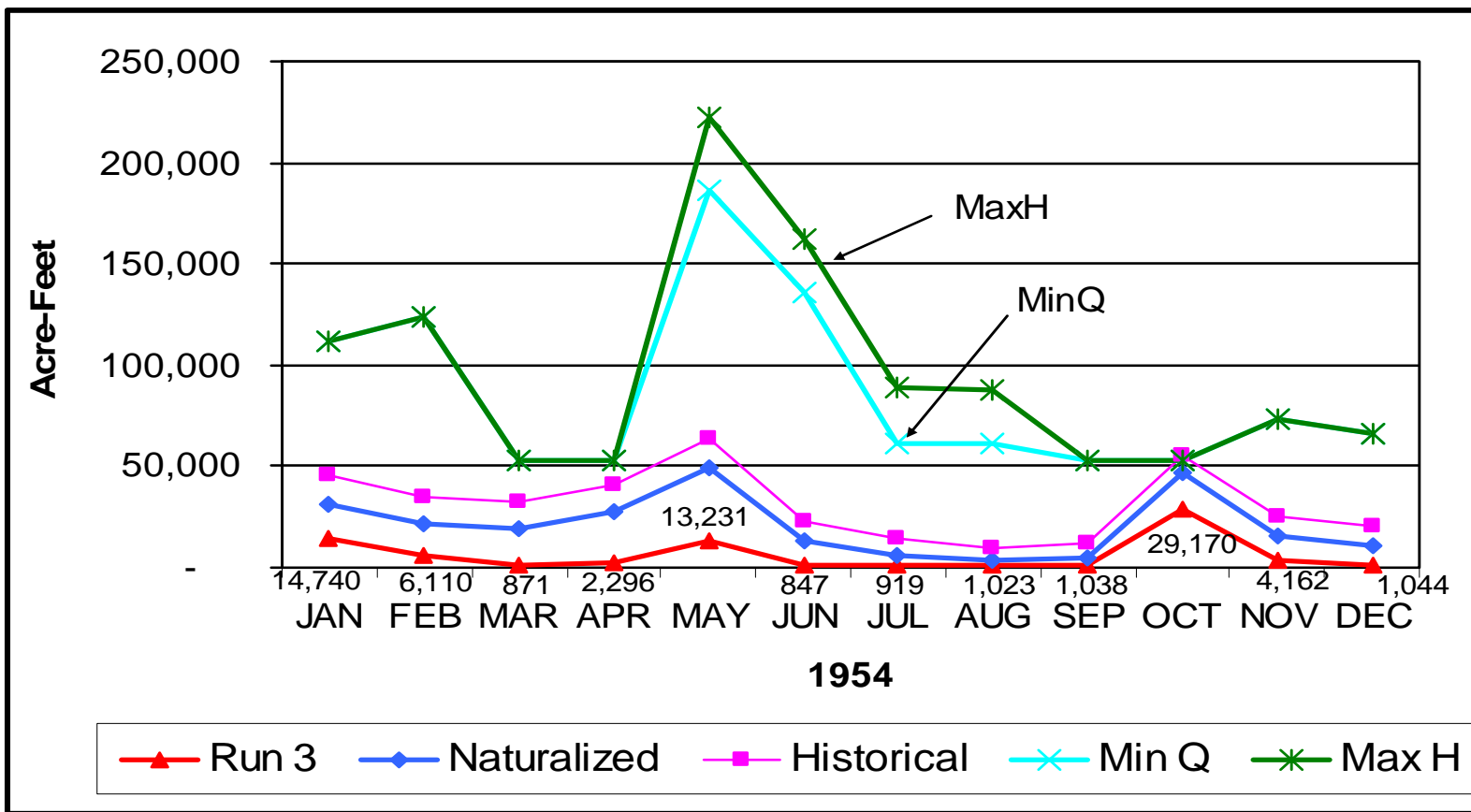


Figure 13.7 Guadalupe Estuary inflow for 1954 (from National Wildlife Federation/WAM data 2003). Note: Numbers in black beside Run 3 data points are the numerical value in acre-feet for that month. MinQ = MaxH Jan.-Apr. and Sept.-Dec.

Conclusion

Even discounting the possibility that naturalized flows are in some cases lower than expected, the comparisons of unappropriated flow to naturalized flow definitely indicate impacts of appropriations on the MinQ and MaxH recommended flows in the estuary studies. After seeing the graphs provided at the TCEQ workshop (figs. 13.1 - 13.5), concerns arise about the impact on freshwater inflow of the continuing process of granting water rights and planning for increased water use. In the following chapters the quantitative aspects of appropriations and planning will be further examined.

CHAPTER 14

WATER PLANNING AND THE RECOMMENDED FLOWS OF THE BAY AND ESTUARY STUDIES

The Consensus Criteria

The default method in the state water planning process for assessing environmental flow impacts of new diversions and reservoirs when there is no site-specific study is the consensus criteria (TWDB 2002b) that was explained in Chapter 8. The bay and estuary studies are, as of the end of 2003, not officially recognized as referenced site-specific studies in the regional or state water plans; therefore, any new project proposed in the planning process has to meet the consensus criteria. The three zones of the criteria were bounded by the median and 25th percentile naturalized flows and the 7Q2 water quality flow value calculated by the TCEQ. The procedure for modeling naturalized flows has been discussed, but more explanation is needed about the 7Q2 flow process.

The 7Q2 Flow

The 7Q2 flows are minimum flows set by the TCEQ to protect the designated uses of a stream segment including recreation, aquatic life, and domestic water supply (Tex. Admin. Code § 307.10). The segments of rivers and major streams are defined units having a similar designated use (Tex. Admin. Code § 307.2) and therefore can vary

in length. The parameters considered to protect those uses include dissolved oxygen, pH, total dissolved solids, and temperature. The authority of the TCEQ to administer the surface water quality standards comes from the Clean Water Act of 1972 and the USEPA reviews the standards of each state (Texas Environmental Profiles 2003). Every three years the state reevaluates the standards and revises them if necessary including the 7Q2 flows.

The 7Q2 is defined as: "The lowest average stream flow for seven consecutive days with a recurrence interval of two years, as statistically determined from historical data" (Tex. Admin. Code § 307.3[a][48]). Note the reference to "historical data" and not modeled data, which can be problematic when using the consensus criteria as discussed in the Region I analysis (Alan Plummer and Associates 2001).

Table 14.1 shows a portion of the table provided in the Texas Administrative Code where the 7Q2 of all defined segments of Texas rivers and streams are listed in

Table 14.1 – 7Q2 flows for the Lower Guadalupe River (from Tex. Admin. Code § 307.10[2])

Segment	Gage	County	Period of Record		7Q2 (ft ³ /s)
			Start Year	End Year	
1803	08176500	VICTORIA	1966	1996	607.4
1803	08175800	DE WITT	1966	1996	572.7
1806	08167500	COMAL	1966	1996	77.1

cubic feet per second. Segment 1803 of the Guadalupe River, highlighted in red in table 14.1, is the most downstream point on the Guadalupe with a calculated 7Q2. Figure 14.1 shows the location in Texas of the USGS gauge site that provided the data for the calculation of the 7Q2. For purposes of this analysis the 7Q2 for the mouth of the



Figure 14.1 Victoria USGS gauge number 008176500 (MapQuest 2004)

Guadalupe/San Antonio Rivers was required; however, recalling that the two rivers converge less than twenty miles inland, there was not a defined segment for the last few miles of the two rivers and the San Antonio segment ended at the confluence. As a result the first upstream site with a calculated 7Q2 was at the Victoria gauge with a 7Q2 flow of 607.4 cfs. Notice also the same river segment contains another gauge farther upstream in DeWitt County where the 7Q2 is lower at 572.7 cfs. The 7Q2 of 607.4 cfs remains the same all the way to the estuary.

MinQ and MaxH Meet the Consensus Criteria

To graphically demonstrate the relationship between the recommended MaxH and MinQ flows of the bay and estuary studies and the water planning process, the Guadalupe

Estuary was again selected. From WAM data generated by the author the monthly naturalized median and 25th percentile flows were calculated and are displayed on the graph (figure 14.2) with the median in pink and the 25th percentile in yellow. As previously noted the naturalized flows may be lower than historical flows (Johns 2003), but are nevertheless still the official naturalized flow output of the WAM as of December 17, 2003. The 7Q2 value in cfs (607.4) was converted to a monthly volume in acre-feet allowing for the different number of days in the months (note the slight dip in February on the red 7Q2 line and the fact that leap year was calculated as ¼ of a day added to each year). The conversion factor was 1cfs for 30 days = 59.5 acre-feet and 1cfs for 1 day = 1.9835 acre-feet (USGS 2004). Finally the MinQ and MaxH values (TPWD 1998) were added and the area enclosed by the MaxH was colored in blue. Note that the MinQ and MaxH are the same except in the months of May through August and the dark blue line inside the light blue field represents the lower MinQ values.

Zone 1 of the consensus criteria would occur when the flow into a new reservoir or upstream of a new diversion is above the naturalized median which is the pink line. Applying the consensus criteria to the graph in figure 14.2, all flows above the naturalized median (pink line) would be available for storage in the reservoir or diversion. Recall that this line being the median, half of the time flows are greater than the median and the surplus above the median is available for new projects in the water plans. More specifically affecting freshwater inflow would be both the potential loss of surge or flood flows that transport sediment to the delta, and the potential loss of some of

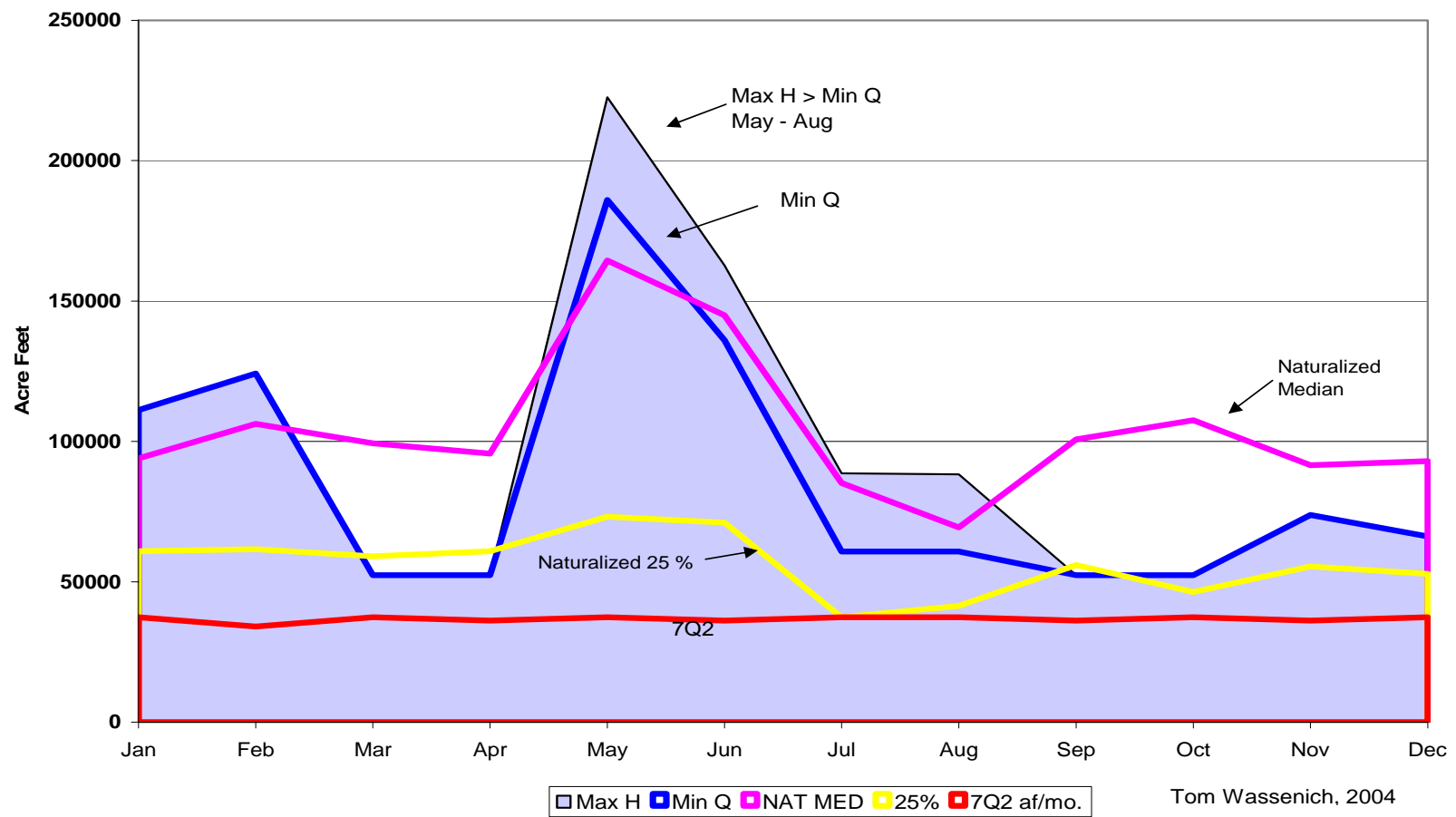


Figure 14.2 – Guadalupe Estuary and Consensus Criteria (from National Wildlife Federation/WAM data 2003)
 Note: MaxH = MinQ, Jan.-Apr. and Sept.-Dec.

the MaxH and MinQ flows in five months of the year – January, February, May, June and August. Even though the area in these months with the blue background above the pink naturalized median line is included in the MaxH or MinQ flow volumes, these flows are considered available for new projects in the water plans. The MinQ flows defined by the area in May above the pink line and below the dark blue MinQ line would also be subject to reservoir storage or diversion in the region plans. The trigger for Zone 2 is when the flow upstream of the reservoir or diversion project is less than or equal to the median, but greater than the monthly 25th percentile flows. At this stage only the 25th percentile flows have to be allowed past the project. In the graph this available-for-diversion flow would consist of all blue background area between the pink median line and the yellow 25th percentile line which includes MinQ flows and some MaxH flows where the MaxH exceeds the MinQ, e.g. July.

In drought conditions or Zone 3 when upstream flow is less than or equal to monthly 25th percentiles, only the 7Q2 flow has to be allowed past the project. As is evident in the graph the 7Q2 is not a percentage value, but simply a constant flow target that only varies monthly in volume with the change in number of days. Note that in July the 7Q2 and the 25th percentile are the same, but in all other months the 25th percentile exceeds the 7Q2. Theoretically this means that all flows below the red 7Q2 line will be for freshwater inflow as far as new projects in the water plans are concerned.

Summary Discussion of the Planning Criteria and Recommended Freshwater Inflows

In addition to the higher flows above the naturalized median that Zone 1 allows for new planning projects, the flows in Zones 2 and 3 are reduced to the lowest value of

the zone once the zone is triggered. This means that whatever flows are remaining in these zones can be used in new projects until that zone flow is depleted at which time the minimum required pass-through flow will jump down to the lowest value of the next zone.

This process only stops at the bottom of Zone 3 with the 7Q2 flow which was never intended to be a minimum freshwater inflow, but rather a minimum flow to preserve instream water quality in rivers (Tex. Admin. Code § 307.10). As can be seen in figure 17.2 the 7Q2 for the Guadalupe River is thousands of acre-feet less than the MinQ and most of the time thousands of acre-feet less than the 25th percentile. Future research should include calculating the total amount of flow allotted for future planning projects that would otherwise be part of the MinQ or MaxH flows.

The consensus criteria appear to guarantee only that the 7Q2 flows will be available for freshwater inflow if the water rights system has not already appropriated the 7Q2 flows with existing permits in which case there will be no future water available for planning. The planning criteria do not address this situation of overappropriation which exists in some Texas rivers, as seen in Chapter 16. At other times the criteria allow either the naturalized median or the 25th percentile to pass through to the estuary which is not a smooth transition process for decreasing flows (TPWD ca. 2001) and results in portions of MinQ and MaxH being consumed by new projects. The fact that naturalized flows rather than historical flows are the trigger for Zone 1 and 2 is beneficial to freshwater inflow in theory, except in a situation like the Guadalupe/San Antonio basin where historical flows are usually greater than naturalized flows (see chapter 11). It will be

interesting to see if there are changes in the methodology of either the criteria or the naturalized flow model to deal with any of these issues in the future planning process.

CHAPTER 15

THE WATERS RIGHTS PROCESS AND THE BAY AND ESTUARY STUDIES

Administrative Aspects of Water Appropriations and the Bay and Estuary Studies

There is no direct mandate in the Texas Water Code or the Texas Administrative Code that the Texas Commission on Environmental Quality use the bay and estuary studies as the sole source for the recommended freshwater inflows. In the Administrative Code § 297.55 is a statement that the Commission has to consider any available information *including the studies* recommended in the Water Code § 11.1491 which are in actuality the bay and estuary studies by the TPWD and the TWDB.

The TWDB staff claims that the studies are used by the TCEQ in water permitting and by the TPWD in making recommendations on permit applications relative to freshwater inflow (Powell 2003). In conversations with TCEQ staff in the water permitting division (Mosier, 2003) they state that the bay and estuary studies are one of the sources referred to when considering permit restrictions to protect freshwater inflow, although the studies are limited since they only have recommended flows for months with higher flows and the recommendations are in monthly time-step while the permit restrictions are specified as instantaneous flow. Conversations with TPWD staff (Loeffler 2003) confirm that they rely heavily on the bay and estuary studies in their recommendations to the TCEQ on water rights applications and amendments.

The administrative ties between the water rights process and the studies lack connectivity in several aspects because the Commission:

- 1) Is not mandated to use the particular studies of TPWD and TWDB to determine freshwater inflow needs.
- 2) Does not have specific instructions or policies on how to apply the MaxH and MinQ recommended flows to the restrictions on water permits for freshwater inflow protection in low flow scenarios.
- 3) Does not have a mandate to use the recommendations of the TPWD concerning freshwater inflow protection in water rights permits and amendments.
- 4) Does not have to include conditions to maintain freshwater inflow in water rights applications and amendments that are more than 200 river miles from the coast.

MinQ and MaxH Meet the Water Rights Process

The MaxH and MinQ are the only current state-prepared scientific flow recommendations intended to preserve the productivity of the major bays and estuaries in Texas (except for the Matagorda Bay). There are many references as to the role of the studies in the determination of the impact of new water rights and amendments on the bays and estuaries, but as previously explained the continuity is lacking between the study recommendations and the TCEQ water rights process for there to be effective application of the MaxH and MinQ flows. However since the studies are referred to by both the TCEQ and the TPWD in recommendations to the TCEQ, I will compare them with the other minimum flow systems that the TCEQ refers to when analyzing the impact of water rights applications and amendments. In conversations with staff in the water rights division (TCEQ 2003) they explained that the methods they use to determine flow

restrictions on new permits within 200 river miles of the coast are a combination of the Min Q, MaxH, the 7Q2, and the Lyons method. All of these have been explained except the Lyons method.

The Lyons Method

In 1979, Barry Lyons, a fisheries biologist with the TPWD, conducted a study to "... determine minimum streamflows needed to support Texas stream fisheries" (Lyons 1979, 1). From studies on the Guadalupe River below Canyon Lake, Lyons concluded that flows equal to 40 percent of the historical median monthly flows in October-February and 60 percent of the historical median monthly flows in March-September would provide minimum flows during critical periods to maintain adequate aquatic habitat (Lyons 1979).

Using the 60 percent and 40 percent criteria, tables were created for many of the rivers of Texas with monthly calculations of the historical median and the 60 percent or 40 percent of median value (depending on the month) at the USGS gauge locations. For the Guadalupe River the most downstream data was at the Victoria USGS gauge 08176500 – the same gauge used earlier for 7Q2 calculations. The minimum flows shown in table 15.1 were recommended in the river segment starting at the Victoria gauge and would apply to the remainder of the river down to the estuary.

Table 15.1 – Guadalupe Lyons Method flows in cfs (Lyons 1979)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yr
390	456	660	672	804	708	540	404	468	333	334	377	468

Interestingly the next upstream gauge in DeWitt County at Cuero, Texas has higher Lyons flow minimums with an annual rate of 580 cfs compared to the Victoria site with 468 cfs. As discussed in chapter 17 the 7Q2 recommended flows at the DeWitt County site were lower than the Victoria site, as would be expected as one moves downstream. The reasons for this lower Lyons value downstream are not clear, but a possible cause could be the fact that historic flow data are used in the calculation of the Lyons flow which could be influenced by major diversions between the two points causing lower downstream flows. The 7Q2 flow is much more complicated to derive than the Lyons and was not analyzed in detail; therefore, their relative values cannot necessarily be compared as to their spatial orientation.

Comparison of the Methods of Water Rights Analysis

Since there does not seem to be a specific method of determining low flow restrictions for new water right applications, it would be interesting to examine all the known methods in comparison to one another. Figure 15.1 displays the MaxH, MinQ, 7Q2, and the Lyons along with the dotted green line representing historical flows and the pink line at the bottom representing Run 3 flows – all for 1954, the worst year of the drought in the Guadalupe Basin. Although this is a lot of data for one graph, the various data patterns for each of the recommended flow methods are somewhat parallel in 1954, making them reasonably distinguishable. Having all of these values on one graph for the worst year of the drought shows how these criteria are related to one another in the drought of record period upon which Texas water planning for most areas of the state is based (TWDB 2002b).

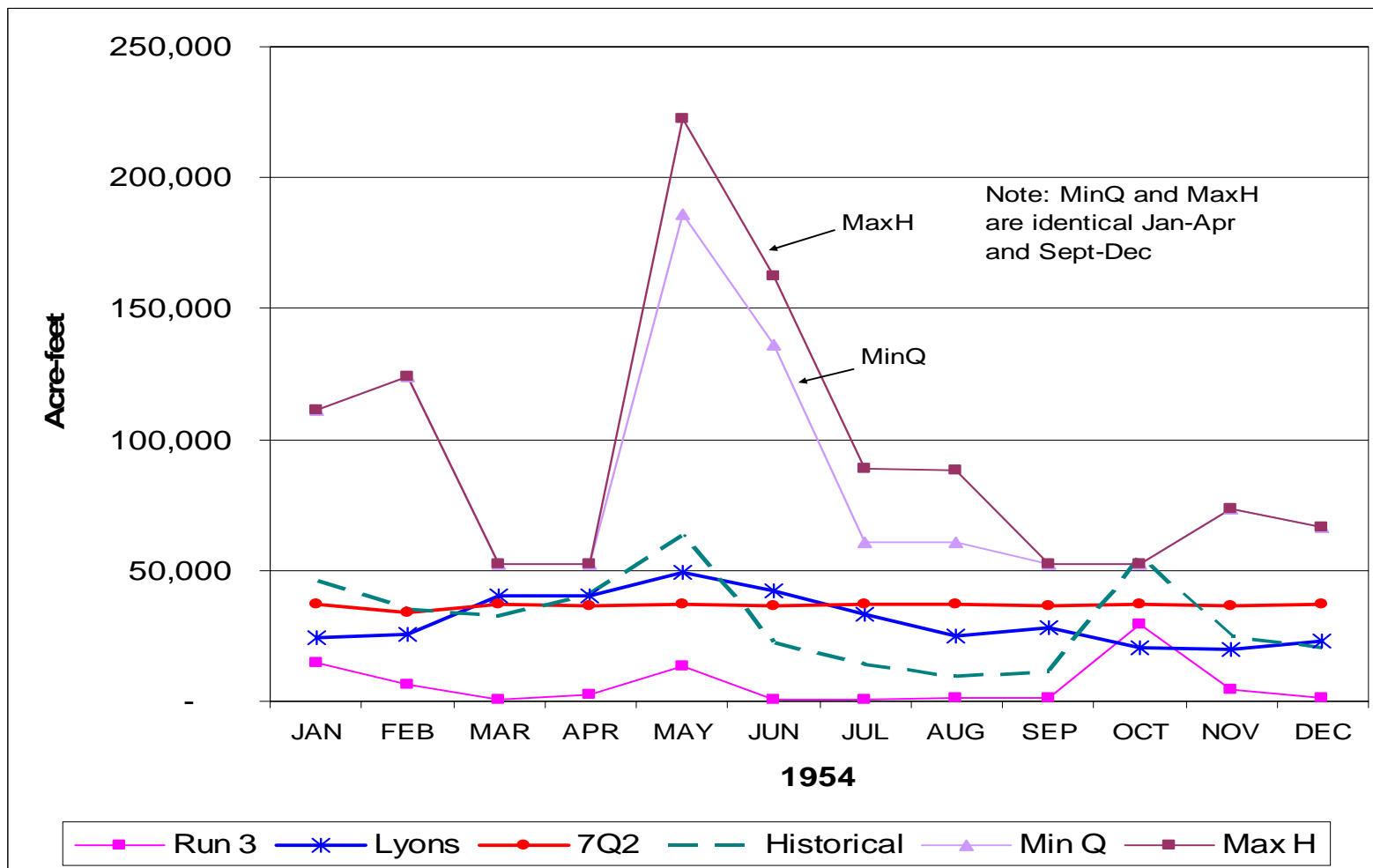


Figure 15.1 – Guadalupe River actual, recommended and modeled flows for 1954 (National Wildlife Federation/WAM data 2003)

The graph in figure 15.1 has some elements previously examined for the year 1954, but here the Lyons and 7Q2 monthly values are added to observe how they relate to the historical flows, the modeled Run 3 (all water rights used) flows and the MinQ and MaxH. This represents some of the data that would be examined at the TCEQ to determine the impact of a new water right application on freshwater inflow. Again it should be mentioned that the Run 3 line appears to reach zero in several months, but it only gets close enough to appear to reach zero with six values around 1000 acre-feet per month in this the driest of the years of record. The Lyons values which are expressed in cubic feet per second were converted to a monthly flow volume using the same methodology as was used with the 7Q2 calculations – the difference being the Lyons flow varies for every month of the year unlike the 7Q2 data that is almost constant with slight variations for months containing less than or greater than 30 days.

The Lyons data in blue crosses the 7Q2 in red twice as it changes in value while the 7Q2 remains virtually the same (except for slight variations in 28 and 31 day months). Since the Lyons and the 7Q2 flows are not completely for the same purpose, it is difficult to compare the relationship of these two flows to one another and to freshwater inflow – the Lyons flow is to maintain inland fisheries habitat (Lyons 1979) while the 7Q2 flow is to maintain various physical, chemical and biological aspects of water quality for segments of rivers with uses such as aquatic life (Tex. Admin. Code § 307.10). The fact that the Lyons and 7Q2 flows are higher than the Run3 line in 1954 shows that restrictions based on either of these two flows would prevent the river from being drawn down to the level of Run 3 in 1954 (worst year of the drought). But recall that Run 3 is

the flow remaining if all current water rights are fully used and there is no return flow; therefore, under existing rules and practices this Run 3 scenario *could* occur in a drought of similar severity since the existing water rights have few restrictions and what restrictions there are would be reflected in the modeled Run 3 flows.

The actual historic flow in 1954, shown in the dark green dotted line, stayed at or near either the 7Q2 or the Lyons, while the Run 3 flow is substantially lower and almost zero in six of the twelve months. By deduction this reduced inflow from the historic to the modeled Run 3 level is due to the effect of the continued granting of water rights since 1954 with only rights after 1985 having flow restrictions to prevent such a severe drawdown at the estuary as shown in figure 15.1.

As can be seen from the graph in figure 15.2 the volume of water rights granted state-wide that do *not* have environmental conditions has approximately doubled from around ten million acre-feet in 1954 to slightly more than twenty million acre-feet in 1985 when environmental conditions were initiated. The portion of the bar graph colored light brown in the upper right corner represents the volume in acre-feet of water rights that have been granted through 2001 that have environmental conditions written into the permit to protect freshwater inflow. As mentioned before, there is no existing mechanism or authority to impose ex post facto requirements on these existing permits that lack environmental conditions (TCEQ 2002).

In the literature on the 7Q2 and the Lyons method there is not discussion of freshwater inflow. As previously described they were designed for various instream flow minima for rivers and streams. As seen in figure 15.1 the 7Q2 for the lower Guadalupe River is less than the MinQ in all of the months, and there appears to be no analysis by

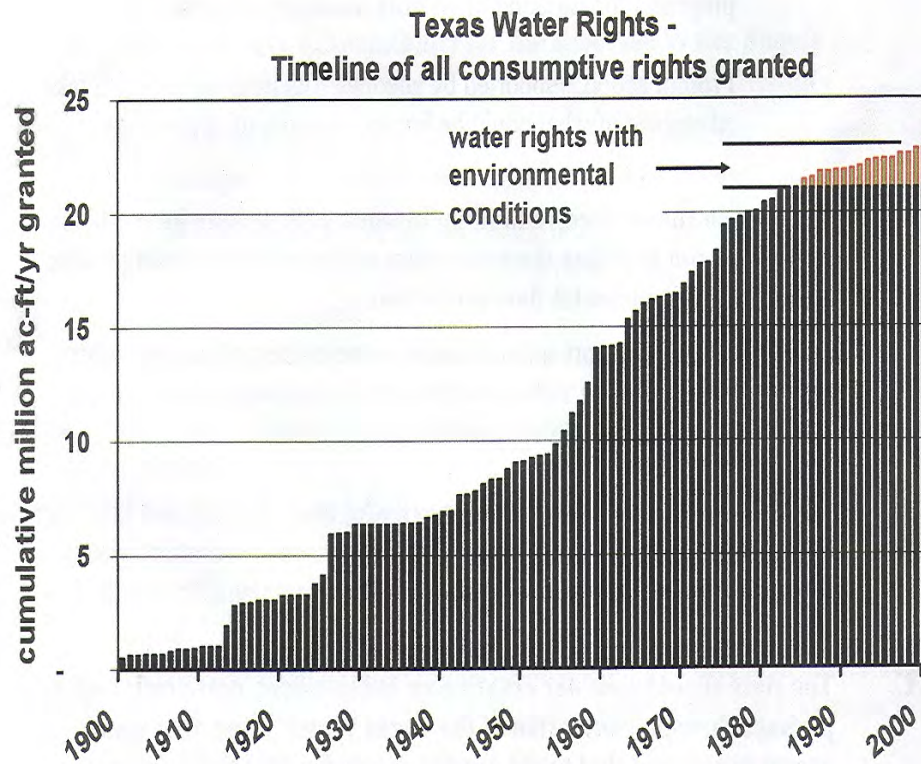


Figure 15.2 – Texas water rights timeline (National Wildlife Federation 2003)

any of the three agencies on the effects of sustained flows at the levels of either the 7Q2 or the Lyons method on the bays and estuaries

For a different perspective, figure 15.3 displays the 7Q2, the Lyons method, Run 3 and MinQ and MaxH on an annual basis for the period of from 1934-1989. On an annual basis at this scale, the MinQ and MaxH appear very close together and much more separated from the 7Q2 and the Lyons than in figure 15.1 which was on a monthly basis. The highly varied flows are evident from the Run 3 and due to the scale having to reach

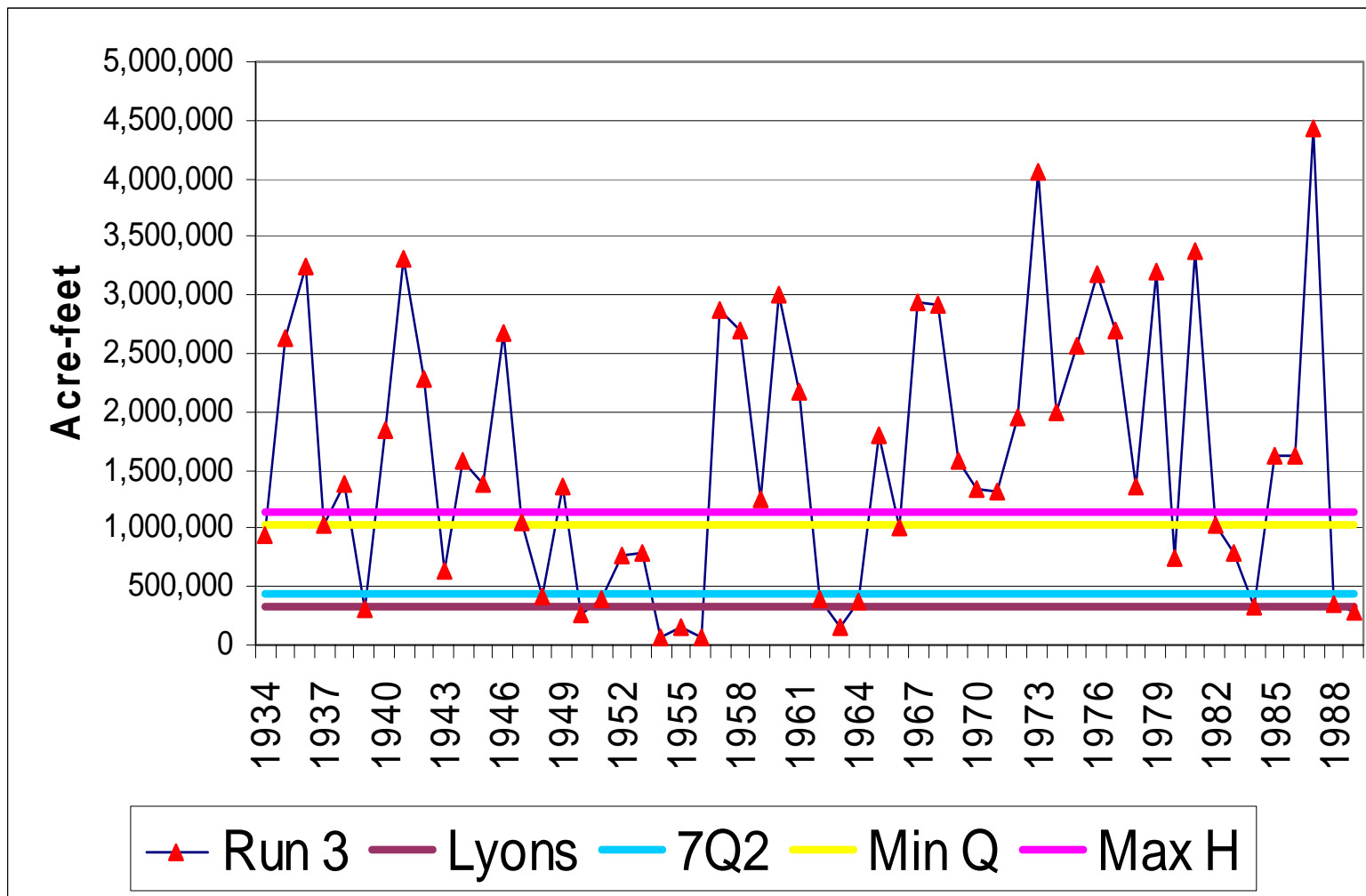


Figure 15.3 – Guadalupe River recommended flows 1934-1989 (from WAM data 2003; Lyons 1979; TCEQ 2003;TPWD 1998)

the five million value, the drought flows below the Lyons appear less significant, but still 8 of the 56 years or 14 percent, fall below even the Lyons and in 22 years or about 40 percent of the time the MinQ is not met.

Summary Discussion of Water Rights and Bay and Estuary Studies

In the TPWD (1998) study of the Guadalupe Estuary there is discussion on the impact of low flows on the estuary, although not with much detail. The 7Q2 and the Lyons method are not specifically addressed, but the management recommendations call for no increase in the frequency of reduced freshwater inflow levels beyond historical occurrences (TPWD 1998). There is concern for any exacerbated increase in the severity, frequency, or duration of droughts which could either reduce overall fishery production or favor one species at the expense of another (TPWD 1998). The lack of target flows for low flow and/or drought years was not in the legislative mandate, so it is not a deficiency of the study per se, but rather a missing piece of the multi-agency process of establishing conditions in water rights to protect freshwater inflow.

The TPWD did rerun the TXEMP optimization model on the Guadalupe Estuary for lower flow scenarios by reducing the harvest target from the 80 percent used in the MinQ/MaxH model run down to 50 percent. At the 50 percent level of production the MaxH was predicted to be 0.76 million acre-feet per year down from the original MaxH of 1.15 million acre-feet (TPWD 1998). The TPWD points out that *historically* (1941-1987) there were only five years with less than 0.76 million acre-feet and that this flow is the equivalent of the 10th percentile flow. What is missing from this quantitative analysis is the modeled effect of all the water rights being fully utilized as in Run 3 of the WAM. In 1998 when the Guadalupe study was published, the WAM was not complete and

therefore the projected impact of all existing water rights on flows at the estuary was not available.

The following information and observations lead to the conclusion that the Guadalupe Estuary model appears to have limited applicability in low flow situations:

- 1) Figure 15.1 shows that based on comparing Run 3 to historical flows that the frequency and duration of low flows in a drought comparable to 1954 are increased as the result of granting water rights.
- 2) Figure 15.2 shows the increase over time of the volume of water rights granted before there were environmental conditions added to them starting in 1985.
- 3) As the volume of water rights without environmental conditions approached its maximum level in 1985 (figure 15.2), Texas did not experience extended conditions as severe as the drought of record in the 1950's which can be indirectly confirmed by observation of the Run 3 flows in figure 15.3 and the fact that the 1950's were the drought of record.
- 4) The fishery production data used in the TXEMP model was gathered for various species in the years spanning 1959-1987 (TPWD 1998).
- 5) The drought of record for the Guadalupe Estuary ended in 1956 before the data period that was referenced for fishery production totals in the model (1959-1987).
- 6) Only in the last few years of the model data period from 1985 to 1987 would the total actual diversions begin to reflect the impact of all the water rights granted without environmental restrictions – based on the assumption that actual diversions would increase at somewhat the same rate as the steadily increasing volume of water rights shown in figure 15.2. The full effect of pre- 1985 water

rights will only be felt when they are fully utilized. Of the approximate 21 million acre-feet of consumptive rights granted state-wide as of 1999 (fig. 15.2) only 6.72 million acre-feet were used in 1999 (TWDB 2002b).

- 7) The WAM data was not available to examine the model especially under the Run 3 conditions of full use of current (as of the date the TPWD study was performed) water rights with no return flows.

Therefore the model of the Guadalupe Estuary would appear to be optimistic in projecting future conditions when all current water rights are fully used with no return flow in conditions similar to the record drought of the area. In more general terms the model of the Guadalupe Estuary appears to have limited applicability in low flow situations. This is also assuming that the environmental conditions added to permits within 200 river miles of the coast since 1985 are adequate in preventing any further reduction in freshwater inflows that would affect fishery production and that new unrestricted permits more than 200 river miles from the coast would have no effect on fishery production.

There seems to be a missing administrative and quantitative connection between the recommended flows of the bay and estuary studies and the methods used to determine environmental flow conditions in new water rights and amendments. There are neither specific instructions on the utilization of the MaxH and MinQ flows for determining environmental restrictions on water rights, nor are there existing models specifically designed to determine low-flow regimes necessary to sustain bays and estuaries especially in extended dry periods if all water rights are fully utilized (Run 3). Meanwhile the staff at TCEQ is required to determine the minimum flow restrictions on

new permits and amendments as they are applied for, using the somewhat disconnected tools of MaxH, MinQ, 7Q2, and the Lyons method plus the data from the WAM. As of February 23, 2004 there were 149 pending water rights applications at the TCEQ (TCEQ 2004).

CHAPTER 16

AN ANALYSIS OF CANYON DAM FLOOD FLOW MANAGEMENT

In chapter 8 the role of the United States Army Corps of Engineers (USACE) in managing the flood pool of its reservoirs was discussed. Since flood control requires alteration of the natural flows of the river to minimize the higher flows, the result is alteration in the timing that these higher flows would have reached the estuary.

Alteration of the timing of freshwater inflows can affect the productivity of the estuary (TPWD 1998). There are existing analyses of reservoir operations for some reservoirs in Texas. The USACE determined that the average number of flood events that reach the Nueces Estuary have been reduced from 2.3 per year to 0.8 per year since the completion of Choke Canyon Reservoir in 1982 (USACE 2002). It should be noted that the USACE does not manage the Choke Canyon Reservoir.

As stated previously, it is not in the scope of this work to analyze the flow management system of all of the reservoirs managed by the USACE in Texas. However, a quantitative analysis of one reservoir for a chosen period can provide an example of the potential impact of flood management on downstream flow patterns in the river that can ultimately affect freshwater inflow.

Methodology of the Analysis

The analysis chosen was a graphic comparison for a full month of a flood control reservoir managed by the USACE. Comparisons were made of inflow to the reservoir, controlled outflow from the flood pool, and total outflow from the reservoir including flood pool releases and conservation pool releases by the Guadalupe Blanco River Authority. As in other analyses in this document, I chose the Guadalupe Basin for this study. The USACE manages the Canyon Lake Reservoir on the Guadalupe River (fig. 6.2) which is designed mainly for flood protection and conservation (USACE 2004a).

October, 2003 was chosen as the sample month for analysis. Since data were required from both the USGS and the USACE, a month had to be found with no missing or questionable data in either agency's data base. For inflow from the Guadalupe River upstream, USGS streamflow data were used from the Spring Branch gauge number 08167500, which is the nearest gauge upstream of Canyon Lake (fig. 16.1). The USACE provides computed and adjusted inflow amounts for Canyon Lake in its Internet data base; however, there were repeated instances of negative flows and missing data that would make analysis difficult. The USGS Spring Branch gauge had sufficient data for October, 2003, but there were questions about its accuracy for this analysis due to its location being approximately 10 river miles upstream of the lake (TPWD 2003–2004b). To determine the viability of the gauge data, the Spring Branch USGS gauge data were compared to the USACE inflow data for a period when there was consistent output from both data bases. As expected, the upstream USGS gauge flows were always slightly lower than the downstream computed USACE inflows. This difference is

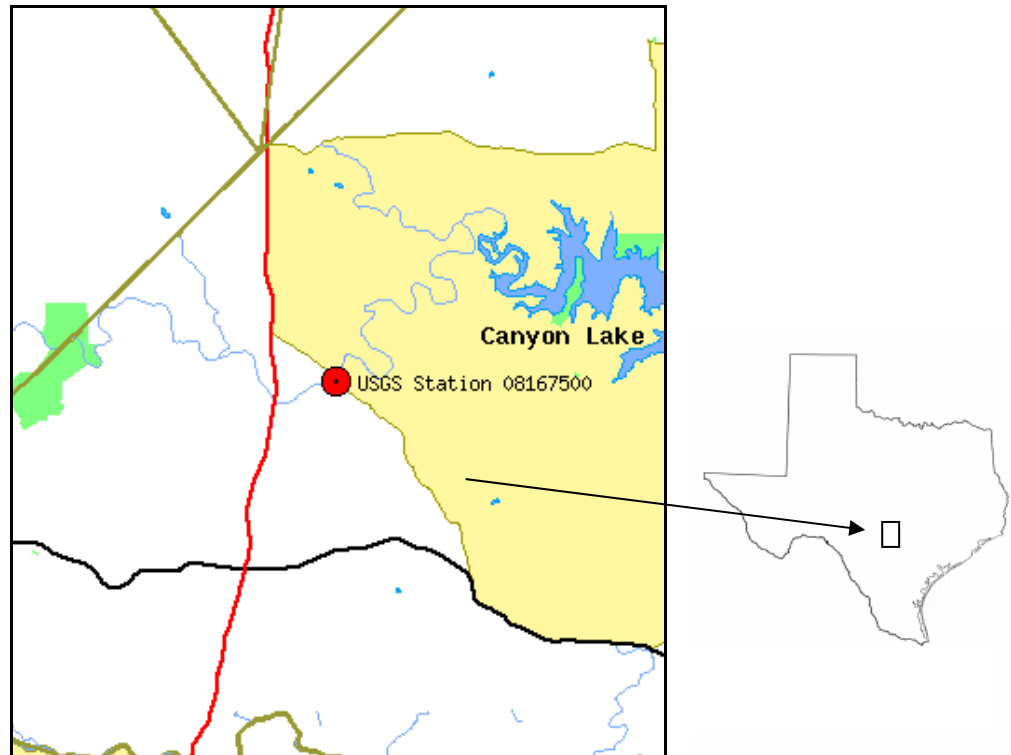


Figure 16.1 – Map of Spring Branch USGS gauge number 08167500 (USGS 2004).

assumed to be due to the added runoff between the sites, and the existence of one or more creeks entering the river below the gauge (TPWD 2003–2004b). It was determined that the Spring Branch gauged flows could substitute for the incomplete USACE computed inflows for this analysis. The objective of this analysis is to point out the relative differences in inflows and outflows and the actual differences are of secondary importance.

From the USACE on-line data base the mean daily releases from the flood pool were found for October, 2003. The only calculation for a combined total daily reservoir outflow (flood pool plus conservation pool) was the turbine outflow. It was not clear if the outflow of the turbine units was the same as the total outflow of the reservoir. To avoid possible error, again the closest USGS gauge was selected. The Sattler, TX, gauge

number 08167800 (fig. 16.2) lies approximately one mile downstream of the outlet of the reservoir (TPWD 2003–2004b). It was determined that this gauge would provide sufficient accuracy of reservoir outflow because it was relatively close to the reservoir (one mile), and reflected the combined flows of the turbines and any other outlets of Canyon Dam.

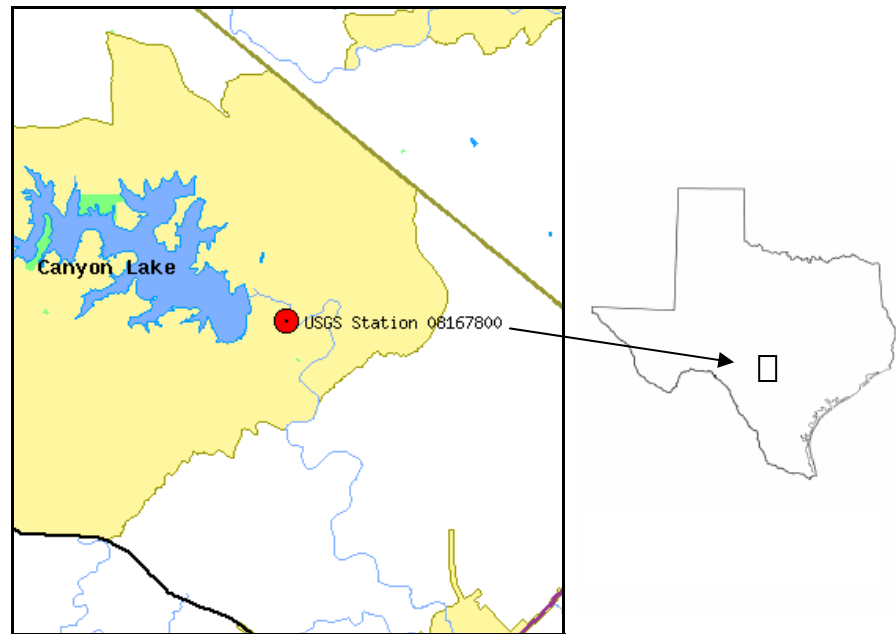


Figure 16.2 – Map of Sattler, TX USGS gauge number 08167800 (USGS 2004)

Analysis of Outflow Comparison

The graph shown in figure 16.3 displays the workings of a reservoir (Canyon) managed by the USACE in a month with noticeable variances of inflow, total outflow, and flood pool outflow. These fluctuations occurred while elevations of the conservation pool were maintained to within a one foot range, varying from 908.28 to 909.29 feet above sea level. The conservation pool maximum elevation is officially 909.00 feet with any water above that considered part of the flood pool. The yellow line representing the

inflow of the Guadalupe River in October, 2003 showed a peak on the 13th of 1970 cfs (table 16.1). Up to that point in October the USACE had been releasing a fairly constant amount from their flood pool represented by the red line. Through the 16th of October these flood pool releases generally ranged from 127 cfs to 116 cfs. As the river inflow (yellow line) began increasing on the 8th of October, the total outflow (black line) began to fall slightly while releases from the flood pool (red line) also dropped slightly from 127 to 116 cfs.

Starting on the 8th the elevation of the lake began to increase reflecting the increase in river flow and at the same time showed a slight decrease in total outflow and flood pool outflow (table 16.1). Due to the scale of the graph the elevation changes are not visible. For actual data see table 16.1. The surface area of Canyon Lake is over 8000 acres (USACE 2004a). A one-foot fluctuation in the lake level can mean a change of approximately 8000 acre-feet of water. This is mentioned to show an example of just a few of the variables that have to be considered when managing a reservoir.

As the river flow peaked at 1970 cfs on October 14th the total outflow (black) began increasing while the flood pool release tapered to zero by the 17th. This represents the USACE slowing down and stopping discharge from the flood pool while at the same time the GBRA was increasing the outflow from its conservation pool. The total outflow includes the flood pool release if there is any.

The inflow quickly dropped off within a few days of the peak, while the total outflow continued to increase. The peak elevation for the month of 909.29 feet occurred on October 15th, two days after the peak inflow. On the 16th the total outflow surpassed the river inflow and remained higher till the 25th. For the last week of October the

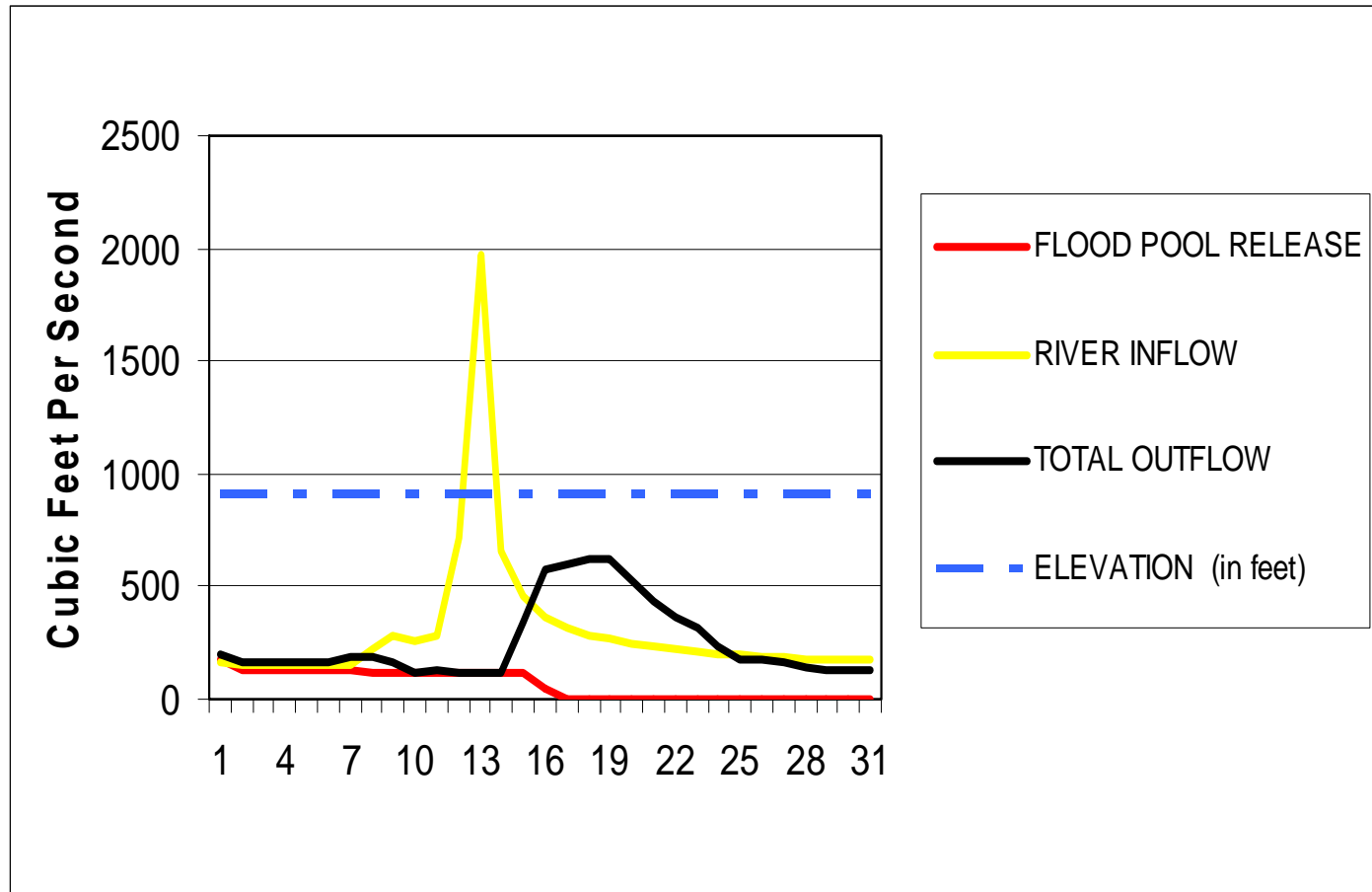


Figure 16.3 – Comparison of Canyon Lake daily inflow/outflow for October 2003 (USGS 2004 and USACE 2004). Note: Elevation varied from 908.27 to 909.29 feet.

Table 16.1 – Canyon Lake flow data for October, 2003 (USGS and USACE)

DATE	FLOOD POOL RELEASE	RIVER INFLOW	TOTAL OUTFLOW	ELEVATION (in feet)
1-Oct-03	172.00	159.00	199.00	908.30
2-Oct-03	127.00	153.00	162.00	908.29
3-Oct-03	127.00	149.00	161.00	908.27
4-Oct-03	127.00	149.00	161.00	908.27
5-Oct-03	127.00	150.00	161.00	908.27
6-Oct-03	127.00	153.00	168.00	908.28
7-Oct-03	127.00	154.00	191.00	908.28
8-Oct-03	123.00	218.00	187.00	908.31
9-Oct-03	116.00	280.00	169.00	908.37
10-Oct-03	116.00	257.00	122.00	908.39
11-Oct-03	116.00	284.00	127.00	908.55
12-Oct-03	116.00	716.00	121.00	908.66
13-Oct-03	116.00	1970.00	119.00	909.14
14-Oct-03	116.00	661.00	118.00	909.28
15-Oct-03	116.00	454.00	345.00	909.29
16-Oct-03	48.00	363.00	577.00	909.24
17-Oct-03	0.00	317.00	602.00	909.18
18-Oct-03	0.00	285.00	625.00	909.10
19-Oct-03	0.00	266.00	626.00	909.02
20-Oct-03	0.00	249.00	525.00	908.97
21-Oct-03	0.00	236.00	435.00	908.94
22-Oct-03	0.00	224.00	368.00	908.91
23-Oct-03	0.00	213.00	317.00	908.90
24-Oct-03	0.00	205.00	238.00	908.89
25-Oct-03	0.00	199.00	174.00	908.90
26-Oct-03	0.00	191.00	172.00	908.90
27-Oct-03	0.00	186.00	163.00	908.88
28-Oct-03	0.00	181.00	143.00	908.88
29-Oct-03	0.00	180.00	133.00	908.83
30-Oct-03	0.00	178.00	134.00	908.84
31-Oct-03	0.00	178.00	134.00	908.85

inflow exceeded the outflow. After October 16th the USACE did not discharge from its flood pool.

Conclusions

By graphically depicting the operation of Canyon Reservoir in a given month, the

varying effects of the reservoir operation on downstream flow can be observed. To avoid confusion only the river inflow and total outflow will be discussed here. These two value sets reflect the "before and after" results of reservoir operation. The elevation and flood pool release values are secondary data showing more detail about the operation methods.

The inflow and outflows remained close for the first week with outflow exceeding inflow. This was followed by a surge in inflow while outflow remained the same. As the inflow tapered downward, the total outflow increased and exceeded the inflow for several days. For the last week of October inflows and outflows remained fairly close, but inflow exceeded outflow. It is obvious that downstream flows when compared to upstream flows are affected by the operation of the reservoir, especially timing of the flows.

To determine the effects of a major flood control reservoir on downstream flows is a complicated process. To determine the effects of a reservoir on freshwater inflow is an even more complex process and several questions would have to be answered:

- 1) How far is the reservoir from the coast?
- 2) What would be the evaporation loss in the river from the reservoir to the coast?
- 3) Does the operation of the reservoir affect the downstream flows seasonally, or are the timing alterations generally of a shorter time frame?
- 4) Flows to the estuary:
 - What portion of the reservoir releases actually flow to the estuary?
 - How much of the outflow is actually diverted for consumptive use?
 - How much of the outflow would be diverted if all existing rights were fully utilized and there was no return flow?
- 5) Using the changes in timing of freshwater inflow, what would be the effects on the productivity of the estuary?

These are obviously just some of the questions that would need to be answered to determine the effects of reservoir operation on freshwater inflows. Possibly not all reservoirs would need analyzing due to distance from the coast. However, the maximum distance of influence of reservoirs on the timing of freshwater inflow needs to be determined.

This analysis provides a snapshot of the state of the operation of a USACE managed flood control reservoir. It shows in a one-month sample period the alterations of timing of reservoir outflow compared to inflow. It is not my intent to quantify the amount or duration of timing alterations, or the effect of those alterations on freshwater inflow. The operation of these types of flood control reservoirs, some more than 200 river miles from the coast, should be examined at least from an overall perspective to determine if more finite analysis is needed. The effects of the alteration of the timing of flows on freshwater inflow need to be further analyzed.

CHAPTER 17

A TOUR OF FRESHWATER INFLOW PROTECTION THROUGH WATER RIGHTS PERMITS

Up to this point the various components of the system of freshwater inflow protection in Texas have been analyzed both as individual entities and in relation to other parts of the system. The process of granting water rights, where freshwater inflow is both protected by conditions on permits and given away by the nature of the process, has been explored administratively and quantitatively, but only in general terms. Another perspective can be gained by examining actual water rights permits over time to reveal both the administrative and quantitative changes that have occurred in the process and the actual integration of other components of freshwater inflow protection with the water appropriation process.

Methodology of Permit Research

With over 6500 active water rights it was not possible to examine all of them. For research purposes a sample number were chosen by their proximity to the coast, volume of the permit, and date of the permit. Starting in 1985 there have been approximately 3300 water rights issued that are still in the active TCEQ data base last updated November 18, 2003. The actual permit detail is obtained from microfilm files or sometimes for newer permits, from hardcopy files at the TCEQ Central File Room in Austin, Texas.

The permits were issued under the name of the agency granting water rights at the time of issuance. The earliest permit discussed here (1960) was under the authorization of the then Texas Water Commission (TWC). In 1993 the agency name was changed to the Texas Natural Resource Conservation Commission (TNRCC) which became the Texas Commission on Environmental Quality (TCEQ) officially in 2004, although implementation started September 1, 2002 (TCEQ website 2004). Some permits were applied for under one agency name and reviewed or granted under a subsequent agency name. All permits are on file at the Texas Commission on Environmental Quality.

Permits to be examined were first selected from the data base which shows the basic information of the type displayed in table 17.1. Note that the "Date" column has only sequential five-digit numbers. These are an Excel worksheet function and represent the number of days a particular date occurred after January 1, 1900.

Table 17.1 – Sample of active water rights data base (from TCEQ 2003)
Note: Certain columns were omitted for display reasons.

WR #	Date	Amount	Use	Stream Name	County	Remarks
2	26183	164.8	3	RIO GRANDE	Willacy	
3	26183	250	3	RIO GRANDE	Willacy	COMBINING ORDER 9/7/89
3	23655	368	1	RICHLAND CRK	Navarro	
4	26183	2.5	3	RIO GRANDE	Willacy	CLASS B-TO CHANGE LA C TO STARR CO
7	26183	242.5	3	RIO GRANDE	Willacy	
7	26183	87	3	RIO GRANDE	Willacy	
7	26183	50	1	RIO GRANDE	Willacy	
7	26183	23.2	1	RIO GRANDE	Willacy	AMENDED 6/23/2003: CONVERTED IRR TO MUNI
8	26183	5	3	RIO GRANDE	Willacy	
8	26183	20	3	RIO GRANDE	Starr	AMENDED 5/10/96: NEW DIVERSION POINT
10	26183	368.415	3	RIO GRANDE	Cameron	AMEND 5/2/88: MATHERS COMBINED INTO 135
12	26183	162.5	3	RIO GRANDE	Cameron	5/11/81,11/14/86
14	26183	150	3	RIO GRANDE	Cameron	
15	23907	50000	2	NECHES RIVER	Jasper	

They are useful for numerical calculations, for instance sorting pre-1985 water rights.

After further review of the actual permits on microfilm, the relevant permits were copied along with the environmental analyses from the agency if available.

First the water permit numbering system will be explained. Until the Water Rights Adjudication Act of 1967 (Tex. Water Code § 11.301-341) water rights were based both on the principles of riparian ownership and prior appropriation discussed earlier, with many of these rights unrecorded. The Act called for all claims for water to be recorded under the prior appropriation system in a process called adjudication (Kaiser 2002). Claims were based on actual use during the years 1963-1967 and each right was administered through the courts – with most adjudications completed in the 1970's and 1980's except for a few rights on the Rio Grande which are only now being adjudicated.

In appendix D is an example of an adjudicated water right number 12-5366. The "12" refers to the associated river basin which is the Brazos River. Note the priority date for the right is April 4, 1960, and the date of the adjudication of all the rights on the related portion of the Brazos River was June 1, 1987. April 4, 1960, is the priority date of the original permit number 1964 which was granted to Dow Chemical Company and was part of another adjudication as briefly explained in the body of the certificate of adjudication. To avoid unnecessary discussion and possible confusion, not all permit numbers will be referenced here – only associated numbers that demonstrate the numbering process. Dow sold 45,000 acre-feet of their original right to Brazosport Water Authority who amended Permit 1964 from industrial to municipal use which created amended Permit 1964C shown in the first line of the page titled "Amendment to Permit." This amended Permit 1964C was granted October 13, 1987 after the original right was

adjudicated – still retaining the original priority date. Note also an application number 2158C at the top of the "Amendment to Permit" page. Sometimes in the TCEQ data base they refer to the application number while at other times they use the adjudication number without the river basin number. This discussion of the administrative numbering system is not intended to confuse the reader, but rather to illustrate the complexity of the water rights system and the inherent difficulty in researching specific permits.

Two sample permits are included in appendix D, the just-discussed Brazosport Water Authority permit which was a pre-1985 permit with no environmental restrictions, and the December, 2000, San Marcos River Foundation (SMRF) draft permit that contains arguably more environmental analysis than any prior permit due to the issues raised by the application. Microfilm and hard copy are not always available in the files if they are being used by TCEQ staff or are the subject of a court case. Availability is less for permits issued in the past few years since they may not be in the data base and/or staff may still be completing administrative tasks on a new permit and not have placed them at the Central File Room. The SMRF permit, although denied, is the most recent permit available, draft or otherwise, that contains the environmental analyses using the bay and estuary studies and the WAM, is located near or at the coast, and is for a large amount of water. There are some other large water rights pending, but the draft permits which contain the detail and environmental analysis are not yet complete.

Pre-1985 Permits and Post-1985 Amendments

As discussed, water rights prior to 1985 had no restrictions for environmental flow protection, either for instream flow or bay and estuary inflow. Even when these pre-1985 permits were amended after 1985 they did not contain environmental flow

restrictions. An example of both of these situations is Certificate of Adjudication 12-5366 and its subsequent amended Permit 1964C in the name of the Brazosport Water Authority with a priority date of 1960 discussed earlier which are included in appendix D (TWC 1960).

On the page titled "Amendment to Permit" which changes the use of the 45,000 acre-feet from industrial to municipal, there are no restrictions or special conditions except that the permit is subject to all superior and senior water rights which is a fundamental requirement of all water rights. In the certificate of adjudication referring to the original permit with a priority date of 1960 there are also no special conditions other than the reference to senior water rights. The certificate of adjudication recognizes the original permit with its pre-1985 lack of flow restrictions for instream use or freshwater inflow, even though the adjudication process occurred post-1985.

The amended permit number 1964C is an also an example of changing the use of a permit without adding restrictions for environmental flows even though the amendment was issued in 1987 when environmental restrictions on new permits began. Under the "No Injury" rule (Tex. Admin. Code § 297.45) an amendment shall be approved unless it increases the amount of diversion which remains at 45,000 acre-feet in this case and therefore has to be accepted. It should be noted that in the third paragraph of the Certificate of Adjudication there is a clerical error in which the original permit is referred to as "1946B" instead of 1964B – just another example of some of the obstacles in water rights research.

Certificate of Adjudication 12-5366 is an example of a large (45,000 acre-feet) water right in a coastal county (Brazoria) that was issued pre-1985 (1960) and was

subsequently amended (Permit 1964C in 1987) after 1985, that contains no environmental flow restrictions in either document. In addition this water was allowed to be transferred from one river basin to another.

Post-1985 Permits

Permit 5317, 1990 – Saltwater Barrier

In 1990 Permit 5317 (TWC 1990) was issued for a saltwater barrier in the coastal county of Jefferson in the Trinity-Neches Coastal Basin. The environmental effects of saltwater barriers were previously examined in the discussion of a recent barrier dam project on the Neches River (LNVA 2002; Wilde 2000; Dukes ca. 1998) and apparently are not considered a significant factor in freshwater inflow issues. The special conditions of the permit state that the adjustable barrier is allowed to be in place only "at times of saltwater intrusion . . . and shall not prevent downstream flows into Sabine Lake" (TWC 1990, 2). In an Interoffice Memorandum from the Instream Uses Unit (TWC 1990) is an environmental analysis of the permit relative to instream uses and bays and estuaries. The barrier is determined to have no impact on Sabine Lake since no water is diverted for consumptive use and the barrier will be in place only at times that saltwater is intruding upstream and therefore will not prevent downstream flows into Sabine Lake, the inland estuary.

This analysis shows the post-1985 emphasis on instream flow and bay and estuary effects that is not seen in the permit files before 1985. Here the permit itself did not reflect this new emphasis, but the accompanying staff environmental examination shows the trend; however, as previously discussed there appears to be a lack of concern for the

obvious alteration of salinity regimes by saltwater barriers that continues in 2003. The emphasis of the agency's concern is whether there is a reduction in total flow.

Permit 5369, 1991 – Clear Creek

In 1991 Permit 5369 was issued for a water right in Harris County on Clear Creek which flows into Galveston Bay. Although relatively small (130 acre-feet) this permit is interesting because it is only a few miles from the coast (the total drainage area of Clear Creek is only 41.7 square miles) and shows the increasing and evolving scrutiny of instream flow and freshwater inflow. A special condition is included in the permit that only allows the water to be diverted when the flow exceeds 1.0 cfs for protection of instream uses and senior downstream water rights (TWC 1991a).

There is no mention of bay and estuary flow in the permit – only in the accompanying environmental analyses where they state the permit is less than 200 miles from the Gulf of Mexico (TNRCC 1991a). The agency staff calculated that the appropriation of 130 acre-feet is 0.394 percent of the average annual flow at the diversion site and with a permit restriction of 1.0 cfs, the bays and estuaries should not be significantly impacted. The 1.0 cfs figure was based on protection of water quality and aquatic habitat protection – not on freshwater inflow. Note that the recent round of bay and estuary studies and the WAM models were not available at this time, so at least for this small permit within a few miles of the coast, the staff relied on the minimum flow needed for water quality and aquatic habitat protection to determine the overall minimum flow restriction. It is interesting that in the environmental analysis is a statement that Clear Creek does not meet swimmable criteria due to frequent elevated fecal coliform (bacteria) levels, but that with the 1.0 cfs restriction the quality will not be degraded.

There is not space in this document to delve into water quality issues except to point out here that water quality standards are used as a substitute for freshwater inflow standards and that a new permit is granted as long as the quality of the stream segment is not *further* deteriorated by the new permit.

Permit 5430, 1992 – Houston Ship Channel

Permit 5430 was granted in 1992 for 500 acre-feet of freshwater from Buffalo Bayou, which is part of the Houston ship channel and the San Jacinto River basin that flows into Galveston Bay. There are no restrictions or conditions in the permit as to when this amount can be diverted. In the environmental analysis this segment is described as having poor water quality and no aquatic life uses; therefore, this permit will not significantly impact the quality or habitat of the segment. The permit is described as not having significant impact on the bays and estuaries although there is a statement that: "... the cumulative effects of all water rights in the San Jacinto Basin upon the receiving bays and estuaries is unknown" (TWC 1992a, 2).

This permit is interesting in that it lacks instream flow restrictions while at the same time mentions that the cumulative effects of water rights on the estuaries are not known.

Permit 5446, 1993 – Cedar Lake Creek

This 1993 permit for 2545 acre-feet from Cedar Lake Creek, a small creek in coastal Brazoria County in the Brazos-Colorado basin is authorized to divert only when the flow of the creek exceeds two cfs, which the environmental analysis determined would protect instream use and water quality. The analysis further concludes that the

bays and estuaries should not be measurably impacted by this diversion, but mention is again made of the lack of knowledge concerning the cumulative impact of water rights on the estuaries (TWC 1993b).

What is notable about this permit is a statement that since there is no other water right on this small creek, all of the flows are available for appropriation. By deduction this would mean that even though two cfs would be required to remain in the stream, any amount above that could be appropriated as long as it did not exceed the total amount of water in the stream and was available some percent of the time. This particular diversion was calculated as having 75 percent availability in 61 percent of the months (TWC 1993a). The historical streamflow data for this creek averaged 20,419 acre-feet annually with a maximum annual flow of 58,517 acre-feet and a minimum annual flow of 1696 acre-feet (a.f.) which is close to the minimum required flow of 1447.94 acre-feet (2cfs X 723.97 a.f./yr). Since the statement was made that all flows in Cedar Lake Creek above two cfs are available for appropriation and the cumulative effect of water rights on estuaries is not known, it could be assumed that at least the average flow minus the minimum flow could be appropriated. The resulting calculation would be 20,419 a.f. (average) minus 1447.94 a.f. (minimum flow of 2 cfs) leaving 18,971 acre-feet available for appropriation on this small creek.

In conclusion even in 1993, only minimum flows for water quality and stream habitat were considered, while bay and estuary flows were not directly addressed at least in smaller permits. As a result of not considering bays and estuaries as part of the whole hydrological system that includes creeks and rivers, the water rights system allows all surplus flows to be appropriated in a stream the size of Cedar Lake Creek.

Permit 5466, 1996 – City of Victoria

In 1996 the City of Victoria, Texas on the lower Guadalupe River was granted Permit 5466 for 20,000 acre-feet for municipal use. Although the bay and estuary studies were still not complete in 1996, there is substantial discussion of bay and estuary flows and provisions for their protection in the permit itself as well as in accompanying documents. The permit was filed in May, 1993, but was not granted until January, 1996 which is a rather extended time for administrative procedure in the water rights process.

The Texas Parks and Wildlife Department assumed an active role in the permitting process for Permit 5466 and even requested a contested case hearing which is the TPWD's prerogative under Texas Parks and Wildlife Code § 12.024. In a letter from the TPWD dated May 17, 1995 requesting the hearing, the department stated that the applicant had inadequately responded to department concerns on issues including the impact of the proposed diversion on San Antonio Bay which is a part of the Guadalupe Bay and Estuary system. The TPWD also mentioned that environmental assessments that normally are available from the Commission were delayed and not available to the department (McKinney 1995).

In a subsequent letter dated January 10 (McKinney 1996) the TPWD withdrew its request for a hearing, stating that the special conditions that were added to the permit alleviated the department's concerns regarding possible impact on fish and wildlife that depend on the Guadalupe River and its estuary, San Antonio Bay. In the "Special Conditions" section of Permit 5466 two flow regimes are described – normal and low. The USGS gauge at Victoria is downstream of the permitted diversion. When flows at this gauge are equal to or greater than the normal flows shown in table 20.2, the permittee

can divert at the authorized maximum diversion rate which is 150 cfs. When flow at the Victoria gauge downstream is equal to or less than normal, diversion is limited to 10 percent of the flow at the diversion point. The diversion may not cause the flow at the Victoria gauge to go below the "Low Flow" limit. If flows are equal to or less than the "Low Flow" no diversions are allowed (TNRCC 1996). Another significant condition on Permit 5466 is a requirement to return all wastewater flows to the Guadalupe River to reduce the impact of the diversion on instream flow and freshwater inflow. Normally a wastewater permittee has the option of reusing wastewater and is not obligated to return it to the stream; however, the TPWD had expressed a concern about the future uncertainty of the return flows from Victoria's wastewater that was alleviated by this condition.

In table 17.2 the 7Q2 and the Lyons flows are displayed in addition to the Normal and Low flows defined in the Victoria permit for comparison. Although this permit was not specifically discussed with the staff in the water permitting section of TCEQ, the general methods of determining flow restrictions for permits were discussed (Mosier 2003–2004). Normally the staff refers to any specific studies that have been performed on the portion of the river affected, followed by an analysis of the 7Q2, the Lyons

Table 17.2 – Special conditions of Victoria permit in cfs (from TNRCC files 1995, and TCEQ 2003; assembled by author)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Normal	387	440	660	687	1260	995	540	414	490	353	357	374
Low	150	150	200	250	200	250	300	300	200	150	150	150
7Q2	572	572	572	572	572	572	572	572	572	572	572	572
Lyons	390	456	660	672	804	708	540	404	468	333	334	377

Method and the bay and estuary studies in no particular order. In early 1996 there were preliminary MinQ and MaxH results for the Guadalupe Estuary from Longley's work (1994). However, the MinQ and MaxH are higher than the "Normal" flows in the permit conditions which, as described in the permit itself, closely follow the Lyons flows except for the months of May and June when the permit calls for flows substantially higher than the Lyons flows. These higher May and June flows are specifically addressed in the permit as:

. . . a flow rate for the months of May and June based on a prorated share of the minimum flow values calculated to maintain beneficial inflows for the living resources and ecological integrity of the Guadalupe Estuary (TNRCC 1996).

While there is no accompanying explanation in the TCEQ files of the methodology of this pro-rating of "normal" flows to minimum beneficial flows, the MinQ for the Guadalupe Estuary in May and June (table 10.3) is the equivalent of 3025 cfs and 2285 cfs respectively using the conversion factor of 1 cfs for 24 hours = 1.9835 acre-feet. The "normal" flows for May and June of 1260 and 995 cfs respectively are approximately 40 percent of the MinQ values for that month while the ratios of the other months are substantially lower percentages. It is important to note the use of the "minimum" beneficial flows implying but not naming the MinQ of the TPWD (1998) Guadalupe estuary study. This appears to be a decision made by someone at the TCEQ to choose the MinQ over the MaxH for this pro-rated computation, and later the MinQ will be the recommended flow in the SMRF permit. A discussion of this preference for the MinQ versus the MaxH in water permit conditions was not found.

It is interesting that the "normal" flows are less than the 7Q2 in eight of the twelve months. The 7Q2 is the minimum flow necessary to maintain the parameters associated

with the use of the particular stream segment where the diversion is located. A perspective of the quantitative relationship between the 7Q2, the Lyons and the MaxH and MinQ for the Guadalupe River at the estuary is provided in figure 18.3 in chapter 18. The basis of the Low Flow conditions is not explained in the literature. Observation of the Low Flow values shows that they are substantially less than either the 7Q2 or the Lyons Method.

Permit 5466 shows the growing emphasis of freshwater inflow considerations in permits as of 1996, and the increasing role of TPWD in the water rights process; however, there still seems to be only consideration of minimum flows based on flow regimes for instream flow, with some modification based on the bay and estuary studies as seen in the higher May and June "normal" flows. There also appears to be an unexpressed willingness by the Commission to appropriate most of the flow above these conditional minimums defined in the permit which can be problematic for freshwater inflow protection at flows higher than the minimum prescribed conditions.

Permit 5696, 2000 – Clear Creek

Permit 5696 granted in October, 2000, for 486 acre-feet on Clear Creek a tributary of Galveston Bay in Harris and Galveston Counties is of interest both as an indicator of the state of freshwater inflow protection in 2000, and in comparison to Permit 5369 issued on the same small coastal creek in 1991, that was discussed earlier in this chapter. By the time of the issuance of Permit 5696 in 2000, data from the WAM were available for the San Jacinto River basin and the MaxH and MinQ for Galveston Bay had been modeled by the TWDB. The resulting environmental analysis for Permit 5686 contains much more detail, and consequentially, the permit contains a more

complex minimum flow condition system than the earlier 1991 Permit 5369 on the same waterway. These conditions prescribe the minimum flows below which the permit cannot be diverted. Table 17.3 provides a comparison of the minimum flow conditions in the two Clear Creek permits that were granted nine years apart. Although the newer Permit 5696 mentions freshwater inflows in the actual permit while the older Permit 5369 does not, there are no specific reservations of freshwater inflow in either permit.

The newer Permit 5696 also reveals an alteration by the then TNRCC staff of the historical median flows for Clear Creek, which resulted in a reduction of the 7Q2 flow in several months of the year (TNRCC 2000a). Since the 7Q2 was the basis for the minimum flow restrictions for this permit, this alteration subsequently reduced those restrictions. These alterations to the median are shown in red type in columns 2 and 3 of table 17.3 and will be discussed in more detail later in this section.

The special conditions in the newer Permit 5696 only allow water to be diverted when the flow of Clear Creek exceeds (a) 5.5 cfs from January through June and (b) 2.1 cfs from July through December (TNRCC 2000b). Permit 5369 in 1991 for 130 acre-feet had a less restrictive minimum flow of only 1.0 cfs in all twelve months (table 17.3).

The environmental analysis for the 2000 permit reflects the availability of the new tools available in 2000, like the WAM and the bay and estuary studies. Ironically the data from the newly available WAM was used to derive lower minimum required flows than were originally proposed in the environmental analysis as discussed above. As the TCEQ staff was using the Lyons Method to determine flows necessary to preserve aquatic and riparian habitats, they noticed that the May through September historical median flows used to calculate the Lyons Method appeared inordinately high in several

Table 17.3 – Median flow analysis of Clear Creek 2000 (from TNRCC data in cfs)
 Note: Numbers in red show adjustments to the median and resulting changes

Month	Historical Median	Adjusted Median	Recommended Lyons	2000 Min. Flow Condition	1991 Min. Flow Condition
Jan	15.73	15.73	6.29	5.5	1.0
Feb	13.77	13.77	5.50	5.5	1.0
Mar	7.87	7.87	4.72	5.5	1.0
Apr	9.83	9.83	5.89	5.5	1.0
May	19.67	10.69	6.41	5.5	1.0
June	23.60	6.68	4.00	5.5	1.0
July	25.56	2.40	1.44	2.1	1.0
Aug	17.70	2.01	1.20	2.1	1.0
Sept	11.80	4.70	2.82	2.1	1.0
Oct	3.93	3.93	1.57	2.1	1.0
Nov	5.90	5.90	2.36	2.1	1.0
Dec	7.87	7.87	3.14	2.1	1.0

months (2nd column, red print, in table 17.3), possibly influenced by return flows from upstream rice irrigation (TNRCC 2000a). Using the naturalized flows from the newly developed WAM, the staff was able to determine the average monthly deviations from the median and adjust the median downward. The lower adjusted median flows, reflecting the subtraction of return irrigation water amounts from historical flows, resulted in reduced Lyons flows (3rd column, red print, table 17.3) in May through September. Table 17.3 provides a comparison of the historical median flows, the adjusted median flows based on the WAM data, the recommended Lyons flows, the actual minimum flow restrictions for Permit 5696 in the year 2000, and the minimum

flow conditions for Permit 5369 in 1991. The adjustments to the median flows in May through September were significant. For example, the July median was reduced from 25.5 cfs to 2.4 cfs. To simplify the restrictions in the permit, similar monthly flows were grouped into two periods in a year, resulting in the 5.5 cfs minimum flow restriction January to June, and the 2.1 cfs restriction from July to December described above and seen in the next to last column of table 17.3.

By using the modeling concept of naturalized flows that predict what flows would have been if there were no diversions or human influence (logically the highest flows), the Commission was able to reduce the historical median flow values which reduced the Lyons flows, and thereby lowered the minimum flow standards of Permit 5696 from a preliminary standard of 13.0 cfs for May-August to the adopted minimums of 6.41 cfs for May, 4.0 for June, 1.44 for July, and 1.20 for August (Jiang 2000). Since the Lyons Method is based on historical flows, it can reflect increasing diversions over time which result in lower flows; however, in a situation like that in Permit 5696, historically there were upstream discharges resulting in higher flows over time, and the staff responded by recalculating historical streamflow without the upstream discharges included – resulting in lower minimum flows. The theory of the application of the Lyons Method is difficult to grasp and the method appears to be flexibly applied to different projects as further explained in the following paragraph.

The environmental analysis for Permit 5696 has three major components – aquatic and riparian habitats (previously discussed using the Lyons Method), water quality, and bays and estuaries. For water quality the 7Q2 estimated flow to maintain the existing uses of the stream was determined to be 0.47 cfs; therefore, the staff concluded

that the higher flows described by the Lyons Method for aquatic and riparian habitat would adequately maintain the stream quality. In the 7Q2 discussion in the environmental analysis is a statement that when the Lyon's Method monthly values do not exceed the 7Q2 flow value, then the 7Q2 value is used for that particular month (TNRCC 2000a). This appears to be contrary to what occurred when Permit 5466 was authorized in 1996 for the City of Victoria, which used the Lyons flows in eight of the twelve months even though they were lower than the 7Q2. There could be extenuating circumstances to explain this variation in application of Lyons and 7Q2 flows between the two permits, or possibly changes in policies between 1996 and 2000, or the existence of other data not presented in the analyses of either permit, but the application of the two instream flow methods is not well-defined, especially when intermingled with the protection of freshwater inflow for bays and estuaries.

There is however, definition in the Texas Administrative Code of the use of the 7Q2 in relation to minimum flows:

Low-flow criteria [7Q2] listed in appendix B of §307.10 of this title are not for the purpose of regulating flows in water bodies in any manner or requiring that minimum flows be maintained in classified segments (Tex. Admin. Code § 307.8 [a][3]).

and in relation to bays and estuaries:

Low-flow criteria defined in this section and listed in Appendix B of §307.10 of this title apply only to river basin and coastal basin waters. They do not apply to bay or gulf waters or reservoirs or estuaries (Tex. Admin. Code § 307.8[a][4]).

There is no discussion in the literature of the actual use of the 7Q2 for calculating freshwater inflows. It does not appear to be intended for this use as discussed in Rule § 307.8 of the Administrative Code.

Officially how is the 7Q2 value intended to be used? The Administrative Code defines the 7Q2 as a statistic determined from historical data which is the ". . . lowest average stream flow for seven consecutive days with a recurrence interval of two years. . ." (Tex. Admin. Code § 307.3[48]). In Appendix B of § 307.10 (Tex. Admin. Code) is a table of the 7Q2 values for the classified stream segments in Texas. These 7Q2 values are referred to as "low-flow criteria" in § 307.8(a)(3) (Tex. Admin. Code), and are described as being ". . . solely for the purpose of defining the flow conditions under which water quality standards apply to a given water body." These water quality standards cover various uses of classified stream segments including:

- Recreation (includes maximum *E. coli* bacteria levels)
- Water supply (includes maximum allowable concentrations of various chemicals)
- Aquatic life (includes minimum levels of dissolved oxygen)
- Additional criteria
 - Dissolved solid criteria including chloride and sulfate
 - pH
 - Temperature
 - Toxic materials

The Administrative Code further states that some water quality standards do not apply at flows that are lower than the 7Q2 (Tex. Admin. Code § 307.3). In § 307.8(a)(1)(A) of the Administrative Code are listed the stream standards that do not apply below 7Q2 flows including:

- 1) Numerical chronic criteria for toxic materials.
- 2) Maximum temperature differentials.

3) Dissolved oxygen criteria for unclassified waters.

The 7Q2 statistical value is used to define the critical low-flow condition of streams in Texas that have been classified and are routinely monitored. Smaller unclassified water bodies are monitored less often (TCEQ 2003–2004b). According to the USFWS (2000), the 7Q2 is the flow at which the impacts of permitted discharges are analyzed. Statutorily it is not to be used for regulating minimum flows in a stream, nor does the 7Q2 apply to estuaries. However, in practice, the 7Q2 is referred to both as source of instream flow minimums, and less directly as a value for freshwater inflow minimums.

The bay and estuary section of the environmental analysis for Permit 5696 (TNRCC 2000a) is surprisingly brief, but the brevity may be an indicator of the lack of applicability of the studies to minimum flows in water permits. Permit 5696 is the first permit of the ones examined in this section where the TCEQ staff had access to recommended flows to the estuary; although, the final Trinity-San Jacinto Estuary study was not officially completed until 2001. After a brief four-line explanation of the study and that the MinQ (note MinQ, not MaxH) for the Galveston Estuary of 5.22 million acre-feet is a seasonal target value, the analysis states:

As an individual event, the diversion of 460.33 acre-feet per year will minimally impact Galveston Bay and the Trinity-San Jacinto Estuary System (TNRCC 2000a, 4).

It may not be applicable to analyze the methods of determining minimum flow conditions in small permits as opposed to larger ones, but there have been statements by the TCEQ that the cumulative effect of these smaller permits on the estuaries is not known (TWC 1992a); therefore, one would think the methodology of the environmental analysis of

these small permits would be cautionary on the side of protection and as such would be worthy of analysis. Except for the Victoria permit in 1996 no other major coastal area water right was found to demonstrate specific efforts to protect freshwater inflow. Having not found a large coastal water right granted since the WAM and bay and estuary studies were available as reference tools for determining minimum flows, the denied permit of the San Marcos River Foundation was selected for analysis.

The San Marcos River Foundation Application, 2000-2003

Background

Even though the application by the San Marcos River Foundation (SMRF) was denied by the Commissioners in 2003, the permit had been declared administratively complete and recommended for approval by the staff of TCEQ – meaning the draft permit had been completed including the hydrological and environmental analyses. In December 2000 the SMRF had applied for 1.15 million acre-feet of water for instream flow in the Guadalupe River and freshwater inflow into the Guadalupe Estuary (TCEQ 2000). In a copy of the permit in appendix D the various acre-feet totals may not exactly coincide with this discussion, but to explain all of the details would be lengthy and unproductive for the reader. A brief explanation of the numbers follows.

The 1.15 million acre-feet was the amount equal to the MaxH of the TPWD (1998) study of the Guadalupe Estuary and was to be measured at the coast. In addition the SMRF applied for a lesser amount of instream flow equal to the historic monthly median of the San Marcos River – approximately 150,000 acre-feet to be measured at a point on the Lower San Marcos River near its confluence with the Guadalupe River. The TCEQ added the San Marcos River flow to the Guadalupe River flow and thus made the

application state that 1.3 million acre-feet had been applied for, even though one could argue the instream flow of the two rivers was the same water.

A careful reader will notice that the actual amount recommended to be granted in the draft permit is 980,494 acre-feet, not 1,150,000. This reduced amount is the result of two factors – the first factor being the determination by staff that the flow required for preservation of the estuary should be the MinQ which is 1.03 million acre-feet. The second factor is that the location of the measuring gauge for this permit is several miles upstream of the estuary at a highway bridge for convenience. Therefore the entire flow applied for would not be available at that point due to contributions from downstream runoff, rainfall and tributaries (TCEQ 2003d). Mention should also be made that the SMRF also defined the flows applied for in varying amounts for each month of the year to match the MaxH monthly recommendations in the TPWD (1998) study.

The Environmental and Hydrological Analyses

The analyses performed on the SMRF application as part of the process of issuing a draft permit brought to light the applicability and connectivity or lack thereof of the three principle components of freshwater inflow protection – the water rights process, the bay and estuary studies, and the water planning process. The water rights process is the epicenter of the freshwater inflow process where all three components merge and interact – the granting of water rights through special permit conditions either protect or reduce freshwater inflow, the bay and estuary studies recommend the desirable freshwater inflow, and the water plans define future permits and their impact before they become actual sanctioned appropriations.

Even though the SMRF application was denied by the three governor-appointed Commissioners of the TCEQ, the work completed by the TCEQ staff to arrive at administrative completeness of the permit was of the same scope as the work required if the permit would have been accepted, barring possible changes by other parties to the process. Therefore, the various analyses by the TCEQ staff are considered a relevant example of the state of the protection of freshwater inflow in Texas in 2003. A major issue that the staff did not have to confront was the minimum flow below which the permit could not be used. As seen in the previous discussion, permits for diversion or impoundments since 1985 generally have special conditions defining the lowest flow levels below which pumping or impoundment are not allowed, leaving flows below that minimum available for instream flow and freshwater inflow. Since the SMRF permit was for instream flow with no diversion, the minimum flow condition did not apply, so the critical decision of how to apply the MaxH and MinQ to low flow situations did not have to be resolved. In the memorandum (appendix D), there is as much discussion about the portion of the application for instream use on the San Marcos River as there is discussion on freshwater inflows. Although instream flow and freshwater inflow are obviously related, only the issues related to freshwater inflow will be covered in this discussion since that is the focus of this study.

Included in the interoffice memorandum with the environmental analysis (appendix D) was a discussion of the consistency of the SMRF permit application with the state and regional water plans. Since the year of this analysis was 2002, the first round of the five year regional plans had just been completed and compiled into the state water plan. According to the staff discussion the Region L planning area which included the

Guadalupe and San Antonio Rivers addressed freshwater inflows by using the consensus criteria and the recommendations of the TPWD (1998) study for the Guadalupe Estuary. Since the SMRF application was also based on the TPWD study, the staff concluded that the request was consistent with the regional and state water plans (TCEQ 2003e). Also they claimed that the SMRF permit would serve to mitigate the impacts of reduced freshwater inflows on the endangered Whooping Crane which had been identified as one of the concerns in the Region L Water Plan.

In the environmental analysis of the SMRF permit TCEQ staff discussed the lack of connectivity between the requested monthly volume in acre-feet and the need to establish an instantaneous flow for the permit (TCEQ 2003d). The staff calculated that if the requested annual volume of 1.15 million acre-feet were converted to a daily flow it would equal almost 1600 cfs while the median flow at the estuary is only 1100 cfs. The median annual volume of flow at the estuary is 1.5 million acre-feet during the 47 year period of record (TCEQ 2003d). Therefore they concluded that the total volume requested would only be available by including natural runoff events – not just by a simple defined flow level. It was suggested that the selected inflow value for the permit be considered an average inflow since neither the MaxH or MinQ were available in all years; therefore, the total inflow should be allowed to fluctuate annually with ". . . substantially higher inflows during wet years and lower inflows during dry years" (TCEQ 2003d, 5), but no other specifics were mentioned in the analysis.

Freshwater inflow necessary to maintain salinity in the tidal flats and marshes of the estuary was described by the staff as critical to the survival of the endangered Whooping Crane that winters in the Guadalupe Estuary (TCEQ 2003d); however, staff

concluded that either the MaxH or MinQ could provide acceptable inflow levels. They mentioned that the TPWD recommended MaxH because it provides a proportionally higher yield of blue crab (the Whooping Crane's primary diet [Tom Stehn 2001]) and brown shrimp relative to the amount of freshwater inflow difference between MaxH and MinQ. If one reads between the lines here, there could be some disagreement between the TCEQ valuation of MaxH compared to MinQ and the TPWD valuation of the two recommended flows. It is assumed that there was a lot of pressure on the TCEQ staff about the relative significance of the MaxH flow versus the MinQ flow as the TCEQ staff at that time had to define the application of the TPWD estuary flow recommendations to a water right with the awareness that precedents were being set for future water permits.

A separate hydrological analysis was performed by the Surface Water Availability Team and again only the MinQ was examined. The resulting amount of 980,494 acre-feet was the amount authorized in the draft permit, and was described as the MinQ (1.03 million acre-feet) pro-rated as previously discussed to the measuring point upstream of the estuary. The team calculated that this pro-rated MinQ amount was available in 4 percent of the years and 44 percent of the months.

An important observation was included in the environmental analysis that in one sentence elucidates the disconnection between the bay and estuary studies and the water rights process.

The TPWD recommendations do not include an evaluation of the amount of freshwater inflow needed to maintain low salinity areas and provide refugia conditions for estuarine species and prevent saltwater intrusion into low salinity areas during dry conditions (TCEQ 2003d, 6).

However, because the SMRF permit was for instream flow and *not diversion*, the low flow conditions did not have to be defined in the permit. Unlike a diversion permit, the

minimum flows below which the permit could not be used were irrelevant to an instream flow permit. As a result the minimum flows for bays and estuaries in a major water right permit have not been completely dealt with by the TCEQ. We will have to wait for a large permit application within 200 river miles of the coast to know how the TCEQ Commissioners will respond to freshwater inflow requirements.

The SMRF draft permit and the accompanying Interoffice Memoranda of water availability, environmental analysis and hydrological analysis are included in Appendix D. These documents unintentionally but effectively present a brief but thorough discussion of the state of freshwater inflow protection in 2003 not available in the literature – especially concerning the interaction of the different agencies and components of freshwater inflow protection in the water rights process which is the linchpin of the protection process.

CHAPTER 18

CRITICAL ISSUES AND KEY ASPECTS

Information and Understanding Gained in this Study

This research highlights issues that have a significant effect on freshwater inflow protection. These are: central authority and balance of power, TCEQ commission structure and practices, role of environmental interests, status and limitations of bay and estuary studies, questions about data for the studies, questions about the Water Availability Model, and criticism of freshwater inflow protection.

No Central Authority or a Balance of Power?

One of the principle underlying problems of freshwater inflow protection in Texas is the fact that freshwater inflow is basically the responsibility of three agencies – the TCEQ, the TPWD, and the TWDB, with no central authority or means for effective coordination. Gerston (1995) claims that there are nineteen federal, state and local entities monitoring Texas estuaries with no real direction, but the three agencies discussed here (TCEQ, TPWD, TWDB) are the "hands on" agencies that affect inflows directly in practice and are authorized to do so statutorily.

In trying to unravel the system of protection and its sometimes overlapping responsibilities, it became evident that the system may lack administrative

effectiveness because of its organizational structure – not because each entity did not perform its task. Even were every agency to function with perfect cohesiveness, with three agencies involved in various aspects of the process and no one agency in charge of water issues overall except for the legislature, it may not be possible for effective protection to occur. The legislature is responsible not just for water issues but all matters of the state, and is not intended to manage a system such as water on a day to day basis. The Texas Legislature only meets regularly a maximum of 140 days every two years as defined in the Texas Constitution (Article 3, § 5 and § 24).

From another perspective, the multiple agency system over water issues in general and freshwater inflow in particular is an effective method of balancing the power between various factions that the agencies directly or indirectly represent. With the Texas Water Development Board representing the developers of water (hence its title), and the Texas Parks and Wildlife Department representing the concerns of fish and wildlife, the Texas Commission on Environmental Quality is left with the job of appropriating water. By allowing the TWDB to control water planning with which the water appropriations have to comply and the TPWD to comment to the TCEQ on environmental effects of proposed water rights and amendments, there appears to be a check and balance system to prevent the water resources of Texas from being dominated by either the development faction or the conservation faction. As in most check and balance systems there are questions of imbalance.

Is the TCEQ a Neutral Agency?

Generally the TCEQ appears to represent whichever side (water developer versus conservationist) controls the three-member commission that can overrule the

recommendations of its staff and only has to *consider* the TPWD recommendations on water appropriations (Tex. Water Code § 11.147). This statement does not imply that all participants in the process of water appropriation are either totally development oriented or totally conservation oriented. However, in water issues, like many other policy issues, when it comes to power politics, lines tend to be drawn and the players are categorized. The three commissioners are appointed by the governor who also chooses which one will be chair. Depending on the viewpoint of the governor and his or her appointees, the commission can vary its orientation towards development or conservation of water. Although all three principal agencies related to water issues have governor-appointed commissions, the TCEQ by design and application has more direct influence on the amount of water appropriated. By virtue of the TPWD and the TWDB having defined roles as representing the conservation aspect and the water development aspect respectively, the TCEQ is the virtual "swing vote" in the system of freshwater inflow protection in Texas. Depending on the sentiments of the governor and his or her appointees to the commission, water for bays and estuaries may vary substantially in priority.

The potential influence of commissioners on freshwater inflow issues is magnified by the key role of the TCEQ as the appropriator of water and the fact that there are only three TCEQ commissioners, meaning two like-minded members of the commission can have significant influence on the direction of freshwater inflow protection during their six-year terms. For comparison the TWDB has a six-member commission with six-year terms (TWDB 2004) and the TPWD has a nine-member commission serving six-year terms (TPWD 2004).

Although the actual areas of influence associated with each of the current commissioners is part of the state of freshwater inflow protection, the orientation of the commission can quickly change with the appointment of a new commissioner every two years or the election of a new governor every four years, especially if there is a change of political party. What is less likely to change are the roles of the agencies, particularly the power that the TCEQ commissioners and the governor have over the water rights process and subsequently the protection of freshwater inflow.

There are three agencies overseeing development, studies, and appropriations of water, with no one agency officially in charge of the protection of freshwater inflow. In reality it is the governor through his or her appointments of the TCEQ commissioners that holds significant power over issues of freshwater inflow. While the TCEQ does not directly control the bay and estuary studies or the water planning process, the three commissioners (or two in reality) have significant influence on the amount of water preserved for the bays and estuaries. This de facto power was evidenced by the commission's denial of the SMRF application in March, 2003, (TCEQ 2003a) overriding the recommendation of the TCEQ staff that the permit be granted (TCEQ 2003d). Further action by the commissioners in November, 2003, resulted in the dismissal of five other pending instream flow/freshwater inflow applications from conservation groups and river authorities. Without going into detail of these complicated permits, one of which (SMRF) is in the court system as this is written, the relevant point here is that the commission, under influence of the lieutenant governor, (TCEQ 2003a; Bowen 2003) overruled the staff recommendation for granting the permit, citing there was no statutory authority to grant a permit solely for instream flow. The commissioners stated that the

intent of the legislature was not clear on granting applications solely for instream flow and under advice from the lieutenant governor, the commission would allow the legislature to revisit the issue as outlined in SB 1639, 2003.

Environmental Representation in Water Planning

The State Water Plan describes eleven interests that were identified in Senate Bill 1, 1997 that are to be represented in each regional planning group, including environmental interests (TWDB 2002b). The other ten interests are: public, counties, municipalities, industries, agricultural, small business, electric-generating utilities, river authorities, water districts, and water utilities. What differentiates this group of ten from the environmental interests is the fact that all ten generally represent consumers of water that would not necessarily have freshwater inflow protection as their leading concern. While a representative of the public or coastal county interests might ally with the environmental interests on issues of freshwater inflow protection, this cannot be assumed. Since nine of the sixteen planning regions do not contain coastline, there would be even less chance of an interest group from a non-coastal region, besides environmental interests, stressing freshwater inflow protection.

Incomplete Bay and Estuary Studies

The responsibility of the bay and estuary studies is shared jointly by the TPWD and the TWDB and there are different interpretations by the two agencies as to the completeness of the studies. The TWDB states that the studies for all the major estuaries have been completed (Powell 2003) and the TXEMP model results are displayed on its website (TWDB 2003-2004). At the time of completion of this work the TPWD had

finished their analysis and publication of only three of the estuary studies (Loeffler 2004), while the LCRA on its own completed the published Matagorda Bay study (Martin et al. 1997).

The fact that three of the major estuary studies have not been published in final form by the TPWD will slow down even the possibility of establishing an overall system of freshwater inflow protection until all the studies are complete. The incomplete studies include large and important estuaries (Sabine-Neches, Mission-Aransas, and Upper and Lower Laguna Madre). Adding to this delay is the fact that the minor estuary studies are not projected to be completed until 2006.

In the shorter term the fact that some studies are incomplete poses an impediment to the usage of the completed study results in the current water planning process. There may be a reluctance to impose more severe water use restrictions on one planning region versus another, just because one region contained a bay with a completed flow recommendation study. The assumption is that the recommended flows of the studies would be higher than the default criteria used in estuaries with no recommended flow studies. These types of flows were compared for the Guadalupe Estuary in chapter 17 and the results showed the recommended flows of the default criteria were much lower than the recommended flows of the studies by TWDB and TPWD.

Limitations of the Bay and Estuary Studies as Tools for Planning and Appropriation

While the MaxH appears to be a useful flow recommendation for the management of freshwater inflows, there is a need for more quantitative guidance for estuary inflow in low-flow situations caused by natural or anthropogenic activities. Since the MaxH, at

least in the Guadalupe/San Antonio Basin, is close to the naturalized median flow (fig. 17.1), it is inevitable that flows lower than the MaxH will occur in approximately half of the years, if historical trends do not vary. The bay and estuary studies provide little guidance for these lower flow years, other than general statements proposing mimicking historical natural fluctuations as much as possible (TPWD 1998). This lack of flow recommendations for years with flows lower than the MaxH or even MinQ, was not an omission by the agencies – but rather the result of the intent of the studies being to analyze flows required for long-term estuarine productivity (Loeffler 2004).

The lack of flow recommendations for low-flow years has caused the TCEQ to use minimum flow standards for rivers (7Q2 and the Lyons Method) as substitutes for minimum freshwater inflows when granting water permits. There are no studies that show what the effect is on the health of an estuary of using flows less than the MaxH or MinQ, especially for an extended period of time.

Questions about the Basis of the Data for the Studies and the LCRA Methodology

There has been concern since the first bay and estuary studies were completed in 1998 that the use of commercial catch data could be a statistical problem, as previously discussed in chapter 13. The LCRA's choice of using sampling data instead of commercial data in its Matagorda Bay study (Martin et al. 1997) was notable along with its variation in methodology from the TPWD/TWDB standards described by Longley (1994) – especially their critical flow methodology that was a significant departure from the TPWD/TWDB concept of MinQ and MaxH. Challenges to the data used in the Galveston Bay and Guadalupe Estuary studies discussed in chapter 13 also involved

questions about the validity of commercial catch data. It will be interesting to see if these variations in methodology, and challenges to the data, result in alterations to the methodology of future estuary studies.

Questions about the Water Availability Model

In chapter 14 the problems with the Water Availability Model were discussed. The naturalized flows of the Guadalupe and Neches Rivers were inconsistent with the historical flows (Johns 2003-2004; Alan Plummer and Associates 2001). It can be assumed there may be more questions as to the validity of the modeled naturalized flows on other rivers in Texas. The naturalized flows and Run 3 are key elements of the WAM that have enabled administrators, decision-makers, and planners to calculate the impact of existing unused water rights on the rivers and estuaries of Texas. The naturalized flows are the base on which the various runs of the WAM are built. With naturalized flows for some rivers in doubt, the various runs of the WAM for those rivers are also questionable. Without confidence in these elements of the WAM, determining both the current and future state of freshwater inflow protection becomes problematic.

Criticism of Freshwater Inflow Protection from Agencies, Planning Groups and Committees

An important finding of this study was the amount and variety of sources of criticism of freshwater inflow protection in Texas, especially from agencies and planning groups. Criticism came from not only conservation groups (Texas Living Waters Project 2003) and the USFWS (2001), but criticism or simply statements of shortcomings were found from sources as diverse as the National Estuary Program (Gerston 1995) the

TPWD (n.d.), the LCRA (Martin et al. 1997), the engineers for the Sabine-Neches Region I Planning Group (Alan Plummer and Associates 2001), the TWDB State Water Plan (TWDB 2002b), and even the Interim Report of the Texas Joint Committee on Water Resources (2002) for the 2003 Legislative Session. The widespread agreement on problems in the system of freshwater inflow protection could mean that there is opportunity for constructive change. The primary forum for that change is the Study Commission on Water for Environmental Flows created by Senate Bill 1639, 2003 and due to report its recommendations by December 1, 2004.

Key Aspects of Freshwater Inflow Protection

The following summary provides a brief overview of the state of freshwater inflow protection in Texas in 2003:

- 1) Of the many components of freshwater inflow examined, the implementation of protection resides in the three agencies – TCEQ, TPWD, and TWDB. However, since there are problems with the process of protection, the entities in charge of these three agencies—the governor who appoints them, the legislature that established them and ultimately the voters who elect both, should be included in the list as the parties ultimately responsible for protection of freshwater inflow.
- 2) Although not officially designated the lead agency in freshwater inflow protection, the TCEQ through its control of the appropriation of water rights with special conditions for protection of freshwater inflow, is the de facto lead agency. The governor, through his or her appointments of the three commissioners, exerts significant influence over the TCEQ.

3) There are three principal means of freshwater inflow protection – the bay and estuary studies, the regional and state water plans, and the water rights process, but they are not well-integrated and operate using different quantitative standards and with different missions with no one agency or entity in charge day to day of all three areas.

- a) **The bay and estuary studies** that are co-managed by the TPWD and the TWDB contain recommendations for each estuary of optimum model output and minimum model output meeting all model constraints, but offer no specifics on management of low-flow situations for use in the water plans (TWDB 2002b) or the water rights process (TCEQ 2003d).
- b) **The regional and state water plans** administered by the TWDB rely on their own consensus criteria for quantification of freshwater inflow protection. However, the criteria in combination with the lack of environmental restrictions on pre-1985 water rights do not provide adequate protection of freshwater inflow (USFWS 2001; TWDB 2002b).
- c) **The TCEQ and the water rights permitting process** are principally concerned with minimum flows below which a water right cannot be diverted; therefore, the bay and estuary studies are not much assistance in this water rights process (TCEQ 2003d), so the commission relies on various studies of instream flow for river segments or default criteria that are designed for maintenance of instream water quality (7Q2) and aquatic habitat (Lyons Method). None of these values were intended to quantify flow regimes for protection of freshwater inflow in low flow situations.

Overview of the System

From the standpoint of holistic management, rivers and estuaries in Texas should be managed on the basis of the entire drainage area. The basins of some Texas rivers such as the Rio Grande include Colorado, New Mexico and Mexico. Officially we are currently bound to a state management system; however, the existing system to manage the protection of freshwater inflow in Texas is not only smaller than the state, but fragmented and not well-defined. This study has described rivers being managed with little emphasis on estuaries, water rights being granted without well-defined freshwater inflow protection formulas, and water plans being made using different protection criteria than those used for appropriations of water or the bay and estuary studies.

The purpose of this study was not to present alternatives and solutions as much as to evaluate the current state of protection of freshwater inflow in Texas. The current state can be described as disjointed and disconnected as to agency responsibilities and criteria used, and imbalanced in its constituencies in planning and appropriation with a predominance of water users versus conservationists and representatives of other interests that are concerned about adequate inflows for healthy bays and estuaries.

CHAPTER 19

FUTURE RESEARCH

Analyses Proposed by the TWDB

To coordinate with the next cycle of regional water plans the Texas Water Development Board responded to requests from the regional planning groups and environmental interest groups by proposing a methodology of streamflow analyses that the TWDB would present to the regional planning groups before they complete their initial plans in 2006 (TWDB 2002a). The goal of these analyses is to provide the planning groups with information using data from the WAM of anticipated streamflow conditions under various scenarios including the past represented by the naturalized flows, the present represented by Run 8, and the future represented by Run 1 of the WAM. For review, Run 8 (here referred to as the present) provides available flow assuming the maximum amount used in the past 10 years with all unused flows returned, including term water rights and reservoir siltation estimated at 2000 levels. Run 1 (referring to the future) assumes all current rights are fully utilized with all unused flows returned, no term water rights, and reservoirs remain at as-built capacity.

Importantly, the design of these analyses will be by river basin instead of planning region since the WAM is designed around a basin area. Although not discussed in the proposal (TWDB 2002a) these basin-related data are highly relevant because it could possibly cause regional planning groups, especially those not on the coast, to be more

aware of the effects of water planning and practice on the whole river system including the estuaries – not just the region for which they are responsible.

According to the proposal (TWDB 2002a) the staff of the TWDB will perform the following tasks for the regional planning groups:

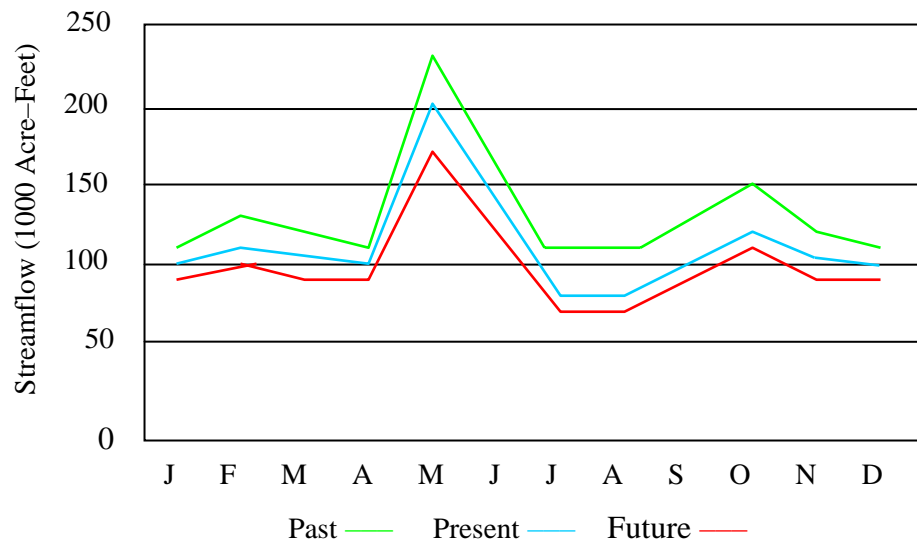
- Select three representative control points in each basin, *one being at the mouth of the river basin* (control points are WAM language for data points on a river where all WAM data are subtotaled and available flow is calculated – for example the Guadalupe/San Antonio River has over 30 control points).
- For these selected control points the staff will provide (1) naturalized flow, (2) Run 8 available flow and, (3) Run 1 available flow – representing the past, present and future in that order.
- Provide Run 1 and Run 8 data at the selected points through the year 2060.
- Compute the 10th, 25th, and 50th percentile flows for naturalized, Run 8 and Run 1.

Also when target flows such as MaxH are available, provide the frequency at which these flows occur in the past, present and future.

As to what to do with these results, the TWDB states the resulting data are for consideration by the regional planning groups and possible inclusion in their 2006 Regional Water Plans (TWDB 2002a).

After the completion of the regional plans in 2006 and before the state plan is completed in 2007, the TWDB staff will also provide a WAM Run 1 that includes all surface water management strategies recommended in the 2006 Regional Plans. Using this WAM data the staff will compute the 10th, 25th, and 50th percentile flows through the year 2060 for all regions and provide graphical displays. An example of the graphical

output proposed is in figure 19.1. The TWDB further states that additional graphics may be developed based on input from planning groups, other interest groups, and technical experts. For example, they propose a graph showing the frequency of the MaxH or MinQ flows in the past, present, and future (TWDB 2002a). An analysis of the recommended MaxH and MinQ flows would be a useful tool in analyzing the impact of planning projects on freshwater inflow.



In the figures above, past conditions are represented by naturalized flows, present conditions are represented by WAM Run 8 regulated flows, and future conditions are represented by WAM Run 1 regulated flows (quote from TWDB 2002).

Figure 19.1 – Adapted from TWDB sample graph for 2007 State Water Plan (TWDB 2002). Note: This graph does not represent any particular Texas river basin and is only for example.

The proposal by the TWDB for statistical analyses of the next round of water plans is a step in the right direction in the protection of freshwater inflow. However, there are inconsistencies, questions about the choice of certain WAM runs, and missing elements. The inconsistencies are in the use of naturalized flows without mentioning or

considering the alleged problems, at least in the Guadalupe and Neches basins, when comparing naturalized to historical flows.

The choice of WAM Run 1 to represent the future impact of the water plans is questionable primarily because of the assumption that all unused water will be returned to the stream. Appropriated water does *not* have to be returned to the stream and can be used and reused (Tex. Admin. Code § 297.49). If there is surplus water it only has to be returned to the stream if that can be accomplished through gravity flow and is "reasonably practical" to do so (Tex. Admin. Code § 297.49[b]). It would seem like an incomplete picture of future water availability to base the calculation on the assumption that water rights holders would voluntarily return their flows fifty years from now, especially in a serious drought, at the same rate they are returning flows currently, since most permits do not mandate their return. In this research several hundred water rights were reviewed in detail and very few contained specific requirements for return of unused flows.

A current example of the potential pitfall in assuming all return flows will continue is the application to the TCEQ by the City of Austin for 100,000 acre-feet of water the city currently discharges into the Colorado River as wastewater. The application is being challenged by the LCRA which claims that if granted, this water right would adversely affect downstream water rights, instream flows, freshwater inflows to the bays and estuaries, and long-term water planning (LCRA 2002b). The LCRA also is concerned with the implications of this permit on the water plans:

The granting of this permit would derail years of work on regional water planning. The Lower Colorado Regional Water Planning Group developed for this region a long-term water plan that specifically planned for the continued use

of Austin wastewater discharges. All members of the Region K Group, including the City of Austin, approved this plan, and the State of Texas has approved it. Austin made a similar proposal to the Lower Colorado Regional Water Planning Group during a two-year planning process, but its peers along the Colorado River Basin thoroughly rejected Austin's arguments. Now it appears that Austin is trying to get administratively what it could not get in the state's water planning process (LCRA 2002b).

The quotation above dramatically states the LCRA's description of the lack of connectivity of planning with the water rights process. Indirectly the issue of reuse brought up by this application and protest indicate some of the problems with using Run 1 for 2060 water availability estimates that count on levels of wastewater return matching current return flows.

What is missing from the TWDB proposal for analyses of the next water plans is a statement of the objectives to be accomplished with the information produced. This is not to say that the TWDB or the author(s) of this particular proposal are negligent or that they intentionally omitted expanded goals and objectives beyond the provision of the information. Having analyzed the system of freshwater inflow protection, it is not clear which agency would benefit from the proposed information and what measures could be taken if significant problems were discovered, much less which agency *should* be defining the objectives to be accomplished with this new information. Nevertheless it is encouraging to see the TWDB and the planning process performing comparative analyses of proposed water projects.

Overall, these attempts by the TWDB to present analyses of the effects of the next round of planning on instream and freshwater inflows reflect attempts at adaptive resource management. Nudds (1999, 180) describes adaptive resource management as "learning while doing," which is the process unfolding in the second round of water

planning. The structure of the water plans with five year planning cycles in regions based somewhat on river basin geography, with input received in each planning cycle from various defined interest groups, provides a forum for adapting to new information.

I have questions about whether this adaptation may be too little too late. Why were the analyses proposed by the TWDB not performed in the first round of plans? To some extent the fact that certain water projects are in the first round of plans implies they are feasible and can be counted on by the regions for future water use. Granted the projects were required to meet the consensus criteria, but as shown in chapter 17 there does not appear to be synthesis between the criteria of the plans and the recommended flows of the bay and estuary studies. As previously discussed, there are also no stated objectives for the application of this new information that TWDB proposes for the second round of planning.

Since the application of this new information is not well-defined, it will be up to the interest groups concerned about the preservation of freshwater inflows to ensure that the water plans utilize this additional knowledge. This brings up the issue of the representation of interest groups in the planning process, discussed in chapter 20. With the limited influence of conservation groups in the planning process, the possibilities of the new TWDB analyses resulting in improvement of freshwater inflow protection in the next water plan will be limited.

Suggested Research

The following research topics are important for both short and long term protection of freshwater inflow:

- 1) The quantitative impact of the consensus criteria on each bay and comparison to the MaxH and MinQ.
- 2) Detailed analysis of post-1985 water rights. How much freshwater inflow have they protected for each estuary?
- 3) Examine the management of reservoir releases, including both flood pool and conservation pool releases. Determine the effects of the timing of these releases on estuarine productivity and consider options of release timing. Determine if the statutory 200 river mile limit for reservoir impact is a relevant distance for actual effects of reservoirs on estuaries.
- 4) Consider ramifications of the WAM naturalized flows and groundwater decisions on the Guadalupe/San Antonio River and other naturalized flow interpretations on other rivers. Possibly change methodology of naturalized flows, especially related to groundwater.
- 5) Analyze the effects of Run 3 drought scenarios on estuarine productivity for each basin including proposed water projects from the state water plan. Re-analyze with each five-year planning cycle.
- 6) Find an existing or create a unified minimum freshwater inflow protection system that is usable by planners and appropriators in even low-flow situations, while protecting the environment of the estuaries including in extended drought situations.
- 7) Study the effects of extended low flows on the estuaries. Have methodology in place ready for a real-time study when a drought occurs.

- 8) In coordination with number 6, continue analyzing each estuary and building a data base using bag/seine data as well as commercial catch. Perform periodic model verifications as new data is obtained. If possible install a system of remote sensing salinity measuring devices in the estuaries to examine continually flow levels versus salinity.
- 9) In conjunction with the recently started (2003) instream flow studies of the rivers of Texas, analyze the methodology and results as they are derived and compare them to the freshwater inflow studies of the corresponding estuaries. Examine for relationships and compare recommended flows. If the two flow recommendations do not correspond in some scientific fashion, reexamine the methodology to determine if some factors are being overlooked either in the river flow methodology or in the freshwater inflow methodology.

Benefits of This Research

I hope that the information and conclusions generated by this study will provide concerned citizens, lawmakers, and administrators with some of the tools they need to implement measures to protect adequate freshwater inflow for the bays and estuaries of Texas. Realizing that an issue of this complexity is not quickly or easily resolved and that politics and weather – two of the most volatile systems that man has to confront, are key elements in water policy, I certainly do not anticipate a solution to freshwater inflow protection as a result of this work alone. Rather I hope that further research can build on the platforms I have established and through a process of updating this analysis, create an atmosphere of awareness and knowledge that will result in an effective and sustainable system of freshwater inflow protection in Texas.

CHAPTER 20

2004 UPDATE

The original timeframe of this document ended with the close of the Texas Legislature in early June 2003 and the establishment of the Study Commission on Water for Environmental Flows as required in Senate Bill 1639. The San Marcos River Foundation appealed their denied Permit to the court system and its status is virtually unchanged as of November, 2004. Senate Bill 1639 stated that no new water rights strictly for environmental flows could be applied for and therefore, the TCEQ denied the other pending instream flow and freshwater inflow applications.

As this book was being prepared for publishing in late 2004, I felt an obligation to cover any activities that had occurred since the original work that could have major impact on the freshwater inflow issue in Texas. The most significant activities were the completion of the *Science Advisory Committee Report on Water for Environmental Flows* in December, 2004 and a substantial increase in applications for consumptive water rights. These will be discussed in the two following sections.

SECTION A: THE SCIENTIFIC ADVISORY COMMITTEE REPORT ON WATER FOR ENVIRONMENTAL FLOWS

The SAC Charge and Scope of Work

The Science Advisory Committee (SAC) is the subcommittee of the Study Commission on Water for Environmental Flows mandated by Senate Bill 1639. The 9-member SAC was appointed by the Study Commission in February, 2004 and consists of

recognized expert engineers, lawyers, biologists, hydrologists and economists from Texas.

The Study Commission established a charge for the SAC to assist the Commission in its mission as defined by SB 1639. The elements of the charge are (SAC 2004):

- 1) Provide a description of the current hydrologic conditions, streamflow patterns across the state in major river basins, and freshwater inflow patterns for major bay and estuary systems along the coast, relative to historical and existing environmental flows.
- 2) Evaluate the analytical tools and/or procedures that are used or available to assess the requirements for preservation, maintenance, or enhancement of aquatic resources and riparian habitat.
- 3) Identify ecological parameters or ecosystem characteristics to be considered in determining environmental flow need for the state's surface water resources and identification of implementation options.
- 4) Provide any other technical information the Science Advisory Committee feels would be beneficial to the Study Commission on Water for Environmental Flows.

The SAC established its own Scope of Work addressing the specific technical areas that were analyzed. A list and brief summary follow:

- 1) Surface Water Management in Texas – The basic concepts of how surface water is managed and accounted for.
- 2) Current State Agency Roles – The responsibilities of the TCEQ, TWDB, and TPWD.
- 3) General Hydrologic Conditions – Temporal and spatial variation in flows in Texas rivers in different parts of the state. Current and historical trends in flow conditions. Flow conditions for specific basins and bays and estuaries.
- 4) Environmental Flow Tools and Procedures – Review and discuss procedures for determining necessary flows for protection of both rivers and bays and estuaries. This includes processes used by the state agencies. The SAC will also examine the instream flow studies for rivers and streams that have begun initial review of methodology in late 2003 and are ongoing as of December, 2004. This instream

flow analysis overseen by the National Academy of Science was required by SB 2 in the 2001 (78th) Legislature.

- 5) Instream Flow Methodologies – Review and analysis of the Lyons Method and the Consensus Criteria.
- 6) Bay and Estuary Methodologies – Review and analyze the bay and estuary studies as to their scientific soundness and foundation. Apply these methodologies to certain bays and estuaries.
- 7) Environmental Flow Criteria – Address the important ecological parameters and/or characteristics that should be considered in determining environmental flow needs for surface water systems. Consideration of the economic and social implications of providing different levels of protection, e.g., preservation, maintenance, enhancement. Also the role of uncertainty and associated risks due to insufficient data and unverified modeling.
- 8) Environmental Flow Implementation Strategies – Examine existing procedures for protecting flows such as reservations in new and amended water rights and the Water Trust. Also examine new approaches for providing environmental flows including programs used in other states.

Much of the SAC Report addresses aspects of freshwater inflow and instream flow already covered in this document. Relevant areas of the SAC Report that were not included in my original work or were expanded will be discussed in detail in the following sections.

Economic Considerations

A significant portion of the Chapter entitled "Environmental Flows" is devoted to discussion of the economic aspects of freshwater inflow. Ecosystem sustainability is a general term comprising several uses of water left in the river, stream or estuary. Although many of these uses do not pass through markets and are used by the consumer at no charge, their value is described as enormous.

Economic value is not the same as market value. "It is widely recognized that the price actually paid to use water, if one is paid at all, rarely reflects its full economic

value" (SAC 2004, 5.7). The price of water for many uses is determined only by the cost of providing it and this is often subsidized. For many uses such as environmental flows there is no price at all. These processes do not include a competitive market where buyer and seller interact to establish a value. If the price of water accounted for all private and social values associated with water's various uses, water would be optimally used in a way that would yield the most benefits to society (SAC 2004).

Non–Use Values

Direct values from environmental flows are referred to as "non–use values" (SAC 2004, 5.8). Non–use values refer to individuals' willingness to pay for water even though they do not expect to use it or benefit from it immediately. Also called "preservation values" (SAC 2004, 5–8), non–use values arise from three human tendencies:

- 1) Desire to preserve the individual's option to enjoy the benefits of instream flows, e.g. experiencing a healthy ecosystem at some point in the future.
- 2) Desire to leave this option as a legacy for others in current and future generations.
- 3) Satisfaction from simply knowing that water flows will ensure that a system will continue.

Few studies have been undertaken on non–use values of environmental flows, but the values derived are often large, especially for special recreation sites or preservation of endangered species and unique ecosystems (SAC 2004). Three studies are mentioned:

- 1) Wyoming, Colorado, and Alaska – non–use values estimated at \$40–\$80 per non–use household per year (Greenley et al. 1982; Madariago and McConnell 1987).
- 2) California's Mono Lake – non–use values accounted for more than 80% of total willingness to pay to preserve the lake's level (Loomis 1987).

- 3) Four New Mexico Rivers – willingness to pay for minimum flows was \$73.99 per year (Berrens et al. 2000).

Use values primarily associated with recreational activities such as rafting and fishing have been the focus of environmental flow valuation research. Although these use values differ from non-use in an economic sense, use values can complement environmental flow values. The results of various studies on values of water for recreational use include:

- 1) Montana's Big Hole and Bitterroot Rivers - \$10 - \$25 per acre-foot per year at 100 cfs decreasing to \$0 at 2000 cfs (Duffield et al. 1992).
- 2) Colorado's Cache la Poudre River - \$14.50 per acre foot for fishing and \$13.44 per acre foot for shoreline recreation falling to zero as streamflow increased (Daubert and Young 1981).

Water Demand and Water Use

Water is unique as a natural resource in the wide variety of uses it can provide. These uses fall into two broad categories: human use including municipal, industrial, and agricultural; and environmental use, which is often referred to as environmental flows. There are also complexities of instream human uses including navigation, hydropower generation, and recreation. Economists are faced with the problem of sorting out these uses that overlap the human and environmental categories. As defined by economics the optimal use of water is achieved by allocating it across these various uses to maximize the total benefits. To calculate the maximum total benefit the economic value associated with each use needs to be established.

When evaluating the economic benefits of various uses of water it is necessary to distinguish between water demand and water use. The term water use simply refers to the quantity of water used over a given period of time, historic, current or future. The

rates applied for these uses are historic or current use rates, whereas water demand does not assume there are per capita use rates. Instead the quantity of water used is related to the value to the user including influences of scarcity, price, and economic value. Using the principles of water demand, human demand for agricultural, municipal, and industrial purposes that have different economic values can be dealt with as an aggregate sum of varying values. An example would be municipal demand comprising high value purposes (drinking, bathing, and laundry) and low value purposes (lawns, car washing, and swimming pools). Similarly, agricultural demand consists of higher value crops (fruits and vegetables) and lower value crops (alfalfa and sugar cane). Total human demand for water is an aggregation of differing values for a variety of purposes. Water demand as streamflow has added spatial and temporal considerations that may be important in determining optimal allocation. An example would be seasonal needs for certain critical biological species or upstream versus downstream considerations.

Having discussed some of the principles of optimum allocation of water based on economic principles, the SAC report states that it is rare to allocate water based on economic efficiency. Political, social and environmental/ecological criteria are also considered. For instream flows ecological criteria could play a primary role in determining the allocation of water for ecosystem needs. However, once these flows are allocated, economic considerations could assist in achieving these ecological streamflows in the least-cost fashion. Also as previously mentioned these same environmental flows can provide benefits to humans in the form of recreation, aesthetics, hydro-power, etc. The tools of economic analysis can assist in quantifying the additional value of these overlapping uses as compared to water designated for environmental flows.

Environmental Flow Assessment Tools for Rivers and Streams

Texas Instream Flow Studies Program

The Texas Instream Flow Studies (TIF) Program was created as a result of SB 2 in 2001 that called for studies to determine environmental flow needs for Texas rivers and streams. In August, 2003 the three state environmental agencies (TCEQ, TPWD, and TWDB) completed a draft Technical Overview document describing how the studies would be carried out. The time frame for priority subbasins calls for completion dates staggered from 2004 to 2010. The second stage of the TIF Program involves an assessment by the National Academy of Sciences (NAS) of the proposed scientific and engineering methods. The NAS report is due before the end of 2004. The SAC recommends that a coordinating agency be assigned for certain aspects of these studies before they progress much further.

The scope of the TIF Studies is described as having five riverine components: hydrology, biology, geomorphology, water quality, and connectivity. The term connectivity refers to the movement and exchange of water, nutrients, sediments, organic matter, and organisms within the riverine ecosystem (SAC 2004). The state agencies do not believe it will be possible to address all of these components in a quantitative manner for each subbasin that is to be studied. At the minimum each component will be evaluated in the planning phases as to its applicability, feasibility, and importance to the accuracy of that particular subbasin study and model. The SAC comments on this process:

As envisioned by the state agencies, an instream flow study in Texas is largely a fish and wildlife resource evaluation of a river segment, sometimes a more comprehensive subbasin evaluation, but rarely a comprehensive evaluation of an entire basin. The goals and purposes can be varied but usually include the desire to determine the impacts of riverine flow alteration on the fish and wildlife communities (SAC 6–12, 2004).

Critique of State Analytical Procedures for Rivers and Streams

The SAC is critical of the simplicity of the statistical desk–top methods – the Lyons Method and the Consensus Criteria already discussed in the body of this document. Additional discussion of another analytical procedure sometimes used in Texas called the Instream Flow Incremental Methodology (IFIM) is also included in the SAC Report. I did not include it because it is not used by TCEQ staff in water rights analysis (Mosier, 2003–2004). It has been applied to several water supply reservoir projects to establish flow requirements for protecting aquatic resources. Some of these projects were: O. H. Ivie Reservoir, Little Cypress Creek Reservoir, Canyon Lake hydropower, and several Lower Colorado River sites. According to the SAC, the IFIM is "the comprehensive methodology most commonly employed within the United States and globally, with applications in at least 20 countries" (SAC 6–6, 2004). Developed in the 1970's this methodology addresses habitat, water quality, sediment transport, and hydrology. Since this method was developed there have been many advances in habitat modeling. Many of the IFIM concepts are incorporated into the TIF Program. Commenting on the IFIM the SAC states: "Ostensibly, the comprehensive methods provide more scientifically defensible instream flow recommendations at the price of appreciably more resource commitment than the statistical desk–top models [referring to the Lyons and the Consensus Criteria]" (SAC 6–14, 2004).

Although the IFIM incorporates modern high–technology monitoring of the stream environment, it suffers from scientific and operational deficiencies (SAC 2004). The correlation of the detailed hydraulic or GIS modeling and measurement provided by IFIM with the biology is "at best tenuous" (SAC 6–14, 2004).

The relation of distribution of habitat to some measure of stream ecosystem function is not clear, nor does there seem to be a specific program to establish this relation. The suggestion that the IFIM results can be used to 'optimize' flows is even more vaporous (SAC 6–14, 2004).

Operationally the IFIM which forms the basis for the TIF Studies is labor intensive and expensive. Because of these aspects the TIF Program for only six subbasins of five rivers will take seven years with each river taking three to five years. The SAC calls for an intermediate system to address streamflows in rivers that become contentious before these studies are complete. These intermediate studies need to include hydrological and biological observations in order to have at least the potential of establishing relationships. The SAC suggests digitizing the great amount of habitat and stream biology data that has been collected in Texas since the 1970's to make it available to stream ecologists. The effort to accomplish this can be done at a fraction of the cost of one IFIM study. At a minimum this data could be used in testing the validity of either the Lyons or the Consensus Criteria methods.

The SAC describes the TIF Studies methodology as a scientifically based approach for establishing environmental flows that reflects the varying relationship between hydrology and the physical and biological conditions in different systems. The SAC questions how the TIF program will be carried out and applied in a specific basin or subbasin and how it will be used to establish conditions for protecting instream environmental uses. They call for all stakeholders and interest groups to be involved and

not just the three state agencies, and the program must be subject to rigorous scientific review.

Instream Flow Methods Used Outside of Texas

Several statistical desk-top methods and more comprehensive instream flow techniques are briefly summarized in the SAC Report, but the program receiving the most coverage in the study is The Nature Conservancy's Ecologically Sustainable Water Management (ESWM) Program. The ESWM Program is currently being used on the Savannah River in Georgia to establish instream flows. Protocols of the ESWM program include a desk-top method for establishing initial environmental flow values, an expert panel to review results and decide which measures to implement, and adaptive management procedures to address scientific uncertainty (SAC 2004).

In the Savannah River case an array of connected ecotypes and flow regimes were addressed including inland rivers, wetlands, bays, and estuaries. Flow prescriptions were provided for three flow levels (low flows, high flows, and over-bank floods) in three climatic states (drought, average, and wet years).

Environmental Flow Assessment Tools for Bays and Estuaries

The bay and estuary study methodology used by the TPWD and the TWDB is examined and critiqued by the SAC: "Despite the apparent complexity of the State Methodology, only a small subset of the calculations determines the answer" (SAC 6-21, 2004). The SAC further states: "Application of the beneficial-inflow results remains problematic" (SAC 6-26, 2004).

The SAC lists several deficiencies of the State Methodology (Longley 1994) that are the basis for the initial estuary analysis performed for each bay by the TWDB (SAC 6–26, 2004):

- 1) Commercial harvest is an inadequate measure of abundance.
- 2) Statistical methods are rather simple compared to the complexity of estuary organism behavior.
- 3) Characterization of inflow by bimonthly sums and the selection of these sums as independent variables is questionable.
- 4) The optimization solution is over-constrained by the limits on the range of monthly flows. These limits rather than the behavior of the relationships of harvest to flow primarily dictate the answer.
- 5) There is no justification provided for the selection of the bounds (lower decile to median) on monthly flows.

The SAC elaborates on the overlying concept of an optimal solution: "It is not clear that seeking an optimal solution, even if it can be correctly obtained, is the right answer to the question" (SAC 6–27, 2004). The optimum flows for major bays in Texas are annual flow volumes that exceed the cumulative storage of all reservoirs in those basins, so the question arises how to manage those projects. Also the optimum sequence of monthly flows does not occur in the historic record. No year has had all or even a majority of monthly flows within $\pm 20\%$ of the MaxH values. "The question of what flows (volumes and seasons) are *necessary* for the maintenance of that health [ecosystem health] has not been addressed" (SAC 6–27, 2004).

The TPWD verification of the model resulting in the actual recommendation of estuary inflow is also critiqued for two reasons:

- 1) Reliance on TXBLEND salinity projections which have not been widely and successfully applied to estuaries. TXBLEND has not been satisfactorily calibrated for Texas estuaries.

- 2) TPWD protocol emphasizes the differences between MinQ and MaxH, but does not answer the question of what flows are necessary for maintenance and health of the bay.

Both steps of the state analytical procedure (the TWDB model runs and the TPWD verification process) "... are inadequately documented and incapable of corroboration" (SAC 6.28, 2004). The data for each bay analysis is not contained in the studies and has to be requested from the TWDB. The statistical procedures are inadequately described. Some documentation has been lost. TXBLEND, a key element used by the TPWD in their analysis, until recently was not available to the public because it contained proprietary computer codes.

The SAC Report concludes their critique:

... the state analytical procedure – because both the TWDB and TPWD procedures address only the much higher flows of the optimum conditions (*minQ and maxH*) – fail to provide any information about the important low-flow regime. Considering that the agencies have had decades to address the problem of freshwater inflow needs, this omission is inexplicable (SAC 6–28, 2004).

Bay and Estuary Methods Used Outside Texas

Several methodologies for examining bays and estuaries both in the United States and around the world are briefly analyzed in the report. In its summary the SAC says that the thread that links all these studies is that they seek to protect the *habitat* that support the ecosystem services such as recreation and commercial fisheries (SAC 2004). The exception is the approach used in Texas where the emphasis is optimizing commercial harvest. The approaches examined varied from highly technical to highly value laden, but all focused on the habitat except the Texas approach. The science of the habitat approach varies because the ecosystem components vary among estuaries. Once the

valued ecosystem components are identified for a particular estuary, more narrow and focused studies can be performed to establish flows necessary to support organisms and communities of organisms of concern.

Implementation Strategies for Environmental Flows

Strategies for implementing the necessary flows for the environment fall into two categories, regulatory and market-based (SAC 2004). Regulatory methods utilize the state's legal and regulatory powers to allocate water for environmental purposes. In basins where there is still water available for appropriation, regulatory strategies can stipulate that a certain amount of water be reserved for environmental flows. Where not enough water is available for environmental flows, a market-based strategy where existing water right holders voluntarily enter into transactions to convert water rights to environmental flows is more politically expedient.

Regulatory Environmental Flow Strategies

Several strategies are analyzed in Chapter 7 of the SAC Report including:

- 1) Environmental flow permits.
- 2) Environmental flow conditions attached to new water right permits.
- 3) Water taxes – a fixed percentage of a transferred water right would be returned to the state for use as environmental flows.
- 4) Reservation of return flows – a percentage of historically discharged return flows would be reserved for environmental flows.
- 5) Public interest – the state would assert superceding interest on existing permits including unused water rights, placing restrictions on existing permits, or even condemning existing rights. Obviously this would be a contentious process.

Market-Based Environmental Flow Strategies

Water markets exist in most Western states including Texas. In the East, states including Florida, North Carolina, and New York are considering establishing water markets. The recognition of instream flow water rights is necessary for water marketing to provide environmental flows. Instream flow rights are recognized in some form in almost every Western state. Private ownership of environmental water rights is rare and most are owned by the state or where permitted, by non-profit groups. Environmental water sales have occurred in every state except Wyoming. In 1990 only \$500,000 was spent in the Western United States for environmental water rights (SAC 2004). Current estimates for environmental water acquisition in the West are \$20 million per year.

Water trusts, water banks and water leasing are discussed as part of an environmental water marketing strategy. Other states' programs that could be applied in Texas that could enhance environmental water markets are also examined including:

- 1) State funding to acquire water rights for deposit in the Texas Water Trust.
- 2) State tax incentives to encourage donations to the Water Trust.
- 3) Creation of a private non-profit entity for acquiring instream flow water rights.
- 4) Provisions for private ownership of instream water rights.
- 5) Policies such as a mitigation strategy that provide incentives for private-sector funding of instream flow water rights.

Adaptive Management

The principles of adaptive management are recommended as necessary for management of environmental flows due to the inevitable changing science in the future. The SAC stresses the fact that adaptive management per se does not guarantee protection

of adequate environmental flows. To accommodate the uncertainties that are unavoidable in environmental flow issues, adaptive management can establish scientifically determined ranges for how much targets can be altered up or down as new science appears.

The SAC Summary of Findings

The SAC listed the following observations in their summary (SAC 2004):

- 1) A one-size fits all answer is not correct within Texas. Due to the varying hydrologic, climatologic, and aquatic environments in Texas some parts are more fragile than others. This variety must be taken into account in the science as well as the policy.
- 2) Future scientific studies need to focus in more detail on the specific relationship between sound ecological environment and streamflows. The interconnections between streamflows and biology of riverine and estuarine systems should be the focus.
- 3) Completion of the Texas Instream Flow Studies program and improvement of the bays and estuaries freshwater inflow studies are essential.
- 4) Participation by stakeholders and water interests in the environmental flow program and rigorous scientific review are of paramount importance to achieving acceptable environmental flows. The process must be as transparent as possible.
- 5) For evaluating environmental flows for rivers and streams, statistical desk-top methods and associated technical analyses must be enhanced to facilitate regulatory permitting actions until such time as the Texas Instream Flow Studies program is completed. The Lyons method and Consensus Criteria have limitations as currently applied. Enhanced methodologies to replace them may be necessary in the long term as the Texas Instream Flow Studies program may be too complex and time-consuming for every situation.
- 6) The TWDB's State Methodology and the TPWD's "verification" process used to develop freshwater inflow recommendations for the state's bays and estuaries exhibit scientific shortcomings that must be addressed. Shortcomings include use of commercial harvest, questionable statistical methods, lack of relationship between optimum solution and actual harvests, and the fact that optimum patterns of inflow do not occur in natural hydrology. One of the most important questions about freshwater inflow goes

unanswered by the state's process – "what inflows must a bay receive to maintain its ecosystem over the long term?" (SAC 8–3, 2004).

- 7) Adaptive management and precautionary principle methods must be incorporated into the scientific study, management strategy implementation, and regulatory permitting phases of future environmental flow activities. When the risks of environmental damage are high any future adaptive management strategy should err on the side of caution while also limiting supply risk for water for human uses.
- 8) There are both regulatory strategies and market–based strategies that can be used to provide for environmental flows. Both mechanisms exist in Texas but they are not adequate to ensure target environmental flows. Existing strategies should be enhanced and new strategies explored to provide a framework for effective preservation of instream and estuarine flows.

Author's Comments on the SAC Report

Economic Analysis

Although the report of the SAC is not necessarily expected to shape law and policy, it does have the ear of the legislature by the nature of the process that created the report. The discussion of economic considerations regarding environmental flows does not recommend specific formulas for determining relative values for those flows, but does reference studies done in other states. The SAC study covers the issue of water being under–priced in general: ". . . the price actually paid to use water, if one is paid at all, rarely reflects its full economic value" (SAC 5–7, 2004). Also the report makes it clear that environmental flow values are not reflected in the price of water: "For many uses, no price exists at all. Such is the case with environmental flows . . ." (SAC 5–7, 2004). It is encouraging to see such statements in a document of this importance. Perhaps the principles discussed in Chapter 5 and the cited works will contribute to a dialogue on the value of environmental flows that will assist in a state-wide system of preserving flows for rivers, streams, and estuaries.

Environmental Flow Assessment Tools

Instream Flow Studies

The Texas Instream Flow Studies (TIF) Program is well-analyzed and the analysis is timely considering it was being initiated in late 2003 and the NAS report is due at the end of 2004. The SAC is openly critical of the Lyons Method and the Consensus Criteria which are of questionable value in their current state. Even if it was beyond the SAC's scope of work, I would have preferred a suggestion that the State Water Planning Process not be allowed to use the Consensus Criteria to evaluate future projects. Major projects are being tentatively approved in the Region Water Planning Process using the unsubstantiated methods of the Consensus Criteria. Following Region Plan approval, the TCEQ is left the task of appropriating these projects using the limited tools at its disposal.

The Instream Flow Incremental Methodology (IFIM) is scrutinized and although the IFIM is implemented nation-wide, the SAC introduces questions concerning the IFIM's ability to link hydrology and biology. The SAC is frank in questioning the ability of a process as labor-intensive as the IFIM which is the basis of the TIF to be completed in time to make policy decisions on each basin. An intermediate system is called for to address streamflow in rivers that become contentious before the TIF studies are complete. Perhaps the SAC learned from the problems of inapplicability and lengthy time-frame of the bay and estuary studies, that complex studies are not often performed in time and do not provide the necessary answers for policy to be made.

In its coverage of instream flow methods outside of Texas the most noticeable method discussed is The Nature Conservancy's Ecologically Sustainable Water Management (ESWM) program. This process is getting a lot of attention in various water forums in Texas and appears to be being considered as a viable method for Texas instream flow analysis for agency use while more complex studies are being performed.

Bay and Estuary Studies

The SAC presents a thorough analysis of the shortcomings of the Texas bay and estuary methodology for establishing target inflows. Unfortunately the SAC charge from the Legislature and the subsequent SAC's own Scope of Work did not include offering specific methods for determining environmental flows that would apply across the full climatological and hydrological spectrum from drought to flood for each estuary. Other methodologies used throughout the world were examined and could provide the basis for individual estuaries in Texas. The SAC stresses that having only one environmental flow methodology is not sufficient to cover the variety of estuaries in Texas.

The lack of specific recommendations for bay and estuary inflow targets cannot be blamed on the SAC. With no mandate from the Legislature, no paid scientific staff, and unpaid committee members who were only part-time for one year, it is unrealistic to think that a specific applicable solution for each estuary could be derived.

Market-Based Environmental Flow Strategies

While the SAC does recognize that acquiring water rights for environmental flows through various mechanisms including purchase and lease would require substantial resources, the committee fails to present a realistic estimate of how much

money it would take to buy enough water to protect bays and estuaries. The report states that total acquisitions of water for the environment in the Western United States were estimated at \$20 million in 2003 while from 1990 – 1997 only \$11 million was spent (Landry 2003). Using the SMRF application as a reference for a basin's water needs (1.15 million acre–feet for the Guadalupe Basin), the cost to purchase that amount assuming an estimate of \$600 per acre–foot would be \$690 million (conservative approximation based on \$708 per acre–foot estimate for senior rights on the San Marcos River [Turner, Collie, and Braden and Crespo Consulting 2004]). This amount is for environmental flows for *only one basin* and is over *34 times the total current Western United States expenditures*. The amount of funding required for market–based methods is so high that it should not be considered a major panacea for preserving instream flows.

Another factor that is a significant impediment to preserving estuary inflow through market–based strategies using existing water rights is the point of diversion issue. All water rights no matter what the use (diversion or instream) have a point of diversion. If a senior water right were purchased for instream flow or donated to the Water Trust, the instream use of that water right would only be applicable to the original point of diversion as defined in the permit. Therefore, instream flow below that point and from there to the estuary would not be guaranteed by the purchase, conversion, or donation of the right for environmental flows. To be truly effective in preserving freshwater inflow and instream flow below the point of diversion, the point would have to be moved to the coast. This would affect all downstream users and would be very contentious. The task of moving diversion points could be as politically unpopular as some of the regulatory strategies discussed such as superceding public interest. The SAC

mentioned point of diversion issues in the "Cons" of *regulatory* strategy alternatives such as modifying permits, new instream flow permits, etc., but for some reason failed to discuss diversion as an issue in *market-based* strategies. The necessity to move diversion points to provide adequate environmental flows needs to be stressed in this report. The legislature should not be led into thinking that market-based strategies will solve instream flow issues simply by the purchase, lease, or donation of water rights. Most or all of the diversion points of these rights would have to be moved downstream to effectively preserve freshwater inflow. A thorough explanation of these limitations should have accompanied this portion of the study.

Quality and Accomplishments of the Report

The SAC Report is a step in the right direction for preservation of environmental flows in Texas. Considering the limited resources and time-frame, the well-qualified Scientific Advisory Committee completed a detailed analysis of existing policy and science as well as methods used in other states and internationally. This report will serve legislators, legislative staff, agency staff, and the public as a reference document for the state of the protection of instream and freshwater inflow in Texas as of 2004. The SAC's legislative charges were completed and the SAC Report provides a necessary step in the hopeful improvement of instream and freshwater inflow in Texas.

SECTION B: MAJOR PENDING WATER RIGHT APPLICATIONS

Several large water right applications that are still pending were filed in 2003 and 2004 by major municipalities and river authorities. With Senate Bill 1639 putting a moratorium on instream flow water right applications, the bay and estuary models being

reevaluated by the Scientific Advisory Committee, and the denied instream flow water right application of the SMRF in the court system, this "scramble" to acquire much of the remaining flows was expected. In addition to these recent applications, four large pre-2003 applications are still pending before the TCEQ. The following table 20.1 summarizes the pending major applications: Note: RFH means a request for an administrative hearing has been filed which means a group or individual(s) have objected to the application. This does not mean the TCEQ will grant a hearing. If a hearing is not granted it can be appealed to the court system.

Table 20.1 – Pending water right applications at TCEQ (TCEQ, 2004)

APPLICANT	AMOUNT (Ac.Ft.)	DATE FILED	COMMENTS
Sabine River Authority	293,900	2/14/2003	RFH Toledo Bend Res.
San Jacinto River Authority/ City of Houston	32,500	3/17/2003	Lake Houston
San Jacinto River Authority/ City of Houston	80,000	3/17/2003	RFH
City of Houston	580,923	1/14/2004	RFH Return Flows
City of Houston	160,000	1/14/2004	RFH
Brazos River Authority	421,449	7/6/2004	Proposed 100,000 ac.ft. to Water Trust
City of Austin	100,616	4/12/2002	RFH Return flows Proposed 16,350 ac.ft. to Water Trust
LCRA	850,000	Filed 3/31/99 Admin. complete 2/28/2001	RFH Off-channel res.
LCRA	est. 100,000	11/12/2002	RFH for Austin's Return Flows
GBRA	289,600	11/26/2002	Lower Diversion Project

These major water right applications total about 2.8 million acre–feet per year and represent a significant potential impact on environmental flows if the permits are issued without sufficient environmental flow restrictions. As shown by this document and the SAC Study, the current methods for determining environmental flow restrictions are inadequate. The 2.8 million acre–feet represent approximately 40% of the total surface water used in Texas in 2000 which was 6.83 million acre–feet. From another perspective these pending applications are approximately 10% of the total 27 million acre–feet of consumptive surface water rights in the state (this number includes some industrial permits for brackish water from estuaries).

The Near–Term Forecast for Freshwater Inflow

In addition to the pending water rights previously discussed, there are 109 more applications awaiting approval by the TCEQ in early December 2004. There are no immediate plans to stop or alter this process of granting water rights for consumptive use while at the same time not allowing any applications solely for instream use. In one encouraging note an application by the Canyon Regional Water Authority for approximately 5500 acre–feet of water for municipal use on the mid–stem of the Guadalupe River was recommended for denial by the staff and executive director of TCEQ due to the lack of available water in that stretch of river (TCEQ 2000a). The Texas Parks and Wildlife Department has filed a request for hearing on one of the pending LCRA applications – a step not often taken by one department in an action by another department although authorized in the Water Code (Texas Parks and Wildlife Code § 12.024).

The next session of the Texas Legislature convenes in January 2005 and will by then have available the recommendations of the Study Commission on Instream Flows and its subcommittee the Scientific Advisory Committee as tools to enable improved environmental flow legislation. From a perspective of environmental flow preservation, at least the amount of attention to the issue is increasing. Whether or not we see effective environmental flow legislation either for long-term water planning and studies or for short-term water permit policies remains to be seen.

Chapter 21

2005 Update

The 2005 Legislature and SB3

Hopes for a solution to the management of environmental flows were high as the 2005 legislative session began. Prior to the session, representatives of water supply and environmental groups had come to a consensus and recommended provisions for a bill to protect instream flows and freshwater inflows. The bill was hailed by both sides as an “omnibus” piece of legislation. Many of the recommendations of the Scientific Advisory Committee were included in the proposed legislation including continuation of the Study Commission on Environmental Flows. Although the environmental flows provisions were included in Senate Bill 3 (SB3) that passed the Senate, the bill did not make it through the House in the main session. There were also no bills passed related to freshwater inflow in either of the two subsequent special sessions in 2005.

Several factors prevented the final passage of SB3 and there is not agreement on which factor was the most influential. Water as well as many other issues was dwarfed by the issue of school finance reform, which was the major concern of the whole legislative session and the two special sessions. SB3 also included what would turn out to be several controversial groundwater provisions that were not part of the environmental flows portion. In addition, a fee for water users that could be added on to residential water bills also received a lot of resistance. Some of the proposed revenue from these fees was to assist in the development of water infrastructure. Another portion of SB3 that aroused controversy included water conservation issues.

Commission Rule Changes

In the absence of any new legislation on environmental flows, there are ongoing discussions about the various agencies that govern water implementing rule changes to provide mechanisms for environmental flow protection. Agencies and commissions have limited power to more closely define the application of statutes such as the Water Code without waiting for the legislature or courts to do so. This is accomplished by creating or changing the rules of the related commission. The legislature can send the commission a statement of support or opposition to a rule (Tex. Government Code § 2001.032) but the rule making is done at the commission level. The control mechanism for this process is the requirement that the rule be cross-referenced to a specific statute. The statutes can only be changed by the legislature while the rules are controlled by the associated commission. This is a gray area of administrative law and there would obviously be reluctance by commissions to exercise this role. The commissions are aware that it is the legislature that controls their budgets every two years; therefore, there is a de facto check and balance to this system.

With the backlog of pending water rights applications, some of which are substantial, there is pressure on the TCEQ from water suppliers to grant these applications, while at the same time the environmental groups are calling for a greater degree of protection of environmental flows than in the recent past. State officials, administrators, legislators, and subcommittees have made numerous statements about the importance of environmental flows. Further, the TCEQ Commissioners have expressed concern and frustration about the inadequacy of the current rules for granting water rights and providing protection of environmental flows. Critics have referred to the current

method of granting water rights as a case-by-case method with no real overall system for dealing with environmental flows. There will most likely be heated debates over this rule making process, if it occurs. There is a possibility that the Governor will call another special session in 2006 to once again address school finance, and possibly there will be another attempt at introducing environmental flows legislation.

Pending Court Cases on Environmental Flows

As mentioned earlier in this paper, several environmental groups had filed water right applications for environmental flows, mainly to estuaries, but also to Caddo Lake. Following denial by the TCEQ, these permits were appealed to the court system and the initial court hearings on these cases will occur in the late fall of 2005. No decisions are expected on these cases in the near future.

Pending Water Right and Reuse Applications

As of September 23, 2005 there were 122 pending water right applications before the TCEQ. All of the major applications discussed in the previous 2004 update are still pending. These 2004 pending major applications total approximately 2.8 million acre-feet. There has been a significant change to one of these major water right projects with the withdrawal by the San Antonio Water System (SAWS) from the Lower Guadalupe Diversion Project. This project included GBRA, SAWS, and the San Antonio River Authority (SARA). The application for 289,600 acre-feet was designed to move water from the Lower Guadalupe River near the coast back to San Antonio by a 160 mile long pipeline. It is not certain what the future of this project will be. Part of the project involved studies on the effects of this water withdrawal on the endangered whooping

crane flock that winters near the mouth of the Guadalupe. As of the writing of this section the permit is still pending at TCEQ and the studies will continue.

There have been 55 new applications and amendments filed for calendar year 2005 as of September 23. Many of the amendments are for change of use or addition of use. One of the larger water right applications of note was filed by the North Texas Municipal Water District for the interbasin transfer of 113,000 acre-feet of water from Lake Texoma on the Red River to the Trinity and Sabine Rivers. Chlorides and sulfates are so high in this water from the Red River Basin that the permit states the water will either be blended with higher quality water or treated with a desalination process. The district mentions in the application that it will be applying for reuse of this water in the near future. Since the water is from another basin, the district claims there will be no environmental impacts from the reuse of this water since it is new to the basins of use. The permit states that neither existing nor future water right holders should come to rely on the availability of return flows from this permitted water. The fact that reuse is mentioned in the initial water right application is a sign of increasing awareness of reuse possibilities.

Twenty of the 122 pending applications are for reuse via bed and banks permits, which seem to be growing in popularity. Bed and banks permits allow the user to divert wastewater that was discharged upstream and reuse it again. The term “bed and banks” refers to the fact that the bed and banks of the river are used to convey the wastewater downstream before it is diverted for reuse. This is also called indirect reuse. There is another form of reuse called direct reuse where the water is not discharged, but is instead held off stream and reused. A permit is sometimes required for direct reuse if there are

water quality concerns, but there is no burden of proving non-injury to other existing permits or effects on environmental flows. A water right holder has the right to use its diverted water over and over, and, unless specified in the permit (which is rare), does not have to discharge any of the water back into the stream. It is only when the water is discharged and then diverted downstream that a bed and banks permit is necessary with the ensuing requirements.

An indirect reuse or bed and banks permit is much more complex than a direct reuse permit. The general assumption by TCEQ is that the applicant has to basically apply for a new water right although the details of the process are not clear. The TCEQ is struggling with the rules for bed and banks permits that were authorized in SB1 in 1997. One of the main issues is how to treat wastewater that is derived from surface water versus groundwater. At a TCEQ Commission workshop on reuse in August, 2005 one commissioner stated that private groundwater does not become state water when discharged into a stream while another opined that it becomes state water. Both agreed that surface water once discharged becomes state water. The assumption is that once the water is state water, it is subject to the rules of appropriation including determination of no injury to previous water right holders and no impact on necessary environmental flows.

The commissioners discussed other issues including which Water Availability Model (WAM) assumptions to use in analyzing indirect reuse permits. Should the assumption be that no wastewater is returned to the stream by other water rights holders when determining no injury or environmental flow effects? One argument was for including only wastewater that was historically discharged. This would lead to the issue

of differentiation between historically discharged wastewater versus future discharged wastewater and how to model those flows regarding the no injury rule. The commission's current practice for new water right permits is to assume that there is no return flow from existing water rights including unused portions. For term permits return flows are modeled using the maximum diversion in the last ten years.

The TCEQ Commissioners agreed to hear comments and to hold another work session on reuse permits. As of the August 12, 2005 workshop there were 20 pending reuse applications, and the commissioners agreed that eighteen of those permits would be reviewed by staff using existing policy, since they were applied for before the previous workshop on reuse in February, 2005. There are also two newer permits filed since that workshop, and there was not agreement on whether the old rules should apply to them. It appears likely that some rule interpretations on reuse permits are forthcoming.

Obviously the interpretation of rules on indirect reuse permits can affect freshwater inflows. The current policy of examining the historically discharged amount from the perspective of instream flow and freshwater inflow has the potential to at least partially reserve some of this discharge for environmental flows. But, as mentioned many times, the mechanism for determining the flows needed for the bays and estuaries is still deficient. In addition, the concept of not examining future discharged flows from an environmental flow perspective is of concern. Given that this future discharge does not have to even be discharged into the stream, one could argue that it should not have environmental restrictions. On the other hand since there are essentially no reservations for environmental flows in over-appropriated rivers, one could argue that future discharges should be subject to restrictions to provide environmental flows.

Summary

Depending on whether one is an optimist or not, the state of environmental flows has or has not improved since the 2003 Legislative Session. At the least, the subject of environmental flows has become more prominent among the players since then, beginning with the creation of the Study Commission on Environmental Flows. The Study Commission established the Scientific Advisory Committee (SAC) that issued its report in December 2004. This report was critical of the administrative state of environmental flow protection and the science that is currently being used by the agencies whose job it is to protect freshwater inflow. The SAC report also recommended several improvements to the modeling and administrative practices of the relevant agencies. There is disappointment that the report of the Scientific Advisory Committee was not incorporated into any effective legislation in the 2005 Legislature. However, optimists might point out that at least there is a report, which is critical of the status quo, and contains recommended improvements, and that there was a bill (SB3) that was introduced in the 2005 session that contained many of the SAC recommendations.

The court systems are also beginning to struggle with the environmental flow applications, but no decisions are anticipated anytime soon. Again an optimist might conclude that at least the issue of environmental flows is in the courts.

In the administrative area, the optimist sees discussion by various agency staff expressing awareness that it is up to the agencies and commissions to develop rules to deal with environmental flows. With the large number of pending water rights and reuse applications and no new direction from the legislature, the three agencies, the Texas Commission on Environmental Quality, the Texas Water Development Board (TWDB),

and the Texas Parks and Wildlife Department (TPWD), will have to shoulder the load of improving environmental flow protection. Within these three agencies it will take not only commitment by the staff and executive directors, but in the end, approval by the governor-appointed commissioners to establish new rules. This could be a difficult process with many political obstacles. At least for the next several months, the agency rule-making process is the main forum for environmental flow preservation.

Looking ahead to 2006, there is the possibility of another special legislative session. Although this session would be mainly for the continuing discussion of school finance reform, there is the opportunity for the introduction of new legislation regarding environmental flows management.

APPENDIX A

MAPS

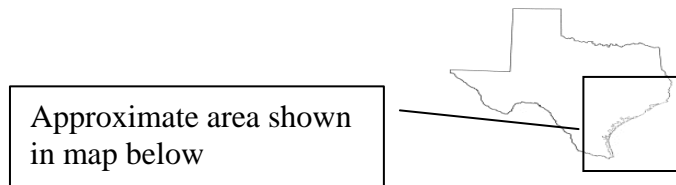


Figure A-1: Texas boundaries (Base map courtesy of General Libraries, The University of Texas at Austin 2004)

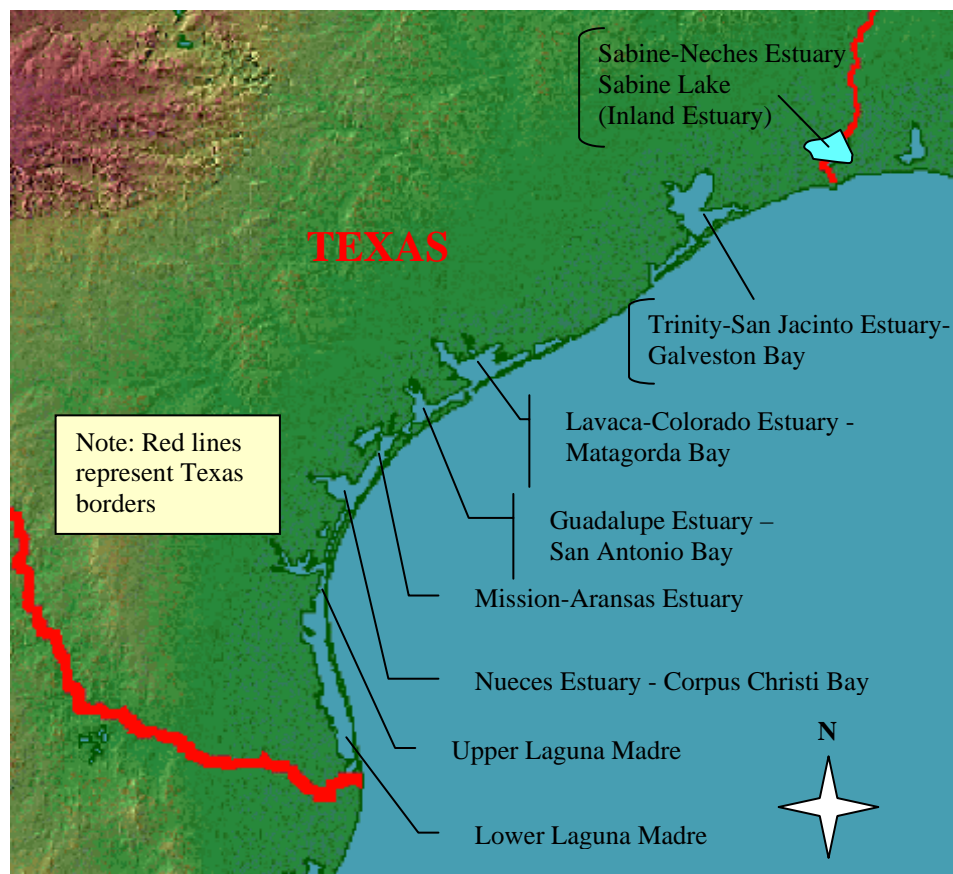


Figure A-2: Map of major Texas Estuaries (Base map courtesy of General Libraries, The University of Texas at Austin 2004). Note: Sabine Lake enhanced for visualization.

Water Availability Evaluation for New Perpetual Rights

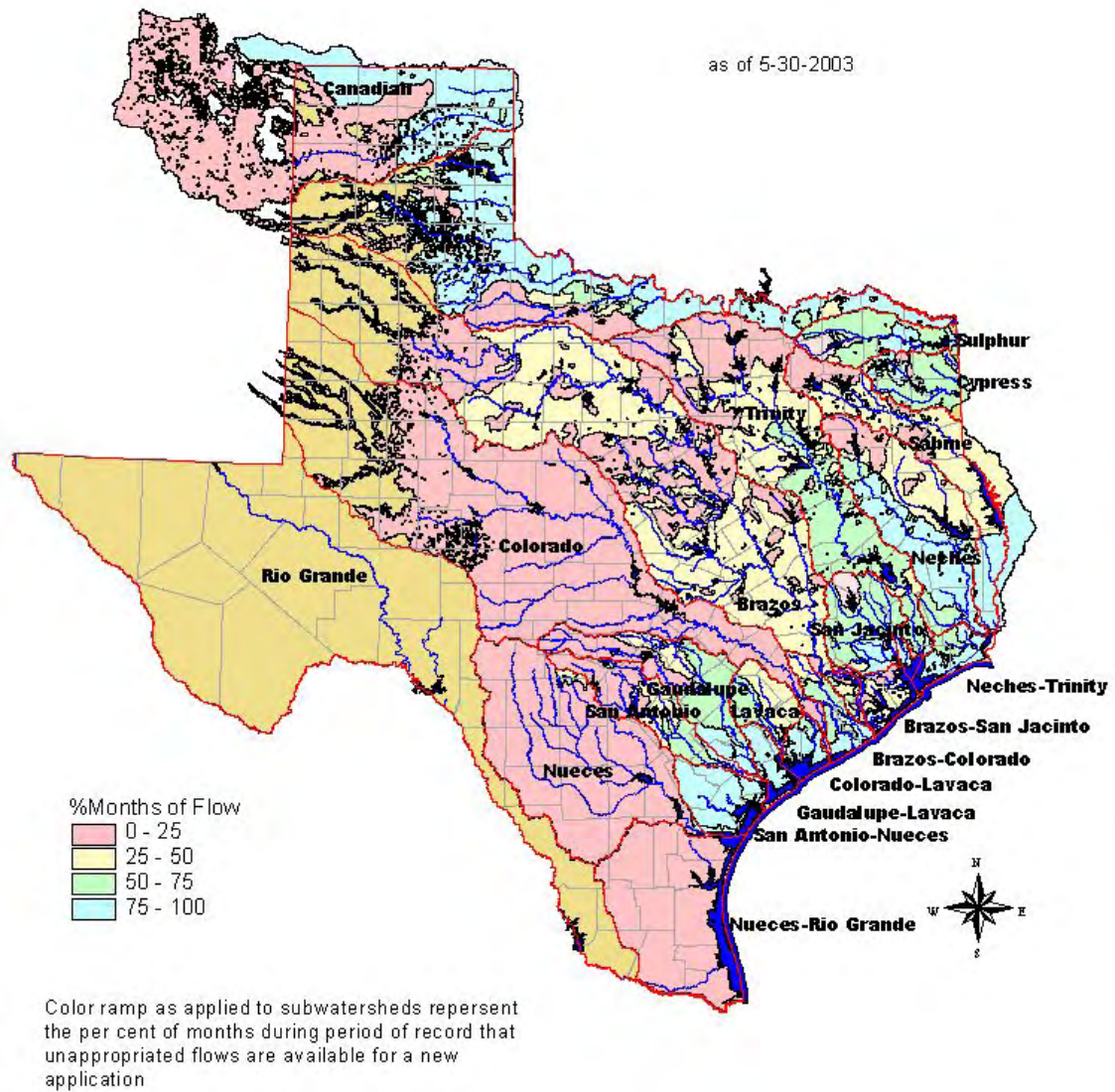


Figure A-3: Water availability in Texas river basins (TCEQ 2004)

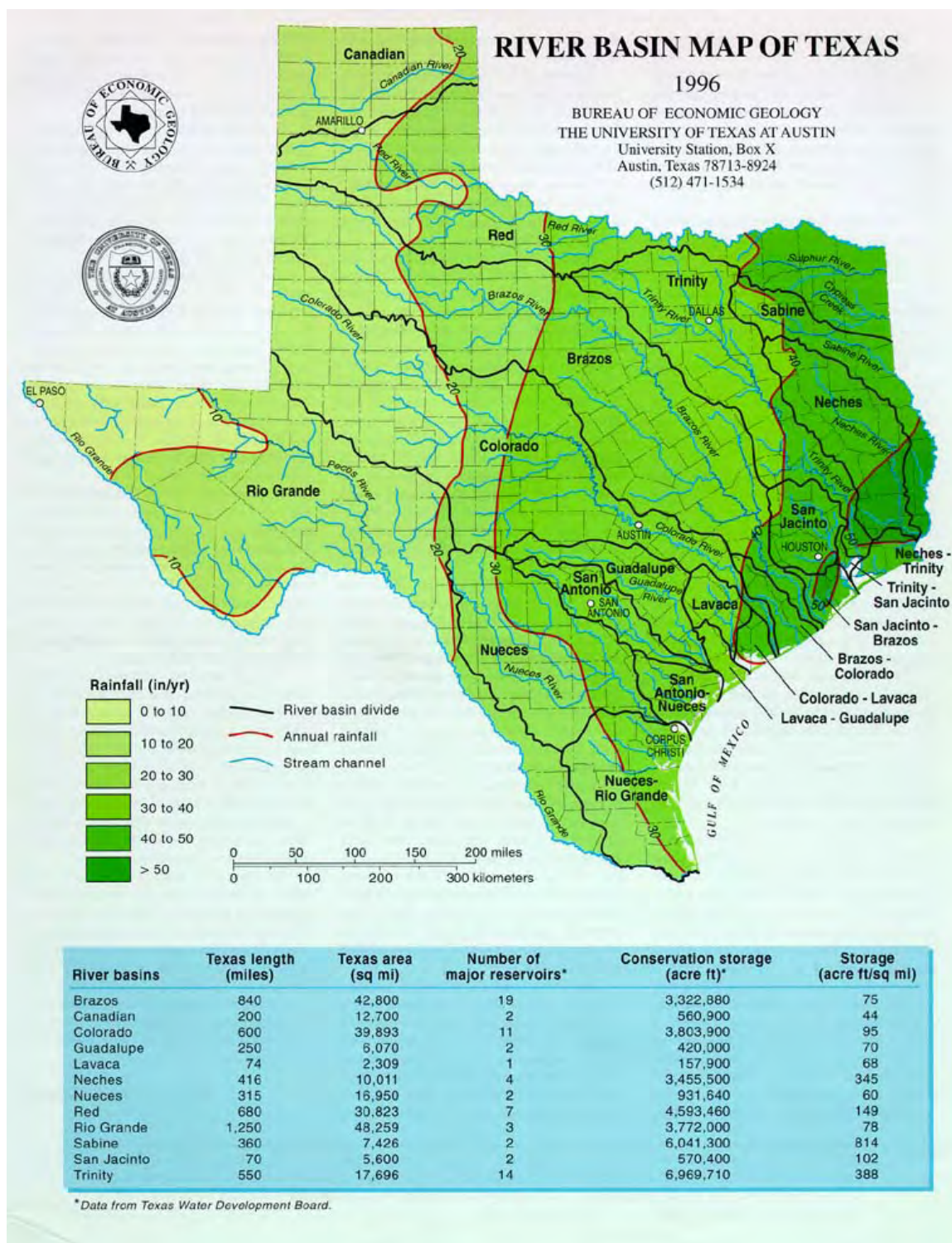


Figure A-4: Texas rivers, basins, and rainfall (The University of Texas at Austin General Libraries, 2004)



Figure A-5: Map of Texas cities and roads (World Sites Atlas 2004). Note: Size of type indicates relative size of cities and towns.

APPENDIX B

WATER RIGHTS AND RESERVOIRS

Table B-1: Active water rights by river basin August 2002 (TNRCC 2002)

Basin Name	Active* Water Rights	Size Category of Water Right				Total ** Appropriated Water acre-feet
		>= 100,00 acre-feet	>=10,000- <100,000 acre-feet	>= 1,000- <10,000 acre-feet	<1,000 acre-feet	
Canadian	39	1	1	0	37	164,789
Red	272	1	9	30	232	642,006
Sulfur	54	1	5	6	42	379,291
Cypress	82	1	8	5	68	412,070
Sabine	180	6	5	6	163	1,887,732
Neches	232	5	8	10	209	4,065,309
Neches-Trinity	102	1	4	41	56	330,363
Trinity	593	10	21	25	537	4,367,486
Trinity-San Jacinto	17	0	1	7	9	44,524
San Jacinto	120	3	5	11	101	636,586
San Jacinto-Brazos	58	2	4	16	36	4,484,227
Brazos	1,154	6	34	57	1,057	2,679,164
Brazos-Colorado	66	0	2	16	48	92,396
Colorado	1,222	7	12	42	1,161	5,350,376
Colorado-Lavaca	32	1	3	7	21	975,444
Lavaca	55	1	0	12	42	163,589
Lavaca-Guadalupe	7	0	0	2	5	4,560
Guadalupe	353	9	7	18	319	6,266,722
San Antonio	264	0	3	12	249	186,750
San Antonio-Nueces	17	0	2	2	13	33,408
Nueces	259	2	2	15	240	539,981
Nueces-Rio Grande	84	3	2	25	54	1,771,293
Rio Grande	968	11	33	104	820	6,992,372
TOTALS	6,230	71	171	469	5,519	42,470,438

* Contractual permits/agreements are excluded

** Includes both consumptive and nonconsumptive rights

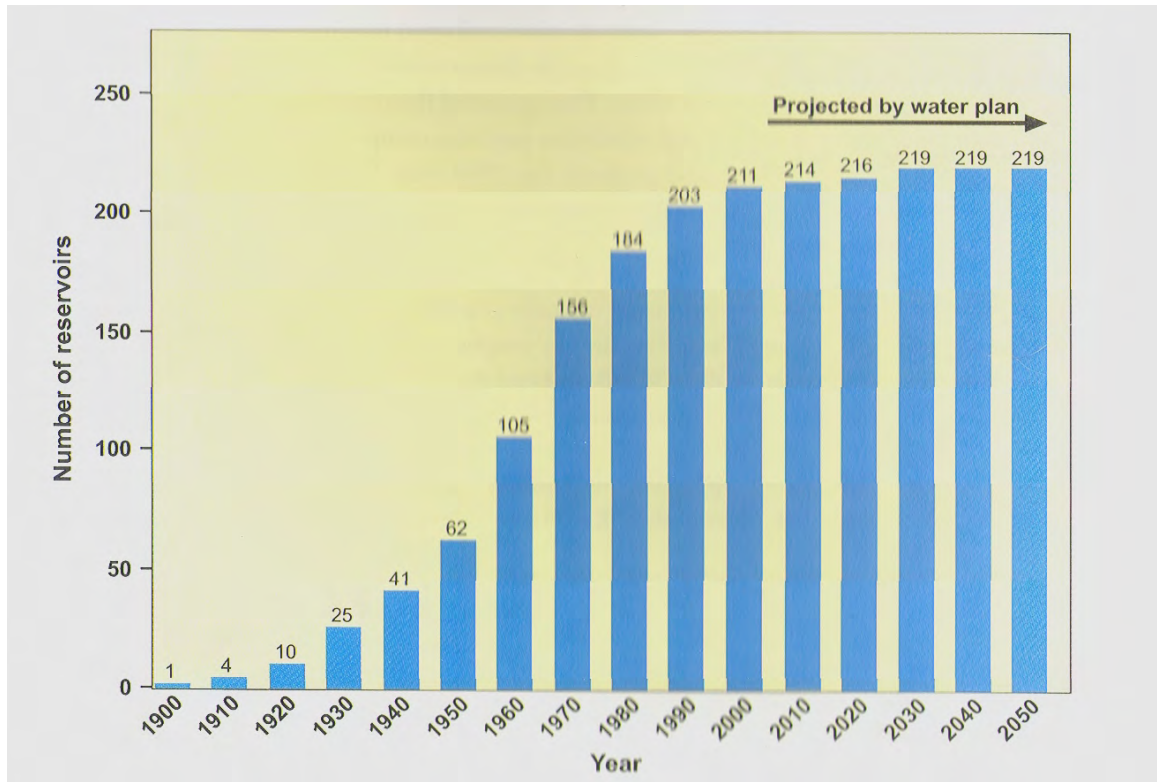


Figure B-2: Number of reservoirs > 5000 acre-feet by year (TWDB 2002b)

APPENDIX C

BAY AND ESTUARY MODEL OUTPUT

Definitions for terms used in various graphs:

- MinQ-Sal – Minimum flow required to satisfy the salinity constraint
- MinQ – Minimum flow to satisfy all model constraints
- Target Q – Minimum flow to satisfy targets of LCRA methodology
- MaxH – Maximum harvest flow satisfying all model constraints based on harvest data from commercial fisheries.
- MaxQ – Maximum flow satisfying all model constraints
- MaxC – Maximum catch flow satisfying all model constraints based on catch data from TPWD sampling.

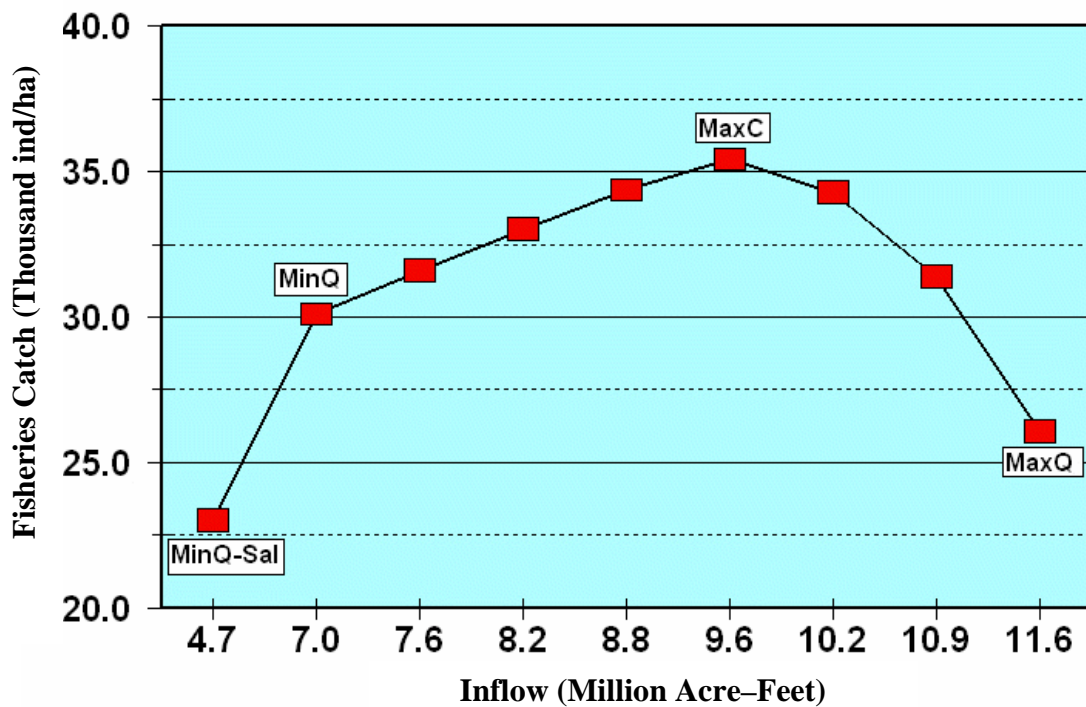


Figure C-1: TXEMP results for Sabine-Neches Estuary (TWDB 2004)

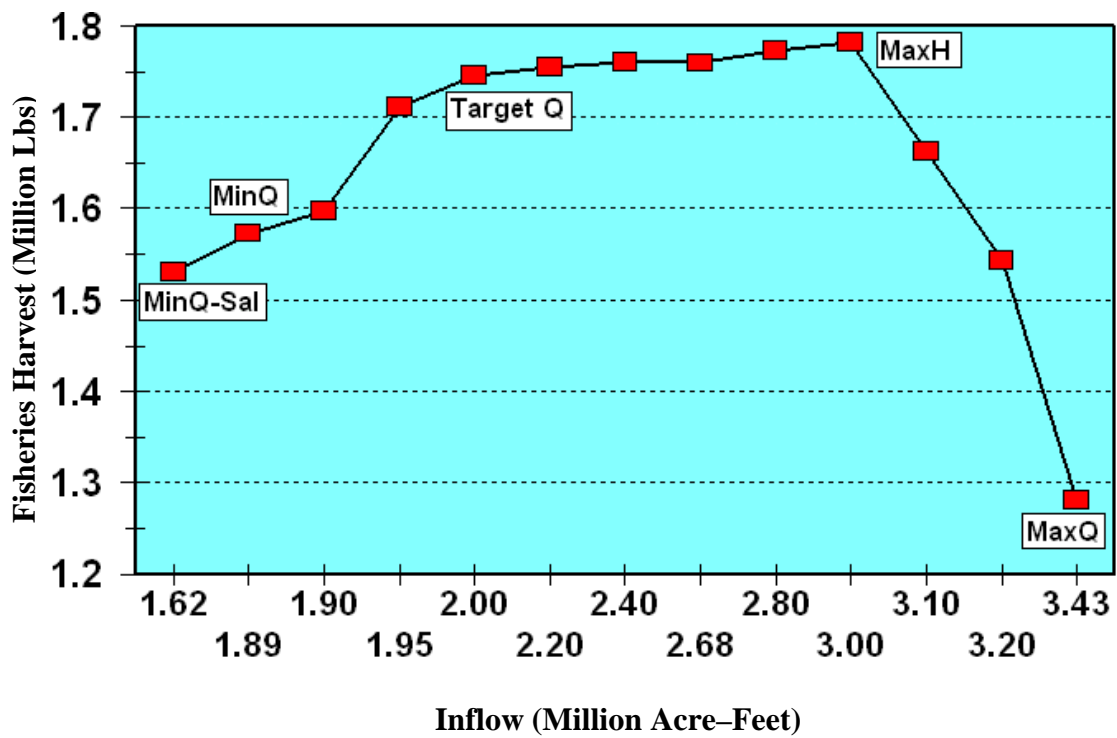


Figure C-2: TXEMP results for Lavaca-Colorado Estuary (TWDB 2004)

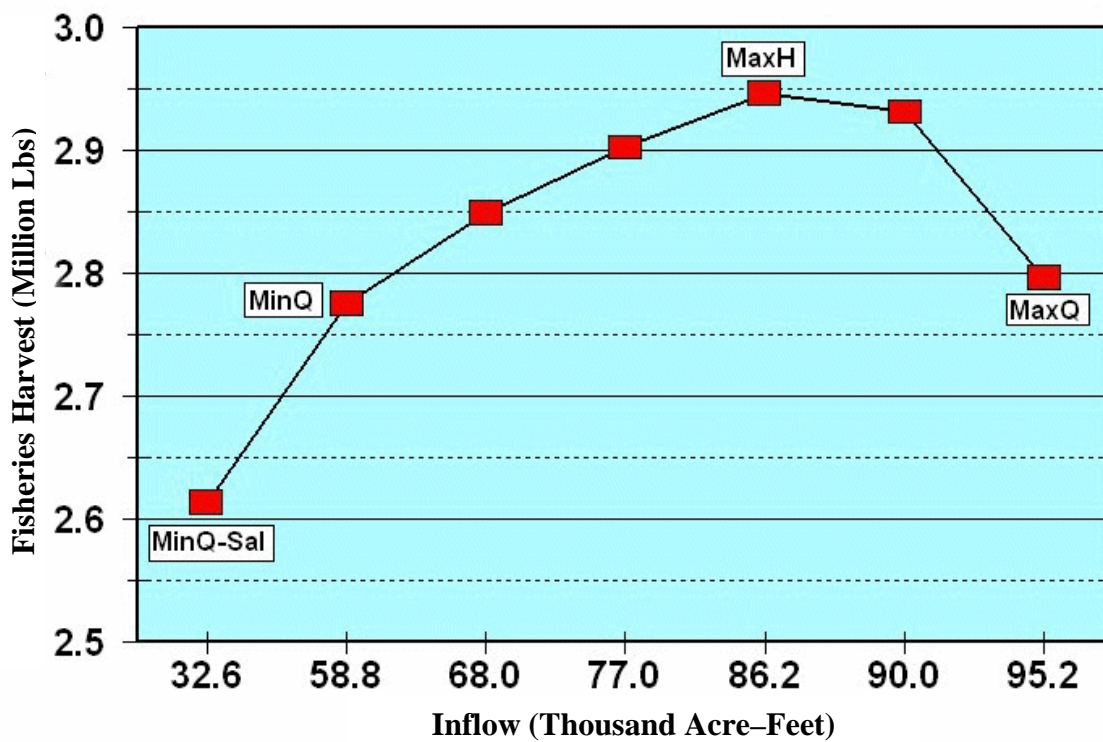


Figure C-3: TXEMP results for Mission-Aransas Estuary (TWDB 2004)

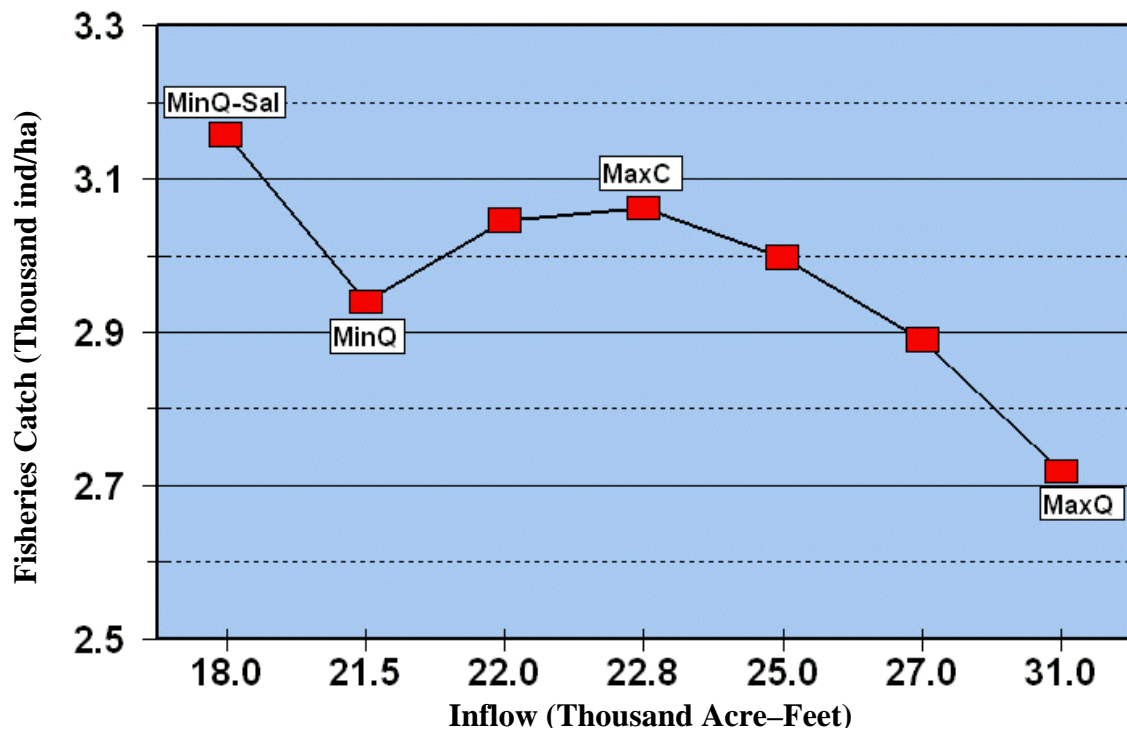


Figure C-4: TXEMP results for Upper Laguna Madre Estuary (TWDB 2004)

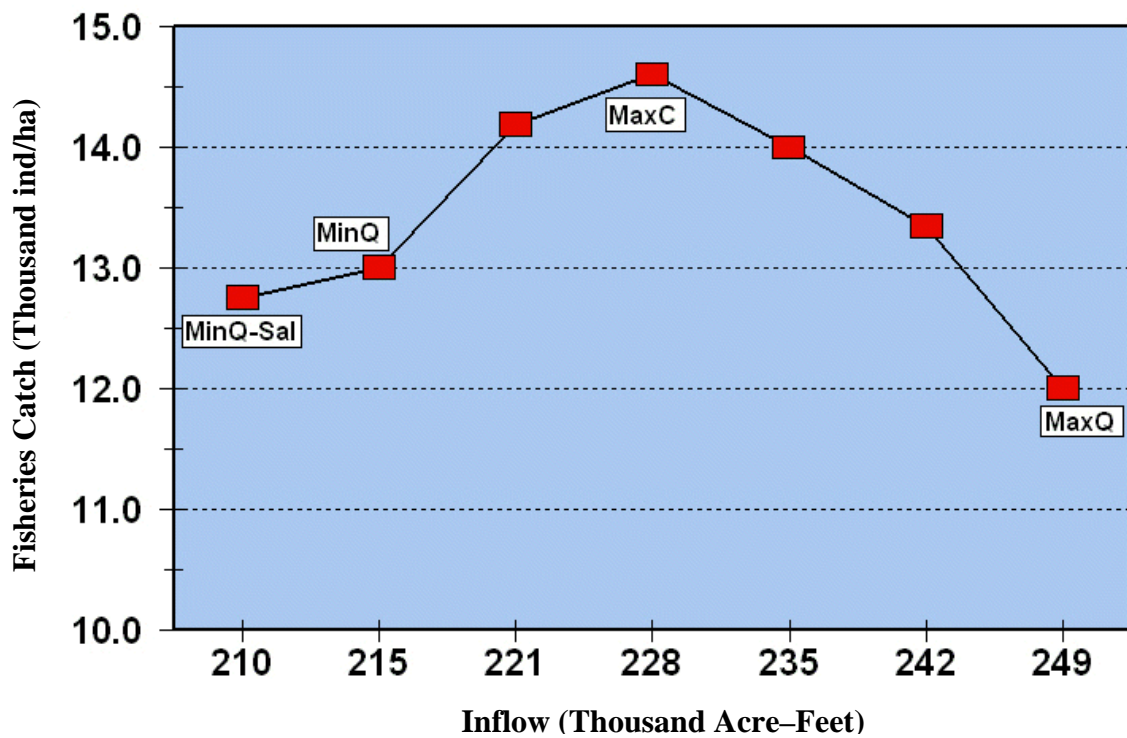


Figure C-5: TXEMP results for Lower Laguna Madre Estuary (TWDB 2004)

APPENDIX D

COPIES OF WATER PERMITS

Description of contents of appendix D:

D-1: Water Permit Number 12-5366 from 1960 to Brazosport Water Authority and a subsequent amendment, Permit 1964C from 1987 (6 pages total).

D-2: Draft Permit Number 5724 from 2000 to the San Marcos River Foundation and accompanying water availability and environmental analyses from the TECQ (18 pages total).

Quality of display – In the electronic version of this appendix, the reduced visual quality of the enclosed permits can be attributed to the fact that they were not available electronically and by necessity were scanned using a Hewlett-Packard Scanjet 4670 set at the highest quality. In addition, some of the documents were copies made of microfilm from Central Records at the Texas Commission on Environmental Quality that were then scanned so they are essentially fourth generation reproductions. Effort was made to preserve their readability. Print copy versions of this thesis will show some improvement in quality for this appendix since the last scanning operation was not necessary.

D-1: WATER PERMIT NUMBER 12-5366 AND
SUBSEQUENT AMMENDMENT

CERTIFICATE OF ADJUDICATION

CERTIFICATE OF ADJUDICATION: 12-5366 OWNER: Brazosport Water Authority
25 Oak Drive
Lake Jackson, Texas 77566

COUNTY: Brazoria PRIORITY DATE: April 4, 1960

WATERCOURSE: Brazos River BASIN: Brazos River

WHEREAS, by final decree of the 21st Judicial District Court of Bastrop County, in Cause No. 18,762, In Re: The Adjudication of Water Rights in the Brazos IV Segment of the Brazos River Basin and the San Jacinto-Brazos Coastal Basin dated June 1, 1987 a right was recognized under Permit 1946B authorizing the Dow Chemical Company to appropriate waters of the State of Texas as set forth below:

WHEREAS, pursuant to an agreement between the Dow Chemical Company and Brazosport Water Authority, dated January 1, 1987, recorded in Volume 412, Page 815 of the 1987 Official Records bearing file number 14779 of Brazoria County, Texas, Brazosport Water Authority acquired 45,000 acre-feet of water per annum from that portion recognized the Dow Chemical Company pursuant to Permit 1946B for industrial purposes;

WHEREAS, by an amendment to Permit 1946B, issued on November 2, 1987, the Texas Water Commission authorized the conversion of said 45,000 acre-feet of water from industrial to municipal purposes and authorized the owner to transfer all or any part of the 45,000 acre-feet of water from the Brazos River Basin for use in the San Jacinto-Brazos Coastal Basin and/or the Brazos-Colorado River Basin;

NOW, THEREFORE, this certificate of adjudication to appropriate waters of the State of Texas in the Brazos River Basin is issued to Brazosport Water Authority, subject to the following terms and conditions:

1. USE

Owner is authorized to divert and use not to exceed 45,000 acre-feet of water per annum from the Brazos River for municipal purposes and to transfer all or any part of said water from the Brazos River Basin for use in the San Jacinto-Brazos Coastal Basin and/or the Brazos-Colorado Coastal Basin.

2. DIVERSION

A. Location:

As described in Certificate of Adjudication 12-5328 owned by the Dow Chemical Company.

Certificate of Adjudication 12-5366

B. Maximum rate: As described in the aforesaid Certificate of Adjudication 12-5328.

3. PRIORITY

The time priority of owner's right is April 4, 1960.

4. SPECIAL CONDITIONS

A. This Certificate of Adjudication is issued subject to the acknowledgment by Brazosport Water Authority and all of its customers that water may not be available on a firm basis under this certificate.

B. This Certificate of Adjudication is also issued without prejudice to the Authority's right to obtain additional water from storage to firm up or supplement the supply of water available hereunder.

The location of pertinent features related to this certificate are shown on Pages 30 and 32 of the Brazos IV River Segment Certificates of Adjudication Maps, copies of which are located in the office of the Texas Water Commission, Austin, Texas.

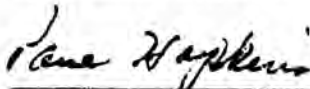
This certificate of adjudication is issued subject to all terms, conditions and provisions in the final decree of the 21st Judicial District Court of Bastrop County, Texas, in Cause No. 18,762, In Re; The Adjudication of Water Rights in the Brazos IV Segment of the Brazos River Basin and the San Jacinto-Brazos Coastal Basin dated June 1, 1987 and supersedes all rights of the owner asserted in that cause.

This certificate of adjudication is issued subject to senior and superior water rights in the Brazos River Basin.

Certificate of Adjudication 12-5366

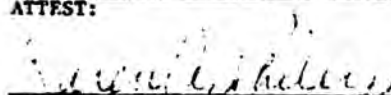
This certificate of adjudication is issued subject to the Rules of the Texas Water Commission and its continuing right of supervision of State water resources consistent with the public policy of the State as set forth in the Texas Water Code.

TEXAS WATER COMMISSION


Paul Hopkins, Chairman

DATE ISSUED:

ATTEST:


Faren A. Phillips, Chief Clerk

AMENDMENT TO PERMIT

APPLICATION NO.	2158C	PERMIT NO.	1964C	TYPE:	Amendment
Permittee :	Brazosport Water Authority	Address :	25 Oak Drive Lake Jackson, TX 77566		
Received :	June 9, 1987	Filed :	August 20, 1987		
Granted :	October 13, 1987	County :	Brazoria		
Watercourse :	Brazos River	Watersheds:	Brazos River Basin San Jacinto - Brazos Coastal Basin, and Brazos - Colorado Coastal Basin		

WHEREAS, the Texas Water Commission finds that jurisdiction over the application is established; and

WHEREAS, Brazosport Water Authority ("BWA") filed the application on June 9, 1987, and The Dow Chemical Company ("Dow") subsequently joined in the application; and

WHEREAS, BWA has purchased, pursuant to the agreement dated as of January 1, 1987 by and between Dow and BWA, a 45,000 acre-feet of water per annum portion of Permit No. 1964; and

WHEREAS, BWA and Dow have requested an amendment to Permit No. 1964, as previously amended, to authorize a change in the purpose of use of the 45,000 acre-feet of water per annum portion of Permit No. 1964 purchased by BWA from industrial to municipal use, and to authorize the transbasin diversion of all or any part of such water from the Brazos River Basin for use in the San Jacinto-Brazos Coastal Basin and the Brazos-Colorado Coastal Basin, to the extent such authorization does not presently exist; and

WHEREAS, Dow's right to divert and use industrial water under Permit No. 1964, as amended, is hereby reduced by 45,000 acre-feet of water per year; and

and WHEREAS, no person protested the granting of this application;

WHEREAS, the issuance of this amendment is not adverse to any party; and

WHEREAS, the Commission has complied with the requirements of the Texas Water Code and Rules of the Texas Water Commission in issuing this amendment; and

NOW, THEREFORE, this amendment to Permit No. 1964, as amended previously, is issued to Brazosport Water Authority subject to the following terms and conditions:

1. USE

- (a) Permittee is authorized to divert and use not to exceed forty-five thousand (45,000) acre-feet of water per annum, measured at the points of diversion authorized under Permit No. 1964, as amended previously, for municipal use.
- (b) Permittee is authorized to transfer all or any part of the 45,000 acre-feet of water authorized herein from the Brazos River Basin for use in the San Jacinto-Brazos Coastal Basin and/or the Brazos-Colorado Coastal Basin.

2. SPECIAL CONDITION

- (a) This permit is issued subject to the acknowledgement by BWA and all of its customers that water may not be available on a firm basis under this amendment.
- (b) This amendment is issued without prejudice to BWA's right to obtain additional water from storage to firm up or supplement the supply of water available under this amendment.

This amendment is issued subject to all terms, conditions and provisions contained in Permit No. 1964, as previously amended, except as herein amended.

This amendment is issued subject to all superior and senior water rights in the Brazos River Basin.

BWA agrees to be bound by the terms, conditions and provisions contained herein and such agreement is a condition precedent to the granting of this amendment.

All other matters requested in the application which are not specifically granted by this amendment are denied.

This amendment is issued subject to the Rules of the Texas Water Commission and to the right of continuing supervision of State water resources exercised by the Commission.

TEXAS WATER COMMISSION

DATE ISSUED:

November 2, 1967

/s/ Paul Hopkins
Paul Hopkins, Chairman

ATTEST:

/s/ John O. Houchins
John O. Houchins, Commissioner

/s/ Karen A. Phillips
Karen A. Phillips, Chief Clerk

/s/ B.J. Wynne, III
B. J. Wynne, III, Commissioner

D-2: SMRF Permit with Accompanying Analyses

DRAFT

PERMIT TO
APPROPRIATE STATE WATER

APPLICATION NO. 5724		PERMIT NO. 5724		TYPE §11.121	
Permittee:	San Marcos River Foundation	Address:	P.O. Box 1393 San Marcos, TX 78667-1393		
Filed:	December 21, 2000	Granted:			
Purpose:	Instream uses	Counties:	Gonzales, Refugio, and Calhoun		
Watercourse:	San Marcos River, tributary of the Guadalupe River, and the Guadalupe River	Watershed:	Guadalupe River Basin and the San Antonio River Basin		

WHEREAS, the applicant, San Marcos River Foundation, seeks authorization to appropriate up to approximately 1.3 million acre-feet of water per annum for maintaining streamflows for beneficial, non-consumptive, instream use and to maintain beneficial inflow of freshwater to the Guadalupe Estuary at two reference points within the Guadalupe River Basin; and

WHEREAS, the first reference point for measurement of these requested streamflows is on the southwest bank of the San Marcos River accessible to the public at Palmetto State Park in Gonzales County, approximately 10 miles northwest of the City of Gonzales, located at 29.586°N Latitude and 97.574°W Longitude; and

WHEREAS, the second reference point is on the west bank of the Guadalupe River accessible to the public at the State Highway 35 bridge, approximate 2.3 miles northeast of Tivoli, Texas, Refugio and Calhoun Counties, located at 28.479°N Latitude and 96.863°W Longitude; and

WHEREAS, the applicant indicates its intent to convey this requested appropriation of state water into the Texas Water Trust; and

WHEREAS, the applicant indicates that they will share the ownership, management, control and costs associated with this authorization, if it is granted; and

WHEREAS, the second reference point is subject to the Texas Coastal Management Program (CMP) and must be consistent with the CMP goals and policies; and

WHEREAS, of the total 1.3 million acre-feet of water requested, the applicant has provided specific flow rates and volumes relative to the first reference point and volumes relative to the second reference point; and

WHEREAS, the applicant seeks to appropriate 157,469 acre-feet of water per annum of streamflow for instream uses at the San Marcos River reference point, with the following monthly requested flow volumes: 13,343 acre-feet for January; 12,832 acre-feet for February; 14,450 acre-feet for March; 15,769 acre-feet for April; 18,016 acre-feet for May; 15,263 acre-feet for June; 12,328 acre-feet for July; 10,453 acre-feet for August; 10,592 acre-feet for September; 10,945 acre-feet for October; 11,306 acre-feet for November; and 12,175 acre-feet for December; and

WHEREAS, the applicant requests that the above monthly volumes of water for the San Marcos River reference point also be authorized as corresponding instantaneous minimum flow rates in cubic feet per second (cfs) as follows: 217 cfs for January, 229 cfs for February, 235 cfs for March, 265 cfs for April, 293 cfs for May, 257 cfs for June, 201 cfs for July, 170 cfs for August, 178 cfs for September, 178 cfs for October, 190 cfs for November, 198 cfs for December; and

WHEREAS, the applicant also seeks to appropriate 1,147,400 acre-feet of water per annum of streamflow for instream uses at the Guadalupe River reference point, with the following monthly requested flow volumes: 111,200 acre-feet for January; 124,200 acre-feet for February; 52,400 acre-feet for March; 52,400 acre-feet for April; 222,600 acre-feet for May; 162,700 acre-feet for June; 88,600 acre-feet for July; 88,300 acre-feet for August; 52,400 acre-feet for September; 52,400 acre-feet for October; 73,800 acre-feet for November; and 66,200 acre-feet for December; and

WHEREAS, the Texas Commission on Environmental Quality finds that jurisdiction over the application is established; and

WHEREAS, *(protest information will go here)*; and

WHEREAS, the Texas Commission on Environmental Quality rules define instream use as the beneficial use of instream flows for such purposes as fisheries, aquatic and riparian wildlife habitat, fresh water inflows for bays and estuaries, and the rules define instream uses as a beneficial use of water; and

WHEREAS, the Executive Director has calculated water availability at the first reference point using a simulation representative of the full utilization of existing water rights and determined that the recommended amount of flow is available in none of the years and in 26% of the months; and

WHEREAS, the Executive Director has calculated water availability at the second reference point using a simulation representative of the full utilization of existing water rights and determined that the recommended amount of flow is available in 4% of the years and in 44% of the months; and

WHEREAS, the Texas Commission on Environmental Quality rules provide non-consumptive instream use permits are not required to be based upon the continuous availability of historic normal streamflow; and

WHEREAS, the Texas Commission on Environmental Quality finds that the issuance of the permit is consistent with the goals and policies of the Texas Coastal Management Program; and

WHEREAS, the Texas Commission on Environmental Quality finds that its issuance of this permit will benefit the public welfare; and

WHEREAS, the Texas Commission on Environmental Quality has entered an Order granting the application; and

WHEREAS, the Commission has complied with the requirements of the Texas Water Code and Rules of the Texas Commission on Environmental Quality in issuing this permit; and

WHEREAS, the South Texas Watermaster has jurisdiction over this water right;

NOW, THEREFORE, Water Use Permit No. 5724 is issued to the San Marcos River Foundation subject to the following terms and conditions:

1. USE

- A. Permittee is authorized an instream beneficial use located on the San Marcos River, tributary of the Guadalupe River, Guadalupe River Basin, in Gonzales County at 29.586°N Latitude and 97.574°W Longitude at the following flow rates in each of the respective months: January-131 cubic feet per second (cfs); February-123 cfs; March-119 cfs; April-140 cfs; May-156 cfs; June-137 cfs; July-109 cfs; August-82 cfs; September-109 cfs; October-110 cfs; November-108 cfs; December-119 cfs.
- B. Permittee is authorized an instream beneficial use located on the Guadalupe River, Guadalupe River Basin, in Refugio and Calhoun Counties, at 28.479°N Latitude and 96.863°W Longitude, not to exceed 980,494 acre-feet of water per annum.

2. TIME PRIORITY

The time priority for this permit is December 21, 2000.

3. SPECIAL CONDITIONS

- A. This permit is issued for instream uses. Any future application to amend this use as a consumptive use will require review as a new appropriation and the authorized amount may be reduced.
- B. Permittee shall install a device within an accuracy of plus or minus 5% that will be used to measure and account for the instantaneous flow rates at the reference points on the San Marcos River and on the Guadalupe River. Permittee shall allow representatives of the Texas Commission on Environmental Quality (South Texas Watermaster) reasonable access to the property to inspect the measuring device.

This permit is issued subject to all superior and senior water rights in the Guadalupe River Basin and the San Antonio River Basin.

Permittee agrees to be bound by the terms, conditions and provisions contained herein and such agreement is a condition precedent to the granting of this permit.

All other matters requested in the application which are not specifically granted by this permit are denied.

This permit is issued subject to the Rules of the Texas Commission on Environmental Quality and to the right of continuing supervision of State water resources exercised by the Commission.

TEXAS COMMISSION ON
ENVIRONMENTAL QUALITY

For the Commission

Date issued:

DRAFT

Texas Natural Resource Conservation Commission

INTEROFFICE MEMORANDUM

To: Iliana Delgado, Application Manager
Water Rights Permitting Team

Through: *sgk/oz*
Lann Bookout, Team Leader
Surface Water Availability & Interstate Compacts Team

From: Kathy Alexander, Hydrologist
Surface Water Availability & Interstate Compacts Team

Subject: San Marcos River Foundation
Application 5724
San Marcos and Guadalupe Rivers, Guadalupe and San Antonio River Basins
Gonzales, Calhoun and Refugio Counties

August 26, 2002

WATER AVAILABILITY ANALYSIS

Application Summary

The San Marcos River Foundation has requested an appropriation of 157,469 acre feet per annum from the San Marcos River, as measured at Palmetto Bend State Park, Gonzales County, to protect instream uses with the following distribution:

Month	Flow (cfs)	Vol. (acft)	Month	Flow (cfs)	Vol. (acft)
January	217	13,343	July	201	12,328
February	229	12,832	August	170	10,453
March	235	14,450	September	178	10,592
April	265	15,769	October	178	10,945
May	293	18,016	November	190	11,306
June	257	15,263	December	198	12,175

The purpose of this application is to maintain beneficial streamflows in the San Marcos River. No consumptive use of the water is requested.

Additionally, the applicant has requested an appropriation of 1,147,200 acre feet per annum for

instream uses from the Guadalupe River, as measured at the State Highway 35 Bridge, in Calhoun and Refugio Counties. The requested amount, 1,147,200 acre feet of water, would remain in the Guadalupe River and provide freshwater inflows to the estuary with a seasonal distribution as follows:

Month	Vol. (acft)	Month	Vol. (Acft)
January	111,200	July	88,600
February	124,200	August	88,300
March	52,400	September	52,400
April	52,400	October	52,400
May	222,600	November	73,800
June	162,700	December	66,200

The requested volume and seasonal distribution were derived from the freshwater inflow recommendations developed by the Texas Parks and Wildlife Department for the Guadalupe-San Antonio Estuary. The confluence of the San Antonio and Guadalupe Rivers is upstream of the State Highway 35 Bridge, so water appropriated or reserved for freshwater inflows into the Guadalupe-San Antonio Estuary, would be derived from both basins. No consumptive use of water is requested at this location.

Water Availability Analysis

The Commission's water availability model for the Guadalupe and San Antonio River Basins protects existing water rights based on the prior appropriation doctrine. The applicant's request was modeled with a priority date of December 21, 2000.

San Marcos River Location

Based on studies performed on the San Marcos River, as well as habitat-specific data collected on the mainstem of the Guadalupe River, TNRCC Resource Protection staff recommended that the 157,469 acre feet requested at the San Marcos River location be reduced to 87,106 acre feet and distributed as follows:

Month	Flow (cfs)	Vol (acft)	Month	Flow (cfs)	Vol (acft)
January	131	8,041	July	109	6,690
February	123	7,063	August	82	5,033
March	119	7,304	September	109	6,475

April	140	8,316	October	110	6,752
May	156	9,575	November	108	6,415
June	137	8,138	December	119	7,304

TNRCC Hydrology Staff evaluated the application using a simulation representative of the full utilization of each water right's permitted amount. This WRAP simulation was performed using the monthly distribution supplied by the applicant. The simulation results indicate that unappropriated water sufficient to satisfy the annual demand of 87,106 acre feet at the San Marcos River location is available in none of the years and 26% of the months.

Guadalupe River Location

TNRCC Hydrology Staff evaluated the application using a simulation representative of the full utilization of each water right's permitted amount. Staff used the MinQ volume and seasonal distribution derived from the freshwater inflow recommendations developed by the Texas Parks and Wildlife Department for the Guadalupe-San Antonio Estuary. Because the MinQ flow recommendations were developed for the San Antonio Bay, which receives some inflows from the Lavaca-Guadalupe and San Antonio-Nueces Coastal Basins as well as inflows from the Guadalupe Basin below the Tivoli gage, the annual amount was prorated to the applicant's requested diversion location at the Tivoli gage. A simulation was performed using the monthly distribution as indicated above. The simulation results indicate that unappropriated water sufficient to satisfy the annual demand of 980,494 acre feet at the Guadalupe River location is available in 3.6% of the years and 44% of the months.

"No Injury" Rule Analysis

Because WRAP inherently protects senior water rights in accordance with the prior appropriation doctrine, a comparison of pre-and-post application reliabilities was not necessary for this analysis.

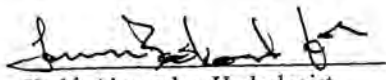
Conclusion

Using a simulation representative of the full utilization of each water right's permitted amount, unappropriated water sufficient to meet the demand of 87,106 acre feet is available at the San Marcos River location in 0% of the years and 26% of the months. Unappropriated water sufficient to meet the demand of 980,494 acre feet at the Guadalupe River location was available in 4% of the years and 44% of the months.

Pursuant to §297.42(d), staff may grant applications that are not based upon the continuous

availability of historic, normal stream flow, including applications for non-consumptive instream uses. Because of this, staff can support the granting of a water right authorizing the appropriation of 87,106 acre feet per year at the San Marcos River location and 980,494 acre feet per year at the Guadalupe River location for non-consumptive instream use.

The applicant's priority date is December 21, 2000, according to the date the application was filed. It should be noted that the applicant is located within the jurisdiction of the South Texas Watermaster.


Kathy Alexander, Hydrologist

HYDROLOGY UNIT ANALYSIS FACT SHEET

Applicants: San Marcos River Foundation
 Water Right: 5724
 Stream: San Marcos and Guadalupe Rivers

Basin: Guadalupe and San Antonio
 Counties: Gonzales, Calhoun, Refugio
 Requested Amount: 157,469 AF/Y and
1,147,200 AF/Y

Input

Changes made to .dat

UC	SMLU	131	123	119	140	156	137	
UC		109	82	109	110	108	119	
UC	TIVO	105974	118363	49937	49937	177258	129608	
UC		57942	57942	49937	49937	70331	63089	
WR	CP10	87106	SMLU20001221	1	1	1		P5724_1
** MINQ PRORATED TO TIVOLI								
WR	CP38	980494	TIVO20001221	1	1	1		P5724_2

Study Period: 1934-1989

Annual Demand: 87,106 acre feet at upstream reference point (CP10) and 980,494 acre-feet at downstream reference point (CP38)

At CP 10: Annual Demand Diverted in 0 Percent of Years
 Monthly Demand Diverted in 26 Percent of Months
 At CP 38: Annual Demand Diverted in 4 Percent of Years
 Monthly Demand Diverted in 44 Percent of Months


Remarks: Prorated Min Q values were used to determine availability at the Guadalupe River location and Instream Uses staff recommended that applicants request for 157,469 acre feet per year at the upstream diversion point be reduced to 87,106 acre feet per year.

Signature:  Date: 

INTEROFFICE MEMORANDUM

To: Iliana Delgado, Application Manager
Water Rights Permitting Team

Date: September 4, 2002

Thru:  Lann Bookout, Senior Hydrologist
Surface Water Availability and Interstate Compacts Team

From: Doyle Mosier, Aquatic Scientist V
Resource Protection Team

Subject: San Marcos River Foundation
Application No. 5724
San Marcos and Guadalupe Rivers, Guadalupe and San Antonio River Basins
Gonzales, Calhoun, and Refugio Counties

Environmental reviews of water right applications are conducted in accordance with §11.147, §11.1491, §11.150, and §11.152 of the Texas Water Code and with TNRCC administrative rules which include 30 TAC §261.21 through §261.26, §261.41 through §261.43, and §297.53 through §297.56. These statutes and rules require the TNRCC to consider the possible impacts of the granting of a water right on fish and wildlife habitat, water quality, and instream uses associated with the affected body of water. Possible impacts to bays and estuaries are also addressed. Examples of significant impacts are those that affect natural resources; result in deterioration of water quality or flood protection; result in unallowable reduction of identifiable instream uses; endanger species of plant and animal life and their habitat; significantly reduce productivity of the bay and estuary systems; or contribute to a series of related projects that involve individually minor but collectively significant adverse impacts.

ENVIRONMENTAL ANALYSIS

The San Marcos River Foundation has requested (1) an appropriation of 157,469 acre feet per annum from the San Marcos River, as measured at Palmetto Bend State Park, Gonzales County, to protect instream uses instantaneous flow (cubic feet per second) with the following monthly distribution: January- 217; February- 229; March- 235; April- 265; May- 293; June- 257; July- 201; August- 170; September- 178; October- 178; November- 190; December- 198. Since the expressed purpose of this request is to maintain beneficial streamflows in the San Marcos River, there would be no consumptive use of the water.

Additionally, the applicant has requested an appropriation of 1,147,400 acre-feet per annum for instream uses from the Guadalupe River as measured at the State Highway 35 Bridge in Calhoun and Refugio Counties. The requested amount would remain in the Guadalupe River and provide freshwater inflows into the Guadalupe-San Antonio Estuary and would be delivered to the estuary with a seasonal distribution (in thousands of acre-feet): January- 111.2; February- 124.2; March- 52.4; April- 52.4; May- 222.6; June- 162.7; July- 88.6; August- 88.3; September- 52.4; October-

52.4; November- 73.8; December- 66.2. The requested volume and seasonal distribution were derived from the freshwater inflow recommendations for the Guadalupe-San Antonio Estuary developed by the Texas Parks and Wildlife Department (1998). The confluence of the San Antonio and Guadalupe Rivers is upstream of the proposed reference point at the State Highway 35 bridge, so water appropriated, or reserved for freshwater inflows into the Guadalupe-San Antonio estuary, would be derived from both basins. Since the intent of the applicant is to assure adequate freshwater inflows into the Guadalupe estuary and the reference location is within the intertidal zone, there would be no consumptive use of the water requested.

INSTREAM USES

Recreational Uses:

Guadalupe River at State Highway 35 Bridge: The Guadalupe River and its major tributary streams, the Comal and San Marcos Rivers, are among the most heavily recreated waterways in Texas. Recreational use on the Guadalupe River downstream of Canyon Reservoir became so intense that Comal County formed a Water-Oriented Recreation District (WORD) with taxing authority in 1987 to manage this resources along with Canyon Reservoir. A review of tax revenue generated by the WORD from 1988-1997 indicate a strong relationship between flow and revenue. Downstream of New Braunfels, the Guadalupe River is impounded by a series of small hydro-electric dams, creating a nearly continuous chain of small reservoirs from New Braunfels to Gonzales. The larger of these reservoirs are heavily used for boating, water skiing, swimming, and fishing. Recreational use of the San Antonio River is limited due to water quality concerns and lack of access. Access is limited to road crossings with the exception of Goliad State Historical Park at Goliad. The Texas Parks and Wildlife Department include camping, picnicking, hiking, fishing, boating (no ramps provided for river access), swimming and nature study as activities available in the park. Since the applicant's request on the mainstem Guadalupe River is located well downstream of significant recreational uses and within the intertidal zone, this application would have negligible impacts on these resources.

The Guadalupe River is intertidal at the proposed reference/measuring point and enters the Guadalupe-San Antonio estuary approximately seven miles downstream. The primary recreational uses of the Guadalupe-San Antonio estuary are fishing, boating and swimming. The Guadalupe Delta Wildlife Management Area is located at the mouth of the river and provides hunting, fishing, and wildlife viewing opportunities. The Aransas National Wildlife Refuge, located on San Antonio Bay, is the winter home of the Whooping Crane and a popular birding and nature study area. The proposed action would provide inflows at a level identified as needed to meet the freshwater inflow needs of the estuary, consequently, the impact on these resources would be beneficial.

San Marcos River: The San Marcos River supports a variety of activities throughout its entire length. The reach between Aquarena Springs (San Marcos) and Martindale is heavily used for swimming, tubing, snorkeling, canoeing and kayaking. The amount and type of recreational activity on the river changes substantially downstream, primarily due to a reduction in water clarity and

accessibility. While there are several public access points, campgrounds, tube and canoe rentals from Martindale upstream, access downstream of Martindale is limited to major road crossings and Palmetto State Park. Palmetto State Parks supports a variety of water related activities including swimming and canoeing. Since this is one of the most scenic stream reaches in the state (Texas Parks and Wildlife Department, 1976), canoeing is a particularly popular activity in the lower reach of the San Marcos River. Since the proposed action would protect instream flows within a range considered adequate for a range of water-related recreational activities, recreational resources in the lower reach of the San Marcos River would be benefitted by this application.

Aquatic Habitats:

The Guadalupe River and its major tributaries support a diverse and unique aquatic community. Two of the major tributaries of the Guadalupe River are spring runs associated with two of the largest spring systems in the state. The Comal River, which enters the mainstem Guadalupe River in New Braunfels, is fed by Comal Springs. The San Marcos River, which is the spring run for San Marcos Springs in San Marcos, enters the Guadalupe River in Gonzales County, upstream of the City of Gonzales. Both of these Rivers and their associated springs are critical habitat for a number of federally endangered species: Texas Wild Rice (*Zizania texana*), the fountain darter (*Etheostoma fonticola*), the Comal Springs Dryopid Beetle (*Stygoparnus comalensis*), and the Comal Springs Riffle Beetle (*Heterelmis comalensis*), and the Texas Blind Salamander (*Typhlomolge rathbuni*). The Guadalupe River mainstem supports a disjunct population of the river darter (*Percina shumardi*), which is listed as a threatened species by the the State of Texas. The Cagle's Map Turtle (*Graptemys caglei*) is endemic to the Guadalupe River basin and is a candidate species for listing as Federally Endangered. *Graptemys caglei* occurs in the Guadalupe River as far downstream as Victoria and is also found in the San Marcos River mainstem. The proposed actions would not adversely impact the aquatic ecosystems within the Guadalupe River basin.

There have been several investigations on the relationship between flow and physical habitat availability in the Guadalupe River Basin. Paul Price Associates, Inc. performed a limited study on the San Marcos River in 1998 under contract to the City of San Marcos approximately 35 miles upstream of Palmetto State Park (Price and Sullivan, 1998). An instream flow study for the San Marcos River was recently completed by the Texas Parks and Wildlife Department (2001) for the San Marcos River upstream of its confluence with the Blanco River, more than 50 miles upstream of Palmetto State Park. An interagency study (Texas Natural Resource Conservation Commission, Texas Parks and Wildlife Department, Texas Water Development Board, and the Guadalupe-Blanco River Authority) is being conducted to identify appropriate flow conditions in the mainstem Guadalupe River. Although the Texas Parks and Wildlife Department (2001) made no specific recommendations, a review of their study indicates an average flow of about 120 cubic feet per second provides adequate physical habitat for the macrophyte community in the upper reaches of the river. A review of the data presented in the City of San Marcos study indicates an average flow of 120-130 cubic feet per second is needed to provide habitat for flow dependent species. These studies were performed well upstream of the proposed reference marker at Palmetto State Park and in stream reaches with different geomorphic and biological characteristics. The proposed reference marker site is located about 16 miles upstream of the confluence of the Guadalupe River and the stream habitat through this reach is more similar in appearance to the mainstem Guadalupe River,

albeit smaller.

In the Guadalupe River study, staff evaluated the relationship between flow and flow-sensitive habitat types. Results indicated that optimal habitat for flow sensitive species was available at a level approximating the long-term median flow and that habitat decreased gradually to a flow rate of about 78% of the long-term median flow, then began to decline sharply. At lower flows, the amount of habitat available for flow-dependent species declined dramatically with further reductions in flow. Based on these results, target flow recommendations were made for the Guadalupe River at Gonzales and used in the Guadalupe-Blanco River Authority's amendment to Certificate of Adjudication No. 18-2074, as Amended. Since Gonzales is downstream of the confluence of the San Marcos and Guadalupe Rivers, the relative contribution of the San Marcos River to those target flows can be determined. The table below indicates the long-term median, the Lyons default criteria (Bounds and Lyons, 1978), and the optimized flow and target flow contributed by the San Marcos River to the GBRA's target flow levels at Gonzales (in cubic feet per second):

Month	Median Flow	Default Methodology (Lyons)	Optimized Flow	Target Flow
JAN	217	130	169	131
FEB	229	137	179	123
MAR	237	142	185	119
APR	265	159	207	140
MAY	286	172	223	156
JUN	248	149	193	137
JUL	196	118	153	109
AUG	167	100	130	82
SEP	178	107	139	109
OCT	178	107	139	110
NOV	190	114	148	108
DEC	198	119	154	119

Water Quality: The proposed reference measuring point on the San Marcos River at Palmetto State Park is located within Segment 1808 of the San Marcos River. Segment 1808 of the San Marcos River is described in the State of Texas Water Quality Inventory as the reach of the San Marcos River from just upstream of it's confluence with the Blanco River to it's confluence with the Guadalupe River. This reach is listed as effluent limited and supports all identified uses- contact recreation, public water supply, and high aquatic life use. The mainstem Guadalupe River downstream of it's confluence with the San Marcos River is listed as Segment 1803 (Guadalupe River downstream of the San Marcos River) is also designated for contact recreation, high aquatic life use, and public water supply. Since the proposed action is non-consumptive and would leave the requested flow in the river, it would have no adverse effect on the water quality of these segments. The proposed reference measuring point on the Guadalupe River at the State Highway 35 bridge is located near the upstream boundary of Segment 1801 of the Guadalupe River

(Guadalupe River Intertidal). This segment is classified as effluent limited and supports contact recreation and an exceptional aquatic life use designation. Intertidal segments do not support public water supply since they are characteristically brackish. The proposed action, as requested, would have no adverse impact on water quality standards within Segment 1801. However, the request is for a monthly volume in acre-feet and does not address flow rate. If the requested volumes were provided as a constant rate, the minimum daily flow in the Guadalupe River entering the estuary would be nearly 1,600 cubic feet per second. Since the median annual flow is only about 1,100 cubic feet per second, this rate of flow would be unavailable most of the time. A more likely scenario would be that the total volume requested would be provided during natural runoff events.

Wetlands and Terrestrial Habitat: The application would have no adverse impacts on wetlands or terrestrial habitat within the Guadalupe-San Antonio Basin.

Bays and Estuaries The Guadalupe-San Antonio Estuary receives freshwater inflows from the San Antonio River the Guadalupe River basin with total drainage area of more than 10,000 square miles. The Guadalupe-San Antonio Estuary is one of the seven major estuaries located along the Texas Coast and supports major commercial and recreational fisheries. The Aransas National Wildlife Refuge, the only remaining over-wintering habitat for the federally endangered Whooping Crane (*Grus americana*), is also located on San Antonio Bay. Maintenance of suitable salinity conditions within the marshes and tidal flats inhabited by Whooping Cranes is critical to the survival of this species.

Freshwater inflow needs for the Guadalupe-San Antonio estuary were evaluated by the Texas Water Development Board and the Texas Parks and Wildlife Department using the historical relationship between freshwater inflows and landings data for seven economically important species (Blue crab, Oyster, Red Drum, Black Drum, Spotted Seatrout, Brown Shrimp, and White Shrimp). The results of the interagency study was used by the Texas Parks and Wildlife Department to develop freshwater inflow recommendations for this estuary (Texas Parks and Wildlife Department, 1998). The TPWD evaluated two acceptable alternate flow scenarios for the bay system. The MaxH inflow is the amount of water, when distributed seasonally, that produces the maximum harvest of the seven fish and finfish species examined. The MinQ inflow is the inflow amount that results in 80% of the maximum harvest (the harvest produced by the MaxH inflow). The model simulations indicate that 1.15 million acre-feet of annual freshwater inflow, if delivered with a seasonal distribution similar to that presented below, will produce more than 2.9 million pounds of harvest. Alternately, an annual freshwater inflow of 1.03 million acre-feet per annum (MinQ) produces approximately 2.54 million pounds of finfish and shellfish.

While either solution could be considered an acceptable inflow level, the TPWD recommended the MaxH solution because it provides a proportionally higher yield of Blue Crab and Brown Shrimp than the MinQ solution relative to the amount of water provided. In either case, the total inflow value selected should be considered an *average* annual inflow, and the actual freshwater inflow should be allowed to fluctuate annually, with substantially higher inflows during wet years and lower inflows during dry years. TPWD's analysis indicates that the estuary has received more than 1.5 million acre-feet of water annually 50% of the time during the 47 year period of record examined (the median annual inflow).

Guadalupe Estuary Freshwater Inflow Needs (Acre-Feet):

Month	MinQ-50H*	MinQ	MaxH
Jan	93,360	111,200	111,200
Feb	104,270	124,200	124,200
Mar	52,420	52,420	52,420
Apr	52,420	52,420	52,420
May	68,670	186,050	222,600
Jun	60,850	135,980	162,700
Jul	60,850	60,860	88,610
Aug	60,850	60,850	88,330
Sep	52,420	52,420	52,420
Oct	52,420	52,420	52,420
Nov	52,420	73,830	73,830
Dec	52,420	66,200	66,200
Total	763,370	1,028,850	1,147,350

*MinQ-50H: harvest target is equal to or greater than 50% of Mean; no biomass ratio constraints;
 provides: 100% of required sediment need, 93% of harvest target (w/o oyster), 89% of nutrients.

The San Marcos River Foundation has requested the annual amount recommended by the TPWD to optimize the harvest of finfish and shellfish (MaxH) using the monthly distribution.

It should be noted the bulk of freshwater flows into estuaries by volume during high flow events such as spring rains and hurricanes and should not be considered a constant demand during low flow periods. The TPWD recommendations do not include an evaluation of the amount of freshwater inflow needed to maintain low salinity areas and provide refugia conditions for estuarine species and prevent saltwater intrusion into low salinity areas during dry conditions. The Guadalupe-San Antonio Estuary has historically received proportionately much higher base flow than other estuarine systems in Texas since three of the four historic major springs (San Marcos, San Antonio, and Comal Springs) are located within the basin. Flow from the San Antonio Springs have been reduced as a result of pumping from the Edwards Aquifer, but base flow has been replaced by wastewater discharges in the area. This is particularly significant since the Aransas National Wildlife Refuge, which is the wintering area for the federally endangered Whooping Crane (*Grus americana*), is located on San Antonio Bay. When salinities approach 23 ppt or greater in the marshes, Whooping Cranes must travel in order to find suitable drinking water, expending significant energy and becoming exposed to greater predation (Personal Communication, Tom Stehn, Aransas National Wildlife Refuge). An evaluation of historic flow data for the Guadalupe and San Antonio Rivers indicate that base flow is substantially less variable than for other Texas rivers.

SUMMARY

The San Marcos River Foundation has requested an appropriation for a total of 1.3 million acre-feet of water for beneficial instream uses on the San Marcos River at two reference points in the Guadalupe River basin. Since there would be no consumptive use of the water and it would remain in the stream, the issuance of such a permit would effectively become the minimum streamflow restriction for all upstream water rights with a priority date later than December 21, 2000. While instream uses staff recognize the environmental benefit of this request and do not argue that providing a flow level that would mimic natural conditions, it should be noted that the Resource Protection Team staff review applications to appropriate state water for consumptive uses (municipal, agricultural, industrial, etc.) and recommend streamflow restrictions deemed appropriate to protect instream uses, including environmental needs.

San Marcos River at Palmetto State Park: The first reference point is located near Luling at the Palmetto State Park would protect streamflows in the San Marcos River. The requested amount of 157,469 acre-feet per annum would be distributed monthly at a rate of flow equivalent to the monthly median flow of the San Marcos River. Studies performed on the San Marcos Rivers (TPWD 2000; Price & Associates 1998) as well as habitat specific data collected on the Guadalupe mainstem suggest that a flow level of less than the historic median provides adequate instream flow. Resource Protection staff recommend that, if the application is granted, the volume granted be reduced to reflect a volume equivalent to the amount that would be placed as an environmental flow restriction for a permit to appropriate state water for consumptive uses. For the San Marcos River at Palmetto State Park, the amount that would be recommended on a monthly basis is given in the following table:

	Month	Requested Flow (cfs)	Requested Amount (Acre-Feet)	Recommended Flow (cfs)	Recommended Amount (Acre- Feet)
	JAN	217	13,343	131	8,041
	FEB	229	12,832	123	7,063
	MAR	237	14,450	119	7,304
	APR	265	15,769	140	8,316
	MAY	286	18,016	156	9,575
	JUN	248	15,263	137	8,138
	JUL	196	12,328	109	6,690
	AUG	167	10,453	82	5,033
	SEP	178	10,592	109	6,475
	OCT	178	10,945	110	6,752
	NOV	190	11,306	108	6,415
	DEC	198	12,175	119	7,304
	TOTAL		157,472		87,106

The recommended flow (cfs) is consistent with a minimum flow requirement that would be placed on other water rights permits.

Guadalupe River at S.H. 35 Bridge: The San Marcos River Foundation's requested appropriation for the Guadalupe River near the intertidal zone is specifically designed to provide freshwater inflows into the Guadalupe-San Antonio Estuary. Staff interpretation of the TPWD recommendations are that the recommended inflow value (MaxH) should be provided to the estuary during an average year, with the assumption being that inflows will mimic a natural seasonal and annual variation around that target. Resource protection staff recommend that the requested amount need only be available during an average flow year, not every year.

MaxH inflow is the amount of water that produces the maximum harvest of the seven fish and finfish species examined, subject to the constraints of the Texas Water Development Board's Estuarine Mathematical Programming or Optimization Model (TXEMP). MinQ is the inflow amount that produces a minimum freshwater inflow as predicted by the TXEMP model and is equivalent to 80% of the maximum harvest. Either solution could be considered an acceptable inflow level.

Staff notes that if this were an application for a consumptive use (municipal, agricultural, industrial, etc.), Water Code Section 11.147 would require the Commission to also consider other competing beneficial uses.

This instream assessment was conducted using current TNRCC operating procedures and policies and available technical data. The recommendations in this environmental analysis are for the protection of instream uses including water quality and do not necessarily provide protection to downstream senior water rights; that analysis is addressed in the hydrology memo and restrictions may be applicable as necessary. Authorizations granted to the permittee by the water rights permit shall comply with all special conditions of applicable State and Federal permits.


Doyle Mosier
Instream Uses Team

LITERATURE CITED

- Bounds, R.L., and B.W. Lyons. 1979. Existing reservoir and stream management recommendations statewide minimum streamflow recommendations. Federal Aid Project F-30-R-4.
- Price, Paul and Michael Sullivan. 1998. Instream Flow Study of the San Marcos River. Report prepared for the City of San Marcos, January 1998. 78pp.
- Saunders, Kenneth S., Keven B. Mayes, Tim A. Jurgensen, Joseph F. Trungale, Leroy J. Kleinsasser, Karim Aziz, Jacqueline Renee Fields, and Randall E. Moss. 2001. An evaluation of spring flows to support the upper San Marcos River spring ecosystem, Hays County, Texas. Resource Protection Division, Texas Parks and Wildlife Department,

San Marcos River Foundation
Application No. 5724
Page 9 of 9
September 4, 2002

· Austin, Texas. CDROM . 33pp.

Texas Parks and Wildlife Department. 1979. An Analysis of Texas Waterways: A report on the physical characteristics of rivers, streams, and bayous in Texas. Texas Parks and Wildlife Department, 240pp.

WORKS CITED

- Alan Plummer and Associates, Inc. 2001. *East Texas Region, Regional Water Plan environmental flow requirements review draft*. Internet. Available from <http://www.twdb.state.tx.us/rwp/IPDFs/Regional%20Plan%20Main%20Text/Task%205%20Appendix%20C.pdf>; accessed 17 February 2004.
- Alber, Merryl and Janice Flory. 2002. *The effects of changing freshwater inflow to estuaries: A Georgia perspective*. Georgia: Georgia Coastal Research Council. Internet. Available from <http://www.marsci.uga.edu/coastalcouncil/inflow1119.pdf>; accessed 5 September 2003.
- Berrens , R.P., A.K. Bohara, C.L. Silva, D. Brookshire, M. McKee. 2000. Contingent Values for New Mexico instream flows: With tests of scope, group-size Reminder and temporal reliability, *Journal of Environmental Management*, 58: 73-90. Cited in Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.
- Blackburn, Jim. 2003. *Sustainability and water for Texas*. Internet. Available from <http://www.ruf.rice.edu/~eesi/sustain/BLACKBURN.doc>; accessed 1 March 2004
- Block, Wendy M. and Frederick Richardson. n. d. A case of the blues: The inequity of groundwater regulation in Texas. Internet. Available from http://www.ar.utexas.edu/planning/forum/vol17pdfs/v7block_web.pdf; accessed 6 January 2004.
- Bowen, Greg. 2003. Landmark water-rights application decided today. *The Victoria Advocate*, 19 March. Internet. Available from <http://www.thevictoriaadvocate.com>; accessed 25 March 2003.
- Bowen, Greg. 2004. Allocating the Guadalupe. *The Victoria Advocate*, 25 January. Internet. Available from <http://www.thevictoriaadvocate.com/front/v-print/story/1639616p-1930200c.html>; accessed 22 February 2004.
- Brock, D.A. 1995. *Nitrogen budget and proposed minimal nitrogen requirement for the Guadalupe Estuary, Texas*. Submitted for publication. Quoted in Texas Parks and Wildlife. 1998. *Freshwater inflow recommendation for the Guadalupe Estuary of Texas*, 58. Coastal Studies Technical Report No. 98-1. Austin, TX.
- Buckley, Robert G. J. Randy Young, and Mike Thralls. 1998. Aging watershed projects: A growing national concern. *Conservation Voices*, October/November, 1998, 22–24. Internet. Available from <http://www.nrcs.usda.gov/>; accessed 8 July 2004.

- Chen, Chen-Tung Arthur. 2002. The impact of dams on fisheries: Case of the Three Gorges Dam. In *Challenges of a changing earth*, eds. W. Steffen, J. Jager, D. J. Carson, and C. Bradshaw Springer Berlin, chapter 16. Internet. Available from [www.sarcs.org/documents/steff-Chapter 16.Challenges%20of%20a%20Changing%20Earth.pdf](http://www.sarcs.org/documents/steff-Chapter%2016.Challenges%20of%20a%20Changing%20Earth.pdf); accessed 14 October 2003.
- Chenoweth, Todd. 2003. *Commissioners Work Session*. 17 July.
- City of San Marcos. 2004. *San Marcos today*, Chapter 2. Internet. Available from <http://www.ci.san-marcos.tx.us>; accessed 7 January 2004.
- Clarkson, Judith M. 1987. Policy options for protecting freshwater inflows to bays and estuaries in Texas. M.P.A. thesis, University of Texas at Austin.
- Coastal Bend Bays and Estuaries Program. 1998. Coastal Bend bays plan CBBEP – 1. Internet. Available from [http://www.sci.tamucc.edu/ccbnep/Home/ Plan/cbbin.pdf](http://www.sci.tamucc.edu/ccbnep/Home/Plan/cbbin.pdf); accessed 3 February 2004.
- Coastal Bend Bays and Estuaries Program. 2001. The state of the bay. A report for the future SFR-61/CBBEP-3. Austin: Texas Natural Resource Conservation Commission.
- Cognitive Science Laboratory. 2004. Web WordNet. Internet. Available from [http://www.cogsci.princeton.edu/cgi-bin/webwn2.0?stage=1 &word=bay](http://www.cogsci.princeton.edu/cgi-bin/webwn2.0?stage=1&word=bay); accessed 5 February 2004.
- Comprehensive Everglades Restoration Plan. 2004. *Rescuing an endangered ecosystem*. Internet. Available from <http://www.evergladesplan.org>; accessed 29 May 2004.
- Corpus Christi Bay National Estuary Program. 2003. *A conceptual ecosystem model of the Corpus Christi bay national estuary program study area*. Internet. Available at <http://www.sci.tamucc.edu/ccbnep/FinalReport/pdf/ccbo8/PDF.pdf>; accessed 23 February 2004.
- Costanza, Robert, John Cumberlan, Herman Daly, Robert Goodland, and Richard Norgaard. 1997. *An introduction to ecological economics*. Boca Raton, Florida: St. Lucie Press.
- Daubert, J. T. and R. A. Young. 1981. Recreational demands for maintaining instream Flows: A contingent valuation approach, *American Journal of Agricultural Economics*, vol. 63: 666-676. Cited in Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.

- Dice, L.R., 1943. *The biotic provinces of North America*. Univ. Mich. Press. Ann Arbor, Mich. Quoted in *Texas Water Development Board. 1997. Water for Texas, A consensus-based update to the state water plan, vol.II, Technical planning appendix. 2-25*. Document No. GP-6-2. Austin, Texas: Texas Water Development Board.
- Doering, Peter and Robert H. Chamberlain. n.d. *Establishing minimum and maximum freshwater inflows to the Caloosahatchee Estuary, FL*. Internet. Available from <http://conference.ifas.ufl.edu/jc/papers/geer/9oralgr/DoeringP.doc>; accessed 21 September 2003.
- Duffield, J., C. Neher, and T. Brown. 1992. Recreation benefits of instream flow: Application to Montana's Big Hole and Bitter Root Rivers, *Water Resources Research*, vol. 28: 2169-2181. Cited in Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.
- Dukes, Charles. ca. 1998. *Sam Rayburn: water, fish and rice*. Internet. Available from <http://www.tpwd.state.tx.us/texaswater/sb1/primer/primer1/samray.phtml>; accessed 18 February 2004.
- Duxbury, Alyn C., Alison B. Duxbury and Keith A. Sverdup. 2000. *An introduction to the world's oceans*. Boston: McGraw Hill.
- Earl, Richard A. and Charles R. Wood. 2002. Upstream changes and downstream effects of the San Marcos River of Central Texas. *Texas Journal of Science*. Vol. 54, No. 1, February, 69–88.
- Eckhardt, Gregg. 2003-2004. *The Edwards Aquifer homepage*. Internet. Available from <http://www.edwardsaquifer.net/>; accessed 2003-2004.
- Eckhardt, Gregg. 2003. *Laws and regulations applicable to the Edwards Aquifer*. Internet. Available from <http://www.edwardsaquifer.net/rules.html>; accessed 30 December 2003.
- Federal Water Pollution Control Act. 33 U. S. Code. Section 1330.*
- Flannery, Michael S., Ernst B. Peebles, and Ralph T Montgomery. 2002. A percent-of-flow approach for managing reductions of freshwater inflows from unimpounded rivers to Southwest Florida estuaries. *Estuaries*, Vol. 25, No. 6B, December, 1318-1332.
- Galveston Bay Estuary Program. 2001. *State of the bay symposium V*. CTF-09/01 GBEP T-5. Austin, TX: Texas Natural Resource Conservation Commission.

- Galveston Bay National Estuary Program. 1995. *The Galveston Bay plan - the comprehensive conservation and management plan for the Galveston Bay ecosystem*. Publication GBNEP-49.
- Gerston, Jan. 1995. Estuary Program Balances Sustainability, Community Needs. *Water Resources* 21, No. 4 (Winter 1995): 1-12. Internet. Available from <http://www.tamu.edu/newsletters/TexasWaterResources/twr-v21n4.pdf>: accessed 14 September 2003
- Gillilan, David M. and Thomas C. Brown. 1997. *Instream flow protection: Seeking a balance in western water use*. Washington, D.C.: Island Press.
- Golden Triangle Audobon Society. 2003. *Newsletter*. 11 November. Internet. Available at <http://www.goldentriangleaudobon.org/Publications/Newsletters/bo0311/view>; accessed 20 February 2004.
- Greenly, D., R. Walsh, and R. Young. 1982. *Economic benefits of improved water quality*. Boulder, CO.: Westview Press. Cited in Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.
- Gulfbase. n.d. *Laguna Madre*. Internet. Available from <http://www.gulfbase.org/bay/view.php?bid=LAGUNA>; accessed 24 February 2004.
- Harvey, Tom. 2003. The View Ahead. *Texas Parks and Wildlife Magazine*, July, pp. 79-81.
- HDR Engineering. 1999. *Water availability in the Guadalupe-San Antonio River Basin*.
- HDR Engineering. 2002. *South Central Texas Regional Water Planning Area 2006 Regional Water Plan scope of work*. Internet. Available from http://www.watershedexperience.com/Region_L_Scope__from_HDR.doc; accessed 21 October 2003.
- Irlbeck, M. J. and G. H. Ward. 2000. *Analysis of the historic flow regime of the Nueces River into the upper Nueces Delta and of the potential restoration value of the Rincon Diversion Demonstration Project*. Pages C-1 through C-24 in R. G. Harris, ed. *Concluding report: Rincon Bayou demonstration project. Vol. II. Findings*, United States Department of the Interior, Bureau of Reclamation, Oklahoma-Texas Area Office, Austin, TX. Cited in Texas Parks and Wildlife Department. 2002. *Freshwater inflow recommendation for the Nueces Estuary*, 32. Austin, TX.
- Jiang, Shijan. 2000. Hydrologist. Interoffice memo from permit to appropriate state water no. 5696. TCEQ Central File Room. Austin, TX.

- Johns, Ph.D., Norman. 2003-2004. Water Resources Scientist for the National Wildlife Federation, Austin, TX. Communications by phone, e-mail, and in person.
- Kaiser, Ron. 1998. *A primer on Texas surface water law for the regional planning process*. Paper presented at Texas Water Law Conference, 1 October 1998. Austin, TX.
- Kaiser, Ron. 2002. *Ownership of water in Texas*. Paper presented at Texas Agricultural Extension Service Workshop, 19 April 2000. Updated October 2002.
- Kelly, Mary and Melinda Taylor. 2003. *Options for protecting environmental flows in Texas*. Paper presented at Texas Water Law CLE Conference, 2 October 2003.
- Kelly, Sharon Marie. 1986. An Evaluation of Legal Strategies for Protecting Freshwater Inflows into Texas Estuaries. M.S. thesis, Texas A&M University.
- Kimmel, Jim, Ph.D. 2004. *Developing interpretation*. Internet. Available from http://www.rpts.tamy.edu/tce/nature_tourism/interpretation.htm; accessed 5 May 2004.
- Kimmerer, W. J. 2002. Physical, biological, and management responses to variable freshwater flow into the San Francisco Estuary. *Estuaries*, December, 1275-1289.
- Landry, Clay. 1998. *Saving our stream through water markets: A practical guide*. Political Economy Research Center, Bozeman, MT.
- Liebbrand, N.F. 1987. *Estimated sediment deposition in Lake Corpus Christi, Texas, 1975-1985*. U.S. Geological Survey, Austin, TX. Quoted in Longley, W. L., ed. *Freshwater inflows to Texas bays and estuaries: Ecological relationships and methods for determination of need*, 66. Austin, TX: Texas Water Development Board and Texas Parks and Wildlife Department, 1994.
- Living Waters Project. 2003. Main website. Internet. Available from <http://www.texaswatermatters.org>; accessed 2003-2004.
- Loeffler, Cindy. 2003-2004. Water Resources Branch Chief, Texas Parks and Wildlife Department, Austin, TX. Communications by phone, e-mail, and in person.
- Longley, W. L., ed. 1994. *Freshwater inflows to Texas bays and estuaries: Ecological relationships and methods for determination of needs*. Austin, TX: Texas Water Development Board and Texas Parks and Wildlife Department.
- Loomis, J. 1987. The economic value of instream flow: Methodology and benefit estimates for optimal flows, *Journal of Environmental Management*, vol. 24:

- 169-179. Cited in Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.
- Lower Colorado River Authority (LCRA). 1993. *Memorandum of agreement*. In Martin et al. 1997. *Freshwater inflow needs of the Matagorda Bay System*. Austin, TX: Lower Colorado River Authority.
- Lower Colorado River Authority. 2002a. *Application to the Texas water development board requesting grant funds to develop regional water plan for region K*. Internet. Available from http://www.twdb.state.tx.us/RWPG/scopes/Region_K.pdf; accessed 20 December 2003.
- Lower Colorado River Authority. 2002b. *Austin's bed and bank permit application*. Internet. Available from http://www.lcra.org.newsstory/2002/20021118_Austin_Bed_Banks_QA.html; accessed 6 March 2004.
- Lower Colorado River Authority. 2002c. *Recommended revisions to the water management plan*. Internet. Available from http://www.lcra.org/water/docs/WMP_changes.pdf; accessed 23 February 2004.
- Lower Colorado River Authority. 2003-2004. Main website. Available from <http://www.lcra.org>; accessed 2003-2004.
- Lower Guadalupe Water Supply Project. 2004. *Executive summary*. Internet. Available from <http://www.lgwsp.org/PDF/ExecSummary031704.pdf>; accessed 9 July 2004.
- Lower Neches Valley Authority. 2002. *Neches River saltwater barrier*. Internet. Available from <http://www.lnva.dst.tx.us>; accessed 20 February 2004.
- Lyons, Barry W. 1979. *Existing reservoir and stream management recommendations-Statewide minimum streamflow recommendations*. As Required by Federal Aid in Fisheries Restoration Act Federal Aid Project F-30-R-4 Statewide Fishery Management Recommendations.
- Madriago, B. and K. McConnell. 1987. Exploring existence value. *Water Resources Research*, vol. 23: 936-942. Cited in Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.
- MapQuest. 2004. Main website. Internet. Available from <http://www.mapquest.com>; Accessed 28 May 2004.

- Marquette, Catherine. 2003. Cultural Ecology. Internet. Available from <http://www.indiana.edu/~wanthro/eco.htm>; accessed 1 December 2003.
- Martin, Quentin, Doyle Mosier, Jim Patek, Cynthia Gorham-Test. 1997. *Freshwater inflow needs of the Matagorda Bay System*. Austin, TX: Lower Colorado River Authority.
- Martin, Quentin. 2001. LCRA *Interoffice Memorandum to Gary Powell, Texas Water Development Board, April 24, 2001. Subject: Evaluation process for freshwater inflows during non-drought years under the SB1 Region K Plan*. Internet. Available from http://www.twdb.state.tx.us/rwp/k/submitted_Files/RegK_Errata/Appendix8A.doc; accessed 20 February 2004.
- McCarl, Bruce, Carl Dillon, Keith O. Keplinger, R. Lynn Williams. 1999. *Limiting pumping from the Edwards Aquifer: An economic investigation of proposals, water markets and springflow guarantees*. Internet. Available from <http://ageco.tamu.edu/faculty/mccarl/papers/264.pdf>; accessed 23 February 2004.
- McKinney, Daenne Dr. 2002. *Regional water planning in Texas*. Internet. Available from <http://www.ce.utexas.edu/prof/mckinney/ce385d/Papers/Regional/WaterPlanning.pdf>; accessed 29 September 2003.
- McKinney, Larry Dr. 1995. Letter from Texas Parks and Wildlife Department to Texas Natural Resource Conservation Commission. In file of Texas Natural Resource Conservation Commission. 1996. Permit to appropriate state water no. 5466. TCEQ Central File Room. Austin, TX.
- McKinney, Larry Dr. 1996. Letter from Texas Parks and Wildlife Department to Texas Natural Resource Conservation Commission. In file of Texas Natural Resource Conservation Commission. 1996. Permit to appropriate state water no. 5466. TCEQ Central File Room. Austin, TX.
- McKinney, Larry Dr. 1997. Troubled Waters Part I. *Texas Parks and Wildlife Magazine*, January, 4-7.
- National Oceanic and Atmospheric Administration (NOAA). n.d.. *Sabine Lake user's guide*. Internet. Available from http://response.restoration.noaa.gov/software/gnome/pdfs/Sabine_UG.pdf; accessed 20 February 2004.
- National Oceanic and Atmospheric Administration. 1999. *NOAA's coastal assessment and data synthesis system – Physical and hydrologic characteristics of coastal watersheds*. Internet. Available from http://spo.nos.noaa.gov/projects/cads/data_references/pandh/P_and_Hdoc.pdf; accessed 28 September 2003.

- National Public Radio (NPR). 2002. *Drought saps once-wild Rio Grande*. Internet. Available from <http://www.npr.org/programs/atc/features/2002/apr/riogrande/>; accessed 20 February 2004.
- National Wildlife Federation. 2003-2004. *Texas watersheds: Living waters*. Internet. Available from <http://www.nwf.org/resourceLibrary/details.cfm?officeID=F8FE2B57-65BF-QA01-018F6F90CCB5F499&catID=6388517C%2D65BF%2D09FE%2DBADE4282EB885FF3>; accessed 2003-2004.
- Natural Resource Conservation Service (NRCS). 1998. *First flood prevention dam – Cloud Creek site*. Internet. Available from http://www.nrcs.usda.gov/programs/ws_reinvent/wsr_main/cloudck.html; accessed 8 July 2004.
- Natural Resource Conservation Service (NRCS). 2004a. Main website. Internet. Available from <http://www.nrcs.usda.gov/>; accessed 8 July 2004.
- Natural Resource Conservation Service (NRCS). 2004b. *Texas project dams*. Internet. Available from http://www.nrcs.usda.gov/programs/WSRehab/project_dams_by_state/TX.html; accessed 8 July 2004.
- Nature Conservancy. 2002. *Nature Conservancy, Coastal Bend Bays & Estuaries Program buy land in partnership to help Corpus Christi protect Nueces River Delta*. Internet. Available from <http://nature.org/wherewework/northamerica/states/texas/press/press883.html>; accessed 19 February 2004.
- Nevada Division of Water Planning. 2004. *Nevada water facts*. Internet. Available from <http://water.nv.gov/Water%20planning/wat-fact/equiv.htm>
- Nipper, M., J.A. Sanchez Chavez, and J.W. Tunnell, Jr., Editors. 2004. Texas Coastal Management Program. In *Gulfbase: Resource database for Gulf of Mexico research*. Internet. Available from <http://www.gulfbase.org/project/view.php?pid=tcmp>; accessed 28 May 2004.
- North American Lake Management Society. n.d. *Lake and water word glossary*. Internet. Available from http://nalms.org/glossary/1keyword_s.htm; accessed 22 February 2004.
- Nudds, Thomas D. 1999. Adaptive management and the conservation of biodiversity. In *Practical approaches to the conservation of biological diversity*, eds. Richard K. Baydack, Henry Campa III, and Jonathan B. Haufler, 179-193. Washington, D. C.: Island Press.
- Nueces River Authority. 2004. *Choke Canyon/Lake Corpus Christi reservoir system pass-thru status report*. Internet. Available from <http://www.nueces-ra.org/ccwater/passthru.html>; accessed 2 June 2004.

- Odum, Howard T. 1971. *Environment, power, and society*. Chapel Hill: University of North Carolina.
- Oregon Department of Land Conservation and Development. n.d. *The Oregon estuary plan book*, chapter 1: Estuaries in Oregon. Internet. Available from <http://www.inforain.org/mapsatwork/oregonestuary/>; accessed 23 September 2003.
- Powell, Gary. 2003. Discussion before the Texas Water Development Board. In Texas Water Development Board. 2003. In *Briefing and discussion on Texas Water Development Board environmental flow studies*. Minutes of Board meeting 19 February.
- Region H. 2002. *Region H regional plan revision*. Internet. Available from http://www.twdb.state.tx.us/RWPG/scopes/Region_H.pdf; accessed 20 December 2003.
- Region I. 2002. *East Texas regional water plan 2005 Scope of work*. Internet. Available at http://www.twdb.state.tx.us/RWPG/scopes/Region_I.pdf; accessed 20 December 2003.
- Robbins, Dean. 2002. Quoted in Texas Joint Committee on Water Resources. *Interim report to the 78th Legislature*. 2002. Austin, TX: State of Texas. Internet. Available from <http://www.Senate.state.tx.us/75r/senate/commit/C895/Downloads/water.pdf>; accessed 16 September 2003.
- Saxion, Howard J. 1990. *Environmental Decisions in the Public Policy Arena: Protection of Texas Bays and Estuaries and the Freshwater Inflow Issue*. Ph.D. diss., University of Texas at Dallas.
- Scientific Advisory Committee (SAC). 2004. *Scientific Advisory Committee report on water for environmental flows. Prepared for Study Commission on Water for Environmental Flows*. 78th Texas Legislature.
- Sells, Danny D. ca. 2000. *Statement before the U.S. House of Representatives Committee on Agriculture*. Internet. Available from <http://www.nrcs.usda.gov/>; accessed 8 July 2004.
- South Central Texas Regional Water Planning Group. 2001. *South Central Texas regional water planning area regional water plan*.
- Stehn, Tom. 2001. *Relationship between inflows, crabs, salinities and whooping cranes*. Internet. Available from http://www.learner.org/jnorth/tmcrane/Stehn_CrabDocument.html; accessed 22 November 2003.
- Texas Administrative Code. 2004. Internet. Available from <http://www.sos.state.tx.us/tac/index.shtml>; accessed 2003-2004.

- Texas Center for Policy Studies. 2002. *Protecting our freshwater "environmental" flows*. Internet. Available from <http://www.texascenter.org>; accessed 10 September 2003.
- Texas Commission on Environmental Quality. 2000. *Draft permit to appropriate state water no. 5724*. TCEQ Central File Room. Austin, TX.
- Texas Commission on Environmental Quality (TCEQ). 2002. *Water rights and instream uses*. Internet. Available from http://www.tnrcc/state/tx.us/water/quality/02_twqmar/02-305b/02_program_summary/11-instuse.pdf; accessed 21 October 2003.
- Texas Commission on Environmental Quality. 2003a. Commissioners regular meeting, attended by author. Austin, TX, 19 March.
- Texas Commission on Environmental Quality. 2003b. Commissioner's regular meeting, attended by author. Austin, TX, 19 November.
- Texas Commission on Environmental Quality. 2003c. Commissioners work session attended by author. Austin, TX, 17 July.
- Texas Commission on Environmental Quality. 2003d. *Environmental analysis for draft permit to appropriate state water no. 5724*. TCEQ Central File Room. Austin, TX.
- Texas Commission on Environmental Quality. 2003e. *Interoffice memo for draft permit to appropriate state water no. 5724*. TCEQ Central File Room. Austin, TX.
- Texas Commission on Environmental Quality. 2003-2004a. Communication by e-mail, phone, and in person with various staff members in Austin, TX.
- Texas Commission on Environmental Quality. 2003-2004b. Main website. Internet. Available from <http://www.tnrcc.state.tx.us>; accessed 2003-2004.
- Texas Commission on Environmental Quality. 2004. *Water rights permitting and availability*. Internet. Available from <http://www.tnrcc.state.tx.us/admin/topdoc/gi/228>; accessed 23 February 2004.
- Texas Comptroller of Public Accounts. 2004. *Texas mileage guide*. Internet. Available from <http://www.window.state.tx.us/comptrol/texastra.html>; accessed 24 April 2004.
- Texas Constitution. Internet. Available from <http://www.capitol.state.tx.us/txconst/toc.html>; accessed 2003-2004.

- Texas Environmental Profiles. 2003. *Texas surface water quality standards*. Internet. Available from http://www.texasep.org/html/wql/wql_1swq_stand.html; accessed 20 February 2004.
- Texas Environmental Profiles. 2004. *State efforts to protect coastal waters*. Internet. Available from http://www.texasep.org/html/wql/wql_5cst_sttex.html; accessed 28 May 2004.
- Texas Government Code. Internet. Available from <http://www.capitol.state.tx.us/statutes/fv.toc.htm>; accessed 18 December 2003.
- Texas Groundwater Protection Committee. 2004. *TGPC member roles*. Internet. Available from <http://www.tgpc.state.tx.us/TWDB'sRole.html>; accessed 27 February 2004.
- Texas Joint Committee on Water Resources. 2002. *Interim report to the 78th Legislature*. Austin, TX: State of Texas. Internet. Available from <http://www.Senate.state.tx.us/75r/senate/commit/C895/Downloads/water.pdf>; accessed 16 September 2003.
- Texas Living Waters Project. 2003. *Key shortcomings of the state water plan*. Internet. Available from http://www.texaswatermatters.org/water_planning_shortcomings.htm; accessed 2 October 2003.
- Texas Natural Resource Conservation Commission (TNRCC). 1996. *Permit to appropriate state water no. 5466*. TCEQ Central File Room. Austin, TX.
- Texas Natural Resource Conservation Commission. 1998. *Water availability modeling, An Overview*. GI-245.
- Texas Natural Resource Conservation Commission. 2000a. *Environmental analysis for permit to appropriate state water no. 5696*. TCEQ Central File Room. Austin, TX.
- Texas Natural Resource Conservation Commission. 2000b. *Permit to appropriate state water no. 5696*. TCEQ Central File Room. Austin, TX.
- Texas Natural Resource Conservation Commission. 2001. *WAM resolved technical issues*. Internet. Available from <http://www.tnrcc.state.tx.us/permitting/waterperm/wrpa/sam.html#program>; accessed 12 February 2004.
- Texas Natural Resource Conservation Commission. 2002. *TNRCC strategic plan fiscal years 2003-2007*, Vol 2, chapter 6 "Water supply". Internet. Available from http://www.tnrcc.state.tx.us/admin/topdoc/sfr/035_02/035_02.html; accessed 12 December 2003.

- Texas Parks and Wildlife Code*. 2004. Internet. Available from <http://www.capitol.state.tx.us/statutes/pw.toc.htm>; accessed 2 December 2003.
- Texas Parks and Wildlife Department (TPWD). n.d. *Environmental target flows*. Internet. Available from <http://www.tpwd.state.tx.us/texaswater/sbb1/enviro/envwaterneeds/envwaterneeds.html>; accessed 3 October 2003.
- Texas Parks and Wildlife Department. 1998. *Freshwater inflow recommendation for the Guadalupe Estuary of Texas*. Coastal Studies Technical Report No. 98-1. Austin, TX.
- Texas Parks and Wildlife Department. 1999. *Self evaluation report, policy issues*. Internet. Available from http://www.tpwd.state.tx.us/admin.pdf_docs/policy_issues.pdf; accessed 26 October 2003.
- Texas Parks and Wildlife Department. 2001. *Freshwater Inflow recommendation for the Trinity-San Jacinto Estuary of Texas*. Austin, TX.
- Texas Parks and Wildlife Department. 2002. *Freshwater inflow recommendation for the Nueces Estuary*. Austin, TX.
- Texas Parks and Wildlife Department. 2003a. *Federal Endangered Species Act*. Internet. Available from <http://www.tpwd.state.tx.us/nature/endang/regulations/us/>; accessed 3 October 2003.
- Texas Parks and Wildlife Department. 2003b. *First water rights donated to Texas water trust*. Press release. 15 September. Internet. Available from <http://www.tpwd.state.tx.us/news/news/030915.phtml>; accessed 18 December 2003.
- Texas Parks and Wildlife Department. 2003-2004a. Communication by e-mail, phone, and in person with various staff members in Austin, TX.
- Texas Parks and Wildlife Department. 2003-2004b. Main website. Internet. Available from <http://www.tpwd.state.tx.us/>; accessed 2003-2004.
- Texas Parks and Wildlife Department. 2004. *Environmental target flows*. Internet. Available from <http://www.tpwd.state.tx.us/texaswater/sb1/enviro/enviro.phtml>; accessed 4 February 2004.
- Texas Parks and Wildlife Department. ca. 2001. *Texas bays and estuaries program, freshwater inflow needs recommendations*.
- Texas State Historical Association. 2002. *Toledo Bend Reservoir*. Internet. Available from <http://www.tsha.utexas.edu/handbook/online/articles/view/TT/rot4.html>; accessed 25 February 2004.

- Texas Water Code*. 2004. Internet. Available from <http://www.capitol.state.tx.us/statutes/wa.toc.htm>; accessed 2003-2004.
- Texas Water Commission (TWC). 1960. *Permit to appropriate state water no. 12-5366*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1990. *Permit to appropriate state water no. 5317*. TCEQ Central File Room, Austin, TX.
- Texas Water Commission. 1991a. *Environmental analysis for permit to appropriate state water no. 5369*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1991b. *Permit to appropriate state water no. 5369*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1992a. *Interoffice memo: Environmental analysis for permit to appropriate state water no. 5430*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1992b. *Permit to appropriate state water no. 5430*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1993a. *Hydrology analysis fact sheet for permit to appropriate state water no. 5446*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1993b. *Interoffice memo: Environmental analysis for permit to appropriate state water no. 5446*. TCEQ Central File Room. Austin, TX.
- Texas Water Commission. 1993c. *Permit to appropriate state water no. 5446*. TCEQ Central File Room. Austin, TX.
- Texas Water Development Board (TWDB). 1997. *Water for Texas, A consensus-based update to the state water plan, vol.II, technical planning appendix*. Document No. GP-6-2 Austin, Texas: Texas Water Development Board.
- Texas Water Development Board. ca. 1998. *Environmental information for Senate Bill 1 regional water planning areas*. Internet. Available from <http://www.twdb.state.tx.us/RWPG/twdb-docs/env-info.htm>; accessed 6 December 2003.
- Texas Water Development Board. 2002a. *Concept and proposal for method of stream flow assessment to be utilized during current regional and state water planning efforts*. Internet. Available from <http://www.twdb.stat.tx.us/rwpg/twdb-docs/Streamflow.pdf>; accessed 4 March 2004.
- Texas Water Development Board. 2002b. *Water for Texas - 2002*. Document No. GP-7-1. Austin, TX: Texas Water Development Board.

- Texas Water Development Board. 2003a. *Comparison of original and revised fisheries equations used in the analysis of Galveston Bay and the Trinity-San Jacinto Estuary after correcting for data inconsistencies*. Paper presented at TCEQ Water Rights Advisory Work Group attended by author, November 2002. Austin, TX.
- Texas Water Development Board. 2003b. *GAM*. Internet. Available from http://twdb.state.tx.us/gam/GAM_define.htm; accessed 24 February 2004.
- Texas Water Development Board. 2003c. *Regional Water Planning 2002-2006*. Internet. Available from <http://www.twdb.state.tx.us/RWPG/twdb-docs/RWP%20One%20Pager.htm>; accessed 14 February 2003.
- Texas Water Development Board (TWDB). 2003-2004. Main website. Available from <http://www.twdb.state.tx.us>; accessed 2003-2004.
- Texas Water Development Board (TWDB). 2004. *Freshwater inflow needs studies*. Internet. Available from http://hyper20.twdb.state.tx.us/data/bays_estuaries/b_nEpage.html; accessed 12 March 2004.
- Texas Water Matters*. 2003. Internet. Available from <http://www.texaswatermatters.org.htm>. Accessed 10 October 2003.
- Texas. 2003. *Senate Bill 1639*. Internet. Available from <http://www.capitol.state.tx.us/>; accessed 4 December 2003.
- Trinity River Authority (TRA). 2003. Galveston Bay modeling effort of great interest to water supply stakeholders. *Intra, Newsletter of the Trinity River Authority of Texas* (Oct./Nov.). Internet. Available from http://www.trinityra.org/PDF_files/Oct-Nov%202003.pdf; accessed 23 February 2004.
- Trungale, P.E., Joseph F. 2003-2004. J. F. Trungale Engineering and Science. Communications by phone, e-mail and in person.
- Turek, James G., Timothy E. Goodger, Thomas E. Bigford, and John S. Nichols. 1987. *Influence of freshwater inflows on estuarine productivity*. Woods Hole, Massachusetts: National Marine Fisheries Service, NMFS-F/NEC-46.
- Turner Collie and Braden and Crespo Consulting. 2004. City of San Marcos water supply master plan draft report.
- United Nations. 2003. *International year of freshwater*. Internet. Available from <http://www.wateryear2003.org>; accessed 8 January 2004.

- United States Army Corps of Engineers (USACE). 2002. *Nueces River Basin 905(b)*. Internet. Available from http://www.swf.usace.army.mil/pubnotice/Nueces/Report_pgs_21-30.pdf; accessed 29 May 2004.
- United States Army Corps of Engineers. 2004a. Ft. Worth District website. Internet. Available from <http://www.swf.usace.army.mil/>; accessed 25 May 2004.
- United States Army Corps of Engineers. 2004b. Galveston District website. Internet. Available from <http://www.swg.usace.army.mil/>; accessed 25 May 2004.
- United States Army Corps of Engineers. 2004c. Main website. Internet. Available from <http://www.usace.army.mil/>; accessed 25 May 2004.
- United States Army Corps of Engineers. 2004d. *Incorporating the National Research Council's mitigation guidelines into the Clean Water Act Section 404 Program*. Internet. Available from <http://www.mitigationactionplan.gov/nas404program.pdf>; accessed 28 May 2004.
- United States Dept. of the Interior. 2004. *Bureau of Reclamation*. Internet. Available from <http://www.doi.gov/pfm/ar5bor.html>; accessed 28 May 2004.
- United States Dept. of State. 2003. *Overview: The role of DOS regarding United States oceans interests*. Internet. Available from <http://www.state.gov/g/oes/ocns/>; accessed 8 January 2004.
- United States Environmental Protection Agency (USEPA). 2000. *National estuary program*. Internet. Available from <http://www.epa.gov/owow/estuaries/about1.htm>; accessed 3 October 2003.
- United States Environmental Protection Agency. 2003. *Challenges facing our estuaries*. Internet. Available from <http://www.epa.gov.OWOW/estuaries/about3.htm>; accessed 3 September 2003.
- United States Fish and Wildlife Service (USFWS). 2000. *Section 10 wastewater management*. Internet. Available from <http://www.efmis.fws.gov.EFMIS/Util/handbook>; accessed 3 May 2004.
- United States Fish and Wildlife. 2001. *Accomplishment report - Texas Senate Bill 1 requires regional water planning*. Internet. Available from <http://ars.fws.fov/regmap.cfm?arskey=3165>; accessed 28 September 2003.
- United States General Accounting Office. 2003. *Freshwater supply: States' views of how federal agencies could help them meet the challenges of expected shortages*. GAO-03-514. Washington, D. C.

United States Geological Survey (USGS). 2004. Estimated use of water in the United States in 1990 conversion factors. Internet. Available from <http://www.usgs.gov/watuse/wuconv.html>; accessed January through July 2004.

United States Geological Survey. 2004a. Main website. Internet. Available from <http://www.usgs.gov>; accessed 20 May 2004.

The University of Texas at Austin General Libraries. 2004. Internet. Available from <http://www.lib.utexas.edu/maps/>; accessed January through July 2004.

Water Supply Act. U. S. C. Section 390b.

Wilde, Gene R. 2000. *Distribution, movements, and habitat use by paddlefish in the Lower Neches River, Texas*. Internet. Available from <http://www.lnva.dst.tx.us/projects/fisheries02.htm>; accessed 20 February 2004.

World Sites Atlas. 2004. North America map collection. Internet. Available from <http://www.sitesatlas.com/Maps/Maps/NAmer.htm>; accessed 21 May 2004.

Wurbs, Ralph A. 2000. *Reference and Users Manual for the Water Rights Analysis Package (WRAP)*. TR-180. College Station, Texas: Texas Water Resources Institute.