United States Department of the Interior

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MAR 2 7 2006

Mr. Neil (Nick) E. Carter
Federal Aid Coordinator
Texas Parks and Wildlife Department
4200 Smith School Road
Austin, Texas 78744-3291

Dear Mr. Carter:

We received the Final Report for E-38-HP Habitat Conservation Planning for the Development of the Edwards Aquifer Authority Habitat Conservation Plan. Due to current workload and staffing limitations we will not be commenting on this report.

Thank you for your continued efforts with this program. If you have any questions, please contact me at 512 490-0057, ext. 248.

Sincerely,

William Seawell
for
Robert T. Pine
Supervisor

Enclosures

cc: Debra Jones, Federal Aid, Region 2 Regional Office, Albuquerque, NM

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. E -38-HP

Endangered and Threatened Species Conservation

Habitat Conservation Planning for the Development of the Edwards Aquifer Authority Habitat Conservation Plan

Prepared by:

Bob Hall

TEXAS PARKS & WILDLIFE

Robert Cook
Executive Director

Matt Wagner
Program Director, Science, Research & Diversity

Mike Berger
Division Director, Wildlife

6 February 2006

FINAL REPORT

STATE: Texas **GRANT NUMBER:** E – 38-HP

GRANT TITLE: Habitat Conservation Planning for Development of the Edwards Aquifer Authority Habitat Conservation Plan

REPORTING PERIOD: From November 1, 2002 through December 31, 2005

OBJECTIVE(S):

1) To develop a HCP with measures to protect the Comal and San Marcos spring ecosystems and mitigate any incidental take of listed species that would occur as a result of low spring flows.
2) To complete and EIS that would include the HCP of Objective 1 as the preferred alternative.

Summary of Progress:

Please see Attachment A.

Significant Deviations:

None.

Location: All, or part, of Atascosa, Bexar, Caldwell, Comal, Guadalupe, Hays, Medina and Uvalde Counties, Texas

Cost:

Financial Status Report not available at time of report submission.

Prepared by: Bob Hall **Date:** February 6, 2006

Approved by: [signature] **Date:** February 10, 2006
Neil (Nick) E. Carter
Federal Aid Coordinator

ATTACHMENT A

Summary of Progress

In November 2002, the Authority submitted the initial draft of its HCP/EIS to the Authority's Board of Directors, the Citizen's Advisory Committee, Biological Advisory Team, South Central Texas Water Advisory Committee, TPWD, and the U.S. Fish & Wildlife Service (USFWS) to allow the stakeholders the opportunity to provide further input into the development of the Authority's HCP/EIS.

The grant to develop the HCP/EIS was provided after the development of the Draft November 2002 HCP/EIS. Interlocal Agreement #121221 specified tasks for the development of the HCP/EIS was initially signed by both parties in June 2003 and was amended March 2004 to extend the term.

Interlocal Agreement #121221, as amended

Interlocal Agreement #121221 required the Authority to complete six deliverables in a two-year period to develop the HCP/EIS. At the end of 1993, it was apparent that the complex nature of the project, the number of stakeholders with competing interests and the time required in the review and rewrite process would prevent the completion of this project in 1994. In Section VII, Special Conditions, it is noted that circumstances outside the control of the Performing Agency may prevent the completion of the project within the timeline agreed upon. On March 16, 2004, Interlocal Agreement Contract #121221 was extended through December 31, 2005.

Further correspondence with the Grantors noted that the purpose of the grant was to aid in the development of the HCP and EIS; therefore Tasks #4 and 5 listed in Interlocal Agreement #121221, as Amended, Section II, Statement of Services to be Performed, were deleted.

The remaining four tasks addressed:

Task #1. Complete Draft HCP/EIS for EAA Board approval.

Task #2. Authority approval and submission of the Draft HCP/EIS to the USFWS.

Task #3. Make the Draft HCP/IES available for public review.

Task #4. Write and submit a final report describing the work accomplished during years 1, 2 & 3, based on USFWS Federal Aid Reporting Guidelines.

Task #1 & Task #2 included modifying the EAA's initial draft HCP/EIS (Draft November 2002 HCP/EIS) to address the critiques provided by the USFWS and stakeholders.

Task #2 and Task #3 work that occurred during 2004 and 2005, included:

1) Inclusion of the results of additional biologic modeling and evaluation studies that were completed in 2003 and 2004. A revised Draft January 2004 HCP/EIS was completed and delivered to the Authority for internal review.
2) Holding a meeting with the USFWS staff on April 9, 2004 to discuss status of the HCP and to describe and discuss the concept of intensive management areas that would be developed on site to support the spring ecosystem species during periods of severe drought.
3) Holding a meeting with the Consultants on June 8, 2004 to discuss changes and revisions to the Draft January 2004 HCP/EIS. The changes and revisions were completed to the Draft January 2004 HCP/EIS by July 2004.
4) Reviewing the Draft July 2004 HCP/EIS by the Authority's Research and Technology Committee and the Authority's Board during meetings held in July, August and September 2004. Several amendments by Authority Board members were incorporated into the Draft July 2004 HCP/EIS.
5) Submitting the Draft July 2004 HCP/EIS, as Amended, to the USFWS, TPWD, other stakeholders and the general public for comment. Four public meetings were held by the Authority to receive public comments. These meetings were held in Victoria (November 1, 2004), New Braunfels (November 8, 2004), Uvalde (November 16, 2004), and San Antonio (November 17, 2004). In addition, a Biological Advisory Team meeting was also held on November 17, 2004 to discuss and receive comment and two facilitated meeting with major stakeholders were held February 9 and February 17, 2005.
6) Responding to comments on the Draft July 2004 HCP/EIS, as Amended. Withdrawal limits were removed from the document and the HCP was separated from the EIS. This was done because the issue of withdrawal limits are outside the control of the Authority and are not resolved at this time. Separating the HCP from the EIS was done to facilitate the review of the HCP. The EIS will be revisited, revised and included as either an integral part of the final HCP/EIS or as a stand alone document when the issues connected with withdrawal limits are resolved.

Task #4 is completed with this report. CD's of the draft HCP reports and comments are attached.

Major Task	Estimated Completion Date	Completion Date
Complete Draft HCP/EIS for EAA Board Approval	Mar-04	Jul-04
USFWS Review of Draft HCP/EIS	Sep-04	Sep-04
Public Review of Draft HCP/EIS	Sep-04	Nov-04
Submission of Draft HCP/EIS to USFWS	Mar-05	May-05

Summary

Forces outside the control of the Authority have hampered the development of the HCP/EIS. The Authority submitted the Draft July 2004 HCP/EIS, as Amended to the USFWS and the public for comment in September 2004. In response to the comments, the Authority continues to work toward a resolution of total withdrawal amounts from the Edwards

Aquifer and Demand Management/Critical Period. In addition, the HCP was separated from the EIS and submitted to the USFWS as the Draft March 2005 HCP.

The Authority considers the HCP and EIS developed at this time and will continue to refine them until their final acceptance and the issuance of the incidental take permit by the USFWS.

Attachments

Electronic copies attached include:

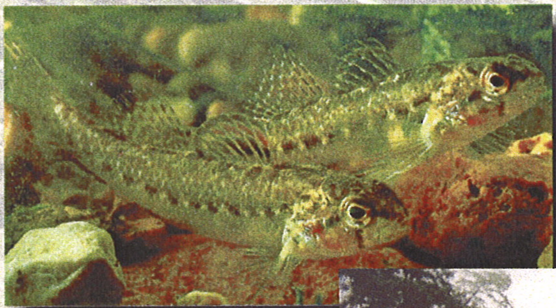
One (1) copy Draft November 2002 HCP/EIS
One (1) copy Draft January 2004 HCP/EIS
One (1) copy Draft July 2004 HCP/EIS
One (1) copy Draft July 2004 HCP/EIS, as amended
One (1) copy Comments on Draft July 2004 HCP/EIS, as amended
One (1) copy Draft March 2005 HCP

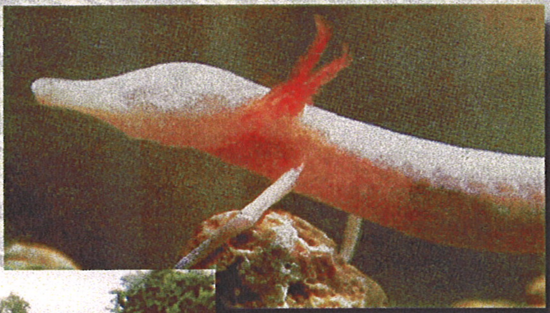
Edwards Aquifer Authority

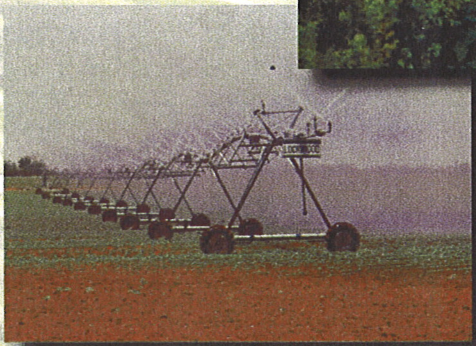
Draft

Edwards Aquifer

Habitat Conservation Plan







March 2005

Draft

Edwards Aquifer Habitat Conservation Plan

Prepared for
Edwards Aquifer Authority

Prepared by
Hicks & Company/RECON

In Association With

BIO-WEST, Inc.
LBG-GUYTON ASSOCIATES

March 2005

Cover Page Photo Credits:

Fountain Darter	*Glenn Longley*
Texas Blind Salamander	*Glenn Longley*
Center Pivot Irrigation	*TDWD: Leroy Williamson*
San Marcos River	*Nicole Roark*
San Antonio Skyline	*Roy Frye*

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TABLES

FIGURES

Additional Figures (See Appendix 8)

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Chapter 1 Introduction

The Edwards Aquifer Authority (Authority) has prepared a Draft Edwards Aquifer Habitat Conservation Plan (EAHCP) in support of an application for an Incidental Take Permit (ITP) for eight animal and one plant species listed as threatened or endangered by the U.S. Fish and Wildlife Service (USFWS). This section identifies, in general terms, the regulatory and management measures proposed by the Authority for protecting these species, which are dependent to varying degrees upon the Edwards Aquifer and associated Comal and San Marcos Springs.

1.1 Goals

The overall goals for the development of the EAHCP were identified through a mission statement developed by the Authority's HCP Workgroup, based upon recommendations provided by the EAHCP Citizens' Advisory Committee (CAC) (See Appendix 6 for organization and function of these groups). The mission statement below provides goals that are the broad, guiding principles for development and implementation of the EAHCP.

To develop a long-term regional HCP that will optimize use of the Edwards Aquifer while:

1) Minimizing and mitigating negative impacts upon federally-listed species dependent upon springflow from Comal and San Marcos Springs through aquifer demand management, springflow protection, and other management strategies; and

2) Diminishing the negative impact of the plan on the regional economy and economic interests of all of the stakeholders.

Specific biological objectives for each species are listed in Sections 7.2.

1.2 Covered Species

The ITP will cover nine federally-listed species that depend upon water in or directly discharged from the southern portion of the Edwards Aquifer system (Figure 1.3-1):

Fountain darter (*Etheostoma fonticola*)
San Marcos gambusia (*Gambusia georgei*)
San Marcos salamander (*Eurycea nana)*
Texas blind salamander (*Eurycea rathbuni*)
Comal Springs riffle beetle (*Heterelmis comalensis*)
Comal Springs dryopid beetle (*Stygoparnus comalensis*)

Peck's Cave amphipod (*Stygobromus pecki*)
Texas wild-rice (*Zizania texana*)
Whooping crane (*Grus americana*)

All of the above species (Covered Species) are listed as endangered by the USFWS except the threatened San Marcos salamander. Cagle's map turtle (*Graptemys caglei*), a candidate for listing, is also included in the HCP and will be covered under the Section 10(a)(1)(B) Permit if listed in the future.

The Texas blind salamander is a subterranean species, occurring in the aquifer near San Marcos Springs. The Comal Springs dryopid beetle is known to occur in the aquifer near Comal Springs and Fern Bank Springs. Peck's cave amphipod is known to occur in the aquifer near Comal Springs and Hueco Springs. The fountain darter and Comal Springs riffle beetle occur in the spring-fed aquatic ecosystems of both Comal and San Marcos Springs, while the San Marcos salamander and Texas wild-rice occur only in the aquatic ecosystems associated with San Marcos Springs. The San Marcos gambusia is endemic to the San Marcos Springs ecosystem. It has not been observed since 1983 and may be extinct.

Cagle's map turtle (*Graptemys caglei),* a candidate for listing, is endemic to the Guadalupe River system of south-central Texas. The whooping crane (*Grus americana*), listed as endangered, is dependent during winter upon marshes and wetlands in the Guadalupe River Estuary that are sustained in part by freshwater inflows from the Guadalupe and San Antonio Rivers. Flows of the Guadalupe River downstream of the confluence with the San Marcos River are partially dependent upon the discharge of the Edwards Aquifer through Comal Springs and San Marcos Springs; thus, potential impacts to these downstream species are addressed.

1.3 Background

The primary threat to the aquifer-dependent listed species is the intermittent loss of habitat from reduced springflows. Springflow loss is the combined result of naturally fluctuating rainfall patterns, regional intermittent pumping, and temporal drawdown of the aquifer. The southern portion of the Edwards Aquifer serves more than 1.7 million people as their primary source of water (based upon population estimates for the year 2000 for eight counties within the jurisdiction of the Edwards Aquifer Authority [U.S. Census Bureau 2000a]), and current water use has increased to the extent that variable precipitation, coupled with regional pumping, contributes to loss of springflow—the primary threat to the listed species. Other threats include invasive non-native species, recreational activities, predation, direct or indirect habitat destruction or modification by humans (e.g., reservoir construction, bank stabilization, and control of aquatic vegetation), and other factors that decrease water quality (U.S. Fish and Wildlife Service 1996).

Human population in the EAHCP Planning Area (Figure 1.3-2) is expected to increase by more than 63 percent—or nearly 1.3 million people—between the years 2000 and 2030, with a concurrent increase in water demand (TWDB 2003).

Under the ESA, the USFWS is responsible for designating the minimum springflow levels required at San Marcos and Comal Springs to ensure survival of the endangered species (see Appendix 7).

1.3.1 Administration of Rights to Withdraw Water from the Edwards Aquifer

In Texas, the administration of water rights depends upon the type of water in question—surface water or groundwater. Surface water is governed by the "appropriation doctrine." According to this doctrine, the State of Texas owns all water in streams and rivers and grants permission to use the water through an administrative process. An important feature of the appropriation doctrine is seniority, determined by the date on which the user first began drawing the water.

Since 1904, administration of groundwater has basically occurred in Texas under the common law "Rule of Capture." Under this rule an owner of land may drill a well to seek groundwater, withdraw any groundwater that may be encountered, and place the water to beneficial use without limitation as to amount, place, or purpose of use, without incurring any liability to the owner of an adjacent well.

Although the Rule of Capture remains in effect, groundwater conservation districts, such as the EAA, may through rulemaking modify the operation of the Rule of Capture within their boundaries under the specific authority provided by their organic act or by Chapter 36, Texas Water Code.

The first groundwater district was established in 1951, and as of 2003, 87 groundwater districts had been established. While the Texas Water Code and the establishment of groundwater conservation districts offered a significant opportunity to provide a regulatory system, few groundwater districts issued permits for or restricted withdrawals from all large-capacity wells within their districts. Only one district actually specified a limit on total annual withdrawals.

In 1993, the Texas legislature passed the Edwards Aquifer Authority Act (the EAA Act[1]), creating the Authority. Nevertheless, litigation delayed agency start up by three years, until 1996.

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[1] Senate Bill 1477 (Act of May 30, 1993, 73rd Leg., R.S., ch. 626, 1993 Tex. Gen. Laws 2350, as amended by Act of May 28, 1995, 74th Leg., R.S., ch. 3189, 1995 Tex. Gen Laws 2505, and Act of May 16, 1995, 74th Leg., R.S., ch. 361, 1995 Tex. Gen. Laws 3280, and Act of May 6, 1999, 76th Leg, R.S., ch. 163, 1999 Tex. Sess. Law Serv. 634, Tex. Gen. Laws.

The general intent of the EAA Act was to create a new regional entity to "manage, conserve, preserve, and protect the aquifer and to increase the recharge of, and prevent pollution of water in, the [Edwards] aquifer." The following are among the major functions of the Authority as established by the Act:

- Manage and control withdrawals of water from the Edwards Aquifer (the aquifer) through the issuance of permits and the registration of wells;
- Protect the water quality of the aquifer;
- Protect the water quality of the surface streams to which the aquifer provides streamflow;
- Achieve water conservation;
- Maximize the beneficial use of water available for withdrawal from the aquifer;
- Protect aquatic and wildlife habitat;
- Protect species that are designated as threatened or endangered under state or federal law;
- Provide for in-stream uses, bays, and estuaries;
- Protect water supplies;
- Protect the operation of existing industries;
- Protect the economic development of the state;
- Prevent the waste or pollution of water in the aquifer; and
- Increase recharge of water to the aquifer.

The above statutory functions provide a standard by which the pumping alternatives described in this document can be evaluated. The EAA Act includes several other important water management principles to govern the aquifer:

- Each permit must specify the maximum rate and total volume of water that the water user may withdraw in a calendar year;
- To the extent water is available for permitting, the Authority shall issue existing users a permit for withdrawal of an amount of water equal to the user's maximum beneficial use of water without waste during any one calendar year of the historical period (June 1, 1972, to May 31, 1993);

- If the total amount of water used without waste exceeds the amount of water available for permitting, to meet the amount available for permitting the Authority shall adjust the amount of water authorized for withdrawal under the permits proportionately;

- An existing irrigation user shall receive a permit for not less than two acre-feet a year for each acre of land the user actually irrigated in any one calendar year, during the historical period;

- An existing user who has operated a well for three or more years during the historical period shall receive a permit for at least the average amount of water withdrawn annually during the historical period; and

- Through water management practices, procedures, methods, or programs, including the implementation of alternative management practices, the Authority shall ensure that, not later than December 31, 2012, continuous minimum springflows of Comal and San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law.

Based upon the above functions, the Authority began developing regulations in 1996, and has continued with additional rulemaking each year to the present. As a primary focus of this process, the Authority developed rules for implementing its permit program.

The Authority began issuing permits in January 2001, and all permits issued by the Authority are effective on January 1 of the year after the permit was issued by the Board. As an example, all permits issued by the Board in 2001 were effective on January 1, 2002. Through December 2004, after technical review of Applications for Initial Regular Permits by Authority staff, the Authority issued proposals on IRPs that represented approximately 564,100 acre-feet per year of groundwater withdrawals as shown in Table 1.3-1 below.

Table 1.3-1. IRP approvals through December 2004

Category of Use	Proposed Initial Regular Permit Amounts (by use and acre-feet)
Municipal	229,000
Industrial	72,100
Irrigation	263,000
Total	564,100

Through 2004, the Authority has issued final decisions on 1,078 IRP applications, representing approximately 98 percent of all applications filed with the Authority. The Authority has issued 867 permits and denied 211 permit applications. The Authority has issued a total of 564,100 acre-feet of Edwards Aquifer permitted groundwater withdrawal rights per annum.

Approximately 19 protested permit applications remain, representing approximately 4,665 acre-feet of Edwards groundwater withdrawal rights.

The Authority has also developed rules establishing "Demand Management/Critical Period Management" (DM/CPM) mandated by the Act. The DM/CPM basically is designed to reduce water withdrawals from the aquifer during times when index wells or springflow fall below prescribed levels. The DM/CPM requires increasingly restrictive staged reductions in allowable withdrawals, based upon both the permitted user's authorized withdrawals and index well levels or volume of springflow for each successive stage of the Plan. The Authority is also developing a Comprehensive Water Management Plan (CWMP) to address long-range, regional water resource planning issues. This plan, along with the existing Groundwater Management Plan (1998-2008), will define the short- and long-term functions and goals of the Authority and complement the administration of aquifer withdrawals.

1.3.2 Incidental Take Permit and Habitat Conservation Plan

The Edwards Aquifer Authority (applicant) is applying for an ITP from the USFWS to allow incidental take of the previously described federally-listed endangered and threatened species, and one candidate species that is anticipated for listing, under Section 10(a)(l)(B) of the ESA. This take will be incidental to otherwise lawful activities that would occur as a result of water withdrawals within the jurisdiction of the Authority. These withdrawals are necessary for domestic and livestock, irrigation, municipal, industrial, and monitoring well uses, within the southern portion of the Edwards Aquifer (Figure 1.3-1).

The ITP application includes documentation that complies with the application requirements of 50 CFR 17.22(b)(l) for an ITP under Section 10(a)(1)(B) of the ESA. This documentation identifies the impacts of the proposed take; describes how the impacts will be minimized, monitored, and mitigated through the EAHCP; and demonstrates that measures identified in the EAHCP will not appreciably reduce the likelihood of the survival and recovery of the species in the wild.

Under the Act, the Authority's general jurisdiction wherein it asserts its water quantity management authority extends to all or part of Atascosa, Bexar, Caldwell, Comal, Guadalupe, Hays, Medina, and Uvalde Counties. The Edwards Aquifer refers to that portion of an arcuate belt of porous, water-bearing, predominantly carbonate rocks known as the Edwards and Associated Limestones in the Balcones Fault Zone. The southern region of the aquifer extends from west to east to northeast, beginning in the west at the hydrologic division near Brackettville in Kinney County, which separates underground flow toward the Comal and San Marcos Springs from underground flow to the Rio Grande Basin. The southern region of the aquifer extends through Uvalde, Medina, Atascosa, Bexar, Guadalupe, and Comal counties and terminates in Hays County at the hydrologic division near Kyle, which separates flow toward the San Marcos River from flow toward the Colorado River Basin. Figure 1.3-2 shows the approximate extent of the Authority's jurisdiction. While the Authority's jurisdiction is limited to the eight counties named above, the use and management of the Edwards Aquifer potentially affects a larger area.

In addition to being the primary water source for users within the Authority's boundaries, the Edwards Aquifer also supplies a portion of the flow in the Guadalupe River Basin downstream of Comal and San Marcos Springs. Moreover, the EAA Act establishes a five-mile buffer zone northward beyond the Authority's general jurisdictional boundary, wherein the Authority may assert its water quality authority. Consequently, the area of interest established as the EAHCP Planning Area includes the eight counties within the Authority's jurisdiction proper, an additional four counties that contain that portion of the Authority's jurisdictional five-mile buffer located over the Edwards Aquifer contributing zone, and an additional five counties that are adjacent to the Guadalupe River from its confluence with the Comal and San Marcos Rivers to its mouth. Representatives from these five downstream counties are a part of the South Central Texas Water Advisory Committee, a non-voting entity created by the Act. This 17-county EAHCP Planning Area is shown in Figure 1.3-2.

In order to minimize and mitigate incidental take, the Authority has identified a number of measures (Chapters 5 and 6) to provide protection for the Comal and San Marcos Springs and dependent species identified in the EAHCP.

1.4 Covered Activities

The Authority's primary statutory obligations are to manage the withdrawal of groundwater from the Edwards Aquifer and protect the quality of the water of the aquifer. The Authority seeks coverage for the Authority's programs that implement these two statutory functions in this HCP and coverage for permittees who are subject to Authority regulations. The Authority may carry out its statutory powers and responsibilities to amend rules from time to time and substitute alternative practices, procedures, and methods for reductions in pumping if the effect of the amendment maintains the baseline springflows proposed in the HCP.

1.4.1 Authority Permit Program

The Authority permit program in general consists of the following elements: EAA Rules Ch. 711 Groundwater Withdrawals, subchapters A Definitions; B General Provisions; C Exempt Wells; D Interim Authorization; E Permitted Wells; F Standard Groundwater Withdrawal Conditions; G Groundwater Available for Permitting, Proportional Adjustments, Equal Percentage Reductions; H Abandonment; I General Prohibitions; J Aquifer Recharge, Storage, and Recovery Projects; K Additional Groundwater Supplies; L Transfers; and M Meters, Alternative Measuring Methods, Reporting; and 715 Comprehensive Water Management Plan Implementation, subchapters A Definitions; B Variance Procedures; C Groundwater Conservation and Reuse Rules; D Demand Management and Critical Period Management Rules; E Withdrawal Reduction Rules (not yet adopted); and F Regular Permit Retirement Rules (not yet adopted). The Authority's programs that implement the two statutory functions include: Regulation of Permitted Withdrawals—Initial Regular Permits, Additional Regular Permits, Term Permits, Emergency Permits, Monitoring Well Permits, Aquifer Recharge Recovery Permits, and Other Aquifer Management Strategies;

- Regulation of Exempt Wells;
- Regulation of Interim Authority Status Wells;
- Regulation of Well Construction; and
- Regulation of Recharge Zone Protection.

1.4.2 Edwards Aquifer Authority Permittees

Because the EAHCP is considered a regional HCP, coverage for aquifer pumping by individual holders of Authority permits would be included in the ITP issued to the Edwards Aquifer Authority.

1.5 Proposed Action and Decisions Needed

The proposed federal action would be the issuance of a Section 10(a)(1)(B) permit (ITP) by the USFWS to allow incidental take of Texas blind salamander, fountain darter, San Marcos gambusia, Texas wild-rice, Comal Springs riffle beetle, Comal Springs dryopid beetle, Peck's cave amphipod, San Marcos salamander, Cagle's map turtle (if listed in the future), and whooping crane for the 50-year period in the areas shown on Figure 1.5-1. These areas primarily include subterranean, inter-connected, water-filled caves and conduits within the Edwards Aquifer Authority jurisdictional boundary; the San Marcos Springs Complex, Spring Lake, San Marcos River to below the A.E. Wood Fish Hatchery, and Fern Bank Springs (all in Hays County); the Comal Springs Complex, the Comal River including Old and New Channels, and Hueco Springs (all in Comal County); the Guadalupe River (from the confluence with the Comal River to Guadalupe Bay), Aransas National Wildlife Refuge in Aransas County, and portions of San Antonio Bay, Matagorda Island, and San Jose Island (in Aransas and Calhoun Counties).

Decisions to be made by the USFWS are as follows:

- Is the proposed take incidental?
- Are the impacts of the proposed take minimized and mitigated to the maximum extent practicable?
- Is adequate funding provided to implement the measures proposed in the submitted HCP?

- Is the proposed take such that it will not appreciably reduce the likelihood of the survival and recovery of the species in the wild?

- Are there other measures that should be required as a condition of the ITP?

In considering the above decisions, the USFWS may: issue the ITP with the submitted EAHCP; issue the ITP with a modified EAHCP; issue the ITP with other specific management requirements and mitigation measures; or deny the ITP.

1.6 Public Involvement

1.6.1 Public Meetings

Numerous public meetings were held by the Edwards Aquifer Authority Board to receive comments, suggestions, and guidance concerning the development of the EAHCP. These meetings included the full Board; Board Subcommittees comprising the EAHCP Work Group and Research and Technology Committee; and public hearings to involve stakeholders throughout the southern Edwards Aquifer Region. This EAHCP incorporated suggestions and comments from the general public and stakeholders. Three scoping meetings also occurred as part of the NEPA process.

1.6.2 Citizens Advisory Committee

The passage of Senate Bill 1272 during the 76th Texas Legislature in 1999 required the Authority to appoint a Citizens Advisory Committee (CAC) to assist in preparing the regional EAHCP and the application for an ITP. The purpose of the CAC is to advise the Authority in development of the EAHCP, assist in determination of the scope of the EAHCP, recommend mitigation measures and other EAHCP conditions, provide a forum for public discourse and conflict reconciliation, help meet public disclosure requirements, oversee EAHCP progress and development, and most importantly, build consensus among diverse organizations and interests. Accordingly, a 26-member panel was appointed by the Authority in a manner to assure representation by all affected interests in the Edwards Aquifer region. Participants include private landowners; irrigators; water purveyors; private consultants; and representatives from major cities, as well as federal, state, and local governmental agencies and universities. A complete listing of participants and organizations is contained in Appendix 6, Public Involvement.

1.6.3 Biological Advisory Team

The passage of Senate Bill 1272 (referenced above) also required that the Authority, "… together with the [Texas Parks and Wildlife] commission and landowner members of the Citizens Advisory Committee [CAC], shall appoint a biological advisory team [BAT]. At least one member [of which] shall be appointed by the commission and one member by the landowner members of the Citizens Advisory Committee. The member appointed by the commission serves as presiding officer of the team. The team shall assist in the calculation of harm to the endangered species and the sizing and configuring of habitat preserves." The Authority has appointed a six-member committee to fulfill this function. A complete listing of members is contained in Appendix 6, Public Involvement.

1.7 Other Required Actions

Before a decision can be made regarding the issuance of an ITP, the USFWS must comply with the consultation requirements stipulated in Section 7 of the ESA for any federal action (issuance of the ITP by the USFWS) on the environment. No other formal federal, state, or local permits or approvals are required prior to the decision by the USFWS.

1.8 Alternatives Considered during the Development of the HCP

In developing an EAHCP for the Edwards Aquifer region, several potential alternatives were considered but not carried forward as viable alternatives in this analysis, because they did not meet all of the goals of the EAHCP. Alternatives eliminated from further consideration include:

1.8.1 No Restrictions on Aquifer Pumping

One alternative for a sole-source regional water supply aquifer, absent any regulatory authority, would be the common law Rule of Capture with no limits on pumping from the aquifer, including no restrictions during drought periods. Since 1934, as a result of minimal regulation, the amount of annual aquifer discharge from wells has steadily increased to a peak of 542,000 acre-feet in 1989 (EAA 1999). Subsequently a chain of events, which involved extensive litigation, culminated in state legislation that created the Edwards Aquifer Authority. The "no pumping restrictions" alternative is not available or applicable because the EAA Act imposes mandated pumping limits and schedules for implementation.

1.8.2 Regional Habitat Conservation Plan Mandated by Court Order

In June 1995, a draft regional HCP was prepared for and under the direction of the U.S. District Court for the Western District of Texas (Moore and Votteler 1995). This 314-page document resulted from discussions and information generated by a 10-member court-appointed panel that included a Court Monitor, the City of San Antonio, the Uvalde County Underground Water Conservation District, the Medina Underground Water Conservation District, the Edwards Underground Water District, the San Antonio River Authority (SARA), the Guadalupe-Blanco River Authority (GBRA), the City of San Marcos, the City of New Braunfels, and the Nueces River Authority. This HCP was built around the assumption that protection of threatened and endangered species could be achieved if minimum flows specified by the USFWS were maintained at both Comal and San Marcos Springs. It identified 12 specific measures that ranged from water quality protection to development of new water sources to incorporation of biological protection measures. Specifically, the measures included:

$ Water quality protection per ordinance adopted by the San Antonio City Council in 1995, expanded to the entire recharge zone;

$ Water conservation efforts including reuse of treated wastewater by San Antonio Water System (SAWS), SARA, private corporations, and others;

$ Control of the exotic rams-horn snail to support lowering USFWS established jeopardy levels at Comal Springs;

$ Use of Medina Lake as a source of water for municipal and industrial uses, and modification of Medina Lake Spillway to increase reservoir firm yield;

$ Duplication of the Seco Creek Watershed Water Quality Project in an additional 13 counties to increase aquifer recharge;

$ Construction of recharge structures on streams flowing through the recharge zone;

$ Importation of groundwater from the Carrizo-Wilcox Aquifer;

$ Importation of surface water from the Guadalupe River (Lake Dunlap) into the Edwards Aquifer area (agreement of April 19, 1995, between SAWS, SARA, and GBRA);

$ Injection and storage of treated water into the Carrizo-Wilcox Aquifer for later use (aquifer storage and recovery);

$ Importation of water from the Colorado River Basin, purchased from the Lower Colorado River Authority;

$ Development and implementation of drought management plans; and

$ Removal of threatened or endangered species to refugia per emergency measures developed by USFWS.

Activities associated with the development of the regional HCP as directed by the U.S. District Court ceased shortly after the draft document was prepared when a stay of the Court Monitor's activities was issued in October 1995 by the U.S. Fifth Circuit Court of Appeals. Consequently, the HCP was never presented to a court-appointed panel or endorsed by any members.

This HCP was not included for further consideration because: (1) the draft HCP resulted directly from court action that was reversed on appeal by a higher court of jurisdiction; and (2) the draft HCP did not designate a specific applicant, whereas in 1993 the EAA Act explicitly delegated (Article 1, Section 1.01 and Section 1.11(d)(9)) the authority for protecting the aquifer's aquatic life and holding a permit, "…pertaining to the Endangered Species Act…", to the Edwards Aquifer Authority (which became operational in 1996). It contained measures that depended upon actions by many entities other than the EAA and would potentially require multiple signatories to an implementation agreement. Finally, this alternative contained measures that were included in other alternatives that are considered and evaluated below.

1.8.3 Extending Existing or Proposed Habitat Conservation Proposals/Plans Developed by Other Entities

Several other habitat conservation plans exist or are being prepared, which address similar goals and objectives for protecting endangered and threatened species, but for reasons discussed below, were not included in the alternatives to be evaluated.

1.8.3.1 Biological Opinion Issued for Four Military Installations Located in San Antonio, Texas

A biological opinion was issued by the USFWS for actions proposed by the Department of Defense to mitigate adverse impacts upon listed species from the direct withdrawal of water from the Edwards Aquifer by Fort Sam Houston, Lackland Air Force Base, Kelly Air Force Base, and Randolph Air Force Base (USFWS 1999a). Reasonable and prudent measures contained in the biological opinion include: (1) reducing dependence upon Edwards Aquifer groundwater by implementing scheduled reductions in aquifer withdrawals; (2) implementing drought management plans requiring staged water restrictions according to varying drought conditions; (3) contributing to refinement of the Edwards Aquifer computer model; and (4) practicing water, species, and habitat conservation through all means, including public education programs and partnering with other agencies.

1.8.3.2 Proposed HCP Developed by Bexar Metropolitan Water District

A proposed HCP was submitted by the Bexar Metropolitan Water District (BMWD) to the USFWS on December 22, 1998, in support of an application for an ITP to cover BMWD's operations as a major municipal water supplier for San Antonio (BMWD 1998). Proposed HCP measures included a pro-rata reduction in withdrawals from the Edwards Aquifer, such reductions being based upon BMWD's proportional historic use of aquifer water relative to the use by other municipal water purveyors; development of alternative water sources; implementation of measures to increase water use efficiency; implementation of water conservation measures; and development and implementation of critical period measures. This proposed HCP is still under review by the USFWS.

1.8.3.3 San Marcos River Habitat Conservation Plan Cooperatively Developed by the City of San Marcos, Texas, and Texas State University

The City of San Marcos, Texas, and Texas State University have cooperatively prepared and submitted a draft HCP to cover city activities along the San Marcos River that could involve incidental take of listed species (City of San Marcos 2004). Activities to be covered by the HCP involve river management measures and development activities along the river. These include control of aquatic vegetation, constructing river access points and retention ponds, stabilizing eroding banks, construction at Aquarena Center, repairing Rio Vista dam, trail-building, and removing deposited sediments from selected locations. Proposed HCP measures include: (1) site-specific vegetation control using mechanical methods in and immediately below Spring Lake and below Sewell Park, and scheduled maintenance to avoid accumulation of large amounts of vegetation downstream; (2) use of screens and application of caution in removal of sediments; (3) development of a protocol for vegetation management treatments during low flows; (4) use of stream-side protection measures for development, including vegetation buffers, berms, and silt fences; (5) controlled access to and use of Spring Lake by divers; (6) monitoring of known locations of listed species to determine changes in population distribution or abundance; (7) restricted use of water from Spring Lake for adjacent landscape watering, particularly during drought conditions; and (8) closely monitored and controlled use of pesticides on the Aquarena golf course.

Measures mentioned in Sections 2.2.3.1 and 2.2.3.2 of the San Marcos HCP would directly contribute to stabilization of springflows of both Comal and San Marcos Springs by reducing aquifer withdrawals. Measures identified in 2.2.3.3 relate specifically to protecting San Marcos Springs from factors other than maintenance of springflow (approval of City of San Marcos HCP by USFWS is expected in 2004). While all of the above plans involve measures that overlap and complement the alternatives considered below and collectively contribute to the protection of the spring ecosystems, none of the plans taken individually would merit consideration as a regional Edwards Aquifer HCP alternative because of limitations in scope or regional control.

1.8.3.4 Conservation Agreements or Habitat Conservation Plans Not Requiring a Federal Permit Issued under Section 7 or Section 10(a) of the Endangered Species Act.

Chapter 83 of the Texas Parks and Wildlife Code was amended in 1999 by the 76th Texas Legislature (Senate Bill 1272) to provide for "Conservation Agreements for Protection of Species." Subsection 83.005, Paragraph (b) provides that a Conservation Agreement include an agreement between the state or political subdivision of the state and the United States Department of the Interior under the federal act that does *not* relate to a federal permit (a permit under Section 7 or Section 10(a) of the ESA). Subsection 83.012, Paragraph (2) encourages state governmental entities to develop and implement HCPs rather than regional HCPs.

As noted in Section 1.4, compliance with the ESA is necessary if water withdrawal from the Edwards Aquifer is to be regulated under provisions of the EAA Act. Without the proposed action (issuance of an ITP under Section 10(a) of the ESA), the Authority could face significant difficulty in meeting its mandated functions and goals under the Act if violations of the ESA occur due to reduced or no springflows that would result in unauthorized "take" of threatened or endangered species. Section 9 (a) and (b) of the ESA prohibits "…any person…to take any such species…." Section 10 provides that the Secretary of the Interior "…may permit, under such terms and conditions as he shall prescribe—any taking otherwise prohibited by Section 9…if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity."

The ESA further provides in Sections 11(a) & (b) civil and criminal penalties for violation of the provisions of the ESA, including fines and imprisonment. Without the issuance of an ITP under Section 10(a), those withdrawing water from the aquifer would potentially be exposed to these provisions of the ESA. In light of this potential federal liability under the ESA, alternatives involving conservation agreements, alternative management strategies, or HCPs that are not protected by a Section 10(a) ITP do not meet the purpose and need for the proposed action and have been eliminated from further consideration.

1.8.3.5 No Action Alternative

This alternative includes aquifer management under current state law and existing rules administered by the EAA. Under this alternative, actions mandated by state law would be implemented, as necessary, however, there would not be an EAHCP and a regional ITP would not be issued. Therefore, pumping activities would not be covered under a regional ITP, and there would be no EAHCP contingency measures for protecting species dependent upon the spring ecosystems during periods of severe drought. The Authority would still function as a political subdivision of the State of Texas to manage the southern portion of the Edwards Aquifer as mandated by the EAA Act. Such management currently employs phased reductions in the amount of water that may be used or withdrawn by users of the aquifer to meet mandated withdrawal limits specified by the Act.

1.8.3.6 Optimized Biological HCP Alternative

This alternative would employ aquifer management strategies to maintain aquifer levels sufficient to assure springflow at Comal Springs during worst drought conditions, including those equivalent to the drought of record. Aquifer management would result in a higher water level in the aquifer, allowing more groundwater for discharge through Comal and San Marcos Springs, thus providing higher flows to the spring ecosystems. However, much less aquifer water would be available for irrigation and municipal and industrial needs, as pumping reductions would be driven by the requirement to maintain springflow levels at Comal and San Marcos Springs. Under this alternative, regional irrigation, municipal, and industrial economic activities that are dependent upon the aquifer could not be supported at currently projected levels, resulting in severe economic impacts.

1.8.3.7 Alternatives Involving Optimized Aquifer Pumping Not Supported by Stakeholder Consensus

Several alternatives were evaluated involving aquifer management strategies that incorporated DM/CPM reductions linked to total annual withdrawals. However, these alternatives were not supported by stakeholder consensus.

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Chapter 2 Plan Area

2.1 Plan Area Boundaries

The EAHCP Planning Area includes the eight counties under the Authority's jurisdiction, an additional four counties that contain that portion of the Authority's jurisdictional five-mile buffer located over the Edwards Aquifer contributing zone, and an additional five counties in the South Central Texas Water Advisory Committee's jurisdiction that are adjacent to the Guadalupe River from its confluence with the Comal and San Marcos Rivers to its mouth. This 17-county EAHCP Planning Area is shown in Figure 1.3-2.

The EAHCP Planning Area may be further subdivided into four regions that are listed below. A brief description of each region follows.

2.1.1 Western Region (Edwards, Kinney, Real, and Uvalde Counties)

These four counties occur on the western side of the Edwards Aquifer. They are largely agricultural and lie over a major ecological region boundary separating the Edwards Plateau to the north from the South Texas Brush Country to the south.

2.1.2 Central Region (Atascosa and Medina Counties)

These counties lie over the south-central portion of the Edwards Aquifer. They are largely agricultural, but the eastern portion of Medina County is being affected by the western encroachment of urban development associated with the San Antonio metropolitan area. This region also lies over a major ecological region boundary separating the Edwards Plateau to the north from the South Texas Brush Country to the south.

2.1.3 Eastern Region (Bexar, Caldwell, Comal, Guadalupe, Hays, and Kendall Counties)

This region includes the large urban centers of San Antonio and other cities along the Interstate Highway (IH) 35 corridor. The region is ecologically and physiographically diverse, containing four ecological regions: the Edwards Plateau, South Texas Brush Country, Blackland Prairie, and Oak Woods and Prairies.

2.1.4 Downstream Counties (Calhoun, Dewitt, Gonzales, Refugio, and Victoria Counties)

This region represents downstream interests that rely upon instream flows from the Guadalupe River System, which depends in part upon spring discharge from the Edwards Aquifer. This area includes three ecological regions: Oak Woods and Prairies, Blackland Prairie, and Gulf Coast Prairie and Marshes.

These regions are more fully discussed in Appendix 3, Plan Area Affected Environment, Sections 3.4 Agriculture, Section 3.5 Demographics, Section 3.6 Economy, and Section 3.7 Land Use.

2.2 Permit Area

The Incidental Take Permit area (Figure 2.2-1) includes: subterranean, water-filled caverns within the Edwards Aquifer Authority jurisdictional boundary; the San Marcos Springs Complex, Spring Lake, San Marcos River to below the A.E. Wood Fish Hatchery, and Fern Bank Springs (all in Hays County); the Comal Springs Complex, Comal River, including old and new channels, and Hueco Springs (all in Comal County); the Guadalupe River (from the confluence with the Comal River to Guadalupe Bay), Aransas National Wildlife Refuge in Aransas County, and portions of San Antonio Bay, Matagorda Island, and San Jose Island. Any incidental take for EAHCP species would be expected to occur in the above-named aquifer locations, spring complexes, rivers, and bay systems.

2.3 Affected Environment

A description of the affected environment relevant to the proposed HCP is provided in Appendix 3, Plan Area Affected Environment. Topics include: Biological Resources, Physical Environment, Water Resources, Agriculture, Demographics, Economy, Land Use, Cultural Resources, and Air Quality. These sections provide the baseline conditions for the environmental and socioeconomic resources that have been evaluated with respect to the alternatives considered.

Chapter 3 Permit Area

The Permit area (Figure 2.2-1) includes: subterranean water-filled caverns and pools within the Edwards Aquifer Authority jurisdictional boundary; the San Marcos Springs Complex, Spring Lake, San Marcos River to below the A.E. Wood Fish Hatchery, and Fern Bank Springs (all in Hays County); the Comal Springs Complex, Comal River, including Old and New Channels, and Hueco Springs (all in Comal County); the Guadalupe River (from the confluence with the Comal River to Guadalupe Bay), Aransas National Wildlife Refuge in Aransas County, and portions of San Antonio Bay, Matagorda Island, and San Jose Island. Any incidental take for HCP species is expected to occur in the above named spring complexes, rivers, and bay systems.

The EAHCP specifically provides coverage for incidental take of the Covered Species resulting from water withdrawals permitted by the Authority and other activities authorized under its regulatory authority as defined by state law, within the Authority's jurisdiction, and that meet the conditions specified in this chapter and in the Implementing Agreement (IA) to be completed for parties responsible for implementation measures and attached as Appendix XX. In addition, the EAHCP provides for incidental take associated with activities identified in the EAHCP and IA as measures to minimize, mitigate, and monitor potential impacts to Covered Species. These include activities at Comal and San Marcos Springs undertaken as part of the implementation of the EAHCP by the Authority, state and federal agencies, or other entities designated under the terms of the EAHCP and IA.

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Chapter 4 Incidental Take

The proposed EAHCP will not assure continuous springflow under all conditions, and the risk that low flows may increase in frequency and duration or that flow might completely cease may potentially be higher as aquifer pumping increases. Covered Species will be protected by withdrawal restrictions under an enhanced DM/CPM in combination with a higher level of funding for captive propagation measures, adaptive management strategies, and implementation of Edwards Aquifer Optimization Technical Studies. Many EAHCP measures discussed below (Chapter 6, Measures to Mitigate and Monitor Potential Impacts) will focus on contingencies in anticipation of expected low flows or complete cessation of flow. The following sections provide a baseline discussion of potential incidental take of Covered Species associated with the proposed EAHCP. Section 4.4 describes the impact assessment concept and procedures and provides a summary of the determination of the potential impact of the proposed EAHCP.

4.1 Comal Springs/River Ecosystem

4.1.1 Fountain Darter

Hydrological events occurring at Comal Springs during the drought of record have recently been described (LBG-Guyton 2004) and are summarized at the end of Section 3.1.2.2 in Appendix 3. There is little information available for the period before or after the drought of record to help determine the effects of that event on the fountain darter, when the springs in the Comal River ceased flowing from June 13 to November 3, 1956. Photos taken when Comal Springs ceased flowing indicate residual pools in the Landa Lake area. (Figures 3.1-4c and 3.1-4d in Appendix 3.) Although the species was not reported to be present in the Comal River after the drought (Schenck and Whiteside 1976), it is also the case that the Comal River was poisoned with rotenone by the Texas Fish, Game, and Oyster Commission in 1951, prior to the drought. While the poisoning was intended to remove the exotic Rio Grande cichlid *(Cichlasoma cyanoguttatum*), the event must also have severely reduced the population size of the fountain darter and probably contributed to the extirpation of the original population of the species from the Comal River sometime between 1954 and 1973. Additional factors may have included temperature variations due to spring runs ceasing to flow for a five-month period in 1956, and a flood from Blieders Creek in 1971 (USFWS 1996b; Linam et al. 1993; Schenck and Whiteside 1976).

Because of the high fecundity of the species, however, it can quickly respond to favorable conditions and rebound from short-term habitat losses. Since the reintroduction in 1975 of 457 individuals into the Comal River from the San Marcos River, the population has recovered, and currently (as of 2004) the species is abundant in both the Comal and San Marcos Rivers (BIO-

WEST 2003a, 2003b). Population estimates are highly variable and difficult to develop with any confidence due to the number of variables that influence fountain darter population dynamics, but high quality habitat is abundant and the density of darters found in many habitat types is very high.

Ongoing research and monitoring continue to confirm the importance of aquatic vegetation to the fountain darter. For all sample efforts the Authority is aware of, the type and quality of the aquatic vegetation greatly affect the density of fountain darters in an area and, in aggregate, the total number of fountain darters in the Comal Springs/River ecosystem. Reduced springflow presumably decreases both the quantity and quality of most vegetation types that comprise fountain darter habitat—a condition that is defined as "take" by USFWS—however there is great difficulty in accurately assessing the point at which this first occurs. Since the USFWS first identified a critical discharge value at which "take" was believed to occur, there have been additional data gathered that might influence the determination of this value. Observations made during the Authority's Variable Flow Study (an Edwards Aquifer Optimization Technical Study), suggest that the area where habitat would first decrease in quantity and quality is in the uppermost reach of Landa Lake, near the confluence of Blieders Creek ("marginal" fountain darter habitat), and the critical discharge value at which this begins to occur is approximately 150 cfs.

Fountain darter habitat quality varies throughout the Comal Springs/River ecosystem and the EAHCP designates two categories: prime and marginal habitat. Prime habitat areas include Landa Lake and the Old Channel. The uppermost reach of Landa Lake above Spring Island and the entire New Channel are considered marginal habitat. This distinction is important for guiding management response plans that attempt to maximize the suitability and availability of the highest quality habitat. Any loss of habitat, however, regardless of quality, is considered take under the USFWS definition.

At 150 cfs total Comal River discharge (observed in the summer of 2000), Spring Runs 4 and 5 (marginal habitat near Blieders Creek) ceased flowing and the amount of upwelling flow in the immediate area was also considerably reduced. Under those flow conditions, there is potential for loss of aquatic vegetation quantity and quality and for increases in water temperature in the immediate area. Observations from the Variable Flow Study show that prime habitat areas are maintained at springflows of 150 cfs total Comal River discharge, suggesting that impacts to the fountain darter are minimal in those areas under such conditions. As the Comal Springs/River ecosystem approaches 80 cfs, there is potential for legitimate risk to the fountain darter population through loss of marginal habitat and some prime habitat. However, since low-flow data documenting impacts are not available or have not been made available to the Authority, this increased risk is considered only "potential" rather than absolute. Also, because this type of data is very limited and/or inaccessible, an approach for evaluating key fountain darter habitat (aquatic vegetation) and fountain darter populations is proposed to more accurately describe actual risk under such discharge conditions.

4.1.2 Comal Springs Riffle Beetle

Similar to the fountain darter, calculating risk for the Comal Springs riffle beetle is subject to the many habitat and population parameters that potentially affect the population dynamics, but a limited amount of life history information adds additional complications. Although considerable contributions to the Comal Springs riffle beetle knowledge base have been made through field and laboratory evaluations associated with the Authority's Variable Flow Study, there are still many ecological data gaps for this species. A major unknown factor is how the Comal Springs riffle beetle survived the drought of record, when springflow ceased for a period of approximately five months. The size and condition of the population prior to and following that event are also unknown factorscritical in predicting the susceptibility of this species to future low-flow conditions. It is also unclear what proportion of the population may use subterranean habitats and how deep suitable habitat may extend.

In the absence of sufficient data, the Authority has evaluated take and increased risk conditions based only upon surface habitat availability. This may be a conservative approach considering the potential that this species may regularly occupy subsurface habitat or be able to use such habitat for extended periods as a mechanism for drought survival. It is believed that take of this surface habitat begins to occur at 120 cfs. It has been documented (mostly anecdotally) that during the late 80's and mid-90's the spring runs at Comal started to lose wetted area at approximately 120 cfs. The modeling effort conducted by USFWS (draft) also shows that wetted area in the Comal River, particularly in areas of Comal Springs riffle beetle habitat, is lost between 150 and 100 cfs. The Authority believes that, as the Comal Springs/River ecosystem approaches 80 cfs, there is a potential for increased risk to the Comal Springs riffle beetle population, as flow decreases in the primary habitat of Spring Runs 1 and 3 and upwelling flows decrease in other areas of high-quality habitat. The potential for risk greatly increases as flows decrease from 80 cfs to 0 cfs.

4.1.3 Comal Springs Dryopid Beetle and Peck's Cave Amphipod

As described in the USFWS contingency plan (USFWS 1996), the Comal Springs dryopid beetle and Peck's Cave amphipod are subterranean species. An assumption of the EAHCP is that as subterranean species, mechanisms exist for these species to retreat into the Edwards Aquifer should springflows cease at the spring outlets at Comal Springs. With that assumption, a modest amount of springflow should be sufficient to protect habitat for these species. Therefore, a conservative measure for take for the Comal Springs dryopid beetle and Peck's Cave amphipod is 40 cfs total discharge in the Comal River, in which some springs remain flowing and provide habitat for the subterranean species up to the spring openings. Although some springs will have ceased flowing at this total discharge value, wetted area remains near the spring openings, and only a minimal amount of habitat is lost as individuals retreat into the aquifer. The Authority believes that as the Comal Springs/River ecosystem approaches 20 cfs, there is a potential for legitimate risk to the Comal Springs dryopid beetle and Peck's Cave amphipod populations, as upwelling flows decrease in many springs that might support populations of each near their openings. The potential for risk greatly increases as flows decrease from 20 cfs to 0 cfs.

4.2 San Marcos Springs/River Ecosystem

4.2.1 Fountain Darter

Hydrological events occurring at San Marcos Springs during the drought of record have recently been described (LBG-Guyton 2004) and are summarized at the end of Section 3.1.2.3 in Appendix 3. During the summer of 1956, the springs reached a recorded low of 46 cfs, but never ceased flowing. All of the species dependent upon this spring ecosystem survived this event, apparently without any human intervention.

As discussed in the Comal Springs/River Ecosystem section (4.1), ongoing research and monitoring continue to confirm the importance of aquatic vegetation to the fountain darter. For all sample efforts the Authority is aware of, the type and quality of the aquatic vegetation in the system appear to be primary factors affecting the density of darters in the San Marcos Springs/River ecosystem. Therefore, take as defined by the USFWS is triggered at the level at which aquatic vegetation declines. For the San Marcos Springs/River ecosystem, this potential for decline occurs in the downstream-most areas of fountain darter habitat, because of increasing water temperatures and potential impacts upon aquatic vegetation. The potential for habitat decline corresponds with approximately 100 cfs total discharge in the San Marcos River. As the San Marcos Springs/River ecosystem approaches 60 cfs, potential risk to this species increases (increased risk). Again, the word "potential" must be stressed, as low-flow data documenting impacts are not available or have not been presented to the Authority. Therefore, the same approach as described for the fountain darter at Comal Springs is proposed for implementation at San Marcos Springs.

4.2.2 San Marcos Salamander

As with the fountain darter, there is little information available before or after the drought of record to determine the effects of that event on the San Marcos salamander population when the springs in the San Marcos River were reduced to 46 cfs total discharge. Ongoing research and monitoring continue to confirm the importance of suitable habitat to the San Marcos salamander. Suitable habitat for the San Marcos salamander is defined as silt-free rocks, ranging in size from one to eight inches (5cm to 20cm) diameter, with surrounding aquatic vegetation and floating mats of algae (primarily *Lungbia* sp) in the headwaters of the San Marcos River. For all sample efforts the Authority is aware of, the quality and quantity of this habitat in the system are the most important factors determining the density of salamanders in the San Marcos Springs/River ecosystem. For the San Marcos Springs/River ecosystem, the potential for reduction in the quantity and quality of suitable habitat would likely take place first in the downstream-most portion of the San Marcos salamander range, the spillway below Spring Lake dam. The potential for habitat decline corresponds with approximately 80 cfs discharge in the San Marcos River. As the San Marcos Springs/River ecosystem declines below 80 cfs, the potential for risk increases (increased risk). The word "potential" must be stressed, as low-flow data documenting impacts are not available or have not been presented to the Authority.

4.2.3 Texas Blind Salamander

Similar to the Comal Springs dryopid beetle and Peck's Cave amphipod, the Texas blind salamander is a subterranean species. An assumption of the EAHCP is that as subterranean species, mechanisms exist for these species to retreat into the Edwards Aquifer should springflows cease at the spring outlets at San Marcos Springs. With that assumption, a conservative measure for take for the Texas blind salamander, which includes potential indirect habitat loss associated with springflow reductions, is 40 cfs total discharge in the San Marcos River. As the San Marcos Springs/River ecosystem declines below 20 cfs, the potential for risk increases (increased risk). The word "potential" must be stressed, as low-flow data documenting impacts are not available or have not been presented to the Authority. Therefore, a monitoring approach is again proposed for implementation at San Marcos Springs to evaluate potentially deteriorating conditions, rather than the establishment of a single value.

4.2.4 Texas Wild-rice

It is recognized that as a plant species, Texas wild-rice carries no federal protection. Regardless, the Authority's focus is to maintain the biological objectives and integrity of the habitat set forth in this EAHCP. The current take number established by the USFWS for Texas wild-rice is 100 cfs total discharge in the San Marcos River. Additional data that were not available at the time that the USFWS established that critical value might influence its calculation. Such information includes past and present research being conducted at the San Marcos National Fish Hatchery and Technology Center, the Texas Parks and Wildlife Department (TPWD) instream flow assessment, and monitoring conducted through the Variable Flow Study (an Edwards Aquifer Optimization Technical Study). A more appropriate critical discharge value at which take begins to occur may be 110 cfs, which better reflects the point at which declines in Texas wild-rice are possible as a result of reduced springflow.

As the San Marcos Springs/River ecosystem approaches 80 cfs, the potential for risk increases (increased risk). The word "potential" must be stressed, as low-flow data documenting impacts are not available or have not been presented to the Authority. Therefore, the same approach (range to be determined by actual measurements, as opposed to a set number for all circumstances) as described for the other EAHCP species, is proposed for implementation for Texas wild-rice.

Although springflow is unarguably important to Texas wild-rice, management of certain potential impacts to Texas wild-rice at lower flows does not necessarily require limiting aquifer withdrawals. For instance, the build-up of aquatic vegetation mats on Texas wild-rice and other vegetation creates sub-optimal conditions; similarly, recreational activity in the immediate vicinity of plants that are in vulnerable (shallow) areas can have negative impacts. Both of these impacts can be reduced or eliminated by management activities other than aquifer withdrawal reductions. Therefore, this EAHCP proposes that, as a management action, a plan be developed and implemented for the breaking up of aquatic vegetation mats from Texas wild-rice and other aquatic vegetation during low-flow periods. Although recreation is outside of the jurisdiction of the Authority, the EAHCP also includes measures for identifying recreational impacts and maintaining open dialogue with the stakeholders directly responsible for recreational interests in the San Marcos River. In addition, the high sediment load in the river, which has occurred as a result of development in the watershed (Earl and Wood 2002), has created conditions in which Texas wild-rice plants are at a greater risk of being disturbed and stressed than in the past. These conditions have created a shallow “shelf” or spit of newly deposited sediments in the 273 yards (250 meters) of stream downstream of Sessoms Creek, where many of the plants are in shallower water and, therefore, subject to greater recreational and herbivory impacts than before the increased sediment load (Figure 4.2-1). The City of San Marcos has developed measures for reducing sedimentation in the upper San Marcos River with coverage under a separate HCP (City of San Marcos 2004). Without such measures, greater springflow would be needed to mitigate effects of the sedimentation.

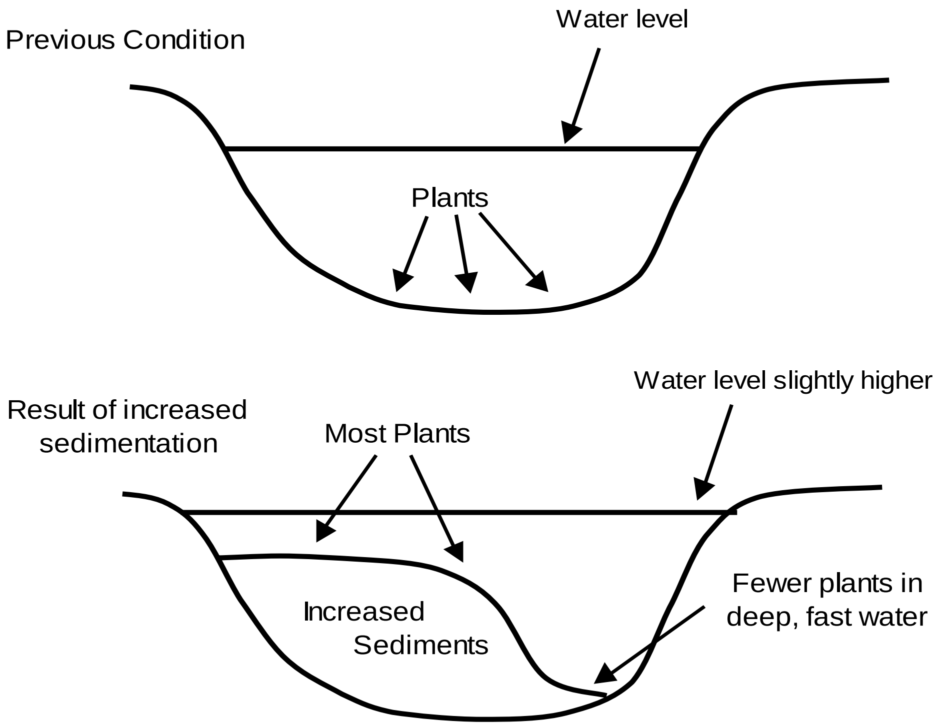

Figure 4.2-1. Diagrammatic Representation of Increased Sediment Loads in the San Marcos River Downstream of Sessoms Creek.

4.3 Downstream Waters

4.3.1 Cagle's Map Turtle

Recent studies conducted on species-habitat relationships of the Cagle's map turtle indicate a myriad of ecological factors potentially influencing population abundance. Major life requisites include: water velocity, water level, abundance of particular species of riverbank vegetation including willow (*Salix spp*.), riffle areas that provide habitat for aquatic insects that are a major food source for the turtle, and the availability of basking and nesting sites on the river that are affected by releases of impounded water (Sections 3.1.3.9 in Appendix 3). Consequently, the definition of take as a direct result of decreased springflow cannot be quantified or estimated. The Authority recognizes that declines in the population of Cagle's map turtle may be affected in part by reduced flows in the Guadalupe River resulting from reduced springflow. Ecological benefits to the Comal and San Marcos Springs ecosystems resulting from protection of springflow through those measures included in the EAHCP would also extend to Cagle's map turtle, as springflow protection measures would also result in moderating declines in river flows downstream during drought conditions, assuming river flows are passed through existing impoundments. Findings from Killebrew et al. (2002) suggest changes in stream flow resulting from operation of on-channel dams in support of hydroelectric generation may have as much or greater adverse effect on the turtle than prolonged low-flow conditions.

4.3.2 Whooping Crane

Recent studies suggest decreased instream flows in the Guadalupe River and associated decline in freshwater inflow into the Guadalupe Estuary could indirectly influence the health of endangered whooping cranes by affecting the production of blue crabs, a primary food source (Sections 3.1.3.10 in Appendix 3). Evidence also indicates that, as coastal marsh salinities exceed 23 parts per thousand, whooping cranes begin moving to other areas to obtain fresh water to drink, exposing them to new territory and change in daily habits with attendant risk for increased injury or mortality. The Authority recognizes that take of the whooping crane resulting from either reduced habitat suitability through changes in food availability or increased salinities in the estuary could occur from indirect effects of reduced flows into the Guadalupe River Estuary as affected by reduced springflow. However, the definition of take as a direct result of decreased springflow cannot be quantified or estimated. Ecological benefits to the Comal and San Marcos Springs ecosystems resulting from protection of springflow through those measures included in the EAHCP would also extend to the whooping crane, as springflow protection measures would also result in moderating declines in river flows downstream, thus also moderating declines in freshwater inflow into the Guadalupe Estuary and concurrent decline in the quality of whooping crane habitat. Ecological benefits from springflow contributions to the lower Guadalupe River could be affected by downstream water development projects. Current studies are ongoing to assess impacts to the Guadalupe Estuary from the proposed Lower Guadalupe River Diversion Project SCTN-16 (Appendix 1).

4.4 Impact Assessment Methodology and Evaluation of the Proposed EAHCP

To best examine the potential impacts of the proposed HCP on the diversity of species associated with the Edwards Aquifer and its two largest spring systems, Comal and San Marcos Springs, the initial focus must be on existing conditions and trends that have occurred during the recorded history. Thus, a detailed assessment of the hydrologic conditions in the recorded history was conducted, and potential scenarios for future management of the aquifer were evaluated in conjunction with species-specific biological information. A summary of the founding concept and methodologies used as well as the final determination of the potential impact of the proposed HCP are presented here.

A host of environmental attributes shapes the partitioning of habitat and controls distributions of the various species in the Comal and San Marcos Springs ecosystems. These attributes include flow (depth and velocity), temperature, substrate size and distribution, oxygen content, turbidity, and other physical and chemical conditions that combine with biotic influences to control population dynamics of individual species (USFWS 1996). Although each of these parameters is important individually, they are influenced by springflow as a group. Consequently, perpetuation of native aquatic biodiversity and ecosystem integrity depends upon maintaining or restoring some semblance of natural flow variability (e.g. Minckley and Meffe 1987; Kinsolving and Bain 1993; Walker and Thoms 1993; Sparks 1992; Richter et al. 1996). The potential for survival of native species and natural communities is reduced if conditions in the environment are forced outside of their ranges of natural variability (Resh et al. 1998; Swanson et al. 1993).

In instances where natural flow variability can be maintained or restored (i.e., modifying a single parameter and restoring the ecosystem to pre-human contact), benefits to the native community are greatest. However, this is an unrealistic scenario in most cases, and implausible in the Comal and San Marcos ecosystems. These two spring ecosystems have been substantially altered by man. Alterations have included placement of dams, extensive channelization, high recreational demands, extensive development in the riparian zone, storm water runoff, non-point source pollution, aquifer pumping, exotic species introduction (including parasites on native species), et cetera. These alterations have caused major impacts upon the makeup and interactions of the residing aquatic communities over the past 70 years. The species in these two systems have adjusted to these conditions. Changes, including an increase in springflow to levels that occurred prior to these activities, would affect the community in ways that cannot be predicted. Therefore, the premise to the analysis presented here is: maintaining a flow regime similar to the recorded hydrograph, taking into consideration species-specific biological needs, will provide the most reliable means of limiting the impact upon endangered and threatened species in the Comal and San Marcos Springs ecosystems.

Regarding species-specific biological requirements, the factor most frequently discussed with concern to all species is the quantity of springflow. With the exception of the San Marcos gambusia, each of the species of concern is currently present in its respective spring ecosystem, which might be interpreted to indicate persistence through the drought of record (the fountain darter was reintroduced into Comal Springs after the drought of record occurred and the San Marcos gambusia was sampled subsequent to the drought of record). Thus, it could be expected that these species would continue to survive if environmental conditions were to resemble the recorded history. The caveat to this expectation is that a conservative strategy should be the goal at very low flows. For example, while there is no clear evidence that the lack of flow from Comal Springs was the causative event for the disappearance of the fountain darter in that system in the 1950s (a rotenone poisoning probably also contributed [Linam et. al 1993; Schenck and Whiteside 1976]), any period of zero flow would introduce the potential for reduced survival of some species. Maintaining a hydrograph similar to that of recorded history, while providing a measure of safety against periods of zero flow, would provide the best means of protecting the aquatic community as a whole and also meet the goal of survival of the EAHCP species.

4.4.1 Impact Assessment

The biological impact assessments for the Comal and San Marcos Springs ecosystems were conducted in two phases. The first phase involved examining the variability of streamflow to evaluate each aquatic ecosystem as a whole. This approach focused solely on the recorded hydrograph and how closely each management scenario would allow a future hydrograph to reproduce it. The second phase involved a discussion of the best available biological information as it relates to past and projected springflows. Incorporating the information available in Phase 2 with the findings of Phase 1 resulted in a conservative approach that focuses on the ecosystem health as a whole, but takes into consideration the needs of individual species.

Phase 1

This phase began with an examination of the long-term streamflow data for Comal and San Marcos Springs to create statistical descriptions of recorded flow variability and identify springflow targets. Figures 4.4-1 and 4.4-2 present the recorded hydrographs for both the Comal and San Marcos Springs, respectively. These figures detail the variability that has occurred in the two systems during the recorded history.

Using the Edwards Aquifer groundwater simulation model (GWSIM-IV), LBG-Guyton conducted a series of model runs to predict the impact of a range of aquifer withdrawal conditions on Comal and San Marcos springflows, including scenarios with critical period management reductions included. The period of record chosen for their model runs and all hydrologic analyses for Comal Springs was 1934-1989 (the period of recharge data available from the US Geological Survey (USGS)). Although recharge estimates for the region since 1989, they have not been distributed into model input data sets. Use of the GWSIM IV model represents the best available data. However, it is widely accepted that placing great emphasis on specific predicted outcomes from the model is not recommended. Consequently, the Authority is optimistic that the new aquifer model under development by the U.S. Geological Survey will serve as a better predictive instrument.

There were two components of the initial Indicators of Hydrologic Alteration (IHA) results that suggested that running the analysis for additional time periods would enhance the evaluation. Due to the intensity of the drought of record, the results suggest that only a dramatic reduction in future annual withdrawals, possibly below levels that maintain human health and safety, would maintain conditions similar to those in recorded history. Thus, two additional time frames were chosen for analyses, the period of record excluding annual recharge during the drought of record (1950-1957) and the period of time between when the fountain darter was reintroduced into Comal Springs and the last year of USGS calculated recharge (1975-1989).

LBG-Guyton noted that the influence of groundwater pumpage is considerably greater in the Comal Springs ecosystem, and the range of springflow conditions in the San Marcos Springs ecosystem changes little with respect to various annual withdrawal scenarios. Based upon this observation, IHA evaluations of the potential impacts of each Edwards Aquifer annual withdrawal scenario were conducted for the Comal Springs ecosystem; potential impacts in the San Marcos Springs ecosystem were discussed qualitatively. Finally, because these evaluations were based upon the modeling outputs of the GWSIM-IV model, they are directly correlated with the validity of those model results.

Phase 1 (Hydrologic Alteration)

The highest attainment rate (closest fit to the target range) for the 33 IHA parameters fell within the 150,000 acre-feet per year and 250,000 acre-feet per year annual withdrawal range. Based upon this analysis, the period-of-record hydrograph would be matched most closely with annual withdrawals that fall in this range.

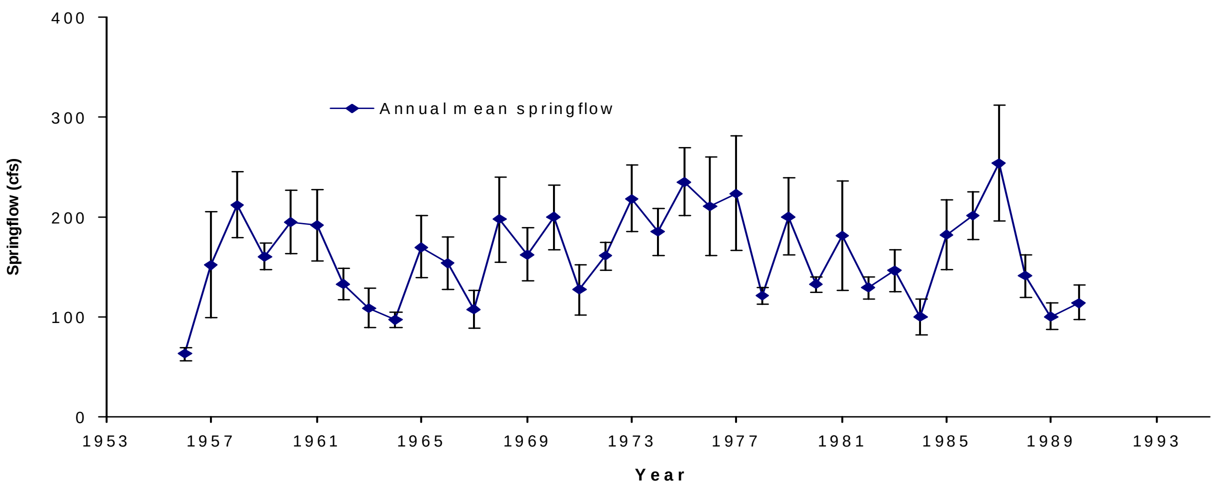

Figure 4.4-1. Recorded annual mean springflow from San Marcos Springs, 1956-1989, at USGS gauge 08170500. Error Bars represent +/- one standard deviation of monthly means from the annual mean.

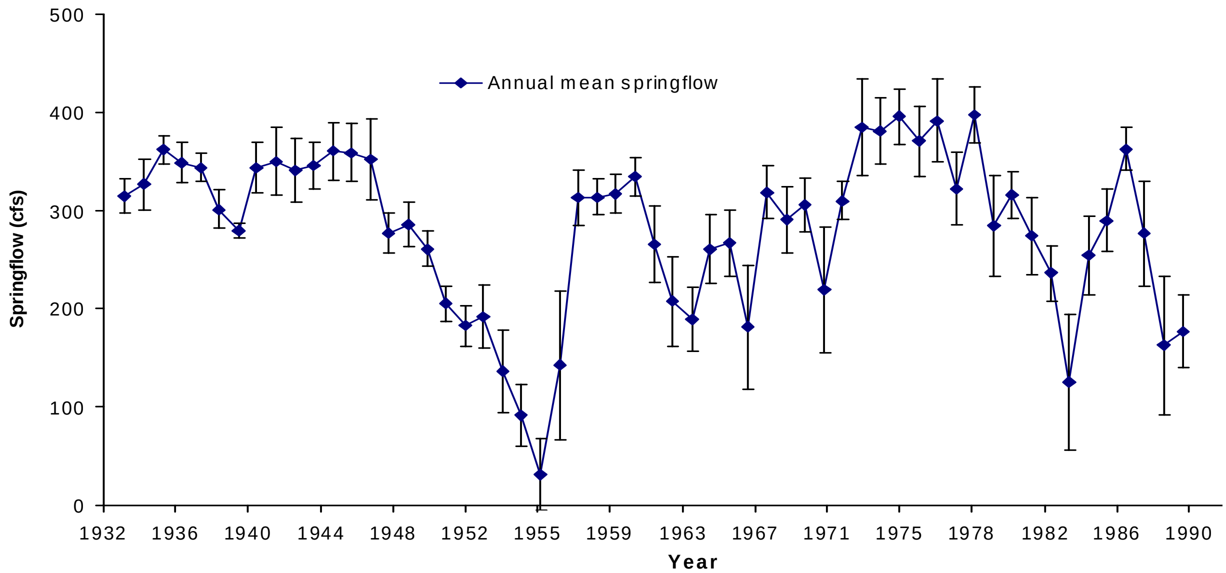

Figure 4.4-2. Recorded annual mean springflow from Comal Springs, 1934-1989, at USGS gauge 08169000. (Error Bars represent +/- one standard deviation of monthly means from the annual mean.)

Although annual withdrawal scenarios below 125,000 acre-feet/year produce springflow in excess of 100 cfs all the time, the IHA analysis shows that these scenarios increase discharge considerably relative to recorded conditions and result in moderate hydrologic alteration. According to the period-of-record analysis, hydrologic alteration is considerable when annual withdrawals increase above 375,000 acre-feet per year without any critical period reductions. Several scenarios with critical period measures fell below this threshold of "high" hydrologic risk for future impacts. The hydrologic alteration associated with the two additional time periods modeled were also evaluated. In general, the hydrologic alteration was dampened when additional data sets were used that excluded the drought of record and looked separately at the period of time since the fountain darter was reintroduced at Comal Springs.

Phase 2 (Biological Risk)

For this phase, we examined the available information regarding impacts upon the flora and fauna within the Comal and San Marcos Springs ecosystems relative to the amount and quality of usable habitat that remains available to each species. Because of the dynamic nature of stream ecosystems, the amount of suitable habitat available to each species fluctuates in response to a number of variables. One of the most significant of these is streamflow. Periods of drought pose risks to many of the species in both the Comal and San Marcos Springs ecosystems because of the resulting periods of low flow and potential loss of suitable habitat. Other requirements for suitable habitat include such parameters as adequate water quality; preferred vegetation composition; low incidence of competitive, non-native species; and other more species-specific conditions.

4.4.2 Risk Categories

Information gathered under Phases 1 (hydrologic alteration) and 2 (biological risk) was used to divide each component into four categories: low, moderate, high, and severe, as indications of deviation from historical conditions. Categories were developed independently for each risk factor, and the proposed HCP has one ranking for each to fully evaluate the anticipated impact of a water management scenario.

For hydrologic alteration, the lowest index value indicates the closest approximation of historic conditions. Because there appears to be an exponential increase in values extending from the lowest to greatest deviation from historic conditions, the rankings with the smallest range compirse the low category; greater ranges were given to higher risk categories. Biological risk is based upon the requisite species information from Phase 2 and the number of days that a particular alternative reduces springflow to critical discharge values. Critical discharge values reflect the potential for negative effects on the EAHCP species. Based upon a review of existing literature and ongoing studies, spring discharge below 100 cfs (combined flow at Comal Springs) was chosen as a trigger for when fountain darter populations may experience noticeable effects. Frequent and/or lengthy periods of time at or below this value could have negative impacts upon the populations. Other critical values that were included in the calculation of biological risk are 60 and 30 cfs, because negative impacts increase with decreasing flows. Ultimately, at 0 cfs, negative impacts may occur to all components of the aquatic biological community. To incorporate all of these critical discharge values into a single risk factor, the length of time that an alternative reduces flow to each of these levels was assigned a weighted value. The weighting factors account for the progressively higher impacts at the lower critical discharge values (i.e., declining to 0 or 30 cfs discharge yields a higher impact than a decline to 100 cfs). The resulting values for the critical discharge levels are summed into a single index value, which can be used to assess a given scenario in the proposed HCP relative to biological risk.

Both hydrologic alteration and biological risk are discussed below for each of the three time frames used in the evaluation. These include the period of record, the period of record excluding the drought of record, and the last 15 years of calculated recharge. For a comparison that includes all three of these time frames to assess future risk, the period of record serves as the worst-case scenario of conditions that have a low probability of recurrence; the period of record without the drought of record compares alternatives under the next most serious drought conditions; and the 1975-1989 analysis allows a comparison during relatively good conditions with moderate, short-term droughts.

4.4.3 Evaluation of Proposed HCP

There is no way to predict exactly how much recharge will occur in the future, therefore, modeling for each of the alternatives was conducted using the period of record to predict future recharge. This includes a significant drought that lasted from 1950 to 1956 and was the most prolonged period of sustained drought in the past 347 years, according to tree-ring analysis conducted by Therrell (2000). With this event included in the analysis, extended periods of zero flow in the Comal River are predicted under the proposed HCP. Regardless of the conditions applied for the proposed HCP, springflows cannot be guaranteed, since the amount of recharge is a direct response to the amount of rainfall received. Although periods of zero flow may be detrimental to many species, such conditions have occurred in the past, and each of the species currently listed as threatened or endangered either survived or has been successfully reintroduced. There is little biological data for either the Comal or San Marcos Springs/River ecosystems before or immediately after the drought of record to fully describe the short-term impacts of zero springflow in the Comal Springs/River ecosystem. A rotenone treatment of Landa Lake conducted by the Texas Fish, Game, and Oyster Commission prior to the drought probably exacerbated the biological impacts of the drought. However, over time, each ecosystem has recovered from periods of reduced habitat and populations of individual species increased as habitat was restored.

Hydrologic alteration and biological risk categories were assigned to alternatives considered in this analysis. The specific impacts to the ecosystem and individual species will vary between and within risk categories. These categories serve to estimate the overall relative impact of the proposed HCP. Potential improvements to the risk category ranking as a result of alternative measures are also discussed. Those measures that would directly affect aquifer levels and resulting surface discharge at Comal Springs, San Marcos Springs, and other springs within the jurisdiction of the Edwards Aquifer Authority may decrease the potential risk and affect the risk category ranking.

Regional Permit, Authority Proposed Habitat Conservation Plan

During the period of record, there were 144 days in which the Comal River was at zero flow, 237 days at or below 30 cfs, 523 days at or below 60 cfs, and 1,148 days at or below 100 cfs. Although the springs stopped flowing in the Comal River during the drought of record, water was still present in Landa Lake (Figure 3.1-4c and Figure 3.1-4d). Compared with these numbers, the Edwards Aquifer groundwater simulation model (GWSIM-IV) indicates that an approximation of the proposed HCP would result in more time at or below these thresholds over the same time period. Although the model can indicate the amount of time at zero flow, it does not indicate whether Landa Lake will dry completely or maintain pools as during the drought of record. Using the model, a 450,000 acre-feet-per-year annual withdrawal level, under regular permits under certain aquifer conditions over the period of record with critical period reductions, would result in over 2,400 days at or below 30 cfs, and more than 1,400 days at zero flow. This is nearly ten times the number of days that Comal Springs actually went dry during the period of record (144 days). This decreases in the analysis with the drought of record excluded, but would still result in approximately 100 days at zero flow and slightly more than 400 days at 30 cfs, at a 450,000 acre-feet-per-year annual withdrawal level under regular permits under certain aquifer conditions. Employing the last 15 years of recharge data (1975-1989) the model predicts fewer than 5 days at or below 30 cfs with the same annual withdrawal scenario.

Calculations of biological risk from these raw data and hydrologic alteration from IHA analysis result in the following rankings for the proposed HCP. Over the period of record a ranking of high hydrologic alteration and severe biological risk would occur through the life of the permit. The analysis for the proposed HCP over the period of record with the drought of record excluded also shows high hydrologic alteration, but a drop in biological risk from severe to high. Over the last 15 years of recharge data (1975-1989) the anticipated hydrologic alteration would be moderate and biological risk would be low through the life of the ITP.

The EAHCP identifies numerous measures designed to minimize risk to the species. The Authority will facilitate and participate to the extent practicable in developing Edwards recharge enhancement structures (Measure 1.1) which are expected to increase discharge at Comal and San Marcos Springs by approximately 80,000 acre-feet per year. This is a relatively large amount of additional water that could improve hydrologic alteration and biological risk categories. This water would be most valuable during a time of minimal recharge, when the recharge capacity of a moderate rainfall event could be magnified. Since the impacts cannot be quantitatively predicted with any accuracy, a qualitative assessment is necessary. This would have the effect of lowering hydrologic and biological risk, but may not provide enough additional springflow during critical times to affect the risk category rankings. Precipitation enhancement (Measure 1.2), Water quality protection (Measure 1.3), and Water conservation and reuse requirements (Measure 1.4) would also occur under the proposed HCP and are expected to increase aquifer recharge and reduce pumping demand, although actual effects cannot be quantified.

As evident above, an analysis of the proposed HCP that takes into account the drought of record indicates an increased probability of very low flows for extended periods of time. If a repeat of these conditions occurs, off-site refugia and captive propagation will be mandatory to ensure the continued survival of the species. The following captive propagation measures under the proposed HCP would have no direct impacts, but could play a vital role in the survival of these species under periods of adverse environmental conditions, thus indirectly impacting the spring ecosystems:

- Assist with funding field collection and distribution of species to refugia (Measure 4.1);
- Assist with funding refugia for existing stock (Measures 4.3, and 4.4);
- Assist with funding salvage of additional species for refugia, (Measures 4.5); and
- Funding costs for labor to manage and maintain refugia (Measure 4.6).

In addition to off-site refugia, intensive management areas are a possible measure that may reduce the dependence on off-site refugia as the primary means of protecting species during critical low flows. Funding to study and implement such strategies would be available under the proposed HCP (Measures 6.2 and 6.3). Maintaining species in their habitats during critical low flows would provide a substantially better option for the well-being of the species than having to remove individuals and temporarily sustain them until conditions improve. With intensive management areas in place, biological risk may be reduced to a lower category. Under the assumption that intensive management could maintain 60 cfs in the Comal River with sufficient quality to continue to maintain species in the wild, biological risk could be reduced from high to moderate over the period of record with the drought of record excluded (Table 4.4-1).

Table 4.4-1. Comparison of hydrologic alteration and biological risk of proposed HCP at Comal Springs with and without intensive management in place over each of the three time periods used in IHA analysis.

Alternative	Annual Withdrawal Level (acre-feet) under regular permit under certain aquifer conditions	Critical Period Percent Reductions	Hydrologic Alternation/Biological Risk		
			1934-1989	1934-1949 & 1958-1989	1975-1989
Proposed HCP	450,000	as proposed	High / Severe	High / High	Mod / Low
Proposed HCP (w/ intensive management areas)	450,000	as proposed	High / Severe	High / Mod[a]	Mod / Low

[a] With assumption that intensive management maintains 60 cfs and maintains species in the wild.

The following Adaptive Management Strategies included for the proposed HCP would have no direct impacts on the EAHCP species, but could provide information that would play an important role in further assessing species-specific and/or ecosystem-wide adaptations to the EAHCP:

- Aquatic vegetation enhancement/restoration (5.1, 5.2);
- Continued evaluation of aquatic vegetation response to low flow/elevated temperature (5.3);
- Management and research to determine parasite impact upon the fountain darter (5.4);
- Continued evaluation of drought survival mechanisms of the Comal Springs riffle beetle; low-flow laboratory evaluation, and subsequent field-based study of hyporheic population density (preliminary study completed) (5.7);
- Determination of life history requirements of the three endangered invertebrates, including population dynamics, distribution, tolerance/sensitivity (temperature, water quality, contaminants), and reproduction (5.8); and
- Development and implementation of a management plan for vegetation mat removal during low flow (5.10).

The remaining proposed HCP Adaptive Management Strategies would not have any direct impacts upon EAHCP species, but would eventually lead to better management of the Edwards Aquifer, thus ultimately leading to enhanced protection of the spring systems:

- Improve accuracy of USGS gauge below Spring Lake (5.5);
- Establish discharge monitoring gauge on Old (original) Channel of Comal River (5.6); and
- Establish water quality monitoring network of three wells near San Marcos and Comal Springs (5.9).

The research proposed for each of the EAHCP species could provide critical information for managing populations during periods of low flow. Careful monitoring and management actions designed to protect the EAHCP species during those periods could greatly improve the probability of survival of each.

All Edwards Aquifer Optimization Technical Studies and Other Technical Studies (Measures 6.1 through 6.3) would be funded under the proposed HCP. Although these studies would have no impacts upon aquatic ecosystems, they may provide valuable input and benefit management of the species and their habitats to improve the likelihood of survival for each EAHCP species.

Other Springs

Given the widely varying springflow changes indicated by the historical record for Hueco and Leona Springs, they might experience erratic low flows or a flow stoppage under the proposed HCP which may be expected to cause high-to-severe hydrologic alteration and high-to-severe biological risk under each of the time frames evaluated. Under historic and current conditions, the San Antonio and San Pedro Springs have been known to stop flowing on a regular basis.

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Chapter 5 Measures to Minimize Potential Impacts

The following discussion addresses the actions that the Authority proposes to undertake to minimize the potential effects of permitted water withdrawals on springflows and the Covered Species that depend upon them at Comal and San Marcos Springs. These actions establish water withdrawal limits during drought conditions in a manner that diminishes potential adverse effects to the Covered Species. These actions are included in Table 5-1 below.

The proposed EAHCP will provide for a 50-year regional 10(a) Permit that, during DM/CPM, will require pumping to be reduced to 346,400 acre-feet per year, if the worst drought conditions were in effect for an entire calendar year.

5.1 Comprehensive Aquifer Management

Aquifer management under the proposed HCP would be consistent with the Authority's 30-year Water Supply Plan, which is a part of the Comprehensive Water Management Plan (CWMP) mandated by the EAA Act. For the development of the CWMP, the Authority has generally adopted the planning methods and assumptions specified for the Texas Senate Bill 1 (SB1) regional water plans. These plans, pursuant to SB1 and associated rules of the TWDB, are intended to assess the current and projected water demands and availability of current water supplies, to identify water supply needs, and to evaluate and recommend strategies for meeting the identified water needs. Aquifer management may include implementation of the following measures:

1.1 Edwards Recharge and/or Recirculation Enhancement Features;

1.2 Precipitation Enhancement Program (South Central Texas Regional Water Plan Strategy SCTN-5);

1.3 Water Quality Protection (Chapter 713, Edwards Aquifer Authority Rules);

1.4 Water Conservation and Reuse Requirements (Chapter 715, Subchapter C, Authority Rules); and

1.5 Implementation of alternative management practices, procedures, or methods allowed by the EAA Act that are currently undefined or unidentified.

Table 5-1 Summary of HCP measures (revised February, 2005)

Summary of HCP Measures
1.0 Edwards Aquifer Management Strategies Consistent with EAA 30-year Water Supply Plan (a part of the Comprehensive Water Management Plan)
1.1 Edwards recharge and/or recirculation enhancement features.
1.2 Precipitation enhancement (South Central Texas Regional Water Plan SCTN-5).
1.3 Water quality protection (Chapter 713, Edwards Aquifer Authority Rules).
1.4 Water conservation and reuse requirements (Chapter 715, Subchapter C, Authority Rules†).
1.5 Implementation of alternative management practices, procedures, or methods allowed by the EAA Act that are currently undefined or unidentified. The Authority will provide financial support to the Service in the event the Service seeks Federal funds for recharge projects specifically intended to support additional springflow during drought and/or augmentation of stream flow or springflow.
2.0 Aquifer Pumping Withdrawals
2.1 Pumping withdrawals will be determined by initial and additional regular permits above aquifer level 665' as measured by Index Well J-17 and above 865' as measured by Index Well J-27**.** Aquifer withdrawals will be reduced to 449,950 acre-feet per year when aquifer levels fall below 665' for J-17 and 865' for J-27.
3.0 Demand Management/Critical Period Management
3.1 When the aquifer level declines to 665, total pumpage will be 449,950 ac-ft/yr. Annual water budget required for each pumper, with four stage DM/CPM reductions when the aquifer reaches the following levels: Stage 1 (J-17 =650': maximum pumpage = 436,300 ac-ft/yr; Stage II (J-17 =640: maximum pumpage = 422,800 ac-ft/yr.; Stage III(J-17=630 or J-27=845: maximum pumpage =382,000 ac-ft/yr; Stage IV (J-17= 627 or J-27 = 842: maximum pumpage = 346,400 ac-ft/yr).
4.0 Captive Propagation
4.1 Assist with funding field collection and distribution of species to refugia.
4.2 Assist with funding new salamander facility at the San Marcos National Fish Hatchery.
4.3 Assist with funding refugia for existing captive stock at San Marcos National Fish Hatchery.
4.4 Assist with funding refugia for existing captive stock at Uvalde National Fish Hatchery.
4.5 Assist with funding salvage of additional species for refugia.
4.6 Fund costs for personnel labor to manage and maintain refugia.
5.0 Adaptive Management Strategies
5.1 Aquatic vegetation enhancement (reintroduction/establishment of native species) in select areas.
5.2 Aquatic vegetation restoration (reintroduction/reestablishment of native species) after low-flow events.
5.3 Continued evaluation of aquatic vegetation responses to low flow/elevated temperature.
5.4 Management/research to determine parasite impact to fountain darter (current EAA Variable Flow Study).

Table 5 (continued)

5.5 Improve accuracy of USGS gauges below Spring Lake and Landa Lake (ongoing).
5.6 Establish discharge monitoring gauge on Old Channel of Comal River.
5.7 Continue evaluation of drought survival mechanisms of the Comal Springs riffle beetle; low-flow laboratory evaluations, and subsequent field-based study of hyporheic population density (preliminary study completed).
5.8 Determine life history requirements of the three endangered invertebrates, including population dynamics, distribution, tolerance/sensitivity (temperature, water quality, contaminants), and reproduction.
5.9 Establish water quality monitoring network of three wells near Comal and San Marcos Springs.
5.10 Develop and implement management plan for vegetation mat removal during low flow.
5.11 Refine estimate of amount of pumpage from exempt wells.
5.12 Determine effects of contaminants on Covered Species.
5.13 Determine gains and losses to instream flows in the Guadalupe River.
6.0 Edwards Aquifer Optimization Technical Studies
Biological Assessment Studies
6.1 Water Quality/Variable Flow Monitoring Study (ongoing).
Studies to Determine Feasibility of Providing Supplemental Water to Spring Ecosystems
6.2 Studies to determine tolerance of individual species to the ranges of various water quality parameters expected with on-site intensive management areas.
6.3 Pilot study of intensive management areas in both the San Marcos and Comal Rivers.

† Rules have been proposed but have not yet been adopted by the Authority Board.

5.2 Demand Management/Critical Period Management

The Authority's rules currently provide for a DM/CPM program. *See* EAA RULES CH. 715, SUBCH. D. The Authority may, from time to time, amend its current rules if the effect of the amendment is to maintain the baseline springflows described in the proposed EAHCP. As presently implemented, the EAHCP involves a four-stage DM/CPM that would interrupt certain authorizations to withdraw groundwater from the aquifer during certain low index-well or springflow conditions. The DM/CPM would not apply to withdrawals made from exempt wells, monitoring wells, or recharge recovery wells, or under emergency permits. However, the DM/CPM would reduce withdrawals under initial and additional regular permits to a maximum limit of 346,400 acre-feet per year, assuming the reductions were in effect for an entire calendar year (Table 5.2-1). Each owner of an initial regular permit will submit to the Authority for approval a quarterly withdrawal schedule, to include anticipated withdrawals.

Table 5.2-1 Aquifer withdrawals.*

	San Antonio Pool		Uvalde Pool		
DM/CPM Stage	**J-17 Index Well Trigger**	**Pumpage (Acre-feet/Year)**	**J-27 Index Well Trigger**	**Pumpage (Acre-feet/year)**	**Total Pumpage (Acre-feet/year)**
	665'	355,750	865	94,200	449,950
I	650'	342,100	Not Applicable	94,200	436,300
II	640'	328,600	Not Applicable	94,200	422,800
III	630'	302,400	845	80,100	382,500
IV	627'	273,900	842	72,500	346,400

*Withdrawals if aquifer remains at designated level for one calendar year.

For initial regular permits and interim authorization status, the DM/CPM will establish an annual water budget with quarterly withdrawal schedules and, in the event low aquifer levels and/or springflow triggers in the DM/CPM are reached, critical period reductions to 346,400 acre-feet per year. The four-stage DM/CPM will require withdrawal reductions in both the San Antonio and Uvalde pools according to the schedule and triggers noted below.

5.2.1 San Antonio Pool

As presently implemented, Demand Management Stage I will involve a reduction to 342,000 acre-feet per year (except for crop irrigation), triggered by any one of the following events:

- the J-17 index well level falling below 650 ft. msl; *or*

- the San Marcos Springs average 5-day flow falling below 110 cfs; *or*
- Comal Springs average 5-day flow falling below 220 cfs.

Demand Management Stage II would involve a reduction to 328,600 acre-feet per year (except for crop irrigation), triggered by any one of the following events:

- the J-17 index well level falling below 640 ft. msl; *or*
- the San Marcos Springs average 5-day flow falling below 96 cfs; *or*
- Comal Springs average 5-day flow falling below 154 cfs.

Critical Period Stage III would involve a reduction to 302,400 acre-feet per year (including crop irrigation), triggered by any one of the following events:

- the J-17 index well falling below 630 ft. msl; *or*
- the San Marcos Springs average 5-day flow falling below 80 cfs; *or*
- Comal Springs average 5-day flow falling below 86 cfs.

Critical Period Stage IV would involve a reduction to 273,900 acre-feet per year (including crop irrigation) if, 30 days after commencement of Stage III Critical Period, the level of the J-17 index well remains below 630 ft. msl or reaches 627 ft. msl.

5.2.2 Uvalde Pool

As presently implemented, the Stage III-Critical Period for the Uvalde Pool will involve a reduction to 80,100 acre-feet per year, triggered by the J-27 index well level falling below 845 ft. msl. Stage IV Critical Period reductions to 72,500 acre-feet per year for the Uvalde Pool would be triggered if the water level at the J-27 Index Well is less than 845 ft. msl 30 days after the commencement of Stage III Critical Period.

5.2.3 Other Aquifer Management Strategies

The Authority may also pursue additional management strategies for the Edwards Aquifer consistent with the EAA 30-year Water Supply Plan, a part of the CWMP (Appendix 1). These strategies include:

- Alternative water management strategies, practices, procedures, or methods of any kind satisfying the requirements of §§ 715.12 and 715.220 of the Authority's rules.

- Recharge structures that are built and authorized by a recharge recovery permit pursuant to Authority rules. Water available for aquifer withdrawal under this option will be determined in accordance with a recovery permit issued pursuant to Authority rules.

- Precipitation Enhancement Program (South Central Texas Regional Water Plan Management Strategy SCTN-5, Appendix 1, Section 3.2.4). Precipitation enhancement (Measure 1.2) is expected to increase rainfall, runoff, and aquifer recharge, while reducing irrigation demand in all of the river basins, although actual effects have not been quantified.

- Measure 1.3, Water quality protection (Chapter 713, Edwards Aquifer Authority Rules), includes as Final Authority Rules Subchapters A-G, which set out provisions to regulate well construction, operation, and maintenance (A-F) and regulated-substance tanks (G). The rules are designed to protect water quality in the Edwards Aquifer as well as aquifer-related resources such as the Comal and San Marcos springs ecosystems. Additional rules to protect surface water quality in the recharge and contributing zones of the aquifer are under consideration by the Authority.

- Measure 1.4, Water conservation and reuse requirements (Chapter 715, Subchapter C, Authority Proposed Rules), includes proposed rules (Subchapter C, Part 1) that would require municipal, industrial, and irrigation users to implement best management practices within the context of individual groundwater conservation plans.

- Implementation of alternative management practices, procedures, or methods allowed by the EAA Act (Measure 1.5) that are currently undefined or unidentified.

The San Antonio Water System (SAWS) has completed construction of an Aquifer Storage and Recovery (ASR) project (South Central Texas Regional Water Plan Management Strategy SCTN 1-a, Appendix 1, Section 3.2.13). The primary purpose of the SAWS ASR project is to store large quantities of water for future use. Located in southeastern Bexar County, the ASR project uses the Carrizo Aquifer as a facility to store Edwards water during periods of rainfall excess for withdrawal during dry periods. Sixteen wells and a 60-inch transport pipeline have been completed. As of December 2004, more than one billion gallons (3,545 acre-feet) of Edwards water had been injected into this sand aquifer. The ASR project is expected to initially store 11,250 acre-feet and will expand to 22,500 acre-feet in later years.

In a separate effort, SAWS has initiated construction of a large water development project within the Carrizo-Wilcox aquifer in Wilson and Atascosa Counties, involving construction of well fields, pump stations, and a water transport pipeline to San Antonio.

Chapter 6 Measures to Mitigate and Monitor Potential Impacts

The EAHCP includes measures intended to mitigate and monitor impacts resulting from the actions covered by the ITP. These measures fall into three categories: captive propagation, adaptive management strategies, and Edwards Aquifer Optimization Technical Studies. Springflow at Comal and San Marcos Springs may decline to levels at which take is expected to occur, even with the DM/CPM measures identified above. This is expected to occur infrequently during the ITP period, however, the mitigation and monitoring measures listed below are intended to provide the means to anticipate and respond to events or circumstances that might adversely affect populations of the Covered Species.

The priorities and appropriate levels of effort for each of the specific measures listed below will be established initially by the EAA Research and Technology and Committee and refined during the development and implementation of the Adaptive Management Program (AMP) discussed in more detail in Chapter 7 Adaptive Management Program. The AMP will provide the structure and guidance for coordination and integration of conservation activities for the Covered Species at Comal and San Marcos Springs.

Activities identified below will be undertaken within the constraints of funding from the Authority's annual budget and endowment, as well as other funding sources, including but not limited to support from local, state, and federal agencies, and non-governmental organizations.

6.1 Captive Propagation

The following measures are focused upon the development of active breeding populations of the Covered Species in locations or facilities not dependent upon the same factors affecting the natural populations at Comal and San Marcos Springs. These populations should be of the same genetic makeup as the natural populations and provide a source for reestablishment of the natural populations if conditions at the springs result in local extirpation. Reference numbers correspond with HCP measures listed in Table 5-1.

4.1 Assist with funding field collection and distribution of species to refugia.

4.3 Assist with funding refugia for existing captive stock at San Marcos National Fish Hatchery.

4.4 Assist with funding refugia for existing captive stock at Uvalde National Fish Hatchery.

4.5 Assist with funding salvage of additional species for refugia.

4.6 Fund costs for personnel labor to manage and maintain refugia.

6.2 Adaptive Management Strategies

The following measures will provide data and information that are critical to the development and implementation of the AMP. Reference numbers correspond to HCP measures listed in Table 5-1.

5.1 Enhance aquatic vegetation (reintroduction/establishment of native species) in select areas.

5.2 Restore aquatic vegetation (reintroduction/reestablishment of native species) after low-flow events.

5.3 Continue to evaluate aquatic vegetation responses to low flow/elevated temperature (current EAA Variable Flow Study).

5.4 Determine parasite impact upon fountain darter through management/research (current EAA Variable Flow Study).

5.5 Improve accuracy of USGS gauges below Spring Lake and Landa Lake (ongoing).

5.6 Establish discharge monitoring gauge on Old Channel of Comal River.

5.7 Continue to evaluate drought survival mechanisms of the Comal Springs riffle beetle through low-flow laboratory evaluations and subsequent field-based study of hyporheic population density (preliminary study completed).

5.8 Determine life history requirements of the three endangered invertebrates, including population dynamics, distribution, tolerance/sensitivity (temperature, water quality, contaminants), and reproduction.

5.9 Monitor water quality of spring discharge and at three monitor wells near Comal and San Marcos Springs. Analytes will include common ions, pH, temperature, metals, pesticides, VOCs, and other constituents that have the potential to harm the Covered Species.

5.10 Develop and implement a management plan for vegetation mat removal during low flow.

5.11 Refine estimate of amount of pumpage from exempt wells.

5.12 Determine effects of contaminants (e.g., pesticides, VOCs) on Covered Species.

5.13 Determine gains and losses to instream flows in the Guadalupe River.

6.3 Edwards Aquifer Optimization Technical Studies

A number of technical studies being undertaken by the Authority support the development of a program to optimize the management of the Edwards Aquifer as well as the EAHCP. These include biological assessments, aquifer flowpath modeling, and evaluation of potential recharge enhancement. Reference numbers correspond with HCP measures listed in Table 5-1.

6.3.1 Biological Assessment Studies

6.1 EAA Water Quality/Variable Flow Monitoring Study. This study will provide better understanding and knowledge of water-quality- and springflow-related habitat requirements of flora and fauna inhabiting Comal and San Marcos Springs for establishing future aquifer operating levels.

6.3.2 Studies to Determine Feasibility of Providing Supplemental Water to Spring Ecosystems

6.2 Studies to determine tolerance of individual species to the ranges of water quality parameters expected with on-site intensive management areas.

6.3 Pilot study of intensive management area plans in both the San Marcos and Comal Rivers.

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Chapter 7 Adaptive Management Program

Based upon the Captive Propagation measures, AMP Strategies, and Edwards Aquifer Optimization Technical Studies, the Authority will implement an AMP with goals and objectives targeted at:

- Guiding long-term monitoring and research planning;
- Further defining critical attributes and linkages within and between resource categories;
- Promoting an improved understanding of key factors that drive changes in the system;
- Making qualitative and quantitative assessments of resource changes resulting from various flow regimes; and
- Providing information to stakeholders and managers regarding the potential impacts/benefits of various flow regimes in the Comal and San Marcos Springs/River ecosystems.

7.1 Biological Goals

The biological goals for the Authority's EAHCP are (1) to secure the survival of the threatened and endangered species in the Comal and San Marcos Springs/River ecosystems; and (2) to maintain or enhance the essential habitat functions of both the Comal and San Marcos Springs/River ecosystems.

7.2 Objectives

The objectives identified in this EAHCP define measurable standards of desired future resource conditions to be achieved by all stakeholders in the Authority's AMP. The biological objectives for the individual species covered in the EAHCP are detailed in the individual species discussions below in Sections 7.8 and 7.9.

7.3 General Management Actions

Overall management actions that will guide the direction of the EAHCP will include:

- Maintain springflows in the Comal and San Marcos Springs/River ecosystems through management of minimum flows during periods of limited recharge by implementing DM/CPM pumping restrictions;
- Develop and implement a monitoring strategy that minimizes impact but increases sampling frequency at lower flows to enhance the likelihood of detecting a critical loss of habitat or decrease in population abundance of Covered Species;
- Develop and implement water quality and instream flow management responses for each species to maximize suitability and availability of the highest quality habitat during low-flow conditions;
- Provide a framework for initiating and carrying out the removal and temporary refuge of individuals of each species in the event that habitat within intensive management areas becomes extremely limited or population numbers decline dramatically;
- Develop and implement management of populations in appropriate refugia;
- Develop and implement a management plan for removal of vegetation mats over aquatic vegetation (including Texas wild-rice);
- Continue educational outreach programs on conservation and water quality protection over the recharge zone; and
- Identify potential sources of contaminants that may harm the Covered Species.

7.4 General Performance Metrics

A process will be developed to evaluate performance of the EAHCP measures and management strategies. These measures and strategies will include:

- Frequency or necessity of DM/CPM pumping restrictions.
- Level of the aquifer as measured t the Bexar County Index Well J-17.
- Total discharge from Comal and San Marcos Springs.
- Monitoring strategy:

  Reliability of estimates of habitat availability and population abundance for each species to track overall ecosystem conditions; and

  Refinement of estimates of mean habitat availability and population abundance as a target for management response criteria.

- Management responses for the protection of high-quality habitat during low-flow conditions:

  Availability of suitable habitat for each HCP species during low flow; and

  Relative abundance of each HCP species during low flow.

- Refugia program:

  Relative abundance of each species requiring intensive management area efforts;

  Survival of appropriate numbers of individuals of each species (specified in the USFWS contingency plan [currently under revision]);

  Propagation under refugia conditions; and

  Successful reestablishment of any species requiring off-site refugia efforts or redistribution of any species requiring intensive management area efforts following the low-flow period.

- Vegetation mat removal program:

  Frequency of mat development between removal efforts; and

  Condition of plants in areas susceptible to mat development.

- Educational outreach program:

  Quantity and quality of materials presented to the general public and cooperative stakeholders;

  Awareness and attitude of general public and cooperative stakeholders to critical issues; and

  Response of general public and cooperative stakeholders toward conserving water and limiting water quality problems over the recharge zone.

- Water quality monitoring for contaminants that may harm the Covered Species.

7.5 Implementation Monitoring

The Authority will ensure that all management objectives are implemented to meet requirements specified in the Performance Metrics through implementation of the AMP and the reporting procedure outlined in Chapter 8.

7.6 Effectiveness Monitoring

7.6.1 DM/CPM Implementation

Under the Authority's current DM/CPM plan, the water levels in index wells J-17 and J-27 and discharge from the Comal and San Marcos Rivers all serve as triggers that initiate pumping restrictions. The ability of the DM/CPM restrictions to protect springflow will be measured by the number of days total discharge falls below certain values (e.g., 30, 60, 100, and 150 cfs) or springflow ceases entirely. In addition, available habitat and population abundance will be monitored for each species according to the plan detailed below.

7.6.2 Biological Monitoring (Comprehensive and Critical Period)

A comprehensive biological sampling plan (Variable Flow Study) established by the Authority in 2000 gathers baseline and critical period data about habitat availability and population abundance of the HCP species to fill important gaps regarding the ecological condition of the Comal and San Marcos Springs/River ecosystems. This comprehensive sampling plan will be continued for the life of the permit (Edwards Aquifer Optimization Technical Study 6.1, Table 5-1) and will provide a means to monitor changes that may result from management actions.

This comprehensive monitoring plan will continue to accumulate baseline data for refinement of estimates of "average" or "healthy" community conditions. The monitoring will also increase in magnitude, including increased frequency and number of parameters examined, as discharge falls to specific levels. Additional monitoring during low-flow periods will enhance perceptibility of critical changes in important habitat parameters. The discharge "trigger" levels for additional monitoring and other management responses (Tables 7.6-1 and 7.8-2 through 7.9-4 below) were chosen based upon available data that suggest that changes in population dynamics or habitat availability may occur when discharge falls to, or below, these values. These trigger levels may be refined as additional data are gathered through the Variable Flow Study monitoring efforts.

In addition to long-term monitoring efforts that increase in intensity below the specified trigger levels, a critical period monitoring component is incorporated into the Variable Flow Study that initiates full-scale sample efforts at specified trigger levels. To date, only two low-flow sampling efforts have been triggered, both of which occurred at Comal Springs in the late summer of 2000. The flow at Comal Springs was reduced to 145 cfs but then rapidly increased with several intense rainfall events. As part of the long-term monitoring component of this HCP,

Table 7.6-1. Triggers and management responses for fountain darter at Comal Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring (Phase I)	Total discharge <150 cfs and >80 cfs	Aquatic vegetation mapping, dip net sampling, and visual parasite observations conducted every other month.	Aquatic vegetation mapping in 4 Variable Flow Study sites. Dip net sampling and visual parasite observations in 50 high-quality habitat sites.
Increased Monitoring (Phase II)	Total discharge <80 cfs	Aquatic vegetation mapping conducted monthly; dip net sampling, visual parasite observations, and visual aquatic vegetation assessment conducted weekly.	Aquatic vegetation mapping at 4 Variable Flow Study sites. Dip net sampling and visual parasite observations in 50 high-quality habitat sites.
Off-Site Refugia	<50% of mean aquatic vegetation and <20% darter abundance **OR** <30% of mean aquatic vegetation and <30% darter abundance	A positive trigger will require a confirmation follow-up of fountain darter abundance. A confirmed trigger will initiate collection of fountain darters in each reach of the Comal River for transport and maintenance in the San Marcos NFHTC.	Total vegetation coverage measured for each plant type, weighted according to fountain darter preference, and summed for comparison to mean (mean determined by Variable Flow Study). Fountain darter abundance calculated as proportion of 50 dipnet sites with darters present (five minute samples; 5m x 5m prime habitat area).
Regulating Flow in Old and New Channels	Total discharge <80 cfs	Regulation will follow the recommended distribution of flow between Old Channel and New Channel described in Table 6.7-2.	This action is important to maximize the highest quality habitat for fountain darters when flows are declining.
Intensive Management Areas (Phase I)	Total discharge <80 cfs	Habitat modification: water channeled through highest quality Landa Lake habitat into the old channel (decreases retention time and temperature).	Goal is to maintain temperature in prime habitat in Landa Lake and Old Channel reach below 27^{O}C - February to May and below 29^{O}C - June to January. This unproven plan would require both engineering and environmental feasibility studies.
Intensive Management Areas (Phase II)	Total discharge <60 cfs	Supplement water up to 60 cfs to maintain 60 cfs in system at all times; would require the water source for supplementation to have similar water chemistry that supports habitat and fountain darter populations in the intensive management areas.	Goal is to maintain temperature in prime habitat in Landa Lake and Old Channel reach below 27^{O}C - February to May and below 29^{O}C - June to January. This unproven plan would require both engineering and environmental feasibility studies.

the critical period component of the Variable Flow Study will be maintained until sufficient documentation of low-flow events has been completed as determined by the Authority and the USFWS. It is this monitoring strategy that will be adapted into the long-term comprehensive monitoring and help refine critical trigger levels for increased monitoring and appropriate management responses. Data gathered during this full-scale effort will also provide information on potential impacts of the sampling methodology on reduced habitat and potentially reduced populations.

The scope of the Variable Flow Study may be modified on a yearly basis at the discretion of the Authority with consent of the USFWS. The current Variable Flow Study (BIO-WEST 2003), as approved by the Authority and USFWS, has the following monitoring components:

- Aquatic vegetation mapping for select reaches;
- Fountain darter sampling (drop nets, dip nets, visual);
- San Marcos salamander sampling (SCUBA and snorkel);
- Texas wild-rice physical observations and annual mapping;
- Comal Springs riffle beetle monitoring;
- Comal invertebrate sampling (drift-net sampling over spring orifices);
- Parasite evaluations concerning the fountain darter; and
- Ramshorn and other exotic snail monitoring.

The components are designed to effectively determine whether the conservation measures are achieving the biological goals and objectives set forth in the EAHCP. A more detailed description of the sampling methodologies, frequencies, and sample locations is found in the Variable Flow Study monitoring plan (BIO-WEST 2003).

7.7 Core Adaptive Management Strategies

This section outlines the Authority's AMP to protect habitat and populations of endangered species in both the Comal and San Marcos Springs/River ecosystems in the event of limited recharge. Although the focus of the Authority will be to meet the objectives set forth for the individual species, the demands of balancing all environmental needs in the context of adjacent human needs could prove difficult in times of limited recharge to the Edwards Aquifer.

7.7.1 Risk Assessment, Estimation of Take, and Drought of Record

Because biological data typically exhibit great variability and there are many habitat and population parameters that potentially affect the population dynamics of a species, it is very difficult to assess the threat of extirpation. This is particularly true of aquatic species because of limited means of sampling and an environment susceptible to rapid change in many habitat parameters. In any natural setting, the unpredictability of the effects of an individual event (e.g., extended low-flow period), often highly correlated with conditions immediately prior to the event, hampers development of preset target conditions necessary to maintain habitat. To predefine expected impacts to a species based upon certain conditions is a very difficult task. The USFWS has defined "take" based upon only one variable, total discharge. However, for the management plan outlined here, a greater range of parameters is used to assess biological risks associated with deviating from the objectives set forth above for the individual species.

Although protection of springflows to prevent a decline to the level of take is incorporated into the DM/CPM rules, it is possible that conditions may reach the level of take or worse, such as occurred during the drought of record. Although this HCP provides measures to protect springflow, it does not guarantee springflow during a repetition of the drought of record or a worse drought. That event included several years of very limited recharge, and there is always the potential that such conditions may occur again during the life of the permit (although the probability of occurrence based upon the historical record appears very low, as discussed in Section 3.2.1.2 in Appendix 3). This program provides a framework for addressing such conditions, if they should occur, by providing measures to mitigate effects of such droughts on the species. The DM/CPM restrictions should limit the period of time at or below take, but in the event that discharge falls to these levels, additional measures need to be in place to monitor changes closely and further protect habitat.

The Authority proposes a conservative approach that incorporates regular biological monitoring before and after and frequent monitoring during such events. It is important to accurately define dynamic ecosystem conditions prior to the onset of a limited recharge period to assess potential threats during an extended period under those conditions. Biological monitoring during a period of declining spring discharge will permit a close examination of actual population and habitat conditions when flow declines to or below take levels. This approach differs from the traditional one of establishing one fixed number for total discharge, below which the species is at risk and above which it is not. Instead, fixed numbers of total discharge are used to trigger additional sampling and, in conjunction with those sampling results, to more accurately define biological risk and population changes. Fixed sampling outcomes (which may be adapted with approval from the primary stakeholders), coupled with fixed discharge levels, elicit specific management responses. This is a more dynamic process that takes into account actual conditions rather than predetermined hypotheses of what conditions might be expected at certain discharge levels based upon very limited data.

7.7.2 Program Outline

This AMP outlines key parameters that are important to each species and provides the best estimate of critical values that will elicit management responses. These measurements include: increased vigilance of ecosystem conditions (more frequent sampling); on-site intensive management area efforts; and salvage efforts targeted as a last resort to collect and provide refuge for individuals during conditions that have deteriorated beyond those expected for continued species existence in the wild. The estimated management response triggers (Tables 7.6-1 and 7.8-2 through 7.9-4) and biological relevance that are incorporated into the management response for each action are based upon the biological data available to the Authority, three years of monitoring associated with the Variable Flow Study, and professional judgment relative to low-flow conditions for which data are not available. Until specific low-flow data are collected as proposed (Critical Period component) in the long-term monitoring section, the best available biological data coupled with professional judgment lead the Authority to believe that the proposed critical values are sufficient to support viable populations of Covered Species and their habitats.

One of the options discussed for Covered Species is off-site refugia (described in detail in Section 7.8). Although the DM/CPM restrictions and adaptive management responses are designed to maintain conditions that allow populations of Covered Species to persist in the wild through periods of limited recharge that may reasonably be expected during the life of the permit, there remains the possibility that salvage efforts (off-site refugia) will be necessary. The initiation for such efforts differs by species; an outline is provided below in Section 7.8 for conditions necessary to resort to this step for each respective species.

Another option discussed for many species is establishment of on-site intensive management areas. While such actions would be initiated before off-site refugia, they will require both engineering and environmental feasibility studies to fully assess their merit before they may be relied upon as tools for protecting habitat.

7.8 Comal Springs/River Ecosystem Adaptive Management Activities

7.8.1 Fountain Darter

A summary of proposed trigger levels for initiation of management responses for the fountain darter in the Comal Springs/River ecosystem is found in Table 7.6-1.

Biological Objectives

- Maintain adequate springflow to meet the following conditions:

Minimize extent of range and time that water temperature is >27 degrees Celsius;

Maintain >70 percent of mean abundance* of aquatic vegetation in prime habitat;

Maintain >30 percent of mean abundance* of aquatic vegetation in marginal habitat; and

Maintain adequate (within historical range) water quality.

- Determine food supply and dynamics within key aquatic vegetation (once determined, maintain food supply in key aquatic vegetation);
- Determine potential effect of parasite(s) and other exotic species (if impacts evident, minimize impacts); and
- Determine potential impact of predation during lower flows (if present during lower flows, minimize impacts).

*Based upon existing Variable Flow Study data (will be updated by future sampling events where total discharge >150 cfs in the Comal River and >100 cfs in the San Marcos River).

Additional Monitoring – Phase 1

As a consequence of discharge dropping to the level of take (presently defined as 150 cfs) in the Comal River, the following specific monitoring activities will occur every other month until discharge falls to Phase 2 (80 cfs) or increases to above 150 cfs.

- Aquatic vegetation mapping—Four sites established by the Variable Flow Study to include Upper Spring Run reach, Landa Lake, Old Channel reach, and New Channel reach; and.
- Dip-net sampling/visual parasite evaluations —Five-minute presence/absence surveys to be conducted at 50 sites in high-quality habitat (Upper Spring Run reach (5), Landa Lake (20), Old Channel reach (20), and New Channel reach (5).

Additional Monitoring – Phase 2

As discussed above, if discharge continues to decline and falls to 80 cfs or lower, increased risk may be observed. Under these conditions, the same sampling procedures that occur in Phase 1 will be conducted, but more frequently (monthly for aquatic vegetation mapping and weekly for dip netting).

Regulating Flow in the Old and New Channels

Below 80 cfs, careful regulation of flow between the high-quality habitat in the Old Channel and marginal habitat of the New Channel is paramount. Most flow typically travels down the New

Channel while the Old Channel typically maintains 40-60 cfs. However, it becomes important during times of limited discharge to verify that the maximum amount travels down the Old Channel until flows drop to critically low levels. Below 50 cfs, the full 40 cfs will no longer be allowed to travel down the Old Channel in order to maintain some habitat in the New Channel at all times. While manipulation of the culvert that regulates this flow is the responsibility of the USFWS in coordination with the City of New Braunfels, the Authority will coordinate to monitor conditions and assist with streamflow regulation efforts. The Authority proposes that the schedule in Table 7.8-1 be followed as closely as possible during periods when flow in the Old Channel is at or below 40 cfs, assuming the absence of a supplemented water supply.

Table 7.8-1. Regulation of flow in the Old and New Channels of the Comal River.

Comal System (cfs)	Old Channel (cfs)	New Channel (cfs)
80	40	40
60	40	20
40	30	10
30	25	5
20	15	5
10	10	0

This schedule maximizes protection of the highest quality habitat (Old Channel) while still maintaining some flow in the marginal habitat of the New Channel until total discharge falls to 10 cfs or below. However, the plans for on-site intensive management areas proposed below will attempt to maintain 60 cfs total discharge in the Comal River at all times.

Off-Site Refugia

It is important to note that the proposed habitat triggers for off-site refugia are not solely dependent upon discharge. Off-site refugia efforts could be triggered as high as 80 cfs (in lieu of intensive management areas, which would otherwise begin at that discharge) or not at all, even if total discharge drops to 0 cfs (if intensive management areas maintain habitat and population abundance above trigger levels).

Two variables will be considered in concert with total discharge in the Comal River to assess the need to initiate refugia efforts for fountain darter populations: availability of sufficient habitat (aquatic vegetation) and presence/absence of darters throughout the known range. The total amount of aquatic vegetation under such conditions will be compared to mean aquatic vegetation coverage during favorable conditions (determined from all past and future Variable Flow Study samples at or above 150 cfs, but excluding samples initiated specifically to study “high-flow events”). Data collected outside of favorable conditions (below 150 cfs or after high-flow events) are extremely valuable to determine low- and high-flow impacts, respectively, but should not be used to adjust the value used as an indicator of average habitat condition. The mean will be calculated by assigning a rank value to each vegetation type, based upon fountain darter preference, and multiplying this weighting factor by the sum of each type from all four reaches used in the Variable Flow Study. The second variable, fountain darter presence/absence, will be calculated as a proportion of dip-net samples that have fountain darters present. Sampling will consist of 50 five-minute surveys, each of which covers a 16.5 square foot (5m x 5m) area in prime habitat. As an example, 10 sites with darters out of 50 sites equals 20 percent and 15 sites with darters equals 30 percent.

Using both of these variables, in addition to total discharge, increases the likelihood of correctly identifying deteriorating conditions that might not easily be observed using only one method. Similarly, it reduces the probability of initiating a massive salvage effort when unwarranted. The modification of mean habitat condition with future data also provides an advantage by allowing for the refinement of data comparison over time.

The proposed trigger levels are as follows:

Less than 50 percent mean aquatic vegetation AND less than 20 percent darter presence,

OR

Less than 30 percent mean aquatic vegetation AND less than 30 percent darter presence.

The reason for the higher percentage of darter abundance for the second trigger level is the expectation that the number of darters in high-quality habitat will increase as the amount of available habitat decreases (clumping effect).

Confirmation samples will be very important for this management plan. The trigger levels are designed to provide a conservative buffer that will allow time to verify conditions with a follow-up sample. In addition, when low discharge triggers additional monitoring, sampling will be frequent enough to observe a trend in conditions over time to help evaluate whether conditions have truly deteriorated to the point that off-site refugia are necessary. For the fountain darters, habitat assessment (aquatic vegetation mapping) is too time consuming to verify with a follow-up sample; however, dip-net sampling can be accomplished by one person within one day. Therefore, triggering the off-site refugia with one of the two scenarios listed above will also require a follow-up dip-net sample the succeeding day to confirm the results. If confirmed, action will be taken to initiate off-site refugia collections.

Intensive Management Areas

There are two phases in the implementation of on-site intensive management areas for the fountain darter in the Comal River. The objective of Phase 1 (80 cfs to 60 cfs) is to maintain water temperatures in the prime habitat areas at a level suitable for darter reproduction in the spring and larval and adult darter survival during the remaining portion of the year. This will be accomplished by diverting water through specific habitat features (higher quality vegetation types) and reducing retention times and heating of water in Landa Lake. The goal of Phase 2 (60 cfs and below) is to supplement enough water to maintain 60 cfs at all times and support both aquatic vegetation and suitable water temperature. Without any data to the contrary, it must be assumed that the water quality constituents of diverted water need to be similar to Edwards Aquifer water for species survival. In order to test the viability of this innovative technology, 1) a detailed engineering and environmental study will be conducted to establish the feasibility of intensive management areas in the Comal Springs/River system, 2) a pilot project will be undertaken to ensure the function of this methodology, and 3) should items 1 and 2 confirm this approach, a long-term monitoring of habitat and populations within the intensive management areas will be incorporated into the comprehensive component of the Variable Flow Study described above.

7.8.2 Comal Springs Riffle Beetle

A summary of proposed trigger levels for initiation of management responses for the Comal Springs riffle beetle is found in Table 7.8-2.

Biological Objectives

- Maintain horizontal and upwelling flows in >70 percent of surface habitat;
- Maintain adequate water quality (parameters maintained within historical ranges);
- Determine extent of subsurface use and spatial distribution (if subsurface use is common, modify surface habitat requirements and modify objectives to include subsurface habitat availability); and
- Determine life history characteristics (life span, tolerance to water quality changes, reproduction, food sources) [minimize impacts].

Additional Monitoring

When take is triggered (120 cfs), weekly monitoring of the Comal Springs riffle beetle populations will be conducted at four sites (Spring Run 1, Spring Run 3, western shore of Landa Lake, and Spring Island upwelling) until discharge increases to a level above 120 cfs.

Off-Site Refugia

Off-site refugia efforts will be initiated below 80 cfs when biological sampling reveals a substantial decline in the number of individuals in the surface layer of substrate in high-quality habitat areas.

The proposed trigger level for off-site refugia is:

> When only one of four monitored sites continues to have six or more adult beetles (collected in a two-hour sampling period).

Table 7.8-2. Triggers and management responses for Comal Springs riffle beetle at Comal Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring	Total discharge <120 cfs	Monitor densities of CSRB's in Spring Run 1, Spring Run 3, western shoreline of Landa Lake, and Spring Island area weekly.	
Off-Site Refugia	Total discharge <80 cfs **AND** populations not maintained	A positive trigger will initiate collection of CSRBs from each habitat location for transport to San Marcos NFHTC.	Maintaining populations requires at least 25% (1 of 4) of sample locations having CSRBs, with a population of > or = 6 adult beetles sampled in 2 hours (based upon previous sampling efforts). A greater effort would result in additional habitat disturbance.
Intensive Management Areas (Phase I)	Total discharge <80 cfs	Habitat modification: water recirculated from Landa Lake back through edge habitat of SR3 and western shoreline and Spring Island upwelling; will need to maintain water temperature either through habitat modification and/or chilling.	This unproven recirculation plan would require both engineering and environmental feasibility studies.
Intensive Management Areas (Phase II)	Total discharge <60 cfs	Supplement water up to 30 cfs to maintain 30 cfs in CSRB key habitat at all times; supplement water from outside source through edge habitat of SR3 and Spring Island upwelling; would require the water source for supplementation to have similar water chemistry that supports habitat and CSRB populations within the intensive management areas.	This unproven supplementation plan would require both engineering and environmental feasibility studies.

Intensive Management Areas

There are two phases in the implementation of on-site intensive management areas for the Comal Springs riffle beetle. The goal of Phase 1 (80 cfs down to 60 cfs) would be to recirculate water (up to 30 cfs) from Landa Lake back into the key edge habitat of Spring Run 3 and/or western shoreline of Landa Lake and to the upwelling habitat of the Spring Island area. At these discharge levels, intensive management areas efforts for the fountain darter would be in place that would limit heating of the potential recirculation water by reducing water retention times in Landa Lake. It is anticipated that Phase 1 would need to be initiated before the edge habitat areas in the spring runs and along the Landa Lake western shoreline lose lateral springflow from shoreline seeps. This should keep individuals in areas that they might otherwise emigrate from, which would result in greater difficulty later trying to reestablish populations that have already retreated. The goal of Phase 2 (below 60 cfs) is to maintain 30 cfs distributed among the three key habitat types described above at all times in order to support beetle habitat. As with the fountain darter intensive management areas, it must be assumed that the water quality constituents of the recirculated water are similar to Edwards Aquifer water for species survival. To confirm the intensive management areas concept, a feasibility study would be conducted, followed by a pilot project, and should viability be established, a monitoring component would be built in to the Variable Flow Study.

7.8.3 Comal Springs Dryopid Beetle and Peck's Cave Amphipod

A summary of proposed trigger levels for initiation of management responses for the Comal Springs dryopid beetle and Peck's Cave amphipod is found in Table 7.8-3.

Comal Springs Dryopid Beetle Biological Objectives

- Maintain adequate water quality within the aquifer (parameters maintained within historical ranges);
- Monitor the bad (saline) water line;
- Determine spatial and temporal distribution of the species in the aquifer; and
- Determine life history characteristics (life span, tolerance to water quality changes, reproduction, food sources) [minimize impacts].

Peck's Cave Amphipod Biological Objectives

- Maintain adequate water quality within the aquifer (parameters maintained within historical ranges);
- Monitor the bad (saline) water line;

Table 7.8-3. Triggers and management responses for Comal Springs dryopid beetle and Peck's Cave amphipod at Comal Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring (Phase 1)	Total discharge <40 cfs	Standard water quality measurements (D.O., conductivity, pH, and temperature) will be monitored weekly at monitoring wells.	Requires the establishment of a water quality monitoring network of 3 wells near Comal Springs.
Increased Monitoring (Phase 2)	Total discharge <20 cfs	Standard (D.O., conductivity, pH, and temperature) and conventional (nutrients, TDS, TOC) water quality parameters will be monitored weekly at monitoring wells.	Requires the establishment of a water quality monitoring network of 3 wells near Comal Springs.
Off-Site Refugia	Total discharge <40 cfs **AND** water quality exceeds 10% of historical range	If water quality trigger occurs during increased monitoring a follow-up confirmation is required succeeding day. A confirmed trigger will initiate collection of individuals of each species for immediate transport to the San Marcos NFHTC.	Requires the establishment of a water quality monitoring network of 3 wells near Comal Springs.

- Determine spatial and temporal distribution of the species in the aquifer; and
- Determine life history characteristics (life span, tolerance to water quality changes, reproduction, food sources) [minimize impacts].

Additional Monitoring – Phase 1

When take is triggered (40 cfs to 20 cfs), weekly monitoring for standard water quality parameters (dissolved oxygen, conductivity, pH, and temperature) will be conducted at a network of three wells located within the immediate vicinity of Comal Springs.

Additional Monitoring – Phase 2

At 20 cfs (increased risk) and below, the weekly water quality monitoring is expanded from standard parameters to standard parameters plus conventional water quality parameters (nutrients, TDS, TOC) at the same network of three wells.

Off-Site Refugia

Off-site refugia efforts will be initiated when water quality sampling reveals a substantial decline in one or more of the parameters measured.

The proposed trigger for off-site refugia is when:

> *Any standard or conventional water quality parameter exceeds the historical range of the water quality parameter for the Edwards Aquifer by 10 percent or more.*

Intensive Management Areas

There are no intensive management areas currently being considered for the subterranean species.

7.9 San Marcos Springs/River Ecosystem Adaptive Management Activities

7.9.1 Fountain Darter

A summary of proposed trigger levels for initiation of management responses for the fountain darter in the San Marcos Springs/River ecosystem is found in Table 7.9-1.

Biological Objectives

- Same as for this species at Comal Springs.

Table 7.9-1. Triggers and management responses for fountain darter at San Marcos Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring (Phase I)	Total discharge <100 cfs and >60 cfs	Aquatic vegetation mapping, dip net sampling, and visual parasite observations conducted every other month.	Aquatic vegetation mapping at 3 Variable Flow Study sites; dipnet sampling and visual parasite observations in 50 high-quality habitat sites.
Increased Monitoring (Stage II)	Total discharge <60 cfs	Aquatic vegetation mapping conducted monthly; dip net sampling, visual parasite observations, and visual aquatic vegetation assessment conducted weekly.	Aquatic vegetation mapping at 3 Variable Flow Study sites; dipnet sampling and visual parasite observations in 50 high-quality habitat sites.
Off-Site Refugia	<50% of mean aquatic vegetation and <20% darter abundance **OR** <30% of mean aquatic vegetation and <30% darter abundance	A positive trigger will require a confirmation follow-up of fountain darter abundance. A confirmed trigger will initiate collection of fountain darters in each reach of the San Marcos River for transport to the San Marcos NFHTC.	Total vegetation coverage will be measured for each plant type, weighted according to fountain darter preference, and summed for comparison to the mean (mean determined through Variable Flow Study). Fountain darter abundance will be calculated as a proportion of 50 dipnet sites with darters present (five minute samples; 5m x 5m prime habitat area).
Intensive Management Areas (Phase I)	Total discharge <80 cfs	Habitat modification - slough arm of Spring Lake divided from main lake to limit dispersion of spring water (decreases retention time and temperature).	Goal is to maintain temperature in prime habitat in Spring Lake and below dam below 27^{O}C - February to May and below 29^{O}C - June to January. This unproven plan would require both engineering and environmental feasibility studies.
Intensive Management Areas (Phase II)	Total discharge <60 cfs	Supplement water up to 60 cfs to maintain 60 cfs in system at all times; would require the water source for supplementation to have similar water chemistry that supports habitat and fountain darter populations within the intensive management areas.	Goal is to maintain temperature in prime habitat in Spring Lake and Spring Lake Dam reach below 27^{O}C - February to May and below 29^{O}C - June to January. This unproven plan would require both engineering and environmental feasibility studies.

Additional Monitoring – Phase 1

As a consequence of discharge declining to the level of take in the San Marcos River, the following specific monitoring activities will occur every other month (regardless of duration of similar flow) until discharge falls to Stage 2 (60 cfs) or increases to above 100 cfs.

Aquatic vegetation mapping—three sites established by Variable Flow Study to include Spring Lake Dam reach, City Park reach, and IH35 reach.

Dip-net sampling/visual parasite evaluations–Five minute presence/absence surveys to be conducted at 50 sites in high-quality habitat (Spring Lake [20], Spring Lake Dam reach [10]), City Park reach [10], and I-35 reach [10]).

Additional Monitoring – Phase 2

When springflow is less than 60 cfs (increased risk), aquatic vegetation mapping will be conducted monthly, while dip-net sampling and visual parasite evaluations will occur weekly.

Off-Site Refugia

It is important to note that the proposed habitat triggers for off-site refugia are not solely dependent upon discharge. Off-site refugia efforts could be triggered as high as 100 cfs or not at all, even if total discharge drops to 0 cfs (if the intensive management areas maintain habitat and population abundance above trigger levels).

As in the Comal River, two variables will be considered in concert with total discharge to assess the need to initiate off-site refugia efforts for the fountain darter population: availability of sufficient habitat (aquatic vegetation) and presence/absence of darters throughout the known range. These variables will be measured and calculated in the same manner as in the Comal River to determine when a trigger has been reached.

The proposed trigger levels are as follows:

Less than 50 percent mean aquatic vegetation AND less than 20 percent darter abundance,

OR

Less than 30 percent mean aquatic vegetation AND less than 30 percent darter abundance.

The reason for the higher percentage of darter abundance for the second trigger level is that it is anticipated that the number of darters in high-quality habitat will increase as the amount of available habitat decreases (clumping effect).

Confirmation samples will be very important for this management program. The trigger levels are designed to provide a conservative buffer that will allow time to verify conditions with a follow-up sample. In addition, when low discharge triggers additional monitoring, sampling will be frequent enough to observe a trend in conditions over time to help evaluate whether conditions have truly deteriorated to the point that off-site refugia are necessary. For the fountain darters, habitat assessment (aquatic vegetation mapping) is too time consuming to verify with a follow-up sample; however, dip-net sampling can be accomplished by one person within one day. Therefore, triggering the off-site refugia with one of the two scenarios listed above will also require a follow-up dip-net sample the succeeding day to confirm the results. If confirmed, action would be taken to initiate off-site refugia collections.

Intensive Management Areas

There are two phases in the implementation of on-site intensive management areas for the fountain darter in the San Marcos River. The objective of Phase 1 (80 cfs down to 60 cfs) is to maintain water temperatures in the prime habitat areas at a level suitable for darter reproduction in the spring and larval and adult darter survival during the remaining portion of the year. This will be accomplished by blocking off water from the slough arm of Spring Lake to reduce retention times and heating of water in the lake. The objective of Phase 2 (60 cfs and below) is to supplement enough water to maintain 60 cfs at all times and support both aquatic vegetation and suitable water temperature in Spring Lake and the San Marcos River. At this point, it must be assumed that the water quality constituents of water used for supplementation need to be similar to Edwards Aquifer water for species survival. As with the proposed Comal intensive management areas, suitability of the San Marcos project would also be tested by conducting: 1) a detailed engineering and environmental study to establish the feasibility of intensive management areas in the San Marcos Springs/River system, 2) a pilot project to ensure the function of this methodology, and 3) should items 1 and 2 confirm this approach, a long-term monitoring of habitat and populations within the intensive management areas would be incorporated into the comprehensive component of the Variable Flow Study.

7.9.2 San Marcos Salamander

A summary of proposed trigger levels for initiation of management responses for the San Marcos salamander is found in Table 7.9-2.

Biological Objectives

Maintain adequate springflow to meet following conditions:

- Maintain >70 percent of physical habitat (silt-free rocks) at all times;
- Maintain adequate water quality (parameters maintained within historical ranges);

Table 7.9-2. Triggers and management responses for San Marcos salamander at San Marcos Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring (Phase I)	Total discharge <80 cfs and >60 cfs	Salamander surveys conducted every other week.	Salamander surveys will be conducted at 3 Variable Flow Study sites (Hotel Reach, Big Riverbed, and eastern spillway of Spring Lake Dam).
Increased Monitoring (Phase II)	Total discharge <60 cfs	Salamander surveys conducted weekly.	Salamander surveys will be conducted at 3 Variable Flow Study sites (Hotel Reach, Big Riverbed, and eastern spillway of Spring Lake Dam).
Off-Site Refugia	<50% of mean suitable habitat and <20% salamander density **OR** <30% of mean suitable habitat and <30% salamander density	A positive trigger will initiate collection of salamanders in each reach of the San Marcos River for transport and maintenance in the San Marcos NFHTC.	Mean suitable habitat and mean salamander density calculated by Variable Flow Study; deviations from means (by percentage) calculated for each site and averaged to yield composite percent deviation from average conditions.
Intensive Management Areas (Phase I)	Total discharge <80 cfs	Habitat modification - slough arm of Spring Lake divided from main lake to limit dispersion of spring water (decreases retention time and temperature).	The goal is to maintain temperature in prime habitat in Spring Lake and Spring Lake Dam reach below 27^{O}C - February to May and below 29^{O}C - June to January. This unproven plan would require both engineering and environmental feasibility studies.
Intensive Management Areas (Phase II)	Total discharge <60 cfs	Supplement water up to 60 cfs to maintain 60 cfs in system at all times; would require the source of water for supplementation to have similar water chemistry that supports habitat and salamander populations within the intensive management areas.	The goal is to maintain temperature in prime habitat in Spring Lake and Spring Lake Dam reach below 27^{O}C - February to May and below 29^{O}C - June to January. This unproven plan would require both engineering and environmental feasibility studies.

- Minimize extent of range and time that water temperature is >27 degrees Celsius; and
- Determine and maintain food supply within suitable physical habitat.

Additional Monitoring – Phase 1

When take is triggered (80 cfs to 60 cfs), the following specific monitoring activity is triggered and will occur every other week (regardless of duration of similar flow) until the next level is triggered or flows are increased to above 80 cfs:

Salamander surveys (SCUBA and snorkel)—three sites established by Variable Flow Study to include Hotel Area (Site 2), Big Riverbed Area (Site 14), and eastern spillway of Spring Lake dam (Site 22).

Additional Monitoring – Phase 2

When springflow is under 60 cfs (increased risk), the same sampling effort described in Phase 1 will occur weekly until flows increase to above 60 cfs.

Off-Site Refugia

It is important to note that the proposed habitat triggers for off-site refugia are not solely dependent upon discharge. Off-site refugia efforts could be triggered as high as 80 cfs (in lieu of intensive management areas, which would otherwise begin at that rate of discharge) or not at all, even if total discharge drops to 0 cfs (if the intensive management areas maintain habitat and population abundance above trigger levels).

As with the fountain darter, two variables will be considered in concert with total discharge to assess the need to initiate off-site refugia efforts for the San Marcos salamander population: availability of suitable habitat and salamander density throughout the known range. The total amount of suitable habitat measured under such conditions will be compared to a mean of total suitable habitat available during favorable conditions (determined from all past and future Variable Flow Study samples at or above 80 cfs, but excluding samples initiated specifically by "high-flow events"). Data collected outside of favorable conditions (below 80 cfs or after high-flow events) are extremely valuable to determine low- and high-flow impacts, respectively, but should not be used to adjust the value used as an indicator of average habitat condition. The second variable, salamander density, will be calculated by finding the mean density among the three sites sampled for the Variable Flow Study. As with the suitable habitat variable, the mean density observed during each sample will be compared to a mean density of all samples taken during favorable conditions (all past and future Variable Flow Study samples at or above 80 cfs, but excluding high-flow events). Using both of these variables, in addition to total discharge, increases the likelihood of correctly identifying deteriorating conditions that might not be easily observed using only one method. Similarly, it reduces the probability of initiating an expensive intensive management area effort or massive salvage effort when unwarranted. The modification of mean habitat condition based upon future data also provides an advantage by allowing for the refinement of data comparison over time.

The proposed trigger levels are as follows:

Less than 50 percent suitable habitat AND less than 20 percent salamander density,

OR

Less than 30 percent suitable habitat AND less than 30 percent salamander density.

The reason for the higher percentage of salamander density for the second trigger level is that it is anticipated that the number of salamanders in high-quality habitat will increase as the amount of suitable habitat decreases (clumping effect).

Intensive Management Areas

There are two phases in the implementation of on-site intensive management areas for the San Marcos salamander. The objective of Phase 1 (80 cfs down to 60 cfs) is to maintain water temperatures at a level suitable for salamander reproduction and survival. This will be accomplished by blocking off water from the slough arm of Spring Lake to reduce retention times and heating of water in the lake. The objective of Phase 2 (60 cfs and below) is to supplement enough water to maintain 60 cfs at all times and support both aquatic vegetation and suitable water temperature in Spring Lake and the San Marcos River. Without any data to the contrary, it must be assumed that the water quality constituents of water used for supplementation need to be similar to Edwards Aquifer water for species survival. As the flow triggers for intensive management areas are the same for the fountain darter and San Marcos salamander, the feasibility study and pilot project discussed above would serve both species. The long-term monitoring component would be adjusted as per the described salamander sampling activities.

7.9.3 Texas Blind Salamander

A summary of proposed trigger levels for initiation of management responses for the Texas blind salamander is found in Table 7.9-3.

Biological Objectives

- Maintain adequate water quality (parameters maintained within historical ranges) within the aquifer;
- Monitor bad (saline) water line; and
- Determine spatial and temporal distribution of the species in the aquifer.

Table 7.9-3. Triggers and management responses for Texas blind salamander at San Marcos Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring (Phase I)	Total discharge <40 cfs	Standard water quality measurements (D.O., conductivity, pH, and temperature) will be monitored weekly at monitoring wells.	Requires the establishment of a water quality monitoring network of 3 wells near San Marcos Springs.
Increased Monitoring (Phase II)	Total discharge <20 cfs	Standard (D.O., conductivity, pH, and temperature) and conventional (nutrients, TDS, TOC) water quality parameters will be monitored weekly at monitoring wells.	Requires the establishment of a water quality monitoring network of 3 wells near San Marcos Springs.
Off-Site Refugia	Total discharge <40 cfs **AND** Water quality exceeds 10% of historical range	If water quality trigger occurs during increased monitoring a follow-up confirmation is required succeeding day. A confirmed trigger will initiate collection of individuals for immediate transport to the San Marcos NFHTC.	Requires the establishment of a water quality monitoring network of 3 wells near San Marcos Springs.

Additional Monitoring – Phase 1

When take is triggered (40 cfs to 20 cfs), weekly monitoring for standard water quality parameters (dissolved oxygen, conductivity, pH, and temperature) will be conducted at a network of three wells located within the immediate vicinity of San Marcos Springs.

Additional Monitoring – Phase 2

When springflow is less than 20 cfs (increased risk), the weekly water quality monitoring is expanded from standard parameters to standard parameters plus conventional water quality parameters (nutrients, TDS, TOC) at the same network of three wells.

Off-Site Refugia

Off-site refugia efforts will be initiated below 40 cfs when water quality sampling reveals a substantial decline in one or more of the parameters measured.

The proposed trigger for off-site refugia is when:

> *Any standard or conventional water quality parameter exceeds the historical range of the water quality parameter for the Edwards Aquifer by 10 percent or more.*

Intensive Management Areas

There are no intensive management areas currently being considered for the subterranean species.

7.9.4 Texas Wild-rice

A summary of proposed trigger levels for initiation of management responses for Texas wild-rice is found in Table 7.9-4.

Biological Objectives

- Maintain >70 percent of Texas wild-rice plants in >1ft water depth (San Marcos River total discharge >60 cfs);
- Maintain adequate water quality (parameters maintained within historical ranges);
- Minimize extent of vegetative mats and time that mats cover Texas wild-rice plants; and
- Determine and minimize impacts from herbivory and recreation during low flow.

Table 7.9-4. Triggers and management responses for Texas wild-rice at San Marcos Springs/River ecosystem.

Management Action	Triggers	Management Response Details	Notes
Increased Monitoring (Phase I)	Total discharge <110 cfs and >80 cfs	TWR coverage mapped for the entire San Marcos River when trigger initially reached. TWR physical parameters monitored every other week in designated vulnerable areas (established by Variable Flow Study).	
Increased Monitoring (Phase II)	Total discharge <80 cfs	TWR coverage for the entire San Marcos River mapped monthly regardless of duration of similar flows. TWR physical parameters monitored weekly.	
Off-Site Refugia	Total Discharge <80 cfs **AND** populations not maintained	A confirmed trigger will initiate collection of individual plants for immediate transport to the San Marcos NFHTC.	Maintaining abundance is defined as at least 30% of total TWR coverage with coverage existing in at least three distinct locations.
Intensive Management Areas (Phase I)	Total discharge <80 cfs	Habitat modification - slough arm of Spring Lake divided from main lake to limit dispersion of spring water (decreases retention time and temperature).	The goal is to maintain temperature in prime habitat in the San Marcos River below 29^{O}C. This unproven plan would require both engineering and environmental feasibility studies.
Intensive Management Areas (Phase II)	Total discharge <60 cfs	Supplement water up to 60 cfs to maintain 60 cfs in system at all times; would require the source of water for supplementation to have similar water chemistry that supports habitat.	The goal is to maintain temperature in prime habitat in the San Marcos River below 29^{O}C. This unproven plan would require both engineering and environmental feasibility studies.

Additional Monitoring – Phase 1

When take is triggered (110 cfs), the following specific monitoring activities are also triggered and will occur at the specified frequency (regardless of duration of similar flow) until the next level is triggered or flows are increased above 110 cfs.

- At 110 cfs, mapping of Texas wild-rice coverage for the entire San Marcos River will be conducted; and

- From 110 cfs to 60 cfs, the Authority will monitor the physical parameters of Texas wild-rice every other week in designated "vulnerable" areas as established by the Variable Flow Study.

Additional Monitoring – Phase 2

When springflow is less than 80 cfs (increased risk), total Texas wild-rice coverage will be mapped monthly under the guidelines specified above and physical visual observations will occur weekly.

Off-Site Refugia

It is important to note that the proposed habitat triggers for off-site refugia are not solely dependent upon discharge. Off-site refugia efforts could be triggered as high as 80 cfs (in lieu of intensive management areas, which would otherwise begin at that discharge) or not at all, even if total discharge drops to 0 cfs (if intensive management areas maintain habitat and population abundance above trigger levels).

The proposed trigger levels are as follows:

Less than 30 percent total coverage compared to coverage at 110 cfs (mapped prior to specific event),

OR

Texas wild-rice stands exist at fewer than three distinct locations.

Intensive Management Areas

There are two phases in the implementation of on-site intensive management areas for Texas wild-rice. The objective of Phase 1 (80 cfs down to 60 cfs) is to maintain water temperatures in Spring Lake and the San Marcos River at a level suitable for Texas wild-rice. This will be accomplished by blocking off water from the slough arm of Spring Lake to reduce retention times and heating of water in the lake. The objective of Phase 2 (60 cfs and below) is to supplement enough water to maintain 60 cfs at all times and support both water depth and suitable water temperature in Spring Lake and the San Marcos River. At this point, it must be assumed that the water quality constituents of the water used for supplementation need to be similar to Edwards Aquifer water for species survival. As the flow triggers for intensive management areas are the same for the fountain darter, San Marcos salamander, and Texas wild-rice, the feasibility study and pilot project discussed above for San Marcos would serve all three species. The long-term monitoring component would be adjusted as per the described Texas wild-rice sampling activities.

7.10 Additional Adaptive Management Activities

As part of adaptive management, additional management/studies/research opportunities for the Covered Species are needed to define conditions necessary to meet specified objectives and assist in refining management response trigger levels outlined in Tables 7.6-1 and 7.8-2 through 7.9-4.

The level of these efforts will correlate with the degree of biological risk anticipated for each alternative. A higher degree of biological risk will increase the number of active management strategies and studies/research needed to fully understand each species' tolerances to low-flow conditions and to minimize potential impacts. Such activities (corresponding measure number in Table 5-1 is indicated) for the proposed HCP alternative will include the following:

7.10.1 Fountain Darter

Active Management Strategies

- Enhancce aquatic vegetation (native reintroductions/establishment) [Measure 5.1]. Plant native species in areas currently without vegetation or where it has recently been removed by natural means (e.g., flooding);

- Restore aquatic vegetation [Measure 5.2]. Plant native species in prime habitat areas where it has been removed as a direct result of low flow;

- Establish discharge monitoring gauge on Old Channel (Comal River) [Measure 5.6]. Enhance ability to monitor flow regulation during low flows for protection of highest quality habitat; and

- Conduct engineering and environmental analysis of intensive management areas [Measure 6.2]. These analyses are critical components of species protection under very-low-flow conditions. Alternatives can be based upon anticipated benefit and costs.

Studies/Research

- Continue study of parasite impacts and life history [Measure 5.4]. Critical low-flow data needed;

- Continue evaluation of aquatic vegetation responses to low flow/elevated temperature (Measure 5.3). Key habitat loss as a component of management response needs more detailed information for accurate implementation;

- Determine tolerance of the species to ranges of water quality parameters expected with intensive management areas (Measure 6.2). These studies are a critical component of any intensive management area effort, as water quality may deteriorate under very low flows that will allow reasonable estimation of attaining necessary water quality conditions under each alternative; and

- Conduct pilot study of intensive management areas plans in both the San Marcos and Comal Rivers (Measure 6.3). A field trial of primary alternatives is vital before they can be relied upon for actual species/habitat protection.

7.10.2 San Marcos Salamander

Active Management Strategies

- Conduct engineering and environmental analysis of intensive management areas (Measure 6.2). These analyses are critical components of species protection under very-low-flow conditions. Alternatives can be based upon anticipated benefit and costs.

Studies/Research

- Determine tolerance of the species to the ranges of water quality parameters expected with intensive management areas (6.2). These studies will be a critical component of intensive management area efforts, as water quality may deteriorate under very low flows, and will allow reasonable estimation of attaining necessary water quality conditions under each alternative; and

- Conduct pilot study of intensive management area plans in the San Marcos River (Measure 6.3). A field trial of primary alternatives is vital before they can be relied upon for actual species/habitat protection.

7.10.3 Texas Blind Salamander

Active Management Strategies

- Establish water quality monitoring network of three wells near San Marcos Springs (Measure 5.9). These wells are necessary for water quality monitoring associated with adaptive management efforts.

7.10.4 Texas Wild-rice

Active Management Strategies

- Enhance aquatic vegetation (reintroductions/establishment of native species) in select areas (Measure 5.1). Some exotic species appear to compete with Texas wild-rice for space. Efforts would involve planting native species in areas currently without vegetation or where it has recently been removed by natural means (e.g., flooding). The success of Texas wild-rice appears to be greater near other native aquatic plant species compared with proximity to non-native species; and

- Develop and implement a management plan for vegetation mat removal during low flow (Measure 5.10). Buildup of free-floating vegetation over Texas wild-rice plants appears to have serious consequences to the health of individual plants; periodic matremoval during low flow will improve the overall health of the population.

7.10.5 Comal Springs Riffle Beetle

Active Management Strategies

- Conduct engineering and environmental analysis of intensive management areas (Measure 6.2). These analyses are critical components of species protection under very-low-flow conditions. Alternatives can be based upon anticipated benefit and costs.

Studies/Research

- Further document spatial distribution in Comal and San Marcos Springs (Measure 5.8). A complete assessment of habitat use is necessary for adequate protection;

- Evaluate use of hyporheos in the field (Measures 5.7 and 5.8). The Comal Springs riffle beetle may use the hyporheos in response to upwelling springflows based upon laboratory evidence. Extensive use of hyporheos would modify management strategies;

- Continue laboratory evaluations of responses to low flow/temperature (Measures 5.7 and 5.8). These are critical parameters and more information is needed to adequately protect the species during critical low-flow conditions;

- Evaluate food sources from literature and laboratory evaluation (Measure 5.8). Very limited information is available, but such information is important for adequate protection of the species;

- Evaluate reproductive strategies from literature and laboratory studies (Measure 5.8). Very limited information is available, but such information is important for adequate protection of the species;

- Determine tolerance to the ranges of water quality parameters expected with intensive management areas (Measure 6.2). Very limited information is available, but it is important for adequate protection of the species; and

- Conduct a pilot study of intensive management area plans in the Comal Springs (Measure 6.3). A field trial of primary alternatives is vital before they can be relied upon for actual species/habitat protection.

7.10.6 Comal Springs Dryopid Beetle and Peck's Cave Amphipod (Comal Springs Only)

Active Management Strategies

- Establish water quality monitoring network of three wells near Comal Springs (Measure 5.9). The network is necessary for water quality monitoring associated with adaptive management efforts.

Studies/Research

- Document spatial and temporal distribution in the aquifer and spring orifices (Measure 5.8). A complete assessment of habitat use is necessary for adequate protection;

- Evaluate food sources from literature and laboratory evaluations (Measure 5.8). Very limited information is available, but it is important for adequate protection of the species;

- Evaluate reproductive strategies from literature and laboratory evaluations (Measure 5.8). Very limited information is available, but it is important for adequate protection of the species; and

- Determine tolerance to water quality parameters in response to low-flow conditions through laboratory studies (Measure 5.8). Very limited information is available, but it is important for adequate protection of the species.

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Chapter 8 Implementation Roles of the EAHCP Participants

8.1 Edwards Aquifer Authority

In addition to the implementation of the DM/CPM limiting water withdrawals during periods of lower aquifer levels, the Authority will provide support and funding for the implementation of the measures of the EAHCP, including administration and reporting of the progress of the effort, coordination of an EAHCP Management Committee, and the development of an AMP.

8.1.1 Administration and Reporting

The Authority will provide an annual report of the progress of implementation of the EAHCP to the USFWS. The annual report will provide information on EAHCP measures implemented during the previous year, funding expended on EAHCP measures, and expected implementation during the next year. The annual report will also provide an assessment of anticipated versus implemented measures during the previous year and a discussion of unexpected events or conditions.

8.1.2 EAHCP Management Committee

The Authority will establish an EAHCP Management Committee (Committee) (or maintain the current Biological Advisory Team [BAT]) to coordinate conservation activities affecting Covered Species at Comal and San Marcos Springs. The Committee will:

- Provide a forum for exchange of information relative to Covered Species;
- Coordinate Covered Species management activities;
- Advise the Authority on budgetary issues relating to management of Covered Species;
- Advise the Authority on priorities for conservation actions; and
- Guide the development and implementation of the AMP and captive propagation program.

The Committee (if superceding the BAT) will be appointed by the Authority and may include representatives with biological or natural resource management roles from the Authority, USFWS, TPWD, Texas State University, the Cities of San Marcos and New Braunfels, and other participating management entities. The composition of the Committee will focus on active management of the Covered Species at Comal and San Marcos Springs.

8.1.3 Development and Implementation of Adaptive Management Process

[to be inserted]

8.2 U.S. Fish and Wildlife Service

[to be inserted]

8.3 Texas Parks and Wildlife Department

[to be inserted]

8.4 Others

The implementation of the EAHCP involves the efforts of several other entities, particularly in the management of Comal and San Marcos Springs and critical surrounding areas. These activities will be in addition to participation in the EAHCP.

Chapter 9 EAHCP Funding

To provide funding for implementation of the EAHCP minimization, mitigation, and monitoring measures as outlined above, the Authority proposes two mechanisms: an endowment and annual funding.

9.1 Endowment

Upon issuance of the ITP, the Authority will establish a $1,000,000 non-wasting endowment to provide funding for key mitigation measures. The fund will be established and managed by the Authority as a separate account. The interest will be used for key mitigation activities as determined by the EAHCP management committee, subject to approval by the USFWS. Any interest not expended will be reinvested in the endowment.

At the end of the term of the ITP, the endowment will be transferred to the USFWS or an agency designated by the USFWS for the exclusive purpose of funding conservation management activities benefiting Covered Species at Comal and San Marcos Springs.

9.2 Annual Funding

The Authority will provide annual funding for implementation of minimization, mitigation, and monitoring measures, as well as administration of the EAHCP, for the term of the ITP. A schedule of estimated annual costs is provided in Table 9.2-1. This funding, projected to total $9,745,000 over the 50-year life of the EAHCP, will be provided from the Authority's annual budget or external funding sources.

Table 9.2-1. Projected costs to fund Authority proposed EAHCP.

MEASURE	FUNDING										
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11 - Year 50 (40 Years)**
4.1 Assist with funding field collection and distribution of species to refugia.	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500	$7,500
4.3 Assist with funding refugia for existing captive stock at San Marcos National Fish Hatchery.	$7,500	$7,500	$7,500	$7,500	$7,500	$0	$0	$0	$0	$0	$0
4.4 Assist with funding refugia for existing captive stock at Uvalde National Fish Hatchery.	$7,500	$7,500	$7,500	$7,500	$7,500	$0	$0	$0	$0	$0	$0
4.5 Assist with funding salvage of additional species for refugia. *	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
4.6 Fund costs for personnel labor to manage and maintain refugia.	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000	$10,000
5.1 Aquatic vegetation enhancement (reintroduction/establishment of native species) in select areas.	$15,000	$15,000	$15,000	$15,000	$15,000	$0	$0	$0	$0	$0	$0
5.2 Aquatic vegetation restoration (reintroduction/reestablishment of native species) after low flow events. *	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000	$15,000
5.3 Continued evaluation of aquatic vegetation responses to low flow/elevated temperature.	$35,000	$15,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.4 Management/research to determine parasite impact to fountain darter (Current EAA Variable Flow Study).	$10,000	$10,000	$10,000	$0	$0	$0	$0	$0	$0	$0	$0
5.5 Improve accuracy of USGS gages below Spring Lake and Landa Lake (ongoing).	$15,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.6 Establish discharge monitoring gauge on original Old Channel of Comal River.	$15,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.7 Continue evaluation of drought survival mechanisms of the Comal Springs riffle beetle; low-flow laboratory evaluations, and subsequent field-based study of hyporheic population density (preliminary study completed).	$35,000	$15,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
5.8 Determine life history requirements of the three endangered invertebrates including population dynamics, distribution, tolerance/sensitivity (temperature, water quality, contaminants), and reproduction.	$25,000	$25,000	$25,000	$25,000	$25,000	$0	$0	$0	$0	$0	$0
5.9 Establish water quality monitoring network of three wells near Comal and San Marcos Springs.	$0	$0	$50,000	$50,000	$0	$0	$0	$0	$0	$0	$0
5.10 Develop and implement management plan for vegetation mat removal during low flow. *	$15,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000

Table 9.2.1 (continued)

MEASURE	FUNDING										
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11 - Year 50 (40 Years)**
5.11 Refine estimate of amount of pumpage from exempt wells.	$25,000	0	0	0	0	0	0	0	0	0	0
5.12 Determine effects of contaminants on Covered Species.	$ 10,000	0	$ 10,000	0	$ 10,000	0	$ 10,000	0	$ 10,000	0	$ 5,000
5.13 Determine gains and losses to instream flows in the Guadalupe River.	0	$ 30,000	0	0	0	0	0	0	0	0	0
6.1 Water Quality/Variable Flow Monitoring Study (ongoing).	$190,000	$190,000	$190,000	$190,000	$190,000	$150,000	$150,000	$150,000	$150,000	$150,000	$75,000
6.2 Studies to determine tolerance of individual species to the ranges of various water quality parameters expected with intensive management areas.	$50,000	$50,000	$0	$0	$0	$0	$0	$0	$0	$0	$0
6.3 Pilot study of intensive management areas in both the San Marcos and Comal Rivers.	$135,000	$115,000	$95,000	$75,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$25,000
TOTAL	**$632,500**	**$527,500**	**$457,500**	**$417,500**	**$352,500**	**$247,500**	**$257,500**	**$247,500**	**$257,500**	**$247,500**	**$152,500**
* Activities contingent on low-flow events									**50 year total**		**$9,745,000**

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Chapter 10 Changed Circumstances, Unforeseen Circumstances, No Surprises, and Other Federal Commitments

Section 10 regulations [50 CFR 17.22(b)(2)(iii)] require that an HCP specify the procedures to be used for dealing with changed and unforeseen circumstances that may arise during the implementation of the HCP. In addition, the Habitat Conservation Plan Assurances ("No Surprises") Rule [50 CFR 17.2, 17.22(b)(5) and (6); 63 FR 8859] defines "unforeseen circumstances" and "changed circumstances" and describes the obligation of the permittees and the USFWS.

10.1 General

The Authority has made every effort to anticipate the minimization, monitoring, and mitigation measures (conservation measures) necessary to conserve the Covered Species and the habitats that support those species and, to that end, have relied upon the best scientific and commercial information available. In addition, the AMP strategies and the flexible provisions regarding the expenditure of mitigation funds provided by the Authority are intended to meet and address future exigencies and emergency situations. Thus, the EAHCP is intended to reduce the potential for adverse, changed, or unforeseen circumstances on the Covered Species and their habitats to a level of insignificance. However, notwithstanding the provisions of the EAHCP, should adverse, changed, or unforeseen circumstances result in, or threaten, a substantial change in the population of any Covered Species or the overall quality of any habitat of that species, as determined pursuant to the procedure outlined hereinafter, the Authority and the USFWS shall cooperate to resolve the adverse impacts in accordance with this section.

The terms *changed circumstances* and *unforeseen circumstances* as defined in this EAHCP are intended to have the same meaning as defined in the Habitat Conservation Plan Assurances ("No Surprises") Rule:

> ***Changed Circumstances:*** If additional conservation and mitigation measures are deemed necessary to respond to changes in circumstances that were provided for in the HCP, the permittee(s) will be expected to implement the measures specified in the HCP, but only those measures and no others; and
>
> ***Unforeseen Circumstances:*** The USFWS will not require the commitment of additional land, water, or financial compensation or additional restrictions on the use of land, water, or

other natural resources, even upon a finding of unforeseen circumstances, unless the permittee(s) consent. Upon a finding of unforeseen circumstances, the USFWS will be limited to modifications within conserved habitat areas and the EAHCP's operating conservation program. Additional conservation and mitigation measures will not involve the commitment of additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources.

10.2 Methodology for Developing Criteria for Changed versus Unforeseen Circumstances

The USFWS, after coordinating with the Authority, will determine changed versus unforeseen circumstances based upon the likelihood of the change or event occurring during an average 50-year period (the proposed term of the EAHCP). These criteria will be refined during the first year of the permit through the collection and analysis of available data on the frequency and magnitude of events identified below. Data will be from the ecosystems covered by the EAHCP or appropriate, scientifically comparable surrogate areas.

The data on natural catastrophic events will be analyzed using applicable statistical methods to describe and predict, within appropriate confidence limits, the probability of occurrence of those events during the term of the permit. To the extent that appropriate data are available, the probabilities of occurrence of invasion by exotic species, or species-specific disease, or any other circumstance that significantly threatens Covered Species or their habitats will also be analyzed.

10.3 Procedure for Determining Occurrence of Unforeseen Circumstances

Prior to making a determination regarding the occurrence of any unforeseen circumstance, the USFWS shall comply with the following procedure:

10.3.1 Notice to Applicants and Participants

The USFWS shall provide written notice to the Authority, together with a detailed statement of the facts regarding the unforeseen circumstance involved, the anticipated impact thereof on the Covered Species and their habitat, and all information and data that support the allegation. In addition, the notice shall include any proposed conservation measure(s) that the Service believes would address the unforeseen circumstance, an estimate of the cost of implementing such conservation measure(s), and the likely effects upon (a) the Authority and its permittees and (b) the existing plans and policies of any involved federal or state agencies.

10.3.2 Response through the Adaptive Management Program

The Authority, in consultation with the USFWS, may choose to perform an expedited AMP analysis of the Covered Species or its habitat affected by the alleged unforeseen circumstance and to modify or redirect existing conservation measures to mitigate the effects of the unforeseen circumstance, within the scope of existing funded conservation actions. To the extent that these modified or redirected conservation measures do not affect conservation of other species, habitats, or key areas, this may be deemed an adequate response to the unforeseen circumstance. If the proposed modifications or redirected conservation actions could affect the conservation of other Covered Species or their habitat(s), the procedure outlined below will be followed.

10.3.3 Submission of Information by Others

The Authority shall have a meaningful opportunity to submit information to the USFWS and shall submit such information to the USFWS within 60 days of the written notice as provided above. Upon the written request of any Applicant or Participant, the time for submission of said information may be extended by the USFWS, which request will not be unreasonably denied.

10.3.4 Authority Review

Within 90 days after the close of the period for submission of additional information, the Authority shall assess (a) the alleged unforeseen circumstances, (b) the proposed additional conservation measure(s), (c) effects upon the species and its habitat and the economy and lifestyles of the Authority and permittees, and (d) possible alternatives to the proposed additional conservation measures which would result in the least adverse impacts upon the economy and lifestyles of the Authority and permittees, while at the same time leading to the survival and recovery of the affected species.

10.3.5 Findings

The USFWS shall have the burden of demonstrating that an unforeseen circumstance has occurred and that such unforeseen circumstance is having or is likely to have a significant adverse impact on the Covered Species or its habitat. The findings of the USFWS must be clearly documented and be based upon the best scientific and commercial data available regarding the status and habitat requirements of the species. In addition, based upon the results of an expedited AMP analysis of the changed or unforeseen circumstance and the information provided by the Applicants and Participants, the USFWS shall provide the justification and approval for any reallocation of funds or resources necessary to respond to the unforeseen circumstance within the existing commitments of the Authority under the EAHCP.

10.4 Changed Circumstances

Events likely to occur or that could reasonably be anticipated during an average 50-year period would be considered changed circumstances. Events expected to occur less frequently than once during an average 50-year period (such as a drought worse than the drought of record) would be unforeseen circumstances. For the purposes of this EAHCP, “changed circumstances” include:

- Listing of a new species not covered by this EAHCP;
- Vandalism, acts of terrorism, or other intentional, destructive illegal human activities;
- Chemical spills or events that result in the deterioration of water quality;
- Floods, water erosion and sedimentation, or droughts of varying intensity to include severe droughts; and
- Invasion by exotic species, disease or parasites, or anthropogenic influences or other circumstances that would degrade the health of the Covered Species or change the quality of their habitats throughout a substantial portion of their distribution.

10.5 Response to Occurrence of Changed Circumstances — Adaptive Management

While the Authority believes that the initial measures to be funded by the EAHCP will be effective to conserve both habitats and the Covered Species, it is anticipated that conditions within the Permit Area, the status of habitats, and the overall conditions of individual species over time will change (changed circumstances). In addition, it is quite likely that additional and different conservation measures, not contained within the EAHCP, will be suggested and be proven to be effective during the term of the EAHCP. Finally, it may be found that measures currently funded by the EAHCP may prove to be ineffective to conserve either species or the habitats in which they dwell. Therefore, the Authority, with the cooperation of USFWS and TPWD, is proposing an AMP to gauge the effectiveness of existing conservation measures and to propose additional or alternative conservation measures, as the need arises and to deal with changed circumstances.

In order to mitigate the impact of changed circumstances defined above requiring immediate response, including vandalism, natural catastrophic events, and invasion by exotic species and/or habitat-specific or species-specific disease, which occur at any time during the plan term (including the first year during which thresholds are being developed), the Authority and the appropriate state and federal agencies will conduct an expedited analysis for the purposes of development of appropriate management responses for the species, habitats, or key areas impacted by any changed circumstance. This expedited analysis will be a function of the AMP.

The analysis will be commenced as soon as the requisite personnel from the Authority and the federal and state agencies can be made available. If specific AMP management analysis has been performed previously for such species, habitat, or key areas, then the management for these affected species, habitats, or key areas will be reviewed in light of the changed circumstances. If management protocols for the species, habitats, or key areas have not been developed previously as part of the AMP established by this plan, then the affected species, habitats, or key areas will be made a priority for analysis and development of appropriate management protocols.

If multiple changed circumstances occur sufficiently close to one another in time such that the response will be significantly delayed due to lack of available personnel, the Authority will meet and confer with the applicable agencies in order to prioritize the analyses which need to be done. The purpose of the prioritizing will be to consider first those species, habitats, or key areas which are most at risk of further impacts.

The outcome of the analyses will be the development of appropriate measures to minimize to the extent practicable the occurrence of adverse effects resulting from the changed circumstances on species, habitats, or key areas. The measures developed will be implemented. Ongoing management activities may continue until new measures resulting from the analyses are developed. However, as the agencies deem necessary, in consultation with the Authority, measures will be promptly implemented to minimize adverse effects prior to completion of the analyses to the extent feasible.

The new listing of a species not covered by this EAHCP may constitute a changed circumstance. The USFWS shall immediately notify the Authority upon becoming aware that a species which is associated with the habitats found in Comal or San Marcos Springs and which is not a Covered Species (an "Uncovered Species") may or has been proposed for listing.

Upon receipt of notice of the potential listing of an Uncovered Species, the Authority may, but is not required to, enter into negotiations with the USFWS regarding necessary modifications, if any, to the EAHCP required to amend the applicable federal permit to cover the Uncovered Species. If the Authority elects to pursue amendment of the applicable permit, the USFWS will provide technical assistance to the Authority in identifying any modifications to the EAHCP that may be necessary to amend the applicable federal permit.

In determining whether any further conservation or mitigation measures are required in order to amend the affected permit to authorize incidental take of such Uncovered Species, the USFWS shall take into account the conservation and mitigation measures already provided in the EAHCP and cooperate with the Authority to minimize the adverse effects of the listing of such Uncovered Species on the covered activities consistent with Section 10 of ESA, as required by the IA.

Once a species is proposed or petition is found to be warranted, the USFWS shall use its best efforts to identify any necessary measures to avoid the likelihood of jeopardy to or take of the Uncovered Species ("no take/no jeopardy" measures).

10.6 Unforeseen Circumstances

For the purposes of this EAHCP, "unforeseen circumstances" are any events not identified as a changed circumstance and specifically include:

- Natural catastrophic events such as fire, droughts worse than the drought of record (or equivalent to the drought of record but occurring more than once during the 50-year term of permit), severe wind or water erosion, floods, and landslides (including landslides, faulting, or alteration of the springs or aquifer as a result of earthquakes) of a magnitude exceeding that expected to occur during the term of the permit.

- Invasion by exotic species and/or habitat-specific or species-specific disease that threatens Covered Species or their habitats, which cannot be effectively controlled by currently available methods or technologies or which cannot be effectively controlled without resulting in greater harm to other Covered Species than to the affected Covered Species.

In making the determination that such an event constitutes an unforeseen circumstance, the USFWS will consider, but not be limited to, the level of knowledge about the affected species and the degree of specificity of the species' conservation program under the EAHCP and whether failure to adopt additional conservation measures would appreciably reduce the likelihood of survival and recovery of the affected species in the wild.

10.7 Response to Occurrence of Unforeseen Circumstances — No Surprises

If, after the conclusion of the process outlined above, the USFWS determines that an unforeseen circumstance has occurred and that additional conservation measures are required to address such circumstance which are not contemplated or capable of implementation by the AMP and procedures of the EAHCP, and provided that the Authority has fully complied with the terms of the EAHCP, any proposed additional conservation measures shall fit, to the maximum extent possible, within the terms of the EAHCP and its AMP. Additional conservation measures shall not require the payment of additional compensation by the Authority or permittees. If additional expenditures are required, the USFWS or any other federal agency shall take additional actions that might lead to the conservation or enhancement of a species that is being adversely affected by an unforeseen circumstance. The costs of these additional actions shall be borne by the USFWS or any other federal agency. However, the USFWS agrees that, prior to undertaking or attempting to impose any action or conservation measure, it shall consider all practical alternatives to the proposed conservation measures and adopt only that action or conservation measure which would have the least effect upon the economy and lifestyle of the Authority and permittees, while at the same time addressing the unforeseen circumstance and the survival and recovery of the affected species and its habitat. The purpose of this provision is to recognize that Congress intended, even in the event of unforeseen, extraordinary, or changed circumstances, that additional mitigation requirements not be imposed upon a Section 10 permittee which has fully implemented the requirements undertaken by it pursuant to an approved habitat conservation plan.

10.8 Response to Occurrence of Unforeseen Circumstances — Adaptive Management

The Authority believes that the initial measures to be funded by the EAHCP will be effective to conserve both habitats and the Covered Species for that period. However, over time, unforeseen circumstances may affect the status of habitats and the condition of individual species within the Comal and San Marcos Springs ecosystems. Therefore, the Authority, with the cooperation of USFWS and TPWD, is proposing an AMP to gauge the effectiveness of existing conservation measures and to propose alternative conservation measures, as the need arises, to deal with unforeseen circumstances, within the budget and scope of the AMP. If existing or additional conservation measures within the budget and scope of the approved EAHCP AMP do not adequately respond to unforeseen circumstances, the Authority will assist and coordinate with any additional conservation efforts undertaken by the USFWS, subject to the limitations of the "No Surprises" Rule.

10.9 Additional Federal Commitments

10.9.1 Augmentation, Not Replacement or Substitution, of Federal Budgets

Each federal agency that is a Participant in the EAHCP process and signatory to the required IA will agree that it shall annually include in its agency budget requests dedicated and earmarked funding adequate to allow the agency to fully operate, manage, maintain, and monitor its lands pursuant to the terms of this EAHCP and to fulfill its obligations to protect the species and ecosystems consistent with statutory obligations imposed by Congress and to actively cooperate with and provide technical assistance to the Authority. In addition, each federal agency will agree that it shall not allow funds allocated by the EAHCP to be substituted for funds which it would otherwise receive from the federal budget process and instead will use EAHCP funds to augment, and not replace, its appropriated funds. Nor will any federal agency receiving funds from the EAHCP move or redirect its own funds from categories currently established to implement conservation measures, plans, or policies to other budget categories. Finally, no state or regional office of any federal agency will take into account any EAHCP funds paid or expected to be paid in allocating available funds among its various offices and departments.

10.9.2 Section 7 Consultations and Conferences

Except as may be specifically provided elsewhere in this EAHCP, nothing in the EAHCP is intended to apply to any activity on federal lands or federally-funded projects that are governed by Section 7 of the ESA. The USFWS shall cause and does intend for any minimization measures that result from the authorization of incidental take pursuant to Section 7 and contained within any biological opinion or conference report to be generally consistent with the minimization measures required by the EAHCP. However, nothing contained in this EAHCP is intended to prohibit or proscribe the USFWS from requiring minimization in excess of that provided for in the EAHCP, should the circumstances so warrant.

10.9.3 Consideration of the EAHCP in Section 4 Findings

The USFWS will specifically inform the Authority of any listing proposal under Section 4 of the ESA for species in the Edwards Aquifer, Comal Springs, San Marcos Springs, or Guadalupe River Watershed in writing. To the extent permitted by law, the USFWS will consider actions undertaken by the Authority in making their determination.

Chapter 11 Clarifications, Minor Administrative Amendments, and Amendments

11.1 Clarifications and Minor Administrative Amendments

From time to time it may be necessary for the USFWS and the Authority, as Administrator of the EAHCP, to clarify provisions of the EAHCP, the IA, or the ITP to deal with issues that arise with respect to the administration of the process or, to be more specific, regarding the precise meaning and intent of the language contained within those documents. Clarifications do not change the provisions of any of the documents in any way but merely clarify and make more precise the provisions as they exist.

In addition, it is contemplated that from time to time it may be necessary to make Minor Administrative Amendments to the documents that do not make substantive changes to any of the provisions of the documents, but which may be necessary or convenient, over time, to more fully represent the overall intent of the Authority and the USFWS. Clarifications and Minor Administrative Amendments to the documents may be approved by the Field Supervisor of the Austin Fish and Wildlife Office of the USFWS and the General Manager of the Authority after review and approval by the Authority and shall be memorialized by letter agreement or by substituted Plan Documents which are modified to contain only the Clarification or Minor Administrative Amendment. It is proposed that any request for Clarification or any proposed Minor Administrative Amendment will be processed and a response provided within 30 days after receipt by the USFWS or the Authority, as the case may be.

The EAHCP may, under certain circumstances, be amended without amending its associated permit, provided such amendments are of a minor or technical nature and that the effect on the species involved and the levels of take resulting from the amendment are not significantly different from those described in the original EAHCP. Examples of minor amendments to the EAHCP that would not require a permit amendment include, but are not limited to, (a) minor revisions to monitoring or reporting procedures and (b) minor revisions in accounting procedures.

To amend the conservation plan without amending the permit, the Authority must submit to the USFWS, in writing, a description of (a) the proposed amendment; (b) an explanation of why the amendment is necessary or desirable; and (c) an explanation of why the Authority believes the effects of the proposal are not significantly different from those described in the original conservation plan. If the USFWS concurs with the proposal, then they shall authorize the conservation plan amendment in writing, and the amendment shall be considered effective upon the date of the written authorization from the USFWS.

11.2 Adaptive Management Changes and Subsequent Listing of Covered Species

It is also anticipated that, over time, the AMP will recommend modifications and changes to conservation measures undertaken and/or financed by the EAHCP. Such future conservation measures may or may not be proposed in this first phase of the EAHCP, but may be developed by the EAHCP Management Committee, the federal and state land managers, and/or the USFWS over time. Conservation measures undertaken pursuant to the AMP shall not require formal amendment of any of the Plan Documents, but shall be processed and approved by the USFWS and the Authority in connection with the periodic review and approval, as described below.

11.3 Amendments

Except as provided for Clarifications and Minor Administrative Amendments, neither the EAHCP, the ITP, nor the IA may be amended or modified in any way without the written approval of the Authority, as Administrator of the EAHCP; all signatories; and the USFWS. All proposed material changes or amendments shall be reviewed by the Authority. Material changes shall be processed as an amendment to the permit in accordance with the provisions of the ESA and regulations at 50 CFR Parts 13 and 17 and shall be subject to appropriate environmental review under the provisions of NEPA.

Amendments to the EAHCP Section 10(a) Permit would be required for any change in the following: (a) the listing under the ESA of a new species not currently addressed in the plan that may be taken by project actions; (b) the modification of any project action or mitigation component under the plan, including funding, that may significantly affect authorized take levels, effects of the project, or the nature or scope of the mitigation program, with the exception of those plan modifications specifically addressed in the original EAHCP and permit application; and (c) any other modification of the project likely to result in significant adverse effects to the Covered Species not addressed in the original EAHCP and permit application.

Amendment of a Section 10(a) Permit must be treated in the same manner as an original permit application. Permit applications typically require a revised conservation plan, a permit application form, an implementing agreement, a NEPA document, and a 30-day public comment period. However, the specific documentation needed in support of a permit amendment may vary depending upon the nature of the amendment.

Chapter 12 Implementation

12.1 Reporting

An annual report of covered activities as well as management activities undertaken under the terms of this HCP will be prepared by the Authority and submitted to the USFWS. The report will summarize information on the management of the aquifer including:

- Permitted withdrawals;
- Reference well levels;
- Springflows at Comal and San Marcos Springs;
- Aquifer recharge;
- Aquifer discharge from wells and springflow;
- Critical period management reductions;
- Adaptive management activities undertaken during the year;
- Expenditures by the EAA on implementation activities;
- Proposed activities for the next year; and
- Water quality.

In addition, the report will summarize species-specific research and management actions undertaken with specific reference to the Biological Objectives identified for each species.

12.2 Implementing Agreement

Section 10(a)(2)(iv) of the ESA states that a conservation plan must specify "such other measures that the Secretary may require as being necessary or appropriate for the purposes of the plan." The USFWS believes it is generally necessary and appropriate to prepare an IA for conservation plans. The purpose of an IA is to ensure that each party understands its obligations under the HCP and Section 10(a) Permit and to provide remedies should any party fail to fulfill its obligations. Therefore, an Implementing Agreement has been prepared for this EAHCP (to be completed and attached as Appendix XX). At the time of this writing, no other measures have been identified by the USFWS.

Each entity that has committed to participate in and contribute to the implementation of the plan will enter into an agreement with the USFWS. This agreement will specify the responsibilities of each agency; the minimization, conservation, and mitigation measures to be implemented; reporting and enforcement procedures; and any other permit conditions USFWS may require.

Chapter 13 List of Preparers

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Chapter 15 Glossary of Terms and Acronyms

Acronyms

ACHP – Advisory Council on Historic Preservation
AMP – Adaptive Management Program
APA– Administrative Procedures Act
APE – Area of Potential Effect
ASR – Aquifer Storage and Recovery
BMP – Best Management Practices
BWL – Bad (Saline) Water Line
CAC – Citizens Advisory Committee
CC/LCC – Choke Canyon/Lake Corpus Christi
CEQ – Council on Environmental Quality
CFR – Code of Federal Regulations
Cfs – cubic feet per second
CO – Carbon monoxide
COE – United States Army Corps of Engineers
CPMP – Critical Period Management Plan
CWMP – Comprehensive Water Management Plan
CZ – Contributing Zone
DEIS – Draft Environmental Impact Statement
DM/CPM – Demand Management/Critical Period Management Plan
EAA – Edwards Aquifer Authority (the Authority)
EAABD - Edward Aquifer Authority Board of Directors
EAHCP – Edwards Aquifer Habitat Conservation Plan
EAOP – Edwards Aquifer Optimization Program
EIS – Environmental Impact Statement
EPA – Environmental Protection Agency
ESA – Endangered Species Act
GBRA – Guadalupe-Blanco River Authority
GIS – Geographic Information Systems
GCP – Groundwater Conservation Plan
GMP – Groundwater Management Plan
GRP – Gross Regional Product
GCW – Golden-cheeked Warbler
HCP – Habitat Conservation Plan
IA – Implementing Agreement
IFBs – Invitation for Bids
IH – Interstate Highway
IRP – Initial Regular Permit
ISD – Independent School District

ITP – Incidental Take Permit
JFA – Joint Funding Agreement
LCRA – Lower Colorado River Authority
MCUWCD – Medina County Underground Water Conservation District
MG/L – Milligrams Per Liter
MSA – Metropolitan Statistical Area
MSL (or msl) – Mean Sea Level
M&I – Municipal and Industrial
NAAQS – National Ambient Air Quality Standards
NAFTA – North American Free Trade Agreement
NAICS – North American Industrial Classification System
NEPA – National Environmental Policy Act
NGWA – National Groundwater Association
NHPA – National Historic Preservation Act
NRHP – National Register of Historic Places
NOI – Notice of Intent
NO_x – Nitrogen Oxides
NRA – Nueces River Authority
NRCS – Natural Resource Conservation Service
NRI – National Resource Institute
O_3 – Ozone
OTS — Optimization Technical Studies
Pb – Lead
PEP – Precipitation Enhancement Program
PM_{10} – Particulate matter (10 micrograms)
$PM_{2.5}$ – Particulate matter (2.5 micrograms)
R&D – Research and Development
RFPs – Request for Proposals
SAL – State Archeological Landmark
SARA – San Antonio River Authority
SB – Senate Bill
SCTRWP – South Central Texas Regional Water Plan
SCTRWPA – South Central Texas Regional Water Planning Area
SCTRWPG – South Central Texas Regional Water Planning Group
SCTWAC – South Central Texas Water Advisory Committee
SHPO – State Historic Preservation Officer
SIC – Standard Industrial Classification
SO_2 – Sulphur Dioxide
SWT – Southwest Texas State University (now designated Texas State University at San Marcos)
SWTJC – Southwest Texas Junior College
TAC – Texas Antiquities Code
TAG – Technical Advisory Group
TARL – Texas Archeological Research Laboratory
TC&B – Turner, Collie and Braden
TCEQ – Texas Commission on Environmental Quality

TDA – Texas Department of Agriculture
TDS – Total Dissolved Solids
TGWA – Texas Groundwater Association
THC – Texas Historic Commission
TNRCC – Texas Natural Resource Conservation Commission (NOW TCEQ)
TPWD – Texas Parks and Wildlife Department
TSDC – Texas State Data Center
TSWQS – Texas State Water Quality Standards
TWC – Texas Water Commission
TWDB – Texas Water Development Board
UCUWCD – Uvalde County Underground Water Conservation District
USDA – United States Department of Agriculture
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey
VEDC – Victoria Economic Development Corporation
WSP – Withdrawal Suspension Program
WORD – Water-oriented Recreation District

Glossary

This glossary was prepared to provide terms commonly used in describing underground and surface hydrological processes. It also provides additional terminology to assist in understanding information provided in this Habitat Conservation Plan. Definitions were derived in part by referencing EAA (1998), Edwards Underground Water District & Edwards Aquifer Research and Data Center (1981), and Eckhardt (2000). Complete references to these citations are found in Chapter 9, References Cited.

abandoned well. a well which is no longer used. In many places, abandoned wells must be filled with cement or concrete grout to prevent pollution of groundwater.

accretion. a gradual increase in land area adjacent to a river.

acequias. water ditches of early San Antonio. Acequias were built to divert river water for cooking, drinking, and irrigation.

acid rain. the acidic rainfall which results when rain combines with sulfur or nitrogen oxide emissions from combustion of fossil fuels.

acre-foot (ac-ft). the quantity of water required to cover one acre to a depth of one foot, equivalent to 43,560 ft^3 (cubic feet), about 325,851 gal (gallons), or 1,233 m^3 (cubic meters).

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

adsorption. the adhesion of a substance to the surface of a solid or liquid. Adsorption is often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to clean up oil spills from waterways.

algal bloom. a phenomenon whereby excessive nutrients within a river, stream or lake cause an explosion of plant life which results in the depletion of the oxygen in the water needed by fish and other aquatic life. Algal blooms can be caused by urban runoff (of lawn fertilizers, etc.) or pollution. The potential tragedy is that of a "fish kill," where the stream life dies in one mass extinction.

alkalinity. the measurement of constituents in a water supply which determine alkaline conditions. The alkalinity of water is a measure of its capacity to neutralize acids. See pH.

alluvium. sediments deposited by erosional processes, usually by streams.

alvusion. a sudden or perceptible change in a river's margin, such as a change in course or loss of banks due to flooding.

aquatic. growing in, living in, or frequenting water.

aquaculture. the raising or fattening of fish in enclosed ponds.

aquiclude. a formation which, although porous and capable of absorbing water slowly, will not transmit water fast enough to furnish an appreciable supply for a well or a spring.

aquifer. a water-bearing stratum of permeable rock, sand or gravel.

artesian aquifer. one type of aquifer in which two impermeable layers surround one permeable water-bearing layer. The water is confined and stored under pressure and will rise above the top of the aquifer when penetrated by a well.

artesian well. a well tapping confined groundwater. Water in the well rises above the level of the confined water-bearing strata under artesian pressure but does not necessarily reach the land surface.

artesian zone. an area where the water level from a confined aquifer stands above the top of the strata in which the aquifer is located.

average annual recharge. amount of water entering the aquifer on an average annual basis. Averages mean very little for the Edwards because the climate of the region and structure of the aquifer produce a situation in which the area is usually water rich or water poor.

bacteria. microscopic unicellular organisms, typically spherical, rod-like, or spiral and threadlike in shape, often clumped in colonies. Some bacteria are pathogenic (causing disease), while others perform an essential role in nature in the recycling of materials (measured in colonies/100 milliliters).

bad (saline) water. characterized by having more than 1,000 milligrams/liter (mg/l) of dissolved solids. It may be low in dissolved oxygen, high in sulfates and have a higher temperature. The bad water line is the southern boundary of good water in the Edwards Artesian Aquifer.

Balcones escarpment. a steep series of fault-formed hills which divide the higher plateau from lower coastal prairies. Escarpments can be formed by erosion, or as with the Balcones, by faulting.

Balcones fault zone. The area bounding the Edwards Plateau having extensive cracks and faults caused by the force of crustal movement.

barrage. any artificial obstruction placed in water to increase water level or divert it. Usually the idea is to control peak flow for later release.

base flow. a theoretical minimum flow of water within a river or stream. .

beneficial use. the amount of water necessary when reasonable intelligence and diligence are used for a stated purpose; Texas law recognizes the following uses as beneficial: (1) domestic and municipal uses, (2) industrial uses, (3) irrigation, (4) mining, (5) hydroelectric power, (6) navigation, (7) recreation, (8) stock raising, (9) public parks, and (10) game preserves.

bioaccumulation. uptake and retention of substances by an organism from its surrounding medium (usually water) and from food.

biomonitoring. a test used to evaluate the relative potency of a chemical by comparing its effect on a group of living organisms (treatment group) with the effect of an untreated group (control group) of the same organisms.

BOD. Biochemical Oxygen Demand. A measure of the amount of oxygen required to neutralize organic wastes.

bog. a type of wetland that accumulates appreciable peat deposits. They depend primarily on precipitation for their water source, and are usually acidic and rich in plant matter with a conspicuous mat or living green moss.

brine. highly salty and heavily mineralized water containing heavy metal and organic contaminants.

calcium carbonate. $CaCO_3$ – the common mineral causing the hard water of the Edwards Aquifer. It is the main component of limestone.

carbonates. the collective term for the natural inorganic chemical compounds related to carbon dioxide that exist in natural waterways.

carbonic acid. H_2CO_3 – The acid formed by the combination of water, supplied by rainfall, and carbon dioxide produced in the atmosphere. This weak acid dissolves the Edwards limestone.

casing. a tubular structure intended to be watertight installed in the excavated or drilled hole to maintain the well opening and, along with cementing, to confine the groundwaters to their zones of origin and prevent the entrance of surface pollutants.

cavern. a large underground opening in rock (usually limestone) which occurred when some of the rock was dissolved by water. In some igneous rocks, caverns can be formed by large gas bubbles.

CERCLA. Comprehensive Environment Response, Compensation and Liability Act. Also known as SUPERFUND. The Act gave EPA the authority to clean up abandoned, leaky hazardous waste sites.

certificate of water right. an official document which serves as court evidence of a perfected water right.

check dam. a small dam constructed in a gully or other small water course to decrease the stream flow velocity, minimize channel erosion, promote deposition of sediment and to divert water from a channel.

chemical weathering. attack and dissolving of parent rock by exposure to rainwater, surface water, oxygen, and other gases in the atmosphere, and compounds secreted by organisms. Contrast physical weathering.

chlorination. the adding of chlorine to water or sewage for the purpose of disinfection or other biological or chemical results.

chlorine demand. the difference between the amount of chlorine added to water, sewage, or industrial wastes and the amount of residual chlorine remaining at the end of a specific contact period.

chute spillway. the overall structure which allows water to drop rapidly through an open channel without causing erosion. Usually constructed near the edge of dams.

circulate. to move in a circle, circuit or orbit; to flow without obstruction; to follow a course that returns to the starting point.

cistern. a tank used to collect rainwater runoff from the roof of a house or building.

climate. Average condition of weather at a given place on Earth over a period of years as exhibited by temperature, precipitation, wind velocity, and humidity.

climatic cycle. the periodic changes climate displays, such as a series of dry years following a series of years with heavy rainfall.

climatic year. a period used in meteorological measurements. The climatic year in the U.S. begins on October 1.

coliform bacteria. non-pathogenic microorganisms used in testing water to indicate the presence of pathogenic bacteria.

collector well. a well located near a surface water supply used to lower the water table and thereby induce infiltration of surface water through the bed of the water body to the well.

colloids. finely divided solids which will not settle but which may be removed by coagulation or biochemical action.

completion. sealing off access of undesirable water to the well bore by proper casing and/or cementing procedures.

composite sample, weighted. a sample composed of two or more portions collected at specific times and added together in volumes related to the flow at time of collection. Compare grab sample.

concentration. amount of a chemical or pollutant in a particular volume or weight of air, water, soil, or other medium.

condensation. The transformation of the gaseous water vapor into liquid water.

conductivity. a measure of the ease with which an electrical current can be caused to flow through an aqueous solution under the influence of an applied electric field. Expressed as the algebraic reciprocal of electrical resistance (measured in microSiemens per centimeter (µS/cm) at ambient temperature). Generally, in water the greater the total dissolved solids content, the greater the value of conductivity. See also specific conductance.

conduit. a natural or artificial channel through which fluids may be conveyed.

cone of depression. natural depression in the water table around a well during pumping.

confined aquifer. an artesian aquifer or an aquifer bound above and below by impermeable strata, or by strata with lower permeability than the aquifer itself.

confining bed or unit. a body of impermeable or distinctly less permeable material stratigraphically adjacent to one or more aquifers.

conjunctive management. integrated management and use of two or more water resources, such as an aquifer and a surface water body.

connate growth. water trapped in the pore spaces of a sedimentary rock at the time it was deposited. It is usually highly mineralized.

conservation. to protect from loss and waste. Conservation of water may mean to save or store water for later use.

consolidated formation. naturally occurring geologic formations that have been lithified (turned to stone). The term is sometimes used interchangeably with the term "bedrock." Commonly, these formations will stand at the edges of a bore hole without caving.

consumptive use. the quantity of water not available for reuse. Evapotranspiration, evaporation, incorporation into plant tissue, and infiltration into groundwater are some of the reasons water may not be available for reuse. Compare non-consumptive use.

contact recreation. activities involving a significant risk of ingestion of water, such as wading by children, swimming, water skiing, diving and surfing. Compare non-contact recreation.

contaminate. to make unfit for use by the introduction of undesirable substances.

correlative rights. rights that are coequal or that relate to one another, so that any one owner cannot take more than his share.

creek. a small stream of water which serves as the natural drainage course for a drainage basin. The term is relative according to size. Some creeks in a humid region would be called rivers if they occurred in an arid area.

crest. the top of a dam, dike, or spillway, which water must reach before passing over the structure; the summit or highest point of a wave; the highest elevation reached by flood waters flowing in a channel.

critical low-flow. low-flow conditions below which some standards do not apply. The impacts of permitted discharges are analyzed at critical low-flow.

cubic foot per second (cfs). the rate of discharge representing a volume of one cubic foot passing a given point during 1 second. This rate is equivalent to approximately 7.48 gallons per second, or 1.98 acre-feet per day.

current. the portion of a stream or body of water which is moving with a velocity much greater than the average of the rest of the water. The progress of the water is principally concentrated in the current. See thalweg.

dam. a structure of earth, rock, or concrete designed to form a basin and hold water back to make a pond, lake, or reservoir.

delta. an alluvial deposit made of rock particles (sediment, and debris) dropped by a stream as it enters a body of water.

demand. the number of units of something that will be purchased at various prices at a point in time. Compare supply.

deposit. something dropped or left behind by moving water, as sand or mud.

desalination. the process of salt removal from sea or brackish water.

detection limit. the lowest level that can be determined by a specific analytical procedure or test method.

diatomaceous. consisting of or abounding in diatoms, a class of unicellular or colonial algae having a silicified cell wall that persists as a skeleton after death.

diluting water. distilled water that has been stabilized, buffered, and aerated. Used in the BOD test.

discharge. water which leaves the aquifer by way of springs, flowing artesian wells, or pumping. The volume of water that passes a given point within a given period of time.

discharge area. an area where groundwater is lost from the aquifer to surface water.

discharge permit. a permit issued by a state or the federal government to discharge effluent into waters of the state or the United States. In many states both State and federal permits are required.

dispersion. the movement and spreading of contaminants out and down in an aquifer.

displacement. distance by which portions of the same geological layer are offset from each other by a fault.

dissolution. the process of dissolving.

dissolved oxygen (DO). amount of oxygen gas dissolved in a given quantity of water at a given temperature and atmospheric pressure. It is usually expressed as a concentration in parts per million or as a percentage of saturation.

dissolved solids. inorganic material contained in water or wastes. Excessive dissolved solids make water unsuitable for drinking or industrial uses. See TDS.

diversion. to remove water from a water body. Diversions may be used to protect bottomland from hillside runoff, divert water away from active gullies, or protect buildings from runoff.

drainage area. of a stream at a specified location is that area, measured in a horizontal plane, enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into the stream above the specified location.

drainage basin. an area bounded by a divide and occupied by a drainage system. It consists of a surface stream or a body of impounded surface water together with all tributary surface streams and bodies of impounded surface water.

driller's well log. a log kept at the time of drilling showing the depth, thickness, character of the different strata penetrated, location of water-bearing strata, depth, size, and character of casing installed.

drought. a long period of time without sufficient rain.

ecosphere. total of all the ecosystems on the planet, along with their interactions; the sphere of air, water, and land in which all life is found.

Edwards and Associated Limestone (Edwards Formation). layers of sediment, deposited during the Cretaceous period which later became limestone rock.

Edwards Aquifer. water bearing zone comprised of Edwards and Associated Limestones.

Edwards Aquifer Region. a region of Texas which obtains its water from the Edwards Aquifer. This area consists of the contributing zone, recharge zone, and the artesian zone of the Edwards Aquifer.

Edwards outcrop. where the Edwards and associated limestone formations are found at the surface. This area is also referred to as the Recharge Zone.

Edwards Plateau. that area west and northwest of the Balcones Fault Zone where the Edwards Formation is essentially flat-lying and is the principal aquifer of the region.

Edwards Underground Water District. the regional governmental entity that preceded the Edwards Aquifer Authority.

effective porosity. the portion of pore space in saturated permeable material where the movement of water takes place.

effective precipitation. the part of precipitation which produces runoff; a weighted average of current and antecedent precipitation "effective" in correlating with runoff. It is also that part of the precipitation falling on an irrigated area which is effective in meeting the requirements of consumptive use.

effluent. any substance, particularly a liquid, that enters the environment from a point source. Generally refers to wastewater from a sewage treatment or industrial plant.

environment. aggregate of external conditions that influence the life of an individual organism or population.

erosion. the wearing away of the land surface by wind, water, ice or other geologic agents. Erosion occurs naturally from weather or runoff but is often intensified by human land use practices.

escarpment. the topographic expression of a fault.

estuarine waters. deepwater tidal habitats and tidal wetlands that are usually enclosed by land but have access to the ocean and are at least occasionally diluted by freshwater runoff from the land (such as bays, mouths of rivers, salt marshes, lagoons).

estuarine zone. area near the coastline that consists of estuaries and coastal saltwater wetlands.

estuary. an area where freshwater from rivers mixes with salt water from the sea and is characterized by reduced salinity. Estuaries are important nurseries for many marine species.

eutrophic. having a large or excessive supply of plant nutrients (nitrates and phosphates). Compare oligotrophic.

eutrophication (natural). an excess of plant nutrients from natural erosion and runoff from the land in an aquatic ecosystem supporting a large amount of aquatic life that can deplete the oxygen supply.

evaporation. the process by which liquid water is transformed into gaseous water vapor due to the heat of the sun.

evapotranspiration. combination of evaporation and transpiration of water into the atmosphere from living plants and soil. Distinguish transpiration.

external cost. cost of production or consumption that must be borne by society; not by the producer.

extinction. complete disappearance of a species because of failure to adapt to environmental change.

fault zone. a region containing several breaks in the Earth's crust along which slippage has taken place.

fault zone aquifer. an aquifer developed in association with a zone of faulting. i.e. Balcones fault zone and the resulting Balcones Escarpment with the associated Edwards fault zone aquifer.

faults. fracture of the Earth's crust accompanied by movement.

fecal coliform. the portion of the coliform bacteria group which is present in the intestinal tracts and feces of warm-blooded animals. A common pollutant in water.

filtration. the mechanical process which removes particulate matter by separating water from solid material, usually by passing it through sand.

“first in time, first in right”. phrase indicating that older water rights have priority over more recent rights if there is not enough water to satisfy all rights.

fixed groundwater. water held in saturated material that it is not available as a source of water for pumping.

flood. an overflow or inundation that comes from a river or other body of water and causes or threatens damage. It can be any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream. It is also a relatively high-flow as measured by either gauge height or discharge quantity.

floodplain. land next to a river that becomes covered by water when the river overflows its banks.

flora. plant population of a region.

flow. the rate of water discharged from a source expressed in volume with respect to time.

flow augmentation. the addition of water to meet flow needs.

food chain. series of organisms usually starting with green plants in which each organism serves as a source of energy for the next one in the series.

fracture. breaks in rocks due to intense folding and faulting; a simple break in which no movement is involved.

free groundwater. water in interconnected pore spaces in the zone of saturation down to the first impervious barrier, moving under the control of the water table slope.

freshwater. water containing less than 1,000 parts per million (ppm) of dissolved solids of any type. Compare saline water.

freshwater/saline water interface. the interface or area that separates total dissolved solids (TDS) values less than 1,000 mg/L (freshwater) from TDS values greater than 1,000 mg/L (saline water). Commonly referred to as the “bad water line.”

gallon. A unit of volume. A U.S. gallon contains 231 cubic inches, 0.133 cubic feet, or 3.785 liters. One U.S. gallon of water weighs 8.3 lbs.

gauging station. a particular site that systematically collects hydrologic data such as stream flow, spring flow or precipitation.

geohydrology. a term which denotes the branch of hydrology relating to subsurface or subterranean waters; that is, to all waters below the surface.

geologic erosion. normal or natural erosion caused by geological processes acting over long geologic periods and resulting in the wearing away of mountains, the building up of floodplains, coastal plains, etc.

groundwater. water that is stored under the Earth’s surface.

groundwater divide. a ridge, or mound in the water table or other potentiometric surface from which the groundwater moves away in both directions.

groundwater hydrology. the branch of hydrology that deals with groundwater; its occurrence and movements, its replenishment and depletion, the properties of rocks that control groundwater movement and storage, and the methods of investigation and utilization of groundwater.

groundwater law. the common law doctrine of riparian rights and the doctrine of prior appropriation as applied to groundwater.

groundwater recharge. the inflow to a groundwater reservoir.

groundwater reservoir. an aquifer or aquifer system in which groundwater is stored. The water may be placed in the aquifer by artificial or natural means.

groundwater runoff. the portion of runoff which has passed into the ground, has become groundwater, and has been discharged into a stream channel as spring or seepage water.

groundwater storage. the storage of water in groundwater reservoirs.

gully. a deeply eroded channel caused by the concentrated flow of water.

hardpan. a shallow layer of earth material which has become relatively hard and impermeable, usually through the deposition of minerals. In the Edwards region hardpans of clay are common.

hard water. water containing a high level of calcium, magnesium, and other minerals. Hard water reduces the cleansing power of soap and produces scale in hot water lines and appliances.

hardness (water). condition caused by dissolved salts of calcium, magnesium, and iron, such as bicarbonates, carbonates, sulfates, chlorides, and nitrates.

head. the pressure of a fluid owing to its elevation, usually expressed in feet of head or in pounds per square inch, since a measure of fluid pressure is the height of a fluid column above a given or known point.

hydroelectric plant. electric power plant in which the energy of falling water is used to spin a turbine generator to produce electricity.

hydrogeology. a term which denotes the branch of hydrology relating to subsurface or subterranean waters; that is, to all waters below the surface.

hydrograph. a chart that measures the amount of water flowing past a point as a function of time.

hydrologic cycle. natural pathway water follows as it changes between liquid, solid, and gaseous states; biogeochemical cycle that moves and recycles water in various forms through the ecosphere. Also called the water cycle.

hydrologic unit. is a geographic area representing part or all of a surface drainage basin or distinct hydrologic feature.

hydrology. a science dealing with the properties, distribution and circulation of water on the surface of the land, in the soil and underlying rocks and in the atmosphere.

hydropower. electrical energy produced by falling water.

hydrostatic head. a measure of pressure at a given point in a liquid in terms of the vertical height of a column of the same liquid which would produce the same pressure.

hydrostatic pressure. pressure exerted by or existing within a liquid at rest with respect to adjacent bodies.

impermeable. material (such as dense rock) that will not permit liquid or water to flow through it.

impervious. the quality or state of being impermeable; resisting penetration by water or plant roots. Impervious ground cover like concrete and asphalt affects quantity and quality of runoff.

impoundment. a body of water such as a pond, confined by a dam, dike, floodgate or other barrier. It is used to collect and store water for future use.

infiltration. the process of water entering the ground through cracks, soil or porous rock.

inland freshwater wetlands. swamps, marshes, and bogs found inland beyond the coastal saltwater wetlands.

instream use. use of water that does not require withdrawal or diversion from its natural watercourse; for example, the use of water for navigation, recreation, and support of fish and wildlife.

interbasin transfer. the physical transfer of water from one watershed to another; regulated by the Texas Water Code.

intermittent stream. one that flows periodically. Compare perennial stream.

interstices. the void or empty portion of rock or soil occupied by air or water.

irrigation. to supply water by artificial means to crops.

irrigation efficiency. the percentage of water applied, and which can be accounted for, in the soil moisture increase for consumptive use.

irrigation return flow. water which is not consumptively used by plants and returns to a surface or groundwater supply. Under conditions of water right litigation, the definition may be restricted to measurable water returning to the stream from which it was diverted.

irrigation water. water which is applied to assist crops in areas or during times where rainfall is inadequate.

lake. an inland body of water, usually freshwater, formed by glaciers, river drainage etc. Usually larger than a pool or pond.

limestone. rock that consists mainly of calcium carbonate and is chiefly formed by accumulation of organic remains.

limiting factor. factor such as temperature, light, water, or a chemical that limits the existence, growth, abundance, or distribution of an organism.

littoral zone. area on or near the shore of a body of water.

lotic system. a flowing body of freshwater, such as a river or stream. Compare lentic system.

marsh. an area periodically inundated and treeless and often characterized by grasses, cattails, and other monocotyledons

MCL - Maximum Contaminant Level. the maximum level of a contaminant allowed in water by federal law. Based on health effects and currently available treatment methods.

median stream flow. the rate of discharge of a stream for which there are equal numbers of greater and lesser flow occurrences during a specified period.

Micrograms. micrograms per liter – mg/L.

migration. the movement of oil, gas, contaminants, water, or other liquids through porous and permeable rock.

milligrams per liter - mg/L. milligrams per liter of water. This measure is equivalent to parts per million (ppm).

minimum stream flow. the specific amount of water reserved to support aquatic life, to minimize pollution, or for recreation. It is subject to the priority system and does not affect water rights established prior to its institution.

municipal sewage. sewage from a community which may be composed of domestic sewage, industrial wastes or both.

municipalities. self-governing urban political units having corporate status.

natural flow. the rate of water movement past a specified point on a natural stream. The flow comes from a drainage area in which there has been no stream diversion caused by storage, import, export, return flow, or change in consumptive use caused by man-controlled modifications to land use. Natural flow rarely occurs in a developed country.

natural resource. any form of matter or energy obtained from the environment that meets human needs.

nitrogen. a plant nutrient that can cause an overabundance of bacteria and algae when high amounts are present, leading to a depletion of oxygen and fish kills. Several forms occur in water, including ammonia, nitrate, nitrite or elemental nitrogen. High levels of nitrogen in water are usually caused by agricultural runoff or improperly operating wastewater treatment plants. Also see phosphorous.

non-consumptive use. using water in a way that does not reduce the supply. Examples include hunting, fishing, boating, water-skiing, swimming, and some power production. Compare consumptive use.

non-contact recreation. recreational pursuits not involving a significant risk of water ingestion, including fishing, commercial and recreational boating, and limited body contact incidental to shoreline activity. Compare contact recreation.

nonpoint source. source of pollution in which wastes are not released at one specific, identifiable point but from a number of points that are spread out and difficult to identify and control. Compare point source.

nonporous. something which does not allow water to pass through it. Compare porous.

nonpotable. not suitable for drinking. Compare potable.

nutrient. as a pollutant, any element or compound, such as phosphorous or nitrogen, that fuels abnormally high organic growth in aquatic ecosystems. Also see eutrophic.

oligotrophic. having a low supply of plant nutrients. Compare eutrophic.

outcrop. exposed at the surface. The Edwards limestone outcrops in its recharge zone.

outfall. the place where a wastewater treatment plant discharges treated water into the environment.

perched water table. groundwater standing unprotected over a confined zone.

percolating waters. waters passing through the ground beneath the Earth's surface without a definite channel.

percolation. the movement of water through the subsurface soil layers, usually continuing downward to the groundwater or water table reservoirs.

perfected water right. a water right which indicates that the uses anticipated by an applicant, and made under permit, were made for beneficial use. Usually it is irrevocable unless voluntarily canceled or forfeited due to several consecutive years of nonuse.

perennial stream. one that flows all year round. Compare intermittent stream.

permeability. the ability of a water bearing material to transmit water. It is measured by the quantity of water passing through a unit cross section, in a unit time, under 100 percent hydraulic gradient.

permeable. having a texture that permits liquid to move through the pores.

pH. numeric value that describes the intensity of the acid or basic (alkaline) conditions of a solution. The pH scale is from 0 to 14, with the neutral point at 7.0. Values lower than 7 indicate the presence of acids and greater than 7.0 the presence of alkalis (bases). Technically speaking, pH is the logarithm of the reciprocal (negative log) of the hydrogen ion concentration (hydrogen ion activity) in moles per liter.

phosphorous. a plant nutrient that can cause an overabundance of bacteria and algae when high amounts are present, leading to a depletion of oxygen and fish kills. High levels of phosphorous in water are usually caused by agricultural runoff or improperly operating wastewater treatment plants. Also see nitrogen.

phreatophytes. plants that send their roots into or below the capillary zone to use groundwater.

physical weathering. breaking down of parent rock into bits and pieces by exposure to temperature, wind and water and the physical action of moving ice and water, growing roots, and human activities such as farming and construction. Compare chemical weathering.

phytoplankton. free-floating, mostly microscopic aquatic plants.

piezometric surface. the imaginary surface to which water will rise from a confined aquifer.

plankton. microscopic floating plant and animal organisms of lakes, rivers, and oceans.

point source. source of pollution that involves discharge of wastes from an identifiable point, such as a smokestack or sewage treatment plant. Compare nonpoint source.

pollutant. any substance which restricts or eliminates the use of a natural resource.

pollution. undesirable change in the physical, chemical, or biological characteristics of the air, water, or land that can harmfully affect the health, survival, or activities of human or other living organisms.

porosity. any property of geologic formations which have the ability to hold and yield water due to the spaces between particles.

porous. having openings which may or may not be connected.

potable. suitable, safe, or prepared for drinking. Compare non-potable.

potentiometric surface. an imaginary surface representing the total head of groundwater and defined by the level that water will rise in a well.

ppb - parts per billion. number of parts of a chemical found in one billion parts of a solid, liquid, or gaseous mixture. Equivalent to micrograms per liter (Ug/L).

ppm - parts per million. number of parts of a chemical found in one million parts of a solid, liquid, or gaseous mixture. Equivalent to milligrams per liter (mg/L).

precipitation. discharge of water from the air in the form of rain, ice or snow.

priority date. the date of establishment of a water right. It is determined by adjudication of rights established before the passage of the Water Code. The rights established by application have the application date as the date of priority.

pump. a device which moves, compresses, or alters the pressure of a fluid, such as water or air, being conveyed through a natural or artificial channel.

recharge. process involved in absorption and addition of water to the zone of saturation.

recharge zone. the area in which water infiltrates into the ground and eventually reaches the zone of saturation in one or more aquifers.

reclaimed water. domestic wastewater that is under the direct control of a treatment plant owner/operator which has been treated to a quality suitable for a beneficial use.

recurrence interval. average amount of time between events of a given magnitude. For example, there is a one percent chance that a 100-year drought will occur in any given year.

reserves. amount of a particular resource in known locations that can be extracted at a profit with present technology and prices.

reservoir. a man-made body of water contained behind a dam.

riparian water right. the legal right held by an owner of land contiguous to or bordering on a natural stream or lake, to take water from the source for use on the contiguous land.

riparian zone. a stream and all the vegetation on its banks.

river basin. the area drained by a river and its tributaries.

rule of free capture. the idea that the water under a person's land belongs to that person and they are free to capture and use as much as they want. Also called the "law of the biggest pump".

runoff. surface water entering rivers, freshwater lakes, or reservoirs.

saline water. water containing more than 1,000 parts per million (ppm) of dissolved solids of any type.

salinity. amount of dissolved salts in a given volume of water.

sediment. solid material (mineral and organic) which has been transported from its site of origin by air, water or ice and has been deposited on the land's surface, river or stream beds, or on the sea floor.

sedimentary cycle. biogeochemical cycle in which materials primarily are moved from land to sea and back again.

sedimentation. a large scale water treatment process where heavy solids settle out to the bottom of the treatment tank after flocculation.

seep. a spot where water contained in the ground oozes slowly to the surface and often forms a pool; a small spring.

septic tank. underground receptacle for wastewater from a home. The bacteria in the sewage decompose the organic wastes, and the sludge settles to the bottom of the tank. The effluent flows out of the tank into the ground through drains.

siltation. the deposition of finely divided soil and rock particles upon the bottom of stream and river beds and reservoirs.

soil erosion. the processes by which soil is removed from one place by forces such as wind, water, waves, glaciers, and construction activity and eventually deposited at some new place.

spray irrigation. application of finely divided water droplets to crops using artificial means.

spring. a place where water flows from rock or soil upon the land or into a body of surface water.

storm water discharge. precipitation that does not infiltrate into the ground or evaporate due to impervious land surfaces but instead flows onto adjacent land or water areas and is routed into drain/sewer systems.

stream. a general term for a body of flowing water.

stream flow. the discharge that occurs in a natural channel.

stream segment. refers to the surface waters of an approved planning area exhibiting common biological, chemical, hydrological, natural, and physical characteristics and processes. Segments will normally exhibit common reactions to external stress such as discharge or pollutants.

subsidence. sinking down of part of the Earth's crust due to underground excavation, such as removal of groundwater.

subterranean. being or lying under the surface of the Earth.

supply. a schedule that shows the various quantities of things offered for sale at various prices at a point in time.

surface impoundment. an indented area in the land's surface, such a pit, pond, or lagoon.

surface irrigation. application of water by means other than spraying such that contact between the edible portion of any food crop and the irrigation water is prevented.

surface water. water on the land’s surface including lakes, streams, rivers and glaciers.

sustainable management. method of exploiting a resource that can be carried on indefinitely. Removal of water from an aquifer in excess of recharge is, in the long term, not a sustainable management method.

sustained overdraft. long term withdrawal from the aquifer of more water than is being recharged.

technology-based treatment requirements. National Pollutant Discharge Elimination System (NPDES) permit requirements based on the application of pollution treatment or control technologies including BTP (best practicable technology), BCT (best conventional technology), BAT (best available technology economically achievable), and NSPS (new source performance standards).

total dissolved solids (TDS). The concentration of dissolved minerals in water, expressed in units of milligrams per liter (mg/L).

transect wells. a group of water quality monitoring wells positioned in a site to monitor water quality changes, such as across the freshwater/saline water interface.

transmissivity. refers to the rate at which limestone allows the transmission of water. Limestone can be highly porous, but not very transmissive if the pores are not connected to each other. Technically speaking, it is the rate at which water is transmitted through a unit width of aquifer under unit hydraulic gradient. Transmissivity is directly proportional to aquifer thickness, thus it is high where the Edwards is thick and low where it is thin, given the same hydraulic conductivity.

transpiration. loss of water vapor to the air from plants.

tributary. a stream that contributes its water to another stream or body of water.

turbid. thick or opaque with matter in suspension. Rivers and lakes may become turbid after a rainfall.

unconfined aquifer. an aquifer, or portion of an aquifer, with a water table and containing groundwater that is not under pressure beneath relatively impermeable rocks.

unconsolidated formations. naturally occurring earth formations that have not been lithified. Alluvium, soil, gravel, clay, and overburden are some of the terms used to describe this type of formation.

undercurrent. the movement of water flowing beneath the land surface within the bed or alluvial plain of a surface stream.

underflow. movement of water through subsurface material.

unsaturated zone. the layer of soil and rock above the water table but below the top layer of earth. This area is also known as the zone of aeration because the spaces between the rock particles are partially filled with air.

vested water right. the right granted by a state water agency to use either surface or groundwater.

void. the pore space or other openings in rock. The openings can range from very small to cave size and are filled with water below the water table.

wastewater. water containing waste including gray water, black water, or water contaminated by waste contact, including process-generated and contaminated rainfall runoff.

water cycle. natural pathway water follows as it changes between liquid, solid, and gaseous states; biogeochemical cycle that moves and recycles water in various forms through the ecosphere. Also called the hydrologic cycle.

water level observation (index) well. a water well used to measure the water level or potentiometric surface of water-bearing strata such as the Edwards Aquifer, Leona Gravel Aquifer, and lower Glen Rose (Trinity) Aquifer.

water pollution. degradation of a body of water by a substance or condition to such a degree that the water fails to meet specified standards or cannot be used for a specific purpose.

water quality criteria. scientifically derived ambient limits developed and updated by EPA, under section 304(a)(1) of the Clean Water Act, for specific pollutants of concern. Criteria are recommended concentrations, levels, or narrative statements that should not be exceeded in a water body in order to protect aquatic life or human health.

water quality standards. laws or regulations, promulgated under Section 303 of the Clean Water Act, that consist of the designated use or uses of a water body or a segment of a water body and the water quality criteria that are necessary to protect the use or uses of that particular water body. Water quality standards also contain an antidegradation statement. Every State is required to develop water quality criteria standards applicable to the various waterbodies within the State and revise them every 3 years.

water table. the interface between the zone of saturation and the zone of aeration, where the surface pressure of unconfined groundwater is equal to the atmospheric pressure.

water well. any artificial excavation constructed for the purpose of exploring for or producing groundwater.

watershed. land area from which water drains toward a common watercourse in a natural basin.

wetland. area that is regularly wet or flooded and has a water table that stands at or above the land surface for at least part of the year, such as a bog, pond, fen, estuary, or marsh.

xeriscape. creative landscaping for water and energy efficiency and lower maintenance. The seven xeriscape principles are: good planning and design; practical lawn areas; efficient irrigation; soil improvement; use of mulches; low water demand plants; good maintenance.

yield. the quantity of water expressed either as a continuous rate of flow (cubic feet per second, etc.) or as a volume per unit of time. It can be collected for a given use, or uses, from surface or groundwater sources on a watershed.

zone of aeration. the subsurface zone where the voids and pore spaces are filled with water under less pressure than that of the atmosphere and air.

zone of saturation. the subsurface zone in which all voids and pore spaces are filled with water under pressure greater than that of the atmosphere.

zooplankton. tiny aquatic animals eaten by fish.

Chapter 16 Index

To be completed after USFWS Revisions.

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Appendix 1

Edwards Aquifer Authority

Draft
30-Year Water Supply Plan

EDWARDS AQUIFER
AUTHORITY

Draft
30-Year Water Supply Plan

March 2001

ACKNOWLEGEMENTS

The Edwards Aquifer Authority (Authority) 30-Year Water Supply Plan was prepared under the guidance and direction of the Aquifer Management Planning Committee and the Comprehensive Water Management Plan Workgroup of the Authority's Board of Directors. The 30-Year Water Supply Plan was coordinated with the Brown-Lewis regional planning effort. Staff input to the 30-Year Water Supply Plan was provided under the direction of Mr. Gregory M. Ellis, General Manger, Mr. Rick Illgner, Program Manager for Planning and Conservation, and Mr. Ray Buck, AICP, Water Resources Coordinator. Mr. Mike Personett, Consultant, assisted throughout the development and writing of the plan.

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30-YEAR WATER SUPPLY PLAN FOR THE EDWARDS AQUIFER REGION

1.0 INTRODUCTION

Management of the Edwards Aquifer to maintain acceptable minimum flows at Comal and San Marcos Springs during drought conditions is central to the mission of the Edwards Aquifer Authority. The Authority, which was established in 1993 by Senate Bill 1477 (73rd Texas Legislature), is mandated to manage the southern portion of the Edwards Aquifer to protect important environmental resources while also protecting water supplies for municipal, industrial, irrigation and other water uses. The Authority's jurisdiction includes all of Bexar, Medina, and Uvalde counties and portions of Atascosa, Caldwell, Comal, Guadalupe, and Hays counties. Within this area, the Authority's enabling act requires that total permitted withdrawals from the aquifer be limited to no more than 450,000 acre-feet per year (ac-ft/yr) through 2007 and to 400,000 ac-ft/yr by 2008, unless the Authority's Board of Directors determines that additional supplies are available from the aquifer. Further, by the end of 2012, the Authority is required to ensure that spring flows are maintained at Comal and San Marcos Springs to protect threatened and endangered species to the extent required by federal law.

At present the Edwards Aquifer is the primary source of water supply for municipal, industrial, irrigation, and other uses within the Authority's jurisdictional area. The imposition of regulatory limits on withdrawals from the aquifer will therefore necessitate implementation of water management strategies, both to supplement available water supplies to satisfy current water demands and to provide additional water supplies to meet the growing water demands of the region.

1.1 Water Supply Planning in the Edwards Aquifer Region

Almost continuously since the mid-1980s, major water purveyors and water users in the Edwards Aquifer Region have been engaged in regional water resources planning with the goal of identifying cost-effective and environmentally acceptable water management strategies for meeting current and future water needs. The most recent effort, initiated and funded under Texas Senate Bill 1 (75th Texas Legislature), recently culminated with the adoption of a regional water supply plan for the South Central Texas Regional Water Planning Area (SCTRWPA), an area which includes all or portions of 21 Texas counties and which encompasses all of the Authority's jurisdictional area. Pursuant to S.B. 1 and rules of the Texas Water Development Board (TWDB), the regional water plans were required to include an assessment of current and projected water demands and current water supply availability, the identification of water supply needs, and an evaluation of strategies for meeting the identified water needs. Specific strategies were to be recommended for individual "water user groups" with current or projected needs through 2030. Long-term strategies or alternative scenarios could also be included in the adopted regional water plans for the period from 2030 to 2050. However, strategy recommendations were not required if it was determined that there are no feasible strategies for meeting particular water needs.

The Authority's enabling act also requires the Authority to adopt a Comprehensive Water Management Plan (CWMP). The CWMP is to include conservation, future supply, and demand management plans; and, a 20-year plan for providing alternative supplies of water to the region, with five-year goals and objectives. In developing the CWMP, the Authority is to:

- Thoroughly investigate all alternative technologies;
- Investigate mechanisms for providing financial assistance for alternative supplies through the TWDB; and
- Perform a cost-benefit and environmental analysis.

The Authority initiated development of its CWMP in 1999. Early in this process it was determined that every effort would be made to coordinate the Authority's water supply planning with the development of the water plan for the South Central Texas Region, both to avoid unnecessary and costly duplication of effort and to ensure consistency. It should be noted that S.B. 1 includes provisions requiring the management plans of groundwater districts to be consistent with adopted regional water plans. Consequently, for the development of the CWMP, the Authority has generally adopted the planning methods and assumptions specified for the S.B. 1 regional planning program. This includes increasing the water supply planning horizon for the CWMP to 30 years and planning on 10-year increments. Although the Authority's statute prescribes five-year increments and goals, the Authority has determined there is minimal value in making the mid-decade interpolations. Particularly, the interpolations are of little value in light of the ten-year schedule for supply development by the SCTRWP. The Authority also agreed to adopt the SCTRWP water demand projections for the area within the Authority's regulatory jurisdiction. It was also agreed that the Authority would use consistent assumptions with regard to water availability from the Edwards Aquifer and consistent methods and assumptions for the evaluation of water management strategies.

In January 2000, a decision was made to delay the completion of the 30-year water supply plan component of the EAA CWMP until the final adoption of the SCTRWP. Specifically, once recommended strategies have been determined for meeting the water supply needs of the larger South

Central Texas Region, those strategies that apply to water users within the EAA's jurisdiction would be "extracted" from the regional plan and would form the basis for the EAA's 30-year water supply plan. Additionally, the cost/benefit analysis, the environmental analysis, and the TWDB funding sections for the 30-year water supply plan will be developed, finalized, and included in the CWMP when the SCTRWP is approved and adopted by the TWDB.

The Edwards Aquifer Authority (the Authority) has also initiated development of a combined Habitat Conservation Pan (HCP) and Environmental Impact Statement (EIS) for submittal to the U.S. Fish and Wildlife Service (USFWS). The focus of the HCP/EIS is to identify regulatory and management measures that, if implemented, will ensure the survival of nine Edwards Aquifer-dependent species, which have been listed, or are candidates for listing, as either threatened or endangered by the USFWS pursuant to the federal Endangered Species Act (ESA). The objective of the HCP/EIS is to satisfy the requirements of the both the ESA and the National Environmental Policy Act (NEPA). If approved by the USFWS, the HCP is expected to provide the basis for the issuance of an "incidental take" permit to the Authority that would allow the "lawful taking" of listed species should flows at Comal and San Marcos Springs fall below "take" levels established by the USFWS.

1.2 Purpose and Organization of Report

The Authority has adopted the recommendations presented in the South Central Texas Regional Water Plan as the 30-year water supply plan component of the Authority's Comprehensive Water Management Plan. Relevant information has been extracted from the regional water plan for the portion of the South Central Texas Regional Water Planning Area that is within the Authority's jurisdiction. This includes information pertaining to currently available water supply, projected water demands, projected water supply needs, and recommended strategies and their estimated costs. The Authority has adopted the recommendations presented in the SCTRWP with the understanding that regional water supply planning is a dynamic process and that SCTRWP is to be updated at a minimum every five-years. Accordingly, water management strategies recommended for implementation may be modified to reflect changing conditions or new information. Also, it is understood that other water management strategies that are of interest to the Authority will continue to be evaluated for possible inclusion in the SCTRWP and the Authority's water supply plan in the future.

In preparing this plan, the Authority relied on published information contained in the "initially prepared" draft and final draft of the SCTRWP and its appendices. In addition, extensive coordination occurred with South Central Texas Regional Water Planning Group's engineering and planning contractor to ensure the accuracy of the information presented in the Authority's water supply plan.

The Authority's 30-year water supply plan is organized into three sections. Section 2.0 presents an overview of projected water demand and currently available water supply for the Authority's jurisdictional area. Also presented is a summary of water supply needs derived from the comparison of estimates of currently available water supply with projected water demands. This supply/demand analysis is presented for a "baseline scenario" of 340,000 acre-feet per year of withdrawals from the Edwards Aquifer, which is the water availability scenario adopted for planning purposes and used in the SCTRWP.

Section 3.0 of this plan provides a summary of water management strategies currently underway and the water management strategies recommended in the SCTRWP for implementation within the Authority's jurisdictional area. This includes information regarding the quantities and timing of water supplies to be provided by each strategy.

Section 4.0 presents a summary of the water supply plan for the Edwards Aquifer Region as presented in the adopted water plan for the South Central Texas Regional Water Planning Area.

2.0 SUPPLY/DEMAND ANALYSIS FOR THE EDWARDS AQUIFER AUTHORITY JURISDICITIONAL AREA

A key element of the S.B. 1 regional water planning process was to identify current and future water supply needs, or alternatively, potential water shortages. The "needs identification" was the result of comparing estimates of currently available water supplies under a "no new development scenario" to projections of future water demand. Water supply estimates under "no new development" refer to current conditions without new or expanded sources of supply. According to TWDB rules, this supply/demand analysis was to be performed for individual water user groups (WUGs). Within the municipal water use sector, all cities with a population of greater than 500 are designated WUGs. The rural areas of each county in the aggregate are also considered an individual WUG as are the aggregated water demands at the county-level for the manufacturing, steam electric power generation, irrigation, mining, and livestock water use categories.

For this analysis, projected water demands and estimates of currently available water supply were extracted from the SCTRWP for those WUGs and portions of WUGs that are located within the Authority's jurisdiction. The "template" for extracting this information was developed through the Trans-

Texas Water Program, West-Central Study Area and has been previously applied in the development of the Authority's CWMP (EAA 2000). It should be noted that the apportionment of projected water demand and currently available water supply for counties that are partially within the Authority's jurisdiction are approximations.

2.1 Water Demand Projections

The area within the Authority's jurisdiction has and is continuing to experience rapid population growth and corresponding increases in water demand. The estimated population of the area was 1.36 million in 1990. This has increased to an estimated population of 1.72 million at present; a 26 percent increase for the decade.

Estimated water use in 1990 and 1996 and water demand projections for the Authority's jurisdictional area are presented in Table 1. As indicated, total water demand within the Edwards Aquifer region is projected to increase by approximately 150,000 ac-ft/yr or by nearly 20 percent over the next 30 years. However, combined, the municipal, industrial, and steam electric water use sectors are projected to increase by more than 188,000 ac-ft/yr (44 percent increase), which at a regional level, is partially offset by a projected decrease in irrigation demand of nearly 39,000 acre-feet (12 percent decrease).

Table 1 – Historical and Projected Water Demand by Use Sector for the EAA Jurisdictional Area

Type of Use	1990	1996	2000	2010	2020	2030
Municipal	259,402	297,786	357,571	399,826	451,148	524,243
Industrial	19,028	34,519	22,192	25,287	28,163	31,117
Steam Electric	24,263	25,714	46,760	53,160	57,160	62,160
Irrigation	336,477	212,904	321,026	306,685	294,215	282,256
Mining	3,064	16,568	11,400	11,236	11,724	12,164
Livestock	5,238	7,276	6,178	6,178	6,178	6,178
Total	**647,472**	**594,767**	**765,127**	**802,372**	**848,588**	**918,118**

It should be noted that the demand projections presented above, which are taken from the initially prepared draft of the SCTRWP, are somewhat higher than recent historical use. The projections are based on forecasts developed by the TWDB in the early 1990's and which are used in the 1997 State Water Plan. For the municipal water use sector, demand projections are based on "dry-year" conditions, relatively high growth rates, and per capita water use rates from the early 1980s. Consequently, municipal water demand projections may not fully account for the significant reductions in per capita water use that have occurred over the past decade, particularly in Bexar County. For example, total reported municipal water use in the Edwards Aquifer area for 1990 and 1996 was 259,402 ac-ft and

297,786 ac-ft, respectively. As indicated in Table 1, current demand (i.e., year 2000) is estimated to be 357,571 ac-ft, which is 20 percent higher than estimated water use during 1996.It should be noted, however, that during 1996 municipal water demands throughout the region were affected by water use restrictions and that the "unconstrained" demand would likely have been appreciably higher that year. In any case, the adopted municipal water demand projections for the region can be considered "conservative" in that current levels of municipal water use are most likely lower than the projection of year 2000 water demand.

The irrigation demand projections presented in Table 1 should also be considered conservative. Unlike municipal water demand, which tend to be relatively consistent from year to year, irrigation demands can vary considerably. For example, in 1990, estimated irrigation water use in Bexar, Medina, and Uvalde counties was 335,061 ac-ft, while in 1996 estimated irrigation water use was only 212,416 ac-ft. The wide variation in estimates of irrigation water use are explained by local weather conditions, economic factors, which influence the amount of irrigated acreage and crop types, and water supply constraints. Also, historical estimates of irrigation water use are based largely on estimates of irrigated acreage and the estimated water use of different types of crops rather than actual measured use. The relatively high year 2000 projection should therefore be regarded as a demand scenario that combines very high acreage levels, high water use under dry conditions, and no water availability constraints or restrictions on use.

Water demand projections for each water use sector, by county, are presented in Tables 2 through 7 below.

Table 2 – Projected Municipal Water Demand within the EAA Jurisdictional Area

Municipal	**2000**	**2010**	**2020**	**2030**
Atascosa	559	600	635	701
Bexar	306,064	338,626	381,015	439,753
Caldwell	5,055	5,526	5,960	6,548
Comal	13,501	16,407	20,263	25,676
Guadalupe	6,028	9,027	10,174	12,547
Hays	12,542	15,254	18,317	23,167
Medina	7,112	7,312	7,467	7,832
Uvalde	6,710	7,074	7,317	8,019
Total	**357,571**	**399,826**	**451,148**	**524,243**

Table 3 – Projected Industrial Water Demand within the EAA Jurisdictional Area

Industrial	**2000**	**2010**	**2020**	**2030**
Atascosa	0	0	0	0
Bexar	16,805	19,682	22,359	24,935
Caldwell	0	0	0	0
Comal	3,450	3,487	3,548	3,799
Guadalupe	942	1,051	1,124	1,193
Hays	93	105	118	129
Medina	302	319	339	361
Uvalde	600	643	675	700
Total	**22,192**	**25,287**	**28,163**	**31,117**

Table 4 – Projected Steam Electric Power Generation Demand within the EAA Jurisdictional Area

Steam Electric	**2000**	**2010**	**2020**	**2030**
Atascosa	0	0	0	0
Bexar	36,000	36,000	40,000	45,000
Caldwell	0	0	0	0
Comal	0	0	0	0
Guadalupe	10,760	10,760	10,760	10,760
Hays	0	6,400	6,400	6,400
Medina	0	0	0	0
Uvalde	0	0	0	0
Total	**46,760**	**53,160**	**57,160**	**62,160**

Table 5 – Projected Irrigation Demand within the EAA Jurisdictional Area

Irrigation	**2000**	**2010**	**2020**	**2030**
Atascosa	1,442	1,341	1,287	1,235
Bexar	40,003	36,879	35,320	33,827
Caldwell	0	0	0	0
Comal	0	0	0	0
Guadalupe	0	0	0	0
Hays	0	0	0	0
Medina	144,413	138,582	132,804	127,270
Uvalde	135,168	129,883	124,804	119,924
Total	**321,026**	**306,685**	**294,215**	**282,256**

Note: The portion of total irrigation demand associated with conveyance and distribution losses from the Bexar-Medina-Atascosa Water District was inadvertently left out of the projections for Medina County. For the year 2000, the amount associated with such losses is approximately 22,000 ac-ft/yr.

Table 6 – Projected Mining Water Demand within the EAA Jurisdictional Area

Mining	2000	2010	2020	2030
Atascosa	0	0	0	0
Bexar	4,963	4,936	5,201	5,406
Caldwell	0	0	0	0
Comal	5,570	5,464	5,628	5,796
Guadalupe	196	198	200	202
Hays	84	82	68	55
Medina	143	128	128	129
Uvalde	444	428	499	576
Total	**11,400**	**11,236**	**11,724**	**12,164**

Table 7 –Projected Livestock Water Demand within the EAA Jurisdictional Area

Livestock	2000	2010	2020	2030
Atascosa	2	2	2	2
Bexar	1,487	1,487	1,487	1,487
Caldwell	416	416	416	416
Comal	178	178	178	178
Guadalupe	566	566	566	566
Hays	121	121	121	121
Medina	1,914	1,914	1,914	1,914
Uvalde	1,494	1,494	1,494	1,494
Total	**6,178**	**6,178**	**6,178**	**6,178**

2.2 Currently Available Water Supply under Alternative Edwards Aquifer Withdrawal Limits

Estimates of currently available water supply for the Authority's jurisdictional area were developed for an Edwards Aquifer pumping scenario of 340,000 ac-ft/yr, 450,000 ac-ft/yr, 400,000 ac-ft/year, 275,000 ac-ft/year, and 175,000 ac-ft/year. As indicated previously, the 340,000 ac-ft/year pumpage scenario was used as the baseline for water availability from the Edwards Aquifer for the SCTRWP. It should be noted and emphasized that the estimates of supply for the Edwards Aquifer pumpage scenario of 340,000 ac-ft/yr is for planning purposes only and does not reflect the Authority's current regulatory policies.

For this analysis, consultants to the SCTRWPG (HDR Engineering) developed estimates of currently available water supplies within the Authority's jurisdiction that are from non-Edwards Aquifer sources. These estimates are added to estimates of supply availability from the Edwards Aquifer for the 340,000 ac-ft/yr pumpage scenario. This information is presented in Tables 8 below.

2.3 Water Supply Needs

A comparison of water supply availability to projected water demands indicates that significant shortages exist within the Authority's jurisdictional area under the baseline Edwards Aquifer pumpage scenario. As indicated in Table 9, at present there is a shortage of approximately 240,000 ac-ft/yr, increasing to the shortages range from nearly 127,000 ac-ft/yr to approximately 402,000 ac-ft/yr at present, increasing to approximately more than 400,000 ac-ft/yr by 2030.

Table 8 – Estimated Supply under 340,000 ac-ft/yr Edwards Aquifer Pumpage Scenario

Edwards Aquifer	**2000**	**2010**	**2020**	**2030**
Municipal	153,680	153,680	153,680	153,680
Irrigation	165,889	165,889	165,889	165,889
Industrial	20,431	20,431	20,431	20,431
Steam Electric	-	-	-	-
Mining	-	-	-	-
Livestock	-	-	-	-
Sub-Total	340,000	340,000	340,000	340,000
Non-Edwards				
Municipal	77,584	72,229	72,116	63,001
Industrial	10,726	10,726	10,726	10,726
Steam Electric	71,768	75,704	75,704	75,704
Irrigation	16,830	16,849	16,774	9,253
Mining	518	488	557	633
Livestock	6,178	6,178	6,178	6,178
Sub-Total	183,604	182,244	181,055	165,495
Total	**523,604**	**522,244**	**521,055**	**505,495**

Table 9 – Estimated Water Needs under 340,000 ac-ft/yr Edwards Aquifer Pumpage Scenario

	2000	**2010**	**2020**	**2030**
Demand	765,127	802,372	848,588	918,118
Supply	523,604	522,244	521,055	505,415
Need/Shortage	**-241,523**	**-280,128**	**-327,533**	**-412,623**

3.0 WATER MANAGEMENT STRATEGIES

As previously indicated, regional water supply plans developed pursuant to S.B. 1 and TWDB rules are required to recommend specific water management strategies, either singly or in combination, to meet identified water needs through 2030. Recommended strategies are to provide a “firm” or dependable water supply under drought-of-record hydrologic conditions. However, recommendations are not required if it is determined that there are no feasible strategies for meeting a particular need.

The SCTRWP includes recommended water management strategies that will meet all current and projected municipal, industrial, steam electric power generation, and mining needs within the South Central Texas Region and within the Authority’s jurisdiction. However, the SCTRWP does not include recommendations for meeting all irrigation needs. Except for limited investments in irrigation water efficiency measures to reduce the magnitude of projected shortages, it was determined by the South Central Texas RWPG that there are no feasible strategies for meeting all projected irrigation demands.

This section provides a summary of the water management strategies included in the SCTRWP for water user groups within the Authority's jurisdiction. This includes water management strategies that are currently being implemented with existing funding, as well as strategies recommended for future implementation. Water supply "yield" estimates are provided for the strategies that are currently being implemented as well as for the recommended strategies. However, cost estimates are provided only for strategies recommended for implementation in the future as this information was not included in the SCTRWP for strategies that are already in progress. It should be noted that water supply yield and cost information is not shown for any of the recommended strategies for the year 2000. The SCTRWP recommends a number of strategies for immediate implementation but makes note that "candidate new supplies shown for the year 2000 are identified, but will not be available immediately." For this analysis, it is assumed that these strategies will be implemented during the current decade and that the supplies will become available by 2010.

In addition to information about the strategies in progress and the strategies recommended for implementation in the future, an overview of strategies recommended for further study is also provided.

3.1 Management Strategies Currently in Implementation

The SCTRWP recognizes seven water management strategies that are currently in some stage of implementation. These are projects for which there is a sponsoring entity and for which funding is already in place. Each of these strategies will provide additional water supply to users within the Authority's jurisdiction in the amounts shown in Table 10. As indicated, the estimated total amount of new supply to be provided by all of these strategies for users within the Authority's jurisdiction is approximately 38,000 ac-ft/yr by 2010, decreasing to 33,000 ac-ft/yr in 2020 and thereafter. A summary of each of these strategies is provided in the subsections that follow.

Table 10 – Water Management Strategies Underway with Existing Funds

Strategy (SCTRWP Identifier)	2000	2010	2020	2030
Schertz-Seguin WSP (SSWSP)	NA	12,470	12,470	12,470
Western Canyon Regional WSP (WCRWSP)	NA	4,500	4,500	4,500
Lake Dunlap WTP Expansion/Mid-Cities Project (CRWA)	NA	5,200	0	0
Carrizo Aquifer - Bexar/Guadalupe Counties (BMWD)	NA	4,000	4,000	4,000
Trinity Aquifer - Bexar County (BMWD)	NA	1,000	1,000	1,000
GBRA Canyon Reservoir Contract Renewal (GBRA)	NA	6,720	6,720	6,720
Hays/IH35 Water Supply Project	NA	4,500	4,500	4,500
Total	**NA**	**38,390**	**33,190**	**33,190**

3.1.1 Schertz-Seguin Water Supply Project (SSWSP)

The Schertz-Seguin water supply project consists of the development of a well field in the Carrizo Aquifer primarily in the southern portion of Gonzales County. The project is being developed by the Schertz-Seguin Local Government Corporation. Full implementation of this strategy will provide 20,000 ac-ft/yr of dependable water supply to users in Bexar, Comal, and Guadalupe counties. The estimated amount of water to be supplied by the project to users within the Authority's jurisdiction is shown in Table 11.

Table 11 – Water Supply from the Schertz-Seguin Water Supply Project for Users within the EAA Jurisdiction (ac-ft/yr)

	2000	2010	2020	2030
Bexar County				
Schertz (outside city)	NA	2,404	2,404	2,404
Guadalupe County				
Schertz	NA	7,596	7,596	7,596
Rural (60% of county total)	NA	1,020	1,020	1,020
Industrial (50% of county total)	NA	450	450	450
Steam Electric (100% of county total)	NA	1,000	1,000	1,000
Total	**NA**	**12,470**	**12,470**	**12,470**

3.1.2 Western Canyon Regional Water Supply Project (WCRWSP)

The Western Canyon Regional Water Supply Project (WCRWSP) is being implemented by the Guadalupe-Blanco River Authority (GBRA) and consists of the construction of a water treatment plant west of Canyon Reservoir and development of a water transmission system to deliver water to project participants. Full implementation of the project will provide a dependable water supply of 10,500 ac-ft/yr to users in Bexar, Comal, and Kendall counties. The estimated amount of water to be supplied by the project to users within the Authority's jurisdiction is presented in Table 12.

It should be noted that implementation of this strategy requires amendment of existing water rights held by GBRA for supply from Canyon Reservoir (Certificate of Adjudication No. 18-2074). The application for amendment of the water rights permit is currently pending before the Texas Natural Resource Conservation Commission (TNRCC).

Table 12 – Water Supply from the Western Canyon Regional Water Supply Project for Users within the EAA Jurisdiction (ac-ft/yr)

	2000	2010	2020	2030
Bexar County				
Fair Oaks	NA	500	500	500
San Antonio	NA	1,813	1,813	1,813
BMWD (other subdivisions)	NA	2,137	2,137	2,137
Rural	NA	50	50	50
Total	**NA**	**4,500**	**4,500**	**4,500**

3.1.3 Lake Dunlap Water Treatment Plant Expansion and Mid-Cities Project

The Lake Dunlap Water Treatment Plant Expansion and Mid-Cities Project is being implemented by the Canyon Regional Water Authority (CRWA). The project will divert water from Lake Dunlap north of the City of Seguin and will deliver water to CRWA participating entities via a water transmission and distribution system. The project will supply a total of 5,200 ac-ft/yr of municipal water supply delivered from Canyon Reservoir under a contract with GBRA. The estimated amount of water to be supplied by the project to users within the Authority's jurisdiction is shown in Table 13. This amount is shown as unavailable in 2020 and thereafter due to expiration of the water supply contract between CRWA and GBRA.

Table 13 – Water Supply from the Lake Dunlap WTP Expansion and Mid-Cities Project for Users within the EAA Jurisdiction (ac-ft/yr)

	2000	2010	2020	2030
Bexar County				
BMWD (other subdivisions)	NA	4,000	0	0
Rural	NA	1,200	0	0
Total	**NA**	**5,200**	**0**	**0**

3.1.4 BMWD Carrizo Aquifer

The Bexar Metropolitan Water District (BMWD) is currently implementing a project to supply a total of 4,000 ac-ft/yr from the Carrizo Aquifer in Bexar and Guadalupe counties to its customers (municipal users) in southern and northeastern Bexar County (i.e., Somerset and other BMWD subdivisions).

3.1.5 BMWD Trinity Aquifer

The BMWD is also implementing a project to supply approximately 1,000 ac-ft/yr from the Trinity Aquifer to its customers in northern Bexar County (i.e., Hill Country Village and Hollywood Park).

3.1.6 GBRA Canyon Reservoir Contract Renewal

The City of New Braunfels has an existing contract with GBRA for the supply of 6,720 ac-ft/yr from Canyon Reservoir with diversion from the Guadalupe River at New Braunfels. The contract has an expiration date of December 5, 2001. Under TWDB guidelines for S.B. 1 planning, the water supply associated with a contract is to be shown as unavailable in the decade following contract expiration. Consequently, a recommended water management strategy for the City of New Braunfels is to renew its existing contract with GBRA. It should be noted that other municipal water users within the Authority's jurisdiction also have water supply contracts with GBRA. However, these contracts do not expire during the 30-year planning period.

3.1.7 Hays/IH35 Water Supply Project

The Hays/IH35 Water Supply Project is currently being implemented to provide water supply to the cities of Kyle and Buda and to rural water users through the Creedmore-Maha Water Supply Corporation. The project involves the delivery of stored water from Canyon Reservoir through a diversion at Lake Dunlap and an existing regional water treatment plant at San Marcos. Full implementation of the project will include construction of a pipeline to deliver treated water from the San Marcos treatment plant to other users in Hays County.

Table 14 – Water Supply from the Hays/IH35 Water Supply Project for Users within the EAA Jurisdiction (ac-ft/yr)

	2000	2010	2020	2030
Hays County				
Rural	NA	4,400	4,400	4,400
Mining	NA	100	100	100
Total	**NA**	**4,500**	**4,500**	**4,500**

3.2 Management Strategies Recommended in the South-Central Texas Regional Water Plan

Sixty-one water management strategies were evaluated during the development of the SCTRWP. With variations of these options, the actual total number of strategies evaluated is 79. For the area included in the Authority's jurisdiction, 13 water management strategies are recommended by the SCTRWP for implementation during the next 30 years. An additional strategy, seawater desalination, is recommended for implementation after 2030. An overview of each recommended strategy, including its water supply yield and estimated annual cost, is presented in the subsections that follow.

It is important to note that for each of the strategies recommended in the SCTRWP there are additional steps, issues, and other considerations, which may influence actual implementation. These factors could result in major delays in project implementation or, potentially, a finding that a particular project is not feasible. Major considerations in project implementation include:

Identification of project sponsors. The sponsoring entity is not identified for many of the recommended water management strategies. For example, strategies recommended for supplying nearly 340,000 ac-ft/yr by 2030 to users in Bexar County are to be implemented by an unspecified "Regional Water Provider for Bexar County". According to the draft SCTRWP, this approach recognizes that implementation of some of the recommended strategies should occur on a regional basis, rather than through the independent actions of individual water suppliers/users. The designation of a Regional Water Provider for Bexar County also "…accounts for the fact that the water management strategies will be developed by individual sponsors or coalitions of sponsors" and that it is uncertain at this time who will actually sponsor particular projects. The bottom-line is that many of the institutional relationships required for the implementation of recommended water management strategies have not yet been fully defined.

Additional feasibility-level planning and engineering design. For the most part, the technical, economic, and environmental analyses conducted for the S.B. 1 planning process should be viewed as a "reconnaissance-level". Before potential project sponsors can or will commit to implementation of particular strategies, most will require much more detailed analyses to prove their feasibility. The water supply industry tends to be risk-averse and individual water suppliers are unlikely to fully commit to implementation of particular strategies until there is a greater degree of certainty of outcomes. Also, once the feasibility of a particular strategy has been demonstrated, there will generally be significant additional effort required for engineering design and site-specific environmental impact assessment.

Project permitting. Most of the major water management strategies recommended for implementation, particularly those involving new supply development, will require both state and federal regulatory approvals. For example, projects involving surface water supplies will generally require both a new or amended state water rights permits and federal approvals under Section 404 of the Clean Water Act. Such regulatory approvals will generally require a thorough evaluation of impacts analysis and may trigger a full environmental review under the National Environmental Policy Act (NEPA). Some of the recommended groundwater supply projects will likely require regulatory approvals by local underground water conservation districts. In addition to adding significant expense and time to project implementation, the regulatory process also provides opportunity for challenge by parties opposed to a particular project. This creates a degree of uncertainty with regard to the outcome of any regulatory process. Through the regulatory review process a project could be significantly modified or required regulatory approvals could be denied. Also, even if approved by regulatory agencies, a project could face legal challenge through state or federal courts.

Project financing. Financing for the construction of projects is another major consideration for most of the water management strategies recommended in the SCTRWP. For the South Central Texas Region as a whole, the estimated annual costs for implementation of recommended strategies ranges from approximately $120 million in the near term to approximately $425 million per year by 2040. This represents capital outlays in the billions of dollars, much of which will have to be financed through private markets, perhaps with state or federal assistance or participation. In any case, there will likely be significant demands on borrowing capacity of project sponsors and, importantly, substantial increases in wholesale and retail water rates.

Taken either individually or in combination, the implementation issues described above may render any particular water management strategy “infeasible”. The risk and uncertainty is generally greater for those strategies that involve the development of new supply sources. Because of the many uncertainties surrounding implementation of the various water management strategies, as well as uncertainty with regard to the magnitude of projected water needs, the South Central Texas RWPG elected to include strategies which, in combination, will provide significantly more water than is apparently needed to meet projected needs under the 340,000 ac-ft/yr Edwards Aquifer pumpage scenario. This approach is intended to provide flexibility to respond to other changes in water supply or demand conditions or in response to project implementation delays. The approach also provides a cushion should particular strategies prove to be infeasible.

The water management strategies recommended to meet current and future needs within the Authority's jurisdiction are summarized in Table 15 and discussed further in the sections that follow:

Table 15 - Recommended Water Management Strategies

Strategy (SCTRWP Identifier)	2000	2010	2020	2030
Municipal Water Conservation (L-10 Municipal)	NA	44,669	43,660	38,291
Irrigation Conservation (L-10 Irrigation and L-15)	NA	27,314	27,314	27,314
Transfers of Edwards Irrigation Rights to Municipal Use (L-15)	NA	40,486	40,486	41,486
Edwards Aquifer Recharge Enhancement (L-18A)	NA	13,451	21,577	21,577
Canyon Reservoir – River Diversion (G-15C)	NA	10,500	15,700	15,700
Lower Guadalupe River Diversion (SCTN-16)	NA	94,500	94,500	94,500
Lower Colorado River Diversion (LCRA)	NA	0	66,000	138,000
Carrizo Aquifer – Wilson and Gonzales (CZ-10C)	NA	16,000	16,000	16,000
Carrizo Aquifer – Gonzales and Bastrop (CZ-10D)	NA	900	4,950	13,450
Simsboro Aquifer (SCTN-3C)	NA	55,000	55,000	55,000
SAWS Recycled Water Program (SAWS)	NA	19,826	26,737	35,824
Purchase Water from a Major Water Provider	NA	10,000	10,500	12,500
TOTAL	**NA**	**332,646**	**406,424**	**509,642**

3.2.1 Municipal Water Conservation (L-10 Municipal)

This strategy consists of the implementation of "aggressive" municipal water conservation policies and programs to reduce projected municipal water demands. According to the initially prepared draft of the SCTRWP, the projected water savings shown in Table 15 are based on public education, accelerated replacement of toilets, and more water-efficient landscape irrigation practices. However, it is not entirely clear how these water conservation measures differ from those associated with the TWDB's "advanced" water conservation scenario, the effects of which are already incorporated into municipal water demand projections. These "built-in" conservation effects are projected to reduce per capita municipal demand by about 12 to 25 percent over the next 30 years. The additional conservation described by this strategy would further reduce per capita municipal use within the Authority's jurisdiction, on average, by an additional seven percent over this period (17 to 32 percent overall).

A major issue relating to the implementation of municipal water conservation programs is the willingness of local water suppliers to commit the required funding on an on-going basis. Also, small communities within the region may not be able to implement some programs cost-effectively (e.g., toilet replacement, public education). The Authority may consider developing a regional approach for the implementation of recommended municipal water conservation programs.

Table 16 – Supply and Estimated Cost for Additional Municipal Water Conservation (ac-ft/yr)

County – Use Sector	**2000**	**2010**	**2020**	**2030**
Atascosa – Municipal	NA	44	47	28
Bexar – Municipal	NA	42,509	41,210	36,533
Comal- Municipal	NA	718	848	718
Guadalupe – Municipal	NA	157	157	5
Hays – Municipal	NA	690	816	699
Medina – Municipal	NA	205	211	73
Uvalde – Municipal	NA	346	371	235
Total	**NA**	**44,669**	**43,660**	**38,291**
Estimated Annual Cost				
Atascosa	NA	$ 10,667	$ 10,645	$ 2,907
Bexar	NA	6,624,964	6,624,964	1,994,968
Comal	NA	192,220	192,220	74,650
Guadalupe	NA	91,753	91,781	44,599
Hays	NA	200,850	203,245	81,103
Medina	NA	72,348	72,348	19,383
Uvalde	NA	84,960	84,960	24,424
Total	**NA**	**$ 7,277,863**	**$ 7,280,169**	**$ 2,242,034**

3.2.2 Irrigation Conservation (L-10 Irrigation and L-15)

This strategy involves the widespread installation of Low Energy Precision Application (LEPA) irrigation systems and the use of furrow dikes to improve on-farm water use efficiency. For irrigated areas that rely on the Edwards Aquifer for supply, this strategy has two components – reductions in irrigation demand to reduce irrigation shortages; and, reductions in irrigation demand with the voluntary transfer of Edwards Aquifer pumpage rights to Bexar County for municipal water use. The SCTRWP recommends that approximately 13,000 ac-ft/yr of irrigation water savings would be used to reduce irrigation shortages, while approximately 32,000 ac-ft/yr would be transferred to the "Regional Provider for Bexar County" for municipal use. However, it was assumed that only 85 percent, or approximately 27,000 ac-ft/yr, would be available for municipal supply during drought due to curtailment of use per the Authority's Critical Period Management Plan. The projected water supply and costs associated with this strategy are summarized in Table 16. According to the SCTRWP, achievement of the estimated irrigation water savings will require the installation of LEPA systems and furrow diking on approximately 84,000 acres in the Edwards Aquifer irrigation area by 2010.

Key issues affecting the implementation of this strategy include the ability and willingness of irrigators to make the necessary investments and resolution of the adjudication of Edwards Aquifer water rights.

However, it is anticipated that much of the costs of irrigation efficiency improvements would be borne by municipal water users. Water rights transfers or leases will also require approval by the Authority.

Table 17 – Supply and Estimated Cost for Irrigation Conservation (ac-ft/yr)

County-Use Sector	**2000**	**2010**	**2020**	**2030**
Bexar – Municipal	NA	27,314	27,314	27,314
Atascosa – Irrigation	NA	163	109	57
Bexar – Irrigation	NA	1,905	1,905	1,905
Medina – Irrigation	NA	5,000	5,000	5,000
Uvalde – Irrigation	NA	5,958	5,958	5,958
Total	**NA**	**40,340**	**40,286**	**40,234**
Estimated Annual Cost				
Bexar – Municipal	NA	$ 992,318	$ 992,318	$ 0
Atascosa – Irrigation	NA	22,505	15,050	0
Bexar – Irrigation	NA	69,209	69,209	0
Medina – Irrigation	NA	181,650	181,650	0
Uvalde – Irrigation	NA	216,454	216,454	0
Total	**NA**	**$ 1,482,136**	**$ 1,474,681**	**$ 0**

3.2.3 Transfers of Edwards Irrigation Rights to Municipal Use (L-15)

The SCTRWP also recommends that municipal water users in Atascosa, Bexar, Medina, and Uvalde counties, and mining users in Medina County, purchase or lease approximately 50,000 ac-ft/yr of Edwards Aquifer irrigation rights. However, it was assumed that only 85 percent, or approximately, 40,000 ac-ft/yr, would be available for use during drought due to curtailment of use per the Authority's Critical Period Management Plan. Also the amount of municipal water supply provided by this strategy would be in addition to the 32,000 ac-ft/yr of transfers of conserved Edwards Aquifer supplies described above. The estimated supply to be provided by this strategy, and its annual costs, are shown in Table 17.

Implementation of this strategy will require resolution of permitting issues for users of water from the Edwards Aquifer and will depend on the willingness of irrigators to sell or lease their water rights. The transfers or leases will also require approval by the Authority. Under provisions of the Authority's enabling act, the holders of Edwards Aquifer irrigation rights can sell or lease up to 50 percent of their water right. As such, the total amount of irrigation water rights transfers could be approximately 120,000 or one-half of the total amount of irrigation water rights issued by the Authority.

Table 18 – Supply and Estimated Cost for Purchase/Lease of Edwards Aquifer Water Rights for Municipal Use (ac-ft/yr)

County - Use Sector	2000	2010	2020	2030
Atascosa – Municipal	NA	500	500	500
Bexar – Municipal	NA	32,986	32,986	32,986
Medina – Municipal	NA	2,900	2,900	2,900
Uvalde – Municipal	NA	4,000	4,000	5,000
Medina – Mining	NA	100	100	100
Total	**NA**	**40,486**	**40,486**	**41,486**
Estimated Annual Cost				
Atascosa – Municipal	NA	$ 47,059	$ 47,059	$ 47,059
Bexar – Municipal	NA	3,104,642	3,104,642	3,104,642
Medina – Municipal	NA	272,941	272,941	272,941
Uvalde – Municipal	NA	376,480	376,480	470,600
Medina – Mining	NA	9,412	9,412	9,412
Total	**NA**	**$ 3,810,534**	**$ 3,810,534**	**$ 3,904,654**

3.2.4 Edwards Aquifer Recharge Enhancement (L-18A)

This strategy consists of the construction of recharge enhancement structures on streams over the Edwards Aquifer recharge zone. These “Type 2” structures are designed to impound stream flows for a few days or weeks following a storm event. Recharge occurs through direct percolation of the impounded water into the aquifer through the streambed. As recommended in the SCTRWP, this strategy includes development of recharge enhancement projects at as many as 15 sites within Bexar, Comal, Hays, Medina, and Uvalde counties. Implementation of these projects would increase the “sustainable” municipal supply from the Edwards Aquifer for users in Bexar County by 21,577 ac-ft/yr (see Table 18). The total estimated project cost is approximately $287 million with an annualized unit cost of water is $1,087 per ac-ft. In addition to the water supply benefits of the project, recharge enhancement would also increase discharges at Comal and San Marcos Springs by approximately 80,000 ac-ft/yr.

It should be noted that these estimates are based on recharge enhancement projects sized to optimize recharge enhancement and minimize cost. The Authority has evaluated and is considering alternative projects at these sites that would be sized to maximize water storage and aquifer recharge. There are also other potential recharge enhancement sites that could be developed primarily to enhance aquifer levels and spring flows.

Actual development of the recommended recharge enhancement projects will require additional site-specific engineering and environmental analyses and both state and federal permitting. In addition, the Authority's policy with regard to “credits” for recharge enhancement is an unresolved issue, which may significantly affect the economic feasibility of particular recharge enhancement projects. Also, while the

SCTRWP indicates that the strategy is to be implemented by the "Regional Water Provider for Bexar County", it may be that the Authority is the logical sponsor for a recharge enhancement program.

Table 19 - Supply (ac-ft/yr) and Estimated Cost for Edwards Aquifer Recharge Enhancement

County-Use Sector	2000	2010	2020	2030
Bexar - Municipal	**NA**	**13,451**	**21,577**	**21,577**
Estimated Annual Cost				
Bexar - Municipal	**NA**	**$ 21,893,245**	**$ 23,455,062**	**$ 23,455,062**

3.2.5 Canyon Reservoir – River Diversion (G-15C)

This strategy consists of the sale of additional stored water from Canyon Reservoir to municipal and mining water users in Comal County. As indicated in Table 19, this strategy would provide 15,700 ac-ft/yr of additional water supply to municipal, industrial, and mining users in Comal County. Implementation of this strategy could involve diversion of the water supply from the Guadalupe River at or above Lake Nolte and the construction of water treatment and transmission facilities. It should be noted that implementation of this strategy is dependent upon TNRCC approval of GBRA's application to amend Certificate of Adjudication No. 18-2074 to increase the authorized water supply yield of Canyon Reservoir.

Table 20 – Supply (ac-ft/yr) and Estimated Cost for Canyon Reservoir Supply

County-Use Sector	2000	2010	2020	2030
Comal – Municipal	NA	5,030	12,700	15,700
Comal – Mining	NA	5,470	3,000	0
Total	**NA**	**10,500**	**15,700**	**15,700**
Estimated Annual Cost				
Comal – Municipal	NA	$ 3,910,610	$ 9,436,100	$ 9,875,300
Comal – Mining	NA	$ 4,252,641	$ 2,229,000	$ 0
Total	**NA**	**$ 8,163,251**	**$ 11,665,100**	**$ 9,875,300**

3.2.6 Lower Guadalupe River Diversion (SCTN-16)

This strategy consists of the diversion of water from the lower Guadalupe River at the GBRA saltwater barrier to off-channel reservoirs with transmission to a regional treatment facility and distribution to municipal water users in Bexar County. The water supply yield of the project, as shown in Table 20, would include presently underutilized surface water rights held by GBRA and Union Carbide Corporation, unappropriated stream flow, and undeveloped groundwater from the Gulf Coast Aquifer. The SCTRWP recommends that the "Regional Water Provider for Bexar County" sponsor this project. The total estimated cost to develop the project is approximately $429 million. The project will provide water supply at an annualized unit cost of approximately $870 per ac-ft.

A project of this magnitude will require extensive additional engineering, economic, and environmental analysis and will be subject to both state and federal regulatory requirements. Current state policy with regard to interbasin transfers of surface water could also affect project feasibility.

Table 21 – Supply (ac-ft/yr) and Estimated Cost for Lower Guadalupe River Diversion

County – Use Sector	2000	2010	2020	2030
Bexar – Municipal	NA	94,500	94,500	94,500
Estimated Annual Cost				
Bexar – Municipal	NA	$75,925,080	$77,059,080	$77,437,080

3.2.7 Lower Colorado River Diversion (LCRA)

This management strategy is based on a proposal by the Lower Colorado River Authority (LCRA), acting in concert with the Lower Colorado Regional Water Planning Group. The strategy consists of the diversion of water from the lower Colorado River near Bastrop and/or Bay City to off-channel reservoirs, transmission to regional water treatment facilities, and distribution to municipal water users in Bexar and Hays counties. The water supply yield of the project includes presently underutilized surface water rights, stored water from the LCRA Highland Lakes, and undeveloped groundwater from the Gulf Coast Aquifer. As indicated in Table 21, the project would initially provide water supply to users Bexar County by 2020 and to users in Hays County by 2030. In addition to the dependable supply to be provided to users within the Authority's jurisdiction, the project would also provide approximately 180,000 ac-ft/yr of additional supply to meet irrigation needs within the Lower Colorado Region.

A project of this magnitude will require significant additional engineering, economic, and environmental analysis and will be subject to both state and federal permitting requirements. A significant issue that has been raised is the potential adverse impacts on freshwater inflows to and the biological productivity of Matagorda Bay. Also, current state policy with regard to interbasin transfers of surface water could affect project feasibility.

Table 22 – Supply (ac-ft/yr) and Estimated Cost for Lower Colorado River Diversion

County-Use Sector	2000	2010	2020	2030
Bexar – Municipal	NA	0	66,000	132,000
Hays – Municipal	NA	0	0	6,000
Total	**NA**	**0**	**66,000**	**138,000**
Estimated Annual Cost				
Bexar – Municipal	NA	$ 0	$ 88,859,760	$134,163,480
Hays – Municipal	NA	0	0	8,804,390
Total	**NA**	**$ 0**	**$ 88,859,760**	**$142,967,870**

3.2.8 Carrizo Aquifer – Wilson and Gonzales (CZ-10C)

This water management strategy consists of the development of well fields in the Carrizo Aquifer in northern Wilson and southern Gonzales counties with transmission facilities to supply municipal water users in Bexar County. Implementation of this strategy would conform to the rules and policies of the Evergreen and Gonzales County underground water conservation districts. Accordingly, approximately 11,000 ac-ft/yr would be supplied from Wilson County and approximately 5,000 ac-ft/yr would be supplied from Gonzales County (see Table 22).

Significant issues that could affect project implementation include permitting from local underground water conservation districts and technical uncertainties with regard to the effects of long- term pumping of the aquifer.

Table 23 – Supply (ac-ft/yr) and Estimated Cost for Carrizo Aquifer in Wilson and Gonzales Counties

County – Use Sector	2000	2010	2020	2030
Bexar – Municipal	**NA**	**16,000**	**16,000**	**16,000**
Estimated Annual Cost				
Bexar – Municipal	**NA**	**$12,496,000**	**$12,496,000**	**$ 6,608,000**

3.2.9 Carrizo Aquifer – Gonzales and Bastrop (CZ-10D)

This strategy involves the development of well fields in the Carrizo Aquifer in northern Gonzales and southern Bastrop counties. However, during the 30-year planning period, only the supply from Gonzales County would be developed. Groundwater produced from Gonzales County would be conveyed to a regional water treatment facility and then distributed to municipal, industrial, and mining water users in Comal and Guadalupe counties. As shown in Table 23, the project would provide 14,000 ac-ft/yr of dependable water supply by 2030. Implementation of this strategy would conform to the rules and policies of the Gonzales County Underground Water Conservation District.

Significant issues that could affect project implementation include permitting from local underground water conservation districts and technical uncertainties with regard to the effects long- term pumping of the aquifer.

Table 24 – Supply (ac-ft/yr) and Estimated Cost for Carrizo Aquifer in Gonzales and Bastrop Counties

County-Use Sector	2000	2010	2020	2030
Comal – Municipal	NA	0	0	5,500
Guadalupe – Municipal	NA	50	600	600
Guadalupe – Industrial	NA	550	550	550
Comal – Mining	NA	0	3,500	6,500
Guadalupe – Mining	NA	300	300	300
Total	**NA**	**900**	**4,950**	**13,450**
Estimated Annual Cost				
Comal – Municipal	NA	$ 0	$ 7,758,600	$ 10,970,600
Guadalupe – Municipal	NA	636,200	1,687,400	490,800
Guadalupe – Industrial	NA	629,200	662,200	449,900
Comal – Mining	NA	0	4,317,100	6,305,000
Guadalupe - Mining	NA	343,200	361,200	245,400
Total	**NA**	**$ 1,608,600**	**$ 14,786,500**	**$ 18,461,700**

3.2.10 Simsboro Aquifer (SCTN-3C)

This strategy involves the development or expansion of well fields in the Simsboro Aquifer in Bastrop, Lee, and Milam counties with transmission to municipal water users in Bexar County. A key element of the project would be to beneficially use groundwater that is produced incidental to lignite mining operations. The strategy would provide 55,000 ac-ft/yr of dependable water supply (see Table 24). San Antonio Water Systems (SAWS) has agreements in place with the Aluminum Corporation of America (ALCOA) and with City Public Service of San Antonio to develop the project.

The Bastrop County portion of the supply from this strategy will be subject to permitting by the Lost Pines Underground Water Conservation District. Significant local opposition to the project has developed in the areas from which groundwater would be produced. There is also some debate with regard to the long-term effects of increased pumping of the aquifer.

Table 25 – Supply (ac-ft/yr) and Estimated Cost for Simsboro Aquifer

County – Use Sector	2000	2010	2020	2030
Bexar - Municipal	**NA**	**55,000**	**55,000**	**55,000**
Estimated Annual Cost				
Bexar – Municipal	**NA**	**$ 47,590,400**	**$ 47,590,400**	**$ 28,029,650**

3.2.11 SAWS Recycled Water Program (SAWS)

SAWS is currently implementing a Recycled Water Program capable of supplying approximately 35,000 ac-ft/yr for non-potable municipal and industrial use in Bexar County. Approximately 25,000 ac-ft/yr is included as currently available water supply. This strategy consists of the phased expansion of the SAWS Recycled Water Program to provide an additional 35,824 ac-ft/yr of dependable water supply for municipal use by 2030 (see Table 25).

The availability of additional customers with suitable non-potable demands that could be supplied with reclaimed water will affect implementation of this strategy. Expansion of the SAWS Recycled Water Program may eventually require development of extensive dual water distribution systems to serve smaller commercial and residential water users.

Table 26 – Supply (ac-ft/yr) and Estimated Cost for SAWS Recycled Water Program

County – Use Sector	2000	2010	2020	2030
Bexar - Municipal	**NA**	**19,826**	**26,737**	**35,824**
Estimated Annual Cost				
Bexar – Municipal	**NA**	**$ 17,264,566**	**$ 17,981,583**	**$ 18,924,359**

3.2.12 Purchase Water from a Major Water Provider

This water management strategy involves the purchase of water supplies from, or participation in the development of new water supplies with an unspecified “Regional Water Provider”. Within the Authority’s jurisdiction, six entities have been designated as Major Water Providers: SAWS, BMWD, GBRA, CRWA, and the cities of New Braunfels and San Marcos. This strategy may also involve the purchase of water supplies from, or participation in the development of new water supplies with the designated “Regional Water Provider for Bexar County”.

Table 27 – Supply (ac-ft/yr) and Estimated Cost for Major Water Provider

County-Use Sector	2000	2010	2020	2030
Hays – Municipal	NA	5,000	5,000	5,000
Bexar – Industrial	NA	0	0	2,000
Bexar – Mining	NA	5,000	5,500	5,500
Total	**NA**	**10,000**	**10,500**	**12,500**
Estimated Annual Cost				
Hays – Municipal	NA	$ 2,995,000	$ 3,015,000	$ 3,015,000
Bexar – Industrial	NA	0	0	1,521,948
Bexar – Mining	NA	3,240,668	4,490,964	4,185,358
Total	**NA**	**$ 6,235,668**	**$ 7,505,964**	**$ 8,722,306**

3.2.13 Aquifer Storage and Recovery – Regional (SCTN-1A)

An aquifer storage and recovery (ASR) project is planned for development in southern Bexar County. The project, which is being developed by SAWS, will involve the temporary storage of water from the Edwards Aquifer in the Carrizo Aquifer in the winter months for subsequent recovery and use in the summer months. The strategy will not increase the overall water supply on an annual basis but will substantially reduce peak municipal water demands on the Edwards Aquifer during the summer and will improve the reliability of current water supplies for all users of the Edwards Aquifer.

3.2.14 Seawater Desalination (SCTN-17)

The draft SCTRWP recommends that a seawater desalination facility be developed on the north shore of San Antonio Bay with transmission of treated water to Bexar County for municipal use. The project would provide 56,000 ac-ft/yr of dependable water supply beginning in 2040, increasing to approximately 84,000 ac-ft/yr by 2050. While included as a recommended long-term strategy in the draft SCTRWP, there are significant concerns with regard to the economic feasibility and potential environmental impacts of seawater desalination.

3.3 Additional Water Management Strategies Recommended for Further Study

In addition to the strategies described above that are recommended for implementation to meet identified needs within the EAA’s jurisdiction, the initially prepared draft SCTRWP also includes recommendations regarding strategies requiring further evaluation. These are:

Brush management (SCTN-4) - This strategy involves the selective clearing of certain invasive species of brush in rangeland areas of the Edwards Plateau. The objective is to reduce the consumption of water through evapo-transpiration and thereby increase surface water runoff and/or groundwater recharge. The practice is currently being studied in the Edwards Aquifer region by the USDA Natural Resource Conservation Service with funding support from a number of sources including the EAA. However, at this time it is not possible to accurately estimate the amount of water that widespread implementation of this strategy could contribute during severe drought. However, the strategy could increase stream flow and groundwater recharge during non-drought periods, which could contribute to water supplies available during drought. In addition to technical uncertainties with regard to the efficacy of brush management as a water management strategy, there are also significant issues associated with funding on-going brush removal and control activities on a large scale and there are significant environmental concerns associated with modification of habitat for threatened and endangered species native to the Edwards Plateau.

Weather Modification (SCTN-5) – Weather modification, or precipitation enhancement, involves the seeding of suitable rain producing clouds by aircraft equipped with silver iodide flares. This strategy is being practiced and evaluated at present in 15 counties of the South Central Texas Region. It is uncertain whether the strategy can increase the amount of water available during drought. However, increased precipitation could contribute directly to dryland crop, livestock, and wildlife production and could increase stream flows and groundwater recharge during non-drought periods. Depending on the timing, increased precipitation could also reduce demands on pumping from the Edwards Aquifer by decreasing crop irrigation requirements.

Rainwater Harvesting (SCTN-9) – This strategy involves the capture, storage, and use of rainwater, typically from the roofs of homes and businesses. Rainwater harvesting could also involve the collection and use of storm water from residential and commercial developments. Typically, rainwater harvesting is implemented on a small-scale basis and the water is used in close proximity to the point of capture. Most systems in use today provide non-potable water supply for irrigation of landscaped areas. However, technology is readily available for on-site treatment of the water to levels suitable for potable uses. Generally, given the cost of rainwater harvesting systems, applications are limited to sparsely settled rural areas where water supply from public water suppliers is cost-prohibitive or where the availability, quality, or cost is a limiting factor on groundwater use.

Additional Municipal Reuse – This strategy would involve development of new or expanded programs to reclaim municipal wastewater for beneficial reuse for non-potable purposes (e.g., landscaped areas, golf courses, cooling water, agricultural irrigation). To the extent that the use of reclaimed water is a substitute for other sources of water, either for current or future uses, the strategy can significantly increase available water supply. As described previously, SAWS is currently implementing a major Water Recycling Program in San Antonio and it is recommended in the draft SCTRWP that this program be expanded significantly in the future. There are undoubtedly other opportunities to develop reuse programs and projects in other communities in the region, particularly those communities with central wastewater collection and treatment facilities. Further study is required to identify and evaluate of such opportunities.

Small Aquifer Recharge Dams – This strategy would involve the construction of small recharge dams on ephemeral streams to retard or capture storm water runoff in order to increase recharge to local aquifers in the region. The strategy appears to be particularly suited to areas overlying the Trinity Group of aquifers, much of which is in the contributing zone of the Edwards Aquifer but generally located outside of the EAA's jurisdiction. Small recharge dams may also reduce soil erosion and sedimentation and may qualify for technical and financial assistance from state and federal agencies.

Edwards Aquifer Recharge and Recirculation – Conceptually, this water management strategy would consist of artificial recharge of the Edwards Aquifer, diversion of resulting increased spring flow, and the return of this water to further recharge the aquifer. Artificial recharge could include enhancement of natural recharge as previously described, or water imported from another source, or a combination. The objective of this strategy would be to maintain minimum flows at Comal and San Marcos Springs and allow additional water to be withdrawn from the aquifer. One variation of this strategy (SCTN-6) was evaluated for the SCTRWP but is not included as a recommended strategy. Given the technical, economic, and legal uncertainties surrounding this strategy, additional research is required.

Cooperation with Corpus Christi for New Water Sources – This strategy involves establishment of a cooperative partnership with the City of Corpus Christi and the Coastal Bend Water Planning Region to further investigate and develop additional water sources for the benefit of both regions. Possibilities include desalination of seawater or brackish groundwater; development of groundwater supplies; and water exchanges, such as providing water from the Colorado River Basin to Corpus Christi in exchange for surface water to recharge the Edwards Aquifer that is committed to the Choke Canyon Reservoir.

Additional Water Storage – This water management strategy would involve construction of large-scale, regional aquifer storage and recovery and/or surface water storage facilities of a size to allow storage of surplus floodwaters for subsequent beneficial use. In addition to the potential for increasing water supplies, implementation of this strategy could buffer daily and seasonal variations in municipal water demand and improve the reliability of water supplies during drought or other emergencies.

4.0 WATER SUPPLY PLAN FOR THE EDWARDS AQUIFER REGION

As described in the previous section, for the Edwards Aquifer Region, the South-Central Texas Regional Water Plan (SCTRWP) includes seven water management strategies that are already in various stages of implementation and recommends implementation of an additional 13 strategies over the next 30 years. Other strategies are recommended for further study and could be included in future updates of the regional water plan. Assuming all of the recommended strategies are implemented in the timeframes indicated in the SCTRWP, total available water supply will increase by 556,832 ac-ft/yr by 2030. For all categories of water demand in the aggregate and assuming 340,000 ac-ft/yr of pumpage from the Edwards Aquifer, implementation of the SCTRWP would satisfy all projected water demands by 2010 and thereafter (Table 27). However, as previously noted, projected irrigation shortages would not be met as the recommended strategies are not considered feasible for meeting irrigation needs.

Table 28 – Water Supply and Demand Balance for the Edwards Aquifer Region with Strategies Recognized in the SCTRWP (ac-ft/yr)

	2000	2010	2020	2030
Projected Water Demand	765,127	802,372	848,588	918,118
Currently Available Water Supply	523,604	522,244	521,055	505,495
Supply from Strategies in Progress	NA	38,390	33,190	33,190
Supply from Recommended Strategies	NA	345,672	435,396	509,642
Shortage/Surplus	**-241,523**	**103,934**	**141,053**	**130,209**

Note: Excludes irrigation water conservation applied to irrigation shortages.

5.0 COST-BENEFIT AND ENVIRONMENTAL ANALYSIS

This section is intended to satisfy the requirements of Article 1, Section 1.25 of the Edwards Aquifer Authority Act, which requires the Authority to "…perform a cost-benefit analysis and an environmental analysis" as part of the development of a plan for providing alternative water supplies to the Edwards Aquifer region. As with other information presented in this plan, the information in this section is drawn entirely from the adopted SCTRWP or from supporting documentation. It was beyond the scope of the current effort to acquire additional data or to perform additional analyses of the costs, benefits, and environmental impacts of the various water management strategies recommended for implementation within the region. As previously noted, many of the recommended strategies will require additional feasibility-level planning and engineering design to refine current estimates of water supply yield and costs. Similarly, many of the strategies will be subject to extensive regulatory review, with particular attention given to full evaluation of potential environmental impacts and evaluation of measures to mitigate or avoid such impacts.

5.1 Cost-Benefit Analysis

A simplified cost-benefit analysis has been developed for the recommended 30-year water supply plan for the Edwards Aquifer region. As noted above, the analysis is based solely on information contained in or developed for the SCTRWP. A more sophisticated cost-benefit analysis, like that which might be performed for a large federally funded water supply project, is beyond the scope of the current effort.

For the purposes of this plan, "cost" and "benefit" are defined as follows:

> **Cost** is the estimated annual costs, in the aggregate, associated with implementation of the 13 "new" water management strategies recommended for implementation to meet projected water needs within the Edwards Aquifer region (see Table 29). Costs are not included for the seven water management strategies that are already in various stages of implementation as these costs were not reported in the SCTRWP.
>
> **Benefits** are the value of the additional water to be provided by the recommended plan in terms of the avoidance of social and economic impacts that would occur if the projected water needs of the Edwards Aquifer region are not fully satisfied. As stated in the SCTRWP, "the social and economic effects of not meeting a projected water need can be viewed as the potential benefit to be gained from implementing a strategy to meet the particular need".

TWDB rules for the regional water planning process required that the social and economic impacts of not meeting identified water needs were to be evaluated. At the request of the SCTRWPG, TWDB staff performed the analysis of impacts using a standard methodology employed for all 16 water planning regions in the state. TWDB used an input-output model to compute the estimated impacts for two measures of social impact of not meeting identified water needs – population and school enrollment - and for three measures of economic impact – gross economic output (sales and business gross income), personal income, and employment. Values for each of these variables were computed for each individual water user group with a projected water shortage and were reported by decade.

Table 29 - Estimated Annual Costs of Recommended Water Management Strategies (in millions of dollars 1999)

Recommended Strategy	2010	2020	2030
Municipal Water Conservation (L-10)	$ 7.28	$ 7.28	$ 2.24
Irrigation Conservation (L-10 and L-15)	1.48	1.47	0
Transfers of Edwards Aquifer Rights (L-15)	3.81	3.81	3.90
Recharge Enhancement (L-18A)	21.89	23.46	23.46
Canyon Reservoir – River Diversion (G-15C)	8.16	11.67	9.86
Lower Guadalupe River Diversion (SCTN-16)	75.93	77.06	77.44
Lower Colorado River Diversion (LCRA)	0	88.86	142.97
Carrizo Aquifer (CZ-10C)	12.50	12.50	6.60
Carrizo Aquifer (CZ-10D)	1.61	14.79	18.46
Simsboro Aquifer (SCTN-3C)	47.59	47.59	28.03
SAWS Recycled Water Program (SAWS)	17.26	17.98	18.92
Purchase Water from Regional Provider	6.24	7.50	8.72
Aquifer Storage and Recovery (SCTN-1A)	NA	NA	NA
Total	**$ 203.75**	**$ 313.97**	**$ 340.60**

For the purposes of this plan, relevant social and economic impact data for the Edwards Aquifer region was extracted from the larger data sets prepared by the TWDB for the South Central Texas region and then re-aggregated for the Edwards Aquifer Region. This was accomplished using the same procedures employed to extract population, water supply, and water demand data for the Edwards Aquifer Region from the SCTRWP. The results are shown in Table 30 below.

Table 30 - Social and Economic Impacts of Not Meeting Projected Water Needs in the Edwards Aquifer Region

Type of Impact	2010	2020	2030
Population	-727,451	-909,357	-1,182,355
School Enrollment	-186,124	-232,031	-299,982
Gross Business Activity	-$ 28.8	-$ 36.2	-$ 47.7
Personal Income	-$ 11.7	-$ 14.7	-$ 19.1
Employment	-422,675	-526,424	-689,956

Note: Values for gross business activity and personal income are expressed in billions of dollars per year in 1999 dollars.

As shown in Table 29, the estimated annual costs to implement the recommended water management strategies, by decade for the planning period, are approximately $204 million in 2010, $314 million in 2020, and $340 million in 2030. Using "avoided" negative impacts on gross business activity as the basis for comparison, the estimated "benefit" of meeting projected water needs in the Edwards Aquifer region is $28.8 billion in 2010, $36.2 billion in 2020, and $47.7 billion in 2030. Expressed as a ratio of benefit to cost, the benefit-cost ratios associated with implementation of the recommended water management strategies are 141, 115, and 140 for each decade, respectively.

5.2 Environmental Analysis

As indicated previously, the Edwards Aquifer Authority Act requires that an environmental analysis be conducted as part of the Authority's plan for providing alternative water supplies to the region. Presented below is a brief discussion of the environmental impact analysis requirements of the National Environmental Policy Act (NEPA) of 1969 and a discussion of the cumulative impacts of the recommended water supply plan on the Edwards Aquifer. Also included is a brief discussion of the potential environmental impacts associated with each of the water management strategies recommended in the methodology required by the TWDB/S.B. 1 and used by the SCTRWP.

5.2.1 National Environmental Policy Act

Again, it should be emphasized that detailed analyses of the potential environmental impacts of each recommended water management strategy was not conducted during the development of the SCTRWP. However, for most of the recommended strategies, thorough environmental review will be required as part of various state and federal regulatory processes. Most notably, any proposed strategy that will involve a "federal action" will be required to comply with NEPA requirements. NEPA, and associated regulations of the White House Council for Environmental Quality, requires federal agencies to evaluate the effects of their proposed actions on the natural and human environment and to consider alternative courses of action. A federal action can include federal funding participation in the implementation of a recommended water management strategy or federal regulatory approval(s) of a strategy (e.g., a Clean Water Act Section 404 permit from the U.S. Army Corps of Engineers).

The NEPA review process is often initiated with the preparation of an environmental assessment (EA). The purpose of an EA is to help the federal agency that is taking a proposed action decide whether a full environmental impact assessment (EIS) is warranted. Generally, an EA is focused only on those resources that have a likelihood of being significantly impacted. Key elements of an EA include:

- A description of the affected environment.
- A description of the proposed action (a.k.a., project), its purpose, and the needs that the action is intended to address (e.g., water supply).
- A discussion of "reasonable" alternatives to the proposed action, including the "preferred" alternative and the "no-action" alternative.

- For the each alternative, an evaluation of the potential environmental, social, and economic consequences or impacts. The EA is to include a discussion of both direct and indirect affects, as well as discussion of appropriate measures to avoid, minimize, or mitigate the potential impacts.
- A description of efforts to coordinate and obtain pertinent information and input from the public and governmental agencies. An EA should address all known and foreseeable concerns.

On the basis of the analysis and information presented in an EA, the sponsoring federal agency may propose and adopt, after public review, a “finding of no significant impact” (FONSI). Alternatively, the agency may determine, either at the outset of the NEPA review process or on the basis of the information in an EA, that there are significant impacts associated with the proposed action that warrant a more thorough evaluation through the preparation of an EIS. An EIS must address all of the key elements of an EA but does so in a more detailed manner and with a higher degree of analysis and supporting documentation. Specifically, in the portion of an EIS that addresses the consequences of a proposed action and the alternatives to the proposed action, a host of potential impacts are to be described and analyzed including:

- Land use impacts
- Impacts on farmland
- Social impacts
- Relocation impacts
- Economic impacts
- Impacts to historical and cultural resources
- Air quality impacts
- Noise impacts
- Visual impacts
- Water quality impacts
- Impacts on wetlands
- Impacts from modification of water bodies
- Impacts to wild and scenic rivers
- Floodplain impacts
- Wildlife impacts
- Impacts to threatened and endangered species
- Coastal zone impacts

- Impacts on energy use
- Construction impacts

5.2.2 Cumulative Impacts of the Recommended Water Supply Plan on the Edwards Aquifer

Based on the results of hydrologic simulations conducted as part of the development of the SCTRWP, implementation of the recommended water management strategies for the Edwards Aquifer Region would have the following cumulative impacts on the Edwards Aquifer:

- Relative to a baseline condition of 400,000 ac-ft/yr of pumpage from the Edwards Aquifer (subject to EAA Critical Period Management Rules), overall withdrawals from the Edwards Aquifer would increase with full implementation of the recommended plan. This is due to the additional yield that would be available as a result of the full development of recommended recharge enhancement projects (L-18a).

- For most of the 56-year historical period of simulation, flows from Comal Springs would increase relative to a baseline condition, particularly during the summer months. The increased spring discharge is attributed to Edwards Aquifer recharge enhancement (L-18A) and the San Antonio Water Systems aquifer storage and recovery project in southern Bexar County (SCTN-1A). It is noted however, that increases in flows from Comal Springs would be partially offset by increased pumpage from the Edwards Aquifer in closer proximity to the springs. This would occur as a result of transfers of irrigation water rights from the irrigated farming areas west of San Antonio to municipal water users in San Antonio and Bexar County.

- Simulations also indicate substantial increases in flows from San Marcos Springs due to the development of a recharge enhancement structure with pumped diversions of surface water in the upper portions of the San Marcos River watershed. Environmental Impacts of Recommended Water Management Strategies

Based on information developed for the SCTRWP, a brief discussion of potential environmental impacts associated with each recommended water management strategy is provided below.

Municipal Water Conservation (L-10 Municipal)

There are no known potential adverse environmental impacts associated with municipal water conservation programs. Rather, implementation of such programs will provide various environmental benefits including reduced demand on limited water supplies and reduced energy use associated with pumping, treatment, and distribution of water. Interior water conservation measures will also reduce wastewater flows, which has been shown to improve wastewater treatment processes. Interior water conservation measures, such as low-flow showerheads and high-efficiency clothes and dishwashers, will also reduce household energy consumption.

Irrigation Conservation (L-10 and L-15)

Improved irrigation efficiency is not expected to result in adverse environmental impacts. Rather, like municipal water conservation, improved irrigation efficiency will reduce demand on limited water supplies and reduce energy use for pumping and water distribution. Agricultural water conservation measures have also been shown to be effective in increasing crop yields and in reducing agricultural non-point sources of water pollution.

Transfers of Edwards Irrigation Rights to Municipal Use (L-15)

Transfers of Edwards Aquifer irrigation water rights to municipal use have some potential to result in changes in land use (e.g., fallowing of farmland) that could in turn affect wildlife habitat. However, such changes could be beneficial to the extent that land cover is returned to a more natural condition for livestock grazing or wildlife purposes. Concerns have been expressed that relocation of some existing Edwards Aquifer withdrawals from the farming areas west of San Antonio to pumping centers in Bexar County may reduce flows at Comal Springs. Hydrologic simulations indicate that moving withdrawals to locations in closer proximity to the springs will reduce aquifer levels in those areas and decrease spring flow. Importantly, implementation of this strategy would not require construction of additional well fields, treatment facilities, or pipelines, thereby avoiding land use and environmental impacts associated with such facilities. It should also be noted that transfers of Edwards Aquifer irrigation water rights to municipal use potentially spreads out the annual usage rather than concentrating it within a four-month growing season.

Edwards Aquifer Recharge Enhancement (L-18a)

Development of the recommended recharge enhancement program has the potential for adverse environmental impacts associated with changes in land use and hydrology. Impacts would include disturbance of aquatic and terrestrial habitat from construction activities, loss of habitat associated with the recharge structure sites, and potential loss of habitat associated with periodic inundation of the reservoir pool during recharge events. Habitat loss has the potential to affect threatened and endangered species, which are known to occur within the areas considered for recharge enhancement. Recharge enhancement will also reduce flows downstream of each site and will reduce the firm yield of the Choke Canyon Reservoir/Lake Corpus Christi system and reduce freshwater inflows to the Nueces Estuary. Finally, recharge enhancement sites on the Nueces, Frio, Sabinal, and Blanco Rivers are located within stream segments recommended by the Texas Parks and Wildlife Department for legislative designation as ecologically unique streams.

The recommended recharge enhancement program would increase average recharge to the Edwards Aquifer by an estimated 135,000 acre-feet per year. Under drought-of-record conditions, recharge enhancement would increase the dependable supply of water from the Edwards Aquifer by nearly 22,000 acre-feet per year. Importantly, a substantial amount of the increased recharge would not be recovered for municipal water supply and would therefore help maintain aquifer levels and would increase flows at Comal and San Marcos Springs by nearly 80,000 acre-feet per year. The increased springflow will contribute directly to the maintenance of critical habitat in and near the springs and will result in increased instream flows and freshwater inflows to the Guadalupe Estuary. Recharge enhancement will also help maintain aquifer levels, thereby reducing pumping costs and decreasing the amount of time users are subject to the Authority's Critical Period Management Rules.

Canyon Reservoir – River Diversion (G-15c)

Because this recommended strategy involves the use of surface water from an existing reservoir, there would be no significant environmental impacts associated with the development of the water supply. However, there would be changes in land use and potential impacts to habitat and cultural resources associated with the pipeline route and the sites for the water treatment plant and transmission pump stations. Generally such impacts can be avoided or minimized in the selection of pipeline routes and sites for major facilities.

Diversions from the Lower Guadalupe and Lower Colorado Rivers (SCTN-16 and LCRA)

Large-scale diversions of surface water flows from the lower Guadalupe River and from the lower Colorado River will reduce freshwater inflows to the Guadalupe Estuary and the Matagorda Bay and Estuary, respectively. Reduced freshwater inflows may adversely impact aquatic habitat and species. To minimize the potential impact much of the surface water diverted under this strategy would occur during high flow periods, when stream flows may exceed targets for freshwater inflows. Conversely, diversions would be restricted during low flow periods to protect senior water rights and environmental flows, during which time groundwater may be used to ensure a dependable water supply during drought. However, the extent and significance of reduced freshwater inflows and the impacts of such will require additional research and investigation.

Implementation of this strategy would also result in land use changes and the potential loss of habitat and cultural resources associated with diversion facilities, off-channel reservoirs, well fields, pipelines, pump stations, and water treatment facilities. However, such impacts can be largely avoided or minimized in the siting of major facilities and the routing of the pipeline.

Groundwater Supply from the Carrizo Aquifer (CZ-10c and CZ-10d)

The development of groundwater supplies from the Carrizo Aquifer in Wilson, Gonzales, and Bastrop counties represents a strategy that will avoid the significant adverse environmental impacts typically associated with the development of similar quantities of surface water. However, in addition to land use impacts associated with well fields, pipelines, and pumping stations, concerns have been expressed about the long-term effects of groundwater withdrawals on water levels and potential decreases in the base flow of streams due to reduced spring discharges. Hydrogeological investigations indicate that the additional groundwater withdrawals associated with the two Carrizo Aquifer strategies will draw down water levels in the aquifer over the planning period and that the lowering of water levels will result in projected decreases in the base flows of both the San Antonio and Guadalupe Rivers, and consequently, reduced freshwater inflows to the Guadalupe Estuary. The projected decreases in stream flow and freshwater inflows would be most pronounced during drought conditions. However, it is believed that these reductions will be largely offset by "enhanced springflow" associated with implementation of recommended recharge enhancement projects and by increasing discharges of treated wastewater effluent.

Simsboro Aquifer (SCTN-3c)

Large-scale development of groundwater supplies from the Simsboro Aquifer in Bastrop, Lee, and Milam counties has raised concerns about the impacts of declining aquifer levels on local groundwater users in the area and about potential decreases in springflow and the base flows of streams. Studies indicate that significant drawdowns of the aquifer will be limited to areas in proximity to well fields and that impacts on nearby wells can be mitigated by deepening wells or by providing connecting impacted users to public water supply systems. Available information also suggests that stream flows in the Brazos and Colorado Rivers would not be significantly impacted by this strategy.

As with other groundwater strategies, development of the Simsboro Aquifer strategy would require changes in land use associated with well field, pipelines, and pumping stations. However, most adverse impacts could be avoided in the siting of these facilities.

SAWS Recycled Water Program (SAWS)

Environmental impacts associated with expansion of the SAWS recycled water program are considered to be minimal. Additional reclaimed water transmission and distribution facilities would be largely located in areas already developed or areas likely to be developed in the future.

Purchase Water from a Regional Water Provider

The potential environmental impacts associated with implementation of this strategy are unknown, as the strategy involves purchases of water from or participation in the development of new water supplies with an unspecified regional water provider.

Aquifer Storage and Recovery – Regional (SCTN-1a)

Environmental impacts associated with the implementation of aquifer storage and recovery projects in proximity to the San Antonio metropolitan area and the City of Victoria are considered to be minimal. Impacts would be limited to changes in land use associated with well field and transmission pipelines. Adverse environmental impacts can generally be avoided or minimize in the siting of these facilities.

Seawater Desalination (SCTN-17)

As with other water management strategies, the development of a large-scale seawater desalination facility would result in potential land use changes, and associated environmental impacts, from the intake structures, treatment facilities, brine discharge, and transmission pipelines. Through proper siting, many of these impacts can be avoided or minimized. However, desalination technologies using membrane filtration have large energy requirements and produce brine with salinity levels that may be three to four times that of seawater. Consequently, disposal of the brine would likely require an outfall sited off-shore in the Gulf of Mexico rather than a discharge to sensitive estuarine ecosystems.

6.0 FINANCING MECHANISMS FOR DEVELOPMENT OF ALTERNATIVE WATER SUPPLY SOURCES

Implementation of the recommended water supply plan for the Edwards Aquifer region will require large capital investments by numerous water suppliers acting either individually or collectively. For the South Central Texas Region as a whole, the estimated capital cost to implement the recommended water management strategies is approximately $4.7 billion (in 1999 dollars). Consequently, the sources and availability of financing is a major concern.

This section provides an overview of potentially available mechanisms and sources for financing implementation of recommended water supply and water conservation strategies. This includes a brief discussion of options for self-financing by water purveyors, financing through commercial sources, financial assistance through the Texas Water Development Board (TWDB) and the Texas Department of Housing and Community Affairs (TDHCA), and federal funding. Importantly, this section is intended to satisfy Article 1, Section 1.25 of the Edwards Aquifer Authority Act, which requires that in developing a plan to provide alternative water supplies to the Edwards Aquifer region the Authority shall "…investigate mechanisms for providing financial assistance for alternative supplies through the Texas Water Development Board..."

6.1 Self-Financing

Some of the water management strategies recommended for implementation within the Edwards Aquifer Region could be financed directly by public agencies, individuals, and private entities. For example, municipalities can (and do) use current tax or utility revenues to fund implementation of urban water conservation programs, to purchase irrigation water rights, and for capital improvements to water supply facilities. In fact, strategies with incremental costs that can be spread out over a long period of time, such as conservation programs, are well suited for funding on an on-going basis from tax or operating revenues. Similarly, small water-related capital improvement projects often can be funded from water utility operating revenues. Also, on-going operations and maintenance expenses associated with water supply facilities are typically funded with operating revenues (e.g., water sales).

Private individuals and businesses may also self-finance water supply and conservation strategies. For example, an irrigator might use operating revenues or the proceeds from the sale of irrigation water rights to purchase and install more efficient irrigation equipment. Similarly, private businesses could use operating revenues to fund water efficiency improvements to their facilities or manufacturing processes.

6.2 Commercial Financing

Most water supply projects that require large capital outlays are financed through commercial sources. Typically, market-rate commercial financing is obtained through the sale of long-term bonds to investors. Principal and interest is paid on the bonds from either tax or utility revenues or a combination. Public sector entities, such as municipalities and water districts, can issue tax-exempt bonds to finance water supply projects while water supply corporations and private businesses can issue taxable bonds. Water projects can also be financed through commercial banks. However, such loans tend to carry somewhat higher interest rates and are typically used only as "bridge" loans until long-term financing can be secured.

6.3 Texas Water Development Board Financing[1]

By law, the principal functions of the TWDB are to:

- Collect and disseminate water-related data;
- Assist with regional water planning and with the planning of regional water, wastewater, and flood protection projects;
- Prepare and periodically update the State Water Plan; and

[1] The information summarized in this section is based on fact sheets and other information provided by the Texas Water Development Board.

- Provide low-cost financial assistance for water-related projects.

The TWDB provides loans and some grants to “political subdivisions” of the state, such as cities, counties, water districts, and river authorities, and to certain not-for-profit water supply corporations. The TWDB issues general obligation and revenue bonds and uses the proceeds to purchase bonds from eligible political subdivisions and not-for-profit water supply corporations. Borrowers then use the funds provided by the TWDB to construct water-related projects. As borrowers repay the principal and interest on the bonds sold to the state, the TWDB uses these payments to service the debt on the state’s bonds. As state bonds are paid off, additional state bonds can be sold to replenish the loan pool. Local and regional governmental entities may benefit from financing through the TWDB by obtaining lower interest rates than may be available through commercial sources. Also, small communities may have difficulty accessing commercial financing and often turn to TWDB for assistance with financing. Private individuals and for-profit corporations are not eligible for TWDB financial assistance.

Since its creation in 1957, the Legislature and voters have approved constitutional amendments authorizing the TWDB to issue up to $4.68 billion in bonds for the financing of water-related projects. This includes $2 billion in new bond issuance authority with the approval of Proposition 19 by the voters on November 6, 2001. With the additional authorization, the TWDB estimates that sufficient funds will be available to meet projected needs for at least the next 10 years.

TWDB administers several programs that could potentially be used to finance the further development and implementation of the recommended water management strategies for Edwards Aquifer region. The TWDB’s principal financial assistance programs are:

- Texas Water Development Fund
- Water Infrastructure Fund
- Rural Water Assistance Fund
- Drinking Water State Revolving Fund
- Clean Water State Revolving Fund
- State Participation Program
- Economically Distressed Areas Program
- Agricultural Water Conservation Loan Program

A brief description of each program follows.

6.3.1 Texas Water Development Fund (TWDF)

The TWDB provides loans to political subdivisions and not-for-profit water supply corporations through the Texas Water Development Fund. The loans, which are offered at non-subsidized rates set 0.35 percent above the TWDB's borrowing costs, can be used for the planning, design, and construction of water-related facilities including:

- Water supply development (e.g., surface water reservoirs, wells, water rights purchases);
- Water supply infrastructure (e.g., pipelines, pumping facilities, storage reservoirs and tanks);
- Water treatment and distribution;
- Wastewater collection, treatment, and disposal; and
- Flood control.

As security for the loans, the TWDB accepts general obligation bonds, revenue bonds, and tax and revenue certificates of obligation. The term of repayment for loans from the TWDF is typically 20-25 years. State law requires that applicants for TWDF loans develop and adopt a water conservation plan and drought contingency plan.

On loans from the TWDF, the TWDB offers a pre-design funding option, which enables applicants to secure a loan commitment and lock-in interest rates based on preliminary engineering, cost, and environmental information. Funds to complete detailed facility planning and environmental studies are provided upon loan closing, while funds for detailed design and facility construction are escrowed until needed. If the pre-design funding option is not used, all project plans, specifications, and permits must be approved and construction bids opened prior to loan closing.

6.3.2 Water Infrastructure Fund (WIF)

Senate Bill 2, Article 4 (77th Texas Legislature) established WIF as a new funding source administered by the TWDB. The WIF can be used to provide loans to political subdivisions of the state for water supply projects and can be used for economic development related to water supply and conservation projects including provision of loans or grants to persons and private entities (e.g., rebates for water-conserving plumbing fixtures). The statute also provides that up to 10 percent of the funds to be allocated annually from the WIF can be in the form of grants, low-interest or zero-interest loans to political subdivisions located outside of Metropolitan Statistical Areas.

The TWDB has indicated its intent to earmark $50 million in state general obligation bond proceeds to the WIF.

6.3.3 Rural Water Assistance Fund (RWAF)

S.B. 2 also established the RWAF as a special account within the state's General Revenue Fund. Through the RWAF, the TWDB can provide low-interest loans to water supply corporations that have a service area population of less then 10,000 and which are located in counties in which no urban area exceeds 50,000 population. The fund can be used to buy-down interest rates on loans. Loans can be used for water supply projects including purchase of water from other water suppliers and consolidation of water systems. The funds can also be used to fund the TWDB's reservoir Storage Acquisition Fund, the Research and Planning Fund, and the Hydrographic Survey Account.

6.3.4 Drinking Water State Revolving Fund (DWSRF)

The DWSRF provides "subsidized" loans to finance projects to facilitate compliance with federal and state drinking water standards or to further the overall public health protection goals of the federal Safe Drinking Water Act. This includes the planning, design, and construction of projects to upgrade or replace water supply infrastructure, to correct violations of drinking water quality standards, to consolidate water systems, and to purchase capacity in water systems. The purchase of land or conservation easements for drinking water source protection is also eligible for funding through the DWSRF.

The DWSRF program is funded in part with capitalization grants provided annually through the U.S. Environmental Protection Agency. The TWDB also provides matching funds using the proceeds of sales of state general obligation or revenue bonds. The blending of federal and state funds results in a long-term interest rate set at 1.2 percent below market rates at the time of loan closing. Currently, the program has a loan capacity of approximately $70 million per year.

All "community" water systems are eligible for assistance including privately owned water systems. Prospective DWSRF applicants must submit information about existing and proposed drinking water facilities to the TWDB for inclusion in the Intended Use Plan developed each year. The Texas Natural Resource Conservation Commission (TNRCC) is responsible for prioritizing projects proposed in the

Intended Use Plan based on public health and safety considerations. Available loan funds are allocated based on a project's priority rating and readiness to proceed.

The pre-design funding option is also available on loans provided through the DWSRF. The maximum repayment period for DWSRF loans is 20 years from completion of project construction. State law requires that applicants for DWSRF loans develop and adopt a water conservation plan and drought contingency plan.

6.3.5 Clean Water State Revolving Fund (CWSRF)

The TWDB also administers the CWSRF, which provides below market rate loans to political subdivisions that have the authority to own and operate sewage systems. Not-for-profit water supply corporations and private entities are not eligible for CWSRF loans. Funds providing through the CWSRF can be used for the planning, design and construction of wastewater collection and treatment facilities, wastewater reclamation and reuse facilities, and for stormwater and nonpoint source pollution control projects.

Like the DWSRF, the CWSRF is funded partially with federal capitalization grants and partially with funds from the sale of TWDB bonds. The interest rate on CWSRF loans is 0.7 percent lower than the current market rate at the time of loan closing. The program has a current loan capacity of approximately $330 million per year.

The pre-design funding option is also available on loans provided through the CWSRF. The maximum repayment period for CWSRF loans is 20 years from completion of project construction. As with TWDF and DWSRF loans, State law requires that applicants for CWSRF loans develop and adopt a water conservation plan and drought contingency plan.

6.3.6 State Participation Program (SPP)

In addition to the TWDF and the two federally subsidized state revolving funds, the TWDB also has the authority to acquire a temporary ownership interest in regional water supply, wastewater, and flood control projects. This can include ownership interest in water rights, land, and facilities. Eligible entities include political subdivisions and not-for-profit water supply corporations that are sponsoring a regional project. With the passage of Proposition 19, the TWDB is authorized to acquire up to a 100 percent interest in any single project. Previously, the maximum level of ownership was 50 percent.

The goal of the SPP is to capture "economies of scale" in optimally sized regional projects that are otherwise unaffordable without state participation. The program allows the graduated deferral of debt service payments on a regional project for a period of 13 years, which provides time for the customer base for a project to grow and augment the applicant's ability to repay deferred principal and interest. Ultimately, the TWDB recovers the full cash expenditure of funds. For example, on a regional project with a financing life of 34 years (the maximum) 100 percent of the interest and principal are deferred during the first two years. During years 13 through 19, the borrower then pays all accruing interest plus equal amounts of previously deferred interest. Then, during years 20 through 34, all of the annual accruing interest plus principal is repaid.

In effect, the SPP facilitates "right sizing" of regional facilities for future growth by allowing the state to "carry" a portion of the project's cost. This may eliminate the need to build parallel facilities or to otherwise replace undersized facilities in the future. The State's share is based on a determination of how much of a project is excess capacity that is currently unaffordable to the sponsor. Also, the remaining portions of a project's costs can be financed through other TWDB loan programs.

As with other TWDB financial assistance programs, applicants are required to adopt a water conservation plan and drought contingency plan.

6.3.7 Economically Distressed Areas Program

In 1989 the Texas Legislature established the EDAP to provide financial assistance through the TWDB in the form of grants, loans, or a combination grant/loan to bring water and wastewater utility services to "economically distressed areas" (e.g., colonias). An economically distressed area is defined as an area:

- In which the potable water supply or sanitary sewer services are inadequate to meet the minimal needs of residents;
- For which local financial resources are inadequate to address water and wastewater service needs; and
- With an established residential subdivision that was in existence on June 1, 1989.

Financing through the EDAP is limited to economically distressed areas within eligible counties, as defined by state law. Prior to application for financial assistance through the EDAP, the county must adopt model subdivision rules to prevent further development of substandard residential subdivisions. Within the Edwards Aquifer Region, only Uvalde County is eligible to receive EDAP funds for economically distressed areas.

6.3.8 Agricultural Water Conservation Loan Program (AWCLP)

The TWDB also administers the AWCLP, which was established by the Texas Legislature in 1985. Through the AWCLP, the TWDB can make loans to soil and water conservation districts, irrigation districts, and underground water conservation districts. "Borrower" districts can use the loans to fund improvements to irrigation district facilities (e.g., water measurement, canal lining, etc.). "Lender" districts can use the funds to make loans to private individuals or companies for the purchase and installation of on-farm irrigation efficiency improvements including upgrades of existing irrigation equipment, new irrigation equipment, preparation of irrigated land for conversion to dryland farming, preparation of dryland for more effective use of natural precipitation, brush control, and precipitation enhancement through weather modification.

6.4 Texas Department of Housing and Community Affairs[2]

The Texas Department of Housing and Community Affairs (TDHCA) administers the Community Development Fund (CDF). The CDF is largely funded from Community Development Block Grants awarded to the state through the U.S. Department of Housing and Urban Development. Through the CDF, the state provides grant funds on a competitive basis for public facility needs including water and wastewater utility improvements. During 1998, approximately $48 million was disbursed by the TDHCA through the CDF. The CDF program is targeted at providing assistance to low and moderate-income communities. It is likely that some communities within the Edwards Aquifer region could receive funding for water supply related projects through the CDF.

Each year, CDF funds are allocated among 24 state planning regions based on population, poverty rates, and unemployment rates. Applications for CDF funding are reviewed and scored by Regional Review Committees and TDHCA staff. Scoring criteria include community distress, the proposed project's benefit to low/moderate income persons, project impact, local matching funds, and other factors. One-half of the scoring for each application is from the Regional Review Committee and one-half from TDHCA staff.

The TDHCA also administers several financial assistance programs targeted at improving living conditions in colonias located within 150 miles of the Texas-Mexico border. These are the Colonia Area Planning Fund, the Colonia Planning Fund, the Colonia Comprehensive Planning Fund, and the Colonia Construction Fund. The latter provides grant funds for plumbing improvements and for connections to water and/or wastewater systems funded through the TWDB Economically Distressed Areas Program.

6.5 Federal Funding

Federal funding of recommended water supply strategies is also a possibility. One mechanism is through the U.S. Department of Agriculture's Rural Utilities Service (RUS)[3], which provides direct and guaranteed loans and grants to develop water and wastewater systems. Funds are available to public entities and not-for-profit corporations serving rural areas and to cities and towns with a population of 10,000 or less. Applicants for direct loans must demonstrate that they are unable to obtain financing from other sources at reasonable rates and terms. Loans can be made for a term of up to 40 years. However, the term of a loan cannot exceed the useful life of the facility or terms established by state statute. Guaranteed loans are made and serviced by commercial lending institutions such as banks and savings and loan associations. The RUS typically will guarantee up to 80 percent of the interest and principal on such loans.

Preference for financial assistance through the RUS is given to public entities, in areas with a population of less than 5,500, for the purpose of restoring a deteriorating water supply or to improve, enlarge, or modify a water facility or inadequate waste facility. Priority is also given to funding request that involve consolidation of small systems and to applicants serving low-income populations.

Another potential avenue for federal funding of water supply strategies is through direct congressional appropriation of funds for a specific project. The congressional funding process occurs in two steps. First, a project must be authorized by statute. This can either be a bill drafted specifically to authorize a particular project or a provision incorporated into an omnibus bill, such as the biennial Water Resources Development Act. In addition to identifying and describing the project, authorizing legislation will

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[2] Information summarized in this section was obtained from the Texas Department of Community Affairs' website.
[3] Information summarized in this section was obtained from the U.S. Department of Agriculture's website.

typically identify a federal agency through which federal funds are to be channeled, establish a maximum amount of federal funding to be appropriated, define non-federal cost-sharing requirements, and define any special conditions relating to project development.

The second step of the process is to secure congressional appropriation of the funds authorized for a project. Typically, an appropriation is made through congressional approval of the annual budget of the agency designated as the federal sponsor. For large projects with development schedules that span multiple years, appropriations of federal funds may need to be obtained each year until project completion.

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Appendix 2

Edwards Aquifer
Recharge and Discharge Data

1934-2002

Table C-1. Estimated Annual Groundwater Recharge to the Edwards Aquifer by Drainage Basin, 1934-2002 (measured in thousands of acre-feet).

Year	Nueces River/ West Nueces River Basin	Frio River/ Dry Frio River Basin	Sabinal River Basin	Area between Sabinal River and Medina River Basin	Medina River Basin	Area between Medina River and Cibolo Creek/ Dry Comal Creek Basin	Cibolo Creek/Dry Comal Creek Basin	Blanco River Basin	Total*
1934	8.6	27.9	7.5	19.9	46.5	21	28.4	19.8	179.6
1935	411.3	192.3	56.6	166.2	71.1	138.2	182.7	39.8	1,258.2
1936	176.5	157.4	43.5	142.9	91.6	108.9	146.1	42.7	909.6
1937	28.8	75.7	21.5	61.3	80.5	47.8	63.9	21.2	400.7
1938	63.5	69.3	20.9	54.1	65.5	46.2	76.8	36.4	432.7
1939	227	49.5	17.0	33.1	42.4	9.3	9.6	11.1	399.0
1940	50.4	60.3	23.8	56.6	38.8	29.3	30.8	18.8	308.8
1941	89.9	151.8	50.6	139.0	54.1	116.3	191.2	57.8	850.7
1942	103.5	95.1	34.0	84.4	51.7	66.9	93.6	28.6	557.8
1943	36.5	42.3	11.1	33.8	41.5	29.5	58.3	20.1	273.1
1944	64.1	76.0	24.8	74.3	50.5	72.5	152.5	46.2	560.9
1945	47.3	71.1	30.8	78.6	54.8	79.6	129.9	35.7	527.8
1946	80.9	54.2	16.5	52.0	51.4	105.1	155.3	40.7	556.1
1947	72.4	77.7	16.7	45.2	44.0	55.5	79.5	31.6	422.6
1948	41.1	25.6	26.0	20.2	14.8	17.5	19.9	13.2	178.3
1949	166.0	86.1	31.5	70.3	33.0	41.8	55.9	23.5	508.1
1950	41.5	35.5	13.3	27.0	23.6	17.3	24.6	17.4	200.2
1951	18.3	28.4	7.3	26.4	21.1	15.3	12.5	10.6	139.9
1952	27.9	15.7	3.2	30.2	25.4	50.1	102.3	20.7	275.5
1953	21.4	15.1	3.2	4.4	36.2	20.1	42.3	24.9	167.6
1954	61.3	31.6	7.1	11.9	25.3	4.2	10.0	10.7	162.1
1955	128.0	22.1	0.6	7.7	16.5	4.3	3.3	9.5	192.0
1956	15.6	4.2	1.6	3.6	6.3	2.0	2.2	8.2	43.7
1957	108.6	133.6	65.4	129.5	55.6	175.6	397.9	76.4	1,142.6
1958	266.7	300.0	223.8	294.9	95.5	190.9	268.7	70.7	1,711.2
1959	109.6	158.9	61.6	96.7	94.7	57.4	77.9	33.6	690.4
1960	88.7	128.1	64.9	127.0	104.0	89.7	160.0	62.4	824.8
1961	85.2	151.3	57.4	105.4	88.3	69.3	110.8	49.4	717.1
1962	47.4	46.6	4.3	23.5	57.3	16.7	24.7	18.9	239.4
1963	39.7	27.0	5.0	10.3	41.9	9.3	21.3	16.2	170.7
1964	126.1	57.1	16.3	61.3	43.3	35.8	51.1	22.2	413.2

Year	Nueces River/ West Nueces River Basin	Frio River/ Dry Frio River Basin	Sabinal River Basin	Area between Sabinal River and Medina River Basin	Medina River Basin	Area between Medina River and Cibolo Creek/ Dry Comal Creek Basin	Cibolo Creek/Dry Comal Creek Basin	Blanco River Basin	Total*
1965	97.9	83.0	23.2	104.0	54.6	78.8	115.3	66.7	623.5
1966	169.2	134.0	37.7	78.2	50.5	44.5	66.5	34.6	615.2
1967	82.2	137.9	30.4	64.8	44.7	30.2	57.3	19.0	466.5
1968	130.8	176.0	66.4	198.7	59.9	83.1	120.5	49.3	884.7
1969	119.7	113.8	30.7	84.2	55.4	60.2	99.9	46.6	610.5
1970	112.6	141.9	35.4	81.6	68.0	68.8	113.8	39.5	661.6
1971	263.4	212.4	39.2	155.6	68.7	81.4	82.4	22.2	925.3
1972	108.4	144.6	49.0	154.6	87.9	74.3	104.2	33.4	756.4
1973	190.6	256.9	123.9	286.4	97.6	237.2	211.7	82.2	1,486.5
1974	91.1	135.7	36.1	115.3	96.2	68.1	76.9	39.1	658.5
1975	71.8	143.6	47.9	195.9	93.4	138.8	195.7	85.9	973.0
1976	150.7	238.6	68.2	182.0	94.5	47.9	54.3	57.9	894.1
1977	102.9	193.0	62.7	159.5	77.7	97.9	191.6	66.7	952.0
1978	69.8	73.1	30.9	103.7	76.7	49.6	72.4	26.3	502.5
1979	128.4	201.4	68.6	203.1	89.4	85.4	266.3	75.2	1,117.8
1980	58.6	85.6	42.6	25.3	88.3	18.8	55.4	31.8	406.4
1981	205.0	365.2	105.6	252.1	91.3	165.0	196.8	67.3	1,448.3
1982	19.4	123.4	21.0	90.9	76.8	22.6	44.8	23.5	422.4
1983	79.2	85.9	20.1	42.9	74.4	31.9	62.5	23.2	420.1
1984	32.4	40.4	8.8	18.1	43.9	11.3	16.9	25.9	197.7
1985	105.9	186.9	50.7	148.5	64.7	136.7	259.2	50.7	1,003.3
1986	188.4	192.8	42.2	173.6	74.7	170.2	267.4	44.5	1,153.8
1987	308.5	473.3	110.7	405.5	90.4	229.3	270.9	114.9	2,003.5
1988	59.2	117.9	17.0	24.9	69.9	12.6	28.5	25.5	355.5
1989	52.6	52.6	8.4	13.5	46.9	4.6	12.3	23.6	214.4
1990	479.3	255.0	54.6	131.2	54.0	35.9	71.8	41.3	1,123.1
1991	325.2	421.0	103.1	315.2	52.8	84.5	109.7	96.9	1,508.4
1992	234.1	586.9	201.1	566.1	91.4	290.6	286.6	226.9	2,486.0
1993	32.6	78.5	29.6	60.8	78.5	38.9	90.9	37.8	447.6
1994	124.6	151.5	29.5	45.1	61.1	34.1	55.6	36.6	538.1
1995	107.1	147.6	34.7	62.4	61.7	36.2	51.1	30.6	531.3
1996	130.0	92.0	11.4	9.4	42.3	10.6	14.7	13.9	324.3
1997	176.9	209.1	57.0	208.4	63.3	193.4	144.2	82.3	1,134.6

Year	Nueces River/ West Nueces River Basin	Frio River/ Dry Frio River Basin	Sabinal River Basin	Area between Sabinal River and Medina River Basin	Medina River Basin	Area between Medina River and Cibolo Creek/ Dry Comal Creek Basin	Cibolo Creek/Dry Comal Creek Basin	Blanco River Basin	Total*
1998	141.5	214.8	72.5	201.4	80.3	86.2	240.9	104.7	1,142.3
1999	101.4	136.8	30.8	57.2	77.1	21.2	27.9	21.0	473.4
2000	238.4	123.0	33.1	55.2	53.4	28.6	48.6	34.1	614.5
2001	297.5	126.7	66.2	124.1	90.0	101.5	173.7	89.7	1,069.4
2002	83.6	207.3	70.6	345.2	93.7	175.5	539.3	150.0	1,665.2
Recharge for the period of record 1934-2002:									
Mean	120.7	135.2	42.6	110.7	62.4	71.5	111.3	44.6	698.9
Median	101.4	123.4	31.5	78.6	61.1	50.1	77.9	34.6	557.8
Recharge for the period of record 1993-2002 (last 10 years):									
Mean	143.4	148.7	43.5	116.9	70.1	72.6	138.7	60.1	794.1
Median	127.3	142.2	33.9	61.6	70.2	37.55	73.55	37.2	576.3

SOURCE: Edwards Aquifer Authority 2003c; USGS 2003.
*Total may not be equal to sum of basin values due to rounding.

Table C-2. Annual estimated groundwater discharge data by county for the Edwards Aquifer, 1934-2002 (measured in thousands of acre-feet).

Year	Kinney Uvalde	Medina	Bexar	Comal	Hays	Total	Total Wells	Total Springs
1934	12.6	1.3	109.3	229.1	85.6	437.9	101.9	336.0
1935	12.2	1.5	171.8	237.2	96.9	519.6	103.7	415.9
1936	26.6	1.5	215.2	261.7	93.2	598.2	112.7	485.5
1937	28.3	1.5	201.8	252.5	87.1	571.2	120.2	451.0
1938	25.2	1.6	187.6	250.0	93.4	557.8	120.1	437.7
1939	18.2	1.6	122.5	219.4	71.1	432.8	118.9	313.9
1940	16.1	1.6	116.7	203.8	78.4	416.6	120.1	296.5
1941	17.9	1.6	197.4	250.0	134.3	601.2	136.8	464.4
1942	22.5	1.7	203.2	255.1	112.2	594.7	144.6	450.1
1943	19.2	1.7	172.0	249.2	97.2	539.3	149.1	390.2
1944	11.6	1.7	166.3	252.5	135.3	567.4	147.3	420.1
1945	12.4	1.7	199.8	263.1	137.8	614.8	153.3	461.5
1946	6.2	1.7	180.1	261.9	134.0	583.9	155.0	428.9
1947	13.8	2.0	193.3	256.8	127.6	593.5	167.0	426.5
1948	9.2	1.9	159.2	203.0	77.3	450.6	168.7	281.9
1949	13.2	2.0	165.3	209.5	89.8	479.8	179.4	300.4
1950	17.8	2.2	177.3	191.1	78.3	466.7	193.8	272.9
1951	16.9	2.2	186.9	150.5	69.1	425.6	209.7	215.9
1952	22.7	3.1	187.1	133.2	78.8	424.9	215.4	209.5
1953	27.5	4.0	193.7	141.7	101.4	468.3	229.8	238.5
1954	26.6	6.3	208.9	101.0	81.5	424.3	246.2	178.1
1955	28.3	11.1	215.2	70.1	64.1	388.8	261.0	127.8
1956	59.6	17.7	229.6	33.6	50.4	390.9	321.1	69.8
1957	29.0	11.9	189.4	113.2	113.0	456.5	237.3	219.2
1958	23.7	6.6	199.5	231.8	155.9	617.5	219.3	398.2
1959	43.0	8.3	217.5	231.7	118.5	619.0	234.5	384.5
1960	53.7	7.6	215.4	235.2	143.5	655.4	227.1	428.3
1961	56.5	6.4	230.3	249.5	140.8	683.5	228.2	455.3
1962	64.6	8.1	220.0	197.5	98.8	589.0	267.9	321.1
1963	51.4	9.7	217.3	155.7	81.9	516.0	276.4	239.6
1964	49.3	8.6	201.0	141.8	73.3	474.0	260.2	213.8
1965	46.8	10.0	201.1	194.7	126.3	578.9	256.1	322.8
1966	48.5	10.4	198.0	198.9	115.4	571.2	255.9	315.3
1967	81.1	15.2	239.7	139.1	82.3	557.4	341.3	216.1
1968	58.0	9.9	207.1	238.2	146.8	660.0	251.7	408.3
1969	88.5	13.6	216.3	218.2	122.1	658.7	307.5	351.2
1970	100.9	16.5	230.6	229.2	149.9	727.1	329.4	397.7
1971	117.0	32.4	262.8	168.2	99.1	679.5	406.8	272.7
1972	112.6	28.8	247.7	234.3	123.7	747.1	371.3	375.8
1973	96.5	14.9	273.0	289.3	164.3	838.0	310.4	527.6
1974	133.3	28.6	272.1	286.1	141.1	861.2	377.4	483.8
1975	112.0	22.6	259.0	296.0	178.6	868.2	327.8	540.4

Year	Kinney Uvalde	Medina	Bexar	Comal	Hays	Total	Total Wells	Total Springs
1976	136.4	19.4	253.2	279.7	164.7	853.4	349.5	503.9
1977	156.5	19.9	317.5	295.0	172.0	960.9	380.6	580.3
1978	154.3	38.7	269.5	245.7	99.1	807.3	431.8	375.5
1979	130.1	32.9	294.5	300.0	157.0	914.5	391.5	523.0
1980	151.0	39.9	300.3	220.3	107.9	819.4	491.1	328.3
1981	104.2	26.1	280.7	241.8	141.6	794.4	387.1	407.3
1982	129.2	33.4	305.1	213.2	105.5	786.4	453.1	333.3
1983	107.7	29.7	277.6	186.6	118.5	720.1	418.5	301.6
1984	156.9	46.9	309.7	108.9	85.7	708.1	529.8	178.3
1985	156.9	59.2	295.5	200.0	144.9	856.5	522.5	334.0
1986	91.7	41.9	294.0	229.3	160.4	817.3	429.3	388.0
1987	94.9	15.9	326.6	286.2	198.4	922.0	364.1	557.9
1988	156.7	82.2	317.4	236.5	116.9	909.7	540.0	369.7
1989	156.9	70.5	305.6	147.9	85.6	766.5	542.4	224.1
1990	118.1	69.7	276.8	171.3	94.1	730.0	489.4	240.6
1991	76.6	25.6	315.5	221.9	151.0	790.6	436.0	354.6
1992	76.5	9.3	370.5	412.4	261.3	1130.0	327.2	802.8
1993	107.5	17.8	371.0	349.5	151.0	996.7	407.3	589.4
1994	95.5	41.1	297.7	269.8	110.6	814.8	424.6	390.2
1995	90.8	35.2	*272.1	235.0	127.8	761.0	399.6	361.3
1996	117.6	66.3	*286.8	150.2	84.7	705.6	493.6	212.0
1997	77.0	31.4	260.2	243.3	149.2	761.1	377.1	383.9
1998	113.1a	51.3	312.4b	271.8c	168.8	917.6	453.5	464.1
1999	104.0	49.2	307.1b	295.5c	143.0	898.8	442.7	456.1
2000	89.1	45.1	283.6b	226.1c	108.4	752.3	414.8	337.5
2001	68.6	33.9	291.6b	327.7c	175.4	890.0	367.7	529.6
2002	74.4	39.5	314.1b	346.9c	202.2	977.1	367.2	609.9
For period of record 1934-2002:								
Mean	71.4	20.5	240.1	223.7	120.8	676.4	304.3	372.2
Median	68.6	13.6	230.3	231.8	116.9	660	310.4	375.8
For period of record 1993-2002 (last 10 years):								
Mean	93.8	41.1	299.7	271.6	142.1	847.5	414.8	433.4
Median	93.2	40.3	294.7	270.8	146.1	852.4	411.1	423.2

SOURCE: Edwards Aquifer Authority 2003c; USGS 2002.
[a] Kinney County well discharge is estimated.
[b] Includes reports of Edwards Aquifer irrigators in Atascosa County.
[c] Includes reports of Edwards Aquifer industrial and municipal users in Guadalupe County.
NOTE: Differences may occur due to rounding.
*In 1995, the USGS revised the method of calculating domestic/livestock pumping, which significantly decreased the estimate for subsequent years.

Table C-3. Annual Estimated Edwards Aquifer Groundwater Discharge by Use, 1955-2002 (measured in thousands of acre-feet).

Year	Irrigation	Municipal	Domestic/ Stock	Industrial/ Commercial	Springs
1955	85.2	120.5	30.1	25.1	127.8
1956	127.2	138.3	28.9	22.4	69.8
1957	68.8	116.1	29.8	22.6	219.2
1958	47.2	113.7	33.4	25.1	398.2
1959	60.0	118.9	31.5	24.2	384.5
1960	54.9	121.1	29.1	23.3	428.3
1961	52.1	124.5	29.6	22.2	455.3
1962	72.7	143.7	28.8	22.8	321.1
1963	75.4	151.8	27.8	21.8	239.6
1964	72.6	140.2	26.3	21.7	213.8
1965	68.0	138.8	27.0	22.3	322.8
1966	68.2	141.8	23.3	22.6	315.3
1967	119.4	171.0	25.1	25.8	216.1
1968	59.3	146.9	25.5	20.0	408.3
1969	95.2	162.0	29.2	21.1	351.2
1970	110.1	167.5	29.3	22.5	397.7
1971	159.4	196.2	28.6	22.6	272.7
1972	128.8	190.5	30.8	21.1	375.8
1973	82.2	177.1	32.3	18.8	527.6
1974	140.4	174.6	33.5	15.1	483.3
1975	96.4	182.5	33.6	15.3	540.4
1976	118.2	182.1	34.6	14.7	503.9
1977	124.2	205.3	38.1	13.0	580.3
1978	165.8	214.2	40.3	11.5	375.5
1979	126.8	208.9	40.7	15.2	523.0
1980	177.9	256.2	43.3	13.7	328.3
1981	101.8	231.8	40.9	12.6	407.3
1982	130.0	268.6	39.5	15.0	333.3
1983	115.9	249.2	38.8	14.7	301.5
1984	191.2	287.2	36.2	15.2	178.3
1985	203.1	263.7	39.2	16.5	334.0
1986	104.2	266.3	42.0	16.8	388.0
1987	40.9	260.9	43.5	18.7	557.9
1988	193.1	286.2	41.9	18.8	369.7
1989	196.2	285.2	38.2	22.9	224.1
1990	172.9	254.9	37.9	23.7	240.6
1991	88.5	240.5	39.5	67.5	354.6
1992	27.1	236.5	34.8	29.0	802.8
1993	69.3	252.0	49.9	36.1	589.4
1994	104.5	247.0	33.9	39.3	390.2
1995	95.6	255.0	11.6*	37.3	361.3
1996	181.3	261.3	12.3*	38.8	212.0
1997	77.4	253.0	12.3*	34.4	383.9
1998	131.9	266.5	13.4*	41.7b	464.1
1999	113.6	273.3	13.4*	42.4	456.1
2000	106.3	261.3	13.4*	33.8	337.5
2001	79.0	245.9	13.4*	29.4	529.4
2002	94.6	228.1	13.6**	31.0	609.9
For period of record 1955-2002:					
Mean	107.8	205.8	30.6	24.2	379.3
Median	103.0	211.6	31.2	22.5	375.7

Year	Irrigation	Municipal	Domestic/ Stock	Industrial/ Commercial	Springs
For period of record 1993-2002 (last 10 years):					
Mean	105.4	254.3	18.7	36.4	433.4
Median	100.1	254.0	13.4	36.7	423.2

SOURCE: Edwards Aquifer Authority 2003c; USGS 2002
NOTE: Differences may occur due to rounding.

*In 1995 the USGS revised the method of calculating domestic/livestock pumpage, which significantly decreased the estimate for subsequent years.
**Revision based on number of new wells permitted in 2001 and 2002.

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Appendix 3

Plan Area Affected Environment

(This Appendix will include all of Chapter 3, of the Edwards Aquifer Authority Draft EAHCP and EIS dated July 2004 as amended 09/21/04. This Appendix will be reproduced in its entirety for the HCP document to be forwarded to the U.S. Fish and Wildlife Service.)

Chapter 3
Affected Environment

3.1 Biological Resources

3.1.1 Regional Flora and Fauna

3.1.1.1 Regional Ecology

Vegetational Areas

The vegetation within the EAHCP Planning Area encompasses portions of the Edwards Plateau, South Texas Brush Country, Blackland Prairie, Oak Woods and Prairies, and Gulf Coast Prairie and Marshes vegetational areas, as originally described by Gould (1975) and later refined by the LBJ School of Public Affairs (1978). The boundaries of each of these ecological areas within Texas are shown in Figure 3.1-1. Within these ecological regions, the Planning Area encompasses 14 dominant plant associations among 17 cover types, as defined and mapped by the Texas Parks and Wildlife Department (McMahan et al. 1984) (Figure 3.1-2). A brief overview of the conditions and representative species found in each of the major vegetational areas is provided below.

EDWARDS PLATEAU

This vegetational area encompasses approximately 24 million acres, including a large portion of the Hill Country in west-central Texas, as well as the Llano Uplift and Stockton Plateau regions. Average annual precipitation increases from west to east across this region. The surface is rough and well drained, being dissected by several river systems. The shallow, variably textured soils are typically underlain by limestone or caliche, or granitic rock in the Llano Uplift region. Land use in this vegetational area is dominated by cattle, sheep, and goat ranching.

Historically, this region was reportedly once dominated by a grassland or open savannah climax community except in the steep canyons and slopes, where junipers and oaks were dominant. However, with the widespread disturbance associated with livestock grazing and the suppression of fire, brush and tree species have been able to spread widely throughout the grassland and savannah areas.

Grasses that are typical of the Edwards Plateau region include switchgrass (*Panicum virgatum*), Indiangrass (*Sorghastrum nutans*), beardgrass (*Bothriochloa* spp.), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Canada wildrye (*Elymus canadensis*), curly mesquite (*Hilaria belangeri*) and buffalograss (*Buchloe dactyloides*). Other plants commonly found within this vegetational area include ashe juniper (*Juniperus ashei*), plateau live oak (*Quercus fusiformis*), Texas oak (*Q. texana*), Texas persimmon (*Diospyros texana*), elbowbush (*Forestiera pubescens*), Texas mountain laurel (*Sophora secundiflora*), prickly-pear cactus (*Opuntia* spp.), and pencil cactus (*O. leptocaulis*) (Hatch et al. 1990).

SOUTH TEXAS BRUSH COUNTRY

This region includes most of South Texas from the Rio Grande to the Coastal Plains and extends on an east-west line between San Antonio and Del Rio. The climate of this region is described as subtropical steppe and is characterized by semi-arid to arid conditions (Larkin & Bomar 1983). The vegetational structure and relative species composition of the South Texas Brush Country has changed dramatically over time. Historically, the dominant vegetation types were brushy savannahs and grasslands. Increased grazing and the suppression of wildfire have led to the spread of woody species from riparian areas and ridges to all parts of the landscape (Inglis 1964).

The historic grasslands were dominated by species of windmillgrass (*Chloris* spp.), bristlegrass (*Setaria* spp.), pappasgrass (*Pappaphorum* spp.*)*, and gramas (*Bouteloua* spp.). Other dominant grasses included bluestems, paspalums, and buffalograss (*Buchloe dactyloides*). Today, these same grasses occur along with many introduced species such as buffelgrass (*Cenchrus ciliaris*), kleingrass (*Panicum coloratum*) and Kleberg bluestem (*Dichanthium annulatum*). Common forbs in the area include prickly pear (*Opuntia* sp.), orange zexmania (*Wedelia hispida*), bush sunflower (*Simsia* sp.), velvet bundleflower (*Desmanthus velutinus*), tallowweed (*Plantago* sp.), lazy daisy (*Aphanostephus* sp.), Texas croton (*Croton texensis*), and western ragweed (*Ambrosia psilostachya*). Although species compositions vary significantly throughout the region, common brush species include mesquite (*Prosopis glandulosa*), various acacias (*Acacia* spp.), brasil (*Condalia hookeri*), blackbrush (*Acacia rigidule*), lotebush (*Zizyphus obtusifolia*), granjeno (*Celtis pallida*), whitebrush (*Aloysia gratissima*), colima (*Zanthoxylum fagara*), Texas persimmon, coyotillo (*Karwinskia humboldtiana*), and guayacan (*Guaiacum angustifolia*). Lowland creeks and arroyos often contain cedar elm (*Ulmus crassifolia*), sugar hackberry (*Celtis laevigata*), and ash (*Fraxinus* spp.) (Hatch et al. 1990; Gould 1975).

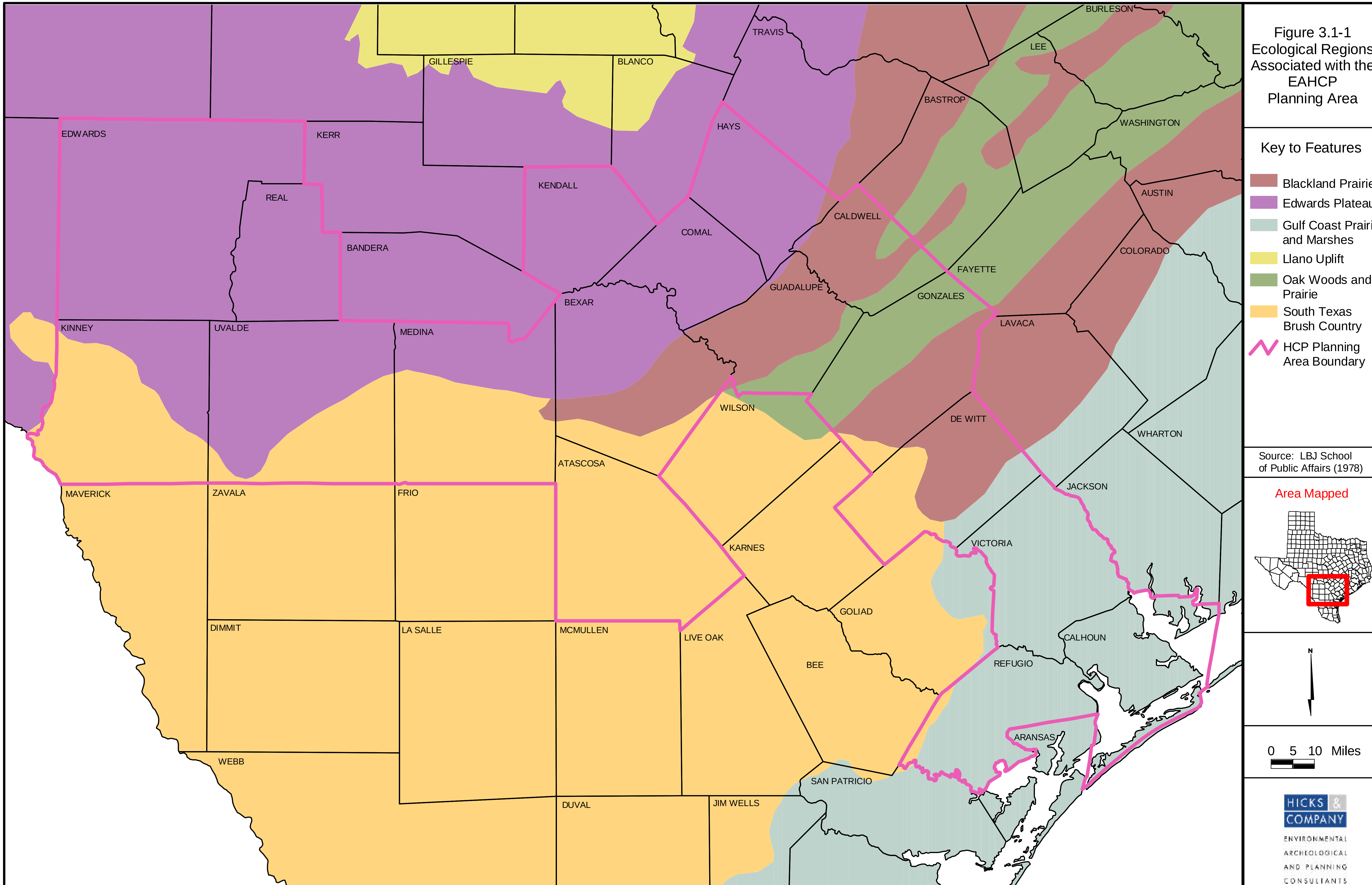

Figure 3.1-1 Ecological Regions Associated with the EAHCP Planning Area

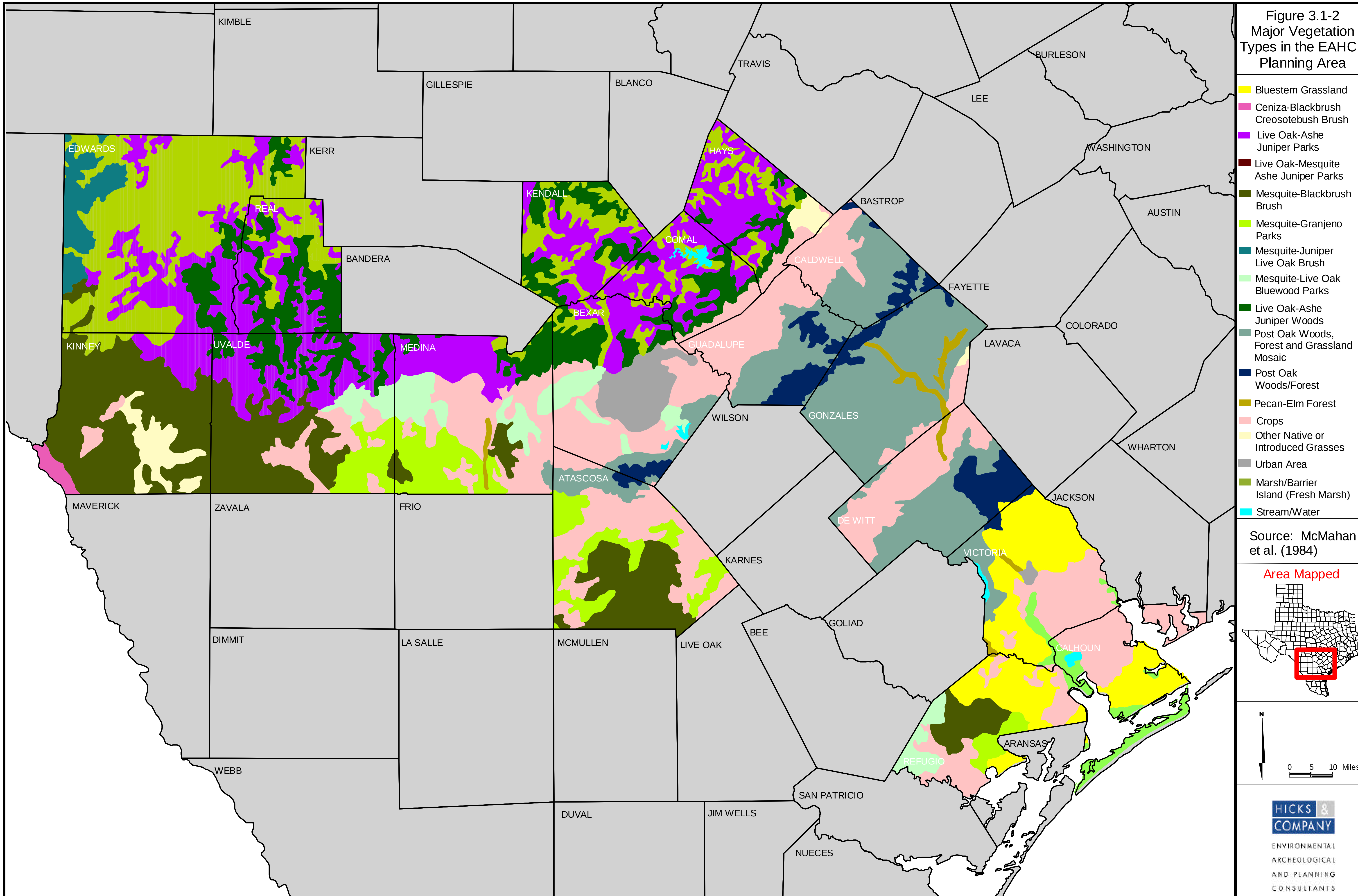

Figure 3.1-2 Major Vegetation Types in the EAHCP Planning Area

BLACKLAND PRAIRIE

The Blackland Prairies vegetational area consists of nearly level to gently rolling topography. This area covers approximately 11.5 million acres from Grayson and Red River Counties in northeast Texas to Bexar County in the south-central region of the state, where it merges with the brushland of the South Texas Plains. Annual precipitation averages 30 inches on the west to 45 inches on the east, and elevations range from 300 to 800 feet above sea level. Blackland soils that occur in the region are so named due to the uniform dark-colored calcareous clay component. These soils are interspersed with gray acid sandy loams. This highly fertile region has been widely used for cultivated agriculture, although use of the land for ranching has become increasingly popular (Gould 1975; Schuster and Hatch 1990). It has been estimated that less than one percent of the once extensive Blackland Prairies remain in a near natural condition (Smeins and Diamond 1986).

Studies have shown that the native vegetation of the Blackland Prairie should be classified as true prairie, typified by medium tall grasslands with scattered deciduous trees, with little bluestem (*Schizachyrium scoparium* var. *frequens*) being a climax dominant (Gould 1975). Big bluestem (*Andropogon gerardi*), Indiangrass, switchgrass, hairy grama (*Bouteloua hirsuta*), sideoats grama (*B. curtipendula*), tall dropseed (*Sporobolus asper* var. *asper*), silver bluestem (*Bothriochloa saccharoides*), and Texas wintergrass (*Stipa leucotricha*) represent other important grasses in the vegetational region. With heavy grazing practices, invading or increasing species such as buffalograss, Texas grama (*Bouteloua rigidiseta*), and smutgrass (*Sporobolus indicus*), along with other annuals may become prevalent (Gould 1975; Correll and Johnston 1970). Improved pastures with introduced grass species such as dallisgrass (*Paspalum dilatatum*) and bermudagrass (*Cynodon dactylon*) are common in the area. Asters (*Aster* spp.), prairie bluet (*Hedyotis nigricans* var. *nigricans*), prairie clover (*Dalea* spp.), and late coneflower (*Rudbeckia serotina*) are common forbs of these prairies (Hatch et al. 1990).

Wooded areas along riparian strips in the Blackland Prairie include such species as black willow (*Salix nigra*), oaks (*Quercus* spp.), pecan (*Carya illinoiensis*), osage orange (*Maclura pomifera*), elms (*Ulmus* spp.), and eastern cottonwood (*Populus deltoides*) (Hatch et al. 1990). Woody invasive species that are commonly found in the vegetational area include post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and cedar elm in the north, with honey mesquite being a common invader in the southern portion of the region (Gould 1975).

OAK WOODS AND PRAIRIE

The Oak Woods and Prairie covers approximately 8.5 million acres in eastern Central Texas, and consists of closely associated and intermingled prairie and woodland or forested sites on slightly acid sandy or clay loams. This narrow, irregular belt is wedged between the east Texas Pineywoods to the east and the Blackland Prairie to the west, and extends into the EAHCP Planning Area from the northeast. Topography throughout this region is gently rolling to hilly, with moderate to deeply dissected drainages. Annual precipitation is 30-45 inches and elevations range from 200-500 feet. Soils are generally light-colored acid sandy-loams or sands in uplands, and light brown to dark gray acid sandy loams to clays in bottomlands. Much of this area has been converted to crop and grazing land.

Typical native woody vegetation in this area includes post oak, blackjack oak, eastern juniper (*Juniperus virginiana*), and hackberries (*Celtis* spp.). Yaupon (*Ilex vomitoria*), American beautyberry (*Callicarpa americana*), and greenbriar (*Smilax bona-nox*) are common understory constituents of wooded areas. Common native grasses in this region include little bluestem, Indiangrass, switchgrass, and Texas wintergrass (*Stipa leucotricha*). Forbs typical of the prairie portions include indigobush (*Amorpha fruiticosa* v. *angustifolia*), senna (*Cassia* sp.), tick-clover (*Desmodium* spp.), prairie-clover (*Petalostemon* spp.), western ragweed, and croton (*Croton* spp.) (Correll and Johnston 1970; Gould 1975).

GULF COAST PRAIRIE AND MARSHES

The southeastern portion of the EAHCP Planning Area lies within the Gulf Coast Prairie and Marshes vegetational area. This vegetational area extends in an arc along the Coastal Bend region of Texas and occupies approximately 9.5 million acres. Marshes represent 500,000 acres of the total with prairies occupying the remainder of this vegetation area in Texas.

Originally, the Gulf Prairies supported tall grass prairie and post oak savannah. Since that time, trees such as live oak (*Quercus virginiana*), post oak, mesquite, Chinese tallow (*Sapium sebiferum*), huisache (*Acacia smallii*), and blackbrush have increased and form thickets in many places. Today the Gulf Prairies are cropped, grazed, and used extensively for urban and industrial purposes. Typical crops include rice, sorghum, cotton, and non-native grasses such as bermudagrass, St. Augustine grass (*Stenotaphrum secundatum*) and introduced bluestems (*Dichanthelium* and *Bothriochloa*). Rangeland of the Gulf Prairie can support climax grasses such as gulf cordgrass (*Spartina spartinae*), big bluestem, little bluestem, Indiangrass, eastern gamagrass (*Tripsacum dactyloides*), gulf muhly (*Muhlenbergia capillaris*), tanglehead (*Heteropogon contortus*), and many species of *Panicum* and *Paspalum*. Climax conditions on the Gulf Prairie are virtually nonexistent today due to influences such as grazing, fire suppression, and human disturbance. In response to these influences, invading plants tend to dominate both woody and annual herbaceous communities. Invading herbaceous plants typical of the Gulf Prairie include yankeeweed (*Eupatorium compositifolium*), broomsedge bluestem (*Andropogon virginicus*), smutgrass, western ragweed, tumblegrass (*Schedonnardus paniculatus*), and threeawns (*Aristida* spp.). Prickly pear and bushy sea-ox-eye (*Borrichia frutescens*) are common woody species of low stature on rangelands of the Gulf Prairies. Typical forbs include aster (*Aster* spp.), Indian paintbrush (*Castilleja indivisa*), poppy mallow (*Callirhoe* spp.), phlox (*Phlox* spp.), bluebonnet (*Lupinus texensis*), and evening primrose (*Oenothera speciosa*) (Hatch et al. 1990).

Gulf Marsh vegetation community composition varies according to salinity regimes within the habitat. Typical emergent Gulf Marsh plants include species of sedges (*Carex* and *Cyperus* spp.), rushes (*Juncus* spp.), bulrushes (*Scirpus* spp.), cordgrasses (*Spartina* spp.), seashore saltgrass (*Distichlis spicata* var. *spicata*), common reed (*Phragmites australis*), marshmillet (*Zizaniopsis miliacea*), longtom (*Paspalum lividum*), seashore dropseed (*Sporobolus virginicus*), knotroot bristlegrass (*Setaria geniculata*), and maidencane (*Panicum hemitomon*). Aquatic forbs common in the Gulf Marshes include pepperweeds (*Lepidium* spp.), smartweeds (*Polygonum* spp.), docks (*Rumex* spp.), bushy seedbox (*Ludwigia alternifolia*), green parrotfeather (*Myriophylum pinnatum*), pennyworts (*Hydrocotyle* spp.), water lilies (*Nymphoe* spp.), narrowleaf cattail (*Typha domingensis*), spiderworts (*Tradescantia* spp.), and duckweed (*Lemna* spp.) (Hatch et al. 1990).

Salty soils of sand and mudflat communities of the Gulf Coast Prairie and Marshes Vegetation area support a unique assemblage of halophytic (salt loving) species. Common herbaceous and woody plants of this community type include spikesedges (*Eleocharis* spp.), fimbries (*Fimbristylis* spp.), glassworts (*Salicornia* spp.), sea rockets (*Cakile* spp.), maritime saltwort (*Batis maritima*), morning glories (*Ipomoea* spp.), and bushy sea-ox-eye (Hatch et al. 1990).

Biotic Provinces

The EAHCP Planning Area encompasses portions of three biotic provinces (following Blair 1950): Balconian, Tamaulipan, and Texan. The boundaries of each of these biotic provinces within the state are shown in Figure 3.1-3. A brief overview of the conditions and representative animal species found in each of these areas is provided below.

BALCONIAN PROVINCE

The western portion of the Planning Area lies within the Balconian biotic province. The majority of the Balconian province occurs on limestone, although the Llano Uplift region contains both igneous intrusions and pre-Cambrian sediments. Low to moderate annual precipitation occurs within this province, and surface drainage is poor to good. Several major rivers and associated tributaries drain this province, and these often flow through steep, rugged limestone canyons. Although historically grassland-dominated, the most common vegetational association now found throughout most of the Balconian Province is the scrub woodland, typically dominated by junipers (*Juniperus ashei*, et al.), plateau live oak, and Texas oak.

The known fauna of this area consists of at least 57 mammal species, 1 land turtle, 16 lizards, 36 snakes, 15 anurans (frogs and toads), and 7 urodeles (salamanders and newts). Common animal species typical of this biotic province include Virginia opossum (*Didelphis virginiana*), fox squirrel (*Sciurus niger*), eastern cottontail (*Sylvilagus floridanus*), collared peccary (*Tayassu tajacu*), nine-banded armadillo (*Dasypus novemcinctus*), white-footed mouse (*Peromyscus leucopus*), hispid cotton rat (*Sigmodon hispidus*), black-tailed jackrabbit (*Lepus californicus*), western box turtle (*Terrapene ornata*), Texas banded gecko (*Coleonyx brevis*), Texas earless lizard (*Holbrookia texana*), Texas horned lizard (*Phrynosoma cornutum*), western diamondback rattlesnake (*Crotalus atrox*), green toad (*Bufo debilis*), northern leopard frog (*Rana pipiens*), tiger salamander (*Ambystoma tigrinum*), and slimy salamander (*Plethodon glutinosus*).

TAMAULIPAN PROVINCE

This region represents the northern limits of the vast semi-arid grassland extending into Central America. In Texas, the Tamaulipan Plains gradually blend with deserts to the west, grasslands to the north and south, and forests and coastal prairies to the northeast and east, respectively. The faunal distribution here illuminates the transitional nature of the province. There are considerable elements of neotropical species, grassland species, and Chihuahuan desert species inhabiting the variety of habitats present.

Some 61 species of mammals, 36 species of snakes, 19 lizards, two land turtles, three urodeles (salamanders and newts) and 19 anurans (frogs and toads) occur, or have recently occurred, in the Tamaulipan biotic province. Bird life is also diverse, with 188 species documented at the Chaparral Wildlife Management Area to the south of the EAHCP Planning Area (Traweek and Brummel 1989). Common species of the Tamaulipan Province include the Mexican ground squirrel (*Spermophilus mexicanus*), hispid pocket mouse (*Perognathus hispidus*), nine-banded armadillo, Virginia opossum, coyote (*Canis latrans*), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), bobcat (*Felis rufus*), collared peccary or javelina, white-tailed deer (*Odocoileus virginianus*), Texas banded gecko, Texas spiny lizard (*Sceloporus olivaceus*), Mexican racer (*Coluber constrictor oaxaca*), checkered garter snake (*Thamnophis marcianus*), western diamondback rattlesnake, Texas indigo snake (*Drymarchon corais erebennus*), Texas toad (*Bufo speciosus*), and Gulf Coast toad (*Bufo valliceps*) (Blair 1950; Dixon 1987; Collins et al. 1982). Common resident bird species with southwestern affinities include the scaled quail (*Callipepla squamata*), Inca dove (*Columbina inca*), roadrunner (*Geococcyx californianus*), Chihuahuan raven (*Corvus cryptoleucus*), golden-fronted woodpecker (*Melanerpes aurifrons*), verdin (*Auriparus flaviceps*), curve-billed thrasher (*Toxostoma curvirostre*), cactus wren (*Campylorhynchus brunneicapillus*), pyrrhuloxia (*Cardinalis sinuatus*), and black-throated sparrow (*Amphispiza bilineata*). Also, many neotropical species occur at their northern range limits within the Tamaulipan Province.

TEXAN PROVINCE

The Texan biotic province in the eastern portion of the EAHCP Planning Area is characterized as an ecotonal region of forest and grassland faunal associations. However, most of the native vegetation has been replaced by cultivated crops, improved pasture grasses, or invasive brush. Consequently numerous native wildlife populations in this province have been decimated. Many habitat specialists, including the least shrew (*Cryptotis parva*), Texas horned lizard, and northern bobwhite (*Colinus virgianus*) have undergone significant reductions in numbers and their distributions severely altered, while other more generalistic species such as the coyote, eastern

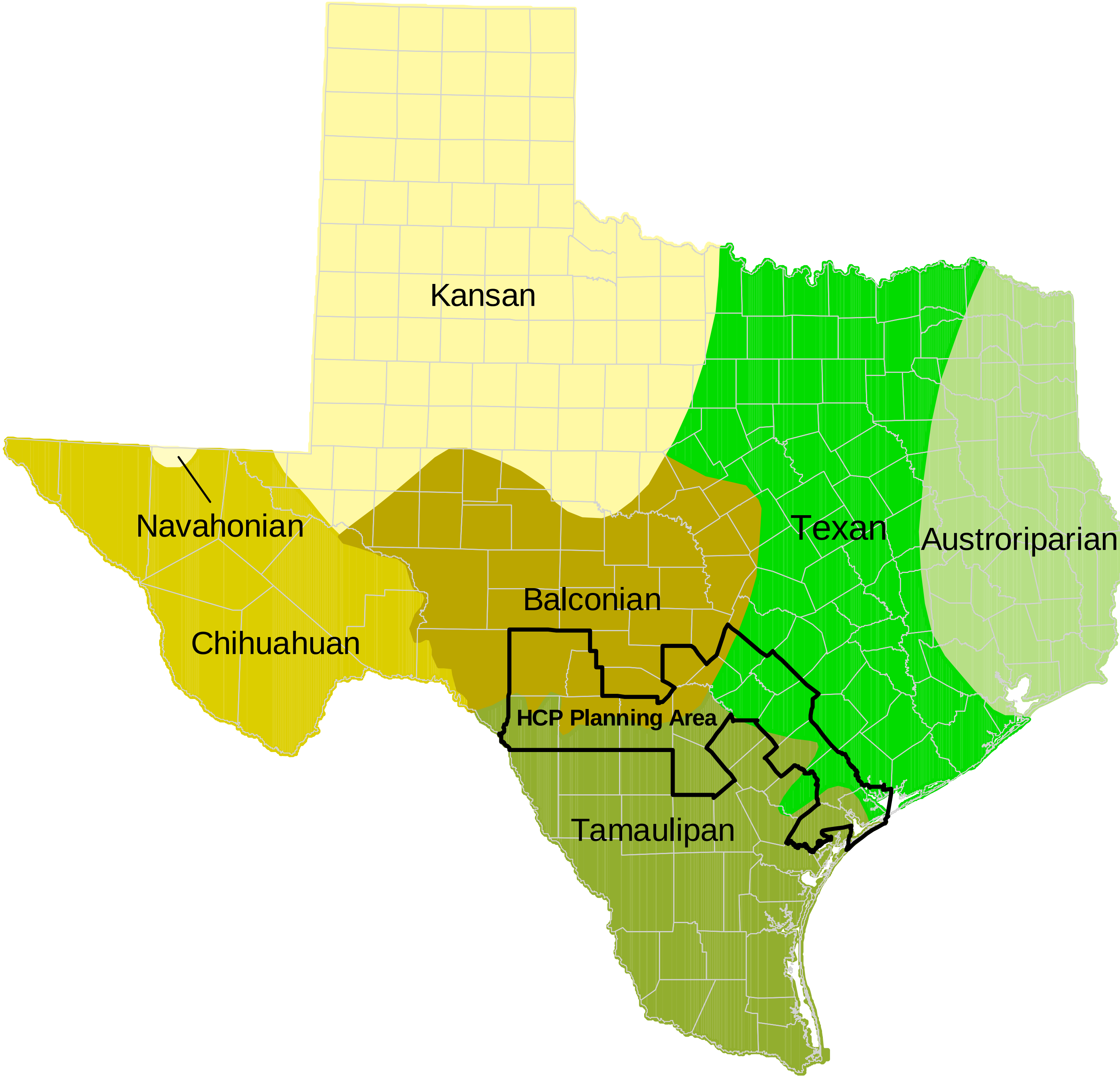

Figure 3.1-3
Biotic Provinces in the EAHCP Planning Area

Source: Blair (1950)

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meadowlark (*Sturnella magna*) and mourning dove (*Zenaida macroura*) apparently have increased in number and habitat occupation.

The Texan biotic province has no endemic vertebrate species, but major drainages traversing the province (i.e., Red, Trinity, Brazos, Colorado, and Guadalupe) support riparian-forested corridors important to the western dispersal of species from the Austroriparian Biotic Province. Some 49 species of mammals occur (or have historically occurred) in the Texan province, of which only eight are grassland species encroaching from the west, southwest, or north. Two species of land turtles, the three-toed box turtle (*Terrapene carolina)* (a forest species) and ornate box turtle (a grassland species), occur in the Texan and slightly more than half (9 of 16) of the lizard species are eastern forest species. The remaining seven are western grassland affiliates. Of the 39 species of snakes documented by Blair (1950), 27 are eastern forest species and 12 are western. For amphibians, the Texan province serves as a barrier between most Austroriparian and Balconian endemics. Five salamanders (all Austroriparian) and 18 species of frogs and toads (13 of which are Austroriparian species) are documented by Blair (1950) in the Texan province.

3.1.1.2 Rare Species Not Endemic to the Edwards Aquifer, Comal Springs, or San Marcos Springs

The 17-county EAHCP Planning Area covers an extensive portion of south-central and south Texas and encompasses a range of terrestrial habitat types, many of which are suitable for rare or otherwise sensitive species. This section discusses rare species occurring within the EAHCP Planning Area that are not endemic to the Edwards Aquifer, Comal or San Marcos Springs. Those rare species that are restricted to the Edwards Aquifer, Comal, and San Marcos Springs (the focus of this EAHCP) are discussed in Section 3.1.2. Table 3.1-1 lists rare fauna and flora that occur within the Planning Area, but are not restricted to the Edwards Aquifer, Comal Springs, San Marcos Springs, or subterranean habitats. Within the Planning Area, nine species of birds, five species of mammals (two of which are considered extinct in this part of their former range), and three species of plants are federally-listed or proposed for listing as endangered or threatened. Life history information for each of the federally-listed or proposed listed species (with the exception of the two extirpated species) is also presented in Table 3.1-1.

Federally-listed Birds of Potential Occurrence

ATTWATER'S GREATER PRAIRIE CHICKEN (ENDANGERED)

The Attwater's greater prairie chicken (*Tympanuchus cupido attwateri*) is a strongly black-barred (neck, breast and belly) grouse with long, wing-like tufts (pinnates) on the sides of its neck. This species is typically about 17 inches in length, its wingspan extends approximately 28 inches, and it weighs about two pounds. This species is one of the most threatened birds in all of Texas, and possibly in the entire U.S. Between 1967 and 1992, the Attwater's greater prairie chicken population has ranged from a high in 1983 of nearly 1,600 to a low in 1995 of 68 individuals. Within its historic range, approximately 97 percent of the species' coastal prairie habitat has been lost, leaving approximately 198,000 acres of suitable habitat remaining (USFWS 1992). Potential counties of occurrence include Austin, Colorado, Fort Bend, Galveston, Goliad, Refugio, and Victoria. Refugio and Victoria Counties fall within the EAHCP Planning Area boundary.

Table 3.1-1. Potential occurrence of rare species in the EAHCP Planning Area not endemic to the Edwards Aquifer, Comal Springs, or San Marcos Springs

Common Name	Scientific Name	County of Potential Occurrence	USFWS Status	TPWD Status
Amphibians				
Black-spotted newt	*Notophthalmus meridionalis*	Bexar, Refugio, Victoria	SOC	T
Aquatic Invertebrates				
Devil's Sinkhole amphipod	*Stygobromus hadenoecus*	Edwards	SOC	SOC
Texas hornshell	*Popenaias popei*	Kinney		SOC
Birds				
American peregrine falcon	*Falco peregrinus anatum*	Atascosa, Bexar, Caldwell, Calhoun, Comal, DeWitt, Edwards, Gonzales, Guadalupe, Hays, Kendall, Kinney, Medina, Real, Refugio, Uvalde, Victoria	DL	E
Arctic peregrine falcon	*Falco peregrinus tundrius*	Atascosa, Bexar, Caldwell, Calhoun, Comal, DeWitt, Edwards, Gonzales, Guadalupe, Hays, Kendall, Kinney, Medina, Real, Refugio, Uvalde, Victoria	DL	T
Attwater's greater prairie-chicken	*Tympanuchus cupido attwateri*	Refugio, Victoria	E	E
Audubon's oriole	*Icterus graduacauda audubonii*	Atascosa	SOC	
Bald eagle	*Haliacetus leucocephalus*	Caldwell, Calhoun, Edwards, Gonzales, Kendall, Kenney, Refugio, Victoria	T-PDL	T
Black-capped vireo	*Vireo atricapillus*	Bexar, Comal, Edwards, Hays, Kendall, Kinney, Medina, Real, Uvalde	E	E
Black rail	*Laterallus jamaicensis*	Refugio	SOC	
Black tern	*Chlidonias niger*	Refugio	SOC	
Brown pelican	*Pelecanus occidentalis*	Calhoun, Refugio, Victoria	E	E
Cerulean warbler	*Dendroica cerulea*	Calhoun, Refugio	SOC	
Common black-hawk	*Butiogallus anthracinus*	Kinney		T
Eskimo curlew	*Numenius borealis*	Calhoun, Victoria	E	E
Ferruginous hawk	*Buteo regalis*	Bexar, Calhoun, Gonzales, Refugio, Victoria	SOC	
Golden-cheeked warbler	*Dendroica chrysoparia*	Bexar, Comal, Edwards, Hays, Kendall, Kinney, Medina, Real, Uvalde	E	E
Henslow's sparrow	*Ammodramus henslowii*	Atascosa, Bexar, Caldwell, Comal, Gonzales, Hays, Medina		

Table 3.1-1. (Continued)

Common Name	Scientific Name	County of Potential Occurrence	USFWS Status	TPWD Status
Interior least tern	*Sterna antillarum athalassos*	Calhoun, DeWitt, Edwards, Guadalupe, Kendall, Kinney, Real, Refugio, Victoria	E	E
Loggerhead shrike	*Lanius ludovicianus*	Atascosa, Bexar, Caldwell, Calhoun, Comal, DeWitt, Gonzales, Refugio, Victoria	SOC	
Mexican hooded oriole	*Icterus cucullatus cucullatus*	Edwards, Kinney		
Mountain plover	*Charadrius montanus*	Atascosa, Bexar, Caldwell, Gonzales, Guadalupe, Refugio, Wilson, Victoria	PT	SOC
Northern gray hawk	*Buteo nitidus maximus*	Refugio	SOC	
Piping plover	*Charadrius melodus*	Calhoun, Refugio	T	T
Reddish egret	*Egretta rufescens*	Bexar, Calhoun, Refugio, Victoria	SOC	T
Rio Grande lesser siren	*Siren intermedia texana*	Refugio	SOC	
Snowy plover	*Charadrius alexandrinus*	Calhoun		
Sooty tern	*Sterna fuscata*	Calhoun		T
Texas olive sparrow	*Arremomonops rufivirgatus rufivirgatus*	Atascosa, Refugio	SOC	SOC
White-faced ibis	*Plegadis chihi*	Atascosa, Bexar, Calhoun, Refugio, Victoria		T
White-tailed hawk	*Buteo albicaudatus*	Calhoun, Refugio, Victoria		T
Whooping crane	*Grus americana*	Atascosa, Bexar, Caldwell, Calhoun, Comal, DeWitt, Gonzales, Guadalupe, Hays, Kendall, Real, Refugio, Victoria	E	E
Wood stork	*Mycteria americana*	Bexar, Caldwell, Calhoun, DeWitt, Gonzales, Real, Refugio, Uvalde, Victoria		T
Zone-tailed hawk	*Buteo albonotatus*	Bexar, Comal, Edwards, Hays, Medina, Real, Uvalde		T
<u>Fish</u>				
Guadalupe bass	*Micropterus treculi*	Bexar, Comal, Edwards, Gonzales, Hays, Kendall, Uvalde, Victoria	SOC	SOC
Headwater catfish	*Ictalurus lopus*	Uvalde		SOC
Prosperpine shiner	*Cyprinella prosurpina*	Kinney		T
<u>Insects</u>				
Flints net-spinning cardisfly	*Cheamatopsche flinter*	Hays, Uvalde		SOC
Leonora's Dancer	*Argia leonarae*	DeWitt, Medina	SOC	
Maculated manfreda skipper	*Stallingsia maculosus*	Bexar, Kinney, Wilson	SOC	
Texas asaphomyian tabanid fly	*Asaphomyia texanus*	Victoria		
<u>Mammals</u>				
Black bear	*Ursus americanus*	Edwards, Kendall, Uvalde	T/SA	T
Cave bat	*Myotis velifer*	Atascosa, Bexar, Caldwell, Comal, Gonzales, Hays, Kendall, Real, Uvalde		
Frio pocket gopher	*Geomys texensis bakeri*	Medina, Uvalde		

Table 3.1-1. (Continued)

Common Name	Scientific Name	County of Potential Occurrence	USFWS Status	TPWD Status
Gray wolf (extirpated)	*Canis lupus*	Edwards	E	E
Jaguarundi	*Hepailurus yagouaroundi*	Atascosa, Calhoun, Kinney, Refugio, Uvalde	E	E
Ocelot	*Leopardus pardalis*	Atascosa, Kinney, Refugio, Uvalde	E	E
Plains spotted skunk	*Spilogale putorius interrupta*	Atascosa, Bexar, Caldwell, Comal, Gonzales, Hays		
Red wolf (extirpated)	*Canis rufus*	Calhoun, Refugio, Victoria	E	E
Texas pocket gopher	*Geomys personatus fuscus*	Kinney		SOC
White-nosed coati	*Nasua narica*	Uvalde		T
<u>Mollusks</u>				
Horseshoe liptooth	*Polygyra hippocrepis*	Comal		
Mimic cavesnail	*Phreatodrobia imitata*	Bexar	SOC	SOC
Palmetto pillsnail	*Euchemotrema cheatumi*	Gonzales		
Texas hornshell	*Popenaias popei*	Kinney		
<u>Reptiles</u>				
Cagle's map turtle	*Graptemys caglei*	DeWitt, Gonzales, Guadalupe, Kendall, Victoria	C	T
Gulf saltmarsh snake	*Nerodia clarkii*	Calhoun, Refugio, Victoria		
Green sea turtle	*Chelonia mydas*	Calhoun, Refugio	T	SOC
Hawksbill sea turtle	*Eretmochelys imbricata*	Calhoun, Refugio	E	SOC
Indigo snake	*Drymarchon corais*	Atascosa, Bexar, Edwards, Kinney, Medina, Refugio, Uvalde		T
Keeled earless lizard	*Holbrookia propinqua*	Atascosa, Bexar, DeWitt, Gonzales, Guadalupe, Hays, Medina, Victoria		
Kemp's Ridley sea turtle	*Lepidochelys kempii*	Calhoun, Refugio	E	SOC
Leatherback sea turtle	*Dermochelys coriacea*	Calhoun, Refugio	E	SOC
Loggerhead sea turtle	*Caretta caretta*	Calhoun, Refugio	T	SOC
Reticulate collared lizard	*Crotaphytus reticulatus*	Uvalde		T
Scarlet snake	*Cemophora coccinea*	Calhoun, Refugio		T
Spot-tailed earless lizard	*Holbrookia lacerata*	Atascosa, Bexar, Caldwell, Comal, Edwards, Kendall, Kinney, Medina, Refugio		
Texas diamondback terrapin	*Malaclemys terrapin littoralis*	Calhoun, Refugio	SOC	
Texas garter snake	*Thamnophis sirtalis annectens*	Atascosa, Bexar, Caldwell, Comal, Gonzales, Hays, Medina	SOC	
Texas horned lizard	*Phrynosoma cornutum*	Atascosa, Bexar, Caldwell, Calhoun, Comal, DeWitt, Edwards, Gonzales, Guadalupe, Hays, Kendall, Kinney, Medina, Real, Refugio, Uvalde, Victoria, Wilson	SOC	T
Texas tortoise	*Gopherus berlandieri*	Atascosa, Bexar, Guadalupe, Kinney, Medina, Refugio, Uvalde, Wilson		T

Table 3.1-1. (Continued)

Common Name	Scientific Name	County of Potential Occurrence	USFWS Status	TPWD Status
Timber/canebrake rattlesnake	*Crotalus horridus*	Bexar, Caldwell, Gonzales, Refugio, Victoria		T
<u>Plants</u>				
Basin bellflower	*Campanula reverchonii*	Kendall		
Big red sage	*Salvia penstemonoides*	Bexar, Guadalupe, Kendall, Real, Wilson	SOC	
Black lace cactus	*Echinocereus reichenbachii v. albertii*	Refugio	E	E
Bracted twistflower	*Streptanthus bracteatus*	Bexar, Caldwell, Comal, Medina, Real, Uvalde	SOC	
Broad-pod rushpea	*Caesalpinia brachycarpa*	Edwards, Kinney	SOC	
Canyon mock-orange	*Philadelphus ernestii*	Hays, Comal, Kendall	SOC	
Comal snakewood	*Colubrina stricta*	Comal	SOC	
Correll's false dragon-head	*Physostegia correllii*	Bexar	SOC	
Edge Falls anemone	*Anemone edwardsiana v. petraea*	Kendall	SOC	
Edwards' Plateau capul negro	*Condalia hookeri* var. *edwardsiana*	Edwards	SOC	
Elmendorf's onion	*Allium elmendorfii*	Atascosa, Bexar, Refugio, Wilson		
Glass mountain coral-root	*Hexalectris nitida*	Comal, Hays, Kendall	SOC	SOC
Hill Country wild-mercury	*Argythamnia aphoroides*	Hays, Comal, Kendall, Uvalde	SOC	
Lindheimer's tickseed	*Desmodium lindheimeri*	Comal, Uvalde		
Park's jointweed	*Polygonella parksii*	Atascosa, Bexar, Guadalupe, Wilson		
Plains gumweed	*Grindelia oolepis*	Refugio		
Sabinal prairie-clover	*Dalea sabinalis*	Uvalde	SOC	
Sandhill woolywhite	*Hymenopappus carrizoanus*	Atascosa, Bexar, Caldwell, Guadalupe, Medina		
Silvery wild-mercury	*Arghthamnia argyraea*	Kinney		
Sonora fleabane	*Erigeron mimegletes*	Edwards, Real, Uvalde	SOC	
South Texas rushpea	*Caesalpinia phyllanthoides*	Bexar		
Texas grease bush	*Forsellesia texensis*	Uvalde	SOC	
Texas largeseed bittercress	*Cardamine macrocarpa v. texana*	Kinney, Uvalde		
Texas purple spike	*Hexalectris warnockii*	Hays	SOC	
Texas snowbells	*Styrax texana*	Edwards, Kinney, Real, Uvalde	E	E
Texas trumpets	*Acleisanthes crassifolia*	Kinney	SOC	
Texas windmill-grass	*Chloris texensis*	Refugio	SOC	
Threeflower broomweed	*Thurovia triflora*	Calhoun, Refugio		
Tobusch fishhook cactus	*Ancistrocactus tobuschii*	Edwards, Kinney, Real, Uvalde	E	E
Warnock's coral root	*Hexalectris warnockii*	Hays		
Welder machaeranthera	*Psilactis heterocarpa*	Refugio, Victoria	SOC	

SOURCES: Texas Parks and Wildlife Department, Biological and Conservation Data Program. August 1999 and March 2000, Special Species Lists for Atascosa, Bexar, and Wilson Counties. United States Fish and Wildlife Service Endangered Species Lists and Information provided by Ecological Services Field Office, Austin, TX.

USFWS (United States Fish and Wildlife Service)

E:	Endangered (in danger of extinction throughout all or a significant portion of its range)
T:	Threatened (likely to become endangered within the foreseeable future)
T/SA:	Federally threatened by similarity of appearance with Louisiana black bear
PE, PT:	Proposed endangered/threatened
DL:	Delisted (no longer protected under the federal Endangered Species Act)
PDL:	Proposed for delisting
SOC:	Species of Concern for which there is some information showing evidence of vulnerability
C:	Candidate; information supports preparing to list as endangered as threatened
(Blank):	Apparently rare, but no official protection at present

TPWD (Texas Parks and Wildlife Department)

E:	Listed as endangered in the state of Texas
T:	Listed as threatened in the state of Texas
SOC:	Species of Concern for which there is some information showing evidence of vulnerability
(Blank):	Apparently rare, but no official protection at present

BALD EAGLE (THREATENED – PROPOSED FOR DELISTING)

The bald eagle (*Haliacetus leucocephalus*) ranges over much of the U.S., Canada, British Columbia, and Labrador. This eagle is primarily a fishing species and prefers habitat associated with large bodies of water and could occur near large lakes or along rivers within the EAHCP Planning Area. In Texas, wintering and nesting activity occurs mainly near large, freshwater impoundments with standing timber located in or around the water (Mabie 1989).

BLACK-CAPPED VIREO (ENDANGERED)

The endangered black-capped vireo (*Vireo atricapillus*) is an insectivorous songbird that nests in low, brushy habitat in portions of Mexico, Texas, and Oklahoma and winters on the Pacific coast of Mexico (states of Durango, Sinoloa, Nayarit, Jalisco, Sonora, Guerrero, and Oaxaca) (USFWS 1991a). Each year, individuals of this species arrive in Texas between late March and late April to breed, and leave by late September. Typically, adult males arrive before females and first-year males, and stay later in the fall. Black-capped vireos construct small, cup-shaped nests in the densest zones of deciduous vegetation, usually suspended from forks in horizontal branches at a height that ranges between 16 and 47 inches from ground level (USFWS 1991a). Breeding habitat throughout the black-capped vireo's range varies considerably in its vegetational characteristics. Generally, it is described as shrubland thicket that varies in size and distribution and where vegetation cover extends to ground level.

The black-capped vireo has suffered a reduction in range and population size since the time of European settlement. However, the black-capped vireo nests in shrubland thickets throughout much of the Edwards Plateau. This species no longer nests in Kansas, occurs in only three locales in Oklahoma, and is likely to be extirpated from its former range in north-central Texas and a portion of the southeastern Edwards Plateau. Populations in the Big Bend and Concho Valley are small. The principle reason for small and declining populations appears to be poor reproductive success, largely because of nest parasitism by brown-headed cowbirds (*Molothrus ater*). Secondary threats to the black-capped vireo include direct habitat loss associated with urban or roadway development, overgrazing or overbrowsing, natural vegetational succession, fire suppression, and brush control. Indirect results of certain types of land uses, such as urbanization-related increases in predation by raccoons, skunks, house cats, and jays also represent a substantial threat to the vireo (USFWS 1991a).

BROWN PELICAN (ENDANGERED)

The brown pelican (*Pelecanus occidentalis*) is a large, dark water bird known to inhabit seacoasts and islands of the Pacific and Atlantic coasts. This species has suffered from human harassment (brown pelicans were viewed by fishermen as competitors) and DDT-induced egg-thinning. Between 1950 and 1960, the estimated population of these birds (based on coastal Christmas counts) went from 595 to 0 (Oberholser 1974). They have since undergone a substantial recovery with 619 breeding pairs along the central and upper portions of the Texas Gulf Coast (Yantis 1990), increasing to an estimated 2,400 breeding pairs in 1995 (TPWD 2003). The central coastal bend represents the heart of the brown pelican breeding population for the state. This species is considered an incidental migrant within the EAHCP Planning Area.

ESKIMO CURLEW (ENDANGERED)

The Eskimo curlew (*Numenius borealis*) has been on the brink of extinction for most of this century. This bird stands about 14 inches in height and feeds on wild fruits and insects. This small curlew breeds on barren tundra of the northwestern American Arctic and migrates to its wintering grounds on the pampas of Argentina via Labrador and the coastal U.S. Sketchy records of its presence in Texas are almost all from spring migration to the U.S. Great Plains, where it stops over en route to the breeding grounds. Oberholser (1974) cites one spring specimen taken in Nueces County in 1877. This species is considered an incidental migrant within the EAHCP Planning Area.

GOLDEN-CHEEKED WARBLER (ENDANGERED)

The golden-cheeked warbler (GCW) (*Dendroica chrysoparia*) is a small insectivorous neotropical migratory songbird that nests only in the mixed juniper-oak woodlands of the Balconian biotic province. This species, which winters in southern Mexico and the Central American countries of Guatemala, Honduras, and Nicaragua, is the only Texas species whose breeding range is entirely confined to the state's boundaries. The known breeding range of the GCW includes 37 Texas counties on the Lampasas Cut Plain, Edwards Plateau and Llano Uplift regions of the state (USFWS 1991b). Golden-cheeked warblers breed in woodlands characterized by a mix of ashe juniper and various deciduous trees including Texas oak, plateau live oak, cedar elm, Texas persimmon, hackberry (*Celtis* spp.), evergreen sumac (*Rhus virens*), Texas ash (*Fraxinus texensis*), redbud (*Cercis canadensis*), and escarpment black cherry (*Prunus serotina*) (USFWS 1991b). Such wooded areas within the EAHCP Planning Area that contain a moderate to high density of trees and canopy cover have been identified as suitable habitat for breeding GCWs. Ashe juniper is often the dominant woody plant and occurs at all sites occupied by the GCW. Female GCWs construct nests from ashe juniper bark, which exfoliates in the form of strips, especially in more mature trees (Pulich 1976).

GCWs return from their winter range to Texas by mid-March of each year. Most GCWs leave the breeding grounds by the end of July (Pulich 1976). The principal threat to the golden-cheeked warbler (and the reason for the species emergency listing in 1990) is habitat alteration and fragmentation resulting from urbanization and certain range management practices. The USFWS (1991b) shows a 35 percent loss of range-wide available habitat since 1962. Other factors that have been implicated in the decline of this species include low oak regeneration rates, oak wilt disease, nest parasitism by the brown-headed cowbird, and increased urbanization, with resulting brush clearing and habitat loss.

INTERIOR LEAST TERN (ENDANGERED)

The interior least tern race (*Sterna antillarum athalassos*) is federally-listed as endangered but the coastal race (*Sterna antillarum*) does not receive federal or state protection. There is no discernible morphological difference between the races of least tern. The race distinctions are based on geographic differences in breeding site selection. This small tern nests in colonies between May and July on barren to sparsely vegetated sandbars, lake and reservoir shorelines, sand and gravel pits, and dike field sandbar islands. There is a lack of wintering data for least terns in general; however, they are known to be present along the Central American coast and northern South American coast (from Venezuela to northeastern Brazil) in winter (USFWS 1990). Occurrences have been documented in several counties within the EAHCP Planning Area.

MOUNTAIN PLOVER (PROPOSED THREATENED)

The mountain plover (*Charadrius montanus*) prefers shortgrass plains of level plateaus and coastal wetlands. It is known from several counties within the Planning Area based on winter and fall sight records, but the occurrence of this species is listed as accidental (i.e., less than five reported sightings) within Central Texas.

PIPING PLOVER (THREATENED IN WINTERING AREAS, ENDANGERED IN BREEDING GROUNDS)

The piping plover (*Charadrius melodus*) is a small, ringed (dark narrow breast band) plover that belongs to a guild (grouping of several bird species with generally similar life habits) of birds referred to as shorebirds. Most members of the shorebird guild feed on invertebrates in shallow water and breed at least as far north as the northern U.S. The main cause for the decline of many members of this guild is habitat modification, both on breeding and wintering grounds. The preservation of high quality wintering grounds for these species is quite important since many, like the piping plover, can spend nine to ten months of the year on them.

This species breeds from south-central Canada to the Great Lakes, across the northern Great Plains regions and coastally from Newfoundland to Virginia, and winters primarily along the coast from South Carolina south to Texas and Florida. Migration to breeding grounds generally takes place between early March and mid-May. The piping plover returns from breeding grounds quickly with migration to the south typically occurring between late July and late October (Oberholser 1974). Migration is a staggered event for this species and stragglers are irregularly documented along the Texas coast in June and July. It is important to note that, although this species does not breed in the project area, it is possible for individuals to be present nearly year-round as migrants. Census work reported by Haig and Plissner (1993) and Nicholls (1989) demonstrate that the Texas Gulf Coast harbors the largest percentage of individual wintering birds (1,904 out of a total of 3,451, or 55 percent).

WHOOPING CRANE (ENDANGERED)

The whooping crane (*Grus americana*) is North America's tallest bird, with a standing height of 5 ft or more. The bird is a large, white crane with a dagger-like, yellow bill, and with reddish skin on the crown that is darker on the face and lower jaw. The whooping crane's tail plumes form a sort of bustle. In flight, the long extended black legs and neck as well as black-tipped wings are characteristic. The whooping crane ranges from Wood Buffalo National Park in the southern Mackenzie Mountains and northern Alberta, Canada south to North Dakota, Iowa, and the central coastal prairie in Texas and southwest Louisiana. In Texas, whooping cranes winter at Aransas National Wildlife Refuge and Matagorda and St. Joseph's Islands in Aransas, Calhoun, and Matagorda Counties (Oberholser 1974). These birds would fly through the southern portion of the EAHCP Planning Area migrating to and from these wintering areas. Whooping cranes are omnivorous, feeding on frogs, minnows, rodents, and berries in the summer and during winter, feeding predominantly on blue crabs and clams. Brackish tidal marshes in the Guadalupe River Estuary provide essential habitat and support the production of clams and crabs for the cranes to eat.

Federally-Listed Mammals of Potential Occurrence

BLACK BEAR (THREATENED DUE TO SIMILARITY OF APPEARANCE)

The black bear (*Ursus americanus*) is federally-listed as threatened due to its similar appearance to the Louisiana black bear (*Ursus americanus luteolus*), a federally-listed threatened species. The black bear, the range of which reportedly encompasses three counties within the western portion of the Planning Area, was once abundant and widely distributed in Texas before European settlement. This species was last known to regularly occur in east Texas between 1900 and 1940 in the swamps and thickets of Hardin County in the Big Thicket (Schmidly 1983). Remaining wild populations of the black bear in the state are generally restricted to the Chisos and Guadalupe Mountains of west Texas and appear to be most common in the Big Bend region. A large percentage of the black bears in west Texas have likely crossed into the state from the rugged mountains of northern Mexico. Individual bears may move long distances and sightings have occurred in central and southern portions of the Edwards Plateau.

JAGUARUNDI AND OCELOT (LISTED ENDANGERED)

Two endangered feline species, the ocelot (*Leopardus pardalis*) and the jaguarundi (*Hepailurus yagouaroundi*), are listed as possible or historical residents in several counties within the Planning Area. The largest resident population of ocelots in Texas is in the eastern Lower Rio Grande Valley on and around the Laguna Atascosa National Wildlife Refuge. No verifiable documentation of a resident jaguarundi population in Texas exists, and the only verified specimen or sightings have occurred along the Texas-Mexico border. Optimal ocelot habitat consists of dense thornshrub communities with greater than 95 percent horizontal cover in the lowest layer (Tewes 1991). The level of information on jaguarundi habitat preferences is scarce because very little field research has been completed to date for this species. Tewes and Schmidly (1987) report jaguarundi utilization of chaparral, primary and secondary forests, grasslands, and savannahs. These species are not expected to occur within the Planning Area.

Federally-Listed Plants of Potential Occurrence

BLACK LACE CACTUS (ENDANGERED)

The black lace cactus (*Echinocereus reichenbachii v. albertii*) is a small, solitary to highly branched columnar cactus with dark purple-black tipped spines. This species is presently known from only three Texas counties along the Gulf Coastal Plain; Refugio County is the only county within the range of this cactus that is within the EAHCP Planning Area. Plants are typically found in mesquite shrublands, usually in open areas between dense clumps of scrubby vegetation that includes mesquite (*Prosopis glandulosa*), brasil (*Condalia hookeri*), goldenweed (*Isocoma drummondii*), ericameria (*Ericameria austrotexana*), and prickly pear (*Opuntia* spp.). Populations are generally found on somewhat saline fine sandy loam soils, within or immediately adjacent to the floodplain of creeks or streams (Emmett 1989).

TEXAS SNOWBELLS (ENDANGERED)

Texas snowbells (*Styrax texana*) is a slender, irregularly branched deciduous shrub that grows on limestone bluffs and cliffs in three central Texas counties, two of which (Edwards and Real) are within the current Planning Area. Vegetation with which Texas snowbells is commonly associated includes Texas oak, Texas ash, agarita (*Mahonia trifoliolata*), silk-tassel (*Garrya lindheimeri*), and wooly-bucket bumelia (*Bumelia lanuginosa* v. *rigida*) (Poole and Riskind 1987).

TOBUSCH FISHHOOK CACTUS (ENDANGERED)

The Tobusch fishhook cactus (*Ancistrocactus tobuschii*) is a small, inconspicuous, usually unbranched tuberculate cactus that is endemic to eight Texas counties in the central and western portions of the southern Edwards Plateau region. Within the current Planning Area, Edwards, Real, Kinney, and Uvalde Counties are within the known range of this cactus. The majority of the earliest-discovered populations of this species occurred on gravelly soils within the floodplain of rivers and streams. However, the habitat type where the majority of Tobusch fishhook cactus populations have since been discovered consists of rocky hilltops or mesa-tops in shallow, limestone-derived soils. Vegetation with which this species is most commonly associated consists of ashe juniper–live oak woodland, although individual plants are usually found in the relatively clear grass and forb-dominated openings away from larger woody plants (Emmett 1995).

3.1.2 Animal and Plant Species in the Edwards Aquifer, Comal Springs, San Marcos Springs, and Karst Ecosystems

The Edwards Aquifer, Comal Springs, and San Marcos Springs form three unique aquatic ecosystems containing a great diversity of species, some of which are endemic (found only in a certain locality or region) to the area. In addition, karst features associated with the Edwards formation contain rare endemic species. Within these systems, a diverse number of highly adapted endemic aquatic and terrestrial species can be found (Table 3.1-2). Table 3.1-3 shows the status of all state and federally-listed species inhabiting these systems.

3.1.2.1 Edwards Aquifer Ecosystem

The Edwards Aquifer lies within the Balcones Fault Zone along the eastern boundary of the Edwards Plateau and extends from a groundwater divide in Kinney County through San Antonio northeast to Bell County (Section 3.3.2.1). The amount of cavernous porosity and its large size makes this one of the most unique karst (dissolved limestone bedrock) aquifers in the world (Longley 1986). Water in the aquifer flows relatively rapidly through underground caverns and there has been some debate as to whether this aquifer should be referred to as an underground river (USFWS 1996a). The recharge zone occurs in the Balcones Fault Zone at the Edwards Aquifer rock outcrop. Groundwater levels typically have seasonal and weather-related variations, with the potential for rapid changes following heavy rainfall events. Even though groundwater levels can change rapidly, water temperatures and quality remain constant (McKinney and Sharp 1995).

The Edwards Aquifer supports a highly adaptive biological assemblage that differs considerably from the Comal and San Marcos Springs aquatic ecosystems. However, the hydrology of the Edwards Aquifer is directly related to the surface water ecosystems as water in the Comal and

San Marcos Springs flows from the aquifer at the base of the Balcones Escarpment (McKinney and Sharp 1995). Therefore, the systems are forever intertwined by components of water quality and thermal conditions while uniquely separate with respect to biological organisms.

A number of species are found only within the aquifer and associated springs and karst formations (see Table 3.1-2). Examples include species of blind catfish, blind salamanders, amphipods, and cave spiders. In a study investigating the occurrence of aquifer biota from 33 wells and two springs in Bexar County, Karnei (1978) reported 18 aquatic species taxonomically representing three phyla, three classes, and seven orders of organisms. Several species are listed by the USFWS as endangered, threatened, species of concern, or proposed for listing. The endangered species addressed by the ITP are discussed in further detail in Section 3.1.3 while the species of concern and proposed for listing species are addressed in Section 3.1.4. Table 3.1-3 provides a comprehensive status listing of rare species occurring in the Edwards Aquifer, associated karst formations, and ecosystems of Comal and San Marcos Springs.

Table 3.1-2. Species endemic to the southern segment of the Edwards Aquifer and associated springs and karst ecosystems

Common Name	Scientific Name	USFWS Status	TPWP Status
AQUATIC ECOSYSTEMS			
Southern Edwards Aquifer			
Ezell's Cave amphipod	*Stygobromus flagellatus*	SOC	SOC
Mimic cavesnail	*Phreatodrobia imitata*	SOC	SOC
Peck's Cave amphipod	*Stygobromus pecki*	E	E
Austin blind salamander	*Eurycea waterlooensis*	C	SOC
Blanco River Springs salamander	*Eurycea pteraphila*		
Robust (=Blanco) blind salamander	*Eurycea robusta*	SOC	T
Texas blind salamander	*Eurycea rathbuni*	E	E
Texas Cave diving beetle	*Haideoporus texanus*	SOC	SOC
Texas Cave shrimp	*Palaemonetes antrorum*	SOC	SOC
Toothless blindcat	*Trogloglanis pattersoni*		T
Widemouth blindcat	*Satan eurystomus*		T
Comal Springs Ecosystem			
Comal blind salamander	*Eurycea tridentifera*	SOC	T
Comal Springs salamander	*Eurycea sp. 8*	SOC	SOC
Comal Springs dryopid beetle	*Stygoparnus comalensis*	E	SOC
Comal Springs riffle beetle	*Heterelmis comalensis*	E	SOC
Fountain darter	*Etheostoma fonticola*	E	E
Horseshoe liptooth (snail)	*Daedalochila hippocrepis*	SOC	SOC
Peck's Cave amphipod	*Stygobromus pecki*	E	SOC
Texas salamander	*Eurycea neotenes*	SOC	SOC
San Marcos Springs Ecosystem			
Comal Springs riffle beetle	*Heterelmis comalensis*	E	SOC
Fountain darter	*Etheostoma fonticola*	E	E
San Marcos gambusia	*Gambusia georgei*	E	E
San Marcos saddle-case caddisfly	*Protoptila arca*	SOC	SOC
San Marcos salamander	*Eurycea nana*	T	T
Texas salamander	*Eurycea neotenes*	SOC	SOC
Texas wild-rice	*Zizania texana*	E	E

Table 3.1-2. (Continued)

Common Name	Scientific Name	USFWS Status	TPWP Status
TERRESTRIAL (KARST) ECOSYSTEMS			
Bracken Bat Cave spider	*Cicurina venii*	E	SOC
Government Canyon Bat Cave spider	*Neoleptoneta microps*	E	SOC
Madla's Cave meshweaver	*Cicurina madla*	E	SOC
Cokendolpher Cave harvestman	*Texella cokendolpheri*	E	SOC
Robber Baron Cave meshweaver	*Cicurina baronia*	E	SOC
Government Canyon Bat Cave meshweaver	*Cicurina vespera*	E	SOC

USFWS (United States Fish and Wildlife Service)
- E: Endangered (in danger of extinction throughout all or a significant portion of its range)
- T: Threatened (likely to become endangered within the foreseeable future)
- SOC: Species of Concern for which there is some information showing evidence of vulnerability
- C: Candidate; information supports preparing list as endangered or threatened

TPWD (Texas Parks and Wildlife Department)
- E: Listed as endangered in the state of Texas
- T: Listed as threatened in the state of Texas
- SOC: Species of Concern for which there is some information showing evidence of vulnerability

Table 3.1-3. Listing status of rare species occurring in the vicinity of the southern segment of the Edwards Aquifer, associated karst formations, and ecosystems of Comal and San Marcos Springs

Common Name	Scientific Name	County of Potential Occurrence	USFWS Status	TPWD Status
Aquatic Invertebrates				
Comal Springs dryopid beetle	*Stygoparnus comalensis*	Comal, Hays	E	SOC
Comal Springs riffle beetle	*Heterelmis comalensis*	Comal, Hays	E	SOC
Devil's Sinkhole amphipod	*Styobromus hadenoecus*	Edwards		SOC
Ezell's Cave amphipod	*Stygobromus flagellatus*	Hays	SOC	SOC
Flint's net-spinning caddisfly	*Cheumatopsyche flinti*	Hays, Uvalde		SOC
Long-legged cave amphipod	*Stygobromus longipes*	Kendall	SOC	SOC
Mimic cavesnail	*Phreatodrobia imitata*	Bexar	SOC	SOC
Peck's Cave amphipod	*Stygobromus pecki*	Comal	E	E
San Marcos saddle-case caddisfly	*Protoptila arca*	Hays	SOC	SOC
Edwards Aquifer diving beetle	*Haideoporus texanus*	Comal, Hays	SOC	SOC
Texas Cave shrimp	*Palaemonetes antrorum*	Hays	SOC	SOC
Amphibians				
Austin blind salamander	*Eurycea waterlooensis*	Travis[1], Hays[1]	C	SOC
Barton Springs salamander	*Eurycea sosorum*	Travis[1], Hays[1]	E	E
Blanco blind salamander	*Eurycea robusta*	Hays	SOC	T
Blanco River Springs salamander	*Eurycea pterophila*	Hays, Kendall		SOC
Cascade Caverns salamander	*Eurycea latitans* complex	Comal, Kendall		T
Comal blind salamander	*Eurycea tridentifera*	Bexar, Comal, Kendall	SOC	T
Comal Springs salamander	*Eurycea* sp. 8	Comal		SOC
Edwards Plateau Spring salamander	*Eurycea* sp. 7	Bexar, Comal, Edwards, Hays, Kendall, Kinney, Medina, Travis, Uvalde		SOC
San Marcos salamander	*Eurycea nana*	Hays	T	T
Texas blind salamander	*Eurycea rathbuni*	Hays	E	E
Texas salamander	*Eurycea neotenes*	Bexar, Hays, Kendall, Kinney, Medina, Uvalde	SOC	SOC
Valdina Farms Sinkhole salamander	*Eurycea troglodytes* complex	Medina, Uvalde		SOC

Table 3.1-3. (Continued)

Common Name	Scientific Name	County of Potential Occurrence	USFWS Status	TPWD Status
Fish				
Blue sucker	*Cycleptus elongatus*	Hays, Kinney, Uvalde, Val Verde	SOC	T
Comanche Springs pupfish	*Cyprinodon elegans*	Uvalde[2]	E[2]	E[2]
Devils River minnow	*Dionda diaboli*	Kinney	T	T
Fountain darter	*Etheostoma fonticola*	Comal, Hays	E	E
Guadalupe bass[3]	*Mictropterus treculi*	Bexar, Comal, Edwards, Hays, Kendall, Uvalde		SOC
San Marcos gambusia[4]	*Gambusia georgei*	Hays	E	E
Toothless blindcat	*Trogloglanis pattersoni*	Bexar	SOC	T
Widemouth blindcat	*Satan eurystomus*	Bexar	SOC	T
Aquatic Plants				
Texas wild-rice	*Zizania texana*	Hays	E	E
Terrestrial Invertebrates				
Bracken Bat Cave meshweaver	*Cicurina venii*	Bexar	E	SOC
Government Canyon cave spider	*Neoleptoneta microps*	Bexar	E	SOC
Ground beetle (no common name)	*Rhadine exilis*	Bexar	E	SOC
Ground beetle (no common name)	*Rhadine infernalis*	Bexar	E	SOC
Helotes mold beetle	*Batrisodes venyivi*	Bexar	E	SOC
Horseshoe liptooth (snail)	*Daedalochila hippocrepis*	Comal	SOC	SOC
Maculated manfreda skipper	*Stallingsia maculosus*	Bexar, Kinney	SOC	SOC
Madla's Cave meshweaver	*Cicurina madla*	Bexar	E	SOC
Cokendolpher Cave harvestman	*Texella cokendolpheri*	Bexar	E	SOC
Robber Baron Cave meshweaver	*Cicurina baronia*	Bexar	E	SOC
Government Canyon Bat Cave meshweaver	*Cicurina vespera*	Bexar	E	SOC
Reptiles				
Cagle's map turtle	*Graptemys caglei*	Comal, Bexar, Edwards, Hays, Kendall	C	T

SOURCE: Texas Parks and Wildlife Department Biological and Conservation Data Program 2000; U.S. Fish and Wildlife Service.

[1]The Barton Springs salamander is found in Travis County and may be affected by activities within the Barton Springs segment of the Edwards Aquifer, which includes portions of northern Hays County.

[2]The Comanche Springs pupfish is not found in the wild in Uvalde County but is listed because it is raised at a fish hatchery in Uvalde County.

[3]Considered to be originally endemic to the headwaters and perennial streams of Edwards Plateau, although it is now found further downstream.

[4]Considered to be extirpated.

USFWS (United States Fish and Wildlife Service)
- E: Endangered (in danger of extinction throughout all or a significant portion of its range)
- P/E: Species proposed to be listed as endangered
- T: Threatened (likely to become endangered within the foreseeable future)
- SOC: Species of Concern
- C: Candidate; information supports preparing to list as endangered or threatened
- (Blank): Apparently rare, but no official protection at present

TPWD (Texas Parks and Wildlife Department)
- E: Listed as endangered in the state of Texas
- T: Listed as threatened in the state of Texas
- SOC: Species of Concern for which there is some information showing evidence of vulnerability

3.1.2.2 Comal Springs Ecosystem

The Comal Springs ecosystem (Figures 3.1-4a and b) is the largest spring system in Texas and in the southwestern United States (Brune 1975), originating from the Edwards Aquifer and located mainly in Landa Park in New Braunfels, Comal County. The system is comprised of four major spring runs that feed into Landa Lake and an undetermined number of smaller springs present in the spring runs and in Landa Lake. The spring runs and Landa Lake form the headwaters of the Comal River, the shortest river in Texas, which spans 3.1 miles before its confluence with the Guadalupe River. From Landa Lake, water flows into two channels, the original "old" channel and a "new" channel created with the construction of a hydropower facility. The two channels rejoin 1.6 miles downstream (McKinney and Sharp 1995).

The old channel retains many of its natural characteristics even though there are some small dams and channelization, and Schlitterbahn, a water theme park, diverts some of the flow. The new channel has a more uniform width and in some areas, a limestone bottom. Several dams have been constructed on the new channel, to control overflow, as well as several parks and tube chutes (McKinney and Sharp 1995). The physical, chemical, and biological characteristics of the Comal Springs and Comal River ecosystem have been recently evaluated to develop an understanding of alternative instream flow strategies for the protection and recovery of threatened, endangered, and other sensitive species (Hardy et al 1999; BIO-WEST 2002b).

Comal Springs has the largest mean discharge of any spring in the southwestern United States, averaging 275 cubic feet per second (cfs) between 1928-1972 (George et al. 1952; Edwards Underground Water District 1974). From June until November of 1956, the springs ceased flowing. At the same time all major springs in the Balcones Fault Zone stopped flowing with the exception of San Marcos Springs (U.S. Army Corps of Engineers 1965). This system exhibits near constant temperatures (annual mean 74.1° Fahrenheit or 23.4° Celsius), excellent water quality, and low nutrient and bacteria levels (USFWS 1996a). Over the years, extensive development along the banks, channel modification, and the natural variability of the springs has resulted in biological community alterations (EH&A 1975). The Comal River has also been affected by recreational activities along the banks including the afore-mentioned network of parks and tube chutes (McKinney and Sharp 1995).

The physical, chemical, and biological characteristics of the Comal Springs and Comal River ecosystem have been extensively evaluated to develop an understanding of alternative instream flow strategies for the protection and recovery of threatened, endangered, or other sensitive species (Hardy et al1999).

Several organisms occurring in the Comal Springs ecosystem are listed by the USFWS as either endangered or species of concern (see Table 3.1-3). The endangered species will be discussed in further detail in Section 3.1.3 with the species of concern addressed in Section 3.1.4.

Effects of the Drought of Record on Comal Springs

The severity of the drought of 1956 and its impact on water levels at Landa Lake are unique in the hydrologic record for central Texas. The most critical period of low flow at Comal Springs was during the summer months of 1956, when the springs went dry. Landa Lake went from being "full" in early June, to being "dry" in August of that year. A description of what occurs at Comal Springs when water levels drop has been previously described (LBG-Guyton Associates 2004) and is summarized below.

Spring runs #1 and #2 stop flowing at Landa Park well water elevation of 622 ft msl., when total Comal Springs flow is about 130 cfs. Spring run #3 stops flowing at Landa Park well water level of 620 ft msl, which is also the current lake level, as controlled by the dam. Total Comal Springs flow at this point is about 50 cfs. Spring runs #1 and #2 went dry during the summer of 1953 and from the summer of 1954 until January 1957, and spring run #3 stopped flowing during the summer of 1955, and also from May until December 1956. Although flow stops from spring runs #1, #2 and #3 at a Landa Park well level of 620 feet msl, there was still flow out of Landa Lake due to spring discharge from the other spring runs into the lake itself. When the water elevation at the Landa Park well declined to about 619 ft msl, total spring discharge went to zero. During 1956, spring discharge was zero for 144 consecutive days, from June 13 to November 3. At this point, flow stopped at the New Channel dam, but water was still able to flow though the culvert to the Old Channel. Below a Landa Park well elevation of approximately 618 ft msl, the elevation of the lake bottom immediately upstream of the culvert prevented flow from reaching the Old Channel culvert. Spring discharge could presumably still occur at water levels as low as the lowest lake-bottom elevation of 613 ft msl. However, for such discharge to occur, an outlet at that elevation would need to be constructed that would discharge to a location (such as Old Channel) at a lower elevation.

Large parts of the lake bottom emerged at a lake elevation of 618 ft msl. The north end of the lake, north of Spring Island, also emerged at about 618 ft. Although there were some deeper pools at the north end, flow from north to south was probably cut off. Figures 3.1-4c and 3.1-4d are photographs of the southern end of Landa Lake that were taken sometime in the summer of 1956. The water level in the individual pools within the lake appeared to be about 617-618 ft msl. The lowest level of Landa Park well (613.34 feet msl) was reached August 21, 1956. The deepest pool, just south of Spring Island had a bottom elevation of 613 ft msl, and newspaper clippings indicate that there may have been 6 inches of water left in the deep pools.

3.1.2.3 San Marcos Springs Ecosystem

The San Marcos Springs ecosystem (Figures 3.1-5a, b, and c) is the second largest in Texas and has the most environmental stability and flow reliability of any spring system in the southwestern United States (USFWS 1996a). This spring system has never stopped flowing in recorded history, although it dropped to approximately 46 cfs during the drought of record occurring in the 1950s. The average discharge from the San Marcos Spring system from 1994 through 2001 was

Figure 3.1-4a
Comal Springs
Ecosystem
Vicinity Map
Spring Run Number
Plate 1
N
0
250
500 Feet
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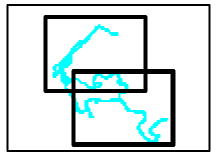
California
Lakeview
Bleders Creek
Houston
Union
Edgewater
Spring Island
Pecan Island
Elizabeth
Torrey
Landa Lake
Landa Park
Schlitterbahn
Old Channel
Dam
San Antonio Street
1
2
3
4

Figure 3.1-4b
Comal Springs
Ecosystem
Vicinity Map

Plate 2 of 2



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0 250 500 Feet

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180 cfs (EAA 2002a) and the stability of its springflow helps support the rare flora and fauna found in Spring Lake and in the San Marcos River.

Spring Lake constitutes the headwaters of the San Marcos River that extends 68.2 miles to its confluence with the Guadalupe River. Temperatures remain nearly constant year-round at 71.1° F (21.7° C) (USFWS 1996a). The biological uniqueness and high degree of endemism found in Spring Lake and in the upper San Marcos River can be attributed to its thermal stability, reliable flow, and consistent water chemistry (USFWS 1996a). Lemke (1989) documented 31 species of aquatic macrophytes (plants large enough to be seen with the naked eye) on the upper San Marcos River. Of these, 23 were native. Increasing competition with exotic species and resulting displacement of native species was noted. A recently observed new exotic species in the San Marcos Springs ecosystem, water trumpet (*Cryptocoryne becketti*), has been observed forming colonies that extend from bank to bank excluding native plant species and threatening the habitats of Texas wild-rice and fountain darter (Tu 2002). Construction and residential development continues to occur along the San Marcos River, although historically to a lesser degree than along the Comal River (EH&A 1975). As with the Comal River, the San Marcos River is a haven for recreational activities.

Upstream flood control dams within the watershed of the San Marcos River have enhanced recharge to the Edwards Aquifer by allowing water behind the dams, which would have gone downstream as irretrievable quickflow, to infiltrate and contribute to the recharge system. Hydrologically, these dams have also reduced the magnitude of scouring flood events downstream, allowing an increase in sedimentation and exotic vegetation encroachment. The San Marcos River has experienced increased sedimentation, which occurs when the sediment supply exceeds the ability of flood events to remove the sediment supply. A recent study was conducted (Earl and Wood 2002) which analyzed the impacts of upstream changes in the San Marcos River. It was found that a major source of the sediment is provided by Sessoms Creek, which receives runoff from the Texas State University campus. Based upon a density of 2.0 g/cm^3, the sediment production rate from campus construction over the three years of construction that began in 1995 would produce an annual sedimentation accumulation in the channel of the San Marcos River of 16 cm/year (6.3 inches per year). Construction on campus has continued since 1998 and it is likely that similar rates of sedimentation have occurred during this time. Projected through 2004, there would have been a total accumulation of 4.7 feet in the upper 273 yards (250 meters) of the San Marcos River channel in the nine years between 1995 and 2004. While these numbers likely have some error associated with them, it is clear that sediments are accumulating at a high rate and that even significant floods are unable to erode and transport them.

Sediments transported downstream in Sessoms Creek alter the depth and width of the San Marcos River channel where they are deposited. They are deposited in areas that are critical to Texas wild-rice, covering the streambed's natural substrate with materials from outside of the aquatic ecosystem that are not optimum substrate for native plant species. The sediments act as fill in the natural channel, making the channel downstream more shallow than natural, creating a spit that extends about half way across the San Marcos River at the confluence with Sessoms Creek, about forty yards downstream of Spring Lake Dam.

Since flood control measures on the San Marcos River have prevented large, scouring floods from occurring, the deposited sediments remain near the confluence of Sessoms Creek and the San Marcos River. The sediments impact Texas wild-rice by covering plants growing in the natural substrate and causing other plants to grow in a less than optimum substrate. The plants that do grow in the sediments are prone to being washed out or having their root balls exposed during high flow events. During low flows, the plants are unnaturally close to the surface of the stream, rather than being safely located in a deeper channel. Being closer to the surface makes Texas wild-rice more vulnerable to drought, low flow conditions, herbivores and recreation. The end result is that more water is needed to increase water depths necessary to minimize impacts to the threatened and endangered species and their habitat.

Even the 1998 flood event was unable to erode and transport this sediment deposit. This analysis may provide insight on the inability of future floods to remove sedimentation deposits. The increased sedimentation could potentially be reduced through a variety of measures such as the implementation of sediment check dams, efforts to reduce erosion, increasing the amount of flow passed through the flood control dams, and the reduction of exotic vegetation; although all of these efforts could have adverse effects on a variety of features within this aquatic ecosystem. Several organisms occurring in the San Marcos Springs ecosystem are listed by the USFWS as either threatened or endangered, species of concern, or species proposed for listing (see Table 3.1-3). The threatened and endangered species will be discussed in further detail in Section 3.1.3 and the species of concern and proposed for listing in Section 3.1.4. Flows of San Marcos Springs have been recently evaluated to better understand the water quantity and quality needs of the spring ecosystem (Saunders et al 2001; BIO-WEST 2002a).

Effects of the Drought of Record on San Marcos Springs

A description of what occurs at San Marcos Springs when water levels drop has been previously described (LBG-Guyton Associates 2004) and is summarized below.

San Marcos Springs is at the end of a flow system for the Edwards Aquifer that includes most of the outcrop, streams, and the Blanco River in Hays and Comal Counties. The springs receive recharge from this area, and they often exhibit a rapid flow response to storm events in this region. San Marcos Springs also appears to receive a regional base flow of about 50 to 100 cfs that bypasses discharge at Comal Springs. Although San Marcos Springs did not go dry during the drought of record in the summer of 1956, spring discharge declined to 47 cfs. Seasonal water level rises and increased flows in the artesian section of the aquifer (San Antonio pool), however, do not result in increases in discharge at San Marcos Springs. The increased flow is in large part captured as increased discharge at Comal Springs.

FIGURE 3.1-4c.: Summer 1956 photo of southern end of Landa Lake, on western shore looking north toward the escarpment. Photo date unknown. Water level elevation in pools is about 617 to 618 ft. Photo provided by George Ozuna of USGS (LBG-Guyton Associates 2004)

FIGURE 3.1-4d. Summer 1956 photo of southern end of Landa Lake, on western shore looking southeast toward the flow-through pool. Photo date unknown. Water level elevation in pools is about 617 to 618 ft. Photo provided by George Ozuna of USGS (LBG-Guyton Associates 2004)

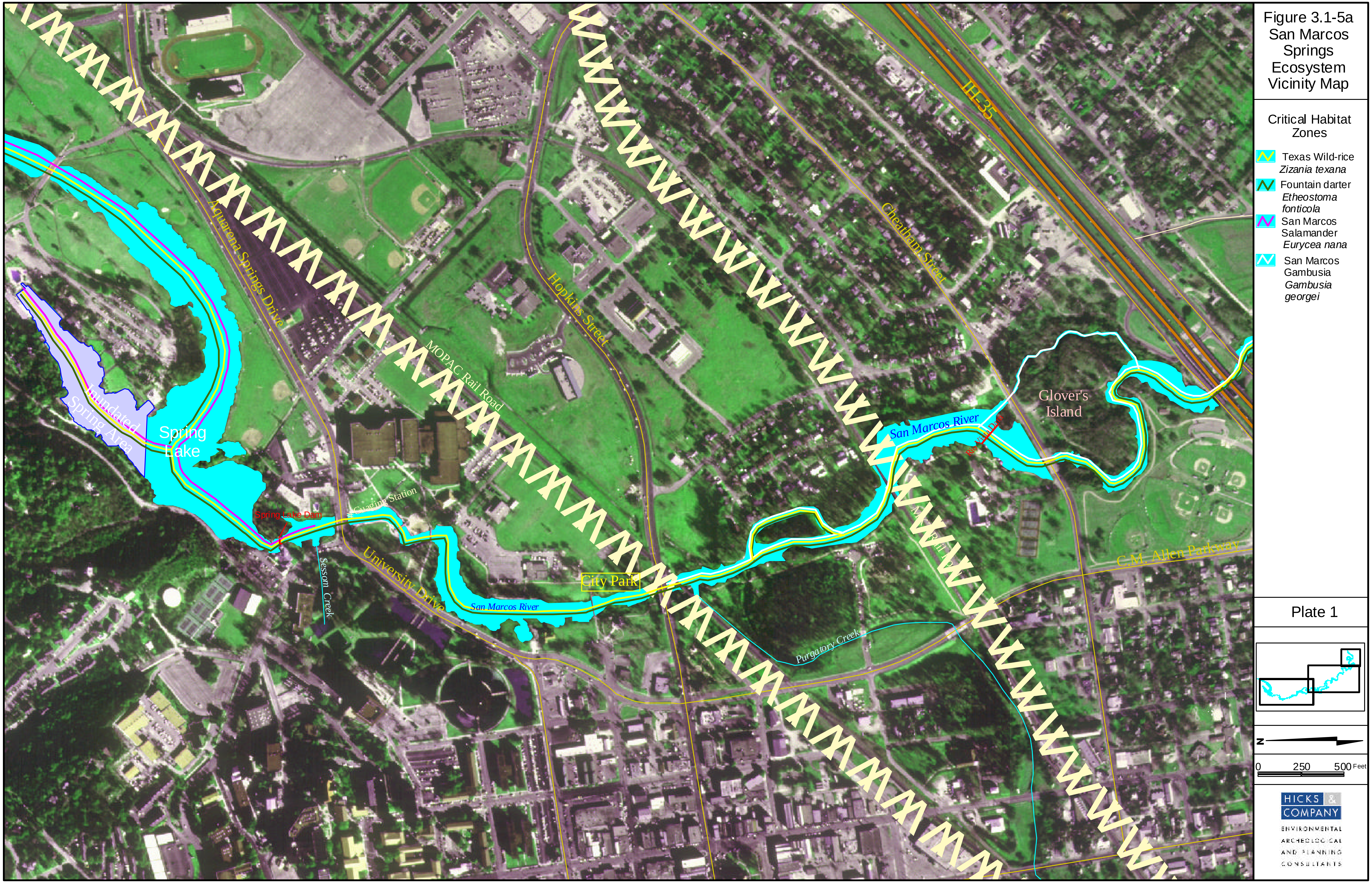


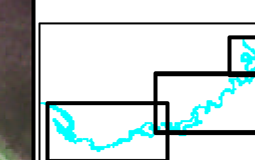
Figure 3.1-5a San Marcos Springs Ecosystem Vicinity Map

Figure 3.1-5b
San Marcos Springs Ecosystem Vicinity Map

Critical Habitat Zones

- Texas Wild-rice *Zizania texana*
- Fountain darter *Etheostoma fonticola*
- San Marcos Salamander *Eurycea nana*
- San Marcos Gambusia *Gambusia georgei*

Plate 2



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0 250 500 Feet

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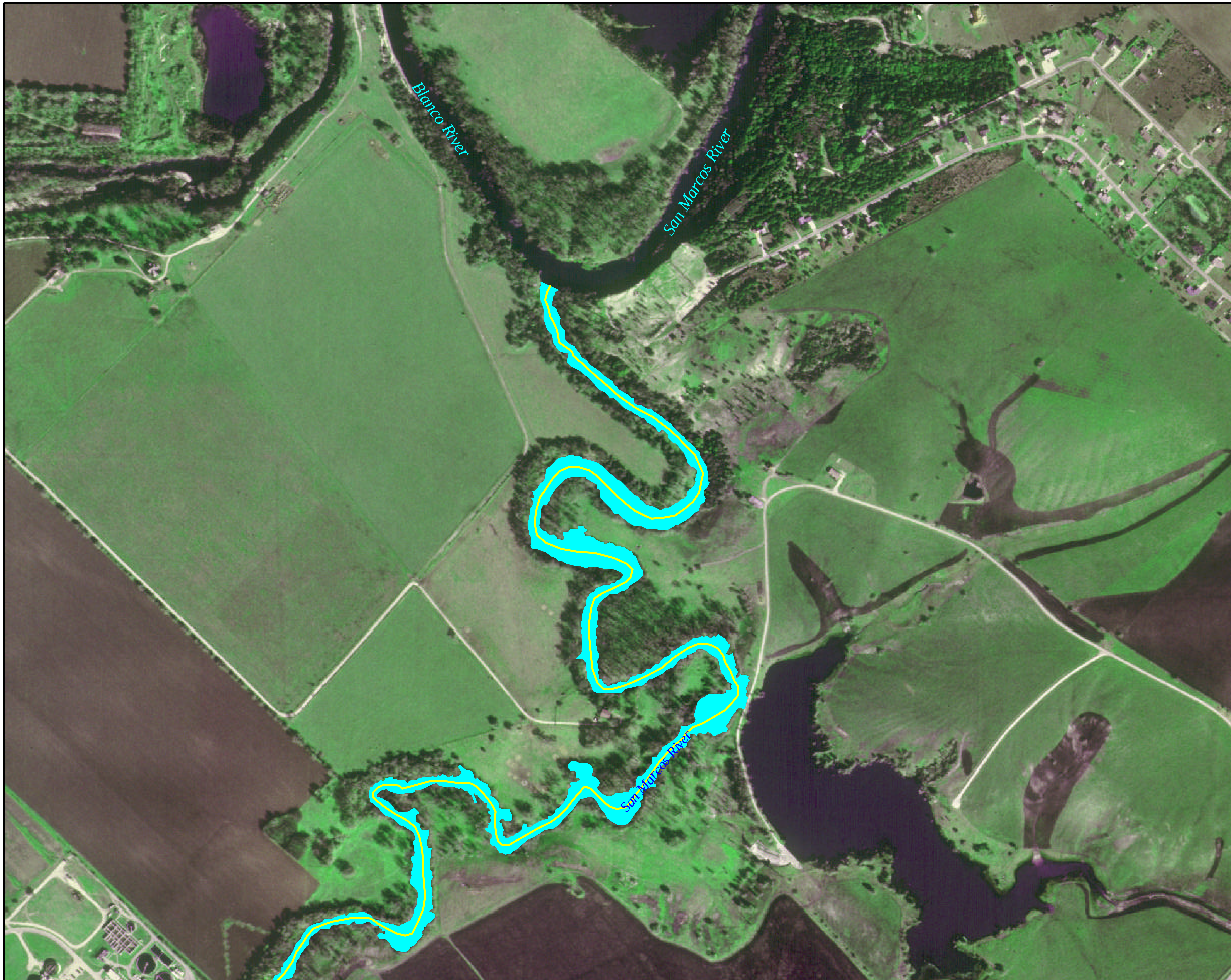
Figure 3.1-5c San Marcos Springs Ecosystem Vicinity Map



Critical Habitat Zones

- Texas Wild-rice *Zizania texana*
- Fountain darter *Etheostoma fonticola*
- San Marcos Salamander *Eurycea nana*
- San Marcos Gambusia *Gambusia georgei*

Plate 3

0 250 500 Feet

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All the spring discharge at San Marcos is through spring complexes in the bottom of Spring Lake. There are no subaerial springs, as occur at Comal Springs. Although some of the springs have distinct orifices where discharge can be measured, most of the spring discharge appears to be through rock rubble or sand boils in large flat sand plain areas. The southern springs appear to discharge groundwater from the regional flow system, while the northern springs receive their discharge from the more localized recharge zone of Hays County. Discharge rates in the southern springs would be expected to be far more stable under varying flow conditions than the northern springs, which should be more variable in proportion to total spring discharge values.

3.1.2.4 Common Components of the Comal and San Marcos Springs Ecosystems

There are several common characteristics of the Comal and San Marcos ecosystems. From a physical standpoint, both systems support a constant flow of water issuing from the Edwards Aquifer at the base of the Balcones Escarpment, a stable thermal environment, and consistently high water quality (McKinney and Sharp 1995; USFWS 1996a). Thus it is not surprising that the systems support similar biological communities. Examples of fish species found in both systems include the fountain darter (*Etheostoma fonticola*), largemouth bass (*Micropterus salmoides*), dusky darter (*Percina sciera apristis*), and largespring gambusia (*Gambusia geiseri*) (USFWS 1996a). Common exotic fish include blue tilapia (*Tilapia aurea*), Rio Grande cichlid (*Cichlasoma cyanoguttatum)* and red-breasted sunfish *(Lepomis auritis)*. Other common species include the Texas salamander (*E. neotenes*), freshwater shrimp (*Palaemonetes* sp.), and several gastropods such as *Amnicola comalensis*, *Goniobasis comalensis*, and the exotics *Thiara granifera, Melanoides tuberculata,* and giant rams-horn (*Marisa cornuarietus*). Aquatic plants found in both systems include Carolina fanwort (*Cabomba caroliniana*), water primrose (*Ludwigia repens*), pondweed (*Potamogeton illinoensis*), eelgrass (*Vallisneria americana*), and arrowhead (*Sagittaria platyphylla*) (McKinney and Sharp 1995). Three exotic plant species, hydrilla (*Hydrilla verticillata*), West Indian hygrophila (H*ygrophila polysperma*) and elephant ear (*Colocasia esculenta*) have significantly altered both ecosystems.

Many of the species living within these two systems have adapted to live within a narrow physiologic range as a result of environmental conditions and some species have become threatened due to their inability to respond to the changing environment (McKinney and Sharp 1995). Thus, both systems are highly susceptible to environmental consequences associated with human activities.

One exotic species which poses a potential threat to both the Comal and San Marcos rivers ecosystems is the giant rams-horn snail, an aquarium species that was first discovered in the San Marcos River in 1983 and in Landa Lake in 1984 (McKinney and Sharp 1995). This snail grazes on aquatic plants and in the 1990s played a major role in reducing plant growth to the extent that mowing was discontinued in Landa Lake. This snail prefers clear streams and pools with temperatures of at least 66.2° F (19° C). When exposed to temperatures colder than this, they withdraw into their shell and only survive for short periods of time. The warmest temperature that giant rams-horn snails can withstand is 102.2° F (39° C). Although the population has diminished since the mid-1990s, the potential for future alteration of the plant communities in these two systems remains and could affect endangered species (McKinney and Sharp 1995).

Another snail species that poses a potential threat to the Comal and San Marcos river ecosystems is the introduced red-rimmed melania (*Melanoides tuberculata*), and an associated parasitic trematode (tentatively identified as *Centrocestus formosanus*). This trematode, which affects the gills of fountain darters, has been found primarily in fish from the Comal River, with only a few individuals recorded from the San Marcos River (Fuller and Brandt 1997). Apparently the darters are not the normal hosts for this trematode since most of the larvae found on the gills are encysted or dead (Fuller and Brandt 1997).

3.1.2.5 Terrestrial Karst Invertebrates Federally-Listed as Endangered

Nine species of terrestrial invertebrates have been listed as endangered by the USFWS (2000). These species are known only from caves and associated karst features in Bexar County, Texas. The group includes three beetles, five spiders, and one harvestman, a relative of the daddy longlegs. All of the species are subterranean, inhabiting caves, sinkholes, or dissolved indentations or passages that lie over limestone rock (USFWS 2000). Three of the species are known only from one cave, while three others are known only from two to five caves. Most of these caves lie over the Edwards Aquifer recharge or artesian zones. Since these species are terrestrial, they are dependent on mesic (moist) areas that may be adjacent to recharge entrances, or subterranean groundwater conduits. These species are highly specialized and adapted, possessing eyes that are very small or entirely absent, and bodies that are long and thin, with no or minimal coloration (USFWS 2000). A discussion of each of the individual species is provided below.

The **Helotes mold beetle (*Batrisodes venyivi*)** has been found in only three caves near Helotes, Texas, just northwest of San Antonio. Two of the caves are located on private property and the owner of one has denied access in recent years so the status of this species in these areas is not known. Fire ants, which pose a major threat to the species, have been documented at both of the accessible caves. The location of the third cave is not known since the collector of the species will not reveal its location, but it is thought to be located on private property as well. The Helotes mold beetle was first collected in 1984 and little is known about the life history of the species (Federal Register 65 (248) 2000).

Two species of ground beetles (no common names) are listed within the EAHCP Planning Area. The first is ***Rhadine exilis***, a cave-dwelling species found in 35 caves in north and northwest Bexar County and is the second most broadly distributed invertebrate cave species listed. It ranges in size from 0.28 to 0.33 inch, is reddish brown, has reduced eyes, and may feed on cave cricket eggs. *Rhadine exilis* is found on cave walls (Veni and Reddell 1999).

The second ground beetle is ***Rhadine infernalis*** and is found from 25 caves in Bexar County. This species has the widest distribution of the nine species listed. There is enough variation within this species that three subspecies have been identified: *R. infernalis n*. is found in six caves, *R. infernalis infernalis* in 16 caves, and *R. infernalis ewersi* in three caves. *Rhadine infernalis* is found in all areas of caves, but mostly near entrances and occurs in silty or other areas with a high organic content. It is an opportunistic feeder consuming arthropods and scavenging on dead arthropods (Veni and Reddell 1999).

The **Government Canyon Bat Cave spider (*Neoleptoneta microps*)** is found in two caves in the Government Canyon State Natural Area in Bexar County. This area is a wildlife preserve and serves to protect the water recharging the Edwards Aquifer. These spiders are tiny, pale colored, and found in webs spun around rocks in dark moist areas. They can tolerate a wide range of temperatures but dry out quickly in drier environments. These cave spiders can drown easily in droplets of water due to their small size so they are not found in areas with dripping water. Much of their time is spent in their web, but they have also been seen walking on the ground near their web (Veni and Reddell 1999).

Madla's Cave meshweaver (*Cicurina madla*) is known to occur in six caves in Bexar County, five west of Leon Creek and one east of Leon Creek on Camp Bullis. These troglobitic spiders do not travel far and do not appear to frequent areas between caves. This species has a more widespread distribution than other *Cicurina* in Bexar County and is thought to be a more recent troglobite. This eyeless spider is pale colored, lives in webs built under and among rocks, and can tolerate a wide range of temperatures but is unable to survive long in low humidity (Veni and Reddell 1999).

The **Cokendolpher Cave harvestman (*Texella cokendolpheri*)** is a spider-like invertebrate found only in Robber Baron Cave in Bexar County. This large cave is located on private property but has been donated to the Texas Cave Management Association, which is interested in its protection and cave habitat improvement. The land over and around the cave is subject to widespread commercial and recreational use (Federal Register 65 (248) 2000). This species primarily occurs in caves, although some are found under rocks and logs. Only sparse information has been gathered concerning their biology including their preference for wet habitats. This species is sensitive to changes in humidity and can die if moisture levels are too low. In captivity, they feed on Collembola (minute, wingless insects) and may use this as a food source in the wild (Veni and Reddell 1999).

Robber Baron Cave also plays host to a spider known as the **Robber Baron cave meshweaver (*Cicurina baronia*)**. As mentioned, this cave is located in a highly urbanized portion of San Antonio and is owned by the Texas Cave Management Association. The cave lies east of the Edwards Aquifer in the Austin Chalk (Veni and Reddell 1999).

The **Government Canyon Bat Cave meshweaver (*Cicurina vespera*)** is a spider found in Government Canyon Bat Cave and another unnamed cave near Helotes in Bexar County (Federal

Register 65 (248) 2000). It was formerly known as the Vesper Cave spider. The areas where these caves are found are rapidly urbanizing (Veni and Reddell 1999).

The **Bracken Bat Cave meshweaver (*Cicurina venii)*** is a cave spider found from Bracken Bat Cave in Bexar County, which is located within a low-density semi-urban neighborhood. They may occur in other caves where immature *Cicurina* have been collected; however, only adults can be identified to species level (Veni and Reddell 1999). This cave was filled in during the building of a home in 1990 and the effects to its cave fauna are unknown at this point. It has been reported that there could be a small opening in the area that may possibly be a source of nutrients for the spider (Federal Register 65 (248) 2000).

These three cave spiders (*Cicurina* sp.) are eyeless, pale colored, live in webs built under and among rocks, and can tolerate a wide range of temperatures but are unable to survive long in low humidity (Veni and Reddell 1999).

3.1.3 Species Addressed by the Section 10(a)(1)(B) Permit

A total of ten species are proposed for coverage under the Section 10(a)(1)B Permit. Eight of these species, listed as endangered or threatened by the USFWS, depend entirely on the Edwards Aquifer, Comal Springs, and San Marcos Springs. A ninth species, the endangered whooping crane, depends on instream flows and subsequent productivity of the Guadalupe Estuary, and is consequently indirectly affected (at least partially) by spring discharge of the Edwards Aquifer. In addition, one candidate species (Cagle's map turtle) is also affected by spring discharge from the Edwards Aquifer and is included (see Table 3.1-3). Listed species addressed in the EAHCP (and date of listing) include:

Endangered

- Comal Springs dryopid beetle (*Stygoparnus comalensis*) (Federal Register 62 (243) 66295-66303, 18 December 1997).

- Comal Springs riffle beetle (*Heterelmis comalensis*) (Federal Register 62 (243) 66295-66303, 18 December 1997).

- Fountain darter (*Etheostoma fonticola*) (Federal Register 35:16047, 13 October 1970).

- Peck's Cave amphipod (*Stygobromus pecki*) (Federal Register 62 (243) 66295-66303, 18 December 1997).

- San Marcos gambusia (*Gambusia georgei*) (Federal Register 45:47355-47364, 14 July 1980).

- Texas blind salamander (*Eurycea* [formerly *Typhlomolge*] *rathbuni*) (Federal Register 32:4001-4010, 11 March 1967).

- Texas wild-rice (*Zizania texana*) (Federal Register 43:17910-17916, 26 April 1978).
- Whooping crane (*Grus americana*) Federal Register 32:4001, March 11, 1967).

Threatened

- San Marcos salamander (*Eurycea nana*) (Federal Register 45:47355-47364, 14 July 1980).

Candidate

- Cagle's map turtle (*Graptemys caglei*)

A brief life history of each species covered in the EAHCP is provided below.

Take and jeopardy flow levels as specified by the USFWS for several of the above listed species are provided in Table 3.1-4.

Table 3.1-4. Take and jeopardy minimum springflow levels (cfs) as specified by the USFWS for five federally-listed species

Federally-Listed Species	Spring System Case	To Avoid Take of Animal Species and Avoid Damage to & Destruction of Plants	To Avoid Appreciable Reduction of Survival & Recovery = JEOPARDY	To Avoid Adverse Modification of Critical Habitat
Texas wild-rice	San Marcos[1,2]	100	100	100
	San Marcos[2,3]		< 100[4,5]	< 100[4]
Fountain darter	Comal[1,6]	200		
	Comal[6,7]	150		
	Comal[1,2]		150[5]	
	Comal[2,7]		60[5]	
	San Marcos[1,2]	100	100	100
	San Marcos[1,2]		< 100[4,5]	< 100[4,5]
San Marcos gambusia	San Marcos[1,6]	100		
	San Marcos[1,2]		100	100
	San Marcos[2,3]		< 100[4,5]	< 100[4,5]
Texas blind salamander	Edwards Aquifer[6]	50[8]		
	Edwards Aquifer[2]		50[8]	
San Marcos salamander	San Marcos[1,6]	60		
	San Marcos[1,2]		60	60

SOURCE: USFWS 1999b (guidance documents provided to Hicks and Company by Austin Ecological Services Office, U.S. Fish and Wildlife Service via letter dated October 5, 1999).

NOTE: These determinations predate the listing of the Comal Springs riffle beetle, Comal Springs dryopid beetle, and Peck's Cave amphipod.

[1]Given current (1993) conditions. [2]15 June 1993 letter. [3]With Edwards Aquifer Management Plan & control of exotics. [4]Currently, cfs undefined. [5]For short (undefined) periods of time. [6]15 April 1993 letter. [7]With control of snail *Marisa.* [8]Refers to San Marcos springflow.

3.1.3.1 Comal Springs Dryopid Beetle (*Stygoparnus comalensis*)

First collected in 1987, the Comal Springs dryopid beetle (*Stygoparnus comalensis*) (Figure 3.1-6) is the only known subterranean aquatic (stygobiotic) species from the family Dryopidae. This species is translucent, is slightly pigmented, has vestigial (non-functioning) eyes, and is about one-eighth of an inch long. Specimens have predominantly been collected from Comal Springs spring run #2 (see Figure 3.1-4a); however, they have also been collected from spring runs 3 and 4 on the Comal River and Fern Bank Spring in Hays County (Barr and Spangler 1992). This species is assumed to be restricted to headwaters of springs and spring runs due to its inability to swim. They are able to maintain a mass of small hydrophobic (unwettable) hairs on their underside where they retain a thin air bubble through which gas exchange occurs during respiration (BMWD 1998; Chapman 1982). As water flow decreases, subsequently decreasing dissolved oxygen levels, this method of respiration loses its effectiveness. Thus, the Federal Register 62:243 (1997) states that the dryopid beetle requires flowing, uncontaminated waters for survival.

3.1.3.2 Comal Springs Riffle Beetle (*Heterelmis comalensis*)

The Comal Springs riffle beetle (*Heterelmis comalensis*) (family Elmidae) (Figure 3.1-7) is known primarily from Comal Springs, and was first collected there in 1976 and described in 1988 by Bosse et al. (1988). Barr (1993) collected a single specimen in the headwaters of the San Marcos River, but no subsequent specimens have been found in that location. Although some riffle beetles are capable of flight, the Comal Springs riffle beetle is a flightless, surface aquatic beetle about one-eighth of an inch long (Federal Register 62:243, 1997). Both larvae and adult riffle beetles are entirely aquatic with the adults feeding mainly on algae and detritus scraped from submerged weeds and rocks (Brown 1987). Comal Springs riffle beetles are found in the flowing, uncontaminated waters of the spring runs, but also occupy areas along the Landa Lake shoreline where springflow is present or in areas of upwelling springflow (including the deepest portions of the Landa Lake; (Bio-West 2002a). Water flow appears to be important to respiration and survival of this species; therefore, a reduction of water flow or drying of the spring runs could be a limiting factor to their survival (Federal Register 62:243, 1997). Previously, it was unclear how the species might respond to reduced springflow. Recent laboratory studies suggest that individuals tend to orient downward in the substrate, and toward flow (Bio-West 2002b), a behavioral response that may permit individuals to move to suitable habitat when springflow is reduced at the surface. However, because this species was not identified until 1976, well after the documented drought of record and cessation of springflow at Comal Springs, the question of survivability of the species during no-flow periods remains unanswered. In addition to behavioral responses, the presence of individuals in deeper areas of Landa Lake, somewhat removed from the spring runs, may have facilitated survival despite loss of habitat and provided a source for recolonization.

David Bowles

Figure 3.1-6
Comal Springs Dryopid Beetle (*Stygoparnus comalensis*)

David Bowles

Figure 3.1-7
Comal Springs Riffle Beetle (*Heterelmis comalensis*)

3.1.3.3 Fountain Darter (*Etheostoma fonticola*)

The fountain darter (*Etheostoma fonticola*) (Figure 3.1-8), a member of the family Percidae, is endemic to the San Marcos and Comal Rivers. This species was first collected in 1884 in the San Marcos River just below its confluence with the Blanco River and in 1891 in the Comal River (Schenck and Whiteside 1976). The historic range of this species on the San Marcos River extends from Spring Lake downstream to just below its confluence with the Blanco River, and in the Comal River from the headwaters downstream to its confluence with the Guadalupe River (Schenck and Whiteside 1976). Currently the fountain darter can be found in the upper portions of the Comal River including Landa Lake and in the San Marcos River system from Spring Lake downstream to the outfall of the San Marcos City wastewater treatment plant (McKinney and Sharp 1995; Schenck and Whiteside 1976).

Between 1954 and 1973, the original population of fountain darters was extirpated from the Comal River (Linam et al. 1993; Schenck and Whiteside 1976). It is believed that a combination of a rotenone treatment by the Texas Fish, Game, and Oyster Commission in 1951 [to remove exotic Rio Grande cichlids (*Cichlasoma cyanoguttatum*)], temperature variations due to the springs ceasing to flow for a six-month period in 1956, and a flood from Blieders Creek in 1971 caused the die off of the fountain darter (Linam et al. 1993; Schenck and Whiteside 1976). Beginning in 1975, a total of 457 fountain darters from San Marcos were re-introduced into the Comal River, from which the present Comal population is descended (Linam et al. 1993; Schenck and Whiteside 1976).

Fountain darters are small (usually <1.0 inch), olive-green in color, with dark markings along the lateral line, dark spots at the base of the tail, opercule, dorsal fin, and around the eye (Gilbert 1887; Schenck and Whiteside 1976). Competing theories have been reported in the literature regarding the wild fountain darters reproductive cycles; some researchers support continuous spawning (Strawn 1955, Hubbs 1985) while other have noted peaks in reproductive activity (Schenck and Whiteside 1977b). Fecundity is believed to be lower in fountain darters than other species of darters and appears to be controlled by both environmental and genetic factors including the influence of repeated spawnings throughout the year. This species exhibits sexual dimorphism, the males having four morphological forms differing in size, color, and shape (Schenck and Whiteside 1977b). Females deposit eggs in aquatic vegetation which are then fertilized by breeding males that produce a small amount of transparent milt (sperm) (Hubbs 1958). Little or no parental care is provided to the eggs or young (Schenck and Whiteside 1977b). Young fountain darters are restricted to the stream bottom in pools until they have grown enough to swim through currents (Collette 1965; Strawn 1955).

Fountain darter habitat requirements include clear, clean, flowing, and thermally constant waters, adequate food supply, undisturbed sand and gravel substrates, rock outcrops, and areas of submergent vegetation (algae, moss, vascular plants) for cover (McKinney and Sharp 1995; Schenck and Whiteside 1977a; USFWS 1996b). Their densities are greatest in areas of filamentous green algae (*Rhizoclonium* sp.) and the moss *Riccia* (BIO-WEST 2003a, 2003b) and are rarely found in areas devoid of vegetation (Schenck and Whiteside 1976; USFWS 1996b). Young fountain darters are found in heavily vegetated areas with low flows, while adults can be found in all suitable habitats (Schenck and Whiteside 1976). This strong preference for aquatic vegetation highlights the concern posed by the grazing activities of the afore-mentioned giant rams-horn snail. The critical habitat has been designated for fountain darters as Spring Lake and its outflow, and the San Marcos River downstream to 0.5 mile below the IH 35 bridge (USFWS 1996b) (see Figures 3.1-5a, b, and c).

Fountain darters appear to have adapted to a relative narrow temperature range at the downstream edges of their available habitat. Water temperature is a concern and laboratory studies have shown a significant decrease in reproductive capacity above 27°C (Brandt et al. 1993, Bonner et al. 1998) and a critical thermal maximum of 34.8°C (Brandt et al. 1993). A more recent study conducted by BIO-WEST (2002c) and Dr. T.H. Bonner has discounted the hypothesis that the 2°C diel fluctuations that occur in the wild have a significant impact on earlier findings. Regardless, these ranges in temperature tolerance observed in the laboratory are similar to other species with “wider geographic and thermal distributions” (Bonner et al. 1998).

Food sources for fountain darters consist of copepods, aquatic insect larvae, and amphipods (McKinney and Sharp 1995; Schenck and Whiteside 1977a). Generally small aquatic invertebrates are the preferred food item; however, type and amount of food consumed changes with growth of the fish (Schenck and Whiteside 1977a). The food sources of fountain darters are different in Spring Lake and the San Marcos River since the invertebrate communities in both systems are different and darters eat what is available to them. Fountain darters feed based on visual clues, primarily during the day, and are stationary feeders; waiting for their prey to come to them (USFWS 1996b; Schenck and Whiteside 1976).

Population estimates of the fountain darter are difficult to make because of its small body size, the range of sampling methods used in the past and the difficulty in accounting for all of the habitat dynamics in calculations. Prior to 1974 all collections gave no indication of the population abundance. When the rotenone treatment occurred in Landa Lake in 1951, an unknown number of fountain darters, along with other native fishes were seined, held in a protected area until the rotenone dissipated and reintroduced (Ball et al. 1952). The stress imposed by this event likely reduced the fountain darter population in the Comal River. The collection by Hubbs and Strawn (1957) that occurred between the rotenone poisoning and the zero springflow conditions in 1956 only indicated that the species was still present, not how many were there. Since that time, despite the difficulties, a few attempts have been made to estimate the population abundance in the San Marcos and Comal Rivers. Schenck and Whiteside (1976) estimated the total population in the San Marcos River at 103,000 but did not provide a confidence range and the authors cautioned that the estimate was not the primary focus of their study. They also estimated 339 fountain darters within a small portion of Spring Lake. As part of that study, Schenck and Whiteside (1976) spent 300 person-hours between March 1973 and February 1975 sampling the Comal River but did not collect any fountain darters there. After the fountain darters were reintroduced into the Comal River in 1975 using individuals from the San

Glenn Longley

Figure 3.1-8
Fountain Darter *(Etheostoma fonticola)*

Jean Krejca

Figure 3.1-9
Peck's Cave Amphipod *(Stygobromus pecki)*

Marcos River, the population became re-established in the former. In 1990, Linam et al. (1993) estimated the total abundance of fountain darters in the San Marcos River (excluding Spring Lake) to be 45,900 individuals with a 90 confidence interval of 15,900 to 107,700. Recent observations in Spring Lake (BIO-WEST 2003a, 2003b) suggest that fountain darter densities are much higher there than in downstream areas and a population estimate that included the lake would be significantly higher. The Linam estimate was calculated using different methods of capture than those used by Schenck and Whiteside (1976) which limits comparisons; however, the earlier estimate falls within the range described by Linam et al. The Linam et al. study also estimated the mean population for the Comal River upstream of Torrey Mill Dam at 168,078 with 95 percent confidence limits of 114,178 and 254,110.

The wide confidence intervals for these population estimates indicate the difficulty in developing them with any real confidence. There are a large number of factors that influence the population that are difficult to account for in a single sample effort. In addition, the fountain darter is short-lived and highly fecund which allows it to respond quickly to changes in habitat availability. Therefore, estimates of population abundance may have changed by the time the numbers are put in print. Population estimates have not been generated from sampling associated with the Variable Flow Study (2000-2004) but the study has documented high densities of fountain darters in the Comal and San Marcos Springs/River ecosystem recently (BIO-WEST, 2003a, 2003b). That study has shown that there is a wide range of habitat suitability among species of aquatic vegetation. Using vegetation composition (high, moderate, and low habitat suitability) may be a more accurate means of estimating the current status of the fountain darter population than developing population estimates.

Recently, there has been an increase of parasitism in the fountain darter, especially in the Comal River. The most serious threat comes from the trematode of the red-rimmed melania, which attacks the gills of the fountain darter causing reddening, swelling, and bleeding. The immune system of the fountain darter is sufficient to rid its body of the trematode, but not until the damage has already been done (BMWD 1998; Fuller and Brandt 1997). Some of the concerns of the impact of this parasite are increased stress, reduced ability to avoid predators, and reduced reproductive capabilities. Recent laboratory studies suggest; however, that the trematodes do not impact reproduction, at least in early stages of infestation and under moderate parasite loads (BIO-WEST 2002c).

3.1.3.4 Peck's Cave Amphipod (*Stygobromus pecki*)

Peck's Cave amphipod (*Stygobromus pecki*) (Figure 3.1-9), is a subterranean aquatic species in the family Crangonyctidae. This species is eyeless and unpigmented, which indicates that its primary habitat lies within the aquifer in permanent darkness. If found outside the spring orifice, individuals are easy prey and so are typically found in the crevices of rocks and gravel. This species was first collected at Comal Springs in 1964 and again in 1965 (Federal Register 62:243, 1997). Most of the specimens collected (over 300) since its description were netted from gravel substrates near the three largest springs of the Comal River (Arsuffi 1993; Barr 1993). In 2002, five individuals were collected from Panther Canyon Well, known to be hydrologically-connected to Comal Springs (USFWS 2003a). One specimen was collected from Hueco Springs, although despite extensive collection efforts, none have been found outside the Edwards Aquifer (Barr 1993; Federal Register 62:243, 1997). Very little is currently known about the life history requirements of this species.

3.1.3.5 San Marcos Gambusia (*Gambusia georgei*)

The San Marcos gambusia (*Gambusia georgei*) (Figure 3.1-10), a member of the family Poeciliidae, was first described by Hubbs and Peden in 1969. It is just one of three species of *Gambusia* native to the San Marcos River, the others being largespring gambusia (*G. geiseri*) and western mosquitofish (*G. affinis*) which have continually been found in greater numbers than the San Marcos gambusia (Hubbs and Peden 1969). This genus originated in Central America and contains more than 30 species of the live-bearing freshwater fishes (USFWS 1996a). *Gambusia* is a well-defined genus and mature males have a thickened upper pectoral fin ray that distinguishes it from related genera (Rosen and Bailey 1963). In the United States, only a limited number of *Gambusia* are native, and of these, the San Marcos gambusia has one of the most restricted ranges (USFWS 1996). As specimens were caught in the late 1800s and again in 1925, it is likely that the San Marcos gambusia have inhabited the area for some time (Hubbs and Peden 1969).

San Marcos gambusia range in size from 1.0 to 1.5 inches, adult females being larger than males (Whiteside 1976). Their scales tend to be strongly crosshatched which is contrary to the less distinct scale markings of the western mosquitofish (USFWS 1996). San Marcos gambusia are usually plainly marked; however, behaviorally aggressive fish may develop a dark stripe on their dorsal fin, a black bar on their cheek, and a dark patch above their pectoral fin (Whiteside 1976). Under normal conditions, their coloring appears to be lemon yellow, bright yellowish orange, or bluish (USFWS 1996a).

The exact locations of early collections of San Marcos gambusia were only recorded as "San Marcos Springs" although they were probably collected near the headwaters of the springs (USFWS 1996a). Over time, the distribution of the San Marcos gambusia appears to have been significantly altered. Only a few records show the fish occurring downstream of the headwaters of the San Marcos River although collections in this area were few prior to 1950. A single individual was taken during a 1953 collection effort below the dam at Rio Vista Park, and since that time, almost all specimens of the San Marcos gambusia have been taken in the vicinity ofthe Interstate Highway 35 bridge downstream to Thompson's Island. The only exception to this was in 1974 when one individual was collected below the outfall of the San Marcos wastewater treatment plant (USFWS 1996a; Longley 1975). Historically, populations of San Marcos gambusia have been low, and were rare during collection efforts in 1978 and 1979 which yielded only 18 San Marcos gambusia from a total of 20,199 (0.09 percent) (Edwards et al. 1980). Populations decreased during a 1981 and 1982 collection effort (0.06 percent of all *Gambusia* collected) and sampling efforts between 1982 and 1995 have not yielded a single individual

Edwards Aquifer Research and Data Center

Figure 3.1-10
San Marcos Gambusia (*Gambusia georgei*)

Heather Brandon

Figure 3.1-11
Texas Wild-rice (*Zizania texana*)

(USFWS 1996a). Intensive collection efforts were conducted in 1990 with no San Marcos gambusia being collected (USFWS 1996a).

San Marcos gambusia prefer quiet, shallow, thermally constant, open waters adjacent to areas of moving water. Historically, they have been found mostly in the upper portions of the San Marcos River on muddy substrates without silting and in areas of shade from overhanging vegetation or bridge structures (Edwards et al. 1980; Hubbs and Peden 1969). At some localities, the introduced aquatic vegetation elephant ear has been found in abundance. Researchers suggest that this nonnative plant may have modified essential aspects of the San Marcos gambusia habitat (USFWS 1996a). Critical habitat has been designated by the USFWS as the San Marcos River from the Highway 12 bridge downstream to just below the IH 35 bridge (USFWS 1996a) (see Figures 3.1-5a, b, and c).

Very little is known about the food preferences of the San Marcos gambusia. It is thought that insect larvae and other invertebrates make up the majority of their diet, as in other poecillids (USFWS 1996a). The reproductive capabilities of this species are not known, although two individuals kept in laboratory aquaria produced clutches of 12, 30, and 60 young, with the largest having been aborted prior to full development (Edwards et al. 1980).

Hybridization of the San Marcos gambusia and the western mosquitofish has been going on since 1925 and was first recognized by Hubbs and Peden (1969). This went on for many years without the introduction of genetic material into either of the parental species; however, a series of collections from 1981 to 1983 indicated that hybrid individuals were becoming more abundant than the pure San Marcos gambusia (USFWS 1996a). This may indicate that hybrid individuals are competing with the San Marcos gambusia and putting stress on native populations. Despite efforts to locate pure San Marcos gambusia, the last known sighting from the San Marcos River occurred in 1983 and the species is now thought to be extinct (McKinney and Sharp 1995).

3.1.3.6 Texas Wild-rice (*Zizania texana*)

Texas wild-rice (*Zizania texana*) (Figures 3.1-11 and 3.1-12), an aquatic perennial grass from the family Poaceae, was originally collected in 1892 and identified as southern wild-rice (*Z. aquatica*). It was later labeled *Z. texana* in 1921, although not recognized as a distinct species. In 1932 amateur botanist W.A. Silveus of San Antonio, Texas collected and recognized Texas wild-rice as a distinct species (Terrell et al. 1978; Poole and Bowles 1999; Silveus 1933). Texas wild-rice is endemic to the San Marcos River and is thought to have evolved in geographic isolation from other species of *Zizania*. The nearest population is a coastal plain population of *Z. aquatica* in southern Louisiana, 400 miles (640 km) away, and is morphologically different from *Z. texana* (Terrell et al. 1978).

Texas wild-rice is primarily an aquatic, monoecious, perennial macrophyte, 3.3 to 6.6 feet long. It is found growing and submerged at a depth of ≤3.3 feet in swift moving, shallow areas of the San Marcos River. During times of low flow, the upper portions of the culms (stems) and leaves become emergent (Terrell et al. 1978; USFWS 1996a). Texas wild-rice is securely attached to the substrate by short spongy roots which are tightly intertwined and develop into a plant colony in 1.0 to 6.0 feet of water (Beaty 1975). The leaves are linear, up to 3.3 feet long, and 0.5 inch wide (Terrell et al. 1978). Flowering typically occurs in the spring and fall but may be seen throughout the year due to the constant water temperatures. There is some debate about the ability of Texas wild-rice to reproduce via seeds; it has done so under laboratory conditions (P. Power USFWS, personal communication) however, many researchers believe this occurs infrequently, if at all, in the wild (Beaty 1975; Emery 1967). Texas wild-rice does reproduce vegetatively, by stolons, and appears to reestablish readily when uprooted and relocated during flood events (BIO-WEST 2003a, 2003b).

Texas wild-rice forms large clumps rooted in sand and gravel sediments which is overlain by Crawford black silt and clay (Vaughan 1986). They grow primarily in the middle of the river in areas with swift moving, shallow water of 3.3 feet or less, (Poole and Bowles 1999). Wild-rice require thermally constant temperatures, clear water, undisturbed stream bottom habitat, protection from floods, and protection allowing inflorescence (flower production) during reproduction (McKinney and Sharp 1995).

Associated plant species that occur in the upper 0.25-mile area of the San Marcos River, which is inhabited by Texas wild-rice, include eelgrass, arrowhead, pondweed, hydrilla, hornwort (*Ceratophyllum demersum*), elodea (*Elodea densa*), and water primrose. In the lower sections of the river, Texas wild-rice is found in isolated clumps and competition from other species is minimal (Terrell et al. 1978; Vaughan 1986). In many places on the river, the exotic elephant ear has invaded the edges of the river, narrowing the river and crowding other aquatic species. Other species such as sycamore (*Platanus occidentalis*), pecan (*Carya illinoensis*), bald cypress (*Taxodium distichum*), live oak (*Quercus fusiformis*), and American elm (*Ulmus americana*) have shaded the river, although it is not known if wild-rice is influenced by the amount of shading by the tree canopy (Vaughan 1986).

When Texas wild-rice was first described in 1933, it was found in abundance in the San Marcos River, as well as in Spring Lake, and in contiguous irrigation ditches, requiring considerable effort by an irrigation company to control its growth (Terrell et al. 1978; Silveus 1933). Thirty-four years after its discovery, its abundance had been significantly reduced. In 1967, Emery found only one plant in Spring Lake, and none in the uppermost 0.5 mile of the San Marcos River. Only scattered plants were found in the next 1.5 miles, and none were found below this point (Emery 1967). Emery rechecked the abundance of Texas wild-rice in the upper portions of the San Marcos River in 1976, and found no plants in Spring Lake. During that investigation, the greatest concentrations of plants were found at the extreme upper and lower segments of the 1.5-mile reach of the river (Emery 1977). He also estimated that Texas wild-rice plants covered 12,169.6 square feet of river habitat. Texas wild-rice was listed as an endangered species in 1978. After the listing, a continued decline occurred in the areal coverage of Texas wild-rice until it had declined to just 4,881 square feet (Vaughn 1986), which is less than half of Emery's 1976 estimate. Recent years have seen a significant increase in areal coverage of Texas wild-rice to 20,404 square feet in 2001. The species is abundant throughout the upper portion of its range, but rare downstream of the I-35 bridge, despite the historic suitability of habitat below this point.

Since June 1989, the TPWD has monitored areal coverage of Texas wild-rice which has averaged 14,794 square feet between 1989 and 1994. The current distribution of Texas wild-rice extends from the upper reaches of the San Marcos River, including several plants in Spring Lake just upstream of the dam and numerous stands just below the dam (Emery and Vaughan did not report wild-rice from this area), throughout the river habitat to an area just below the wastewater treatment plant. Until recently, it had not occurred between the Rio Vista railroad bridge and the Cheatham Street dam (USFWS 1996a), however a single plant is now present in this reach (E. Oborny, BIO-WEST personal communication). Increased sedimentation, water depth and turbidity, and a decrease in current velocities have contributed to a loss of habitat (See Section 3.1.3.2) for Texas wild-rice growth throughout the lower portions of its historic range (Poole and Bowles 1999). While water depth and current velocity are a direct result of the influence of springflow into the San Marcos River, the impacts of increased sedimentation and turbidity on Texas wild-rice are largely a result of urbanization within the contributing watershed. The species' critical habitat has been designated as Spring Lake and its outflow, and the San Marcos River downstream to its confluence with the Blanco River (USFWS 1996a) (see Figures 3.1-5a, b, and c).

The invasion of a new exotic plant, water trumpet (*Cryptocoryne beckettii*), has created a new, very serious threat to Texas wild-rice. The plant, a native of southeast Asia, was introduced into the San Marcos River in 1993 (USFWS 2003b). The plant probably escaped into the river from a dumped aquarium as the plant is very popular in the aquarium trade (Tu 2002). The plant has habitat preferences that are nearly identical to Texas wild-rice and has quickly established in the section of the San Marcos River from the A.E. Wood State Fish Hatchery to the confluence of the San Marcos and Blanco Rivers (USFWS 2003b).

Since August of 2002, through a cooperative effort led by the USFWS San Marcos National Fish Hatchery, over 400 square meters of the noxious plant have been removed from the San Marcos River. Unfortunately, the plant's growth continues to outpace the removal effort and it is now feared that unless more ambitious control measures are implemented, full removal may not be assured (USFWS 2003b).

The cultivation of Texas wild-rice in a controlled environment has been attempted with varying success. Replanting attempts have been made with cultured plants into Spring Lake with disappointing results. Emery was successful under controlled conditions in a spring-fed raceway at Texas State University at San Marcos, with seed storage and germination, seedling survival, pollination, and development of survival clones to the next generation (Terrell et al. 1978). Efforts to grow Texas wild-rice outside the San Marcos River have been unsuccessful (USFWS 1996b).

The recovery plan lists disturbances to the environment and diminished springflow as the main threats to Texas wild-rice (USFWS 1996a). In addition, impacts from recreationists (e.g., tubing), floating debris (aquatic vegetation cut at Spring Lake and by landowners), shade which reduces photosynthesis, or interference with pollination and seed maturation can damage the plants (Beaty 1975; Poole 1992). Herbivory by nutria (*Myocastor coypus*), the introduced giant rams-horn snail (*Marisa cornuarietis*), and waterfowl, as well as competition from aquatic plants are believed to be significant factors in reducing the size and vigor of stands of wild-rice (McKinney and Sharp 1995). Other threats include water quality degradation, waterborne contaminants, genetic erosion of the population, chemical spills, and siltation (Poole 1992; BMWD 1998).

3.1.3.7 Texas Blind Salamander (*Eurycea rathbuni*)

The Texas blind salamander (*Eurycea rathbuni*) (Figure 3.1-13) was first collected in 1895 from the Federal Fish Hatchery in San Marcos, Texas, when they were expelled from an artesian well drilled to supply the hatchery with water (Longley 1978). There is some disparity among the experts as to whether this species belongs to the genus *Typhlomolge* or *Eurycea*. Wake (1966) and Potter and Sweet (1981) supported the recognition of genus Typhlomolge; however, Mitchell and Reddell (1965) disagreed, stating that *E. rathbuni* represents *Eurycea* that has an extreme cave-associated morphology. Based on biochemical, morphometric, and molecular techniques, Chippindale et al. (1994) concluded that the Texas blind salamander is phylogenetically within the Texas *Eurycea* group. This conclusion has been more recently supported by allozyme and mitochondrial genetic (DNA) sequence studies by Chippendale et al. (2000). The USFWS reassigned this species as *Eurycea* and listed it on the March 1999 “Texas Threatened and Endangered Species” list (TPWD 1999).

The Texas blind salamander is a smooth, unpigmented troglobitic (cave-adapted) species, and has a maximum length of 4.7 inches. It has a large and broad head, reduced eyes (two small dark spots beneath the skin), long and slender limbs, four toes on the forelegs and five on the hind legs. There are no definite external characteristics that can be used to determine sex. Due to the presence of juveniles year round, the Texas blind salamander appears to be sexually active throughout the year due to the thermally constant waters of the aquifer. Observations of this species in captivity have shown three spawning events in one year and indicated a clutch size from 8 to 21 eggs per spawning (Longley 1978). Unpigmented eggs were attached to gravel either singly or in groups of 2 to 3 eggs. Constant water temperature within the aquifer is essential for normal egg development (Longley 1978). Eggs hatch within 12 to 16 days after laying and feeding of the larvae begins within 1 month after hatching. Young salamanders feed on copepods while larger salamanders eat amphipods, blind shrimp (*Palaemonetes antrorum*), daphnia, small snails, and other invertebrates. Cannibalism has also been documented with the Texas blind salamander (USFWS 1996a).

Texas blind salamanders have been found in the subterranean waters of the San Marcos area of the Edwards Aquifer in Hays County. They live in water-filled cavernous areas and are neotenic

Martin Heaney and Ed Oborny

Figure 3.1-12
Texas Wild-rice Submerged in the San Marcos River

Glenn Longley

Figure 3.1-13
Texas Blind Salamander (*Eurycea rathbuni*)

(reproduce in the larval form) and aquatic throughout their life. Texas blind salamanders have been observed, in caves with access to the water table, traveling along submerged ledges within the aquifer and swimming small distances before spreading their legs and settling to the bottom. It is likely that they are sensitive to changes in water temperatures, preferring the thermally constant temperatures of the Edwards Aquifer, although more research is needed to determine critical thermal minima and maxima for their various life stages (Longley 1978; Berkhouse and Fries 1995).

All collections of Texas blind salamanders have occurred in Hays County and since its initial collection from the Federal Fish Hatchery, the salamander has been found at Ezell's Cave, San Marcos Springs, Rattlesnake Cave, Primer's Fissure, Texas State University's artesian well, and Frank Johnson's well (Russell 1976; Longley 1978). Previously it had been found in Wonder Cave; however, searches in 1977 did not discover any individuals (Longley 1978). The distribution of this species may be the Edwards Aquifer beneath and near San Marcos and an area as small as 25.9 square miles (USFWS 1996a).

3.1.3.8 San Marcos Salamander (*Eurycea nana*)

The San Marcos salamander (*Eurycea nana*) (Figure 3.1-14) is a member of the lungless salamanders belonging to the family Plethodontidae. *Eurycea* are known as the brook salamanders, and include three species on the Edwards Plateau: the Texas blind salamander, the San Marcos salamander, in the San Marcos River, and the Texas salamander (*Eurycea neotenes*), in the Comal River (USFWS 1996a). It was once thought that the latter two species were the same; however, investigations by Chippendale et al. (1992, 1994, and 1998) have indicated that these two populations are genetically different. The San Marcos salamander is currently listed as a threatened species by the TPWD and as a threatened species by the USFWS (USFWS 1996a) (see Table 3.1-3).

San Marcos salamanders were first collected from the San Marcos Springs and described in 1938 by Sherman C. Bishop. They are small, reaching a maximum length of 2.3 inches (58.4 mm), slender, and light brown in color. Prominent features include large eyes with a dark ring around the lens, well-developed and highly pigmented external gills, moderately short and slender limbs, four toes on the forefeet and five on the hind feet, and a well-developed dorsal fin (USFWS 1996a). Water issuing from the springs has a low oxygen content (30-40 percent saturated), causing the external gills of the San Marcos salamander to have a bright red coloration due to increased blood flow through the gills (Tupa and Davis 1976). San Marcos salamanders are distinct when compared to other neotenic *Eurycea* from Texas, in that they are smaller, more slender, have different coloration, greater number of costal grooves (vertical wrinkles in the skin between front and hind legs), larger eyes relative to their head, and fewer teeth (Tupa and Davis 1976; USFWS 1996a).

San Marcos salamanders are found in Spring Lake in rocky areas around spring openings and downstream of the dam at Spring Lake (Tupa and Davis 1976; Nelson 1993). They require clean, clear waters associated with springs in areas of sand, gravel, large rock, and vegetative cover at depth of 3.3 to 6.6 feet (Nelson 1993; USFWS 1996a). Populations have been found in front of the Aquarena Springs Hotel on concrete banks and in boulders which are covered withan aquatic moss (*Leptodictyium riparium*) (USFWS 1996a). Individuals can also be found in *Lyngbya* sp., a filamentous blue-green algae, which covers shallow sandy substrates and provides a good hiding place by means of camouflage for the salamanders (BMWD 1998; USFWS 1996a). Numerous rooted aquatic macrophytes occur on the boundary of the salamander habitat in suitable depths including arrowhead, water primrose, and eelgrass). Numerous individuals are found within these mats of vegetation at the shallow headwater areas. The vegetation provides a food source for the salamander in addition to protective cover for avoidance of predators (larger fish, crayfish, turtles, and aquatic birds) (Tupa and Davis 1976; USFWS 1996a).

Flowing waters are one of the main requirements for the survival of the San Marcos salamander. They prefer waters that are slightly alkaline (pH 7.2), thermally constant 69.8° to 71.6° F (21-22° C), an oxygen saturation of 40-50 percent, and little variation in bicarbonate alkalinity (220-232 mg/l) (Tupa and Davis 1976). The critical habitat has been designated for the San Marcos salamander as Spring Lake and its outflow and the San Marcos River downstream to 164 feet below Spring Lake Dam (USFWS 1996a) (see Figure 3.1-5a).

The main food source of the San Marcos salamander is amphipods and young brine shrimp. Stomach content analyses have shown that San Marcos salamanders feed on tendipedid (midge fly) larvae and pupae, other small insect pupae and naiads, and small aquatic snails. San Marcos salamanders and the fountain darter often occupy the same habitat and pursue their prey in much the same way. These salamanders wait for the prey to come near their head, then snap forward with an open mouth and engulf their prey, indicating a behavior response to sensory cues from living prey (Tupa and Davis 1976).

Male San Marcos salamanders reach sexual maturity when they reach a snout-vent length of 0.74 inch or total length of 1.37 inches (Tupa and Davis 1976). MacKay (1952) found sperm in all mature males from October to May and postulated that they have a breeding season in June and another in the fall. There are four classes of ova in female San Marcos salamanders: very small clear ova, small opaque-white ova, small yellow ova, and large yellow ova. Those that carried large yellow ova were considered ready for oviposition and were found in almost every month of the year. Large yellow ova were present in females with a snout-vent length greater than 0.78 inch or 1.37 inches (Tupa and Davis 1976).

Courtship and egg deposition have not been observed and no eggs have been collected from the San Marcos salamander's natural habitat. However, in the closely related Comal Springs blind salamander (*Eurycea tridentifera*), courtship, oviposition, and hatching have been observed. Typically *Eurycea* breed in the running water of streams, springs, or caves and their adherent eggs are singly deposited on the bottom and sides of vegetation or rocks (USFWS 1996a). Tupa and Davis (1976) and Bogart (1967) performed studies on the San Marcos salamander that suggests they breed most of the year with a peak in late spring (May and June).

Joe Fries

Figure 3.1-14
San Marcos Salamander (*Eurycea nana*)

Dr. Flavius Killebrew

Figure 3.1-15
Cagle's Map Turtle (*Graptemys caglei*)

Attempts to estimate population size have also been made. The San Marcos salamander population found in the shallow area of Spring Lake along the northern bank in front of the Aquarena Springs Hotel was estimated by Tupa and Davis (1976) to be 20,880. In 1991, the population was estimated at 23,200 in the same area, at 25,238 for rocky substrates around spring openings, and at 5,213 for rocky substrates 492 feet (150 m) downstream of the Spring Lake dam, for a total population estimate of 53,651 (Nelson 1993).

3.1.3.9 Cagle's Map Turtle (*Graptemys caglei*)

Cagle's map turtle (*Graptemys caglei*) (Figure 3.1-15) is a highly aquatic species belonging to the family Emydidae and is listed as a candidate species by the U.S. Fish and Wildlife Service. The shell, legs, and face of this species are prominently marked, with black and yellow to cream colored markings. This species is endemic to the Guadalupe River system in Texas. About 60-70 percent of the individuals are found in the middle Guadalupe River between the towns of Seguin and Cuero, Texas, with remaining individuals distributed in the upper and lower Guadalupe River (Killebrew et al. 2002). However, a small population has also been reported in the San Marcos River in Gonzales County (TPWD leaflet; Killebrew 1991).

Due to their specific habitat requirements, Cagle's map turtles require a diverse river habitat for survival. They prefer shallow riffle areas with moderate to swift flow as well as deep pools with a slower flow rate and a sand substrate (TPWD leaflet; Killebrew 1991). Optimum water velocity for the turtle appears to occur at about 2.4 feet per second, with populations declining at higher velocities (Killebrew et al. 2002). Cagle's map turtles also require suitable nesting sites, most of which are found in close proximity to the water's edge on gently sloping sandbanks along sharp bends in the river. During the day they spend a great amount of time basking, and therefore an abundance of basking areas are essential to provide suitable habitat (Killebrew 1991).

Males spend most of their time feeding underwater in the shallow riffle areas, whereas females and juveniles feed in the deeper, siltier pool areas (Killebrew 1991). Male Cagle's map turtles feed on caddisfly larvae (an aquatic insect) and terrestrial insects when available, whereas females feed mainly on Asiatic clams, snails, and some insects (TPWD leaflet; Killebrew 1991). Highest concentrations of turtles appear to be correlated with an abundance of streamside willow (*Salix* spp.) providing submerged, exposed root habitat for insect (*Trichoptera)* larvae of the family Leptoceridae, a major food source (Killebrew et al. 2002). After nesting season in the fall, female Cagle's map turtles consume high numbers of mollusks which are thought to replace calcium lost during egg formation (TPWD leaflet).

Little is known about the reproductive biology of the Cagle's map turtle, but observations indicate that they nest during late spring and early summer, with an average clutch size of three eggs. Only one clutch is produced per year with nests found on sandy, gently sloping banks of the river. The decline of the Cagle's map turtle has been attributed to loss of habitat from reservoir construction, water diversions, alteration of the shoreline for recreational and home sites, pollution, intentional shooting, and collection for the pet trade (TPWD leaflet). Findings from Killebrew et al. (2002) suggest changes in stream flow resulting from operation of on-channel dams in support of hydroelectric generation, may have greater adverse effect on the turtle than prolonged low flow conditions. Sudden higher velocities tend to scour banks displacing basking sites and creating conditions that would result in the flooding of prime nest sites, resulting in decreased production and increased predation. Sudden lower flows would result in exposure of riffle areas, increasing mortality of those aquatic organisms that are food sources of the turtle. Observations by Killebrew et al. (2002) suggest a drought across the Guadalupe River drainage basin in 1995 and 1996 reduced the amount of water released from hydroelectric dams in the study site. Although there was less water flow through the downstream study site, it appeared to be a stable flow allowing the Guadalupe River to recover during 1995 and 1996, increasing the population of *Graptemys caglei* and resulting basking counts in 1997.

3.1.3.10 Whooping Crane (*Grus americana*)

The tallest bird in North America, the whooping crane (*Grus americana*) (Figure 3.1-16) is one of the most well known species protected under the Endangered Species Act. Adult birds stand nearly 5 feet tall, and display a seven-foot wingspan. Coloration is mostly white with some red and black on the head. The wings have conspicuous black wing tips.

The whooping crane was listed as endangered in 1970. The cranes became endangered because much of their habitat in the native prairies and potholes was lost to agricultural production and other human-induced change. From 1870 to 1920, many whooping cranes were shot for food and sport.

Whooping crane numbers fell from as many as 1,400 in 1870 to only 18 in 1939 (Campbell 1995). As of April 24, 2003, there were 419 known whooping cranes, consisting of 300 that exist in the wild, with 119 in captivity (Whooping Crane Conservation Association 2003). Whooping cranes in the wild are distributed among three populations. The largest and only historical population remaining winters from November to April on or near the Aransas National Wildlife Refuge near Rockport on the Texas Gulf Coast. This flock, consisting of 184 cranes in 2003, nests in the wetlands of Wood Buffalo National Park in the Northwest Territories of northern Canada. The second flock includes 95 non-migratory birds in the Kissimmee Prairie of Florida.

The third flock, comprising 21 cranes, migrates from the Nacedah National Wildlife Refuge in Wisconsin to Florida for the winter. A Rocky Mountain flock that migrated from Grays Lake National Wildlife Refuge in southeastern Idaho to the middle Rio Grande Valley of New Mexico has failed due to inadequate reproductive success.

Cranes live in family groups made up of the parents and 1 or 2 offspring. In the spring, whooping cranes perform courtship displays (loud calling, wing flapping, leaps in the air) prior to nesting. Wintering cranes feed mainly in the fresh, brackish, and saltwater bay and marsh habitats, but


Photo Courtesy of Texas Parks and Wildlife (c) 2000, Bill Reaves

Figure 3.1-16
Whooping Crane *(Grus americana)*

also fly to upland sites to feed. Feeding behavior is governed by the availability of food items that can be diverse. The winter diet includes blue crabs *(Callinectes sapidus)*, clams, frogs, minnows, rodents, small birds, insects, and herbaceous material including berries. Recent studies suggest that abundance and availability of blue crabs (a major winter food source) may affect the health and survival of wintering cranes (Stehn 2001). As blue crab production is affected in part from freshwater inflow into the Guadalupe and San Antonio Bay systems, there is concern about the indirect effects of reduced flows into the bays on whooping crane populations through changes in blue crab production and its availability as a food source.

Two major studies are currently examining the effects of Guadalupe River instream flows on ecological components of the Guadalupe Estuary. The first study, commissioned by the Guadalupe-Blanco River Authority, is investigating whooping crane habitat and effects of changes in freshwater flows on whooping crane populations. The second study has been initiated by the San Antonio River Authority to evaluate the biological productivity of the San Antonio Bay and Estuary and conduct detailed research to determine the freshwater inflow requirements necessary to support the estuary. Both studies are on-going in 2003 and are part of the environmental evaluation of the Lower Guadalupe River Diversion Project (Appendix A, Section 3.2.6) (GBRA 2002).

Preliminary information comparing winter whooping crane population numbers with changes in freshwater inflow into the Guadalupe Estuary (HDR 2002) is illustrated by Figure 3.1-17. Although the health of whooping cranes may be affected by the abundance and availability of blue crabs (crab production is influenced by freshwater inflow in addition to predation, commercial harvest, and other biotic and abiotic factors), Figure 3.1-17 suggests little direct correlation ($r = 0.151$) between freshwater inflow and the number of wintering whooping cranes for the analysis period 1938-2001. Subsequent take of wintering whooping cranes from reduced nutrition through reduced estuarine productivity would be an indirect impact from decreased springflow in combination with other factors. These factors would range from reduced stream flow into the estuary by reduced rainfall within the watersheds of the Guadalupe and San Antonio Rivers, and downstream river diversions for agricultural, municipal, and industrial uses, to other biotic and abiotic factors affecting estuarine productivity. These factors cloud the indirect effects of springflow on the health of whooping cranes, thus preventing estimates of take related directly to springflow. However, to the extent that springflow can be protected, adverse effects of reduced freshwater inflow to estuarine productivity and resulting nutrition of wintering cranes would be mitigated.

3.1.4 Species of Concern/Proposed for Listing

There are many species within the EAHCP Planning Area that are considered species of concern or are proposed for listing as threatened or endangered (see Table 3.1-3). Species of concern are those for which there are not enough data to support listing but which have been identified as species with declining populations, specialized habitat requirements, or widespread habitat alterations. Proposed for listing indicates a species that is currently being considered by the USFWS for listing as threatened or endangered. The following sections provide a brief summary of the locations, habitat requirements, and morphological descriptions of these species.

3.1.4.1 Species of Concern

Aquatic Invertebrates

The Balcones Cave amphipod (*Stygobromus balconis*) is a fairly large troglobitic species that can be found in caves in Hays County. This amphipod prefers the quiet water of pools containing an abundance of organic debris and silt which serves as an important nutrient source. This amphipod appears to be an isolated remnant of *S. americanus* whose range once extended into Texas but is now found only in Oklahoma, Arkansas, Missouri, and Louisiana. There is morphological evidence to suggest that the Balcones Cave amphipod is still undergoing further speciation (formation of a new biological species) within its current range (Holsinger 1966).

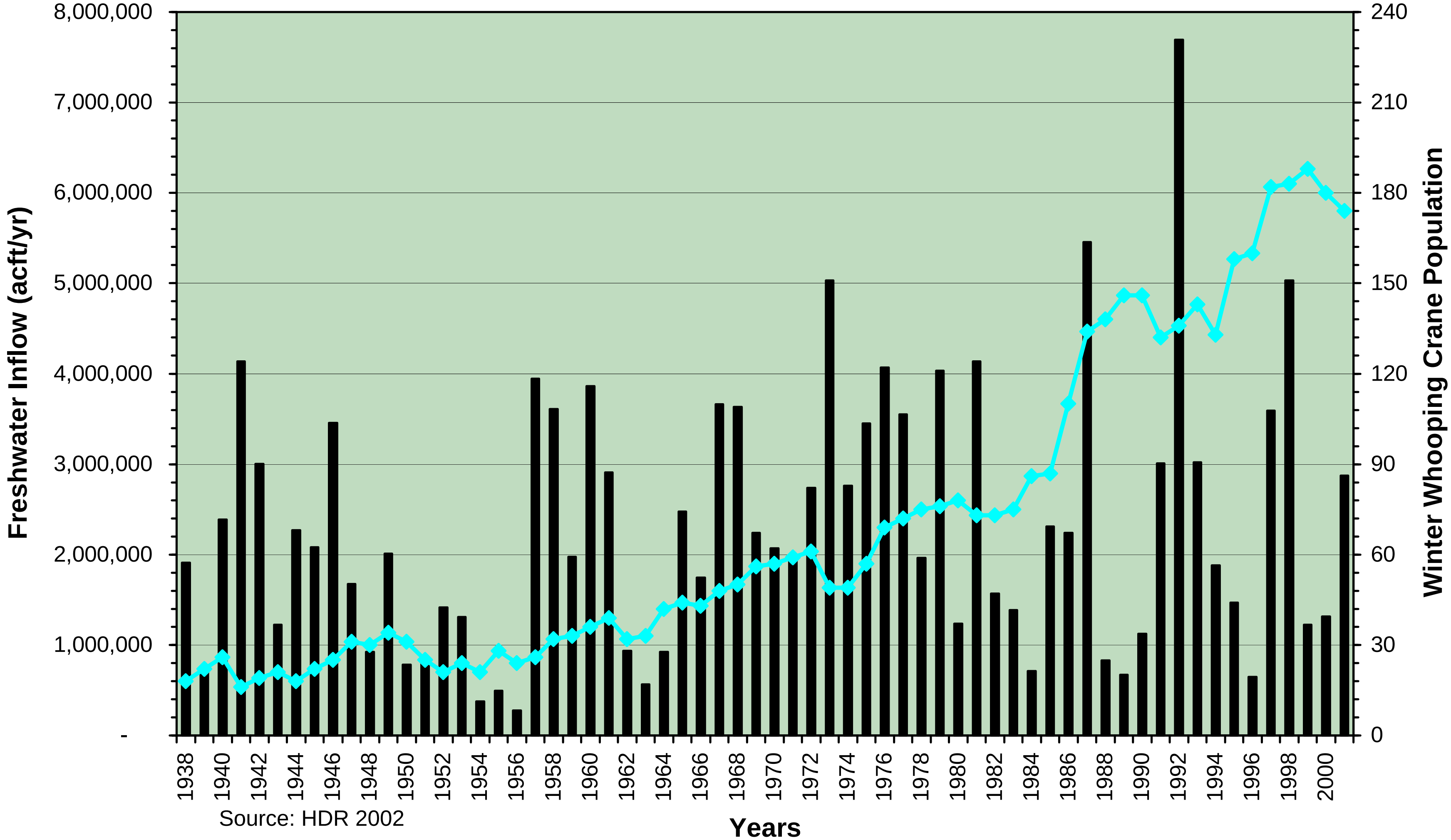
Ezell's Cave amphipod (*Stygobromus flagellatus*) is only known from the Artesian Well at the Texas State University Aquatic Station, Ezell's Cave, Rattlesnake Cave, and San Marcos Springs in Hays county (J.R. Holsinger, personal communication). They are restricted to the subterranean waters of the Edwards Aquifer and very little is known about their specific habitat requirements (Linam 1995).

The Edwards Aquifer diving beetle (*Haideoporus texanus*), also known as Texas cave diving beetle, is restricted to the subterranean waters of the Edwards Aquifer in Hays and Comal counties. Previously, this species was only known from an artesian well on the campus of Texas State University. Recent collections yielded this beetle from Comal Springs and it appears to be more widely distributed in the Edwards Aquifer than previously thought (Bowles and Stanford 1997). The Texas cave diving beetle is the first blind, depigmented, aquifer-adapted water beetle known from North America. They have reduced, nonfunctional eyes and a greater development of sensory setae (hairs) on their wings, legs, and mouth area (Young and Longley 1975).

Another species of concern is the Texas cave shrimp (*Palaemonetes antrorum*). The Texas cave shrimp is one of nine known species of freshwater *Palaemonetes* in North America (Strenth et al. 1988). Extensive research has been conducted to evaluate larval development and reproductive patterns of this subterranean shrimp (Strenth et al. 1988; Strenth and Longley 1990).

The San Marcos saddle-case caddisfly (*Protoptila arca*) is only known from the spring-influenced sections of the San Marcos River in Hays County and has a highly restricted range (Moulton 1996). It requires thermally stable, oxygen-saturated, swift-flowing waters and prefers bare rock bottom habitats. The larvae of this species prefer rocky substrates and woody debris for grazing, and fine gravel and sand areas for constructing the larval cases (Linam 1995; EH & A 1975). Very little is known about the morphology and life history of the San Marcos saddle-case caddisfly.

Figure 3.1-17 Relationship Between Winter Whooping Crane Populations and Freshwater Inflow into the Guadalupe Estuary



Source: HDR 2002

Finally, the mimic cavesnail (*Phreatodrobia imitata*) is restricted to subterranean and immediate surface waters of the Edwards Aquifer. It is only found from Verstraeten Well and O.R. Mitchell Well in the Van Ormy Section of Bexar County (Linam 1995). The shell of this species is elongate-conical and about 0.04 inch (1.0 mm) in length (Hershler and Longley 1986). Little information has been published on the mimic cavesnail and very little is known about the life history of this species.

Aquatic Vertebrates

The Comal blind salamander (*Eurycea tridentifera*) is a troglobitic species found in the Cibolo sinkhole plain area of Comal, Kendall, and Bexar counties (Chippindale et al. 1992). This slender-bodied salamander ranges in size from 1.5 to 2.8 inches, has reduced eyes and pigmentation, red external gills, elongated limbs, and a finned tail (Mitchell and Reddell 1965). In captivity, the courtship behavior, oviposition, and hatching of this species have been observed. Their eggs were deposited on plant material, rocks, and the bottom of a glass aquarium 24 hours after courtship, and hatched 18-23 days later. The Comal blind salamander successfully reproduced at the Dallas Aquarium in artificial spring upwellings. Typically *Eurycea* breed in the running water of streams, springs, or caves and their adherent eggs are singly deposited on the bottom and sides of vegetation or rocks (USFWS 1996a).

Another species of concern is the robust (Blanco) blind salamander (*Eurycea robusta*), which inhabits subterranean streams and has only been found beneath the Blanco River in Hays County. This salamander is a stout-bodied (about 4 inches long), depigmented paedogenetic (producing young while in the immature or larval state) salamander with thin, elongate limbs, reduced eyes, and a thick finned tail tapering at the tip (University of Texas at Austin 2000).

The Texas salamander (*Eurycea neotenes*) can be found in the southern portions of the Edwards Plateau in Bexar, Hays, Kendall, Kinney, Medina and Uvalde Counties. This strictly aquatic species occurs in surface springs, caves, and creek headwaters located under rocks, gravel and leaves (Chippindale et al. 1992; Bruce 1976; Sweet 1982). These salamanders have a slender body, short limbs, are light brown to yellowish in color, have a finned tail, and long and slender gills. They reach an average length of 2.8 inches (Bishop 1962).

A population of salamanders is currently found in the Comal springs ecosystem. This population was initially identified as *E. nana* (Sweet 1978) but further genetic work is required to determine the official classification of this species as it relates to *E. nana*, *E. neotenes*, and *E. rathbuni* (Chippindale et al. 1992). Thus, this population is currently referred to as the Comal Springs salamander (*Eurycea sp.*) As with *E. nana* and *E. neotenes*, this species is found under rocks, gravel, leaves, and aquatic vegetation associated with either horizontal or upwelling springflow.

The blue sucker (*Cycleptus elongatus*) is found in the Edwards Plateau region of Hays, Kinney, Uvalde, and Val Verde Counties. This fish can grow to 31 inches in length and inhabits deep river channels, pools with slow currents, and some lakes. This species prefers runs-riffles in large rivers and is well adapted to this habitat due to its shape, fin placement, and muscular body. The blue sucker is a bottom feeder on midge and caddisfly larvae, fingernail clams, algae, and other plant material. It has been suggested that the construction of dams has contributed to the decline of the species by blocking spawning migration and inundating spawning areas (Lee et al. 1980).

The widemouth blindcat (*Satan eurystomus*) is found in the Edwards Aquifer in the southern portions of Bexar County at depths as great as 2000 feet of water. Like the toothless blindcat (*Trogloglanis pattersoni*), it lacks eyes, pigmentation, and has a reduced swim bladder, although it averages slightly larger in size at 4.5 inches. The widemouth blindcat is a top carnivore in this section of the aquifer feeding mainly on decapods, isopods, amphipods, and possibly the toothless blindcat (Longley and Karnei 1978b).

The toothless blindcat (*Trogloglanis pattersoni*) is one of the most highly specialized catfish known and represents one of the two troglobitic catfish found in North America, the other being the previously discussed widemouth blindcat. It can be found in artesian wells over 1000 feet deep, in the San Antonio pool of the Edwards Aquifer, in the southern portions of Bexar County. This species averages 3.4 inches in length, has reduced eyes, no pigmentation, no air bladder, and a highly specialized mouth. The toothless blindcat is thought to be herbivorous, feeding on fungal growth and dead or dying organisms (Longley and Karnei 1978a).

Terrestrial Invertebrates

The two terrestrial invertebrates listed as species of concern have very little published information describing their morphological characteristics or habitat requirements. The first is the horseshoe liptooth (*Polygyra hippocrepsis*), a terrestrial snail that is only known to occur in Comal County at two locations. It has a restricted distribution and is considered to be very rare (Linam 1995). The other species is the maculated manfreda skipper (*Stallingsia maculosus*), a butterfly found throughout the Edwards Aquifer region. It can be found in semi-arid areas in association with its larval food plant *Manfreda maculosa* (Linam 1995).

3.1.4.2 Other Species

Two additional endangered species, the Barton Springs salamander (*Eurycea sosorum*) and Comanche Springs pupfish (*Cyprinodon elegans*), are mentioned even though they do not directly occur within the EAHCP Planning Area.

The Barton Springs salamander is found in Travis County and federally-listed as endangered. While not occurring in the EAHCP Planning Area, this salamander may be affected by activities within the Barton Springs segment of the Edwards Aquifer, which includes portions of northern Hays County. This species is found in two hydrologically connected sets of springs in and adjacent to Austin's Barton Springs swimming pool. The Barton Springs salamander is strictly aquatic and found among rocks in the spring outflow. It has a slender body, elongated limbs, red external gills, and is a yellowish cream ground color with olive brown mottling (Chippindale et al. 1992).

The endangered Comanche Springs pupfish (*Cyprinodon elegans*) is restricted to San Solomon and Phantom Cave springs, downstream irrigation channels, and Lake Balmorhea in Reeves County. These fish are adapted to harsh desert conditions and can tolerate a wide range of salinities and temperatures. They can grow up to 2 inches (50 mm) in length, feed on algae and small invertebrates, and live one to two years. This species is listed as occurring in Uvalde County because it is raised at the Uvalde National Fish Hatchery (Mary Orms, USFWS, personal communication).

3.2 Physical Environment

3.2.1 Climate

The prevailing climate of the EAHCP Planning Area is classified as Subtropical Subhumid; however, the region lies within a transitional zone between a semi-arid climate to the west and a more humid climate to the east (Larkin and Bomar 1983) (Figure 3.2-1). The Subtropical Subhumid climate type is characterized in general by long, hot summers and short, mild winters. Western parts of the region are influenced by a Subtropical Steppe climate, characterized by semi-arid to arid conditions. Eastern parts of the region, influenced by a Subtropical Humid climate, have higher humidity and experience slightly milder summers. Regional prevailing winds are generally southerly, except during winter, when they are frequently from the north. Latitude, elevation, and proximity to the Gulf of Mexico influence the climate of the region.

Average annual precipitation within the region varies from about 20 inches in western Kinney County to about 40 inches in Calhoun County (Figure 3.2-2); however, in some years the region may receive as much as 50 inches or as little as 10 inches of precipitation (National Oceanic and Atmospheric Administration 2000). On average, the Edwards Aquifer Recharge Zone (EARZ) receives an annual average rainfall of about 30 inches per year (Edwards Aquifer Authority 2003c). Historically, precipitation is highest during May and September. Stalled cool fronts and summer tropical storms may result in increased precipitation amounts. Regional surface water features are subject to evaporation, especially during hot summer months. Average regional monthly gross lake-surface evaporation ranges from approximately 2.5 inches in January to over 9 inches in August (Larkin and Bomar 1983). Evapotranspiration percentages vary throughout the region, with an average of approximately 85 to 90 percent of regional precipitation lost through evapotranspiration (Maclay 1995).

The regional average annual temperature is about 68° Fahrenheit (F) (Figure 3.2-3). Winters are generally mild with average monthly low temperatures ranging from 35.9° F at San Marcos to 61.6° F at Port Lavaca (Larkin and Bomar 1983). Below freezing temperatures occur on average about 20 days each year (National Oceanic and Atmospheric Administration 2000). Summers are hot with average monthly high temperatures ranging from 90.6° F at Port Lavaca to 97.1° F at Uvalde (Larkin and Bomar 1983). Summertime temperatures commonly exceed 100° F.

3.2.1.1 Frequency of Tropical Storms

Tropical storms, including hurricanes, hit the Texas Gulf Coast at a frequency of about 0.67 storms per year (Brown et al. 1974). Occasionally these storms move inland while dissipating, resulting in severe weather over the region. Moisture-laden air masses move inland from the Gulf of Mexico and are forced to rise at the Balcones Escarpment and EARZ, resulting in some of the largest storms ever recorded in the United States. High winds, excessive rainfall, hail, and tornadoes may result from these tropical storms. Flash flooding is common after thunderstorms that produce large amounts of precipitation in a relatively short period of time. One such instance was flooding associated with Hurricane Amelia in August 1978. Between August 1 and 3, 1978, more than 48 inches of rain fell on a ranch in Medina County, the highest three-day precipitation total ever recorded in the U.S. (Caran and Baker 1986).

3.2.1.2 Frequency of Droughts

Serious droughts have been recorded in some parts of Texas in every decade since 1900. Droughts usually result from lower than normal precipitation levels; however, years with above average precipitation totals may experience drought conditions especially after dry periods when increased groundwater pumping results in a shortage of water. Therefore, reporting the *annual average amount of rainfall* does not represent the occurrence of droughts or the impacts that droughts have on the aquifer and the living organisms dependent upon it. Averaging the rainfall data tends to mask the duration and intensity of droughts. In addition, the lack of long-term rainfall data for the area hampers long-term analysis of droughts in the region (Mauldin 2003).

Droughts vary significantly in duration and intensity. At least five droughts of extended duration and extreme intensity have occurred since 1931 in the EAHCP Planning Area (Riggio 1987).

Numerous droughts of shorter duration and less intensity have also been recorded. Between 1931 and 1985 the frequency of occurrence of the three-month drought in the Edwards Plateau region varied from 62 to 70 occurrences, depending on location. During the same period, the frequency of occurrence of the six-month drought varied between 32 and 40 occurrences (Riggio et al 1987). Less than 24 occurrences of the 12-month drought were recorded between 1931 and 1985 (Riggio et al 1987). Although droughts are cyclic in nature, they are not consistent in frequency.

The six-year drought that occurred from 1951 through 1956 is considered the "drought of record" (DOR) for the Edwards Aquifer. This drought resulted in the only known cessation of flow of Comal Springs in 1956, for 144 days (Longley 1995). To better understand the DOR and how it relates to the long-term climate of the aquifer, a study utilizing dendrochronology was conducted on existing data bases to evaluate historic drought patterns in the aquifer region

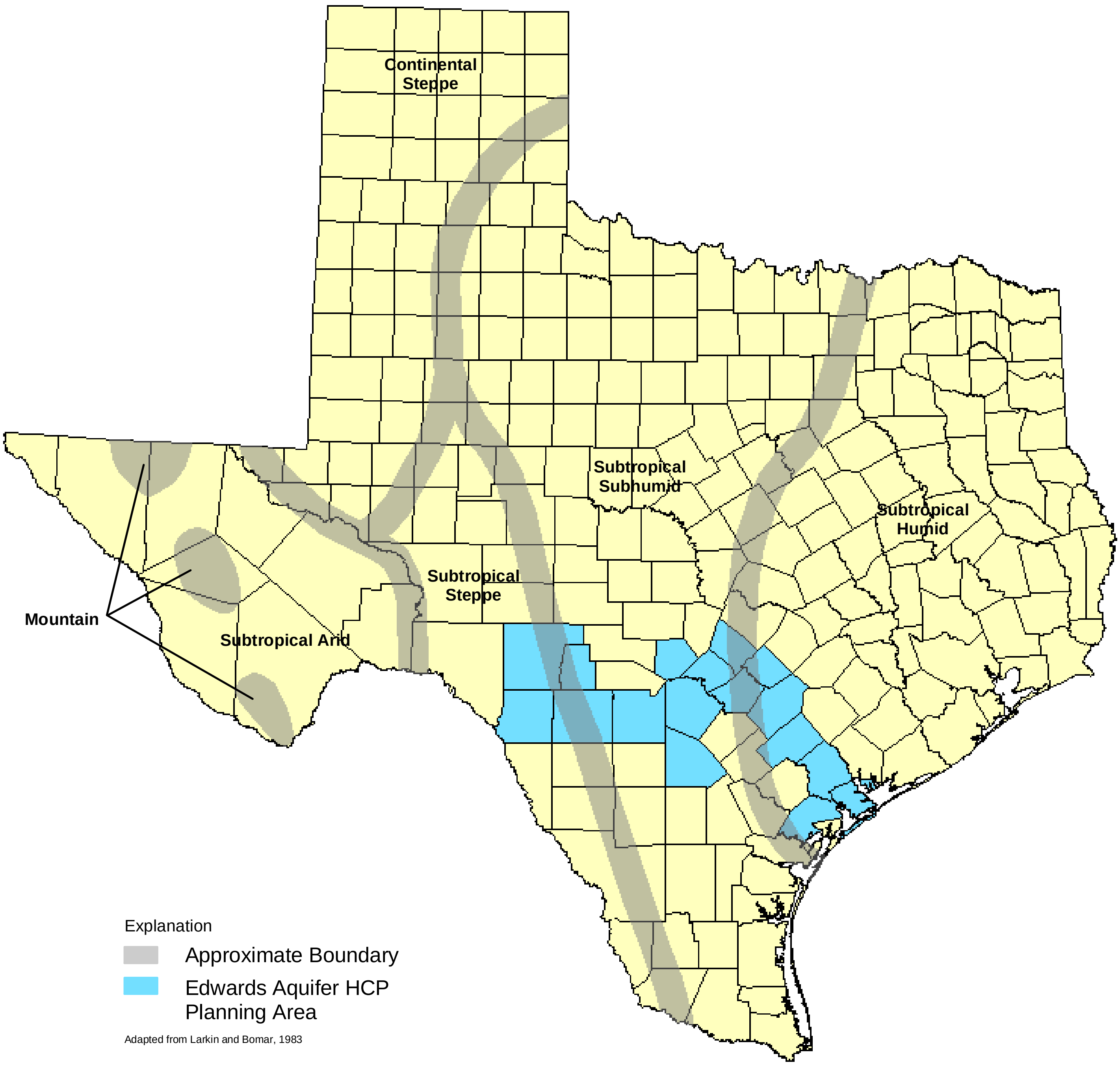
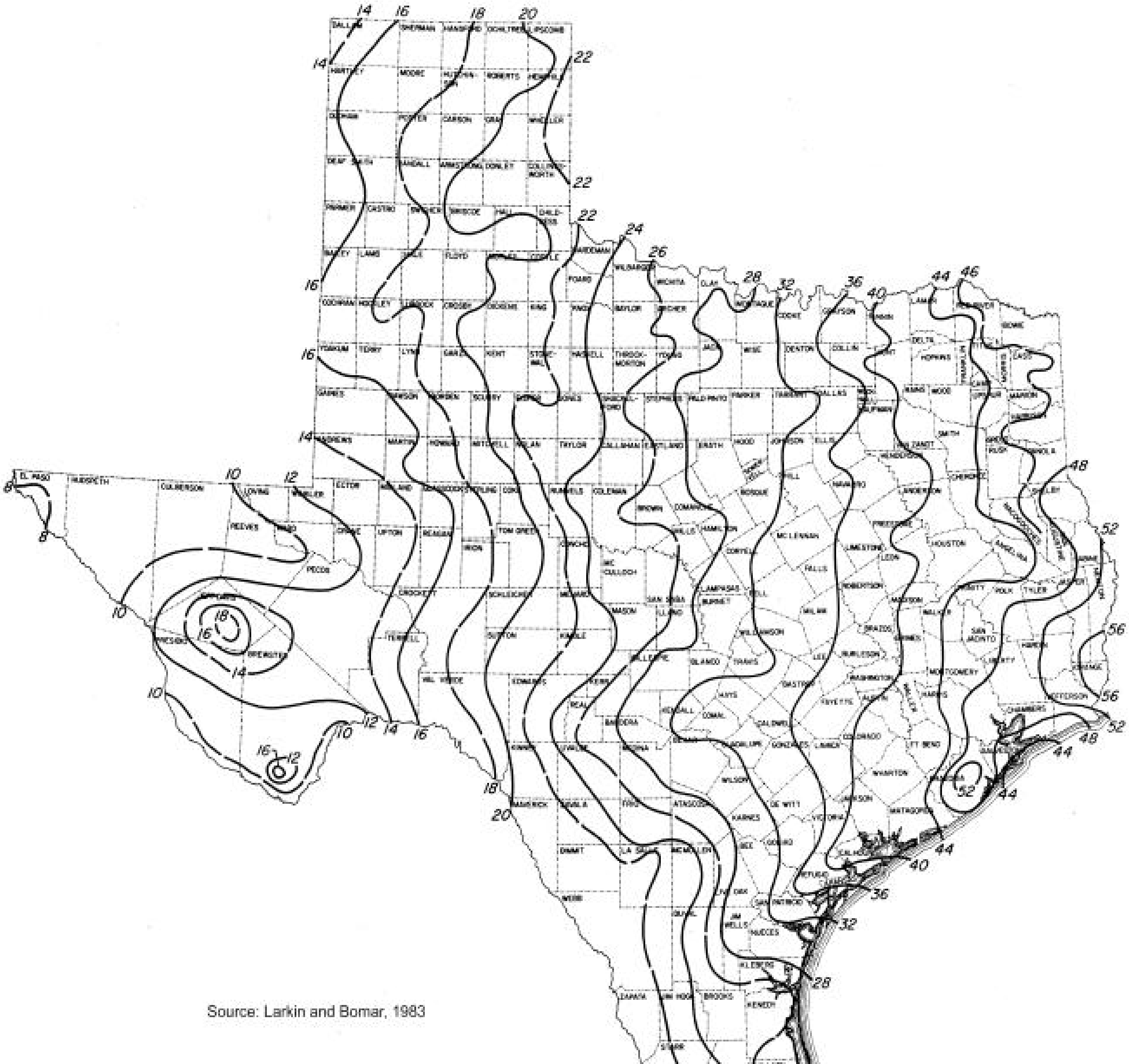
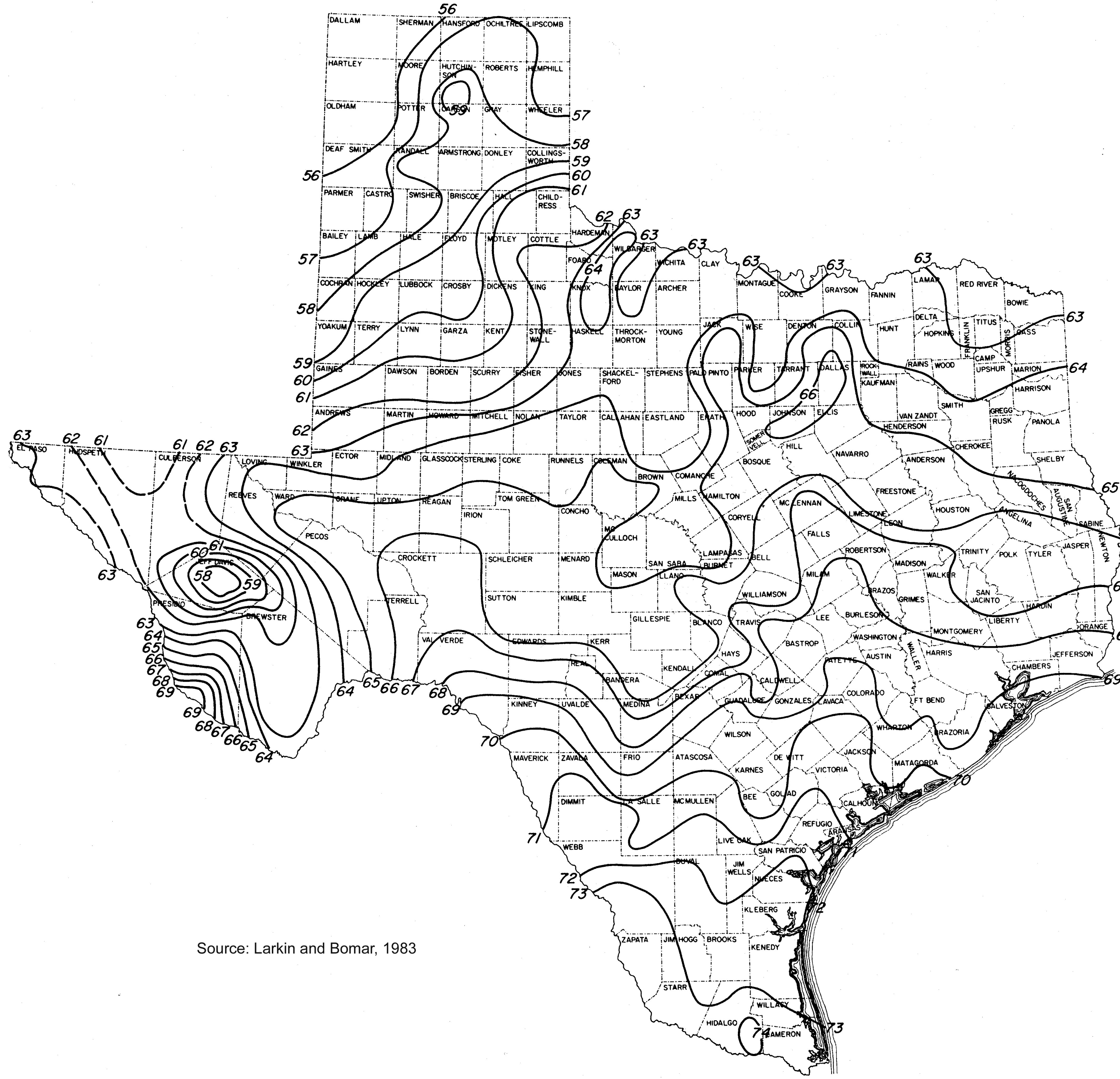


Figure 3.2-1 Climatic Regions of Texas



Source: Larkin and Bomar, 1983

Figure 3.2-2 Average Annual Precipitation In Inches, 1951-1980



Source: Larkin and Bomar, 1983

Figure 3.2-3 Average Annual Temperature (F°), 1951-1980

(Mauldin 2003). Dendrochronlogy is the use of tree-ring analysis to evaluate historic climatic conditions. It is an established, critical element of climate research (Blasing and Fritts 1976; Robinson 1976; Stahle et al. 1985; Stahle and Cleaveland 1988; Cook et al. 1999). An extensive data base of tree-ring data for the southwest was used in the analysis (Cook 2000). Data collected from existing data bases was correlated with the Palmer Drought Severity Index (PDSI) for a 280-year period (1700 – 1979). The PDSI is a standard measure of soil moisture conditions used to classify drought frequency, intensity and duration. It has a range of –4.0 to 4.0, with an average year falling between -0.5 and 0.5. Droughts are defined as –1.0 through –4.0. Over the 280-year period studied, 25.7% of the years were drought years (Mauldin 2003).

Although there are insufficient scientific techniques to accurately predict droughts, several conclusions may be drawn from this best available data. Droughts are not uncommon to the aquifer region; however they are usually short in duration and are generally not too intense. In the time period 1700 through 1979, the aquifer region experienced forty droughts of various lengths. The duration of the average drought was 1.8 years, while droughts that lasted only 1 year were more common. Long-term droughts, defined as those exceeding 3 years in duration, occurred only four times, and three of those were in the 1700's. The fourth, long-term drought was the DOR (1951 – 1956), which lasted 6 years. The DOR was the most intense long-term drought (-2.32 average PDSI, peaking about -3.1); however, six other droughts were more intense for shorter durations (PDSI > -3.1; Mauldin 2003). Therrell (2000) also using tree-ring analysis, concluded that the DOR was the most prolonged period of sustained drought in the past 347 years. The DOR, therefore, appears to be an anomaly, representing only 2.1% of the 280-year period analyzed and only 2.5% of the forty droughts.

3.2.2 Geology

A regional discussion of physiography and geologic history is provided, followed by a more detailed discussion of specific features that most influence the ecosystems associated with the Edwards Aquifer, San Marcos Springs, and Comal Springs.

3.2.2.1 Regional Physiography and Geologic History

The EAHCP Planning Area lies along a physiographic borderland formed by the Balcones Escarpment. This boundary between physiographic regions is evident in the change from the Gulf Coastal Plains and Blackland Prairies on the east to the Edwards Plateau/Hill Country on the west (Figures 3.1-1 and 3.2-4). Across this geographic boundary are changes in almost all the natural attributes of the land—climate, surface water, groundwater, soils, flora, and fauna. Limestone plateaus, a predominant oak-juniper savannah, thin soils, and narrow watercourses in steep canyons characterize the Edwards Plateau region west of the Balcones Escarpment. Terrain is typically steep and rugged, resulting from the numerous streams that dissect the plateau. Groundwater is relatively shallow and occurs from several strata. In contrast, areas east of the escarpment are overlain by deep, fertile soils of the Blackland Prairies and Gulf Coast Prairie and Marshes. These clay soils are highly productive and support intensive agriculture.

The prevailing terrain is generally level to gently rolling and cut by meandering, low-gradient streams. Groundwater is generally deep and may be tepid and brackish. Total relief within the Edwards Aquifer EAHCP Planning Area varies considerably, from mean sea level in Calhoun County to as high as 2,000 feet above mean sea level (msl) in northern Uvalde County.

The Balcones Escarpment is the surface expression of the buried Ouachita Mountain belt, the remnants of which may be seen in Oklahoma, Arkansas, and the Trans-Pecos region of Texas. During the Paleozoic Era, approximately 300 million years ago, tectonic upheavals associated with the collision of North America with parts of South or Central America formed the mountain belt bisecting Texas from north to south. Later, during the Mesozoic Era, the mountains eroded and subsided as rifting occurred and the Gulf of Mexico began to form. Strata of limestone, sandstone, and shale were deposited in the newly formed Gulf of Mexico and buried the roots of this mountain belt.

During the Cretaceous Period a shallow sea covered much of the region. A large barrier reef, the Stuart City Reef, paralleled the coastline and formed a large interior sea, separated from the Gulf of Mexico. Sediments were slowly deposited in this interior sea, eventually forming the strata of limestones, dolomite, and marls present today. These strata of limestones form the Edwards Group, which makes up the bedrock of the Edwards Aquifer.

After the Cretaceous sea retreated, rivers and streams draining the land surface brought sand and mud towards the coast, forming a system of deltas. The prograding deltas began to fill in the coastline until they eventually extended over 250 miles into the Gulf of Mexico. Tertiary-aged clastic sediments were deposited and formed the Gulf Coastal Plains. Later, during the mid-Cenozoic Era, faulting along the buried Ouachita Mountain belt resulted in the dislocation of overlying strata, forming the Balcones Fault Zone. Younger strata were displaced downward toward the Gulf of Mexico and older strata remained higher west of the line, forming the escarpment present today. Present-day rivers and streams in the region meander back and forth, continuously depositing eroded material from upstream and forming large alluvial floodplain and terrace deposits.

3.2.2.2 Edwards Aquifer

Stratigraphy of the confined Edwards Aquifer at Comal and San Marcos Springs is portrayed by Figure 3.2-5. Various strata of limestones, wackestones, dolomite, grainstones, nodular chert, and collapsed breccias make up the aquifer lithology (Ogden et al. 1986). The aquifer is basally confined by the Glen Rose Formation, which is divided into upper and lower units (see Figure 3.2-5). Alternating beds of limestone, dolomite, and marl of the upper unit overlie the lower unit, consisting of limestones and marl. Both units are fossiliferous. The Bureau of Economic Geology (1983) further describes the aquifer as follows. The average thickness is approximately 900 feet. Above the Glen Rose Formation is the Edwards Group, including the Kainer and Person Formations. The lower Kainer Formation consists primarily of honeycombed limestones, averaging approximately 250 feet thick. The upper Person Formation consists primarily of

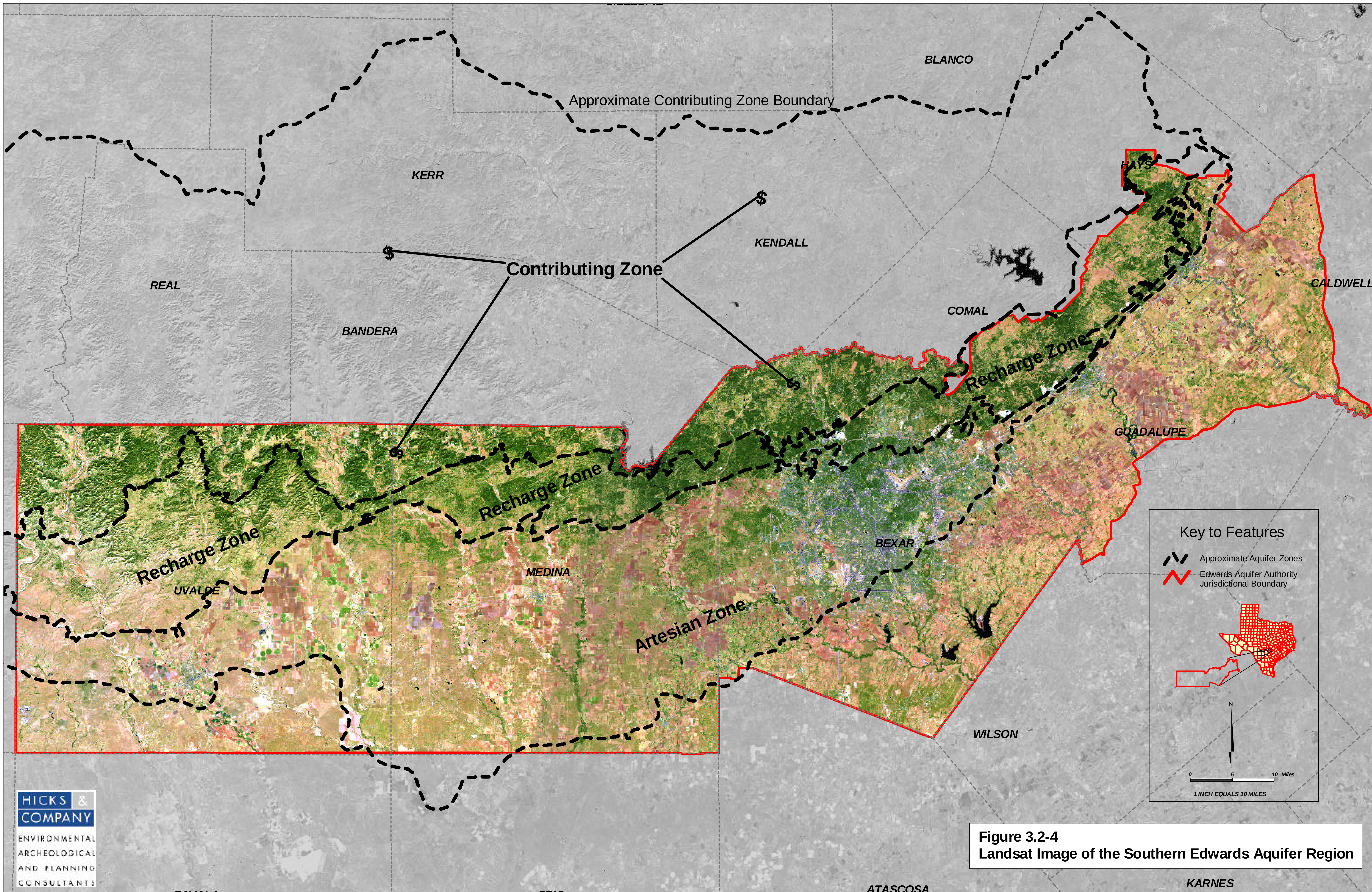


Figure 3.2-4
Landsat Image of the Southern Edwards Aquifer Region

System	Series	Group	Formation	Member	Thickness (ft)	Lithology
Qua-ternary			Alluvium		45	Gravel, sand, and silt
			Terrace Deposits		30	Coarse gravel, sand, and silt
Cretaceous	Gulf	Navarro			500	Upper: marl, sand, and clay Lower: chalky limestone and marl
		Taylor			300-500	
		Austin			200-350	Chalk, marl, and hard limestone
		Eagle Ford			50	Upper: flaggy limestone, shale Lower: siltstone, sandstone
	Comanche	Washita	Buda Limestone and Del Rio Clay		100-200	Upper: dense, hard, nodular limestone Lower: clay
			Georgetown Limestone		20-60	Dense argillaceous limestone with pyrite
		Edwards	Person	Marine/Cyclic	90-150	Limestone and dolomite chalky and recrystallized mix
				Leached/ Collapsed	60-90	Recrystallized dolomite, limestone
				Regional Dense	20-30	Dense, argillaceous limestone
			Kainer	Grainstone	50-60	Limestone, hard, milioloid grainstone
				Dolomitic	150-200	Limestone, calcified dolomite, Kirshberg evaporites
				Basal Nodular	40-70	Limestone: hard, dense, nodular, mottled, and stylolitic
		Trinity	Glen Rose	Upper Member	300-400	Limestone, dolomite, shale, marl
				Lower Member	200-250	Massive limestone with marl beds

Figure 3.2-5 Stratigraphy of the Confined Edwards Aquifer at Comal and San Marcos Springs (after Maclay and Small, 1986 and Crowe, 1994).

shaley, clayey limestone, with an average thickness of approximately 150 feet. The Edwards Group of limestones, dolomites and marls are porous and permeable and form the majority of the Edwards Aquifer. A hydrogeological cross section of the San Antonio segment of the Edwards Aquifer is shown in Figure 3.2-6. Above the Edwards Group is the Georgetown Formation, which is similar in composition to limestones of the Edwards Group and comprises the remainder of the aquifer bedrock. The average thickness is approximately 30 feet. Overlying the Georgetown Formation is the Del Rio Formation, a fossiliferous clay and shale layer forming the upper confining unit of the Edwards Aquifer, and averaging approximately 55 feet thick.

The Balcones Fault Zone is the major structural feature of the aquifer system. Numerous fractures associated with the fault zone cut through the various strata, creating porosity and permeability. Displacement in some areas has offset the aquifer considerably, such as in areas along the Comal Springs Fault (Figure 3.2-7). Major karstification of the Edwards Group occurred during the Cretaceous Period, when exposed limestone was dissolved through solution, creating an extensive honeycombed system of voids and pores, including extensive caverns. This karstification process continues today.

3.2.2.3 San Marcos Springs

Data on the geology of San Marcos Springs and vicinity were taken from Geologic Atlas of Texas maps (Bureau of Economic Geology 1974a, 1974b, and 1983), and publications by W.F. Guyton and Associates (1979), and Crowe (1994). A map showing the local surface geology is included as Figure 3.2-7 and a stratigraphic cross section of San Marcos Springs is included as Figure 3.2-8. A list of local surface formations and their properties is included in Table 3.2-1. San Marcos Springs lie at the base of the Balcones escarpment, within the Balcones Fault Zone. The springs issue from Edwards Group limestones along the San Marcos Springs Fault. This fault displaces the Austin and Taylor Groups against the Person (upper) Formation of the Edwards Group, Georgetown, and Del Rio Formations (see Figure 3.2-7) (Guyton, W.F. and Associates 1979).

To the southeast of the San Marcos Springs Fault the ground is faulted again along the Comal Springs Fault. Formations in the vicinity include the Person Formation, Georgetown Formation, Del Rio Formation, and Buda Formation, as well as rocks of the Eagle Ford Group. Quaternary colluvium accumulates locally on hillsides. Broad surface deposits of Quaternary alluvium cover areas southeast of the San Marcos Springs Fault, concealing the local bedrock. The elevation of the top of the Edwards Group varies from approximately 575 feet msl northwest of the San Marcos Springs Fault to 230 feet msl just southeast of the fault, and to approximately 40 feet below sea level southeast of the Comal Springs Fault (Guyton, W.F. and Associates 1979).

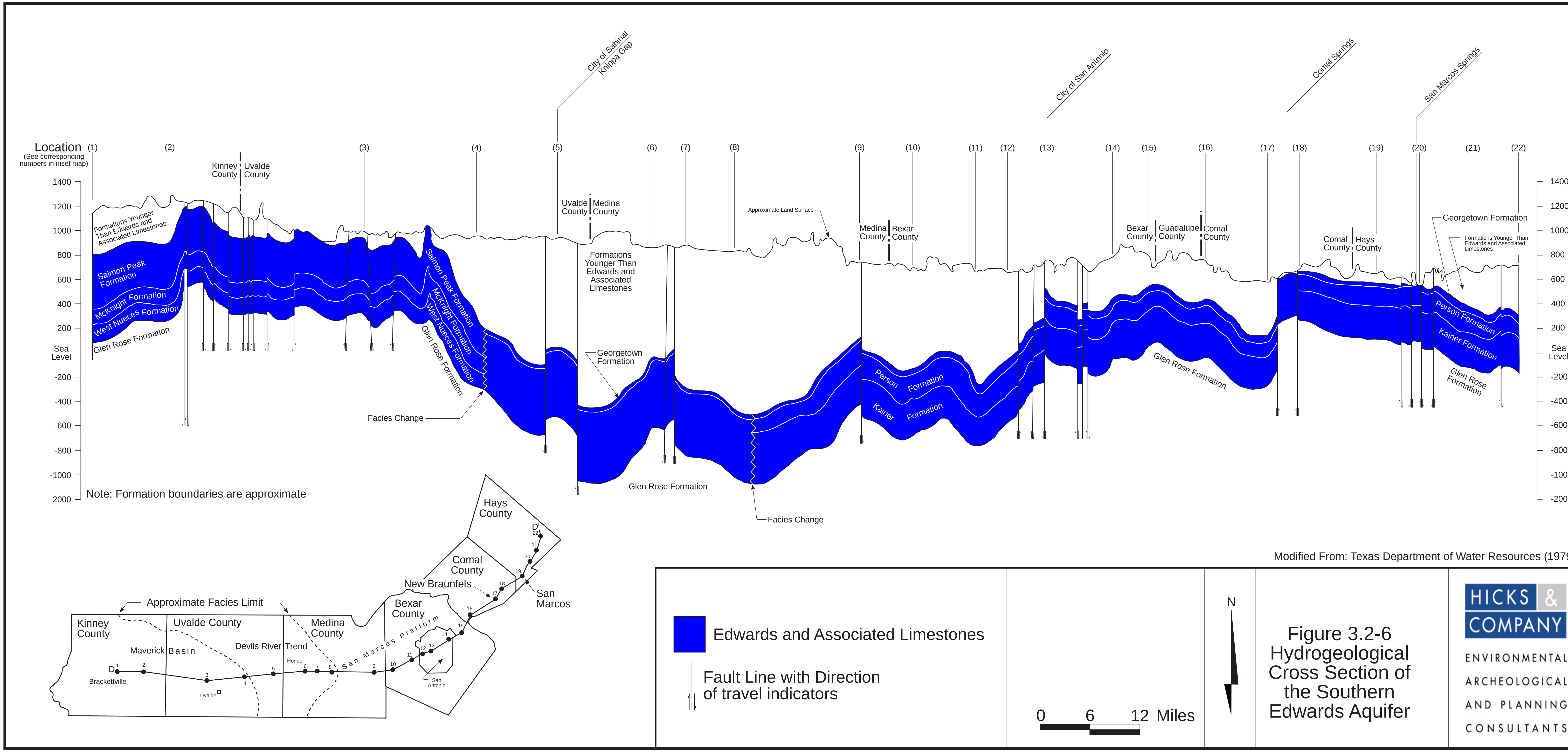


Figure 3.2-6 Hydrogeological Cross Section of the Southern Edwards Aquifer

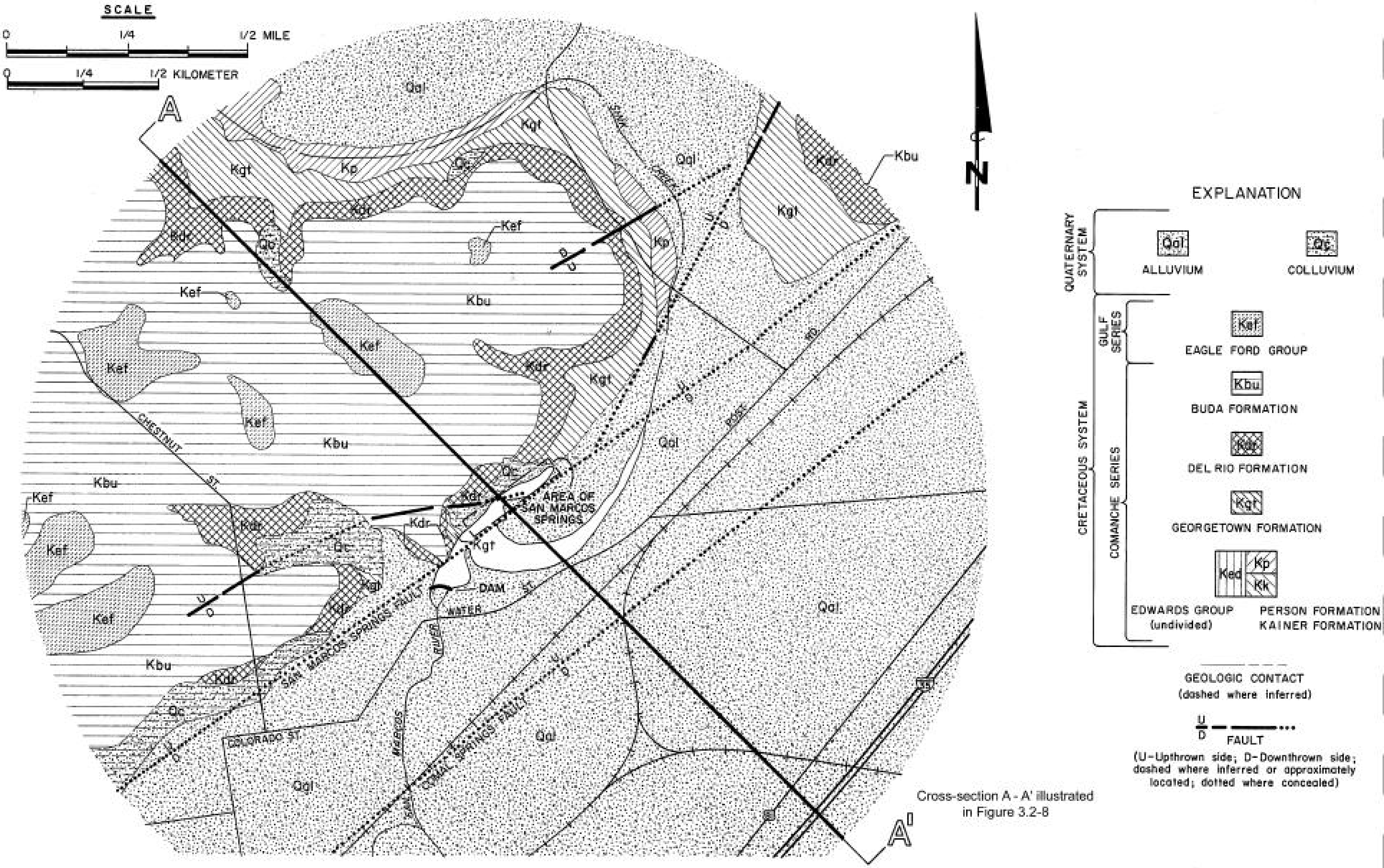


Figure 3.2-7
Surface Geology of San Marcos Springs and Vicinity

Source: Wm. F. Guyton and Associates, 1979

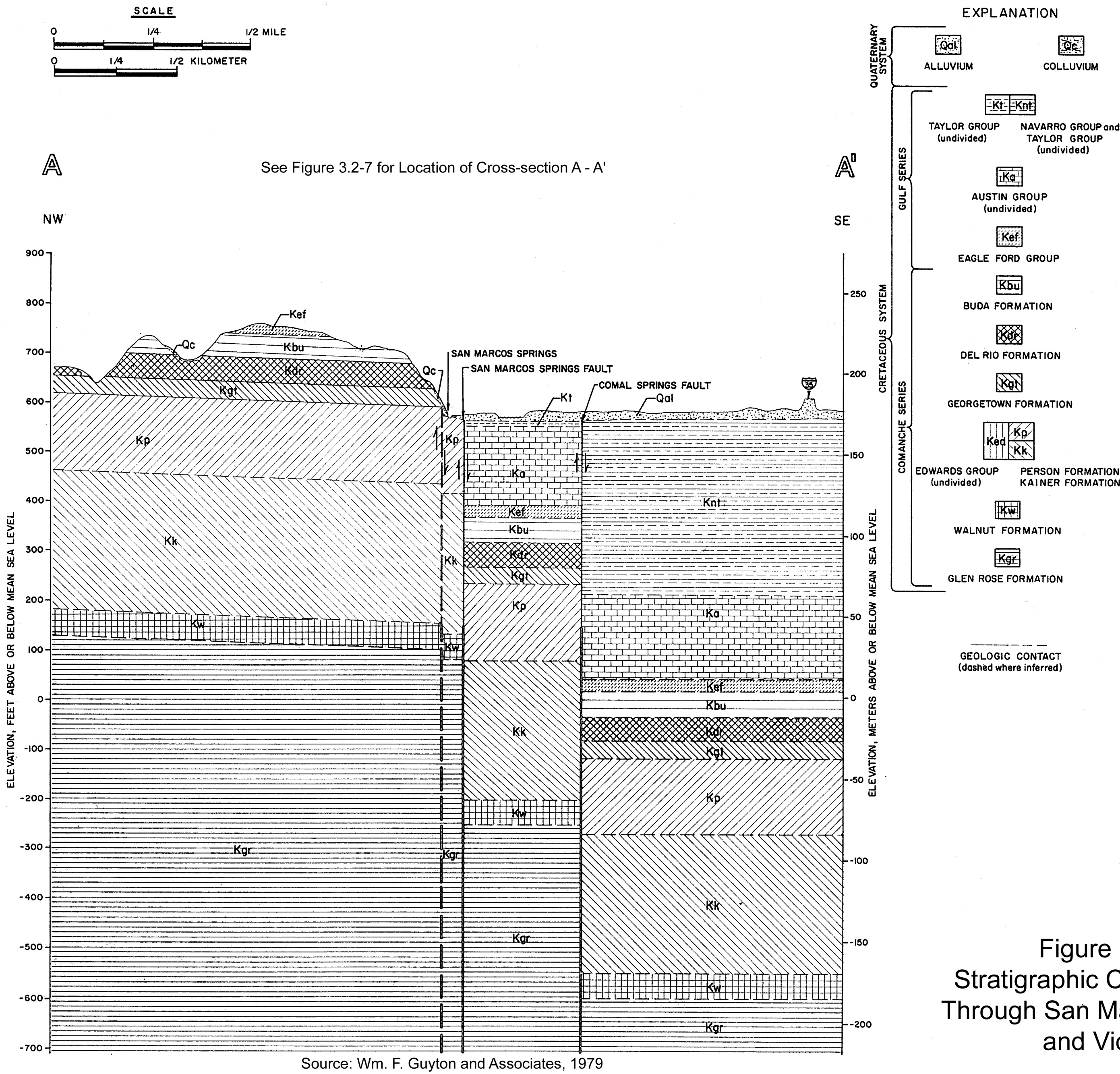


Figure 3.2-8
Stratigraphic Cross-section Through San Marcos Springs and Vicinity

Table 3.2-1. Surface geology, San Marcos Springs and vicinity

Formation/Group	General Description
Quaternary alluvium	Floodplain deposits including low terrace deposits; organic matter, gravel, sand, silt and clay with local caliche in overbank areas; thickness varies; covers areas southeast of San Marcos Springs Fault
Quaternary colluvium	Hillside erosional deposits; poorly sorted to unsorted cobbles, gravel, sand, silt, and clay; thickness varies; found on hillsides northwest of fault
Eagle Ford Group	Cretaceous-aged shale and limestone; upper part—shale, silty, 10 feet thick; middle part—limestone, sandy, flaggy, 4 to 5 feet thick; lower part—shale, calcareous 7 feet thick; total thickness 23 to 32 feet; exposed on hilltops northwest of fault
Buda Formation	Buda Limestone; Cretaceous-aged limestone, fine grained, hard, fossiliferous, commonly glauconitic, thickness 30 to 60 feet; forms the majority of surface bedrock on hills northwest of fault
Del Rio Formation	Del Rio Clay; Cretaceous-aged clay, calcareous and gypsiferous; some thin beds of siltstone; some thin limestone beds of fossils; thickness 40 to 60 feet; exposed strata on hillsides northwest of fault
Georgetown Formation	Mostly limestone, fine grained, nodular, moderately indurated; some shale, calcareous; thickness 10 to 45 feet; exposed on hillsides northwest of fault
Edwards Group	Limestone, dolomite, and chert; limestone, fine grained, chalky to hard, alternating beds of dolomite, fine to very fine grained, porous; thickness approximately 800 feet; locally exposed in streambeds; source of springs

SOURCE: Modified from Bureau of Economic Geology 1974a, 1974b, and 1983.

3.2.2.4 Comal Springs

Data on the geology of Comal Springs and vicinity were taken from Geologic Atlas of Texas maps (Bureau of Economic Geology 1974a, 1974b, and 1983), W.F. Guyton and Associates (1979), and Crowe (1994). A map showing the local surface geology is included in Figure 3.2-9 and a stratigraphic cross section of Comal Springs is included in Figure 3.2-10. A list of local surface formations and their properties is included in Table 3.2-2. Comal Springs lie at the base of the Balcones Escarpment, within the Balcones Fault Zone. The springs issue from Edwards Group limestones along the Comal Springs Fault. Here, the Edwards Group is displaced against the Taylor Group, forming an escarpment with approximately 100 feet of relief (Guyton, W.F. and Associates 1979). Most of the springs issue from the Edwards Group; however, some water may rise into and through deposits of Quaternary alluvium that lie to the southeast of the escarpment (Guyton, W.F. and Associates 1979). A series of two concealed faults run parallel and to the southeast of the Comal Springs Fault. The Edwards Group is relatively shallow southeast of the Comal Springs Fault (Guyton, W.F. and Associates 1979). Local surface geology consists of Edwards Group limestones and Quaternary alluvium.

Table 3.2-2. Surface geology, Comal Springs and vicinity

Formation/Group	General Description
Quaternary alluvium	Floodplain deposits including low terrace deposits; organic matter, gravel, sand, silt and clay with local caliche in overbank areas; thickness varies; covers areas southeast of Comal Springs Fault
Edwards Group	Limestone, dolomite, and chert; limestone, fine grained, chalky to hard, alternating beds of dolomite, fine to very fine grained, porous; thickness approximately 800 feet; exposed northwest of fault; source of springs

SOURCE: Modified from Bureau of Economic Geology 1974a, 1974b, and 1983.

3.2.3 Soils

3.2.3.1 Regional

Soils within the EAHCP Planning Area vary by physiographic region. Soils on the Edwards Plateau are typically shallow on uplands and include very stony, dark, alkaline clays and clay loams. On steep hillsides and valleys, soils are slightly deeper, lighter, and less stony. Soils in bottomlands are typically deep, dark, alkaline loams and clays. Surface drainage in Edwards Plateau soils is rapid. Land is used primarily for cattle and sheep ranching; however, forage crops are grown in the deeper bottomland soils. In the Blackland Prairies soils are typically deep, dark alkaline clays. These soils are moderately to well drained and have a high shrink-swell potential. This high shrink-swell potential poses an engineering concern, since it can cause damage to roads and foundations. These soils support grasslands, pasture, and crops, including cotton, grains, and hay. Soils along the Gulf Coastal Plains include thin, acidic, sandy soils of the Post Oak Belt and deep, dark, clayey soils of the Coastal Prairies. Bottomland soils are generally deep and clayey, but vary considerably along rivers and streams, where large deposits of alluvial material are abundant. These soils are very productive and support grazing as well as rice, grains, cotton, and hay. Surface drainage is slow, resulting in numerous prairie wetlands.

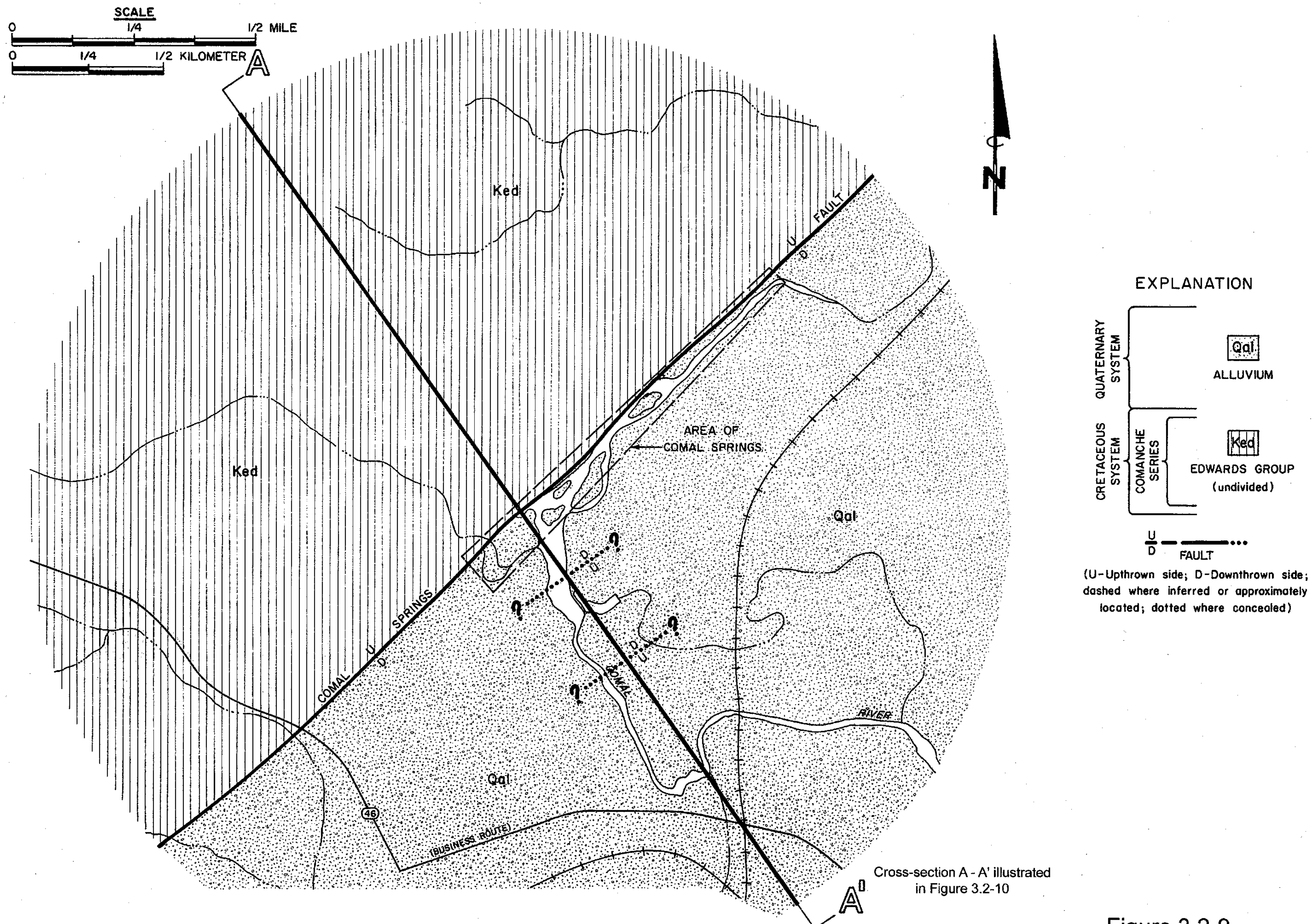
Due to the importance of the San Marcos and Comal Springs and to species covered in this EAHCP, site-specific soils information is provided in the following sections for these areas.

3.2.3.2 San Marcos Springs

Soil data for San Marcos Springs and vicinity were taken from the Soil Survey of Comal and Hays Counties, Texas (Batte 1984). Figures 3.2-11a and 3.2-11b provide a map of soils along the San Marcos River. Table 3.2-3 provides a list of soils types found in the vicinity and their properties. Soils in the vicinity of San Marcos Springs are primarily silty clays and loams of terraces and floodplains. These soils are generally well drained, allowing for rapid surface water runoff. Thick layers of alluvium are present in the San Marcos River floodplain, which may aid local base flow (Crowe 1994). Detailed descriptions of soil series found in the vicinity and their associated units are given in the following sections.

Eckrant Series

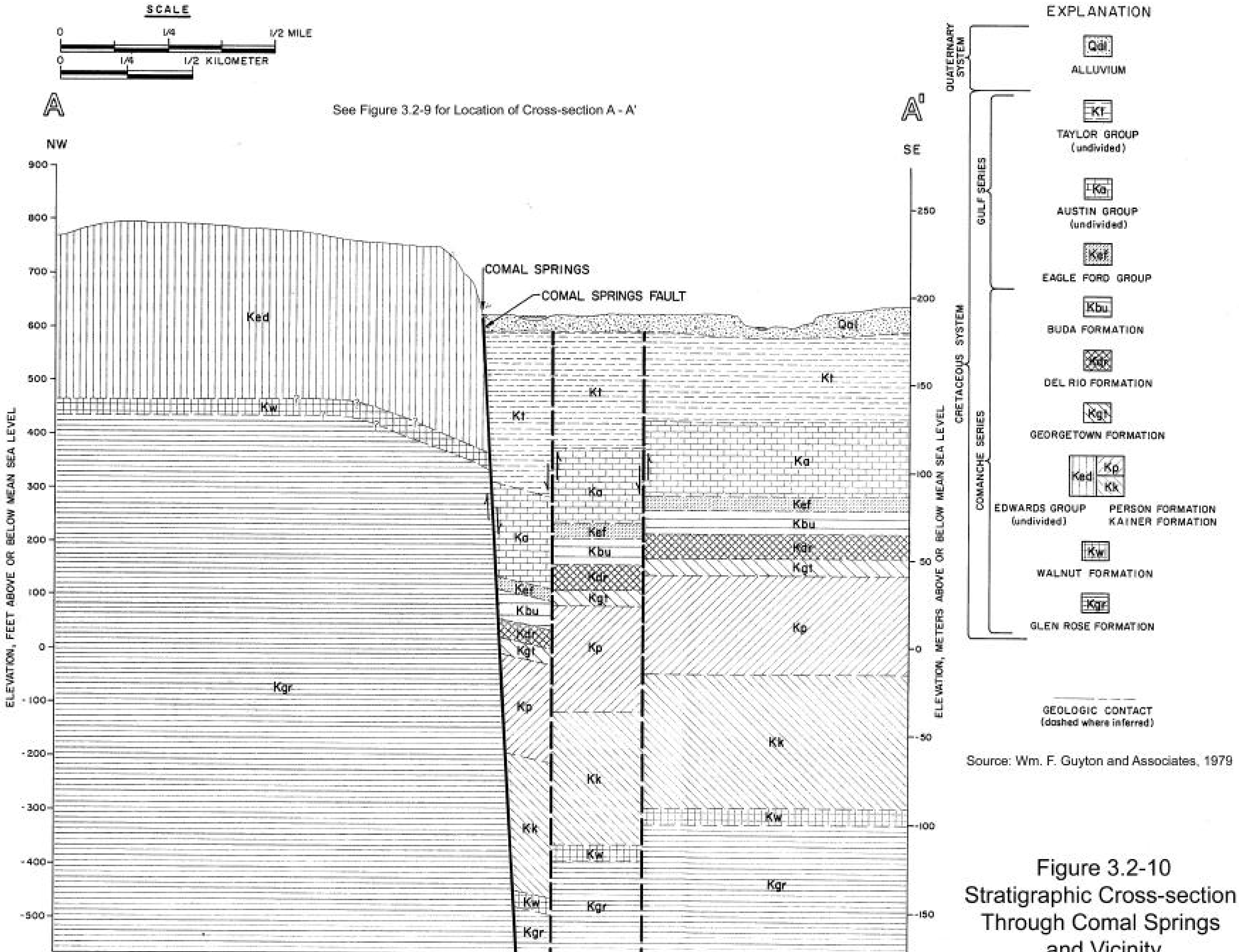
Eckrant soils consist of shallow, extremely stony, well-drained, clayey soils found on undulating to steep uplands and formed over fractured limestones (Batte 1984). Eckrant Series soils in the vicinity of San Marcos Springs include the Eckrant-Rock outcrop complex (steep).



Cross-section A - A' illustrated in Figure 3.2-10

Figure 3.2-9
Surface Geology of Comal Springs and Vicinity

Source: Wm. F. Guyton and Associates, 1979



Source: Wm. F. Guyton and Associates, 1979

Figure 3.2-10
Stratigraphic Cross-section Through Comal Springs and Vicinity

Key to Features

- Creek/Stream
- Railroad
- Matchline
- Water

Soil Types

ByA- Branyon Clay, 0 to 1% slopes
ByB- Branyon Clay, 1 to 3% slopes
CrD- Comfort-Rock outcrop complex, undulating
DoC- Doss silty clay, 1 to 5% slopes
ErG- Eckrant-Rock outcrop complex, steep
FeF4- Ferris clay, 5 to 20% slopes, severely eroded
GrC- Gruene clay, 1 to 5% slopes
HeB- Heiden clay, 1 to 3% slopes
HeC3- Heiden clay, 3 to 5% slopes, eroded
HeD3- Heiden clay, 5 to 8% slopes, eroded
HoB- Houston Black clay, 1 to 3% slopes
KrA- Krum clay, 0 to 1% slopes
KrB- Krum clay, 1 to 3% slopes
LeB- Lewisville silty clay, 1 to 3% slopes
MED- Medlin-Eckrant association, hilly
Oa- Oakalla silty clay loam, rarely flooded
Ok- Oakalla soils, frequently flooded
Or- Orif soils, frequently flooded
Pt- Pits
SuA- Sunev silty clay loam, 0 to 1% slopes
Tn- Tinn clay, frequently flooded

Soil data digitized from Soil Survey of Comal and Hays Counties, Texas (Batte, 1984).

N

Scale 1:8,400

200 0 200 400 600 Feet

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Soils at San Marcos Springs and Vicinity
Figure 3.2-11a

Key to Features

- Creek/Stream
- Railroad
- Matchline
- Water

Soil Types

ByA- Branyon Clay, 0 to 1% slopes

ByB- Branyon Clay, 1 to 3% slopes

CrD- Comfort-Rock outcrop complex, undulating

DoC- Doss silty clay, 1 to 5% slopes

ErG- Eckrant-Rock outcrop complex, steep

FeF4- Ferris clay, 5 to 20% slopes, severely eroded

GrC- Gruene clay, 1 to 5% slopes

HeB- Heiden clay, 1 to 3% slopes

HeC3- Heiden clay, 3 to 5% slopes, eroded

HeD3- Heiden clay, 5 to 8% slopes, eroded

HoB- Houston Black clay, 1 to 3% slopes

KrA- Krum clay, 0 to 1% slopes

KrB- Krum clay, 1 to 3% slopes

LeB- Lewisville silty clay, 1 to 3% slopes

MED- Medlin-Eckrant association, hilly

Oa- Oakalla silty clay loam, rarely flooded

Ok- Oakalla soils, frequently flooded

Or- Orif soils, frequently flooded

Pt- Pits

SuA- Sunev silty clay loam, 0 to 1% slopes

Tn- Tinn clay, frequently flooded

Soil data digitized from Soil Survey of Comal and Hays Counties, Texas (Batte, 1984).

N

Scale 1:8,400

200 0 200 400 600 Feet

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Soils at San Marcos Springs and Vicinity
Figure 3.2-11b

Table 3.2-3. Properties of soils at San Marcos Springs and vicinity

Soil Type (Map Symbol)	Depth (inches)	Hydraulic Conductivity (inches/hour)	Shrink/Swell Potential	Water Capacity (inches/inch soil)
Eckrant-Rock outcrop complex (ErG)	0 to 80	0.2 to 0.6	Moderate	0.05 to 0.12
Ferris clay (FeF4)	0 to 60	< 0.06	Very high	0.15 to 0.18
Heiden clay (1 to 3% slopes) (HeB)	0 to 22	< 0.06	Very high	0.15 to 0.20
Heiden clay (3 to 5% slopes) (HeD3)	22 to 88	< 0.06	Very high	0.12 to 0.20
Houston Black clay (HoB)	0 to 25	< 0.06	Very high	0.15 to 0.20
Lewisville silty clay (LeB)	17 to 36	0.6 to 2.0	High	0.14 to 0.18
Oakalla silty clay (Oa)	0 to 80	0.6 to 2.0	Moderate	0.12 to 0.19
Oakalla soils (frequently flooded) (Ok)	0 to 80	0.6 to 2.0	Moderate	0.12 to 0.19
Orif soils (Or)	0 to 20	6.0 to 20.0	Low	0.03 to 0.08
Tinn clay (Tn)	0 to 25	0.06 to 0.2	High	0.15 to 0.20

SOURCE: Based on Crowe 1994.

Ferris Series

Ferris soils consist of deep, well-drained, clayey soils found on sloping to moderately steep uplands and formed in shale and shaley clays (Batte 1984). Local soils in the Ferris Series include Ferris clay (5 to 20 percent slopes).

Heiden Series

Soils of the Heiden Series include deep, well-drained, clayey soils found on gently sloping to sloping uplands and formed in calcareous and shaley clays (Batte 1984). Heiden Series soils in the vicinity of San Marcos Springs include Heiden clay (1 to 3 percent slopes) and Heiden clay (3 to 5 percent slopes).

Houston Black Series

Houston Black Series soils consist of deep, moderately well drained, clayey soils found on gently sloping to sloping uplands and formed in calcareous clay and shale (Batte 1984). Houston Black soils in the vicinity of San Marcos Springs include Houston Black clay (1 to 3 percent slopes).

Lewisville Series

Lewisville Series soils are deep, well-drained, clayey soils of nearly level to gently sloping stream terraces and formed in calcareous clayey and loamy sediments (Batte 1984). Local soils in the Lewisville Series include Lewisville silty clay (1 to 3 percent slopes).

Oakalla Series

The Oakalla Series of soils is deep, well-drained, loamy soils of nearly level floodplains and formed in calcareous, loamy alluvium (Batte 1984). Oakalla soils in the vicinity of San Marcos Springs include Oakalla silty clay loam (rarely flooded) and Oakalla soils (frequently flooded). Oakalla soils (frequently flooded) are the predominant soil type in and along the San Marcos River.

Orif Series

Orif Series soils consist of deep, well-drained, loamy soils found in nearly level to gently sloping floodplains and formed in recent deposits of gravelly alluvium (Batte 1984). Local Orif Series soils include Orif soils (frequently flooded).

Tinn Series

Tinn Series soils are deep, somewhat poorly drained, clayey soils found in floodplains and formed in calcareous clayey alluvium (Batte 1984). Tinn Series soils in the vicinity of San Marcos Springs include Tinn clay (frequently flooded).

3.2.3.3 Comal Springs

Soil data for Comal Springs and vicinity were taken from the Soil Survey of Comal and Hays Counties, Texas (Batte 1984). Figure 3.2-12 provides a map of soils along the Comal River. Table 3.2-4 provides a list of soils types found in the vicinity and their properties. Soils in the vicinity of Comal Springs are primarily silty clays and loams of terraces and floodplains. These soils are generally well drained, allowing for rapid surface water runoff. A layer of alluvium is present at Landa Lake (Crowe 1994). Detailed descriptions of soil series found in the vicinity and their associated units are given in the following sections.

Table 3.2-4. Properties of soils at Comal Springs and vicinity

Soil Type (Map Symbol)	Depth (inches)	Hydraulic Conductivity (inches/hour)	Shrink/Swell Potential	Water Capacity (inches/inch soil)
Boerne fine sandy loam (BoB)	0 to 16	2.0 to 6.0	Low	0.10 to 0.15
Eckrant-Rock outcrop complex (ErG)	0 to 80	0.2 to 0.6	Moderate	0.05 to 0.12
Krum clay (KrA)	0 to 16	0.2 to 0.6	High	0.15 to 0.20
Lewisville silty clay (LeB)	17 to 36	0.6 to 2.0	High	0.14 to 0.18
Oakalla silty clay (Oa)	0 to 80	0.6 to 2.0	Moderate	0.12 to 0.19
Oakalla soils (frequently flooded) (Ok)	0 to 80	0.6 to 2.0	Moderate	0.12 to 0.19
Orif soils (Or)	0 to 20	6.0 to 20.0	Low	0.03 to 0.08
Purves clay (PuC)	0 to 10	0.2 to 0.6	High	0.12 to 0.18
Seawillow clay loam (SeD)	26 to 48	0.6 to 2.0	Low	0.12 to 0.18
Sunev silty clay loam (SuA)	0 to 15	0.6 to 2.0	Low	0.11 to 0.16

SOURCE: Based on Crowe 1994.

Key to Features

Water

Creek/Stream

Railroad

Soil Types

BoB - Boerne fine sandy loam, 1 to 3% slopes

CrD - Comfort-Rock outcrop complex, undulating

ErG - Eckrant-Rock outcrop complex, steep

GrC - Gruene clay, 1 to 5% slopes

KrA - Krum clay, 0 to 1% slopes

LeA - Lewisville silty clay, 0 to 1% slopes

LeB - Lewisville silty clay, 1 to 3% slopes

Oa - Oakalla silty clay loam, rarely flooded

Ok - Oakalla soils, frequently flooded

Or - Orif soils, frequently flooded

PuC - Purves clay, 1 to 5% slopes

RUD - Rumple-Comfort association, undulating

SeD - Seawillow clay loam, 3 to 8% slopes

SuA - Sunev silty clay loam, 0 to 1% slopes

Soil data digitized from Soil Survey of Comal and Hays Counties, Texas (Batte, 1984).

N

Scale 1:9,600

200 0 200 400 600 800 Feet

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Soils at Comal Springs and Vicinity

Figure 3.2-12

Boerne Series

Boerne Series soils consist of deep, well-drained, loamy soils found on stream terraces and formed in calcareous alluvial sediment (Batte 1984). Boerne Series soils in the vicinity of Comal Springs include the Boerne fine sandy loam (1 to 3 percent slopes).

Comfort Series

Comfort soils consist of shallow, well-drained, clayey soils found on undulating uplands and formed in clay weathered from dolomitic limestone (Batte 1984). Comfort soils in the vicinity of Comal Springs include the Comfort-Rock outcrop complex (undulating).

Eckrant Series

Eckrant soils consist of shallow, extremely stony, well-drained, clayey soils found on undulating to steep uplands and formed over fractured limestones (Batte 1984). Eckrant Series soils in the vicinity of Comal Springs include the Eckrant-Rock outcrop complex (steep).

Krum Series

Krum Series soils consist of deep, well-drained, clayey soils found on nearly level to gently sloping uplands and formed in calcareous clay sediments (Batte 1984). Local soils in the Krum Series include Krum clay (0 to 1 percent slopes).

Lewisville Series

Lewisville Series soils are deep, well-drained, clayey soils of nearly level to gently sloping stream terraces and formed in calcareous clayey and loamy sediments (Batte 1984). Local soils in the Lewisville Series include Lewisville silty clay (0 to 1 percent slopes) and Lewisville silty clay (1 to 3 percent slopes).

Oakalla Series

The Oakalla Series of soils is deep, well-drained, loamy soils of nearly level floodplains and formed in calcareous, loamy alluvium (Batte 1984). Oakalla soils in the vicinity of Comal Springs include Oakalla silty clay loam (rarely flooded) and Oakalla soils (frequently flooded). Oakalla soils (frequently flooded) are the predominant soil type in and along the Comal River.

Orif Series

Orif Series soils consist of deep, well-drained, loamy soils found in nearly level to gently sloping floodplains and formed in recent deposits of gravelly alluvium (Batte 1984). Local Orif Series soils include Orif soils (frequently flooded).

Purves Series

Purves Series soils consist of shallow, well-drained, clayey soils found in gently sloping uplands and formed in material weathered from limestones (Batte 1984). Local Purves Series soils include Purves clay (1 to 5 percent slopes).

Seawillow Series

Seawillow Series soils consist of deep, well-drained, loamy soils found in gently sloping to sloping stream terraces and formed in calcareous alluvial sediment (Batte 1984). Local Seawillow Series soils include Seawillow clay loam (3 to 8 percent slopes).

Sunev Series

Sunev Series soils consist of deep, well-drained, loamy soils found in gently sloping uplands and formed in material weathered from limestones (Batte 1984). Local Sunev Series soils include Sunev silty clay loam (0 to 1 percent slopes).

3.3 Water Resources

The quality and availability of surface and ground water within the EAHCP Planning Area is discussed in this section. Competition for water resources has increased along with the region's population. A summary of existing conditions related to these resources is provided below.

3.3.1 Surface Water

3.3.1.1 River Basins

The southern portion of the Edwards Aquifer lies beneath the Guadalupe, San Antonio, and Nueces River Basins. These river basins cover drainage areas of 6,070, 4,180 and 16,950 squares miles, respectively (Figure 3.3-1a). More specifically, eight drainage systems—the Nueces-West Nueces River basin, Frio-Dry Frio River basin, Sabinal River basin, the area between the Sabinal River and Medina River basin including Hondo Creek, Medina River basin, area between the Medina River and Cibolo Creek/Dry Comal Creek basin, Cibolo Creek–Dry Comal Creek basin, and Blanco River basin—lie over the contributing zone and the Edwards

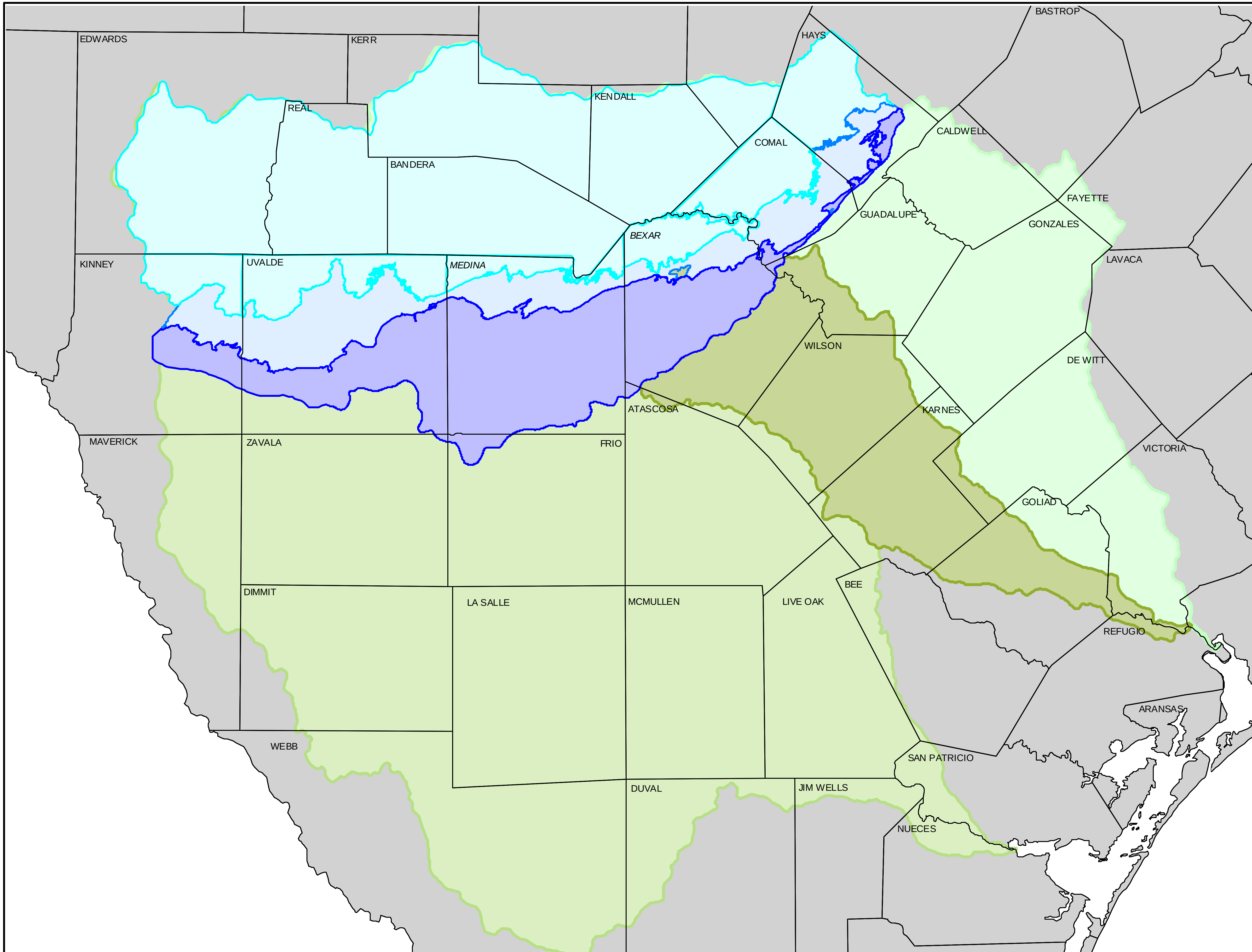

Figure 3.3-1a: River Basins Associated with the Southern Portion of the Edwards Aquifer.

Key to Features

Edwards Aquifer Zones
- Contributing
- Recharge
- Artesian

River Basins
- Guadalupe
- Nueces
- San Antonio

Area Mapped

Source: Texas Natural Resources Information System

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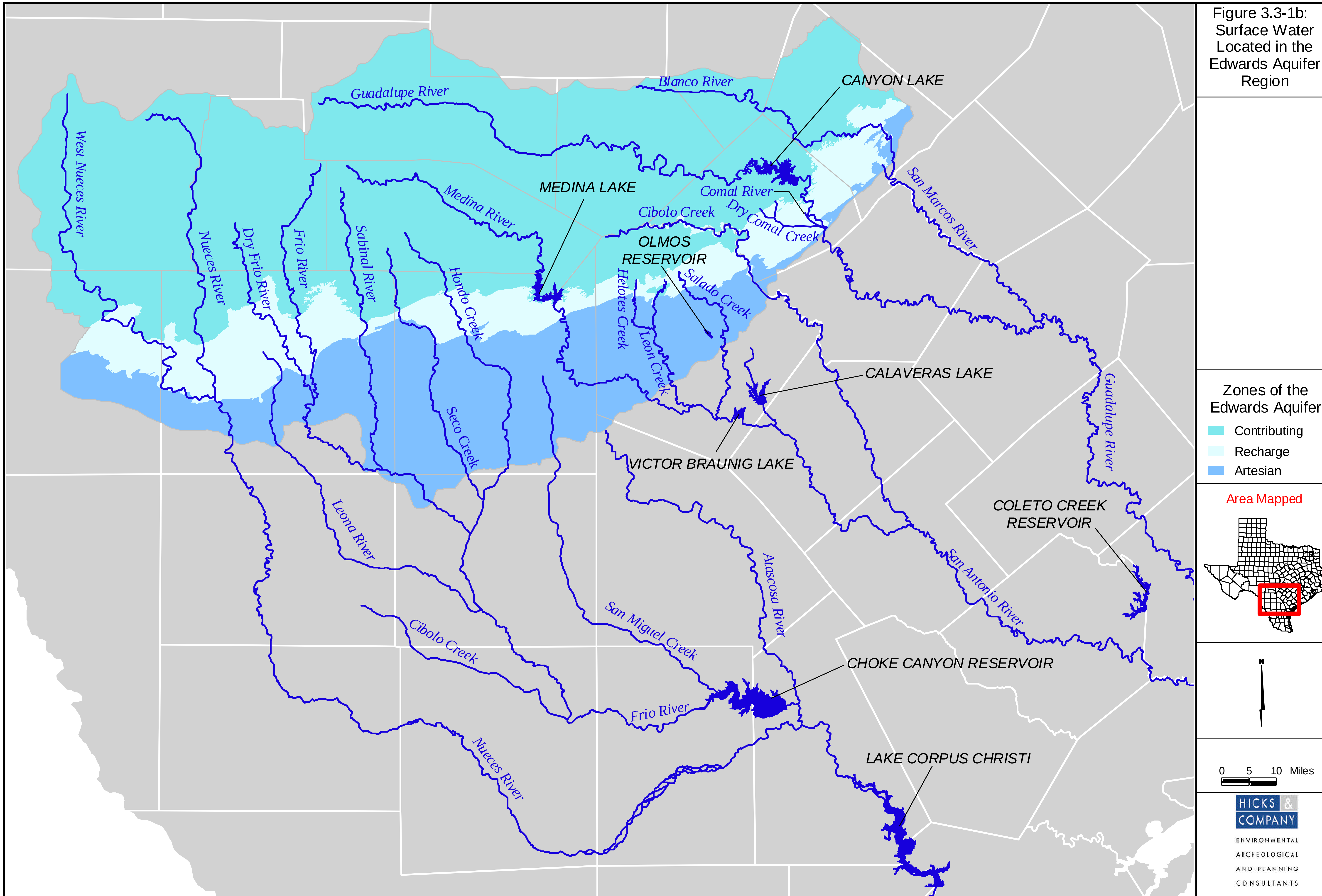
Figure 3.3-1b: Surface Water Located in the Edwards Aquifer Region



Aquifer recharge zone (EAA 2001) (Figure 3.3-1b). Approximately 75 percent of the aquifer recharge comes from rivers in these drainage basins crossing cavernous limestone of the recharge area (Harden 1988). The recharge zone stretches as a band from the area north and west of San Marcos and New Braunfels and extends southwesterly to the north of San Antonio, then westerly through the northern portions of Bexar, Medina, Uvalde and Kinney Counties (see Figure 3.3-1a). A brief discussion of the three major river basins is provided below.

Guadalupe River Basin

The Guadalupe River Basin originates in northwestern Kerr County and drains southeasterly to Guadalupe Bay in the San Antonio Bay System (see Figure 3.3-1a). The Guadalupe River Basin is bordered to the north by the Colorado River Basin, to the south by the San Antonio River Basin, and to the east by the Lavaca River Basin and the Lavaca-Guadalupe Coastal Basin (Texas Natural Resources Conservation Commission [TNRCC] 1998). Drainage area for the Guadalupe River Basin is 6,070 square miles, and the main tributaries to the Guadalupe River are the Blanco and San Marcos Rivers (TNRCC 1996). Major reservoirs in this basin include Canyon Lake and Coleto Creek Reservoir (see Figure 3.3-1b). Canyon Lake covers 8,230 surface acres (TNRCC 1996), while Coleto Creek covers 3,100 acres. The recreational importance of Canyon Lake is discussed in Section 3.6.3.8. Coleto Creek contributions to recreation are discussed in Section 3.6.4.8.

The base flow of the Guadalupe River is affected by stream management as regulated by the TCEQ and the GBRA, discharges from Canyon Lake (as stipulated by the COE) and flows of the Comal and San Marcos Rivers, each river originating from Comal and San Marcos Springs, respectively. The cities of New Braunfels and San Marcos have historically relied on well discharge from the Edwards Aquifer wells for their municipal water supplies. However, both cities have recently developed surface water supplies from the GBRA (HDR Engineering, Inc. 2001).

The City of San Marcos has developed a regional surface water supply project with the GBRA, including the construction by the City of San Marcos of a water treatment plant, and the construction by GBRA of a raw water transmission pipeline to the plant from the Guadalupe River. The City of New Braunfels has also recently developed an additional supply using purchased water from Canyon Reservoir to feed an expansion of its water treatment plant.

The Comal River, the shortest river in Texas and the United States (Texas Almanac 1990-91), runs approximately 3.1 miles before emptying into the Guadalupe River. The San Marcos River also empties into the Guadalupe River near Gonzales in Gonzales County after its confluence with the Blanco River.

Contribution of Aquifer Springflow to Ecotourism and Water-based Recreation

A discussion of the contribution of aquifer springflow to ecotourism and water-based recreation is provided in Section 3.6.3.8, Recreation and Tourism.

Contribution of Aquifer Springflow to the Lower Guadalupe River and the Guadalupe Estuary System

Since a portion of the flow of the Guadalupe River is derived from flows of the Comal and San Marcos Rivers, contributions of Edwards Aquifer discharge to the Guadalupe River via Comal and San Marcos Springs can be significant. Both the quantity and quality of flow of the Guadalupe River subsequently affects biological productivity of the Guadalupe Estuary System including Mission Lake, Guadalupe, Ayres, San Antonio, Mesquite, and Espiritu Santo Bays. The Resource Protection Division of Texas Parks and Wildlife Department has recommended a "lowest target value" freshwater inflow to the Guadalupe Estuary System of 1,150,000 acre-feet per year to fulfill the biological needs of the system on a seasonal basis. Occasional higher inflows above the target level are recommended to maintain the biological productivity and ecological health of the estuary (TPWD 1998). The contribution of various sources of freshwater to the Guadalupe Estuary System is provided in Table 3.3-1.

Table 3.3-1. Average annual freshwater inflow to Guadalupe Estuary System

Source	Inflow (acre-feet/year)	% of Total Inflow
Guadalupe River	1,304,000	42.8
San Antonio River	485,400	15.9
Precipitation	440,000	14.4
Local runoff	460,000	15.1
Edwards Aquifer	360,000	11.8
TOTAL	3,049,400	100.0

SOURCE: CH2M Hill 1986.

The average annual contribution of the Edwards Aquifer according to the above table is about 12 percent. Due to surface water management and weather conditions, the contribution of the Edwards Aquifer to freshwater inflow into the bay system is higher in drought years. Using data provided by Espey, Huston & Associates (1986), McKinney and Watkins (1993) concluded that contributions of the Edwards Aquifer during the drought of record that occurred in 1956 were about 30 percent of the total inflow to San Antonio Bay. In comparison, unpublished information from the Guadalupe-Blanco River Authority (GBRA) compiled from data obtained from the U.S. Geological Survey and Texas Water Development Board and Water Availability Modeling from the Texas Commission on Environmental Quality (TCEQ), indicates contributions of Comal and San Marcos Springs to bay and estuary inflows during the peak summer months of the 1956 drought ranged between 30 and 55 percent (GBRA 2002c). Based on unpublished information obtained from TPWD (2000), the contribution of the Edwards Aquifer springflow to San Antonio Bay and Guadalupe Estuary System during the drought year of 1996 was about 33 percent of the total inflow. Estimates by the GBRA for springflow contribution to the estuary during 1996 were similar, with the highest contribution exceeding 35 percent during the month of July (Votteler 2002). Local runoff to the estuary is contributed from parts of the San Antonio-Nueces and Lavaca-Guadalupe coastal basins.

San Antonio River Basin

The San Antonio River originates in San Antonio and converges with the Guadalupe River just above Guadalupe Bay in Victoria County (see Figure 3.3-1b). The city of San Antonio is in the San Antonio River Basin, which totals a drainage area of 4,180 square miles (TNRCC 1996). The river basin is bounded by the Guadalupe to the north and east and by the San Antonio-Nueces Coastal Basin and Nueces on the west and south. The main tributaries to the San Antonio River are the Medina River, Leon Creek, Cibolo Creek and Salado Creek. The major reservoirs are Medina Lake (5,575 acres), Victor Braunig Lake (1,350 acres), Calveras Lake (3,450 acres), and Olmos Reservoir (flood control only with a capacity of 12,600 acre-feet) (see Figure 3.3-1b).

Water use in the San Antonio River Basin is supplied by groundwater (88 percent) and surface water (12 percent). Aquifers supplying the San Antonio River Basin are the Trinity, Edwards-Trinity, Edwards, Gulf Coast, Carrizo-Wilcox, Queen City and Sparta Aquifers. The Edwards Aquifer supplies nearly all of San Antonio's current water needs.

Nueces River Basin

The Nueces River originates in Edwards County and flows southeasterly to the Gulf of Mexico near Corpus Christi, a distance of approximately 315 miles (TNRCC 1996) (see Figure 3.3-1b). The Nueces River Basin is bordered on the north and east by the Colorado, San Antonio, and Guadalupe River Basins and to the south and west by the Rio Grande and Nueces-Rio Grande Coastal Basin. Drainage area for the Nueces River Basin is 16,950 square miles, and the main tributaries to the Nueces River are the Atascosa River, the Frio River, and the Frio's tributaries, San Miguel Creek, Hondo Creek, Sabinal River, and Leona River. Two major reservoirs in the river basin are the Choke Canyon Reservoir (26,000 acres) and Lake Corpus Christi (19,336 acres) (see Figure 3.3-1b). They are operated as the Choke Canyon-Lake Corpus Christi System, supplying Corpus Christi with approximately 178,000 acre-feet per year. The Frio and Atascosa Rivers join the Nueces just above Lake Corpus Christi. This river basin supports extensive agriculture, including an area of Texas called the Winter Garden in Medina, Uvalde, Zavala, and Frio Counties (Section 3.4.1) (TNRCC 1996).

The Nueces River and its tributaries cross over the fractured limestone of the Edwards Aquifer recharge zone and a substantial amount of this surface water is recharged to the aquifer. Therefore, much of the flowing water in the Nueces River Basin downstream of the recharge zone is storm water.

3.3.1.2 Aquifer-fed Springs

Texas originally had 281 known major non-saline springs, and of these only four were defined as large, having a flow of over 100 cfs. Of the four largest Texas springs, only two remain, San Marcos and Comal Springs (Brune 1975). Both of these springs are supported by the Edwards Aquifer.

Other spring outlets of the aquifer within the jurisdiction of the Edwards Aquifer Authority are Leona Springs, San Antonio Springs, San Pedro Springs, Hueco Springs, and Fern Bank Springs (see Figure 3.3-2). Total flow from all the springs has averaged over 350,000 acre-feet per year and approximately 90 to 95 percent of that total is attributed to Comal and San Marcos Springs (Harden 1968). Sizes of these springs may be compared based on total discharge in 2001 (Table 3.3-2).

Table 3.3-2 Estimated spring discharge from the Edwards Aquifer, 2003 (measured in acre-feet).

	Leona Springs and Leona River Underflow	San Pedro Springs	San Antonio Springs	Comal Springs	Hueco Springs	San Marcos Springs	Total Monthly Discharge From Springs
January	1,318	1,313	11,418	27,560	5,236	19,470	66,315
February	2,465	1,140	9,779	24,310	5,319	17,220	60,233
March	3,880	1,254	10,646	26,080	6,516	18,380	66,756
April	3,410	1,029	7,871	24,300	5,977	16,600	59,187
May	2,695	653	3,549	23,390	5,417	15,100	50,804
June	2,620	631	3,445	22,070	3,814	13,740	46,320
July	2,995	805	5,399	23,130	2,605	13,470	48,404
August	3,090	672	3,968	22,240	3,249	11,930	45,149
September	3,050	761	4,796	22,260	3,360	11,390	45,617
October	3,395	843	5,631	23,310	2,717	11,530	47,426
November	3,475	751	4,894	21,680	1,935	10,270	43,005
December	3,495	729	4,241	22,380	1,534	9,940	42,319
Total	35,888	10,581	75,637	282,710	47,679	169,040	621,535

Data source: USGS, Unpublished Data, May, 2004.
Differences may occur due to rounding.

Comal Springs

Comal Springs, located in the city of New Braunfels in Comal County, is the largest natural springs group in the state and is the source of the Comal River. At 623 feet above sea level, Comal Springs is one of the lowest elevation springs fed by the Edwards Aquifer. The springs discharge from four major orifices and flow into Landa Lake (Abbott and Woodruff 1986) (see Figure 3.1-4a). Individual springs and spring runs have gone dry during recorded history, with the most recent event in 1996. The only time in recorded history that the cessation of spring flows stopped the Comal River was during the Drought of Record, in 1956, for 144 days (Longley 1995). The record high flow for Comal Springs is 1,059 acre-feet per day in 1973. Prior to 1927, when there were fewer wells to intercept the water headed for Comal Springs,

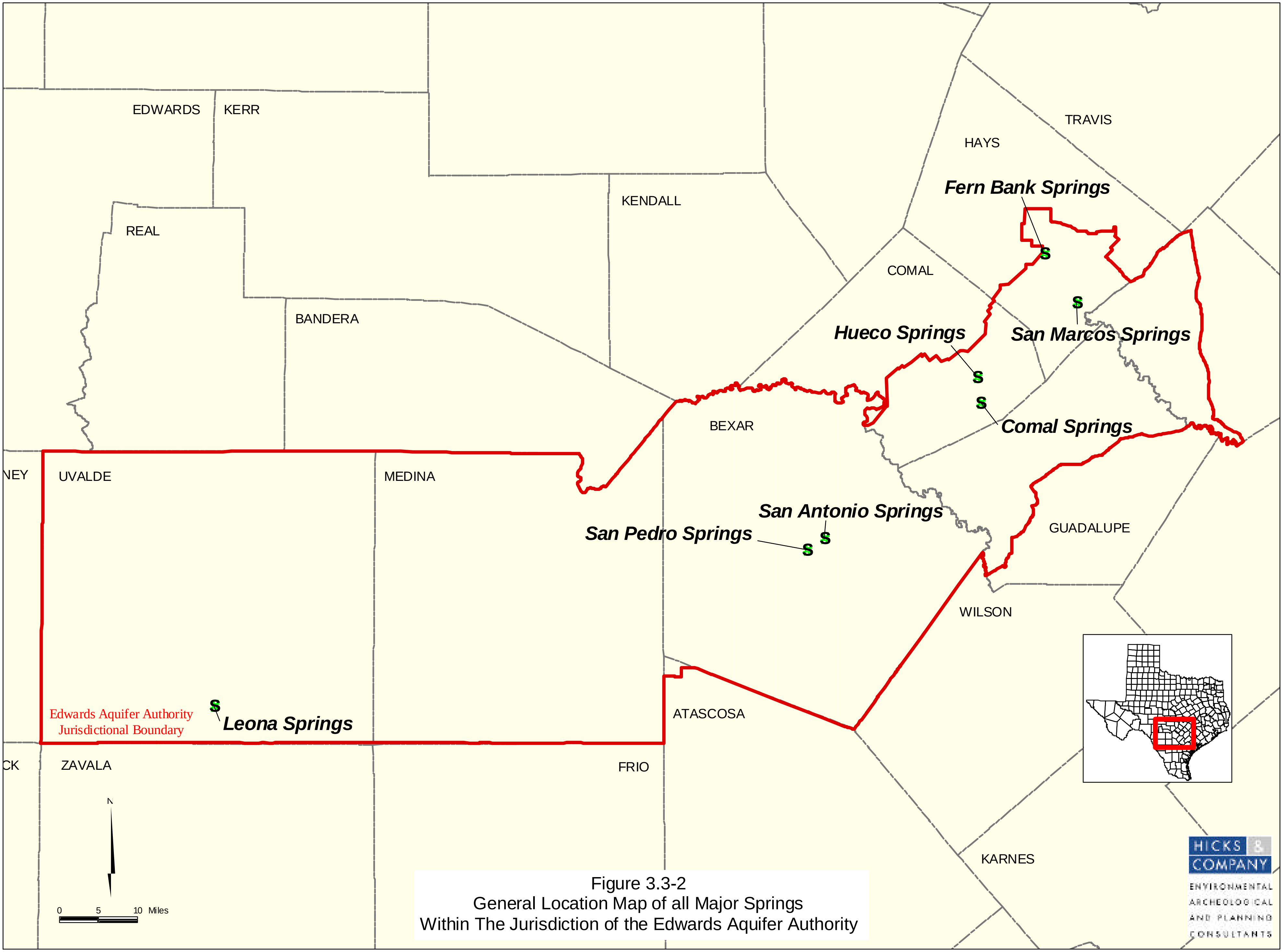


Figure 3.3-2
General Location Map of all Major Springs
Within The Jurisdiction of the Edwards Aquifer Authority

flows were between 220,000 and 290,000 acre-feet per year (Harden 1988). Actual range of springflow at Comal Springs from 1978-1989 is illustrated by Appendix B, Figure 6.

Comal Springs water emerges extremely clear, indicating that the recharge water has traveled a great distance to undergo such filtration (Brune 1981). And indeed it is generally known that Comal Springs does not receive much local recharge water as shown by dye tracer tests (Ogden et al. 1986). Recharge water for Comal Springs enters the Edwards Aquifer approximately 60 miles to the west. Rain water over the recharge area is seen as flow out of Comal Springs approximately one or two months later (Brune 1981). A discussion on the Comal Springs ecosystem including vegetation and wildlife diversity is presented in Section 3.1.2.2.

San Marcos Springs

San Marcos Springs, located in the city of San Marcos in Hays County, and very near the base of the Balcones Escarpment, is the second largest spring group in the state and is the source of the San Marcos River (see Figure 3.1-5a). San Marcos Springs, at 574 feet above mean sea level, exhibit the lowest elevation of the major springs in the southern portion of the Edwards Aquifer. Water issues from six major and several minor orifices at the bottom of Spring Lake. The water in San Marcos Springs averages approximately 72° F with slight seasonal variations. Because San Marcos Springs is lower in elevation than Comal Springs and is further down the pathway of the flow of water within the confined artesian aquifer zone, discharge at Comal Springs appears to dampen effects at San Marcos Springs. Although Comal Springs went dry for approximately 144 days from June through November 1956 (South Central Texas Water Advisory Committee 2000), such an event has never occurred at San Marcos Springs. The springs did reach a recorded low discharge of 91 acre-feet per day (47 cfs) in 1956. The record high daily flow for San Marcos Springs was 627 acre-feet in 1975 (Brune 1981). The average monthly flow during the period 1996 through 2001 was 187 cfs (EAA 2002a). Actual range of monthly springflows at San Marcos Springs from 1978-1989 is illustrated by Appendix B, Figure 7.

Local stream recharge from the Blanco and Guadalupe Rivers and Sink, Purgatory, York, Dry Comal and Alligator Creeks contributes to San Marcos Springs as they cross the recharge zone (Brune 1981). San Marcos Springs are also supplied by "regional underflow past the Comal Springs area" (Guyton et al 1979). Recharge to San Marcos Springs could be enhanced by recharge dams. These aquifer recharge enhancement features could increase discharge at Comal and San Marcos Springs by approximately 80,000 acre-feet per year (Appendix A, page 19). Another suggestion to keep the springs flowing for a few days or weeks, as a last resort, is to lower the level of Spring Lake, forcing the springs to draw water from the surrounding aquifer. However, "the magnitude of the effect that this method would have on springflow is not known" (Uliana 1994). Additional information pertaining to the San Marcos Springs ecosystem is included in Section 3.1.2.3.

Other Springs

Hueco, Fern Bank, San Antonio, San Pedro, and Leona Springs are lesser spring outlets for the Edwards Aquifer (see Figure 3.3-2). These springs generally have declining or erratic flow due to their high elevation, seasonal fluctuations during dry years, and increased pumping from the aquifer.

Hueco Springs, in Comal County, is located three miles north of New Braunfels and 300 feet west of the Guadalupe River. The springs consist of two orifices at a high elevation (approximately 658 feet above sea level), and therefore have variable flow and often go dry or have long periods of low flow during drought (Abbott and Woodruff 1986). The maximum discharge for Hueco Springs was 260 acre-feet per day (131 cfs) in 1968 (Brune 1975) and has averaged about 70 acre-feet per day. Hueco Springs water comes from recharge in the nearby Dry Comal Creek and Guadalupe River basins.

Fern Bank Springs, also referred to by Brune (2002) as Little Arkansas or Krueger Springs, are about five miles east of Wimberley on the south bank of the Blanco River in Hays County. Springflow was documented to vary between five cfs in 1975 to less than one cfs in 1978 (Brune 2002). The site is very scenic as spring discharge cascades to the Blanco River.

San Antonio Springs, originally a complex of over 100 springs (Brune 1981), are located principally on property of the University of the Incarnate Word and near Brackenridge Park within north central San Antonio. Most of the springs are at an elevation of about 672 feet above sea level. The largest spring is called Head of the River or Blue Hole, implying that it is the head of the San Antonio River. Many of the individual springs within the complex can flow during a wet years, such as in 1973 and 1992, but are now frequently intermittent with low or no flow.

San Pedro Springs, in Bexar County, are located in San Pedro Park in San Antonio at 663 feet above sea level. Both San Antonio and San Pedro Springs are recharged by waters over 62 miles to the west where the Frio, Sabinal, and Medina Rivers and Hondo and Leon Creeks cross the Balcones Fault Zone. Both of these springs were very important to the early development of San Antonio, providing water to ancient Payayan Indian settlements, and to Spanish missions established during the early 1700s including the San Antonio de Valero Mission (the Alamo) founded in 1718. Water from these springs is discharged from faults in the Austin Chalk formation. These springs now have erratic or no flow due to well pumping and water is piped in to maintain recreational uses (Brune 1975).

Leona Springs are found in four groupings along or beneath the surface of the Leona River in Uvalde County. Leona Springs, 860 feet above sea level, are recharged by the Nueces River and other streams to the northwest (Brune 1981). These springs were an attractive stop on the Old Spanish Trail and were described as “the purest streams of crystal water” (Brune 1975). Water quality testing of the springs between 1976 and 1985 by USGS detected pesticide compounds, but no occurrences exceeded the maximum contaminant levels for drinking water (USGS 1987).

3.3.1.3 Surface Water Quality

Rules and Regulations Governing Surface Water Quality

Surface water quality is regulated and monitored by the Texas Commission on Environmental Quality (TCEQ) (TNRCC prior to September 1, 2002) and by the federal Environmental Protection Agency (EPA). The State of Texas Water Quality Inventory is prepared by the TCEQ and submitted to the EPA as required by Section 305(b) of the federal Clean Water Act. This effort reports on water chemistry information, data on toxic substances in the water, sediments, fish tissue, contaminants, status and trends in water quality statewide and other historical information (TNRCC 1996). This report assesses water by river or coastal basin where all major bodies of water, creeks, rivers, reservoirs, lakes, bays and estuaries, are divided into monitored segments. The report also includes the degree to which each water body segment supports its designated uses as established by the Texas Surface Water Quality Standards.

The TCEQ defines water body segment classification as follows: "Classified surface waters are listed as water quality limited or effluent limited. Water bodies are classified as water quality limited if one or more of the following are applicable: (1) surface water quality monitoring data indicate significant violations of criteria in the Texas State Water Quality Standards (TSWQS) that are protective of aquatic life, contact recreation, public water supply, fish consumption, or oyster waters uses; (2) advanced waste treatment for point source wastewater discharges is required to meet water quality standards; (3) the segment is a public water supply reservoir (requires special wastewater treatment considerations). All other water bodies are classified effluent limited, indicating that water quality standards are being maintained and that conventional wastewater treatment is adequate to protect existing conditions" (TNRCC 1998). Water body segments that did not support designated uses or water quality criteria are listed on the 2000 State of Texas Clean Water Act Section 303(d) List. TCEQ listed stream segments on the 303(d) list which lie over the Edwards Aquifer (Table 3.3-3) include: Segment #1814, upper San Marcos River; #1815, Cypress Creek; #1903, Medina River below Medina Diversion Lake; #1908, Upper Cibolo Creek; #1910, Salado Creek; #2110, Lower Sabinal River; #2113, Upper Frio River; and #2117, Frio River above Choke Canyon Reservoir (TNRCC 2000).

Section 314 of the Federal Clean Water Act of 1987 requires states to rank major lakes and reservoirs according to their "trophic state" or nutritional status (TNRCC 1998). Data regarding specific water bodies are included in Tables 3.3-4 through 3.3-6 and discussed below.

The Edwards Aquifer Authority maintains data collection sites within the eight major stream basins that contribute significant groundwater recharge to the Edwards Aquifer (Nueces River, Dry Frio River, Frio River, Sabinal River, Seco Creek, Hondo Creek, Medina River and Blanco River). Data collection is used to measure the quality of water recharging the aquifer and the sensitivity of water quality to land use changes in various areas of the Edwards Aquifer region. Based on laboratory analyses of samples collected in 1998, none of the samples contained detectable concentrations of pesticides, herbicides, or volatile organic compounds (EAA 1999).

Table 3.3-3. Stream segments over the Edwards Aquifer and on the 2000 Texas Clean Water Act Section 303(d) List

Segment	Segment Name	Overall Priority	Source	Segment Summary
1814	Upper San Marcos River	Low	Non-point	Sulfate concentration exceeds criterion for general use
1815	Cypress Creek	Low	Point and non-point	Dissolved oxygen concentration occasionally lower than criterion for aquatic life
1903	Medina River below Medina Diversion Lake	Medium	Point and non-point	Bacteria levels exceed criterion for contact recreation in the lower 5 miles
1908	Upper Cibolo Creek	Medium	Point and non-point	Dissolved oxygen concentration occasionally lower than criterion for aquatic life in 2-mile portion southeast of Boerne
1910	Salado Creek	High	Non-point	Dissolved oxygen concentration occasionally lower than criterion for aquatic life in some portions, and bacteria levels exceed criterion of contact recreation
2110	Lower Sabinal River	Low	Point and non-point	Bacteria levels sometimes exceed criterion for contact recreation
2113	Upper Frio River	Medium	Point and non-point	Dissolved oxygen concentration occasionally lower than criterion for aquatic life in a certain area
2117	Frio River above Choke Canyon Reservoir	Medium	Point and non-point	Dissolved oxygen concentration occasionally lower than criterion for aquatic life, and bacteria levels sometimes exceed criterion for contact recreation

SOURCE: Texas Natural Resources Conservation Commission 2000.

Water quality data is summarized for the Guadalupe, San Antonio, and Nueces River Basins below. Each of these river basins encompasses aquifer discharge springs, including the Leona, San Pedro, San Antonio, Comal, Hueco and San Marcos Springs discussed in Section 3.3.1.2.

Guadalupe River Basin Water Quality

The Guadalupe River Basin is characterized in the State of Texas Water Quality Inventory published by the TCEQ (formerly TNRCC) as having generally high-quality water mostly due to the excellent quality and abundance of water discharged from the Edwards Aquifer (TNRCC 1996). TCEQ stream segments that undergo water quality monitoring are summarized in Table 3.3-4. Because Comal and San Marcos Rivers originate from springs fed by the Edwards Aquifer, the quality of these waters, especially at the headwaters, gives a good indication of groundwater quality. The other rivers and creeks flow through the contributing and recharge zones of the Edwards Aquifer and indicate typical water quality of water recharging the aquifer. See Table 3.3-4 for a summary of these segments' water quality as determined by TCEQ in 1996. The only other water entering the aquifer in this river basin is rainwater that falls over the recharge zone.

One non-point source pollution problem has been recently documented in the Guadalupe River Basin. As early as 1986, the presence of the chlorinated hydrocarbons tetrachloroethene, trichloroethene, and 1,2-dichloroethene was found in groundwater seeping into Willow Springs Creek, east of Interstate Highway 35 in San Marcos. Traces of these chlorinated hydrocarbons were also found in fish, prompting the TCEQ to consider adding the site to the state Superfund list (San Antonio Express News, February 2, 2001). Willow Springs Creek empties into the San Marcos River east of Interstate 35 (see Figure 3.1-5b). No traces of these chemicals were found in the San Marcos River.

Table 3.3-4. TCEQ surface water quality inventory summary for the stream segments in the Guadalupe River Basin overlying the Edwards Aquifer

Segment Name	Number	Classification	Designated Water Uses	Water Quality Concerns within Stream Segment
Lower Blanco River	1809	Effluent limited	Contact recreation, high aquatic life, public water supply	None known.
Upper Blanco River	1813	Effluent limited	Contact recreation, exceptional-quality aquatic habitat, public water supply, aquifer protection	Elevated levels of dissolved silver in the lower 25 miles.
Upper San Marcos River	1814	Effluent limited	Contact recreation, exceptional aquatic life	Elevated levels of nitrate plus nitrite nitrogen. Elevated levels of fecal coliform bacteria.
Cypress Creek	1815	Effluent limited	Contact recreation, exceptional aquatic life, public water supply	None known.
Guadalupe River below Canyon Dam	1812	Effluent limited	Contact recreation, exceptional aquatic life, public water supply, aquifer protection	Elevated levels of fecal coliform bacteria. Depressed concentrations of dissolved oxygen just downstream of Canyon Reservoir dam.
Comal River	1811	Effluent limited	Contact recreation, high aquatic life, public water supply	Elevated levels of nitrate plus nitrite nitrogen. Elevated levels of fecal coliform bacteria.
Canyon Lake	1805	Water quality limited	Contact recreation, exceptional aquatic life, public water supply, aquifer protection	Elevated levels of manganese in sediments near upper end of reservoir.

SOURCE: Texas Natural Resources Conservation Commission 1996.

San Antonio River Basin Water Quality

The San Antonio River, below San Antonio and outside the aquifer recharge and artesian zones, is characterized in The State of Texas Water Quality Inventory as historically having poor water quality. This is because the river is a principal recipient of effluent from San Antonio wastewater treatment plants. About 60 percent of water pumped from the Edwards Aquifer for municipal use is returned after treatment to destination streams (CH2M Hill 1986). However, recently the development of advanced wastewater treatment in the city of San Antonio has improved the dissolved oxygen level and aquatic habitat (TNRCC 1996). Main sources of toxic chemicals in the San Antonio River Basin come from urban runoff and municipal wastewater discharges. TCEQ stream segments in this river basin and over the Edwards Aquifer that undergo water quality monitoring are summarized in Table 3.3-5. All of the listed segments flow through the Edwards Aquifer contributing and recharge zones except Medina River below

Medina Diversion Lake, which flows over the Edwards Aquifer artesian zone. Table 3.3-5 provides a summary of these segments' water quality as determined by TCEQ in 1996. The only other water entering the aquifer in this river basin is rainwater that falls over the recharge zone.

Table 3.3-5. TCEQ surface water quality inventory summary for stream segments in the San Antonio River Basin overlying the Edwards Aquifer

Segment Name	Number	Classification	Designated Water Uses	Water Quality Concerns within Stream Segment
Medina River below Medina Diversion Lake	1903	Water quality limited	Contact recreation, high aquatic life, public water supply	Elevated concentrations of diazinon and dissolved silver. Concentrations of nitrate plus nitrite nitrogen, orthophosphorus and total phosphorus exceed screening levels. Elevated fecal coliform bacteria levels.
Medina Lake	1904	Water quality limited	Contact recreation, high aquatic life, public water supply, aquifer protection	Elevated concentrations of manganese in sediment of upper portion of reservoir.
Upper Leon Creek	1907	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	None known.
Upper Cibolo Creek	1908	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	Elevated levels of fecal coliform bacteria. Concentrations of orthophosphorus and total phosphorus exceed screening levels.
Medina Diversion Lake	1909	Water quality limited	Contact recreation, exceptional aquatic life, public water supply, aquifer protection	None known.
Salado Creek	1910	Water quality limited	Contact recreation, high aquatic life, public water supply, aquifer protection	Depressed concentrations of dissolved oxygen. Elevated levels of diazinon, fecal coliform bacteria, nitrate plus nitrite nitrogen, orthophosphorus, arsenic, cadmium, copper and lead most occurring downstream of the city of San Antonio.

SOURCE: Texas Natural Resources Conservation Commission 1996.

Nueces River Basin Water Quality

Water quality in the Nueces River Basin is characterized in the State of Texas Water Quality Inventory as generally of good quality, especially in the less inhabited areas (TNRCC 1996). Much of the flow from the Nueces River and its tributaries enters the Edwards Aquifer. Therefore, water downstream from the recharge zone is mostly comprised of storm water. During low-flow conditions, the Nueces River Basin's water quality level can be substantially degraded due to natural and human activities. TCEQ stream segments in this river basin and over the Edwards Aquifer contributing and recharge zones that undergo water quality monitoring are listed in Table 3.3-6. The Lower Sabinal River (Segment #2110) and the Frio River above Choke Canyon Reservoir (Segment #2117) flow through only the Edwards Aquifer artesian zone and do not contribute to Edwards Aquifer recharge. Table 3.3-6 provides a summary of these segments' water quality as determined by the TCEQ in 1996. The only other water entering the aquifer in this river basin is rainwater that falls over the recharge zone.

Table 3.3-6. TCEQ surface water quality inventory summary for stream segments in the Nueces River Basin overlying the Edwards Aquifer

Segment Name	Number	Classification	Designated Water Uses	Water Quality Concerns within Stream Segment
Lower Sabinal River	2110	Effluent limited	Contact recreation, high aquatic life, public water supply	Elevated levels of nitrite plus nitrate nitrogen, probably due to natural springflow. Elevated levels of fecal coliform bacteria.
Upper Sabinal River	2111	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	None known.
Upper Nueces River	2112	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	Elevated levels of nitrite plus nitrate nitrogen, probably due to natural springflow.
Upper Frio River	2113	Effluent limited	Contact recreation, exceptional aquatic life, public water supply, aquifer protection	None known.
Hondo Creek	2114	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	None known.
Seco Creek	2115	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	None known.
Frio River above Choke Canyon Reservoir	2117	Effluent limited	Contact recreation, high aquatic life, public water supply, aquifer protection	Elevated levels of nitrite plus nitrate nitrogen, probably due to natural springflow. Elevated levels of fecal coliform bacteria due to storm water runoff.

SOURCE: Texas Natural Resources Conservation Commission 1996.

3.3.2 Groundwater

3.3.2.1 Description of the Edwards Aquifer

The Edwards Aquifer, one of nine major aquifers in Texas and referred to as the Edwards Balcones Fault Zone Aquifer by the Texas Water Development Board (TWDB 2002), covers approximately 4,350 square miles across parts of 11 Texas counties (Figure 3.3-3). The aquifer extends from a groundwater divide in Kinney County through the San Antonio area northeast to Bell County. The Edwards Aquifer is comprised of three segments: the southern (San Antonio) segment; the Barton Springs (Austin) segment; and the northern segment. A groundwater divide running west-northwest from the city of Kyle, in Hays County, hydrologically separates the San Antonio and Austin (Barton Springs) segments. At this location, under most conditions, groundwater from the San Antonio and Austin segments do not mix. Generally, groundwater north of the divide flows north, while groundwater south of the divide flows south. The

Colorado River separates the Barton Springs segment from the northern segment. The focus of this groundwater discussion will be on the San Antonio segment of the Edwards Aquifer.

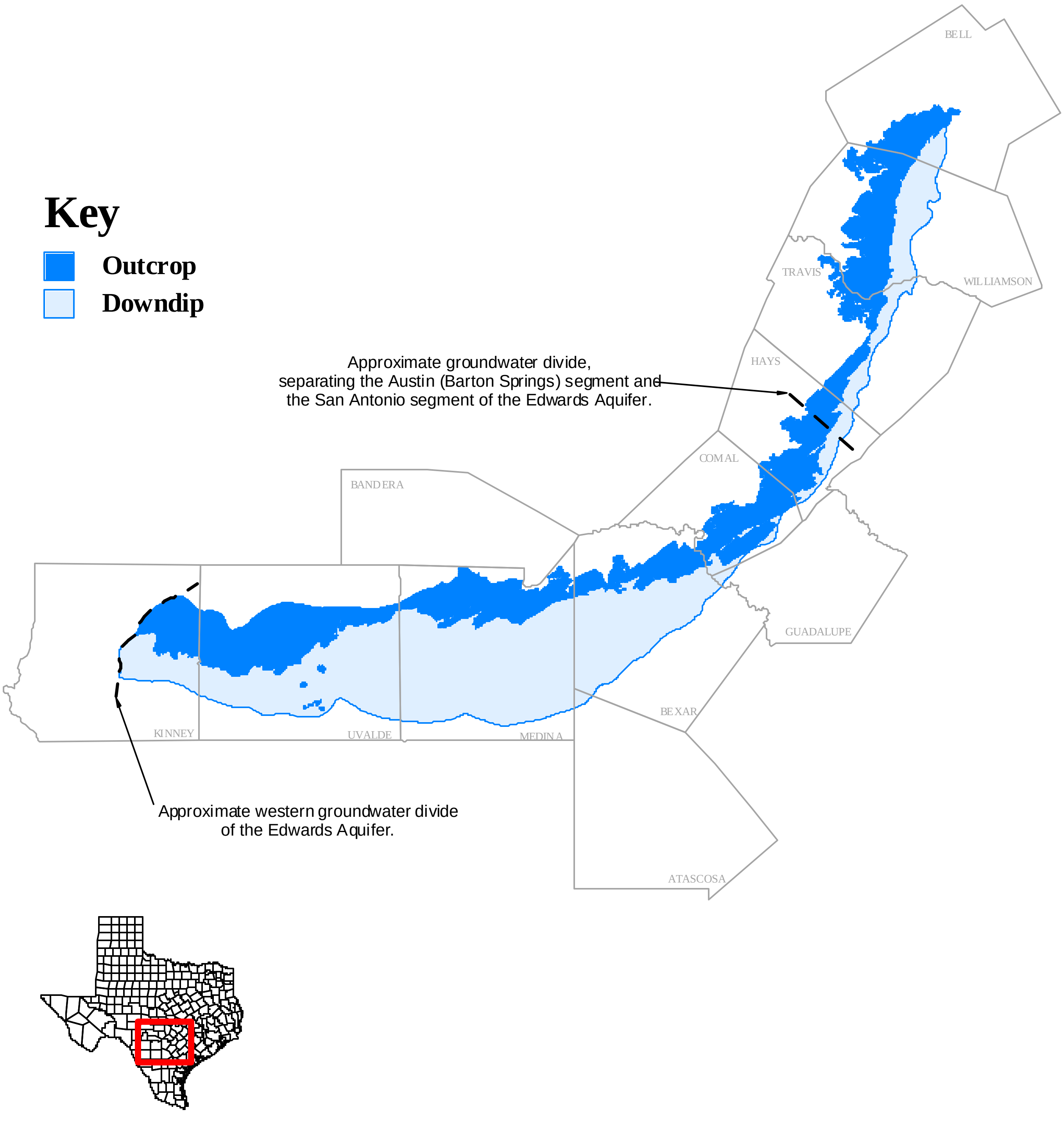
The southern portion of the Edwards Aquifer (San Antonio segment) shown in Figures 1.1-1, 3.2-4, and 3.3-1a is approximately 160 miles long measuring from the city of Brackettville in Kinney County to north of Kyle, in Hays County, Texas. It varies in width from 5 to 40 miles. This segment of the aquifer extends to cover the major part of five counties, Uvalde, Medina, Bexar, Comal and Hays. As described in Section 3.3.1 Surface Water, the Edwards Aquifer lies under several streams in three major river basins, the Nueces, San Antonio and Guadalupe. The San Antonio segment of the Edwards Aquifer holds water that drains from approximately 8,000 square miles in some 12 counties. The water-bearing body of the aquifer itself underlies approximately 3,600 square miles in eight counties. The total volume of circulating freshwater in the Edwards Aquifer is estimated at 173 million acre-feet (Bureau of Economic Geology 1995), making it one of the most productive aquifers in the United States. The aquifer, which historically has been the sole source of water for the city of San Antonio (Maclay 1995), provides base flow to the three river basins mentioned above, and is utilized for municipal, industrial and agricultural needs in and around the Edwards Aquifer region (USGS 1999). Since 1968, annual discharge from springflow and pumping has frequently exceeded average annual recharge.

Groundwater flow within the aquifer is very complex (Maclay 1995). Generally, the water flows south-southeastward from the recharge zone along low permeabilities and steep hydraulic gradients within the unconfined portion of the aquifer. As the water flows into the confined portion of the aquifer, the flow direction changes toward the east and northeast within the low gradient, highly permeable artesian zone. The water is then discharged from several springs, predominantly the Comal and San Marcos Springs (Section 3.3.1 Surface Water). Although the Edwards Aquifer contains vast reserves of water, a large volume of water cannot be extracted without affecting springflow and the overall water budget. This is because the springs are higher in elevation than much of the confined artesian zone. This relationship is similar to a bucket of water with holes at the top that are analogous to the spring locations. Although water is available in the lower portions of the bucket, it cannot be extracted without affecting the flow of water through the holes at the higher levels. The water budget of the Edwards Aquifer (recharge, discharge, and springflow) is discussed in Section 3.3.2.3.

The southern portion of the Edwards Aquifer consists of a recharge zone and artesian zone (see Figure 1.1-1). Each of these components is described below. The aquifer is also affected by a contributing zone.

Contributing Zone

The contributing zone of the San Antonio segment of the Edwards Aquifer is a surface component not technically part of the Aquifer that consists mainly of the drainage basins containing the streams, creeks, and rivers that eventually flow over and lead to the aquifer's



TWDB (1997)

Figure 3.3-3
Map of the Edwards Aquifer

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ARCHEOLOGICAL
AND PLANNING
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recharge zone in the Nueces, San Antonio, and Guadalupe River Basins. The contributing zone encompasses some 4,400 square miles in all or part of Edwards, Real, Kerr, Bandera, Kendall, Gillespie, Blanco, Bexar, Comal, Hays, Kinney, Uvalde and Medina Counties (see Figures 1.1-1, 3.3-1a, and 3.2-4). This area is important because of its substantial contribution to aquifer recharge. Future development in the contributing zone will be important to the Edwards Aquifer.

Recharge Zone

The recharge zone (also known as the unconfined region of the Edwards Aquifer) is an approximately 1,500-square-mile area where heavily faulted and fractured Edwards limestone outcrops at the land surface, allowing large quantities of water to flow into the aquifer. Recharge occurs when streams and rivers cross the permeable formation and a portion of their flow goes underground, or when precipitation or runoff falls directly on the outcrop. Surface water reservoirs on the recharge zone, such as Medina Lake, also contribute large amounts of water to the aquifer. About 85 percent of recharge occurs when rivers and creeks cross the recharge zone and contribute their flow to the underground formation. Except for the Guadalupe River, all rivers and streams that cross the outcrop of the Edwards Aquifer lose major portions of their flows to the aquifer through joints, faults, and sink holes (Maclay 1995). Where the Guadalupe River crosses the recharge zone it may either gain or lose water from the Edwards Aquifer, depending on aquifer levels. There are three river basins that cross the aquifer area: the Nueces, the San Antonio, and the Guadalupe River (see Section 3.3-1). Extending from the west, the Nueces River Basin covers over half of the aquifer area.

Most of the annual average recharge occurs in the western counties of Medina and Uvalde, where the Edwards limestone outcrop is very wide at the surface. In the recharge zone, there are no other geologic formations overlying the Edwards limestone. It is therefore exposed at the surface.

Several major tributaries in the Nueces basin traverse the aquifer recharge zone including the Nueces, West Nueces, Frio, Dry Frio, and Sabinal Rivers, as well as Hondo Creek. The portion of the San Antonio River Basin that is located in the recharge zone extends from the Medina River to Cibolo Creek and includes the headwaters of Leon and Salado Creeks. Only a small portion of the Guadalupe River Basin intersects the eastern aquifer area. However, two of the basin tributaries, the Comal and San Marcos Rivers, are primarily fed by the aquifer at the Comal and San Marcos Springs.

Artesian Zone

The artesian zone (also known as the confined region of the Edwards Aquifer) is located between two relatively impermeable formations, the Glen Rose formation below and the Del Rio clay above. The weight of water entering the aquifer from the recharge zone creates tremendous pressure on water that is already present in the formation. Flowing artesian wells and springs exist where this pressure is sufficient to force water to the surface through faults or wells. Examples of natural springs under artesian conditions are San Marcos and Comal Springs in the northeast. San Antonio Springs and San Pedro Springs in San Antonio are also artesian springs but are dry most of the time because of the large volume of water pumped out of the Aquifer by users in Bexar County. Groundwater movement through the Aquifer is generally controlled by a number of barrier faults that disrupt the continuity of the permeable Edwards limestone. This movement tends to be from the higher elevations in the west to discharge areas in the east. The displacement of strata ranges from very large, which causes permeable and impermeable layers to be juxtaposed, to very small. Water moves more freely through the Aquifer when displacement is minimal. Additionally, groundwater divides exist in the west near Brackettville and in the east near Kyle, so the central portion of the aquifer is hydrogeologically separated from Edwards limestones on either side (see Figure 3.2-6).

Hydraulic Properties

Aquifer transmissivity (the ability of water to pass through the aquifer, as measured by permeability and thickness) is high. According to Maclay and Small (1984), transmissivity of the aquifer in the San Antonio area varies from one to two million square feet per day, allowing some wells in the city of San Antonio to discharge as much as 10,000 gallons per minute or more (Maclay 1995). One particular well was documented by the Authority to produce between 25,000 and 36,000 gallons per minutes. Highest transmissivity was determined to exceed 4,300,000 square feet per day in Comal County near Comal Springs; the smallest was 130 square feet per day in the saline water zone (Maclay and Land 1988). Linear distance at which water may move through the aquifer varies from up to 1,000 feet per day to only a few feet per day (Ogden et al. 1986). Other evidence of high porosity of the aquifer is the ability of aquifer water levels to quickly respond to rainfall and recharge events and rapid decline of water levels over a large area due to increased pumpage.

The Knippa Gap near Sabinal in eastern Uvalde County (see Figure 3.2-6) is a major controller of groundwater flow within the western portion of the Edwards Aquifer. The Knippa Gap is a narrow opening within a complex and extensive system of barrier faults and igneous intrusions. This narrow opening restricts the rapid movement of large amounts of water from the western portion to the eastern portion of the aquifer. Wells to the west of the Knippa Gap display much less variability in water levels than wells to the east. Water entering the recharge zone in northwestern Uvalde County has to flow through the gap to reach the main freshwater zones of the Edwards Aquifer in Medina and Bexar Counties.

Freshwater/Saline Water Interface

The freshwater/saline water interface (also known as the “Bad Water Line” or BWL) delineates the aquifer’s eastern and southern boundaries. It is not an actual, well-defined boundary but rather a transition zone on the southern and eastern limits of the aquifer extending from west of

Kinney County through Bexar County and northward beyond the northern extent of the San Antonio region of the Edwards aquifer. Wells to the south and southeast of this line typically have total dissolved solids (TDS) concentrations of greater than 1,000 mg/l. Wells on the other side of this line typically have TDS concentrations of less than 1,000 mg/l. The reason why the “bad-water line” exists is not clear, in some places it is coincident with geologic features such as faults, in other places there is no obvious geologic control. The presence of “bad” or more saline water appears to be more associated with relative permeabilities of the aquifer rather than a density boundary between two different water types, which commonly exists in coastal sand aquifers. Wells in the transition zone have shown sections of brackish water that overlie freshwater, which in turn overlie brackish water, indicating that the type of rock and porosity influences the salinity of the water.

It has been hypothesized that increased pumping of freshwater from the aquifer may lead to an expansion of the bad-water zone, which could be detrimental to existing irrigation and municipal wells. In 1985, the Authority, in cooperation with USGS, TWDB, and SAWS began testing in the fresh/saline interface area for possible saline-water encroachment into the freshwater zone. In 1997, the Authority reported that there were no significant changes in water quality in the test wells between 1985 and 1997 and that normal changes in aquifer water levels have little effect on the quality of freshwater near the interface.

3.3.2.2 Groundwater Quality

Rules and Regulations Governing Groundwater Quality

Regulations governing the quality of groundwater in Texas have interrelated state and federal regulatory functions. In 1974, the Federal Safe Drinking Water Act was passed to protect sources of public drinking water. This Act, amended in 1996, mandated enforceable drinking water standards established by the Environmental Protection Agency (EPA). The TCEQ (formerly TNRCC) has assumed responsibility for enforcement of drinking water standards in Texas and has established standards as strict or stricter than the EPA. The Edwards Aquifer was designated as a sole source aquifer and TCEQ promulgated rules regulating development activity in the Edwards Aquifer recharge zone and the Edwards Aquifer contributing zone (30 Tex. Administrative Code, Chapter 213). Subchapter A applies to all regulated activities (defined as construction-related or post-construction activity) within the recharge zone, to certain activities within the surrounding transition zone that stretches along the eastern and southern boundary of the recharge zone, and to other activities that may potentially contaminate the aquifer and hydrologically connected surface streams. Persons or entities subject to the rules must submit an Edwards Aquifer protection plan to the TCEQ prior to certain types of construction in the recharge or transition zones of the Edwards Aquifer. The plan must include a geological assessment report identifying pathways for movement of contaminants to the aquifer, and a report on best management practices and measures to prevent pollution of the aquifer. After the plan is approved, notice must also be filed in the county deed records that the property is subject to an approved Edwards Aquifer protection plan. Certain facilities are also prohibited from being built in the recharge or transition zones such as Type 1 municipal solid waste landfills and waste disposal wells. Subchapter B applies to regulated activities in the Edwards Aquifer contributing zone. All activities that disturb the ground or alter a site's topographic, geologic, or existing recharge characteristics are subject to regulation, which would require either sediment and erosion controls or a Contributing Zone (CZ) Plan to protect water quality during and after construction. Exemptions include construction of single-family residences on lots larger than five acres, where no more than one single-family residence is located on each lot; agricultural activities; oil and gas exploration, development, and production; clearing of vegetation without soil disturbance; and maintenance of existing structures not involving additional site disturbance.

Local municipalities have also imposed aquifer protection requirements. The City of Austin has imposed watershed ordinances to require development standards for erosion and sedimentation control, impervious cover limits, stream or creek setback requirements and water quality control. The City of San Marcos has also enacted regulations to protect water quality over the aquifer recharge zone.

The Edwards Aquifer Authority has a water quality program and is in the process of implementing that program through rulemaking. As currently envisioned, the program consists of two elements: well construction regulation and recharge zone protection. Well construction rules have been adopted that regulate the construction, operation, maintenance, abandonment, and closure of wells. *See* EAA RULES ch. 713 (Water Quality), subchs.. A (Definitions), C (Well construction, Operation and Maintenance), and D (Abandoned Wells; Well Closures). The Authority has also adopted Phase I of its recharge zone protection rules generally prohibiting the installation of tanks containing certain regulated substances on the recharge zone. *See id.* 713, subch. G (Recharge Zone Protection). The Authority has constituted a water quality task force to advise the Authority on the merits of adopting Phase II rules that would further regulate activities occurring on the recharge zone (and perhaps the contributory zone) that have the potential to contaminate surface water that recharges the aquifer. This rulemaking, to the extent it occurs, will proceed beginning the summer 2004 and continue through the spring 2005.

Current Status

The groundwater of the Edwards Aquifer is generally known to be of high quality, typically fresh, but hard with an average dissolved solid concentration of less than 500 mg/l (TWC 1992). Cooperative efforts between the Authority, USGS, and TWDB have resulted in a systematic program of water data collection. In 1998, the Authority, in cooperation with the USGS and SAWS, collected water quality samples from 63 wells, 4 springs, and 8 streams. Tests for the wells included measurements of temperature, pH, conductivity, alkalinity, major ions, minor elements (including heavy metals), total dissolved solids, nutrients, pesticides, herbicides, volatile organic compounds (VOCs), and other analytes. Results of the testing (EAA 1998a) indicated some wells within the saline zone in San Antonio, New Braunfels, and San Marcos and private wells in Medina and Uvalde Counties contained some minor metal concentrations (manganese and iron) above the method detection limit. Other well tests indicated extremely low contaminant levels, with only one well exceeding the maximum contaminant level for lead. Otherwise, no detectable levels of VOCs, pesticides, herbicides, other minor elements or major ions were present. Nitrites and nitrates in several wells were above the method detection limits; however, all were below the maximum contaminant level for drinking water (EAA 1998a). Nonenforceable secondary drinking water standards are guidelines for the appearance and odor of water. Occasionally, naturally occurring concentrations of total dissolved solids, fluoride, and iron exceed the secondary standards.

3.3.2.3 The Edwards Aquifer Water Budget

The dynamics of Edwards Aquifer water levels and associated flows of Comal and San Marcos Springs are affected by the rate of water entering the aquifer (recharge) and the rate of water exiting the aquifer (discharge). Recharge, as discussed, occurs from water entering the recharge zone from streams, natural catchments, recharge structures and localized runoff from precipitation events. Seasonal rainfall over the region ultimately controls the rate of recharge. Discharge occurs from withdrawal of water from wells and from natural springs and seeps. An unknown smaller quantity is discharged to the saline water zone (Maclay 1995). Discharge is greatly affected by water demand and rate of pumping. If recharge is high, the aquifer can sustain higher levels of pumping, while maintaining higher levels of springflows. However, if there is low seasonal recharge followed by reduced rainfall and by high rates of pumping, then aquifer levels decrease with resulting decreased spring discharge. Historic recharge and discharge of the Edwards Aquifer and effects to springflow are discussed below.

Groundwater Recharge

Estimates of the average annual recharge of the Edwards Aquifer vary. Maclay (1995) cites an average annual recharge of 635,000 acre-feet. However, Klemt et al. (1979) indicate an average annual recharge of approximately 651,000 acre-feet. Data from the Authority (2003c) indicate an average annual recharge of 699,000 acre-feet for the period of record 1934-2002, and an even higher annual average of 794,000 acre-feet during the period 1993-2002. USGS aquifer recharge data for the years 1934-2002 are listed in Appendix C, Table C-1. Contributions of the major river basins to the average annual recharge during the period of record 1934-2002 are listed in Table 3.3-7.

Table 3.3-7. Contributions of major river basins to average annual recharge of the Edwards Aquifer, 1934-2002

Area	Average Annual Recharge (acre-feet)
Frio River–Dry Frio River Basin	135,200
Nueces River–West Nueces River Basin	120,700
Area between Sabinal River and Medina River Basins	110,700
Cibolo Creek–Dry Comal Creek Basin	111,300
Area between Medina River and Cibolo Creek–Dry Comal Creek Basins	71,500
Medina River Basin	62,400
Blanco River Basin	44,600
Sabinal River Basin	42,600
TOTAL	698,900

SOURCE: Edwards Aquifer Authority 2003c.

Recharge to the aquifer varied greatly during the years 1934-2002 as indicated in Figure 3.3-4. Variability was correlated with annual precipitation and corresponding runoff into the major river and creek basins. Lowest annual recharge (44,000 acre-feet) occurred during 1956 at the peak of the drought of record. Highest recharge (2,486,000 acre-feet) occurred in 1992. Most recharge is contributed by streams crossing the aquifer recharge zone (85 percent). A much smaller portion is contributed by direct precipitation and localized runoff within the recharge zone (15 percent). Rates of infiltration of water carried by the streams across the recharge zone have been estimated by the U.S. Army Corps of Engineers (1965) to range from 500 to greater than 1,000 cfs.

Groundwater Discharge

Water escapes the Edwards Aquifer from wells, and from natural springs and seeps occurring near geological faults along the Edwards formation and Balcones Escarpment. Wells are the principal source of water for agricultural, municipal, and industrial uses in the region. Depths of wells range from less than 500 feet in the unconfined aquifer to more than 3,000 feet in the confined aquifer in the western region (Maclay 1995). Wells in the area can be very large, with casing diameters ranging from 10 to 30 inches and capable of pumping in excess of 35,000 gallons per minute. The contribution of groundwater pumping to total aquifer discharge in 2002 was approximately 38 percent (367,200 acre-feet), while springflow contributed about 62 percent (609,900 acre-feet) (Appendix C, Table C-2). However, over the years 1934 to 2002, the proportion of total discharge contributed by pumping and springflow varies greatly (Figure 3.3-5). Values for average and median discharge are provided in Appendix C, Table C-2. Historic groundwater recharge data are provided in Appendix C, Table C-1.

Well discharge has generally increased over the period of record to a point beginning in 1968 and running through 1989 where annual discharge consistently exceeded the average annual recharge (Maclay 1995). Pumping peaked in 1989 at an estimated level of 542,000 acre-feet. Since 1980, as a result of increased pumping, there has been greater fluctuation of springflow with increased time required for recovery, even during a period that recorded the two highest levels of aquifer recharge (1992 and 1987). Examination of Figure 3.3-5 indicates increases in pumping beginning in 1982, 1987, and 1996, resulting in higher fluctuation of springflow. Groundwater discharge data is provided in (Appendix C, Table C-2).

Function of the Edwards Aquifer in Relation to Critical Periods

In late 1999, the Edwards Aquifer Authority formed a Technical Advisory Group to study aquifer relationships during critical periods when aquifer discharge from springflow and pumping is considerably higher than aquifer recharge. This technical work group, comprised of Authority staff and consultants, met regularly to develop technically based recommendations for trigger levels and demand reductions to slow declining springflow by managing groundwater pumping during critical period conditions. The investigation involved evaluation of

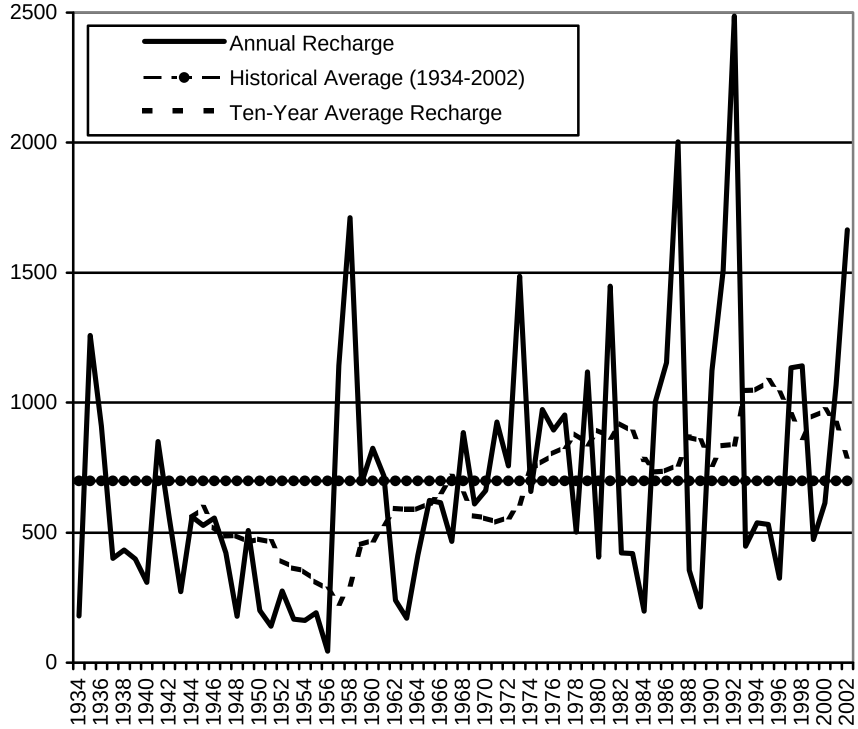

Figure 3.3-4

Estimated Annual Recharg and Ten-year Floating Average Recharge for the San Antonio Segment of the Edwards Aquifer 1934 2002 (Edwards Aquifer Authority (2003c)

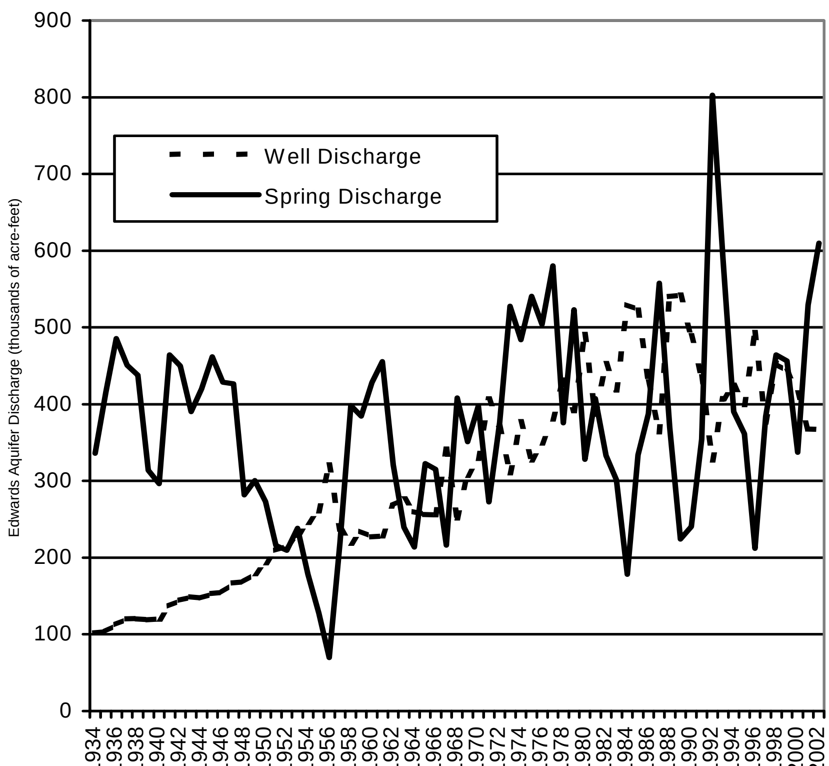

Figure 3.3-5

Groundwater Pumping Compared to Springflow from the Edwards Aquifer 1934-2002 (Edwards Aquifer Authority 2003c) precipitation, recharge, groundwater withdrawal, aquifer levels and spring discharge. The GWSIM-IV groundwater model described in Appendix B was used to assist the evaluation. Findings of the Technical Advisory Group are summarized below:

1. Aquifer levels and spring discharge peak during the 1st (January-March) and 4th (October-December) calendar quarters.

2. Groundwater demand is highest during the 2nd (April-June) and 3rd (July-September) calendar quarters. Irrigation demand is highest in April, May and June; municipal demand is highest in June, July and August.

3. Flows of Comal Springs are highly correlated with aquifer levels measured by the Index Well J-17.

4. All pumping throughout the aquifer region contributes to the aquifer water level problem.

5. A single critical period trigger is not effective.

6. Model simulations indicate that declines in groundwater result from both irrigation, municipal, and industrial demand.

7. Groundwater demand within a geographic area impacts water levels by the same principles of hydrology.

8. Due to high aquifer transmissivity, groundwater levels respond simultaneously to pumping throughout large areas of the aquifer region.

9. Moderate pumping reductions are preferred early in the year rather than deep reductions in summer.

Recommendations developed by the Technical Work Group based on the above findings include:

1. A critical period management plan should have the following goals: 1) to provide continued springflow to the extent required by federal law; and 2) to provide maximum beneficial use of the water resources of the aquifer during critical periods.

2. Aquifer conditions should be evaluated using aquifer index wells and spring discharge.

3. Critical Period should be initiated by either index well water levels or springflow levels (based on a 5-day average) according to which trigger (index well level or springflow level) is reached first.

4. Critical Period should be based on the establishment of a quarterly water management budget by each pumper and include implementation of specified stages of demand management/critical period management reductions.

Contribution of Edwards Aquifer Discharge to Instream Flows into Bays and Estuaries

The contribution of aquifer discharge to the Lower Guadalupe River and the Guadalupe Estuary System is discussed in Section 3.3.1.1, Surface Water in River Basins.

3.4 Agriculture

Agriculture within the EAHCP Planning Area has historically depended on irrigation water pumped from the Edwards Aquifer. The Edwards Aquifer Authority Act created the Edwards Aquifer Authority "for the effective control of the resource to protect terrestrial and aquatic life, domestic and municipal water supplies, the operation of existing industries, and the economic development of the state." The Act affects irrigation water users in a number of ways. Article 1, Section 1.16, Subsection (e) of the Act authorizes the issuance of initial regular groundwater withdrawal permits to existing users for withdrawal of an amount of water equal to the user's maximum beneficial use of water without waste during any one calendar year of the historical period (June 1, 1972 through May 31, 1993). Water users without one year of historical use shall be issued a permit for withdrawal based on an amount of water that would normally be beneficially used without waste for the intended purpose for a calendar year. The Act also states that if the total amount of water determined to have been beneficially used without waste exceeds the amount of water available for permitting the authority shall proportionately adjust the amount of water authorized for withdrawal under the permits to meet the amount available for permitting. An existing irrigation user shall receive a groundwater withdrawal permit for not less than two acre-feet a year for each acre of land the user actually irrigated in any one calendar year during the historical period. An existing user who has operated a well for three or more years during the historical period shall receive a groundwater withdrawal permit for at least the average amount of water withdrawn annually during the historical period.

Article 1, Section 1.16, Subsection (c) states that an owner of a well from which the water will be used exclusively for domestic use or watering livestock and that is exempt under Section 1.33 of Article 1, is not required to file a declaration of historical use. Section 1.33, Subsection (a) exempts wells that produce 25,000 gallons of water a day or less for domestic or livestock use from metering requirements.

(1) One of the options being considered to meet future water supply needs is the transfer of Edwards Aquifer irrigation water to municipal and industrial use. This would involve the purchase or lease of a groundwater withdrawal permit holder's water rights as allowed for in the Act.

Transfer of these permitted irrigation water rights could have a significant effect on agricultural production in the EAHCP Planning Area. Counties that would be particularly affected include Uvalde, Medina, Bexar, and part of Atascosa.

3.4.1 Production

Agricultural enterprises in the EAHCP Planning Area are extremely diverse with regard to commodities produced, ranging from livestock to row crops to aquaculture. For purposes of this section, the EAHCP Planning Area has been divided into four regions (Figure 3.4-1). The Western Region includes those counties overlying the western part of the Edwards Aquifer and includes Edwards, Kinney, Real, and Uvalde Counties. The Central Region includes two counties, Atascosa and Medina. The Eastern Region includes the big urban centers along the Interstate 35 corridor and contains Bexar, Caldwell, Comal, Guadalupe, Hays and Kendall Counties. The Downstream Region includes those counties adjacent to the Guadalupe River to its confluence with San Antonio Bay and the Texas Gulf Coast. Counties in the Downstream Region include Calhoun, DeWitt, Gonzales, Refugio, and Victoria. Agricultural enterprises vary greatly within these regions and range from livestock production to row crops to aquaculture.

The Western and Central Regions are on the northern portion of what is known as the Texas “Winter Garden” area. Prior to European settlement, this area was native grassland and mixed brush. However, much of this land was eventually cleared for both dry land and irrigated farming. Many of the larger ranches were broken up into smaller farms for agricultural production. Today, many crops are produced with heavy reliance on irrigation. Such crops include onions, spinach, beets, cantaloupe, strawberries, and watermelons. Nut trees and some citrus are also grown in the Winter Garden area (Odintz 1999). Other crops include peanuts, corn, cotton, sorghum, wheat, and nursery crops. Livestock production includes cattle, sheep and goats.

The Eastern Region is heavily dominated by urban and suburban areas; however, many agricultural areas still prevail and include livestock production and various crops such as cotton, grain sorghum, and hay. Much of the cropland areas are irrigated in this region. Many small farms, particularly those near large metropolitan areas are being used for part-time or retirement occupations. By 1987, 48 percent of the 1,950 farms in Bexar County contained less than 49 acres (Albrecht 1999).

The Downstream Region also contains extensive agricultural areas although there is less reliance on irrigation than in the other regions, due to higher rainfall and moderated temperatures from weather patterns influenced by the Texas gulf coast. Principal agriculture operations are livestock production including cattle, sheep, hogs, and poultry. Row crops are varied and include cotton, sorghum, peanuts, corn, rice, soybeans, nursery crops, and sunflowers. Substantial acreage is allocated for livestock grazing and hay production.

Agricultural operations throughout the EAHCP Planning Area are being influenced by higher equipment costs, higher energy costs for planting, irrigation, and harvest, and low livestock and crop prices. This has resulted in an increase of larger commercialized operations, and a decrease in the size of family-owned farms and ranches.

Agricultural information including total cropland acreages, irrigated cropland, harvested cropland, numbers of cattle and calves, hogs and pigs, sheep and lambs, and poultry three months old or older is compiled for each county in the EAHCP Planning Area for the years 1987, 1992, and 1997 (Appendix D). The data are from statistics gathered by the USDA and published in their *1997 Census of Agriculture Highlights*, which is published every five years.

Agricultural trend data concerning changes in cropland acres and livestock numbers between 1987 and 1997 are included in Appendix D. However, summaries of this data for each of the four regions within the EAHCP Planning Area are provided below.

Total cropland acres for the Western Region counties increased 23.6 percent from 1987 to 1997, irrigated cropland acres increased 9.8 percent, and harvested cropland acres increased 21.1 percent. Cattle and calf numbers increased 5.1 percent, and sheep and lamb numbers decreased 22.2 percent. Changes in hog and pig numbers and poultry numbers were not included because of incomplete data.

Cropland acres for the Central Region counties increased 5.4 percent from 1987 to 1997, irrigated cropland acres increased 21.9 percent, and harvested cropland acres increased 14.6 percent. Cattle and calf numbers decreased 6.5 percent, hog and pig numbers decreased 55.5 percent, and sheep and lamb numbers decreased 4.4 percent. Changes in poultry numbers were not included because of incomplete data.

In the Eastern Region counties total cropland acres increased 7.5 percent from 1987 to 1997, irrigated cropland acres decreased 0.4 percent, and harvested cropland acres increased 13.1 percent. Cattle and calf numbers decreased 2.4 percent, hog and pig numbers decreased 53.6 percent, sheep and lamb numbers decreased 13.5 percent, and poultry (three months old and older) numbers increased 18.9 percent.

In the Downstream Region between 1987 and 1997, total cropland acres increased 4.1 percent, irrigated cropland acres decreased 38.9 percent, and harvested cropland acres increased 25.1 percent. Cattle and calf numbers increased 14.3 percent, hog and pig numbers decreased 53.9 percent, sheep and lamb numbers decreased 22.4 percent, and poultry (3 months old and older) numbers increased 24.2 percent.

Total cropland acres for all regions combined increased 7.3 percent from 1987 to 1997, irrigated cropland acres increased 8.1 percent, and harvested cropland acres increased 18.7 percent. Cattle and calf numbers increased 4.4 percent, hog and pig numbers decreased 51.8 percent, sheep and lamb numbers decreased 20.1 percent, and poultry numbers decreased 14.8 percent.

Table 3.4-1 gives average water requirements for livestock, but these are only general guidelines. Actual requirements are variable and can be influenced by a number of factors. For example, at 67°F cattle need approximately three pounds of water for every pound of feed while at 115° F they need approximately eight pounds of water for every pound of feed.

Table 3.4-1. Average livestock water requirements

Livestock Type	Gallons/Day/Head
Dairy cows	15 to 25
Beef cattle	7 to 12
Swine (market hogs)	1 to 2.5
Sows plus litter	4.5 to 6
Ewes or lambs	1 to 2
100 laying hens	8 to 10
100 turkeys 10 weeks	10
100 turkeys 25 weeks	15

SOURCE: Doane's Facts and Figures for Farmers.

3.4.2 Water Use

Agriculture in the study area has historically been dependent on irrigation. As indicated by Appendix D, Table D-4, crop yields are much higher with irrigation, and without irrigation some crops could not be grown at all. Tables showing estimated water use for irrigation by county for 1958, 1964, 1969, 1974, 1979, 1984, 1989, and from 1992 to 1997 are provided in Appendix D. Trends in the use of water for irrigation are provided in Section 3.5.5.1 below.

Irrigation water use varies year by year. Historically, seasonal rainfall patterns exerted a prominent role in affecting changes between dry land farming and irrigation. More recently, other factors now affect irrigation acreage. These include greater irrigation efficiency, higher energy costs for electricity and diesel fuel required for pumping, changes in crop prices, and market factors which influence the transfer or purchase of water rights. However, there are indications of long-term trends in irrigation water use for both the upstream and downstream counties.

According to information provided by the Texas Water Development Board (2000a), groundwater irrigation use for downstream counties in 1958 was 17,081 acre-feet. There were variations in the intervening years, but by 1997 irrigation use had decreased to 9,352 acre-feet. Similarly, irrigation through the use of surface water decreased from 17,327 acre-feet in 1958 to 12,222 acre-feet in 1997 (the high for one year was 41,258 acre-feet in 1974).

Western, Central, and Eastern Region counties have also seen changes in the amounts of water used for irrigation. Surface water use in the Western Region was 2,400 acre-feet in 1958, peaked at 6,278 acre-feet in 1974, and was 163 acre-feet in 1997 (Texas Water Development Board 2000a). Groundwater use in the Western Region followed a similar course, rising from 19,352 acre-feet in 1958 to a peak of 162,351 acre-feet in 1989 and falling to 66,261 acre-feet in 1997.

Surface water use in the Central Region was 10,661 acre-feet in 1958, peaked at 43,828 acre-feet in 1989, and was 11,105 in 1997 (Texas Water Development Board 2000a). Groundwater use in the Central Region in 1958 was 42,147 acre-feet, peaked at 160,482 acre-feet in 1989, and was 76,285 acre-feet in 1997.

Eastern Region counties used 17,641 acre-feet of surface water for irrigation in 1958 (Texas Water Development Board 2000a). Surface water use peaked in 1964 at 32,030 acre-feet and fell off to 13,296 acre-feet by 1997. Groundwater use in 1958 was 27,036 acre-feet, peaked at 35,569 acre-feet in 1964 and was 26,648 acre-feet in 1997.

Use of groundwater for irrigation in the 17-county EAHCP Planning Area during the years 1992-1997 varied from a high of 253,400 acre-feet in 1994 to 178,500 acre-feet in 1997 (Appendix D, Table D-4).

3.4.3 Other Agricultural Enterprises

3.4.3.1 Aquaculture

According to the National Agricultural Statistics Service's 1997 Census of Aquaculture, there were 82 aquaculture farms in Texas. Of these farms, 44 used groundwater as their water source. It is not known how many of these farms use water from the Edwards Aquifer. However, aquaculture became an issue with the opening of the Living Waters Artesian Springs Ltd. in 1990. According to the Texas Water Resources Institute (1991) this commercial catfish farm was pumping as much as 35,000 gallons per minute or 50 million gallons per day (77 cfs) through its raceways and discharging more than 94 percent of the water that was pumped into the Medina River. The Edwards Underground Water District and the San Antonio River Authority sued the farm because its operations were increasing coliform levels and violating water quality provisions of the Texas Water Code. Since that time, pumping has been discontinued and all of the water rights have been purchased by the San Antonio Water System. An initial regular groundwater withdrawal permit for the farm to pump 17,724 acre-feet per year was issued in 2002. Since that time, pumping has been discontinued and all of the water rights have been purchased by the San Antonio Water System.

3.4.3.2 Hunting Leases

Leasing of hunting rights has become a very important avenue for earning supplemental income for many agricultural producers in the EAHCP Planning Area and throughout Texas. In 1990 the Texas Agricultural Extension Service prepared a report summarizing leased hunting in Texas (Thomas et al. 1990). It is a summary of information for Texas and by ecological regions within the state. Counties in the study area lie in five different ecological regions (see Figure 3.1-1). The Western, Central, and Eastern Region counties lie in the Edwards Plateau, South Texas Brush Country, and Blackland Prairie ecological regions, while the Downstream Region counties lie in the South Texas Brush Country, Oak Woods and Prairie, and Gulf Coast Prairie and Marshes ecological regions.

According to the report, leasing of hunting rights is a well-established practice in the ecological regions within the EAHCP Planning Area. The mean length of time which respondent properties had been leased was eight years in the Gulf Coast Prairie and Marshes region, nine years in the South Texas Brush Country, ten years in the Oak Woods and Prairie, and fourteen years in the Edwards Plateau. Grazing was the primary agricultural activity occurring on properties in the report, followed by cropland in the Gulf Coast Prairie and Marshes and South Texas Brush Country, small grains in the Edwards Plateau, and timber in the Oak Woods and Prairie. Gun hunting was the primary recreational use for all regions; followed by fishing in the Gulf Coast Prairie and Marshes, and Oak Woods and Prairie; private bird hunts in the South Texas Brush Country; and bow hunts in the Edwards Plateau.

The majority of supplemental hunting leases in all four ecological regions were operated for additional income. Feeding of wildlife was the primary management technique used in each of the regions, followed by building of tanks and ponds in each region except the Edwards Plateau where harvest control was second. More than 60 percent of the respondents in the four regions indicated that the hunting lease would be in operation the following year. Landowners were reluctant to report lease income; thus, estimates are conservative. Reported mean annual lease income for 1989 (the year for which data was gathered) was $9,227 for the Gulf Coast Prairie and Marshes region, $1,870 for the Oak Woods and Prairie region, $7,642 for the South Texas Plains, and $4,600 for the Edwards Plateau. This type of additional income has become an important factor in agri-business. Further, income from hunting leases on private land in Texas will likely increase due to projected higher demand, since public land comprises less than five percent of the total state land area.

3.5 Demographics

3.5.1 Regions

Demographic, economic, and land use data were compiled for the same 17-county EAHCP Planning Area as outlined in Section 1.1. This area includes eight counties within the Authority's jurisdiction proper, an additional four counties that contain that portion of the Authority's jurisdictional five-mile buffer zone located over the Edwards Aquifer Contributing Zone, and an additional five counties in the South Central Texas Water Advisory Committee's jurisdiction that are also adjacent to the Guadalupe River.

In order to simplify the discussion of demographic conditions, the Planning Area has been divided into four regions (see Figure 3.4-1). These are generally based on regions previously defined by Authority rules (EAA 2000a).

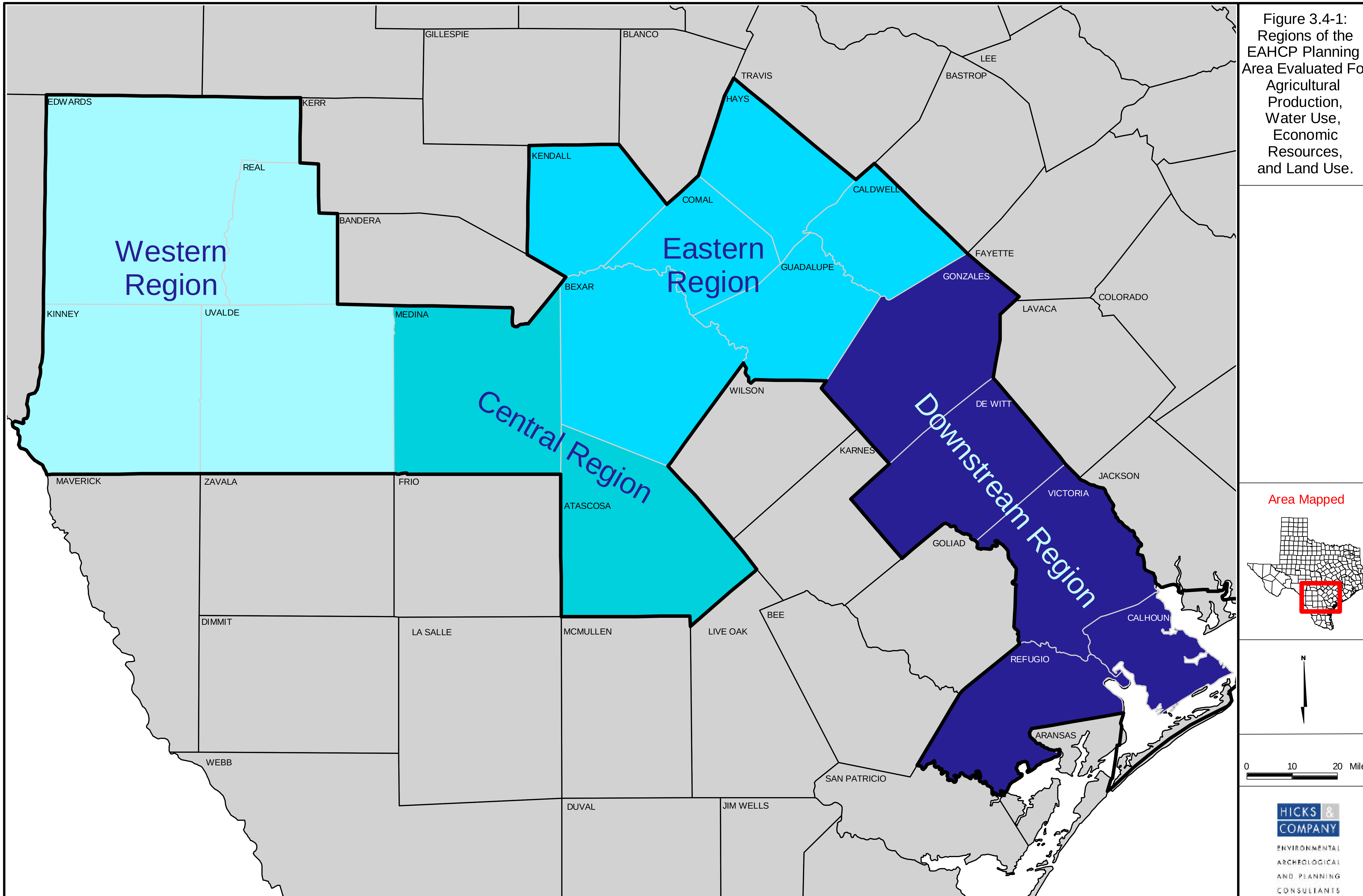

Figure 3.4-1: Regions of the EAHCP Planning Area Evaluated For Agricultural Production, Water Use, Economic Resources, and Land Use.

- **Western Region** (Edwards, Kinney, Real and Uvalde Counties). There are no Metropolitan Statistical Areas (MSAs) within this region.

- **Central Region** (Medina and Atascosa Counties). There are no MSAs within this region.

- **Eastern Region** (Bexar, Caldwell, Comal, Hays, Guadalupe, and Kendall Counties). This grouping keeps the three counties in the EAHCP Planning Area that are part of the San Antonio MSA in the same region and includes the main municipal water users along the I-35 corridor. When San Antonio MSA data is discussed in this section, please note that the MSA includes Bexar, Comal, Guadalupe, and Wilson Counties, but the latter is not part of the EAHCP Planning Area.

  Caldwell and Hays Counties are part of the Austin-San Marcos MSA. No data have been included in this section for the Austin-San Marcos MSA, however, because Caldwell and Hays are only two of five counties that make up the MSA, which is dominated by the much more urban Travis and Williamson Counties.

- **Downstream Region** (Calhoun, DeWitt, Gonzales, Refugio, and Victoria Counties). The Victoria MSA is a single-county MSA and the only one located within this region.

3.5.2 Population Growth

According to the Texas State Data Center, the State of Texas grew by the second largest numerical change of any state between 1990 and 1999, adding 3,057,806 persons. Most of this growth has occurred along the Texas-Mexico border and in the large urban areas of Houston, San Antonio, Austin and Dallas (Murdock et al. 1996). Approximately 85 percent of the state's population lives in metropolitan areas, according to the U.S. Census Bureau (2000a). Between 1990 and 2000, the total population within the EAHCP Planning Area grew by an estimated 19 percent—more than a third of a million people (335,645), according to the U.S. Census Bureau (Table 3.5-1). A majority of this growth (88.9 percent) occurred within the six Eastern Region counties that include the San Antonio MSA and the Comal and San Marcos Springs ecosystems. The remaining 11.1 percent of growth between 1990 and 2000 occurred within the remaining eleven, more rural counties making up the Western, Central and Downstream Regions.

3.5.2.1 Western Region

The Western Region of the EAHCP Planning Area experienced a 10.8 percent increase in population between 1990 and 2000. Historically, Uvalde County experienced steady growth from 1950 to 2000, but Edwards, Kinney, and Real Counties all declined in population between 1950 and 1970, and began to grow again in the 1980s and 1990s (see Table 3.5-1). Today, this region contains less than two percent (1.8 percent) of the entire Planning Area's population.

Table 3.5-1. Population growth in the EAHCP Planning Area, by region and county, 1950-2000

County	1950	1960	1970	1980	1990	2000	% Change 1990-2000
WESTERN REGION							
Edwards	2,908	2,317	2,107	2,033	2,266	2,162	-4.6
Kinney	2,668	2,452	2,006	2,279	3,119	3,379	8.3
Real	2,479	2,079	2,013	2,469	2,412	3,047	26.3
Uvalde	16,015	16,814	17,348	22,441	23,340	25,926	11.1
Subtotal/Avg	24,070	23,662	23,474	29,222	31,137	34,514	10.8
CENTRAL REGION							
Atascosa	20,048	18,828	18,696	25,055	30,533	38,628	26.5
Medina	17,013	18,904	20,249	23,164	27,312	39,304	43.9
Subtotal/Avg	37,061	37,732	38,945	48,219	57,845	77,932	34.7
EASTERN REGION							
Bexar	500,460	687,151	830,460	988,800	1,185,394	1,392,931	17.5
Caldwell	19,350	17,222	21,178	23,637	26,392	32,194	22.0
Comal	16,357	19,844	24,165	36,446	51,832	78,021	50.5
Guadalupe	25,392	29,017	33,554	46,708	64,873	89,023	37.2
Hays (part)*	14,272	15,947	22,114	32,475	52,491	78,071	48.7
Kendall	5,423	5,889	6,964	10,635	14,589	23,743	62.7
Subtotal/Avg	581,254	775,070	938,435	1,138,701	1,395,571	1,693,983	21.4
DOWNSTREAM REGION							
Calhoun	9,222	16,592	17,831	19,574	19,053	20,647	8.4
DeWitt	22,973	20,683	18,660	18,903	18,840	20,013	6.2
Gonzales	21,164	17,845	16,375	16,883	17,205	18,628	8.3
Refugio	10,113	10,975	9,494	9,289	8,828	7,828	-1.9
Victoria	31,241	46,475	53,766	68,807	74,361	84,088	13.1
Subtotal/Avg	94,713	112,570	116,126	133,456	137,435	151,204	10.0
TOTAL	737,098	949,034	1,116,980	1,349,598	1,621,988	1,957,633	19.2

SOURCE: U.S. Census Bureau 2000a.

*Estimated that 80 percent of the total county population resides within the EAHCP Planning Area.

3.5.2.2 Central Region

Population in the Central Region increased 34.7 percent between 1990 and 2000. Atascosa's population decreased between 1950 and 1960, then increased steadily through 2000. Medina's population grew steadily from 1950 to 2000, with an increase of 43.9 percent between 1990 and 2000 (see Table 3.5-1). The Central Region contains approximately 4.0 percent of the Planning Area's total population.

3.5.2.3 Eastern Region

The Eastern Region contains a majority, more than 86 percent, of the Planning Area's total population. Although the population increase for the Eastern Region was 19.2 percent overall from 1990 to 2000, Comal, Guadalupe, Kendall, and part of Hays County EACH grew more than 35 percent between 1990 and 2000. With the exception of a small population decline in Caldwell County between 1950 and 1960, all counties in the Eastern Region have experienced steady rises in population from 1950 to 2000. This region includes Bexar and Comal Counties, which are part of the San Antonio MSA (see Table 3.5-1).

3.5.2.4 Downstream Region

The Downstream Region grew by approximately 10.0 percent from 1990 to 2000. Dewitt and Gonzales Counties experienced declining populations between 1950 and 1970, and Refugio experienced declines from 1950 to 1990. Calhoun and Victoria Counties grew overall from 1950 to 2000 (see Table 3.5-1). Approximately eight percent of the total Planning Area population resides in the Downstream Region counties.

3.5.3 Population Projections

3.5.3.1 Total Population Projections

The total population within the EAHCP Planning Area is projected to increase by more than 63 percent—or by nearly 1.3 million people (1,250,621)—between the years 2000 and 2030, according to updated population projections developed by the Texas Water Development Board (TWDB 2003) (Table 3.5-2). The Eastern Region is expected to experience the largest population increase between 2000 and 2030. This in turn will increase the Region's percentage of the Planning Area's total population from 86.7 percent in 2000 to 88.9 percent in 2030.

Western Region

Population in the Western Region is expected to grow more than 23.8 percent between 2000 and 2030. All counties in this region, excluding Real, are projected to grow during this time period. Uvalde County is expected to grow by the largest percentage (30.4 percent).

Central Region

Population in the Central Region is expected to grow 56.6 percent between 2000 and 2030. Medina County is projected to grow by 58.8 percent within the next 30 years, while the population of Atascosa is projected to increase by 54.3 percent.

Eastern Region

This region, which includes the greater San Antonio area, is projected to increase by 67.5 percent between 2000 and 2030. Kendall, Hays, Guadalupe, Caldwell, and Comal counties are projected to grow more than 100 percent. The remaining county, Bexar, is expected to increase in population by 47.8 percent. These high growth rates are partially explained by the time period covered (2000 to 2030), and by the TWDB forecast assumption that rapid growth will continue, particularly in the San Antonio area.

Downstream Region

This region is projected to grow by 27.2 percent between 2000 and 2030. Calhoun and Victoria counties are expected to grow by more than 30 percent each over the time period. The remaining counties are expected to grow between 6 and 20 percent.

Table 3.5-2. Population projections for regions and counties in the EAHCP Planning Area, 2000–2030

County	2000	2010	2020	2030	% Change 2000-2030
WESTERN REGION					
Edwards	2,162	2,322	2,421	2,364	9.3
Kinney	3,379	3,403	3,462	3,529	4.4
Real	3,047	3,063	3,111	3,042	-0.2
Uvalde	25,926	28,616	31,443	33,802	30.4
Subtotal	34,514	37,404	40,437	42,737	23.8
CENTRAL REGION					
Atascosa	38,628	45,504	52,945	59,598	54.3
Medina	39,304	46,675	54,815	62,416	58.8
Subtotal	77,932	92,179	107,760	122,014	56.6
EASTERN REGION					
Bexar	1,392,931	1,631,935	1,857,745	2,059,112	47.8
Caldwell	32,194	45,958	59,722	71,459	122.0
Comal	78,021	108,219	146,868	190,873	144.6
Guadalupe	89,023	114,878	146,511	180,725	103.0
Hays	97,589	166,342	242,051	302,795	210.3
Kendall	23,743	35,720	50,283	65,752	176.9
Subtotal	1,713,501	2,103,052	2,503,180	2,870,716	67.5
DOWNSTREAM REGION					
Calhoun	20,647	23,556	26,610	29,964	45.1
Dewitt	20,013	20,460	20,964	21,251	6.2
Gonzales	18,628	19,872	21,227	22,260	19.5
Refugio	7,828	8,217	8,505	8,609	10.0
Victoria	84,088	93,073	102,487	110,221	31.1
Subtotal	151,204	165,178	179,793	192,305	27.2
TOTAL	1,977,151	2,397,813	2,831,170	3,227,772	63.3
State of Texas	20,851,790	24,896,901	29,085,203	33,005,640	58.3

SOURCE: Texas Water Development Board 2003.

3.5.3.2 Population Projections by Race

The Texas State Data Center (TSDC) publishes population projections by race. Presidential Executive Order 12898 on Environmental Justice requires an analysis to determine whether proposed federal actions may result in disproportionate, adverse effects on minority or low-income populations. The data in Table 3.5-3 serve as a baseline for environmental justice analyses to take place during the alternatives evaluation phase.

According to the TSDC, Texas' population will continue to become more ethnically diverse between 2000 and 2030. Whereas the Anglo population (composed of White, non-Spanish origin persons) is projected to increase by 14.6 percent from 2000 to 2030, the Black population (consisting of Black, non-Spanish origin persons) is expected to increase by 40.2 percent, the Hispanic population (Spanish-origin persons of all racial and ethnic groups) by 150.9 percent, and the "Other" population (composed of other racial and ethnic groups who are not of Spanish origin, including American Indian, Asian and Middle Easterners) by 335.0 percent. Projected demographic changes within the regions of the EAHCP Planning Area are discussed below.

Western Region

In the Western Region, the Anglo population is projected to decline by 15.3 percent, while the Black population is projected to decline by 10.0 percent between 2000 and 2030 (see Table 3.5-3). In contrast, the Hispanic population is projected to increase by 95.8 percent between 2000 and 2030. All other races are expected to increase by 130.1 percent during that time period. In all counties in this region, Hispanic and Other population are projected to increase between 64.7 percent and up to 158.9 percent between 2000 and 2030, while Black populations are projected to remain the same or decrease in all counties except Kinney County.

Central Region

In Atascosa County, the Anglo population is expected to grow by 1,015.2 percent, while the Black population is expected to decline by 16.7 percent (see Table 3.5-3). In Medina County, the Hispanic population is projected to more than double while the Black population is projected to decrease by almost 100 persons.

Eastern Region

In the Eastern Region, the Anglo population is expected to grow 22.3 percent, and the Black population is expected to grow 22.9 percent (see Table 3.5-3). Hispanic population growth is estimated at 99.8 percent, while Other population is expected to increase 493.4 percent between 2000 and 2030, according to the Texas State Data Center. Notably, the Other population is projected to increase between 52.8 percent and 513.7 percent in the various Eastern Region counties over the forecast period.

Downstream Region

In the Downstream Region, the Black population is projected to increase by 45.6 percent, the Hispanic population by 92.7 percent, and Other by 152.6 percent, while the Anglo population is projected to decrease by 19.5 percent (see Table 3.5-3). In all Downstream Region counties, the Anglo population will decrease between 15.6 and 26.7 percent, while all other populations are expected to increase between 2000 and 2030.

Table 3.5-3. Projections of population by race in the EAHCP Planning Area, 2000-2030

County		2000	2010	2020	2030	% Change 2000-2030
WESTERN REGION						
Edwards	Total	2,884	3,789	4,785	5,825	102.0%
	Anglo	1,217	1,377	1,470	1,518	24.7%
	Black	0	0	0	0	0.0%
	Hispanic	1,656	2,398	3,296	4,288	158.9%
	Other	11	14	19	19	72.7%
Kinney	Total	3,403	3,701	3,994	4,262	25.2%
	Anglo	1,331	1,171	1,031	879	-34.0%
	Black	48	57	56	51	6.3%
	Hispanic	1,981	2,425	2,847	3,262	64.7%
	Other	43	48	60	70	62.8%
Real	Total	2,572	2,696	2,796	2,853	10.9%
	Anglo	1,815	1,718	1,623	1,493	-17.7%
	Black	0	0	0	0	0.0%
	Hispanic	735	939	1,125	1,303	77.3%
	Other	25	39	48	57	128.0%
Uvalde	Total	28,554	34,264	39,999	45,606	59.7%
	Anglo	8,904	8,588	8,040	7,347	-17.5%
	Black	32	30	27	21	-34.4%
	Hispanic	19,378	25,285	31,436	37,650	94.3%
	Other	240	361	496	588	145.0%
Subtotal	Total	37,413	44,450	51,574	58,546	56.5%
	Anglo	13,267	12,854	12,164	11,237	-15.3%
	Black	80	87	83	72	-10.0%
	Hispanic	23,750	31,047	38,704	46,503	95.8%
	Other	319	462	623	734	130.1%
CENTRAL REGION						
Atascosa	Total	38,777	49,393	60,747	72,281	86.4%
	Anglo	1,557	16,953	17,628	17,363	1015.2%
	Black	114	119	108	95	-16.7%
	Hispanic	22,858	31,992	42,578	54,353	137.8%
	Other	228	329	433	470	106.1%
Medina	Total	37,113	47,044	58,160	68,950	85.8%
	Anglo	18,847	23,012	27,569	31,502	67.1%
	Black	763	717	664	589	-22.8%
	Hispanic	17,257	22,953	29,463	36,348	110.6%
	Other	246	362	464	511	107.7%
Subtotal	Total	75,890	96,437	118,907	141,231	86.1%
	Anglo	20,404	39,965	45,197	48,865	139.5%
	Black	877	836	772	684	-22.0%
	Hispanic	40,115	54,945	72,041	90,701	126.1%
	Other	474	691	897	981	107.0%

Table 3.5-3. (Continued)

County		2000	2010	2020	2030	% Change 2000-2030
EASTERN REGION						
Bexar	Total	1,433,576	1,687,648	1,964,248	2,249,396	56.9%
	Anglo	507,045	486,835	451,464	396,092	-21.9%
	Black	92,931	101,699	106,994	106,412	14.5%
	Hispanic	795,519	1,023,886	1,269,647	1,513,182	90.2%
	Other	38,081	75,228	136,143	233,710	513.7%
Caldwell	Total	35,409	46,234	58,307	70,599	99.4%
	Anglo	16,532	19,761	22,751	24,926	50.8%
	Black	4,091	5,779	7,974	10,697	161.5%
	Hispanic	14,475	20,100	26,479	33,387	130.7%
	Other	311	594	1103	1589	410.9%
Comal	Total	80,400	123,199	184,135	261,731	225.5%
	Anglo	61,170	94,496	143,366	206,286	237.2%
	Black	443	467	456	424	-4.3%
	Hispanic	18,356	27,641	39,564	54,109	194.8%
	Other	431	595	749	912	111.6%
Guadalupe	Total	82,786	104,604	129,548	156,707	89.3%
	Anglo	47,233	51,951	54,811	54,751	15.9%
	Black	4,118	4,842	5,466	5,866	42.4%
	Hispanic	30,361	46,289	67,148	93,352	207.5%
	Other	1074	1,522	21,123	2,738	154.9%
Hays	Total	88,692	121,657	159,658	198,176	123.4%
	Anglo	58,456	79,026	102,787	125,991	115.5%
	Black	2,749	3,533	4,261	4,818	75.3%
	Hispanic	26,402	37,082	49,338	62,556	136.9%
	Other	1,085	2,016	3,272	4,811	343.4%
Kendall	Total	22,523	35,092	53,817	79,072	251.1%
	Anglo	18,186	27,678	41,262	58,745	223.0%
	Black	59	61	59	56	-5.1%
	Hispanic	4,151	7,178	12,297	20,077	383.7%
	Other	127	175	199	194	52.8%
Subtotal	Total	1,743,386	2,118,434	2,549,713	3,015,681	73.0%
	Anglo	708,622	759,747	816,441	866,791	22.3%
	Black	104,391	116,381	125,210	128,273	22.9%
	Hispanic	889,264	1,162,176	1,464,473	1,776,663	99.8%
	Other	41,109	80,130	162,589	243,954	493.4%

Table 3.5-3. (Continued)

County		2000	2010	2020	2030	% Change 2000-2030
DOWNSTREAM REGION						
Calhoun	Total	21,700	24,454	26,876	28,925	33.3%
	Anglo	11,068	10,733	9,970	8,921	-19.4%
	Black	588	615	597	539	-8.3%
	Hispanic	9,207	11,808	9,207	17,078	85.5%
	Other	837	1,298	1,876	2,387	185.2%
Dewitt	Total	20,986	22,346	23,689	24,744	17.9%
	Anglo	11,695	10,848	9,837	8,588	-26.6%
	Black	2,622	2,710	2,751	2,668	1.8%
	Hispanic	6,597	8,689	10,985	13,362	102.5%
	Other	72	99	116	126	75.0%
Gonzales	Total	18,921	21,030	23,238	25,403	34.3%
	Anglo	8,822	8,172	7,378	6,466	-26.7%
	Black	1,707	1,833	1,937	1,975	15.7%
	Hispanic	8,284	10,871	13,721	16,755	102.3%
	Other	108	154	202	207	91.7%
Refugio	Total	8,258	9,231	9,490	9,556	15.7%
	Anglo	3,988	3,785	3,400	2,963	-25.7%
	Black	670	706	693	691	3.1%
	Hispanic	3,933	4,703	5,351	5,848	48.7%
	Other	23	37	46	54	134.8%
Victoria	Total	85,468	97,357	108,263	117,101	37.0%
	Anglo	44,589	44,148	41,901	37,625	-15.6%
	Black	5,999	7,734	9,374	11,002	83.4%
	Hispanic	34,118	44,396	55,548	66,697	95.5%
	Other	762	1,079	1,440	1,777	133.2%
Subtotal	Total	155,333	174,418	191,556	205,729	32.4%
	Anglo	80,162	77,686	72,486	64,563	-19.5%
	Black	11,586	13,598	15,352	16,875	45.6%
	Hispanic	62,139	80,467	94,812	119,740	92.7%
	Other	1,802	2,667	3,680	4,551	152.6%
TOTAL	Total	2,012,022	2,433,739	2,911,750	3,421,187	70.0%
	Anglo	822,455	890,252	946,288	991,456	20.5%
	Black	116,934	130,902	141,417	145,904	24.8%
	Hispanic	1,015,268	1,328,635	1,670,030	2,033,607	100.3%
	Other	43,704	83,950	167,789	250,220	472.5%
State of Texas	Total	20,472,285	24,420,249	29,183,018	34,711,256	69.6%
	Anglo	11,195,006	11,875,399	12,475,687	12,827,913	14.6%
	Black	2,321,093	2,649,500	2,974,117	3,253,332	40.2%
	Hispanic	6,317,691	8,810,844	11,963,839	15,852,653	150.9%
	Other	638,495	1,084,506	1,769,375	2,777,358	335.0%

SOURCE: Texas State Data Center 2000.

3.5.4 Population Density

3.5.4.1 Persons Per Square Mile

Population density is measured by dividing population by area and is summarized in Table 3.5-4. The Eastern Region is the densest, with 386 persons per square mile, compared to 32.0 persons per square mile in the Downstream Region, 30.3 persons per square mile in the Central Region, and 6.0 persons per square mile in the Western Region. Overall, 69.8 percent of the population in the EAHCP Planning Area resides in the largest cities in each county, and the aggregate population density is 113.2 persons per square mile, compared to 79.6 persons per square mile for the State of Texas.

Western Region

Approximately 55 percent of the population in this region resides in the four largest cities, Uvalde, Sabinal, Brackettville, and Rock Springs. Uvalde is the largest city in the region with a 2000 population of 14,929 persons. This region has the least dense population of the EAHCP Planning Area, with only 6.0 persons per square mile.

Central Region

This region is relatively rural, with only 20.7 percent of the region's population living in its two largest cities, Hondo and Pleasanton. There are 30.3 persons per square mile in the Central Region.

Eastern Region

The Eastern Region includes the urban areas of San Antonio, New Braunfels, and San Marcos and is the densest region by a large margin. The region has a population density of 386.0 persons per square mile, and 73.3 percent of the region's residents live in its largest cities.

Downstream Region

Approximately 62.0 percent of the Downstream Region's residents live in the largest cities in this region, including Victoria with 60,603 residents in 2000. The region's overall population per square mile is 32.0.

3.5.4.2 Persons Per Household

Another measure of population density is persons per household. These data are available for 1990 and 2000. Analyzing the change in persons per household along with the change in population between 1990 and 2000 provides an indication of whether population density in the EAHCP Planning Area is increasing or decreasing. In general, population appears to be increasing in the Planning Area while population density in terms of persons per household appears to be decreasing (Table 3.5-5). However, measuring population density by persons per square mile is preferable to measuring population density by persons per household when considering issues of service provision.

Table 3.5-4. Population density in the EAHCP Planning Area, 2000

County	Total Area (sq. mi.)	Population	Density (persons per sq. mi.)	Largest City in County	City Population	% of County
WESTERN REGION						
Edwards	2,120	2,162	1.0	Rocksprings	1,285	59.4
Kinney	1,366	3,379	2.5	Brackettville	1,876	55.5
Real	700	3047	4.4	Sabinal	1,586	52.1
Uvalde	1,559	25,926	16.7	Uvalde	14,929	57.6
Subtotal	5,745	34,514	6.0		19,676	57.0
CENTRAL REGION						
Atascosa	1,236	38,628	31.4	Pleasanton	8,266	21.4
Medina	1,335	39,304	29.6	Hondo	7,897	20.1
Subtotal	2,571	77,932	30.3		16,163	20.7
EASTERN REGION						
Bexar	1,257	1,392,931	1,117.0	San Antonio	1,144,646	82.2
Caldwell	548	32,194	59.0	Lockhart	11,615	36.1
Comal	575	78,021	138.8	New Braunfels	36,494	46.8
Guadalupe	714	89,023	125.2	Seguin	22,011	24.7
Hays	680	97,589	143.9	San Marcos	34,733	35.6
Kendall	663	23,743	35.9	Boerne	6,178	26.0
Subtotal	4,437	1,713,501	386.0		1,255,677	73.3
DOWNSTREAM REGION						
Calhoun	1,032	20,647	40.3	Port Lavaca	12,035	58.3
DeWitt	910	20,013	22.0	Cuero	6,571	32.8
Gonzales	1,070	18,628	17.4	Gonzales	7,202	38.7
Refugio	818	7,828	10.2	Refugio	2,941	37.6
Victoria	889	84,088	95.2	Victoria	60,603	72.1
Subtotal	4,719	151,204	32.0		89,352	59.1
Study Area Total	17,472	1,977,151	113.2	Largest Cities	1,380,868	69.8
State of Texas	262,017	20,851,820	79.6	Houston	1,953,631	9.4*

SOURCES: U.S. Census Bureau 2000a.
*Percent of Texas.

Western Region

Persons per household in the Western Region increased from 2.8 in 1990 to 2.9 in 2000. The population grew 10.8 percent between 1990 and 2000.

Central Region

In the Central Region, persons per household decreased from 3.1 in 1990 to 3.0 in 2000. Population increased by 34.7 percent between 1990 and 2000.

Table 3.5-5. Population change and persons per household by region and county in the EAHCP Planning Area, 1999-2000

County	1990 Population	1990 Persons per Household	2000 Population	2000 Persons per Household	Population Percent Change 1990-2000
WESTERN REGION					
Edwards	2,266	2.9	2,162	2.7	-4.6%
Kinney	3,119	2.6	3,379	2.6	8.3%
Real	2,412	2.6	3,047	2.4	26.3%
Uvalde	23,340	3.1	25,926	3.0	11.1%
Subtotal/Average	31,137	2.8	34,514	2.9	10.8%
CENTRAL REGION					
Atascosa	30,533	3.1	38,628	3.0	26.5%
Medina	27,312	3.0	39,304	3.1	43.9%
Subtotal/Average	57,845	3.1	77,932	3.0	34.7%
EASTERN REGION					
Bexar	1,185,394	2.9	1,392,931	2.8	17.5%
Caldwell	26,392	3.0	32,194	3.0	22.0%
Comal	51,832	2.7	78,021	2.7	50.5%
Guadalupe	64,873	2.9	89,023	2.9	37.2%
Hays	65,614	3.0	97,589	2.9	48.7%
Kendall	14,589	2.7	23,743	2.8	62.7%
Subtotal/Average	1,408,694	2.9	1,713,501	2.8	21.6%
DOWNSTREAM REGION					
Calhoun	19,053	2.8	20,647	2.8	8.4%
Dewitt	18,840	2.6	20,013	2.8	6.2%
Gonzales	17,205	2.8	18,628	2.7	8.3%
Refugio	7,976	2.7	7,828	2.6	-1.9%
Victoria	74,361	2.8	84,088	2.8	13.1%
Subtotal/Average	137,435	2.7	151,204	2.8	10.0%
Study Area Total	1,635,111	2.9	1,977,151	2.8	20.9%
State of Texas	16,986,510	2.8	20,851,820	2.8	22.8%

SOURCE: U.S. Census Bureau 2000a.

Eastern Region

Persons per household declined from 2.9 in 1990 to 2.8 in 2000. Population growth increased by 34.7 percent from 1990 to 2000. This region is still rapidly urbanizing due to its large cities and its location along the Interstate Highway 35 corridor.

Downstream Region

In the Downstream Region, persons per household increased from 2.7 in 1990 to 2.8 in 2000. Population grew by ten percent between 1990 and 2000. This region includes the urbanized area of Victoria.

In the State of Texas, persons per household remained the same from 1990 to 2000, although the population grew by 22.8 percent during this time period.

3.5.5 Water Demand

3.5.5.1 Water Demand in the EAHCP Planning Area

Population changes described in previous sections will be accompanied by increased demands for water. Accordingly, water planning to develop regional water plans for 2006 is currently underway throughout the State of Texas. Data used for evaluating water demand projections was developed by the Texas Water Development Board (2003). The EAHCP Planning Area includes counties that fall within three water planning regions established by Texas Senate Bill 1 (75th Texas Legislature) and codified under Section 357.3 of the Texas Water Code, Chapter 16. These regions include Region J – Plateau (Edwards, Kinney, and Real Counties), Region K – Lower Colorado (part of Hays County), and Region L – South Central Texas (Atascosa, Bexar, Caldwell, Calhoun, Comal, Dewitt, Gonzales, Guadalupe, part of Hays, Kendall, Medina, Refugio, Uvalde, and Victoria). The demands for the years 2000 and 2030 are shown in Table 3.5-6. From this table, it is clear that steam electric demand in the Eastern Region is expected to grow by the greatest percentage (40.5) between 2000 and 2030, followed by municipal (30.3), whereas livestock demand is projected to stay the same over the 30-year period. Irrigation demand is projected to decrease throughout the EAHCP Planning Area, presumably due to required reductions in aquifer use for irrigation and mining.

3.5.5.2 Water Demand in the Jurisdictional Area of the Edwards Aquifer Authority

This section provides more focused water demand information specifically for counties and partial counties within the Authority's jurisdictional area. This area is within but smaller than the EAHCP Planning Area (see Figure 1.1-1).

For this analysis, projected water demands (Texas Water Development Board 2003) were compiled for those Water User Groups and portions of Water User Groups that are located within the Authority's jurisdiction. The "template" for extracting this information was developed through the Trans-Texas Water Program, West-Central Study Area and has been previously applied in the development of the Authority's Comprehensive Water Management Plan. It should be noted that the apportionment of projected water demand and currently available water supply for counties that are partially within the Authority's jurisdiction are approximations.

The area within the Authority's jurisdiction continues to experience rapid population growth and corresponding increases in water demand. The estimated population of the area was 1.4 million in 1990 (EAA 1998b). This has increased to an estimated population of 1.7 million at present, a 26 percent increase for the decade.

Table 3.5-6. Regional water demand projections in acre-feet per year, 2010 and 2030

	Municipal Demand			Manufacturing Demand			Steam Electric Demand		
County	2010	2030	% Change	2010	2030	% Change	2010	2030	% Change
WESTERN REGION									
Edwards	445	437	-1.8	0	0	0.0	0	0	0.0
Kinney	1,276	1,304	2.2	0	0	0.0	0	0	0.0
Real	600	577	-3.8	0	0	0.0	0	0	0.0
Uvalde	8,066	8,652	7.3	432	473	9.5	0	0	0.0
Subtotal	10,387	10,970	5.6	432	473	9.5	0	0	0.0
CENTRAL REGION									
Atascosa	6,941	8,335	20.1	6	6	0.0	5,884	6,962	18.3
Medina	7,576	9,656	27.5	67	82	22.4	0	0	0.0
Subtotal	14,517	17,991	23.9	73	88	20.5	5,884	6,962	18.3
EASTERN REGION									
Bexar	262,106	316,423	20.7	25,951	32,775	26.3	17,309	20,196	16.7
Caldwell	6,275	9,173	46.2	15	21	40	0	0	0.0
Comal	18,771	31,598	68.3	7,729	9,314	20.5	0	0	0.0
Guadalupe	17,113	25,595	49.6	2,638	3,249	23.2	10,065	16,844	67.4
Hays (Reg. L)	17,278	29,964	73.4	212	285	34.4	5,331	8,922	67.4
Hays (Reg. K)	7,192	13,453	87.1	691	928	34.3	0	0	0.0
Kendall	4,649	8,142	75.1	0	0	0	0	0	0.0
Subtotal	333,384	434,348	30.3	37,236	46,572	25.1	32,705	45,962	40.5
DOWNSTREAM REGION									
Calhoun	2,948	3,556	20.6	49,784	59,235	19.0	569	530	-6.9
Dewitt	3,064	3,039	-0.8	184	212	15.2	0	0	0.0
Gonzales	4,108	4,624	12.6	2,400	2,822	17.6	0	0	0.0
Refugio	1,249	1,282	2.6	0	0	0	0	0	0.0
Victoria	14,590	16,378	12.3	28,726	35,035	22.0	2,026	2,035	0.4
Subtotal	25,959	28,879	11.2	81,094	97,304	20.0	2,595	2,565	-1.2
Study Area Total	384,247	492,188	28.1	118,835	144,437	21.5	41,184	55,486	34.7

	Irrigation Demand			Mining Demand			Livestock Demand		
County	2010	2030	% Change	2010	2030	% Change	2010	2030	% Change
WESTERN REGION									
Edwards	153	141	-7.8	5	5	0	562	562	0.0
Kinney	13,507	12,373	-8.4	0	0	0	445	445	0.0
Real	137	125	-8.8	5	5	0	176	176	0.0
Uvalde	55,791	51,513	-7.7	313	364	16.3	1,284	1,284	0.0
Subtotal	69,588	64,152	-7.8	323	374	15.8	2,467	2,467	0.0
CENTRAL REGION									
Atascosa	40,885	38,185	-6.6	1,298	1,405	8.2	1,745	1,745	0.0
Medina	54,450	50,005	-8.2	130	137	5.4	1,298	1,298	0.0
Subtotal	95,335	88,190	-7.5	1,428	1,542	8.0	3,043	3,043	0.0
EASTERN REGION									
Bexar	15,273	14,010	-8.3	3,582	4,150	15.9	1,319	1,319	0.0
Caldwell	1,044	824	-21.1	14	16	14.3	918	918	0.0
Comal	204	169	-17.2	2,678	3,029	13.1	298	298	0.0
Guadalupe	1,070	846	-20.9	306	330	7.8	1,057	1,057	0.0
Hays (Reg. L)	353	347	-1.7	142	157	10.6	280	280	0.0
Hays (Reg. K)	11	11	0	12	2	-83.3	220	220	0.0
Kendall	714	685	-4.1	6	6	0	446	446	0.0
Subtotal	18,669	16,892	-9.5	6,740	7,690	14.1	4,538	4,538	0.0
DOWNSTREAM REGION									
Calhoun	15,568	12,096	-22.3	32	36	12.5	342	342	0.0
Dewitt	159	108	-32.1	64	68	6.3	1,689	1,689	0.0
Gonzales	1,304	969	-25.7	28	26	-7.1	5,453	5,453	0.0
Refugio	69	69	0	7	8	14.3	623	623	0.0
Victoria	9,936	7,402	-25.5	3,944	4,906	24.4	1,085	1,085	0.0
Subtotal	27,036	20,644	-23.6	4,076	5,044	23.7	9,192	9,192	0.0
Study Area Total	210,628	189,878	-9.9	12,567	14,650	16.6	19,240	19,240	0.0

SOURCE: Texas Water Development Board 2003.

Water demand projections for the Authority's jurisdictional area are presented in Table 3.5-7. As indicated, total water demand within the Edwards Aquifer region is projected to increase by approximately 158,000 acre-feet per year, or by nearly 34.4 percent over the next 30 years. However, combined, the municipal, industrial, and steam electric water use sectors are projected to increase by more than 170,000 acre-feet per year (53 percent increase), which at a regional level, is partially offset by a projected decrease in irrigation demand of nearly 15,000 acre-feet (11 percent decrease).

Table 3.5-7. Projected water demand by use sector for the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Type of Use	2000	2010	2020	2030
Municipal	273,965	318,478	360,554	400,611
Industrial	29,175	35,710	40,318	44,554
Steam electric	17,528	32,705	39,313	45,962
Irrigation	131,336	126,626	121,483	116,551
Mining	4,920	6,837	7,572	7,946
Livestock	4,961	4,961	4,961	4,961
TOTAL	461,885	525,317	574,201	620,585

SOURCE: Texas Water Development Board 2003

Unlike municipal water demand, which tends to be relatively consistent from year to year, irrigation demands can vary considerably. For example, in 1990, estimated irrigation water use in Bexar, Medina, and Uvalde counties was 335,061 acre-feet, while in 1996 estimated irrigation water use was only 212,416 acre-feet. The wide variation in estimates of irrigation water use may be explained by local weather conditions, economic factors, which influence the amount of irrigated acreage, and water supply constraints. Also, historical irrigation water use data were based largely on estimates rather than actual measured use.

Water demand projections for each water use sector, by county, are presented in Tables 3.5-8 through 3.5-13, below. The tables include data for partial counties, indicated by an asterisk (*). Information provided in Tables 3.5-7 through 3.5-13 reflect updated (lower) water demand projections than indicated by Tables 1-5 in the Authority's 30-Year Water Supply Plan (Appendix A), as revisions to the Plan using these revised (updated) TWDB projections have not been completed and approved by the Authority's Board of Directors as of the date of this document.

Table 3.5-8. Projected municipal water demand within the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Municipal	2000	2010	2020	2030
Atascosa*	447	498	538	573
Bexar	229,694	262,106	290,071	316,423
Caldwell*	3,317	4,578	5,811	6,908
Comal*	10,208	13,519	17,483	22,185
Guadalupe*	7,325	8,625	10,372	12,455
Hays	8,590	13,510	19,225	23,759
Medina	6,616	7,576	8,660	9,656
Uvalde	7,768	8,066	8,394	8,652
TOTAL	273,965	318,478	360,554	400,611

SOURCE: Texas Water Development Board 2003.
*Data for part of the county within EAA jurisdiction.

Table 3.5-9. Projected industrial water demand within the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Industrial	2000	2010	2020	2030
Atascosa*	0	0	0	0
Bexar	21,252	25,951	29,497	32,775
Caldwell*	0	0	0	0
Comal*	6,283	7,729	8,563	9,314
Guadalupe*	1,049	1,319	1,479	1,625
Hays	157	212	249	285
Medina	56	67	75	82
Uvalde	378	432	455	473
TOTAL	29,175	35,710	40,318	44,554

SOURCE: Texas Water Development Board 2003.
*Data for part of the county within EAA jurisdiction.

Table 3.5-10. Projected steam electric power generation demand within the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Steam Electric	2000	2010	2020	2030
Atascosa*	0	0	0	0
Bexar	17,399	17,309	17,275	20,196
Caldwell*	0	0	0	0
Comal*	0	0	0	0
Guadalupe*	129	10,065	14,407	16,844
Hays	0	5,331	7,631	8,922
Medina	0	0	0	0
Uvalde	0	0	0	0
TOTAL	17,528	32,705	39,313	45,962

SOURCE: Texas Water Development Board 2003.
*Data for part of the county within EAA jurisdiction.

Table 3.5-11. Projected irrigation demand within the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Irrigation	2000	2010	2020	2030
Atascosa*	988	1,112	1,067	1,023
Bexar	15,865	15,273	14,628	14,010
Caldwell*	0	0	0	0
Comal*	0	0	0	0
Guadalupe*	0	0	0	0
Hays	0	0	0	0
Medina	56,422	54,450	52,179	50,005
Uvalde	58,061	55,791	53,609	51,513
TOTAL	131,336	126,626	121,483	116,551

SOURCE: Texas Water Development Board 2003.
*Data for part of the county within EAA jurisdiction.

Table 3.5-12. Projected mining water demand within the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Mining	2000	2010	2020	2030
Atascosa*	0	0	0	0
Bexar	2,902	3,582	3,934	4,150
Caldwell*	0	0	0	0
Comal*	1,251	2,364	2,686	2,808
Guadalupe*	270	306	321	330
Hays	129	142	151	157
Medina	118	130	135	137
Uvalde	250	313	345	364
TOTAL	4,920	6,837	7,572	7,946

SOURCE: Texas Water Development Board 2003.
*Data for part of the county within EAA jurisdiction.

Table 3.5-13. Projected livestock water demand within the Edwards Aquifer Authority Jurisdictional Area, 2000-2030 (acre-feet/year)

Livestock	2000	2010	2020	2030
Atascosa*	2	2	2	2
Bexar	1,319	1,319	1,319	1,319
Caldwell*	457	457	457	457
Comal*	149	149	149	149
Guadalupe*	327	327	327	327
Hays	125	125	125	125
Medina	1,298	1,298	1,298	1,298
Uvalde	1,284	1,284	1,284	1,284
TOTAL	4,961	4,961	4,961	4,961

SOURCE: Texas Water Development Board 2003.
*Data for part of the county within EAA jurisdiction.

3.6 Economy

The EAHCP Planning Area maintains a diversified economy that is supported by strong trade and service sectors (including a vibrant tourism industry). The presence of large military bases, agriculture and high technology employment, medical research, biotechnology and higher education also boost the area's economy. Table 3.6-1 summarizes employment by major sectors of the economy for the EAHCP Planning Area. As of November 2001, covered employment and wage data are reported based on the North American Industrial Classification System (NAICS) which has replaced the Standard Industrial Classification System (SIC). Notable changes include increased segmentation of the service sector, the addition of an information sector, and the combination of agriculture, forestry, fishing, hunting, and mining into the Natural Resources and Mining sector.

The EAHCP Planning Area as a whole contained approximately ten percent (9.1 percent) of state employment in the second quarter of 2001. According to the Texas Workforce Commission's employment data for 2001 (2^{nd} Quarter), almost ninety percent (89.2 percent) of the Planning Area's employment is contained in the Eastern Region, which includes three of the four counties contained in the San Antonio Metropolitan Statistical Area (MSA). The Downstream Region contained a little more than seven percent (7.4 percent) of the remaining employment in the area, while the Central (2.0 percent) and Western (1.4 percent) Regions contained two percent or less of the total employment in the EAHCP Planning Area.

As in many regions of the U.S., the technology industry has been responsible for increasing economic growth and prosperity in Texas during the 1990s. The San Antonio MSA accounts for approximately 7.5 percent of the state's technology employment. Three of the four counties that comprise the San Antonio MSA are located within the EAHCP Planning Area—excluding Wilson County. While the Austin-San Marcos MSA accounts for an estimated 10 percent of the state's technology employment, only two (Hays and Caldwell) of the 17 counties in the EAHCP Planning Area are contained in the Austin-San Marcos MSA, and neither of those counties is currently home to significant technology sector employment. According to the Texas Workforce Commission, the "information" sector (a newly created sector to better categorize information services and its effect on the economy) accounts for 3.2 percent of the jobs in the HCP Planning Area. In the Eastern region, it accounted for 3.4 percent of the jobs compared to less than two percent in all the other regions.

A brief summary of the EAHCP Planning Area regions with regard to economic resources is included below. Table 3.6-1 presents employment data for each region. These data do not represent the number of "employees" in each region but the number of jobs in each county, compiled by region. These data differ from the labor force estimates contained in Table 3.6-2, which track the number of people in a county considered eligible to participate in the labor force and whether or not they are employed or unemployed. For example, the employment data contained in Table 3.6-1 for the Central Region indicates that there were only about 17,459 jobs

Table 3.6-1. Employment for the EAHCP Planning Area – 2nd quarter, 2001

Category*	Western Region Total Emp	Western Region % of Total	Central Region Total Emp	Central Region % of Total	Eastern Region Total Emp	Eastern Region % of Total	Downstream Region Total Emp	Downstream Region % of Total	EAHCP Planning Area Total Emp	EAHCP Planning Area % of Total	State of Texas Total Emp	State of Texas % of Total
Natural Resources & Mining	1,638	13.8%	1,160	6.6%	4,048	0.5%	4,192	6.7%	11,038	1.3%	220,720	2.3%
Construction	288	2.4%	887	5.1%	44,771	5.9%	4,644	7.4%	50,590	5.9%	1,092,850	11.6%
Manufacturing	710	6.0%	924	5.3%	57,852	7.6%	9,084	14.4%	68,570	8.0%	587,537	6.2%
Trade, Transportation, & Utilities	2,147	18.1%	4,056	23.2%	142,330	18.6%	11,686	18.6%	160,219	18.7%	1,929,758	20.5%
Information	123	1.0%	257	1.5%	25,948	3.4%	1,047	1.7%	27,375	3.2%	273,001	2.9%
Financial Activities	330	2.8%	620	3.6%	58,286	7.6%	2,916	4.6%	62,152	7.3%	1,036,704	11.0%
Professional & Business Services	222	1.9%	931	5.3%	92,609	12.1%	3,362	5.3%	97,124	11.4%	624,098	6.6%
Education & Health Services	1,269	10.7%	1,866	10.7%	86,332	11.3%	6,402	10.2%	95,869	11.2%	937,512	10.0%
Leisure & Hospitality	1,008	8.5%	1,290	7.4%	85,654	11.2%	5,040	8.0%	92,992	10.9%	853,582	9.1%
Other Services	417	3.5%	403	2.3%	23,872	3.1%	2,186	3.5%	26,878	3.1%	282,927	3.0%
Nonclassifiable	197	1.7%	12	0.1%	305	0.0%	2	0.0%	516	0.1%	9,322	0.1%
Federal Government	277	2.3%	122	0.7%	28,940	3.8%	440	0.7%	29,779	3.5%	177,865	1.9%
State Government	376	3.2%	689	3.9%	19,382	2.5%	971	1.5%	21,418	2.5%	321,279	3.4%
Local Government	2,855	24.1%	4,242	24.3%	92,908	12.2%	10,950	17.4%	110,955	13.0%	1,068,683	11.3%
Total Employment	11,857	100.0%	17,459	100.0%	763,237	100.0%	62,922	100.0%	855,475	100.0%	9,415,838	100.0%

SOURCE: Texas Workforce Commission, 2002. Labor Market Information - Covered Employment and Wages.

*As of November 2001, the Texas Workforce Commission reports Covered Employment and Wages according to the North American Industrial Classification System. Notable changes from the previous Standard Industrial Classification (SIC) system include more detailed segmentation of the Services category and the addition of an Information category including establishments that create, disseminate, or provide the means to distribute information (such as technology-based companies). Agriculture, Forestry, Fishing, and Hunting as well as Mining are reported in the Natural Resources and Mining category.

in that region in the second quarter of 2001. Table 3.6-2, however, indicates that there were eighty-nine percent more (33,046) employees living in that region in 2000. Therefore, workers must be commuting to other counties to work (presumably to the San Antonio MSA). This is a fairly common situation in many of the counties surrounding metropolitan areas such as San Antonio (TWC 2000).

Table 3.6-2. Labor force and unemployment in the EAHCP Planning Area – 1990 and 2000

	Civilian Labor Force		Employed		Unemployed		Unemployment Rate	
County	1990	2000	1990	2000	1990	2000	1990	2000
WESTERN REGION								
Edwards	943	770	884	735	59	35	6.3	4.5
Kinney	1,043	1,135	1,005	1,050	38	85	3.6	7.5
Real	1,029	1,301	957	1,260	72	41	7	3.2
Uvalde	10,817	11,024	9,468	10,239	1,349	785	12.5	7.1
Subtotal/Average	13,832	14,230	12,314	13,284	1,518	946	7.4	5.6
CENTRAL REGION								
Atascosa	12,725	18,406	11,847	17,696	878	710	6.9	3.9
Medina	11,700	15,919	11,068	15,350	632	569	5.4	3.6
Subtotal/Average	24,425	34,325	22,915	33,046	1,510	1,279	6.2	3.8
EASTERN REGION								
Bexar	563,381	676,590	522,408	652,687	40,973	23,903	7.3	3.5
Caldwell	11,778	16,890	11,081	16,342	697	548	5.9	3.2
Comal	25,753	39,947	24,376	38,947	1,377	1,000	5.3	2.5
Guadalupe	32,208	43,472	30,786	42,384	1,422	1,088	4.4	2.5
Hays	33,998	55,058	32,236	53,764	1,762	1,294	5.2	2.4
Kendall	7,417	14,265	7,252	13,971	165	294	2.2	2.1
Subtotal/Average	674,535	846,222	628,139	818,095	46,396	28,127	5.1	2.7
DOWNSTREAM REGION								
Calhoun	8,434	10,044	7,900	9,579	534	465	6.3	4.6
DeWitt	7,815	8,450	7,398	8,151	417	299	5.3	3.5
Gonzales	7,688	7,580	7,456	7,349	232	231	3	3.0
Refugio	3,377	2,811	3,267	2,684	110	127	3.3	4.5
Victoria	36,293	43,165	34,648	41,634	1,645	1,531	4.5	3.5
Subtotal/Average	63,607	72,050	60,669	69,397	2,938	2,653	4.5	3.8
Planning Area Total	776,399	966,827	724,037	933,822	52,362	33,005	5.8	4.0
State of Texas	8,615,795	10,324,527	8,071,312	9,887,039	544,483	437,488	6.3	4.2

SOURCE: Texas Workforce Commission 2000.

The Agriculture Industry segment includes jobs in agricultural production, forestry, commercial fishing, hunting and trapping, and related services including all reported farm and ranch workers, according to the Texas Workforce Commission (TWC). However, TWC estimates that their records include only 47 percent of all agricultural jobs since only reported farm and ranch workers are included (TWC, personal communication 2002). In contrast, the U.S. Agriculture Census provides estimates specifically for farm employment that are considerably higher. These data are collected every five years with the latest data available for 1997 and new data collection underway in 2002. Table 3.6-3 below shows agriculture employment (TWC) and farm employment (U.S. Agriculture Census) for 1997. Although the data are collected using different methodologies and cannot be added together, they do indicate that the number of hired farm workers in the Western, Central and Downstream regions exceed the totals recorded by TWC. In the Eastern region, the number of farm workers counted in the U.S. Agriculture Census was lower than the total employed in the agriculture field according to the TWC. Most likely, the Central and Downstream regions have high numbers of hired farm workers in their labor forces that are not reflected in the TWC data.

According to the TWC, unemployment in the EAHCP Planning Area generally decreased between 1990 and 2000, as it did throughout the State of Texas. When the data are broken down into regions, all regions showed a decline in unemployment with the Western Region containing the highest unemployment rates in the Planning Area (5.6 percent).

Table 3.6-3. Planning Area farm labor (1997)

County/Region	2nd Quarter Agriculture Employment*	Hired Farm Labor – Workers†
Edwards	40	360
Kinney	56	172
Real	19	146
Uvalde	1,090	743
Total Western	1,205	1,421
Atascosa	397	968
Medina	351	1,342
Total Central	748	2,310
Kendall	210	262
Bexar	4,618	2,192
Comal	156	238
Hays	332	441
Guadalupe	210	1,166
Caldwell	146	571
Total Eastern	5,672	4,870
Calhoun	71	298
De Witt	72	782
Gonzales	894	2,425
Refugio	141	388
Victoria	299	580
Total Downstream	1,477	4,473

*SOURCE: Texas Workforce Commission, 1997 Covered Employment and Wages.

†SOURCE: U.S. Agriculture Census, Hired Farm Labor - Workers.

Table 3.6-4 contains the most recent income and poverty estimates for the counties in the EAHCP Planning Area. In 1998, the Western Region counties generally contained the largest percentages of persons living below the poverty rate. Real County contained the largest percentage of persons living below the poverty rate (28.2 percent). As noted in Table 3.6-2, Kinney County had the highest unemployment rate (7.5 percent) among the 17 EAHCP Planning Area counties (as of 2000).

Generally, those counties in the more populous Eastern Region fared better, in terms of poverty estimates, with Comal County containing the smallest percentage of persons living below the poverty rate in the Planning Area in 1998 (9.5 percent). Comal County also contained one of the lowest unemployment rates (2.5 percent) in the Planning Area in 2000 (see Table 3.6-2).

Table 3.6-4. Income and poverty estimates in the EAHCP Planning Area

County/Region	Percentage of Persons of All Ages in Poverty (1998)	Estimated Median Household Income (1998)
WESTERN REGION		
Edwards	27.6	$18,618
Kinney	25.4	$23,815
Real	28.2	$22,855
Uvalde	27.7	$23,603
CENTRAL REGION		
Atascosa	22.2	$28,053
Medina	17.9	$31,149
EASTERN REGION		
Bexar	17.8	$34,210
Caldwell	17.9	$29,961
Comal	9.5	$41,720
Guadalupe	14.3	$36,172
Hays	11.5	$39,273
Kendall	9.7	$42,508
DOWNSTREAM REGION		
Calhoun	18.0	$33,160
DeWitt	20.5	$27,347
Gonzales	24.1	$25,802
Refugio	18.7	$30,265
Victoria	15.1	$36,678
State of Texas	15.6	$35,449

SOURCE: U.S. Census Bureau, Small Area Income & Poverty Estimates, 1998 State & County (FTP Files) Estimates, <www.census.gov/hhes/www/saipe/stcty/sc98ftpdoc.html>.

3.6.1 Western Region

According to the TWC, the Western Region had the smallest percentage of employment in the EAHCP Planning Area in the second quarter of 2001 (Tables 3.6-1 and 3.6-5). Local government; trade; transportation and utilities; and natural resources and mining comprised the majority of the jobs in the Western Region. Nearly 86 percent of employment within the Western Region was concentrated in Uvalde County. Local governments (county, city, school districts, etc.) were the largest employers in Edwards, Kinney, and Real Counties with either Leisure and Hospitality or Nonclassifiable as the second largest employer.

Unemployment has been generally declining in the counties comprising the Western Region, except in Kinney County, where the unemployment rate jumped from 3.6 percent in 1990 to 7.5 percent in 2000. The unemployment rate for the Western Region as a whole decreased between 1990 and 2000, as well (see Table 3.6-2).

Table 3.6-5. Employment and average quarterly wages for the Western Region – 2nd quarter, 1997

Category	Edwards Total Emp	Kinney Total Emp	Real Total Emp	Uvalde Total Emp	Western Region Total Emp	Western Region % of Total
Natural Resources & Mining	35	39	22	1,542	1,638	13.8%
Construction	–	16	43	229	288	2.4%
Manufacturing	0	–	15	695	710	6.0%
Trade, Transportation, & Utilities	51	80	64	1,952	2,147	18.1%
Information	–	–	–	123	123	1.0%
Financial Activities	13	–	21	296	330	2.8%
Professional & Business Services	–	–	9	213	222	1.9%
Education & Health Services	–	15	–	1,254	1,269	10.7%
Leisure & Hospitality	–	121	111	776	1,008	8.5%
Other Services	10	7	9	391	417	3.5%
Nonclassifiable	61	25	111	0	197	1.7%
Federal Government	17	115	7	138	277	2.3%
State Government	57	24	20	275	376	3.2%
Local Government	153	216	211	2,275	2,855	24.1%
Total Employment	397	658	643	10,159	11,857	100.0%
Average Quarterly Wages	5,565	6,226	3,941	5,028	n/a	n/a

SOURCE: Texas Workforce Commission, 2002. Labor Market Information – Covered Employment & Wages.

3.6.1.1 Government

As noted in Table 3.6-1, federal, state, and local governments together employ approximately 30 percent—3,508—of the workforce in the Western Region. School districts are among the region's largest employers. The Uvalde Consolidated Independent School District (ISD) employs more than 700 and the Sabinal ISD employs nearly 100 (City of Uvalde web site 2000). Uvalde is also home to Southwest Texas Junior College (SWTJC), operating Outreach Centers in Del Rio, Eagle Pass and Crystal City (all outside the EAHCP Planning Area). SWTJC employs more than 170 persons. Texas A&M University operates a Research and Extension Center in Uvalde that employs approximately 60. The City of Uvalde currently employs approximately 150 and Uvalde County employs approximately 100 (City of Uvalde website 2000).

3.6.1.2 Services

Service industries include Professional and Business Services, Education and Health Services, Leisure and Hospitality, and other services. Service industries provide approximately 25 percent of the region's employment (2,916 jobs) in the second quarter of 2001. This includes the Uvalde Memorial Hospital, which employs approximately 350 (City of Uvalde web site 2000). There are also at least two major assisted living facilities in the area, which together employ almost 200: Amistad Nursing Home and Uvalde Southwood Nursing (City of Uvalde web site 2000).

The region is also home to some popular tourist destinations, which contribute to services employment. Garner State Park is located in Uvalde County.

3.6.1.3 Trade, Transportation, and Utilities

This sector accounts for 18 percent of jobs in the region. The HEB grocery chain has a facility in Uvalde, employing approximately 250. Wal-Mart also employs more than 100 in Uvalde County and Texas Industrial Service (Unifirst Corp.)—a uniform laundry and supply company—employs approximately 65 (Uvalde County web site 2000).

The Western Region's economy is highly dependent on trucking traffic between the U.S. and Mexico–via the Eagle Pass-Piedras Negras International Bridge and the Del Rio-Ciudad Acuña International Bridge. The North American Free Trade Agreement (NAFTA) has contributed to the region's growth. Statewide Transport/Vulcan Materials is a trucking/asphalt mining company in Uvalde employing more than 100 (Uvalde County web site 2000).

3.6.1.4 Manufacturing

Manufacturing employment accounted for about six percent of the jobs in the Western Region. Major manufacturing facilities in the region are contained in Table 3.6-6. The region's temperate climate provides a healthy environment for a variety of crops and the associated processing plants. In addition, with a large cattle population, the region has several meat packing plants, including Uvalde Meat Processing.

Table 3.6-6. Major manufacturing employers in the Western Region, 2000

Company	Number of Local Employees	Type of Business
AgriLink Foods	400	Packaging frozen foods
Williamson-Dickies	380	Manufacturing work clothes
Sierra Industries	110	Aircraft modifications
South Star Aircraft Interior	65	Aircraft interiors
Miller Aircraft Painting	40	Aircraft painting
TOTAL	995	

SOURCE: Uvalde County web site (2000).

3.6.1.5 Natural Resources and Mining

Natural Resources and Mining includes agriculture, forestry, fishing, hunting, and mining. This sector remains relatively important in the Western Region economy, supplying more than 14 percent of the area's employment in the second quarter of 2001. Of the four counties that comprise the Western Region, Uvalde County has the largest number of natural resources and mining jobs (1,542) relative to its employed population (10,159). Fourteen percent of the Natural Resources and Mining sector jobs in Uvalde were mining jobs, the remaining were agricultural jobs. The percentage of mining jobs was lower in all other counties in the Western Region. See Section 3.4 for more information regarding the agricultural resources in these counties.

3.6.2 Central Region

The Central Region is comprised of the counties of Medina and Atascosa. Hondo is the Medina County seat and Jourdanton is the Atascosa County seat. The Central Region contained approximately 2.0 percent of the total employment in the EAHCP Planning Area in the second quarter of 2001 (see Table 3.6-1), and according to the TWC, local government; trade, transportation, and utilities; and education and health services are the major contributors to the economy in this region. Tables 3.6-2 and 3.6-7 indicate that in 2000 and 2001, there were almost twice as many employed workers (33,046) living in the Central Region than there were jobs (17,459). It is assumed that many of the employed labor force, therefore, commute to work in the San Antonio MSA (TWC 2000).

As in the rest of the state, unemployment in the Central Region generally declined between 1990 and 2000 (see Table 3.6-2). In 1998, the average percentage of persons in poverty was 20 percent and the average estimated median household income in 1998 was $29,601 (see Table 3.6-4).

Table 3.6-7. Employment and average quarterly wages for the Central Region – 2nd quarter, 2001

Category	Atascosa Total Emp	Medina Total Emp	Central Region	
			Total Emp	% of Total
Natural Resources & Mining	899	261	1,160	6.6%
Construction	480	407	887	5.1%
Manufacturing	434	490	924	5.3%
Trade, Transportation, & Utilities	2,249	1,807	4,056	23.2%
Information	178	79	257	1.5%
Financial Activities	268	352	620	3.6%
Professional & Business Services	510	421	931	5.3%
Education & Health Services	1,113	753	1,866	10.7%
Leisure & Hospitality	579	711	1,290	7.4%
Other Services	272	131	403	2.3%
Nonclassifiable	12	0	12	0.1%
Federal Government	60	62	122	0.7%
State Government	127	562	689	3.9%
Local Government	2,062	2,180	4,242	24.3%
Total Employment	9,243	8,216	17,459	100.0%
Average Quarterly Wages	6,170	5,489	n/a	n/a

Source: Texas Workforce Commission, 2002, Labor Market Information - Covered Employment and Wages.

3.6.2.1 Government

Local government provides the largest percentage of employment in the Central Region—nearly 24.3 percent, followed by 23.2 percent in the Trade, Transportation, and Utilities sector and 10.7 percent in Education and Health Services.

3.6.2.2 Services

Service industry employment, including Professional and Business Services, Education and Health Services, Leisure and Hospitality, and Other services, comprises approximately 26 percent of the economy. Atascosa County is home to a major hospital in Jourdanton—Tri-City Community Hospital—that provides 24-hour emergency room service, surgery, general acute care, Magnetic Resonance Imaging (MRI), home health, physical/occupational therapy, and other medical services. In addition, Medina County is home to the Hill Country State Natural Area and Medina Diversion Reservoir. Hunting leases in both counties also contribute to the economy.

3.6.2.3 Manufacturing

Several industries exist within the region including peanut processing and perfume manufacturing.

3.6.2.4 Agriculture

The Region's economy is primarily agricultural with peanuts, strawberries and cattle the main sources of farm income. Atascosa County is called the "Strawberry Capital" of Texas and is home to Poteet. The TWC estimates that there were 1,160 natural resources and mining jobs in the Central Region in the second quarter of 2001. Approximately half of those jobs were agriculture and half were mining. The U.S. Agriculture Census estimates that there were an additional 2,310 farm jobs in the region in 1997. This indicates more hired farm labor than is revealed by the TWC data. See Section 3.4 for more information regarding the agricultural resources in these counties.

3.6.2.5 Trade, Transportation, and Utilities

This sector accounts for 23 percent of jobs in the region. In addition to major highways, rail lines cross the region. The United Parcel Service operates a parcel distribution and drop-off center in Pleasanton in Atascosa County.

3.6.3 Eastern Region

The Eastern Region is the dominant region in the EAHCP Planning Area, in terms of population and employment. As noted above, this region contains a majority of the San Antonio MSA and a small portion of the Austin-San Marcos MSA. In 2000, the San Antonio MSA had a civilian workforce of 775,402, representing over 80 percent of the EAHCP Planning Area's 2000 total civilian workforce of 966,827 (TWC 2002). The projected continued urban growth in the San Antonio area and Interstate 35 corridor will create additional water demand for municipal and industrial purposes. As Tables 3.6-2 and 3.6-4 demonstrate, the Eastern Region has both lower unemployment and poverty rates than the remaining EAHCP Planning Area or state.

Employment and wage data for the Eastern Region is shown in Table 3.6-8.

Table 3.6-8. Employment and average quarterly wages for the Eastern Region – 2nd quarter, 2001

Category	Bexar Total Emp	Caldwell Total Emp	Comal Total Emp	Guadalupe Total Emp	Hays Total Emp	Kendall Total Emp	Eastern Region Total Emp	Eastern Region % of Total
Natural Resources & Mining	2,910	248	491	184	115	100	4,048	0.5%
Construction	37,024	228	2,514	1,767	2,524	714	44,771	5.9%
Manufacturing	42,716	357	5,058	5,380	3,492	849	57,852	7.6%
Trade, Transportation, & Utilities	120,284	1,192	7,480	4,230	7,462	1,682	142,330	18.6%
Information	24,488	51	459	152	712	86	25,948	3.4%
Financial Activities	53,962	248	1,311	804	1,148	813	58,286	7.6%
Professional & Business Services	86,999	354	1,385	1,070	2,411	390	92,609	12.1%
Education & Health Services	76,068	1,381	2,930	2,023	3,366	564	86,332	11.3%
Leisure & Hospitality	73,605	587	4,366	1,813	4,211	1,072	85,654	11.2%
Other Services	21,226	124	848	674	714	286	23,872	3.1%
Nonclassifiable	233	21	11	10	28	2	305	0.0%
Federal Government	28,283	62	178	192	166	59	28,940	3.8%
State Government	14,370	93	156	162	4,524	77	19,382	2.5%
Local Government	77,122	1,431	3,908	4,379	4,759	1,309	92,908	12.2%
Total Employment	659,290	6,377	31,095	22,840	35,632	8,003	763,237	100.0%
Average Quarterly Wages	7,527	5,653	6,196	6,756	6,127	6,544	n/a	n/a

SOURCE: Texas Workforce Commission 2000, Labor Market Information – Covered Employment and Wages.

The Eastern Region's urban economy is characterized by large government, transportation and utilities, trade, and service employers, as well as by a few large manufacturers. Export sectors of the economy, broadly defined as those products and services that are bought with money from outside the region, are an important determinant of a region's economy. Export sectors, for these purposes, can include headquarters of large corporations whose operations occur substantially outside of the service area. Table 3.6-9 shows the largest employers in the San Antonio area with a substantial export impact.

Much of the export-sector employment in the San Antonio MSA is either labor intensive or benefits from knowledge of military operations and equipment. The area has traditionally been viewed as an attractive source of productive labor with a relatively low skill level (Research and Planning Consultants 2000).

3.6.3.1 Government

Government accounts for more than 19 percent of the Eastern Region employment. In San Antonio, the U.S. Department of Defense is the largest single employer. Military employment at the five military installations located in San Antonio totaled approximately 39,277 in the year 2000. Civilian-related employment at the bases totaled 28,619, for a total of almost 68,000 military base related employment (San Antonio Economic Development Foundation 2002a). Local governments still employ more than the Federal government, however, in the Eastern Region.

Table 3.6-9. Major corporate headquarters and regional/divisional offices located in San Antonio, 2002

Employer	Activity	San Antonio Employment
H.E.B. Food Stores	Supermarket chain	17,805
United Service Automobile Assoc.	Insurance	17,069
Southwestern Bell Communications	Telecommunications	8,000
Southwestern Bell Telephone	District division office	4,589
Frost National Bank	Banking service	3,541
Taco Cabana	Fast food chain	3,000
West Telemarketing	Outbound telemarketing	2,850
Southwest Research Institute	Applied research	2,733
QVC Network, Inc.	Order center	2,034
Ultramar Diamond Shamrock	Refining & marketing	2,008
Bill Miller Bar-B-Q	Fast food chain	2,000
Boeing Aerospace Support Center	Aircraft maintenance facility	2,000
The Psychological Corporation	Testing publication materials	2,000
Valero Energy	Oil refining & gasoline marketing	1,950
TeleService Resources Subsidiary of AA	Reservation center	1,850
Citicorp	U.S. customer service center	1,759
Lockheed Martin	Aircraft engine overhaul	1,700
Luby’s, Inc.	Cafeteria chain	1,575
H.B. Zachry Company	General contractors	1,300
United Parcel Service	Central Texas district office	1,075
World Savings and Loan	National customer service center	950
The Capital Group	Mutual funds and investments	819
Clarke American	Check printing	701
Kinetic Concepts, Inc.	Specialty medical products	650
JP Morgan Chase	Credit card customer service center	550
Holt Company of Texas	Construction equipment	463
QWest Communications	Telecommunications	350
Pratt & Whitney	Engine maintenance/repair	330
La Quinta Motor Inns	Motel chain	300
Texace Corporation	Headware manufacturing	244
Dee Howard Company	Aircraft maintenance	240
Tesoro Petroleum Company	Petroleum exploration, extraction & refining	200

SOURCE: San Antonio Economic Development Foundation 2002a.

3.6.3.2 Trade

H.E.B. Food Stores is the largest private employer in the San Antonio region, providing 17,805 jobs in San Antonio.

3.6.3.3 Services

As can be seen from Tables 3.6-8 and 3.6-9, service employment represents the largest sector of the economy in the Eastern Region (approximately 38 percent). Fast-food chains represent some of the largest employers in the area. These businesses, together with the considerable employment in the tourism industry (see Section 3.6.3.8 Recreation and Tourism), account for the very large service sector in the region. There are more than 230 hotels located in San Antonio alone with almost 26,000 hotel rooms. Direct economic impact of the Alamodome sports arena since it opened in 1993 is estimated at over $250 million (City of San Antonio 2000).

3.6.3.4 Manufacturing

While providing relatively fewer jobs than the government, trade and service sectors, manufacturing is important in San Antonio. Table 3.6-10 contains the largest manufacturing companies located in San Antonio. Only 5 of the 30 manufacturers listed began their operations in San Antonio during the 1990s.

3.6.3.5 Financial Activities

This sector contains several large export employers (see Table 3.6-9). United Services Automobile Association, San Antonio's second largest employer, employs 17,069 people, Frost Bank employs 3,541 and CitiCorp employs 1,759. These operations make intensive use of clerical labor, which has historically been in ample supply in the San Antonio workforce.

3.6.3.6 Information

The NAICS Information sector includes major components of the former Transportation, Communication, and Utilities sector, the Manufacturing sector, and the Services sector. The Information sector has benefited in recent years as many telecommunications companies have expanded into San Antonio. Southwestern Bell Communications relocated its headquarters to downtown San Antonio, creating an additional 2,000 jobs in the city. World Savings, CitiCorp, QVC, and the Capitol Group have established San Antonio as a telecommunications center (City of San Antonio 2000). Southwestern Bell's District Division office in San Antonio employs 4,589.

3.6.3.7 Natural Resources and Mining

Natural Resources and Mining are the predominant land uses in the non-urban areas of the region (40 percent agriculture, 60 percent mining). The TWC estimates that agriculture supplied 4,048 jobs to the region in the second quarter of 2001. The U.S. Agriculture Census estimates that there were 4,870 hired farm laborers in 1997. Caldwell and Guadalupe Counties had the largest number of hired farm laborers (571 and 1,166, respectively) in 1997 relative to their employed populations. See Section 3.4 for more detailed information about the agricultural economy in these counties. In recent years, recreational hunting use has become in many cases a more important source of income to ranchers than the leasing of grazing rights.

Table 3.6-10. San Antonio's leading manufacturers, 2002

Company	Year Established	Product	San Antonio Employment
Ultramar Diamond Shamrock	1987	Petroleum refining & marketing	2,008
Miller Curtain Company	1946	Curtains & draperies	1,300
San Antonio Express News	1865	Newspaper	1,200
Coca Cola/Dr. Pepper Bottling	1903	Soft drink bottling	1,100
Lancer Corporation	1967	Soft drink dispensing equipment	1,000
SAS Shoemakers	1976	Shoes, handbags	1,000
Sony Semiconductor Co. of America	1990	Semiconductors	1,000
Structural Metals, Inc.	1947	Steel	883
Fairchild Aircraft	1972	Turboprop aircraft	800
Clarke American	1947	Check printing	701
Martin Marietta Materials Southwest	1934	Crushed limestone, asphalt, concrete, lime, cement, etc.	700
L&H Packing Company	1965	Boned beef & ground beef patties	690
Philips Semiconductor	1984	Semiconductors	670
Friedrich A/C & Refrigeration Company	1886	Commercial refrigeration & room air conditioners	665
DPT Laboratories, Inc.	1940	Pharmaceutical and cosmetics	650
Levi Strauss & Co.	1976	Finishing plant	620
Levi Strauss & Co.	1979	Manufacturing plant	560
Kinetic Concepts, Inc.	1976	Specialty medical products	551
Holt Company of Texas	1963	Construction equipment (Caterpillar dealership)	463
Alamo Iron Works	1878	Iron products	445
Oberthur Gaming Technology	1986	Instant lottery tickets	420
Harris Corporation Communications Division	1969	Microwave radio communication equipment	365
Reyes Industries, Inc.	1994	Textile products	300
York International	1989	Industrial air conditioners and refrigeration systems	286
Moll Industries (formerly Texas Plastics)	1978	Custom injection molding	282
Takata/TK Taito	1996	Automotive safety restraints	262
Texace Corporation	1944	Headware	244
Gaylord Container Corp.	1995	Corrugated cardboard boxes	205
Alcoa/Fujikura, Ltd.	1990	Automotive wiring harnesses	190
Xytronics	1985	Printed circuit board assemblies	76

SOURCE: San Antonio Economic Development Foundation 2002b.

3.6.3.8 Recreation and Tourism

General Discussion

Tourism is an important, multibillion-dollar industry in the San Antonio Metropolitan region (Table 3.6-11). The millions of tourists who visit the area annually are drawn by the area's rich Southwestern cultural heritage, historical sites and numerous headline attractions. San Antonio is one of the top tourist destinations in Texas, according to the Texas Department of Transportation.

Table 3.6-11. Travel and tourism impact for the Eastern Region, 1998

Tourist Impact	Bexar County	Hays County
Spending	$3,110,325,000	$105,910,000
Payroll	$707,500,000	$17,980,000
Employment	56,600 persons	1,200 persons
Local tax receipts	$31,242,677	$1,560,000
State tax receipts	$185,516,250	$8,340,000

SOURCE: San Marcos Convention and Visitors Bureau, personal communication, 2000.

Although difficult to capture in any single employment sector, the recreation and tourism industry has a large influence on both the trade and service employment sectors of the Planning Area's economy. Because many area attractions rely on Edwards Aquifer water, the aquifer affects trade and service sectors. San Marcos Springs, the Comal and Guadalupe Rivers, Sea World, the San Antonio River Walk, the Fiesta Texas theme park and the San Antonio Zoo are all important users of Edwards Aquifer water. Fiesta Texas and numerous area golf courses, either through direct pumping or the purchase of municipal utility water, are dependent upon the Edwards for irrigation water. Visits to these attractions in addition to other locales such as the Tanger Outlet Mall in San Marcos and the Alamo, which are not heavy water consumers, make the area a popular visitor destination. A very large convention industry has developed as a result of the diversity of attractions and activities available in the area.

Tourism attractions are affected directly and indirectly by the issues surrounding the Edwards Aquifer springflows. Certain attractions would benefit from pumping restrictions and higher springflows. The San Marcos and Comal River water recreation facilities would be direct beneficiaries of higher springflows since higher river flows would afford more exciting tubing, canoeing, and rafting. Water recreation below Canyon Dam benefits indirectly from higher Comal Springs springflow since higher springflows result in more water stored behind Canyon Dam during the latter part of the summer available for release, which in turn results in more desirable river conditions (James Inman, Water Oriented Recreation District, Comal County, personal communication 1999).

San Antonio attractions that use water from the aquifer stand to be adversely affected by withdrawal restrictions. The two most notable water-dependent recreational attractions in San Antonio are the River Walk (Paseo de Rio) and Sea World. The River Walk, a water-dependent attraction, is located on the San Antonio River. The river's flow has been augmented by pumping water from the Edwards Aquifer. Similarly, Sea World pumps substantial amounts of Edwards water for its needs. Withdrawal restrictions could affect these attractions.

In addition, Canyon Lake Reservoir on the Guadalupe River in Comal County is a major recreational facility in the region, and contributes greatly to the region's economy. An estimated 1.1 million people visit Canyon Lake each year. Population growth around Canyon Lake has been dramatic, as expected, since the construction of the dam in the mid-1960s. The U.S. Census Bureau did not recognize Canyon Lake as a distinct community until 1980, so the initial growth was not recorded. According to the Canyon Lake Chamber of Commerce, the 42 percent growth in Comal County between 1980 (36,446) and 1990 (51,832) is due largely to the population increase within the Canyon Lake area. By 2000, the population of Comal County had grown to 78,021 persons, an increase of 50 percent since 1980 and 139 percent since 1970. In general, population is expected to double every 20 years (Canyon Lake Chamber of Commerce 2000).

The normal lake level is 909 feet msl, and the lake is usually maintained between 909 and 911 feet msl during the summer, which insures a steady release rate for downstream river recreation and agriculture (GBRA 2000). Should the lake level rise above or drop below these levels, adjustments are made, as directed by the U.S. Army Corps of Engineers.

Comal County has established the only Water-oriented Recreation District (WORD) in the State of Texas. WORD operates much like a municipal water district, but instead of collecting ad valorem or property taxes, the district collects sales taxes and users fees. WORD is centered on the Guadalupe River and includes Canyon Lake but does not include the City of New Braunfels, as that jurisdiction did not choose to participate. WORD, therefore, encompasses about two-thirds of the county.

WORD collects tax revenues in the following categories and at the following rates: camping at 2.5 percent, water oriented businesses (Water/O) at 4.5 percent, marinas at 4.5 percent, and hotel/motel fees at 2.0 percent.

As Table 3.6-12 indicates, water oriented recreation takes place mainly during the second and third quarters of the year. The tourist season is basically 15 weeks long, beginning Memorial Day weekend and running through Labor Day. WORD management estimates approximately 200,000 people floated the Guadalupe River in 1998.

WORD estimates that two acre-feet of water from spring rains captured in Canyon Lake and slowly released during the 15-week tourist season is an adequate supply of water to upgrade the natural summer springflows and maintain recreation activities. This situation occurred in 1995, and WORD estimates more than 350,000 people floated the Guadalupe that year, creating almost

$64 million in economic impacts in the process. As noted in Table 3.6-12, 1996 was a drought year, and the recreation industry in Comal County suffered accordingly. WORD estimates that less than 80,000 visitors came to the Guadalupe River, creating a relatively meager $14.4 million in economic impacts.

Table 3.6-12. Water oriented recreation district funds in Comal County, 1996-1998

Period	Camping[1]	Water/O[2]	Marina[3]	H/Motel[4]	Total Revenue	Approx. # Visitors on Guadalupe[5]
1996						
1st Qtr	$1,042	$633	$8,826	$2,093	$15,720	1,758
2nd Qtr	$7,735	$19,191	$17,138	$7,773	$51,837	53,308
3rd Qtr	$6,691	$8,679	$15,993	$7,842	$39,205	24,108
4th Qtr	$789	$302	$10,450	$2,165	$13,706	839
1996 Total	$16,257	$28,805	$52,407	$19,873	$120,468	80,014
1997						
1st Qtr	$1,393	$1,993	$12,913	$2,028	$18,327	5,536
2nd Qtr	$7,030	$35,384	$16,535	$7,212	$66,161	98,289
3rd Qtr	$8,596	$49,296	$18,176	$11,421	$87,489	136,933
4th Qtr	$819	$838	$9,453	$2,070	$13,180	2,328
1997 Total	$17,838	$87,511	$57,077	$22,731	$185,157	243,086
1998						
1st Qtr	$1,328	$1,127	$12,695	$2,827	$17,977	3,131
2nd Qtr	$12,179	$46,649	$17,994	$9,403	$86,225	129,581
3rd Qtr	$12,823	$33,554	$20,721	$12,037	$79,136	93,206
4th Qtr	$548	$959	$9,759	$5,529	$16,318	2,664
1998 Total	$26,878	$82,289	$61,169	$29,796	$199,656	228,581

SOURCE: James H. Inman, Manager, Comal County Water Oriented Recreation District, written correspondence, November 23, 1999.

[1]Camping tax rate: 2.5%.

[2]Water/O (water-oriented recreation—tubers, rafters, kayakers, and canoers) tax rate: 4.5%.

[3]Marinas (mostly located on Canyon Lake) tax rate: 4.5%.

[4]Hotel/motel tax rate: 2.0%.

[5]Approximate number of visitors on Guadalupe: Water/O revenue divided by tax rate and multiplied by $8.00 (average cost for tube rentals).

Contribution of Aquifer Springflow to Ecotourism and Water-based Recreation

Comal Springs and San Marcos Springs play important roles in the health of the tourist industry in Comal and Hays Counties, respectively. These springs, the Comal and San Marcos Rivers, Canyon Lake, and the middle Guadalupe River, collectively support a large, water-based sector of the regional economy.

According to a TPWD study called *Texans Outdoors: An Analysis of 1985 Participation in Outdoor Recreation Activities* (Nichols and Goldbloom 1989), the primary recreational activities occurring in a region roughly corresponding to the EAHCP Planning Area were nature viewing and freshwater swimming. In this paper the region (Region 18) included the counties of Gillespie, Kerr, Kendall, Bandera, Comal, Guadalupe, Wilson, Karnes, Atascosa, Medina, Frio and Bexar. Nature viewing in this region had approximately 1.2 million total annual participation occasions. An "occasion" is each time someone participates at a site regardless of the length of participation. Those nature viewing Texans are primarily from their own region, but also came from West Texas, Austin area, Houston area, and Laredo area. Freshwater swimming in Region 18 had approximately 3.3 million total annual participation occasions in 1985. Those Texans participating in freshwater swimming are primarily from their own region, but also came from far West Texas/El Paso area, Austin area, Houston area, and counties just to the east of Region 18 (Nichols and Goldbloom 1989).

Tourism spending for overnight visitors in Comal County was estimated to be $161,660,000 in the year 2000, generating $3,340,000 in local sales tax receipts (city and county) and $11,320,000 in State sales tax receipts (Texas Department of Economic Development and Dean Runyon Associates 2001). Day visitors are estimated to generate the same economic impact as overnight guests in Comal County (Meek 2002). As a result, total tourism spending in Comal County was estimated to be approximately $323,000,000 in the year 2000, generating approximately $6,680,000 in local sales tax receipts or approximately 55.3 percent of the total City of New Braunfels and Comal County sales tax receipts of $12,080,000. Water-based recreation is estimated to account for 70 percent of annual tourism revenue in Comal County, generating approximately $4,700,000 in local sales tax revenues in the year 2000 (Meek 2002).

Employment in the leisure and hospitality industry ranged from 11 percent to 15 percent of total Comal County employment during the year 2001. Reflecting the importance of water-based recreation in Comal County, employment in the leisure and hospitality industry rose during the water season from May through September and fell during the rest of the year. For example, leisure and hospitality employment in Comal County averaged 4,625 jobs during the third quarter of 2001 and fell to 3,292 jobs during the fourth quarter, a decrease of 28.8 percent (Texas Workforce Commission 2002).

According to a San Marcos River recreation user survey contained in a graduate thesis (Bradsby 1994), the primary (91 percent) recreation use of the upper San Marcos River was "floating" (defined as canoeing, kayaking and inner tubing) between Memorial Day and Labor Day. The most intense season of recreation activity at the river is summer. Other recorded recreation uses on the upper San Marcos River include swimming, fishing, boating, playing with dog in the water and other. Total use of the upper San Marcos River in the summer time period described was 18,309 for 1984 and 26,874 for 1992. Hydrologic data included in the Bradsby paper state that flow in the San Marcos was lower than the mean average in the summer of 1984 and higher than mean average in the summer of 1992. Bradsby states, "the projected total numbers of recreationists for 1984 (low flow) and 1992 (high flow) differ markedly. Based only on tube rental data, the 1992 summer season surpassed the use of the river in 1984 by 8,565 recreationists. Anecdotal information and observation during the summer of 1984 indicated that reduced flows of the river resulted in a reduction in recreational activity."

The user survey also revealed that the area of greatest importance to the users is the environmental aesthetic, especially water quality. "Stream flow is the critical element . . . for the continued recreational use [of the San Marcos River]," according to the summary of Bradsby's thesis. "As flows lessen, recreational use of the river declines. At some as yet unidentified minimum flow, recreational use of the river would cease altogether." Flow is not the only factor in maintaining the rivers aesthetic value and water quality. The recreationists themselves disturb the substrate and vegetation, and this disturbance is magnified in low flow situations. For example, "at reduced flows, tubers are more inclined to propel themselves down the river" (Bradsby 1994).

Tourism spending for overnight visitors in Hays County was estimated to be $111,970,000 in the year 2000, generating $1,770,000 in local sales tax receipts (city and county) and $8,210,000 in State sales tax receipts (Texas Department of Economic Development and Dean Runyon Associates 2001). Information on the economic impacts of day visitors and water-based recreation in Hays County is not available.

Unlike Comal County, employment in the leisure and hospitality industry remained relatively stable throughout the year in Hays County, ranging from 10.8 percent to 11.8 percent of total employment during the year 2001. For example, leisure and hospitality employment in Hays County averaged 4,205 jobs during the third quarter of 2001 and fell to 3,995 jobs during the fourth quarter, a decrease of only 5.0 percent (Texas Workforce Commission 2000). The stability of tourism employment throughout the year indicates that water-based recreation plays a smaller role in Hays County than in Comal County.

3.6.4 Downstream Region

The Victoria MSA, which is a single-county MSA, dominates the Downstream Region economy. Of the 72,050 civilian employees working in the Downstream Region counties in 2000, 43,165—or more than 60 percent—were in Victoria County (see Table 3.6-2). This region has evolved from an agricultural-based economy. Trade, Transportation and Utilities; Manufacturing; and Local Government employment are the drivers of the Downstream Region economy (Table 3.6-13).

3.6.4.1 Government

Local, state, and federal government accounts for almost 20 percent of the Downstream Region's employment, or 12,361 jobs in the second quarter of 2001.

The Victoria area supports six independent school districts. Together they employ almost 3,500. The Victoria Independent School District alone employs approximately 2,000. Other educational employment includes the Victoria College (approximately 250 jobs) and the University of Houston-Victoria (124 jobs).

The City of Victoria employs a little more than 600 persons, while Victoria County employs more than 550 persons. The Texas Department of Justice has a state prison facility in the region that employs almost 350 persons. Federal employment in the area provides jobs to almost 240 persons and includes a U.S. Border Patrol facility.

Table 3.6-13. Employment and average quarterly wages for the Downstream Region – 2nd quarter, 2001

Category	Calhoun Total Emp	De Witt Total Emp	Gonzales Total Emp	Refugio Total Emp	Victoria Total Emp	Downstream Region Total Emp	% of Total
Natural Resources & Mining	193	101	1,085	245	2,568	4,192	6.7%
Construction	1,893	235	138	186	2,192	4,644	7.4%
Manufacturing	4,154	1,197	764	12	2,957	9,084	14.4%
Trade, Transportation, & Utilities	1,078	1,011	1,275	296	8,026	11,686	18.6%
Information	79	26	64	6	872	1,047	1.7%
Financial Activities	339	418	203	89	1,867	2,916	4.6%
Professional & Business Services	288	137	145	20	2,772	3,362	5.3%
Education & Health Services	318	812	528	64	4,680	6,402	10.2%
Leisure & Hospitality	696	450	226	234	3,434	5,040	8.0%
Other Services	171	255	157	67	1,536	2,186	3.5%
Nonclassifiable	1	0	0	0	1	2	0.0%
Federal Government	46	50	78	39	227	440	0.7%
State Government	78	502	57	36	298	971	1.5%
Local Government	1,293	1,735	1,221	603	6,098	10,950	17.4%
Total Employment	10,627	6,929	5,941	1,897	37,528	62,922	100.0%
Average Quarterly Wages	9,760	5,885	5,821	5,748	7,123	N/a	n/a

SOURCE: Texas Workforce Commission 2002, Labor Market Information – Covered Employment and Wages.

3.6.4.2 Manufacturing

The manufacturing sector in the Downstream Region represents about 15 percent of the region's total employment. The lion's share of manufacturing employment in the area is concentrated in petrochemical, plastics and chemical production plants located in Victoria and Calhoun counties. Accordingly, the area relies heavily on its coastal development, particularly port and water transportation facilities.

A $1.3 billion expansion, which began in 1988, of Formosa Plastics' Point Comfort plant was completed in late 1994. The expansion increased petrochemical processing capacity from 250,000 tons to more than 5 million tons per year. A $42 million port expansion and renovation project started in 1989 by the Port Authority of Port Lavaca-Point Comfort to accommodate Formosa Plastics' increased capacity was completed in December 1994. Since Formosa Plastics' shipping requirements will use only 15 percent of the renovated port's capacity, port officials plan to increase their efforts to attract other petrochemical plants to use their renovated facilities instead of shipping their output to Houston's port. Economic development in the region has been enhanced by the expansion of the Victoria Barge Canal, which connects Victoria to the Gulf Intracoastal Waterway, the deep-water Port of Port Lavaca-Point Comfort, and the growth of the petrochemical plants.

Victoria's manufacturing sector is diverse. A wide variety of products, from concrete products and structural metals to alkalis and chlorine are produced. Inteplast is the area's largest manufacturer with over 1,900 employees.

The major manufacturing employers in the Victoria MSA, as of May 1999, are contained in Table 3.6-14.

Table 3.6-14. Major manufacturing employers in the Victoria MSA, 2001

Company	Product	Employees
Inteplast Group	Plastic products	1,700
Formosa Plastics	Petrochemicals/plastics	1,500
E. I. Dupont de Nemours	Petrochemicals	1,150
Dow Chemical	Petrochemicals	1,047
Alcoa	Aluminum/alumina	963
Kaspar Wire Works	Metal works/plating	850
TYCO Plastics	Plastic bags	316
Circle Y of Yoakum Inc.	Leather products	278
Texas Concrete	Concrete	200
VMW Industries	Specialized equipment	179
Safety Steel Service	Steel fabrication	164
Safety Railway Service	Steel fabrication	164
BP Chemicals	Petrochemicals	157
Lack's	Furniture	135
Victoria Air Conditioning	Mechanical	152
Seadrift Coke	Needle coke	112
Equistar Chemical LP	Petrochemicals	87
Sunoco	Plastic bags	100

SOURCE: Victoria Economic Development Corporation, Dec. 2002.

3.6.4.3 Services

Service sector employment is a mainstay of the Victoria economy. The service sector in the Downstream Region as a whole accounts for nearly 27 percent of the region's jobs. Major industries in the service sector include health services, business services and social services. Five local and regional hospitals provide a large number of service sector jobs. According to the Victoria Economic Development Corporation (VEDC), the Columbia-DeTar Hospital, Victoria Regional Medical Center, Cuero Community Hospital, Memorial Medical Center and Citizen's Medical Center employ about 2,678 people combined. In addition, the Crossroads Home Health

Service and the Arboretum of Victoria provide another 500 medical service related jobs in the region (VEDC 2002).

Refugio County includes a portion of the Aransas National Wildlife Refuge, home to the whooping crane, and a top Texas tourist attraction.

3.6.4.4 Trade, Transportation, and Utilities

This sector employed more than 19 percent of the Downstream Region's work force in the second quarter of 2001. According to the VEDC, major trade employers located in the Victoria MSA in 2001 include HEB Grocery Store (500), Wal-Mart Supercenter (400), Performance Food Group (230), Dillard's (180), Lowe's Home Improvement (140), Lack's Furniture store (135), Victoria Air Conditioning (152), J.C. Penny Department Store (150), Atzenhoffer Chevrolet (156), Target Department Store (100), Sam's Club (115), and the Sears, Roebuck & Co. Department Store (100). The Central Power and Light Company employs over 230 and the Union Pacific Railroad employs an additional 147.

3.6.4.5 Natural Resources and Mining

According to the TWC, Natural Resources and Mining supplied about 6.7 percent of the jobs in the region in the second quarter of 2001. Of these approximately 32 percent were agriculture and 68 percent were mining. The U.S. Agriculture Census estimates that there were 4,473 hired farm laborers in the region in 1997 compared to the TWC 1997 estimate of 1,477 jobs. Gonzales had the largest number of hired farm laborers (2,425) relative to the other counties in the region. See Section 3.4 for more detailed information about the agriculture sector in the Downstream Region counties.

3.6.4.6 Information

According to the VEDC, Southwestern Bell employs an additional 105. The *Victoria Advocate* newspaper employs approximately 220.

3.6.4.7 Construction

Three construction companies employ 1,150 persons: H.B. Zachary Company (400), Brown & Root (400), and King Fisher Marine (350).

3.6.4.8 Recreation

Coleto Creek Reservoir (Victoria County) and Lake Wood on the Guadalupe River southwest of Gonzales (Gonzalez County) are the only two reservoirs in the Guadalupe Blanco River Authority's (GBRA) system which operate public recreation areas. Recreation access at other lakes is limited as shorelines around McQueeney, Placid, Dunlap, and Meadow Lakes are privately owned, with little to no public access (Wilfred Korth, Coleto Creek Park and Reservoir, personal communication, 2000). Coleto Creek currently averages approximately 300,000 visitors per year. Ninety percent of these visitors come from within a range of 140 miles of the Coleto Creek Park, and are repeat users. The Coleto Creek Park generates revenue of approximately $400,000 per year. The bulk of this revenue comes from park entry fees for camping, picnicking, and bass fishing.

Lake Wood currently averages approximately 30,000 visitors per year. Ninety-five percent of these users come from within a range of 90 miles of the Lake and are repeat users. The Lake Wood Recreation Area generates revenue of approximately $90,000 per year. The bulk of this revenue comes from park entry fees for camping and fishing, yearly island lease rentals, and park store sales.

3.7 Land Use

The U.S. Department of Agriculture conducts a Natural Resources Inventory (NRI) every five years. Data analysis is currently underway for information collected in 2002. According to 1997 NRI, the EAHCP Planning Area totals more than 11,105,000 acres. Land uses in the NRI are historically classified in the following categories: cultivated and noncultivated cropland, pastureland, rangeland, forest land, minor land cover/uses (Misc.), urban small and large built-up, rural transportation—roads and railroads, surface water features, federal lands, and lands in the Conservation Reserve Program (Table 3.7-1). The Conservation Reserve Program is a federal program established under the Food Security Act of 1985 to assist private landowners to convert highly erodible cropland to vegetative cover for 10 years.

According to NRI, a significant percentage of land in the EAHCP Planning Area is devoted to rangeland—68.8 percent, or approximately 7,643,200 acres in 1997. Kinney County, at 98.6 percent, has the highest proportion of rangeland in the Planning Area, while Calhoun County at 23.4 percent in 1997, maintains the lowest percentage of rangeland. The next most common uses of land in the Planning Area are cropland (both cultivated and non-cultivated) and pastureland.

The EAHCP Planning Area is 10.1 percent cropland and 9.3 percent pastureland. Urban uses comprised 5.1 percent of the Planning Area. The remaining five land use categories—Miscellaneous (1.3 percent), Transportation (1.3 percent), Surface Water (3.3 percent), Federal Land (0.8 percent) and Conservation Reserve Program lands (0.07 percent)—each comprised less than 5 percent of the total acreage in the Planning Area in 1997.

3.7.1 Western Region

Counties in this region include Edwards, Kinney, Real, and Uvalde. Rangeland is the predominant land use in this region, accounting for most of the land area (3,439,000 acres or 93.5 percent) (see Table 3.7-1). Cropland accounts for about 158,000 acres or 4 percent, followed by transportation at 25,000 acres or less than 1 percent. All other categories (pasture,

Table 3.7-1. Estimated land use in the EAHCP Planning Area, 1997 (thousands of acres)

County	Crops	% Total	Pasture	% Total	Range	% Total	Misc.	% Total	Urban	% Total	Trans.	% Total	Surface Water	% Total	Federal Land	% Total	Conserv.	% Total	TOTAL
WESTERN REGION																			
Edwards	0	0.0	0	0.0	1,347.4	99.3	0.5	0.0	0	0.0	7.8	0.6	1.2	0.1	0	0.0	0	0.0	1,356.9
Kinney	4.5	0.5	0	0.0	861.3	98.6	1.0	0.1	0	0.0	6.2	0.7	0.9	0.1	0	0.0	0	0.0	873.9
Real	0	0.0	2.4	0.5	438.0	97.8	0.3	0.1	2.9	0.7	3.5	0.8	1.0	0.2	0	0.0	0	0.0	448.1
Uvalde	153.0	15.3	9.2	0.9	792.3	79.4	16.3	1.6	9.1	0.9	7.8	0.8	4.1	0.4	0	0.0	5.7	0.6	997.5
Subtotal	157.5	4.3	11.6	0.3	3,439.0	93.5	18.1	0.5	12.0	0.3	25.3	0.6	7.2	0.2	0	0.0	5.7	0.2	3,676.4
CENTRAL REGION																			
Atascosa	132.6	16.8	170.6	21.6	454.5	57.5	7.5	1.0	13.3	1.7	8.8	1.1	3.5	0.4	0	0.0	0	0.0	790.8
Medina	152.6	17.9	52.3	6.1	599.3	70.2	9.3	1.1	19.7	2.3	13.4	1.6	7.5	0.9	0	0.0	0	0.0	854.1
Subtotal	285.2	17.3	222.9	13.6	1,053.8	64.7	16.8	1.0	33.0	2.0	22.2	1.4	11.0	0.7	0	0.0	0	0.0	1,644.9
EASTERN REGION																			
Bexar	141.2	17.6	74.5	9.3	215.4	26.8	16.0	2.0	281.7	35.0	14.9	1.9	11.5	1.4	49.1	6.1	0	0.0	804.3
Caldwell	58.1	16.6	127.6	36.4	127.3	36.3	11.7	3.3	10.2	2.9	7.8	2.2	7.2	2.1	0.5	0.1	0	0.0	350.4
Comal	13.0	3.5	22.6	6.2	264.4	71.9	5.9	1.6	41.0	11.2	5.0	1.4	11.9	3.2	3.9	1.0	0	0.0	367.7
Guadalupe	131.1	28.7	158.3	34.6	112.7	24.7	8.7	1.9	30.0	6.6	9.9	2.2	5.4	1.2	1.0	0.2	0	0.0	457.1
Hays	29.7	6.8	60.6	13.9	275.7	63.4	7.6	1.8	47.9	11.0	9.0	2.1	4.6	1.1	0	0.0	0	0.0	435.1
Kendall	8.4	2.0	8.0	1.9	370.3	87.3	1.9	0.5	30.6	7.2	4.3	1.0	0.9	0.2	0	0.0	0	0.0	424.4
Subtotal	381.5	13.4	451.6	15.9	1,365.8	48.1	51.8	1.8	441.4	15.5	50.9	1.8	41.5	1.5	54.5	1.9	0	0.0	2,839.0
DOWNSTREAM REGION																			
Calhoun	78.0	13.2	21.9	3.7	138.6	23.4	31.2	5.3	22.7	3.8	4.6	0.8	263.2	44.4	32.1	5.4	0	0.0	592.3
De Witt	25.5	4.4	83.2	14.3	456.6	78.4	5.4	0.9	0.6	0.1	6.2	1.1	5.3	0.9	0	0.0	0	0.0	582.8
Gonzales	37.5	5.5	180.3	26.3	435.8	63.6	6.9	1.0	2.7	0.4	13.5	2.0	8.1	1.2	0	0.0	0	0.0	684.8
Refugio	63.2	12.3	26.8	5.2	388.2	75.2	0.8	0.2	3.1	0.6	9.0	1.7	22.5	4.4	0.6	0.1	1.9	0.4	516.1
Victoria	95.0	16.7	34.0	6.0	365.4	64.2	9.9	1.7	48.3	8.5	10.6	1.9	5.6	1.0	0	0.0	0	0.0	568.8
Subtotal	299.2	10.1	346.2	11.8	1,784.6	60.6	54.2	1.8	77.4	2.6	43.9	1.5	304.7	10.4	32.7	1.1	1.9	0.1	2,944.8
Planning Area Totals	1,123.4	10.1	1,032.3	9.3	7,643.2	68.8	140.9	1.3	563.8	5.1	142.3	1.3	364.4	3.3	87.2	0.8	7.6	0.1	11,105.1

Misc: Miscellaneous minor land count uses.
Trans: Rural transportation including roads and railroads.
Conserv: Lands in the Conservation Reserve Program.
Source: U.S. Department of Agriculture Natural Resources Inventory 1997

urban, surface water, conservation reserve lands, federal land, and miscellaneous) comprise less than 1.1 percent of the total land area (3,676,400 acres).

3.7.2 Central Region

The Central Region includes Atascosa and Medina Counties. Rangeland is the predominant land use in both these counties (454,500 acres or 57 percent for Atascosa, and 599,300 acres or 70 percent for Medina). However, cropland comprises 132,600 acres (17 percent) of the total area in Atascosa County, and 152,600 acres (18 percent) of the total area in Medina County. The Central Region contains the highest percentage of cropland of any of the four regions within the EAHCP Planning Area (see Table 3.7-1).

3.7.3 Eastern Region

This region contains Bexar, Caldwell, Comal, Guadalupe, Hays, and Kendall Counties. Within this region rangeland is the predominant land use at 1,365,800 acres (48 percent) followed by pasture at 451,600 acres (16 percent), urban and transportation together at 492,300 acres (17 percent), and cropland at 381,500 acres (13 percent). From Table 3.7-1, remaining land use categories (surface water, federal lands, and conservation reserve lands, and miscellaneous) account for about 6 percent of the total area.

3.7.4 Downstream Region

This region includes Calhoun, De Witt, Gonzales, Refugio, and Victoria Counties. Table 3.7-1 indicates the predominant land use in this region is rangeland, comprising 1,784,600 acres (61 percent), followed by pasture at 346,200 acres (12 percent), surface water at 304,700 acres (10 percent), crops at 299,200 acres (10 percent), and urban/transportation at 121,300 acres (four percent). Remaining land use categories (federal lands, conservation reserve lands, and miscellaneous) account for the remaining three percent.

3.8 Cultural Resources

This section contains the results of an assessment of the potential for cultural resources within the vicinity of Comal and San Marcos Springs, located in Comal and Hays Counties, Texas. Research focused on previously recorded archeological sites, State Archeological Landmarks (SALs), properties listed on the National Register of Historic Places (NRHP), Texas Historical Markers, and other historic properties near the springs only. Water management strategies which will require infrastructure development such as aquifer recharge enhancement projects, pipelines, or pump stations may also impact other cultural resource sites outside the vicinity of the springs. This baseline assessment and subsequent impact analyses will be supplemental when additional information sufficient to allow site-specific descriptions is available. Research was conducted at the Texas Archeological Research Laboratory (TARL) and the Texas Historical Commission (THC).

3.8.1 Regulatory Compliance

Under 36 CFR 800.1 of the Advisory Council on Historic Preservation (ACHP) regulations pertaining to the protection of historic properties, Section 106 of the National Historic Preservation Act (1992, as amended) requires a Federal Agency Head with jurisdiction over a federal undertaking, or one that is federally assisted or federally licensed, to take into account the effect that the undertaking will have on properties included in or eligible for listing on the NRHP. The Section 106 process, as defined in 36 CFR 800.4, requires the federal agency to identify and evaluate the significance of historic properties that may be affected by the proposed undertaking, in consultation with the State Historic Preservation Officer (SHPO) and consistent with the Secretary of the Interior's Guidelines and Standards for NRHP evaluation. If the Agency Head and the SHPO agree that a property potentially affected by the undertaking is NRHP eligible, then they shall apply the Criteria of Adverse Effect found in 36 CFR 800.5 to such a property. If an adverse effect is determined, then the federal agency and the SHPO shall seek ways to either avoid the property or minimize the impacts to it, to the fullest possible extent.

In pursuit of the above regulatory requirements, an effort will be made to identify and evaluate the significance of historic properties located within the Area of Potential Effect for the proposed Edwards Aquifer Habitat Conservation Planning Area. At this point in the Section 106 process, archeological sites and historic structures located within the Area of Potential Effect have been identified through archival information and available state records. Next, they will be evaluated with respect to the National Register Criteria of Evaluation in 36 CFR 60.4. Limited field observations will be conducted where and when access is permitted. Areas of potential for buried prehistoric sites will be identified. Further efforts, and advancement of the Section 106 process, will be conducted in conjunction with the selection of alternatives and the information will be presented in the final EIS.

This project also falls under the purview of the Texas Antiquities Code (TAC) because it involves archeological sites located "on land owned or controlled by the State of Texas or any city, county, or local municipality thereof." Therefore, the THC Archeology Division, under jurisdiction of the TAC, will closely monitor any impacts to these sites as a result of the proposed action. The TAC allows all such properties to be considered as potential SALs and requires that each be examined for their potential significance. Chapter 26 of the THC's Rules of Practice and Procedure for the TAC outlines the standards for determining significance.

3.8.2 Cultural History of Comal and San Marcos Springs

There is some potential that a substantial reduction in springflow could adversely affect cultural resources within the Area of Potential Effect surrounding Comal and San Marcos Springs, especially those that might be buried below Landa Lake, Spring Lake, or along the banks of the Comal or San Marcos Rivers.

Comal Springs are the largest group of natural springs in Texas. Located in New Braunfels, Comal County, Texas, the springs issue from the Comal Springs fault feeding Landa Lake and the Comal River (Brune 1981). Archeological investigations indicate that human occupation in the vicinity of Comal Springs dates to the Paleoindian period.

The first historic accounts of the area date to 1691 and the Spanish explorer Damian Massenet. The Spanish attempts to colonize the area began with the Nuestra Señora de Guadalupe mission which existed between 1756 and 1758. In 1845, Prince Carl of Solms-Braunfels led a group of German settlers to the area and established New Braunfels. The town grew up around the grist and sawmills that were built below the springs. Within ten years, New Braunfels became the commercial center of a growing agricultural area. It became a manufacturing and industrial center thanks to the power generated by flows exceeding 300 cfs (9,000 liters per second) from Comal Springs. New Braunfels supplied goods and provisions to pioneers settling in the surrounding hills of central Texas. By 1850, New Braunfels had become the fourth largest town in Texas (Greene 1996).

The San Marcos Springs, which are the second largest natural cluster of springs in Texas, issue from fissures in the Edwards Limestone under what today is Spring Lake in San Marcos in southeast Hays County Texas. Archeological evidence, which dates to the Paleoindian period, indicates that there has been more than 8,000 years of human activity in the vicinity of San Marcos Springs (TSHA website 2003).

The first Europeans to visit the area were probably members of the Espinosa-Olivares-Aguirre expedition of 1709 (TSHA website 2003). In 1755, the Spaniards established the mission San Xavier and the presidio of San Francisco Xavier which quickly succumbed to Indian attacks. The area remained unsettled for another half century. In the early 19th century, the Spanish made a second attempt with the settlement San Marcos de Neve. This settlement lasted until 1812 when unrelenting Comanche raids and floods forced abandonment of the settlement. The springs remained a stop on the Old San Antonio Road that ran between Northern New Mexico and Nacogdoches. Between the 1830s and 1840s, the first white settlers moved into the area (TSHA website 2003).

As in New Braunfels, the San Marcos Springs allowed the settlers to rapidly industrialize their efforts by harnessing the power of the springs to operate mills and gins. Cattle and cotton became the predominant industry in the area. On March 1, 1848, Hays county was organized, and the young community of San Marcos was designated the county seat. The small town continued to grow up around the springs, and it became a trade center between Austin and San Antonio (TSHA website 2003).

Additional information concerning the prehistoric and historic periods of central Texas is contained in Appendix E.

3.8.3 Archeological Surveys

Several archeological surveys have been conducted in the vicinity of Comal and San Marcos Springs. In March 1996 and March 1997, a survey was conducted by the Center for Archeological Research at the University of Texas, San Antonio in preparation for a development project within Spring Lake Park in San Marcos. In 1984 and 1987, the Texas Parks and Wildlife Department and the Texas Archeological Society surveyed the A.E. Wood Fish Hatchery. 41HY166 and 41HY167 were recorded as a result of these surveys. 41HY133 was recorded in 1977 during a survey conducted by the Soil Conservation Service of the Upper San Marcos Watershed. Numerous other surveys, testing projects, and excavations have been conducted by Texas State University.

In 1986, Prewitt and Associates conducted a survey in New Braunfels that included the area of Landa Park. The survey recorded at least twelve areas of prehistoric activity within the park. The sites and the park were recommended as a SAL, and it was recommended that further construction be monitored. In 1989, a survey was conducted in an area that was to be drilled for wells by the Edwards Underground Water District. Monitoring and limited testing was conducted in 1992 for the New Braunfels Utility Transmission Line Rebuild Project.

3.8.4 NRHP/SAL Properties in Close Proximity to San Marcos Springs

The San Marcos River Sites – Collectively, archeological sites 41HY133, 41HY134, 41HY135, 41HY141, and 41HY161 are a representative group of archeological sites associated with prehistoric occupation around San Marcos Springs and along the San Marcos River.

41HY133 – The Manhole site is located at the confluence of Purgatory Creek and the San Marcos River. At one time, the site was probably an open campsite, midden, and lithic workshop. A surface collection of the site resulted in several chert flakes, cores, scrapers, utilized flakes and an Ensor point. The site has been disturbed by storm sewer construction.

41HY134 – The Girl Scout Hut site consists of a thin lithic scatter and a possible intact hearth feature. The site, which is located within 100 feet of the San Marcos River, has been disturbed by nearby construction and erosion.

41HY135 – This site is located on a prominent knoll 100 feet from the confluence of Purgatory Creek and the San Marcos River. A collection of the site included a few chert flakes. The site has been disturbed by the installation of a nearby sewer line.

41HY141 – This site was exposed during roadway construction. A bulldozer cut exposed buried chert, burned limestone, glass, brick, ashy soil, and historic ceramics. A sample of the artifacts was collected, but no work was conducted on the site. The site sits immediately adjacent to the San Marcos River.

41HY161 – Collection and test excavation of the Fish Pond Site or Ice House Site, which is located immediately adjacent to the San Marcos River, has yielded lithic debris, projectile points, bifaces, core fragments and two prehistoric human burials. The site, which has been heavily disturbed, measures roughly 131 feet by 131 feet. Despite the disturbance, intact cultural resources may still exist as deposits have been found more than six feet below ground surface. The original site recorders recommended this site for further testing and excavation.

The Aquarena Springs Sites – Similar to the San Marcos Sites, 41HY37, 41HY147, 41HY160, and 41HY165 represent the distributional site patterning and behavior of prehistoric peoples around Central Texas' springs.

41HY37 – This site, which measures roughly 100 feet by 100 feet, is a combination prehistoric and historic site. The prehistoric component is an intact, buried, stratified deposit. The historic component consists of the General Edward Burleson Home. Burleson was an officer in the Texas War for Independence, Vice President of the Republic of Texas and a state legislator. The two-room dogtrot style log cabin is not eligible for the NRHP because it has been reconstructed, but the prehistoric component is listed.

41HY147 – This site is located beneath Spring Lake near the west bank of the lake. Excavation of the site has yielded evidence of continuous occupation possibly as far back as the Paleoindian period. A collection of the site included chert flakes, fire-cracked rocks, and projectile points.

41HY160 – The Tee Box 6 site, which is immediately adjacent to Spring Lake, measures about 820 feet north-south by 490 feet east-west. Test excavations of the site unearthed three hearths, a posthole, a stone alignment, and three burned rock middens. Cultural material existed on the surface and down to a depth of nearly nine feet below surface. A collection of the site included chert and bone tools including projectile points, bifaces, drills, scrapers, and cores.

41HY165 – This site is located in the floodplain of the San Marcos River on the southeast shore of Spring Lake. The site, which measures roughly 820 feet east-west by 820 feet north-south, might have been an open campsite. A collection of the site consisted of chert flakes, and bifaces.

3.8.5 Archeological Sites in Close Proximity to San Marcos Springs

3.8.5.1 Sites Potentially Eligible for the NRHP

41HY164 – The Thompson-Cape Dam and Ditch Engineering Structure was the site of the first important industrial activity in Hays County. The dam, artificial sluiceway, and mill-wheel foundation were built along the San Marcos River in 1865. At that time, the area was a large plantation with a family home, servant's quarters, and several outbuildings. No historic artifacts were collected from the surface, but one dart point was collected from a historic bulldozer pile. According to the site recorders, the prehistoric component has probably been destroyed. The sluiceway runs about 1,850 feet downriver from the dam that spans the width of the San Marcos River. At the southern terminus of the sluiceway, the concrete mill-wheel foundation remains.

41HY167 – This site, which measures roughly 328 feet north-south by 246 feet east-west, consists of a buried prehistoric component. The site form notes that the collection of the site consisted of an arrow point, chert flakes, charcoal, mussel shell, and burned clay. Situated within 100 feet of the San Marcos River, it was noted that this site had significant potential, and that the site be preserved or tested in case of possible disturbance.

41HY178 – This site consists of a surface scatter of historic debris and deep, intact, stratified, prehistoric cultural deposits. A collection of the site yielded burned limestone, burned chert, chert scrapers, transferware, pearlware, glass, metal and a limestone and brick house foundation. The site, which measures roughly 98 feet by 165 feet, is situated roughly 100 feet from the San Marcos River. It was recommended as eligible for the NRHP.

3.8.5.2 Archeological Sites

41HY150 – This site, which sits roughly 100 feet from the San Marcos River, consists of a thin scatter of prehistoric and historic debris. The site has been disturbed by construction of the nearby wastewater treatment plant.

41HY166 – This site, which measures roughly 330 feet by 1,000 feet, is a multicomponent prehistoric campsite. An in-situ hearth, several chert flakes, charcoal, bone and mussel shell were discovered during testing. The surveyors suggested that this site is potentially eligible for SAL designation. The site is immediately adjacent to the San Marcos River.

41HY261 – This site has both a historic and prehistoric component. The historic component includes a historic dam, mill, and millrace. The prehistoric component is composed of a lithic scatter and a number of artifacts recovered in shovel testing that includes burned and unburned chert, bone, and clay. This site was recommended for further investigation. It is immediately adjacent to and extends into the San Marcos River.

3.8.6 NRHP/SAL Properties in Close Proximity to Comal Springs

The Lindheimer Home located at 489 Comal belonged to Ferdinand Lindheimer, a soldier in the Texas Revolution. Lindheimer is considered the father of Texas botany. He was the editor of the New Braunfels *Zeitung* from 1852 to 1872. The house is within 100 feet of the Comal River.

41CM25 – At this site, human burials, heat-altered rock, chert tools, and pre-historic ceramics have been found. The site measures approximately 330 feet by 165 feet and may have deposits as deep as two meters below ground surface. The site sits adjacent to the Comal River

41CM190 – This site was discovered during backhoe trenching near the edge of Spring Lake. Burned rock and lithic debris were discovered on the surface and down to about 2 feet below ground surface. The site measured approximately 400 feet north-south by 175 feet east-west. The site is adjacent to Spring Lake.

41CM205 – Located adjacent to the Comal River, this site measures 1315 feet by 985 feet. A survey of the site recorded lithic debris, diagnostic artifacts and a possible burned rock midden to a depth of 50 cm below ground surface.

The Landa Park Sites – Collectively, archeological sites 41CM172, 41CM173, 41CM174, 41CM175, 41CM176, and 41CM177 are a representative group of archeological sites associated with prehistoric occupation around Comal Springs and along the Comal River.

41CM172 – This site is situated on a low stream terrace to the northwest of the Comal River in Landa Park. The surface of the site has been adversely impacted by golf course and roadway construction. Although no subsurface testing was conducted, the surveyor's suggested that the site might have deeply buried undisturbed cultural material.

41CM173 – This site, which measures roughly 360 feet north-south by 130 feet east-west, is located to the north of the Comal River. The site was not shovel tested, and the survey form notes that there has been severe surficial disturbance.

41CM174 is located immediately adjacent to the Comal River. No subsurface testing was conducted, but a dense scatter of lithic materials on the surface of the site was recorded. The surveyor noted a possible midden-like feature within the site boundaries. The site measures 1,082 feet east-west and approximately 200 feet north-south.

41CM175 – This site is located on the east bank of Spring Lake. The site, which measures 165 feet east-west and 50 feet north-south, has been severely disturbed by activity associated with a nearby water treatment plant. No subsurface testing was performed, but water treatment plant construction and activity have exposed numerous chert flakes.

41CM176 – Test excavations of this site unearthed three small hearths and a living surface. A collection included chert flakes, ceramic sherds, burned and cut bone. Cultural deposits reached a depth of 8 to 12 inches. The site is located to the south of Spring Lake adjacent to the Comal River.

41CM177 sits next to the meandering creek that drains Spring Lake into the Comal River. The site is concentrated along the bank of the creek and measures roughly 490 feet by 165 feet. The site includes an unspecified number of possible hearths.

3.8.7 Texas Historical Markers in Close Proximity to Comal Springs

The confluence of the Guadalupe and the Comal Rivers is marked with a Texas Historical Marker. Governor Martin de Alarcon claimed the site on May 8, 1718 for the King of Spain. Early missionaries and army units passing from the east to the western frontier used a crossing at this location. For several years, beginning in 1845, a ferry shuttled people between the shores.

A Texas Historical Marker commemorates the 18th century Spanish Mission Our Lady of Guadalupe. It was established in 1756 on the Comal River after the failure of the Mission San Francisco Xavier de Horcasitas. The mission was governed by two friars and protected by a small civilian brigade. It was unable to withstand the constant onslaught from the Comanches and other Native American tribes, and it closed in March of 1758. The marker stands in Landa Park.

The Texas Germans in the Civil War Marker commemorates three companies from Comal County who were praised for their pride, skill, and high morale in their defense of Texas. Comal County was a rare exception among several heavily German Texas counties that decided to secede. This marker is located within 100 feet of the Comal River.

Joseph Klein, who immigrated to Texas from Germany, built the house at 135 Market Street in 1852. The house was originally built on the corner of San Antonio and Market Street. In 1859, Klein sold the house to William Kuse. Kuse, a shoemaker, used the house for his business. In 1898, Emilie Kuse, William's daughter, moved the house from the corner lot to make room for a hotel that she and her husband opened. Today, the house sits approximately 100 feet from the Comal River.

A Texas Historical Marker indicates the site of an early mill and factory established by John F. Torrey in 1850. Torrey, a pioneer promoter of industry in Texas, operated a gristmill, flourmill, sawmill, a sash, door, and blind factory, a cotton gin, and the first wool factory in Texas at this site. Torrey rebuilt his factory despite Mother Nature's repeated attempts to destroy it with tornadoes and catastrophic floods. Today the house is approximately 100 feet from the Comal River.

3.8.8 Archeological Sites in Close Proximity to Comal Springs

3.8.8.1 Sites Potentially Eligible for the NRHP

41CM221 – This site was discovered during monitoring of construction activity. An uncontrolled collection of artifacts resulted in a very large number of chert flakes, shatter, chert cores, unifaces and bifaces, 20 projectile points, heat-altered chert and limestone, mussel shell, and bone. The lithic material was collected from three distinct cultural zones. The site is 33 feet west of Comal Springs, and it measures roughly 115 feet north-south and 33 feet east-west. It was recommended that this site be protected from future disturbance or mitigated before any disturbance.

3.8.8.2 Archeological Sites

41CM90 – This site is eroding out of the east bank of the Comal River. The site is estimated to be about 300 feet long and possibly 3 feet deep. A surface collection included chert flakes, heat-altered limestone, chert bifaces, scrapers, and cores. No recommendations were made for this site.

41CM167 – This site is located in Landa Park. A visual survey found evidence of a disturbed site throughout the park. The surveyor noted bifacial tools and tool fragments. A revisit to the site resulted in the redefinition of the site into six smaller sites (41CM172, 41CM173, 41CM 174, 41CM175, 41CM177 and 41CM190) connected by a lithic scatter. Collectively, these sites are listed as an NRHP/SAL archeological site.

3.9 Air Quality

To adequately depict the baseline air quality characteristics of the EAHCP Planning Area, several distinct data sets must be collected and evaluated. The ability of the atmosphere to cleanse itself from the accumulation of pollutants must be determined by evaluating the region's dispersal characteristics. Those data which quantify the levels of pollutants in the study area's atmosphere must be examined, and the region's regulatory compliance status must be established. The following subsections provide the data and analyses necessary to adequately characterize the Planning Area's air quality.

3.9.1 Pollutant Dispersion Characteristics

The topography of the EAHCP Planning Area varies from generally flat terrain devoted primarily to agricultural purposes located in the Gulf Coast Prairie and Marshes region to significantly rolling terrain located in the central Texas Edwards Plateau region which is primarily devoted to ranching operations. There are no significant canyons or severe topographic features which would tend to limit the dispersal or channel the flow of airborne pollutants.

Thermal and mechanical turbulence in the atmosphere affect the dispersal of air pollutants. The mixing layer is the layer of air next to the earth's surface through which relatively vigorous mixing occurs. The mixing height and mean wind speed of this layer determine the volume into which pollutants will eventually be mixed. Low mixing heights and light wind speeds decrease dilution of regional pollutant emissions and can trap pollutant plumes near the surface. Higher mixing heights and stronger transport wind speeds will generally increase dilution and dispersal of emissions and result in lesser impacts of pollutants on air quality. Throughout the year, Central and Southeast Texas experiences better than average mixing height conditions (Holzworth 1972). The Edwards Aquifer region typically experiences good to excellent dispersion characteristics.

3.9.2 Regional Compliance Standards

The Clean Air Act, which was last amended in 1990, requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. There are two types of standards, primary and secondary. Primary standards protect against adverse health effects; secondary standards protect against welfare effects, such as damage to crops and vegetation and damage to buildings. The six principal pollutants or "criteria" pollutants addressed in the NAAQS are carbon monoxide, nitrogen dioxide (NO_2), lead (Pb), ozone, particulate matter, and sulfur dioxide (SO_2). The criteria pollutants and their respective averaging periods, standard values, and standard type(s) are listed in Table 3.9-1.

If the levels of the pollutants listed in Table 3.9-1 are higher than what is considered acceptable by EPA, then the area is called a nonattainment area. A nonattainment designation is indicative of inadequate air quality and triggers several federal requirements including the development of an area-wide state implementation plan (SIP) and a transportation conformity analysis. If the criteria pollutant levels meet the national primary or secondary ambient air quality standards, then the region is classified as attainment. An area can also have an unclassifiable designation which is defined as an area that cannot be classified on the basis of available information as meeting or not meeting the national primary or secondary ambient air quality standard for the pollutant. An unclassifiable designation implies attainment and therefore no restrictions are applied.

Air quality within the Planning Area and surrounding region is generally good to excellent. The Planning Area is located within the TCEQ Office of Air Quality Region 11 (Austin), Region 13 (San Antonio), Region 14 (Corpus Christi) and Region 16 (Laredo). These regions are considered to be in attainment or unclassifiable with respect to each of the National Ambient Air Quality Standards.

Table 3.9-1. National Ambient Air Quality Standards

Pollutant	Standard Value*	Standard Type
Carbon Monoxide (CO)		
8-hour Average	9 ppm (10 mg/m^3)	Primary
1-hour Average	35 ppm (40 mg/m^3)	Primary
Nitrogen Dioxide (NO_2)		
Annual Arithmetic Mean	0.053 ppm (100 µg/m^3)	Primary & Secondary
Ozone (O_3)		
1-hour Average	0.12 ppm (235 µg/m^3)	Primary & Secondary
8-hour Average†	0.08 ppm (157 µg/m^3)	Primary & Secondary
Lead (Pb)		
Quarterly Average	1.5 µg/m^3	Primary & Secondary
Particulate (PM_{10}) Particles with diameters of 10 micrometers or less		
Annual Arithmetic Mean	50 µg/m^3	Primary & Secondary
24-hour Average	150 µg/m^3	Primary & Secondary
Particulate ($PM_{2.5}$) Particles with diameters of 2.5 micrometers or less		
Annual Arithmetic Mean	15 µg/m^3	Primary & Secondary
24-hour Average	65 µg/m^3	Primary & Secondary
Sulfur Dioxide (SO_2)		
Annual Arithmetic Mean	0.03 ppm (80 µg/m^3)	Primary
24-hour Average	0.14 ppm (365 µg/m^3)	Primary
3-hour Average	0.50 ppm (1300 µg/m^3)	Secondary

*Parenthetical value is an approximately equivalent concentration.
ppm=parts per million µg/m^3 = micrograms per cubic meter
SOURCE: TNRCC 1999

On July 16, 1997, EPA issued revised air quality standards for particulate matter ($PM_{2.5}$) and ozone which are more restrictive than the current NAAQS standards for the respective pollutants. Based on data collected from 1997 through 1999, all counties within the Edwards Aquifer Planning Area are currently designated in attainment of all NAAQS Standards. Based on this status, EPA will use the eight-hour ozone standard and the $PM_{2.5}$ standards to judge the future air quality of all communities within the Planning Area. Preliminary data collected since 1999 shows that several counties within the Planning Area could be designated nonattainment for ozone beginning in 2003 or later. These counties include Hays, Caldwell, Bexar, Comal, and Guadalupe.

3.9.3 Relevant Pollutants

The TCEQ has monitored airborne pollutants in the Edwards Aquifer region using both continuous and non-continuous methods for over 20 years. This long-term monitoring of the area's ambient air provides a basis for quantifying the level of pollutants which have been introduced into the atmosphere by stationary sources (i.e., industrial activity), mobile sources (i.e., cars, trucks, buses), area sources (i.e., lawn maintenance, home furnaces, water heaters), and natural phenomenon (i.e., dust storms). The pollutants monitored in the Planning Area include ozone (O_3), inhalable particulate matter (PM_{10}), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and carbon monoxide (CO). Tables 3.9-2 through 3.9-6 show these Planning Area baseline data including highest values and second highest values for the collection sites for the 1997 through 1999 time period. The data show that there have been no violations of regulatory standards within the Planning Area during the monitored period.

Table 3.9-2. Ambient ozone monitoring summary for the nearest TCEQ sites, 1997-1999

Site	Site No.	Year	High 1-hr (ppm)	2nd High 1-hr (ppm)	Exceedance Days
San Antonio, NW	480290032	1997	.123	.103	1
CAMS 23		1998	.113	.107	0
		1999	.120	.109	0
Victoria	484690003	1997	.092	.092	0
CAMS 87		1998	.097	.093	0
		1999	.110	.102	0

SOURCE: TNRCC 1999   ppm = parts per million

Table 3.9-3. Ambient PM_{10} summary for the nearest TCEQ sites, 1997-1999

Site	Site No.	Year	24-hr Max. (µg/m^3)	2nd Highest 24-hr (µg/m^3)	Annual Arithmetic Mean (µg/m^3)
San Antonio	480290034	1997	58	41	20.7
(Culture Center)		1998	60	59	26.1
		1999	49	45	23.9

SOURCE: TNRCC 1999.   µg/m^3 = micrograms per cubic meter

Table 3.9-4. Ambient nitrogen dioxide summary for the nearest TCEQ sites, 1997-1999

Site	Site No.	Year	Annual Arithmetic Mean (ppm)
San Antonio	480290046	1997	.07
Downtown		1998	.08
		1999	.08

SOURCE: TNRCC 1999.   ppm = parts per million

Table 3.9-5. Ambient sulfur dioxide summary for the nearest TCEQ sites, 1997-1999

Site	Site No.	Year	24-hr High (ppm)	2nd High 24-hr (ppm)	3-hr High (ppm)	2nd High 3-hr (ppm)	Annual Arithmetic Mean (ppm)
Corpus Christi,	483550025	1997	.030	.020	.042	.041	.003
West		1998	.035	.029	.073	.066	.003
CAMS 4		1999	.008	.008	.034	.026	.001

SOURCE: TNRCC 1999. ppm = parts per million

Table 3.9-6. Ambient carbon monoxide summary for the nearest TCEQ sites, 1997-1999

Site	Site No.	Year	1-hr High (ppm)	2nd High 1-hr (ppm)
San Antonio	480290046	1997	16.1	10.7
(downtown)		1998	20.0	14.0
CAMS 27		1999	6.5	6.3

SOURCE: TNRCC 1999. ppm = parts per million

3.9.4 Prescribed Burning

The primary instance in which water management would be expected to influence air quality is with regard to prescribed burning for rangeland management. As the state regulatory agency charged with safeguarding air quality, the TCEQ regulates virtually all outdoor burning activities, including prescribed burning under 30 TAC Section 111.211(1). Prescribed burns are defined as burning operations used for the management of forests, rangeland, wildland and wildlife, and coastal salt-marsh areas. These operations are subject to the general requirements for allowed burning which were designed to reduce the likelihood that burning activities will create a nuisance, cause a hazard, or harm the environment. The general requirements are contained in the TCEQ's Local Government Guide to the TCEQ – Chapter 22, Outdoor Burning. The TCEQ delegates primary responsibility for administering outdoor burning activities to the local regional offices. The TCEQ regional offices responsible for outdoor burning activities including prescribed burning within the EAHCP Planning Area are Austin (Hays and Caldwell Counties), Laredo (Kinney County), Corpus Christi (Gonzales, De Witt, Victoria, Calhoun, and Refugio Counties), and San Antonio (all other counties in the Planning Area). The designated TCEQ regional office should be contacted prior to any prescribed brush burning activities associated with water management operations.

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Appendix 4

Tabular Data for Agricultural Production and Irrigation Water Use within the HCP Planning Area

Table D-1. Agricultural Production in the HCP Planning Area, 1997

Counties	Total Cropland (acres)	Irrigated Cropland (acres)	Harvested Cropland (acres)	Cattle and Calves (Num)	Hogs and Pigs (Num)	Sheep and Lambs (Num)	Poultry (3 mo. old or older) (Num)
Western Region							
Edwards	17,061	2,298	2,784	17,533	(D)	41,493	106
Kinney	20,141	3,092	2,517	13,517	28	43,968	0
Real	9,541	297	2,118	7,459	35	9,834	120
Uvalde	159,477	52,933	85,477	67,064	853	32,796	(D)
Subtotal	206,220	58,620	92,896	105,573	916	128,091	226
Central Region							
Atascosa	215,047	29,422	72,372	82,857	1,605	354	1,167
Medina	225,616	44,330	120,394	70,175	1,151	1,644	(D)
Subtotal	440,663	73,752	192,766	153,032	2,756	1,998	1,167
Eastern Region							
Bexar	177,217	12,844	75,041	58,699	3,400	2,088	4,561
Caldwell	105,263	899	36,392	48,442	804	939	648,418
Comal	41,951	133	13,185	13,584	352	2,795	1,125
Guadalupe	164,504	1,217	82,748	53,256	2,196	1,717	111,551
Hays	73,856	546	25,758	27,541	439	2,300	1,028
Kendall	49,167	467	12,881	17,836	2,510	14,210	1,148
Subtotal	611,958	16,106	246,005	219,358	9,701	24,049	767,831
Downstream							
Calhoun	76,071	3,032	57,528	18,421	(D)	165	(D)
DeWitt	150,072	539	41,346	98,281	1,678	627	(D)
Gonzales	178,034	3,246	54,368	159,312	4,368	276	4,318,566
Refugio	110,723	(D)	79,344	38,600	136	(D)	61
Victoria	155,242	3,520	95,644	60,343	356	423	750
Subtotal	670,142	10,337	328,230	374,957	6,538	1,491	4,319,377
Total	**1,928,983**	**158,815**	**859,897**	**852,920**	**19,911**	**155,629**	**5,088,601**

Source: United States Department of Agriculture 2000
Legend: (D) Withheld by USDA to avoid disclosing data for individual farms.

Table D-2. Agricultural Production in the HCP Planning Area, 1992

Counties	Total Cropland (acres)	Irrigated Cropland (acres)	Harvested Cropland (acres)	Cattle and Calves (Num)	Hogs and Pigs (Num)	Sheep and Lambs (Num)	Poultry (3 mo. old or older) (Num)
Western Region							
Edwards	9,656	454	2,372	23,238	(D)	53,723	132
Kinney	13,447	1,591	1,892	23,224	0	63,575	45
Real	15,392	505	2,108	8,680	(D)	13,564	(D)
Uvalde	169,828	51,772	77,818	64,518	(D)	54,628	809
Subtotal	208,323	54,322	84,190	119,660	(D)	185,490	986
Central Region							
Atascosa	200,482	29,757	65,705	89,356	5,701	320	2,800
Medina	213,020	37,330	103,373	76,053	960	1,310	1,482
Subtotal	413,502	67,087	169,078	165,409	6,661	1,630	4,282
Eastern Region							
Bexar	156,327	12,083	66,081	56,117	6,365	1,879	3,564
Caldwell	101,865	750	37,901	46,919	1,995	1,147	1,070,779
Comal	40,280	225	9,925	15,854	1,112	3,494	1,315
Guadalupe	180,137	1,680	83,440	52,560	3,965	2,163	(D)
Hays	48,976	265	19,681	33,105	517	1,417	1,343
Kendall	49,103	912	11,248	21,150	1,957	19,218	1,361
Subtotal	576,688	15,915	228,276	225,705	15,911	29,318	1,078,362
Downstream							
Calhoun	74,862	6,822	54,982	16,222	(D)	(D)	111
DeWitt	154,111	644	37,950	99,963	4,146	2,074	106,278
Gonzales	165,863	1,586	40,306	147,684	7,247	333	3,486,560
Refugio	105,890	130	79,851	40,055	380	0	38
Victoria	148,600	4,580	87,623	56,078	1,263	368	1,060
Subtotal	649,326	13,762	300,712	360,002	13,036	2,775	3,594,047
Total	**1,847,839**	**151,086**	**782,256**	**870,776**	**35,608**	**219,213**	**4,677,677**

Source: United States Department of Agriculture 2000
Legend: (D) Withheld by USDA to avoid disclosing data for individual farms.

Table D-3.Agricultural Production in the HCP Planning Area, 1987

Counties	Total Cropland (acres)	Irrigated Cropland (acres)	Harvested Cropland (acres)	Cattle and Calves (Num)	Hogs and Pigs (Num)	Sheep and Lambs (Num)	Poultry (3 mo. old or older) (Num)
Western Region							
Edwards	4,749	614	1,123	20,641	(D)	43,293	193
Kinney	10,176	2,358	1,788	23,060	(D)	69,844	(D)
Real	8,507	563	1,529	7,903	14	9,234	297
Uvalde	143,468	49,843	72,292	48,887	(D)	42,283	1,124
Subtotal	166,900	53,378	76,732	100,491	14	164,654	1,614
Central Region							
Atascosa	207,320	27,194	64,325	90,464	3,866	239	3,090
Medina	210,838	33,330	103,822	73,126	2,324	1,850	2,242
Subtotal	418,158	60,524	168,147	163,590	6,190	2,089	5,332
Eastern Region							
Bexar	153,530	12,159	67,968	56,289	6,751	1,380	(D)
Caldwell	110,207	831	33,008	47,904	6,089	1,008	855,147
Comal	36,679	168	11,614	17,599	1,223	2,785	2,396
Guadalupe	171,794	1,421	77,076	56,023	5,088	1,478	85,034
Hays	47,572	1,119	17,127	26,708	207	1,553	2,371
Kendall	49,701	442	10,709	20,336	1,528	19,596	2,445
Subtotal	569,483	16,140	217,502	224,859	20,886	27,800	947,393
Downstream							
Calhoun	75,636	6,255	41,718	16,171	209	40	806
DeWitt	154,615	607	38,512	103,118	6,030	805	115,462
Gonzales	151,726	3,132	43,359	123,135	6,727	404	3,359,673
Refugio	106,373	(D)	63,249	33,717	23	(D)	147
Victoria	155,473	6,940	75,444	51,879	1,202	672	2,541
Subtotal	643,823	16,934	262,282	328,020	14,191	1,921	3,478,629
Total	**1,798,364**	**146,976**	**724,663**	**816,960**	**41,281**	**196,464**	**4,432,968**

Source: United States Department of Agriculture 2000
Legend: (D) Withheld by USDA to avoid disclosing data for individual farms.

Table D-4. Irrigation Water Use in the HCP Planning Area, 1992 - 1997

		Year					
County		**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Western Reg.	**Water Origin** (acre-feet)						
Edwards	Surface Water	220	0	0	0	0	0
	Ground Water	0	143	133	133	143	143
Kinney	Surface Water	1,347	0	0	0	0	0
	Ground Water	5,388	9,025	7,479	5,859	8,067	6,987
Real	Surface Water	103	163	133	147	163	163
	Ground Water	69	245	233	220	245	245
Uvalde	Surface Water	2,624	1,067	925	648	846	0
	Ground Water	41,106	105,591	91,614	64,179	83,742	58,886
Subtotals	Surface Water	4,294	1,230	1,058	795	1,009	163
	Ground Water	46,563	115,004	99,459	70,391	92,197	66,261
Central Region							
Atascosa	Surface Water	0	0	0	0	0	0
	Ground Water	37,702	43,729	44,790	47,414	48,827	36,910
Medina	Surface Water	17,159	20,006	17,368	16,742	16,896	11,105
	Ground Water	97,236	64,435	60,170	66,969	67,583	39,375
Subtotals	Surface Water	17,159	20,006	17,368	16,742	16,896	11,105
	Ground Water	134,938	108,164	104,960	114,383	116,410	76,285
Eastern Region							
Bexar	Surface Water	8,366	14,423	11,747	11,309	12,040	10,961
	Ground Water	17,777	33,655	31,929	26,386	28,094	25,575
Caldwell	Surface Water	772	980	1,214	1,476	1,515	1,357
	Ground Water	741	147	147	220	227	203
Comal	Surface Water	8	9	7	12	12	12
	Ground Water	403	17	25	21	23	21
Guadalupe	Surface Water	1,374	62	60	45	332	332
	Ground Water	1,488	8	23	6	41	41
Hays	Surface Water	500	260	218	218	218	218
	Ground Water	0	0	0	0	0	0
Kendall	Surface Water	106	416	505	416	416	416
	Ground Water	274	808	718	808	808	808
Subtotals	Surface Water	11,126	16,150	13,751	13,476	14,533	13,296
	Ground Water	20,683	34,635	32,842	27,441	29,193	26,648
Downstream							
Calhoun	Surface Water	12,138	17,955	23,086	18,829	19,851	11,365
	Ground Water	2,312	1,995	1,651	2,813	2,966	352
DeWitt	Surface Water	11	0	0	0	0	0
	Ground Water	274	81	88	88	88	88
Gonzales	Surface Water	916	432	573	686	1,007	493
	Ground Water	1,375	160	180	254	372	164
Refugio	Surface Water	0	0	0	0	0	0
	Ground Water	0	0	0	0	0	0
Victoria	Surface Water	429	459	133	460	492	364
	Ground Water	10,297	11,012	14,258	11,051	11,797	8,748
Subtotals	Surface Water	13,494	18,846	23,792	19,975	21,350	12,222
	Ground Water	14,258	13,248	16,177	14,206	15,223	9,352
Totals	Surface Water	**46,073**	**56,232**	**55,969**	**50,988**	**53,788**	**36,786**
	Ground Water	**216,442**	**271,051**	**253,438**	**226,421**	**253,023**	**178,546**

Source: Texas Water Development Board 2000

Table D-5. Irrigation Water Use in the HCP Planning Area in 1958, 1964, 1969, 1974, 1979, 1984, 1989

		Year						
County		**1958**	**1964**	**1969**	**1974**	**1979**	**1984**	**1989**
Western Region	**Water Origin** (acre-feet)							
Edwards	Surface Water	210	326	248	207	173	177	667
	Ground Water	0	0	0	108	108	0	0
Kinney	Surface Water	692	1,000	4,325	3,497	3,500	1,212	1,851
	Ground Water	2,301	10,147	12,333	10,820	9,203	9,123	10,498
Real	Surface Water	1,090	1,066	725	941	232	348	709
	Ground Water	0	0	0	0	0	0	475
Uvalde	Surface Water	408	496	879	1,633	1,890	2,005	500
	Ground Water	17,051	33,327	48,523	67,312	74,215	146,560	151,378
Subtotals	Surface Water	2,400	2,888	6,177	6,278	5,795	3,742	3,727
	Ground Water	19,352	43,474	60,856	78,240	83,526	155,683	162,351
Central Reg.								
Atascosa	Surface Water	0	201	178	134	134	0	0
	Ground Water	30,915	43,278	57,977	56,962	55,665	35,039	50,914
Medina	Surface Water	10,661	23,708	29,967	28,634	21,733	37,762	43,828
	Ground Water	11,232	14,461	32,668	41,033	43,637	81,390	109,568
Subtotals	Surface Water	10,661	23,909	30,145	28,768	21,867	37,762	43,828
	Ground Water	42,147	57,739	90,645	97,995	99,302	116,429	160,482
Eastern Reg.								
Bexar	Surface Water	14,845	29,371	7,053	13,953	19,418	15,266	11,517
	Ground Water	24,350	32,400	10,311	13,699	15,832	23,449	23,404
Caldwell	Surface Water	777	347	79	1,563	213	269	909
	Ground Water	213	334	146	97	49	149	111
Comal	Surface Water	72	191	0	20	5	147	9
	Ground Water	215	12	149	172	168	501	481
Guadalupe	Surface Water	750	818	825	1,645	1,013	3,487	1,038
	Ground Water	1,392	1,419	971	1,080	1,330	3,956	1,359
Hays	Surface Water	1,197	1,132	837	822	455	726	301
	Ground Water	866	1,325	1,887	903	118	150	0
Kendall	Surface Water	0	171	267	300	23	38	100
	Ground Water	0	79	247	217	78	282	297
Subtotals	Surface Water	17,641	32,030	9,061	18,303	21,127	19,933	13,874
	Ground Water	27,036	35,569	13,711	16,168	17,575	28,487	25,652
Downstream								
Calhoun	Surface Water	14,479	21,886	37,035	40,456	27,642	24,897	25,750
	Ground Water	260	594	1,544	2,715	8,201	3,246	3,561
DeWitt	Surface Water	446	220	225	166	20	20	12
	Ground Water	559	1,710	564	821	127	128	275
Gonzales	Surface Water	2,103	1,196	972	527	187	498	868
	Ground Water	276	1,392	1,641	1,538	442	1,008	1,297
Refugio	Surface Water	0	17	0	0	0	0	0
	Ground Water	271	338	0	0	0	17	0
Victoria	Surface Water	299	45	0	109	176	133	133
	Ground Water	15,715	13,067	17,338	15,983	25,660	20,201	18,244
Subtotals	Surface Water	17,327	23,364	38,232	41,258	28,025	25,548	26,763
	Ground Water	17,081	17,101	21,087	21,057	34,430	24,600	23,377
Totals	Surface Water	48,029	82,191	83,615	94,607	76,814	86,985	88,192
	Ground Water	105,616	153,883	186,299	213,460	234,833	325,199	371,862

Source: Texas Water Development Board 1991

Table D-6. Non-Irrigated and Irrigated Land Crop Yields* in Bexar, Medina and Uvalde Counties, South Central Texas Region

Crop	Non-irrigated Land	Irrigated Land
Corn	60 bushels/acre	115 bushels/acre
Cotton	350 lbs/acre	960 lbs/acre
Grain Sorghum	3,000 lbs/acre	5,000 lbs/acre
Guar	800 lbs/acre	1,850 lbs/acre
Peanuts	**	3,500 lbs/acre
Sesame	**	1,250 lbs/acre
Winter Wheat/Grain	20 bushels/acre	40 bushels/acre
Winter Wheat/Grazing	45 days/acre	90 days/acre
Spring Wheat/Grain	10 bushels/acre	50 bushels/acre
Beets/Processing	**	14 tons/acre
Cabbage	**	16 tons/acre
Cantaloupe	**	300 cartons/acre
Carrots/Fresh	**	12 tons/acre
Carrots/Processing	**	14 tons/acre
Cucumbers/Fresh	**	6.25 tons/acre
Cucumbers/Pickles	**	8 tons/acre
Lettuce	**	12.5 tons/acre
Onions	**	18.75 tons/acre
Spinach/Fresh	**	450 bushels/acre
Spinach/Processing	**	11 tons/acre
Forage		
Coastal Bermuda/Pasture	200 days/acre	600 days/acre***
Coastal Bermuda/Hay	**	10 tons/acre
Forage Sorghum/Grazing	**	600 days/acre***
Forage Sorghum/Hay	4.5 tons/acre	10 tons/acre

***Source:** "Texas Crop Enterprise Budgets, Southwest Texas District;" Pena, Jose G.; Texas Agricultural Extension Service, Texas A&M University System; Uvalde, Texas 1997. The yields per acre listed here are indications of potential yields for high level farm and ranch management and favorable weather conditions, as opposed to projections of yields for average conditions.
**Not produced on non-irrigated land.
***May stock more than one animal unit per acre.

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Appendix 5

Cultural Resources near Comal and San Marcos Springs:

Historic and Prehistoric Significance and Assessment of Impacts

Appendix 5

Information contained in this appendix summarizes the prehistoric and historic periods in central Texas. Also included is an evaluation of the effects of each of the EIS alternatives on previously recorded archeological sites, State archeological Landmarks (SALs), properties listed on the National Register of Historic Places (NRHP), Texas Historical Markers, and other historic properties within the vicinity of Comal and San Marcos Springs.

1.0 Central Texas Chronological Synthesis of Prehistoric and Historic Periods

Archeological Background

The central Texas archeological area is one of the better-known regions of the state. Most of the prehistoric sites in central Texas are open, unprotected sites sitting or situated on alluvial terraces adjacent to streams or rivers (Black 1989). A typical open site in central Texas contains refuse such as chert flaking debris, broken chert tools, fragmented burned rock, land snails, fragmented animal bone (uncommon), and charred plant remains (rare) (Black 1989). An additional characteristic of open sites is the presence of diagnostic stone tools often representing occupations from different periods or phases and ultimately suggesting repeated use over hundreds or perhaps thousands of years.

Lithic open occupation sites, containing only debris from flint working activities, are most frequently found in upland areas and are often referred to as lithic procurement, quarry, or workshop sites. The residues from such sites are believed to be the result of specialized, short-term activities whether identified as tool maintenance/manufacture locales or intensive chert resource procurement locales.

Most of the chronologies for central Texas are based on four distinct time periods, representing a 12,000-year sequence of occupation. This sequence from Ricklis and Collins (1994) and Johnson (1995) is as follows: Paleoindian (ca. 9200-6000 BC), Archaic (6000 BC- AD 600), Post-Archaic (AD 600-1600), and Historic (AD 1600 to present). Although these divisions represent convenient temporal categories, they are also based in large part on perceived adaptations in subsistence, and are reflected in changes in lithic and other technologies.

Paleoindian (ca. 9200 - 6000 BC)

The early Paleoindian culture in south and central Texas is believed to be related to the better-known big game hunting tradition of the Great Plains (Hester 1980). Most of the well documented early Paleoindian sites in Texas that are associated with extinct megafauna are located north and west of central Texas on the Llano Estacado and adjacent areas of the Southern High Plains. In general, early Paleoindian sites are scarce in central Texas or at least not as visible as later sites. Conversely, later Paleoindian sites are much more numerous in south and central Texas, although both are usually identified from only surface-collected artifacts (Black and McGraw 1985). Subsistence data from several late Paleoindian sites does suggest, however, that small game was being exploited rather than extinct megafauna. These data support the idea that a hunting and gathering lifestyle may have already been adopted across much of southwestern and central Texas before the Early Archaic period.

Early Archaic (ca. 6000 - 3500 BC)

In general, it is posited that Early Archaic occupations were small, widely distributed, and non-specialized (Black and McGraw 1985). Explanation for these characteristics lean to a generalized hunting-gathering strategy involving relatively high group mobility, poorly defined territories, and short-term occupations. Regional population density may have been low, though this impression may reflect more the nature of the sites rather than prehistoric demographic reality (Ricklis and Collins 1994). Incipient middens have been discovered at Early Archaic sites but are considerably rare compared to later time periods.

Middle Archaic (ca. 3500 - 2400 BC)

Changes in adaptive strategies may have promulgated increased population density during the Middle Archaic period. Burned rock middens are the most characteristic site types of the period. The fact that these rock and debris accumulations are often extensive and contain large numbers of diagnostic dart points and other artifacts, argues for dramatically increased population density, more-intensive use of preferred locales, or both of these (Ricklis and Collins 1994).

A commonly suggested role for these features is some kind of specialized processing of plant foods, perhaps acorns (Ricklis and Collins 1994). Others have suggested that the middens may reflect processing of sotol, which may have extended eastward across the Edwards Plateau during the dry period that peaked between about 5000 and 2500 BP, the temporal span of the Middle Archaic (Ricklis and Collins 1994). Thus, if the middens do represent plant processing, it can be inferred that a major shift in subsistence took place. This shift may have involved a change in the environmental mosaic that required adjustments in human subsistence strategies to favor the exploitation of available plant resources such as acorns and perhaps xerophytic species such as sotol and prickly pear.

Late Archaic (ca. 2400 BC - AD 600)

Recent refinements in the central Texas chronology divide the Late Archaic interval into two different subperiods, I and II (Johnson 1995). Subperiod I is marked by the appearance of Bulverde projectile points, which along with later forms (Pedernales, Castroville, and Montell dart points) were used to hunt bison and other large game. Burned rock middens continued to proliferate during the Late Archaic I interval and there is some evidence to suggest that these accumulations of heat broken rocks were the result of pit baking (Karbula 1998). The resources processed may have included yucca, sotol, and perhaps lechugilla. Other middens may simply be dumps for kitchen type debris and contain sizeable quantities of animal bones, broken stone tools, and flint-knapping debris for just this reason (Johnson 1995). Late Archaic peoples, in particular, may have been adept at both hunting and the processing of large volumes of plant food materials.

The Late Archaic II interval (ca. 600 BC-AD 600) may have been a time of increasing mesic conditions for all but the western and southwestern portions of the Edwards Plateau (Johnson 1995). The onset of more mesic conditions may have resulted in decreased numbers of upland xerophytic plants, and perhaps bison as well (Johnson 1995), and may have forced adjustments in prehistoric subsistence strategies. There appears to be a decrease in the number of burned rock middens that can be directly attributable to the Late Archaic II interval. The projectile points used at this time are smaller and are characterized by such styles as Ensor, Fairland, and Frio. There is also evidence that the spread of Eastern Woodland religious cults may have had an influence on the Late Archaic II peoples of central Texas (Johnson 1995).

Late Prehistoric (ca. 600 AD - 1600 AD)

The Late Prehistoric or Post-Archaic (ca. AD 600-1600) (Johnson 1995) in central Texas is marked initially by the replacement of the dart and atlatl with the bow and arrow, as reflected in the shift from dart points to smaller, thinner and lighter arrow points (Ricklis and Collins 1994). Despite the shift to the bow and arrow, there is every indication that the broad-based hunting-gathering economy of the Late Archaic persisted into and through most of the Late Prehistoric period. The latter part of this period is marked by the appearance of pottery and a distinctive complex of tools composed of contracting-stem Perdiz arrow points (unlike the expanding-stem Scallorn point earlier in the period), an abundance of unifacial end scrapers, thin, alternately beveled bifacial knives, and drills or perforators made on flakes and blades. It also appears that bison hunting became an increasingly important economic activity during the later part of this period.

Historic (AD 1600- Present)

The most radical changes in the Native American history of central Texas came during the historic era (Black 1989). The Spanish introduced the horse into North America in the sixteenth century. Nomadic groups, initially the Apaches and later the Comanches, adopted the horse and rapidly altered the aboriginal situation of central Texas. These nomadic groups entered central Texas from the plains and mountain areas to the north and west and within 150 years had forced most of the native peoples to flee. Most groups were simply destroyed by the combined effects of the nomadic raiders and the foreign diseases introduced by the Europeans. Others moved south entering Spanish missions and settlements, or eastward to join various agricultural groups such as the Wichita (Black 1989).

The historic period in Texas theoretically begins with the arrival of Alvar Nunez Cabeza de Vaca and the other survivors of the Navarez expedition on the Texas coast in 1528, although there may have been earlier landings. In any case, the influences of European colonization were not felt strongly in Texas for several centuries (Jones et al., 1994:7). By the middle of the 18th century, however, the Spanish had established missions in east Texas and settlements in south Texas. Additionally, massive depopulation and cultural disintegration was evident among native Indian groups.

2.0 Assessment of Impacts of EIS Alternatives on Cultural Resources near Comal and San Marcos Springs

Each of the proposed alternatives will have a consequence on known, in situ cultural resources. The central issue surrounding the alternatives is determining which alternative will have the least negative consequence on these resources. Each alternative will have similar effects, which are inherent in the interplay between hydro-dynamics and the stratigraphic record. It is very difficult to specifically qualify and quantify these consequences relative to the individual sites surrounding Comal and San Marcos Springs; therefore, it is necessary to speak more generally about effects.

The National Parks Service conducted the most significant study of site inundation dynamics in 1976: The National Reservoir Inundation Study (NRIS). During this study, four categories of impact to archeological resources were recognized. The mechanical impact is defined as “physical erosion and depositional processes associated with any large body of water” (Malof 1999). The biochemical impacts involve the transformation of the stratigraphic record from a terrestrial environment to an aquatic one. Indirect and direct human impacts result when archeological sites are inundated or intermittently inundated; and finally, a blanket category designed to include various miscellaneous impacts was created. Additionally, the NRIS found that impacts occur on multiple levels, including the macro- or regional scale, the meso- or site scale, and the micro- or artifact scale. For the purposes of this study, it is necessary to examine the impacts of all the alternatives on each scale.

2.1 Impact Type

Impacts resulting from mechanical impacts will vary depending upon the location of the site. Sites located near the shoreline will be most affected by wave impact and erosion. The severity of these impacts will depend on the location of the site relative to the slope of the bank, the orientation of the site, and the types of vegetation in the area.

Additionally, it has been suggested, "the type of site and types of features in sites will be differentially more able to withstand destructive forces" (Malof 1999). Deeply buried sites will be less likely to suffer the mechanical effects of periodic inundation because of the layers of stratigraphic protection above them. Of course, depending upon the severity of erosion due to periodic inundation, this protection could be very short-lived. In aquatic environments deeper than those at issue, siltation, essentially the opposite of erosion, can actually preserve sites by burying them under new stratigraphic layers. The downside of this mechanical impact is that sites may be lost under many feet of new deposition rendering them as useless as a site carried away by the waves along the shoreline.

Mechanical impacts on artifact assemblages within a site will be most evident in the results of the wet-dry cycling that are predicted to occur during the course of the year regardless of which alternative is chosen. Ceramic artifacts, bone, pollen, and shell will be the most adversely impacted during these cycles. The result will be the dissolution of these artifacts, and the loss of accompanying data. While lithics may not endure the measure of physical change of other artifact types, movement caused by wave impact may produce the appearance of use wear or erase legitimate evidence of usage.

The vast majority of the archeological sites near Comal and the San Marcos Springs lie on or near to the bank of Landa Lake, Spring Lake, the Comal River, or the San Marcos River. These sites will undoubtedly endure certain mechanical effects caused by each of the alternatives. Due to the location of most of the sites, erosion will be one of the primary detrimental forces. Erosion is a destructive force that is not easily mitigated considering the proximity of these sites to the shoreline. Although none of the alternatives will eradicate the effects of this particular mechanical process on archeological sites the best alternative would be one that ensured the least fluctuation in water levels.

Biochemical impacts or changes result when water inundates a site. At the site level, the primary result is a change in soil composition. This occurs as different elements leech into and out of the soil permanently changing the composition, and potentially erasing the distinction between anthropogenic soils and the surrounding sediments. The repeated periodic inundation and exposure of sites in and surrounding Landa Lake and Spring Lake could completely erase vast amounts of information concerning sites that is found only at the elemental level. In concert with erosion, inundation could severely affect the information content. Inundation is perceived to represent the greatest potential negative impact to archeological sites that are immediately adjacent to the water.

Similar to mechanical impacts, the degree of biochemical impact depends upon artifact type and the conditions of inundation. The pH of the surrounding environment may have an effect on artifacts, but this impact will vary depending upon the artifact type. "In general, alkaline conditions are more conducive to preservation than acidic conditions" (Malof 1999). The most susceptible victims of biochemical change include wood, bone, pollen, and seeds. Generally, lithics would seem to be the least affected. Without full-scale mitigation of individual sites, it would be difficult to minimize the consequences of biochemical processes on sites during periods of inundation. It is probably best, however, for sites to undergo fewer wet/dry cycles, as this cycling would only exacerbate the basic effects of inundation.

The consequences associated with human impacts are well documented. The primary impact to sites is looting. The indiscriminate collection of artifacts results in the loss of the artifact, any associated information, and the disturbance of the stratigraphic and archeological record. The primary finding of the NRIS was the fact that previously remote sites would become much more accessible to people in boats. The public location of the archeological sites discussed in this report have always made them easy targets for professional collectors, amateur archeologists, and unknowing visitors who innocently pick up and walk away with archeological artifacts. Collection and looting will continue at these sites no matter which alternative is chosen. Pollution can be a problem that is a consequence of human behavior but can have mechanical and biochemical effects too. Pollution from fertilizers used in adjacent parks and golf courses are of particular concern to the sites surrounding Comal and the San Marcos Springs.

Miscellaneous impacts may include many variable types of impacts. Malof suggests that a major consequence within this category is the change in floral and faunal types impacting the sites (1999). This impact is recognizable when water levels drop allowing burrowing animals access to areas that had been previously protected from their intrusive and destructive habits. Impacts result when different plant types establish and re-establish themselves during wet and dry cycles. Each cycle is detrimental to the stratigraphic record as a new group of plant species puts its roots into the ground disturbing and mixing the sediments each time.

2.2 Impacts on Cultural Resources

This section provides a listing of the archeological sites impacted by the EIS alternatives. At the end of the section is a brief description of the site (these sites are also described in Section 3.8 of the EIS).

Comal Springs

The following archeological sites designated as National Register of Historic Places/State Archeological Landmarks (NRHP/SAL) would be impacted by each of the alternatives:

41CM25 – At this site, human burials, heat-altered rock, chert tools, and pre-historic ceramics have been found. The site measures approximately 330 feet by 165 feet and may have deposits as deep as two meters below ground surface. The site sits adjacent to the Comal River.

41CM172 – This site is located on a low stream terrace to the northwest of the Comal River in Landa Park. The surface of the site has been adversely impacted by golf course and roadway construction. Although no subsurface testing was conducted, the surveyor's suggested that the site might have deeply buried undisturbed cultural material.

41CM173 – This site, which measures roughly 360 feet north-south by 130 feet east-west, is located to the north of the Comal River. The site was not shovel tested, and the survey form notes that there has been severe surface disturbance.

41CM174 is located immediately adjacent to the Comal River. No subsurface testing was conducted, but a dense scatter of lithic materials on the surface of the site was recorded. The surveyor noted a possible midden-like feature within the site boundaries. The site measures 1,082 feet east-west and approximately 200 feet north-south.

41CM175 – This site is located on the east bank of Spring Lake. The site, which measures 165 feet east-west and 50 feet north-south, has been severely disturbed by activity associated with a nearby water treatment plant. No subsurface testing was performed, but water treatment plant construction and activity have exposed numerous chert flakes.

41CM176 – Test excavations of this site unearthed three small hearths and a living surface. A collection included chert flakes, ceramic sherds, burned and cut bone. Cultural deposits reached a depth of 8 to 12 inches. The site is located to the south of Spring Lake adjacent to the Comal River.

41CM177 sits next to the meandering creek that drains Spring Lake into the Comal River. The site is concentrated along the bank of the creek and measures roughly 490 feet by 165 feet. The site includes an unspecified number of possible hearths.

41CM190 – This site was discovered during backhoe trenching near the edge of Spring Lake. Burned rock and lithic debris were discovered on the surface and down to about 2 feet below ground surface. The site measured approximately 400 feet north-south by 175 feet east-west. The site is adjacent to Spring Lake.

41CM205 – Located adjacent to the Comal River, this site measures 1315 feet by 985 feet. A survey of the site recorded lithic debris, diagnostic artifacts and a possible burned rock midden to a depth of 50 cm below ground surface.

The following archeological site designated as potentially eligible for nomination to the NRHP may be impacted by each of the alternatives as it is adjacent to Landa Lake and may be subject to lake level fluctuations.

41CM221 - This site was discovered during monitoring of construction activity. An uncontrolled collection of artifacts resulted in a very large number of chert flakes, shatter, chert cores, unifaces and bifaces, 20 projectile points, heat-altered chert and limestone, mussel shell, and bone. The lithic material was collected from three distinct cultural zones. The site is 33 feet west of Comal Springs, and it measures roughly 115 feet north-south and 33 feet east-west. It was recommended that this site be protected from future disturbance or mitigated before any disturbance.

An additional archeological site would be impacted by each of the alternatives:

41CM90 – This site is eroding out of the east bank of the Comal River. The site is estimated to be about 300 feet long and possibly 3 feet deep. A surface collection included chert flakes, heat-altered limestone, chert bifaces, scrapers, and cores. No recommendations were made for this site. .

San Marcos Springs

The following archeological sites designated as National Register of Historic Places/State Archeological Landmarks (NRHP/SAL) located immediately adjacent to the San Marcos Springs, Spring Lake, and the San Marcos River would be impacted by each of the alternatives:

San Marcos River Sites

41HY133 – The Manhole site is located at the confluence of Purgatory Creek and the San Marcos River. At one time, the site was probably an open campsite, midden, and lithic workshop. A surface collection of the site resulted in several chert flakes, cores, scrapers, utilized flakes and an Ensor point. The site has been disturbed by storm sewer construction.

41HY141 – This site was exposed during roadway construction. A bulldozer cut exposed buried chert, burned limestone, glass, brick, ashy soil, and historic ceramics. A sample of the artifacts was collected, but no work was conducted on the site. The site sits immediately adjacent to the San Marcos River.

41HY161 – Collection and test excavation of the Fish Pond Site or Ice House Site, which is located immediately adjacent to the San Marcos River, has yielded lithic debris, projectile points, bifaces, core fragments and two prehistoric human burials. The site, which has been heavily disturbed, measures roughly 131 feet by 131 feet. Despite the disturbance, intact cultural resources may still exist as deposits have been found more than six feet below ground surface. The original site recorders recommended this site for further testing and excavation.

Aquarena Springs Sites

41HY160 – The Tee Box 6 site, which is immediately adjacent to Spring Lake, measures about 820 feet north-south by 490 feet east-west. Test excavations of the site unearthed three hearths, a posthole, a stone alignment, and three burned rock middens. Cultural material existed on the surface and down to a depth of nearly nine feet below surface. A collection of the site included chert and bone tools including projectile points, bifaces, drills, scrapers, and cores.

41HY165 – This site is located in the floodplain of the San Marcos River on the southeast shore of Spring Lake. The site, which measures roughly 820 feet east-west by 820 feet north-south, might have been an open campsite. A collection of the site consisted of chert flakes, and bifaces.

The following archeological site is listed on the NRHP would be impacted by each of the alternatives:

41HY164 – The Thompson-Cape Dam and Ditch Engineering Structure was the site of the first important industrial activity in Hays County. The dam, artificial sluiceway, and mill-wheel foundation were built along the San Marcos River in 1865. At that time, the area was a large plantation with a family home, servant's quarters, and several outbuildings. No historic artifacts were collected from the surface, but one dart point was collected from a historic bulldozer pile. According to the site recorders, the prehistoric component has probably been destroyed. The sluiceway runs about 1,850 feet downriver from the dam that spans the width of the San Marcos River. At the southern terminus of the sluiceway, the concrete mill-wheel foundation remains.

Additional archeological sites that would be impacted by each of the alternatives include:

41HY166 – This site, which measures roughly 330 feet by 1,000 feet, is a multi-component prehistoric campsite. An in-situ hearth, several chert flakes, charcoal, bone and mussel shell were discovered during testing. The surveyors suggested that this site is potentially eligible for SAL designation. The site is immediately adjacent to the San Marcos River.

41HY261 – This site has both a historic and prehistoric component. The historic component includes a historic dam, mill, and millrace. The prehistoric component is composed of a lithic scatter and a number of artifacts recovered in shovel testing that includes burned and unburned chert, bone, and clay. This site was recommended for further investigation. It is immediately adjacent to and extends into the San Marcos River.

2.3 Summary of Potential Impacts by Alternative

Each of the four alternatives would have a direct impact on those sites that are situated immediately adjacent to Comal Springs, San Marcos Springs, Landa Lake, Spring Lake, the Comal River, and the San Marcos River. Alternative 1: No Action and Alternative 3: Regional Permit, Authority Proposed Habitat Conservation Plan, would have identical impacts on archeological sites. The two primary impacts are expected to be inundation and fluctuation of water levels from varying flows. Alternative 4, Least Restrictive Aquifer Pumping, would result in highest frequency of lower flows or complete cessation of flow at Comal Springs. Alternatives 1, 3, and 4 would result in less springflow over the course of the management period relative to Alternative 2, Highly Restricted Aquifer Pumping, with Alternative 4 providing the greatest frequency of fluctuation of water levels. Alternative 2 would have the greatest impact on archeological sites. The higher levels would result in a greater negative impact to adjacent archeological sites because a greater proportion of previously dry terrace deposits would be subject to the effects of inundation and erosion. It is important to note that there is a greater probability of impact on sites adjacent to Comal Springs, Landa Lake, and the Comal River because flow changes and resulting exposure from receding water levels is greater than at San Marcos Springs.

2.4 Recommendations

Manipulating the level of the aquifer will probably not adversely affect any nearby historic buildings, but this may not be true for all types of cultural resources. It is important to note that the distributional patterning and density of archeological sites around Comal and San Marcos Springs indicate that there is some possibility that any alternative will have an impact on cultural resources, especially in undisturbed river bank deposits. It is recommended that a reassessment be conducted of any sites that will be impacted. The type and amount of work required to effectively mitigate these effects will be coordinated between the Authority and the SHPO in compliance with Section 106 of the National Historic Preservation Act (1966, as amended) and the Texas Antiquities Code. The scope of work should conform to the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation and Chapter 26 of the Texas Historical Commission's Rules of Practice and Procedure for the Antiquities Code of Texas.

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Appendix 6

Structure for Planning, Development, and Public Involvement

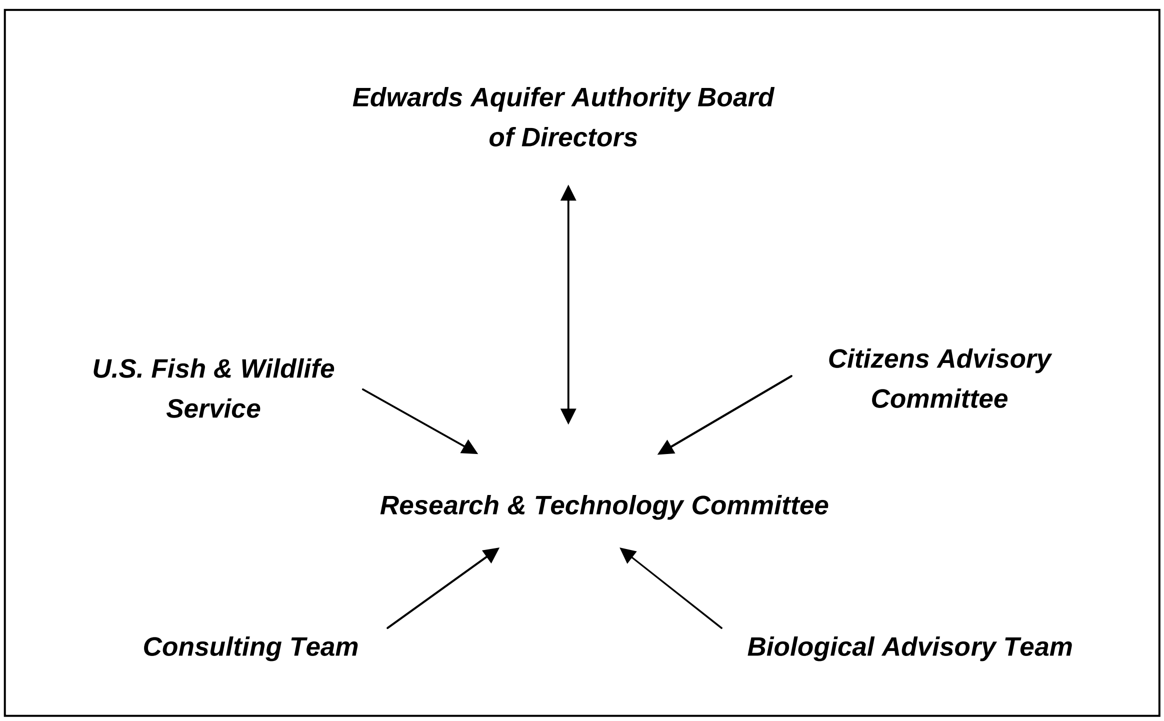
For the

Edwards Aquifer Habitat Conservation Plan

Structure For Planning, Development, and Public Involvement For the Edwards Aquifer Habitat Conservation Plan

The structure for planning and development of the Edwards Aquifer Habitat Conservation Plan (EAHCP) was established from a combination of policy decisions established by the Authority and requirements associated with the passage of Senate Bill 1272 by the 76th Texas Legislature in 1999. Development of the EAHCP was originally guided by a 5-member HCP Work Group which functioned as a subcommittee of the Edward's Aquifer Authority Board's Aquifer Management Planning (AMP) Committee. This evolved into a structure where information transfer passed through the Board's Research and Technology Committee. Additionally, Senate Bill 1272 required the establishment of a Citizens Advisory Committee (CAC) and Biological Advisory Team (BAT) to assist political subdivisions submitting a regional HCP under Section 10(a)(1)(B) of the Federal Endangered Species Act. Figure 1 illustrates the interrelationship of these groups. Meetings of the Edwards Aquifer Authority Board of Directors, the AMP Committee, CAC, and BAT are public meetings, requiring advance public notice and allowing public comment.

Figure 1. Relationship of EAHCP Planning and Development Groups



The membership of the HCP Citizens Advisory Committee is illustrated in Table 1 below.

Table 1. Membership of the HCP Citizens Advisory Committee.

	West	**Bexar County**	**East**	**Downstream**
Municipal/ Purveyor	*Gus Neutze,* Uvalde	*Agatha Wade,* San Antonio Water System; *Chuck Ahrens*, Bexar Metropolitan Water District	*Roger Biggers*, New Braunfels Utilities	*Wayne Cockroft*, City of Victoria
County /Regional/State	*Thomas Boehme,* Medina Co. Groundwater District	*Greg Rothe*, San Antonio River Authority	*Melani Howard*, San Marcos	*Bill Farnsworth*, Victoria Co.
Landowners and Water Users	*Lawrence Friesenhahn,* Uvalde; *Olin Gilliam*, Medina Co.	*Wallace Rogers, III* San Antonio; *Tom Dreiss*, San Antonio	*Emmett McCoy*, San Marcos; *Jack Ohlrich*, New Braunfels; *James Neuhaus*, Hays Co.	*Hugh Charlton*, DuPont, Victoria *Bill Braden*, DeWitt Co.
Government Agency	*Phillip Wright*, Natural Resources Conservation Service	*Marion Erwin*, Dept. of Defense	*John Herron*, Texas Parks and Wildlife Dept.	*Bobby Caldwell*, Texas Commission on Env. Quality
Other	*Con Mims*, Nueces River Authority	*Dean Bibles*, Land/Resource Consultant	*Bill West*, Guadalupe-Blanco River Authority	*John O'Connell*, Calhoun Co.

The function of the BAT is best described by its purpose statement: "The Biological Advisory Team (BAT) to the Edwards Aquifer Habitat Conservation Plan (EAHCP) provides biological guidance to the plan participants. This guidance consists of thorough, critical reviews of any aspect of the EAHCP directly or indirectly affecting the biological integrity of the Edwards Aquifer ecosystem. The Edwards Aquifer ecosystem includes the confined waters of the aquifer, its recharge zone, springs and streams that issue from it, associated instream flow in the lower Guadalupe River and its estuaries, and the resident flora and fauna for these systems. Comments by the BAT on any draft or final documents created by the EAHCP participants or their agents will be collected and prepared in written form. The BAT will assist the EAHCP in calculation of harm to the endangered species that may come from implementation of the plan, and sizing and configuration of habitat preserves where appropriate. The BAT's comments will be based on the best available facts and science." The membership of the BAT consists of six professional biologists as illustrated in Table 2.

Table 2. Membership of the Biological Advisory Team.

Name	Affiliation
Dr. David Bowles, Chair	Texas Parks and Wildlife Department, San Marcos, TX
Dr. Ralph Beeman	Dupont, Inc, Victoria, TX
Dr. Dan Friese	Department of Defense, Brooks Air Force , San Antonio, TX
Dr. Fran Gelwick	Texas A&M Univ. College Station, TX
Melani Howard	City of San Marcos, San Marcos, TX
Clifton Ladd	Loomis Austin, Inc., Austin, TX

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Appendix 7

Legal Background On Springflow Determinations by the U.S. Fish and Wildlife Service

I. Background of the U.S. Fish and Wildlife Service's Springflow Determinations

The Endangered Species Act of 1973, as amended, 16 U.S.C.A. §§ 1531-1544 (West 1985 and Supp. 1998)(hereinafter, the "ESA") contains a variety of protections designed to protect species that the Secretary of the United States Department of the Interior lists as endangered or threatened. Section 9 of the Act makes it unlawful for persons to "take" any listed fish or wildlife endangered species. 16 U.S.C. § 1538(a)(1)(B). By regulation, the "take" prohibition also extends to species listed as threatened. 50 C.F.R. § 17.31(a). The term "take" is defined within the Act as "…to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." 16 U.S.C. § 1532(19). The term "harm" in the statutory definition of "take" is further defined by regulations promulgated by the U.S. Fish and Wildlife Service (the "Service") to mean "an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding or sheltering." 50 C.F.R. § 17.3.

The ESA also places an affirmative duty upon federal agencies to insure that any action authorized, funded or carried out by them is not likely to: (1) "…jeopardize the continued existence of any endangered species or threatened species"; or (2) "result in the destruction or adverse modification of [designated critical] habitat of such species." 16 U.S.C. § 1536(a)(2). In common parlance, these are referred to, respectively, as the requirement to avoid "jeopardy" and "adverse modification of critical habitat." The ESA also generally requires the Service to "develop and implement" what are known as "recovery plans" for each listed species. 16 U.S.C. § 1533(f).

<u>A. In 1993, the Service was judicially ordered to make certain determinations regarding springflow needs for the various listed species.</u>

In 1991, the Sierra Club, in a federal lawsuit styled *Sierra Club v. Lujan*, filed suit against the Service, alleging the Service was failing to adequately protect endangered and threatened species in San Marcos Springs and Comal Springs by failing to develop and disseminate information about the minimum springflows necessary to protect the listed species found in the springs.

In an order dated February 1, 1993, the trial court held in favor of the Sierra Club, ruling that the Service caused a "take" of endangered fountain darters in the summers of 1989 and 1990, in violation of the ESA, by failing to develop and implement recovery plans for the species. *Sierra Club v. Lujan,* 1993 WL 151353, at *12 (W. D. Tex. 1993). The trial court concluded that the Service has a non-discretionary duty under ESA § 4(f), 16 U.S.C. § 1533(f), to "…develop and implement …recovery plans" for the listed species, that identify springflows at which various listed species might be "taken" or "jeopardized." *Id.* at *11, 33-34.

The court made its own springflow findings that were to serve as "…interim springflow findings for all purposes under the ESA until the Service modifies those findings." The court's interim springflow findings are summarized as follows:

1) Fountain darters are: (a) "taken" whenever "Comal springflow drops to some (as-yet) undefined springflow or range of springflows greater than 100 cfs;" and (b) "jeopardized" whenever "Comal springflow drops to some (as-yet) undefined springflow or range of springflows greater than 0 cfs."
2) Critical habitat of Texas wild-rice is "destroyed or adversely modified" whenever San Marcos Springs "drops to some (as-yet) undefined springflow or range of springflows greater than 100 cfs. *Id.* at *27.

The court then ordered the Service to, based upon the available information and in the exercise of its best professional judgment, modify the court's interim springflow findings by identifying:

1) "take" springflow levels for the fountain darter in Comal Springs;
2) "jeopardy" springflow levels for the fountain darter in Comal Springs;
3) "adverse modification of critical habitat" springflow levels for any listed species in San Marcos Spring;
4) "damage or destruction" springflow levels for Texas wild-rice in San Marcos Springs;
5) "take" springflow levels for any listed wildlife species in San Marcos Springs;
6) "jeopardy" springflow levels for any listed species in San Marcos Springs;
7) "take" springflow or aquifer levels for Texas blind salamander; and
8) "jeopardy" springflow or aquifer levels for Texas blind salamander.

Id. at *27-28. The Service was required to make these findings within 45 days of the Court's judgment.

<u>B. In response to the court order in *Lujan*, the Service issued its first "take" springflow determinations in April 1993.</u>

In direct response to the court order, the Service issued and disseminated its determinations of when "take" might occur based on springflow levels at Comal and San Marcos Springs. On April 15, 1993, the Service issued a document entitled: "Springflow Determinations Regarding 'Take' of Endangered and Threatened Species" (hereinafter, the "Service 1993 Take Determinations").

The Service identified the following flow "take" numbers, which are considerably more conservative than the court's interim springflow findings:

<u>For the Fountain Darter</u>

-- "[T]he Service believes that 'take' currently begins to occur in the Comal ecosystem at 200 cfs. If effective control of the giant ramshorn snail could be accomplished, flow levels could be reduced to 150 cfs without resulting in 'take' of the fountain darters."

-- "The Service believes springflows of 100 cfs from San Marcos Springs are required to prevent 'take' of fountain darters." Service 1993 Take Determinations at 5.

For the San Marcos Salamander

-- "The Service believes that as long as springflows from San Marcos Springs exceed 60 cfs that 'take' of San Marcos salamanders due to flows will not occur." Service 1993 Take Determinations at 6.

For the San Marcos Gambusia, "based on the assumption that the San Marcos gambusia still exists in the wild"

-- "The Service believes that 'take' of San Marcos gambusia would occur when springflow at San Marcos Springs reaches 100 cfs." Service 1993 Take Determinations at 6.

For the Texas Blind Salamander

-- "The Service believes aquifer levels should be maintained so there is a flow above 50 cfs from San Marcos Springs to avoid 'take' of this species." Service 1993 Take Determinations at 7.

C. In response to the court order in *Lujan*, the Service issued its first "jeopardy," "critical habitat modification," and "wild-rice" springflow determinations in June 1993.

Also in response to the court order, the Service issued and disseminated its determinations of when "jeopardy," "adverse modification to critical habitat" and "damage and destruction of wild rice" might occur based on springflow levels at Comal and San Marcos Springs. On June 15, 1993, the Service issued a document entitled: "Springflow Determinations Regarding Survival and Recovery and Critical Habitat of Endangered and Threatened Species" (hereinafter, the "Service 1993 Jeopardy and Habitat Determinations") that identified the following "jeopardy," "critical habitat modification," and "wild rice destruction" springflow flow numbers, which are considerably more conservative than the *Lujan* court's interim springflow findings:

For the Fountain Darter

a) Jeopardy

For the Comal ecosystem, we believe flows need to be maintained above 150 cfs to avoid appreciable reduction in the likelihood of survival and recovery of the fountain darter under current conditions. However, with very effective ramshorn snail control and the ability to control the timing and duration of low springflows, flow levels could be reduced to 60 cfs for short time periods during certain times of year. Flows below 60 cfs would likely alter temperatures to levels that would be unsustainable for fountain darter reproduction.

> For the San Marcos ecosystem, we believe flows need to be maintained above 100 cfs to avoid appreciable reduction in the likelihood of survival and recovery of the fountain darter. These flows are necessary to maintain habitat for the fountain darter and to avoid downstream increases in temperature. With a management plan in place to control duration and timing of low flows, flows possibly could be reduced below 100 cfs for short periods of time during certain times of the year. Additional studies are needed to determine specific levels and timing requirements.

Service 1993 Jeopardy and Habitat Determinations at 5-6.

b) Diminution of the value of critical habitat

> [A] flow of 100 cfs is needed to avoid appreciable diminution of the value of critical habitat in San Marcos. With a management plan in place to control duration and timing of low flows and possibly control of exotic species, flow could possibly be reduced below 100 cfs for short periods of time without appreciably reducing the value of critical habitat. Additional studies are needed to determine specific levels and timing requirements.

Id. at 6.

For Texas Wild-Rice

a) Damage and Destruction

> [S]pringflows below 100 cfs would result in damage and destruction of wild-rice by: limiting the inundated flowing areas of the river, thereby leaving some plants out of water; degrading water quality; and exacerbating herbivory and damage from recreation.

Id.

b) Jeopardy

> The minimum springflow required in the San Marcos ecosystem to avoid the appreciable reduction in the likelihood of survival and recovery of Texas wild-rice is 100 cfs. Short-term reductions in flow levels below 100 cfs might be possible if exotic species could be effectively controlled, an aquifer management plan is implemented to control timing and duration of lower flows, and the status and distribution of the species is improved throughout its historic range in the San Marcos ecosystem. Additional study and analysis would be needed before it could be determined that lower flows would not jeopardize the species.

Id. at 6-7.

c) Diminution of the value of critical habitat

> The minimum springflow in the San Marcos ecosystem required to avoid appreciable diminution of the value of critical habitat for Texas wild-rice is 100 cfs. Any reduction in springflows [sic] levels below 100 cfs would require additional study and analysis before it could be determined that lower flows would not degrade critical habitat.

Id. at 7.

For the San Marcos Salamander

Jeopardy and Diminution of the value of critical habitat

> As long as springflows from San Marcos Springs exceed 60 cfs, the appreciable reduction in the likelihood of the survival and recovery of the San Marcos salamander and degradation of its critical habitat will not occur due to flows.

Id. at 8.

For the San Marcos Gambusia, "based on the assumption that the San Marcos gambusia still exists in the wild"

a) Jeopardy

> The appreciable reduction in the likelihood of the survival and recovery of San Marcos gambusia is estimated to occur when springflow at San Marcos Springs decreases to 100 cfs. With an aquifer management plan in place to control duration and timing of low flows, flows can possible be reduced below 100 cfs for short periods of time without jeopardizing the San Marcos gambusia. Additional studies are needed to determine specific levels and timing requirements.

Id.

b) Diminution of the value of critical habitat

> A minimum flow of 100 cfs is needed to avoid degradation of critical habitat for the San Marcos gambusia due to temperature fluctuations. With an aquifer management plan in place to control duration and timing of low flows, flows can possibly be reduced below 100 cfs for short periods of time without degrading critical habitat for the San Marcos gambusia. Additional studies are needed to determine specific levels and timing requirements.

Id. at 8-9.

For the Texas Blind Salamander

> Little is known of the actual extent and health of this subterranean population of salamanders. Based upon current knowledge, the appreciable reduction in the likelihood of the survival and recovery of the Texas blind salamander (due to reduced flows) can be avoided by maintaining San Marcos spring levels above 50 cfs. Additional research is needed to provide insight into the relationship between springflow reductions and movement of the bad water line.

Id.

D. The Service issued a "Recovery Plan" for the species in 1996, leaving the 1993 springflow determinations essentially unchanged.

On February 14, 1996, the Service issued a "San Marcos and Comal Springs and Associated Aquatic Ecosystems (Revised) Recovery Plan" (the "Recovery Plan"). The Recovery Plan was issued for the purpose of delineating the "reasonable actions that are believed to be required to recover and/or protect listed species" dependent upon the aquifer.

Recovery Plan, Disclaimer at iii.

The Recovery Plan did not meaningfully modify the springflow determinations made by the Service in 1993. The Recovery Plan summarized those determinations in Table 2 of the Recovery Plan as follows:

Table 2. U.S. Fish and Wildlife Service determination of minimum springflows needed to prevent take, jeopardy, or adverse modification of critical habitat. All flow rates are given in cubic feet per second (cfs).

Species	Take	Jeopardy	Adverse Modification
Fountain darter in Comal	200	150	N/A
Fountain darter in San Marcos	100	100	100
San Marcos gambusia	100	100	100
San Marcos salamander	60	60	60
Texas blind salamander	50*	50*	N/A
Damage and Destruction			
Texas wild-rice	100	100	100

* Refers to San Marcos springflow
Source: U.S. Fish and Wildlife Service, 1993.

Recovery Plan at 17.

E. The Service's 1993 and 1996 springflow determinations remain essentially unchanged today.

Based upon the 1993 determinations and the 1996 Recovery Plan, the Service's springflow determinations for all of the listed species found at Comal Springs and San Marcos Springs can be summarized as follows:

THREATENED AND ENDANGERED SPECIES (Comal and San Marcos Springs)

SPECIES NAME	WHERE FOUND	FWS' PRELIMINARY SPRINGFLOW NUMBERS							RELEVANT DOCUMENTS
		COMAL (TAKE)	COMAL (JEOPARDY)	COMAL (ADV. HABITAT MOD.)	SAN MARCOS (TAKE)	SAN MARCOS (JEOPARDY)	SAN MARCOS (ADV. CRITICAL HABITAT MOD.)	DAMAGE AND DESTRUCTION OF WILD-RICE	
Comal Springs dryopid beetle (*Stygoparnus comalensis*)	Comal Springs and Fern Bank Springs (Comal Co.), also found in the aquifer	Never specified	Never specified	N/A	N/A	N/A	N/A	N/A	62 Fed. Reg. 66295 (12/18/97)
Comal Springs riffle beetle (*Heterelmis comalensis*)	Comal Springs and San Marcos Springs	Never specified	Never specified	N/A	Never specified	Never specified	N/A	N/A	62 Fed. Reg. 66295 (12/18/97)
Fountain Darter (*Etheostoma fonticola*)	Comal Springs and San Marcos Springs	200 c.f.s (without ramshorn snail control); 150 c.f.s. for "short periods" (with snail control)	150 c.f.s. (without ramshorn snail control and regulatory control); 60 c.f.s. for "short periods" with such controls	N/A	100 c.f.s.	100 c.f.s.; possibly an unspecified lesser amount for short periods with regulatory control	100 c.f.s.; possibly an unspecified lesser amount for short periods with regulatory control and "possibly control of exotic species"	N/A	FWS April 15, 1993 Take Determinations; FWS June 15, 1993 Jeopardy and Habitat Determinations; FWS 1996 Recovery Plan
Peck's cave amphipod (*Stygobromus pecki*)	Comal Springs and Hueco Springs in Comal Co., also found in the aquifer	Never specified	Never specified	N/A	N/A	N/A	N/A	N/A	62 Fed. Reg. 66295 (12/18/97)
San Marcos salamander (*Eurycea nana*)	San Marcos Springs	N/A	N/A	N/A	60 c.f.s.	60 c.f.s.	60 c.f.s.	N/A	FWS April 15, 1993 Take Determinations; FWS June 15, 1993 Jeopardy and Habitat Determinations; FWS 1996 Recovery Plan
San Marcos gambusia (*Gambusia georgei*)	San Marcos Springs (possibly now extinct, not recorded since 1983)	N/A	N/A	N/A	100 c.f.s.	100 c.f.s.; possibly an unspecified lesser amount for short periods with regulatory control	100 c.f.s.; possibly an unspecified lesser amount for short periods with regulatory control	N/A	FWS April 15, 1993 Take Determinations; FWS June 15, 1993 Jeopardy and Habitat Determinations; FWS 1996 Recovery Plan
Texas blind salamander (*Typhlomolge rathbuni*)	San Marcos Springs, also found in the aquifer	N/A	N/A	N/A	50 c.f.s.	50 c.f.s.	N/A	N/A	FWS April 15, 1993 Take Determinations; FWS June 15, 1993 Jeopardy and Habitat Determinations; FWS 1996 Recovery Plan
Texas Wild-rice (*Zizania texana*)	San Marcos Springs and Rive	N/A	N/A	N/A	N/A	100 c.f.s.; possibly an unspecified lesser amount for short periods with regulatory control, exotic species control, and expanded species distribution	100 c.f.s.	100 c.f.s.	FWS April 15, 1993 Take Determinations; FWS June 15, 1993 Jeopardy and Habitat Determinations; FWS 1996 Recovery Plan

SOURCE: U.S. Fish and Wildlife Service, 1993 and 1996.

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Appendix 8

Figures

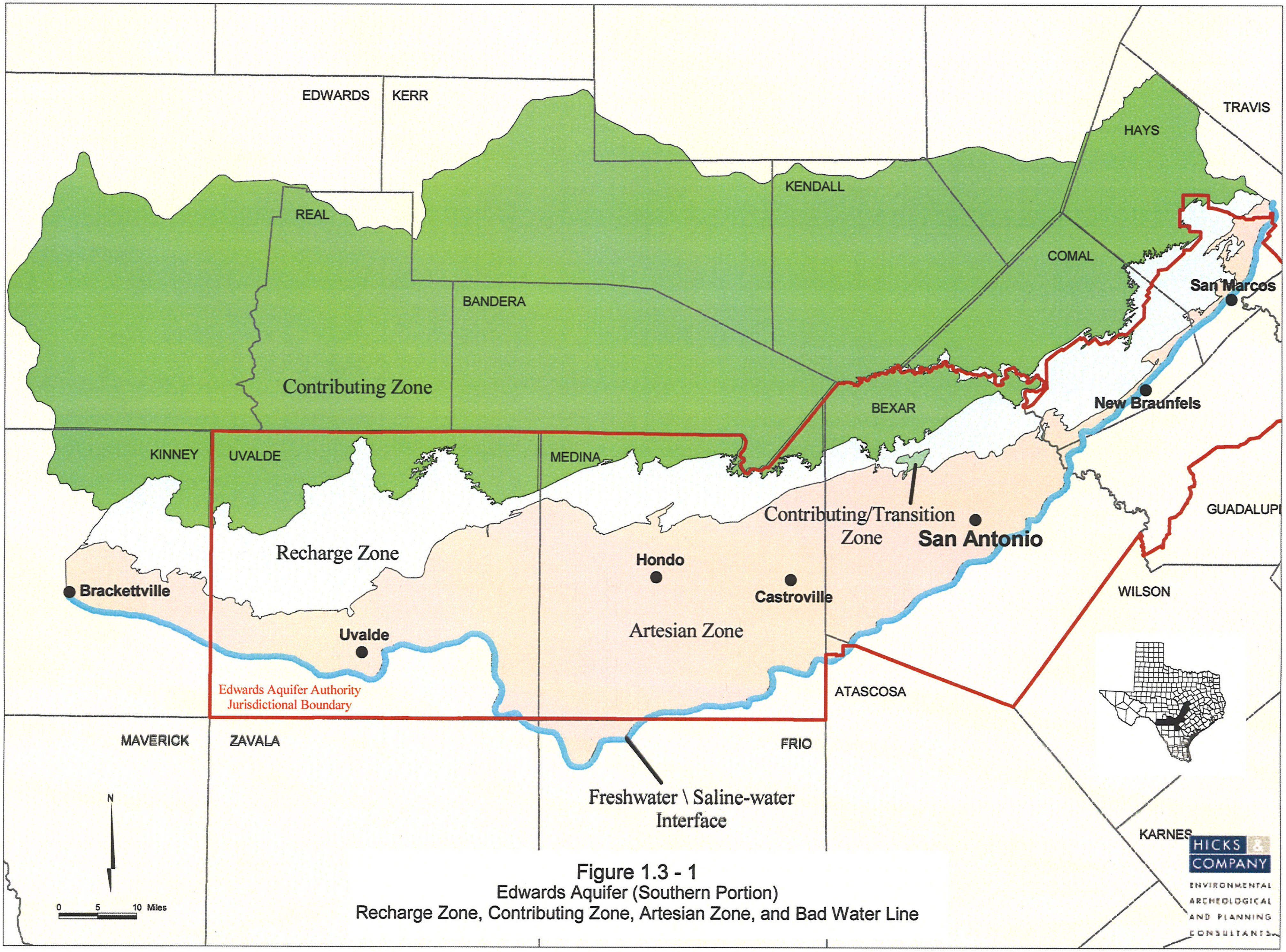

Figure 1.3 - 1
Edwards Aquifer (Southern Portion)
Recharge Zone, Contributing Zone, Artesian Zone, and Bad Water Line

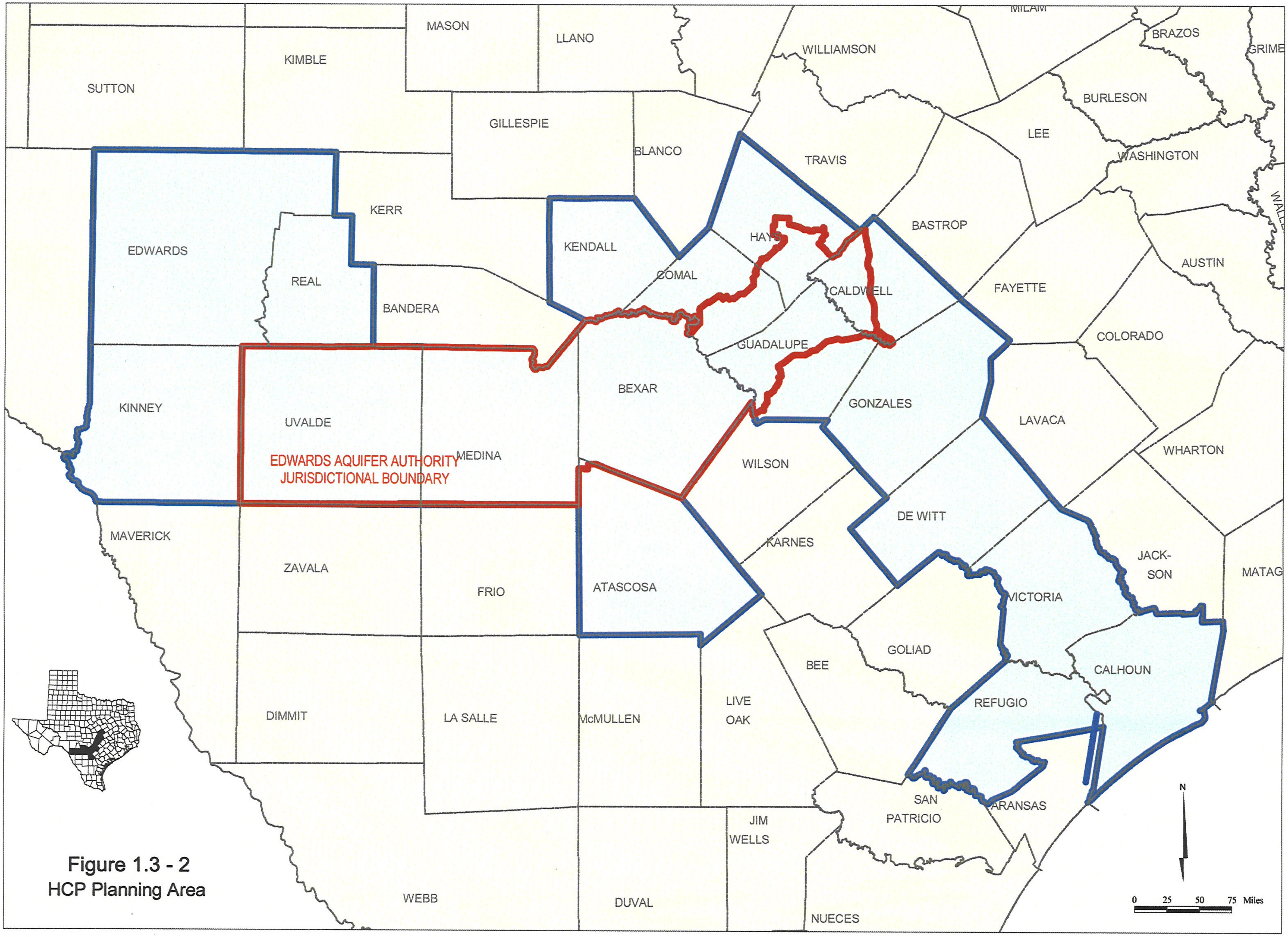

Figure 1.3 - 2
HCP Planning Area

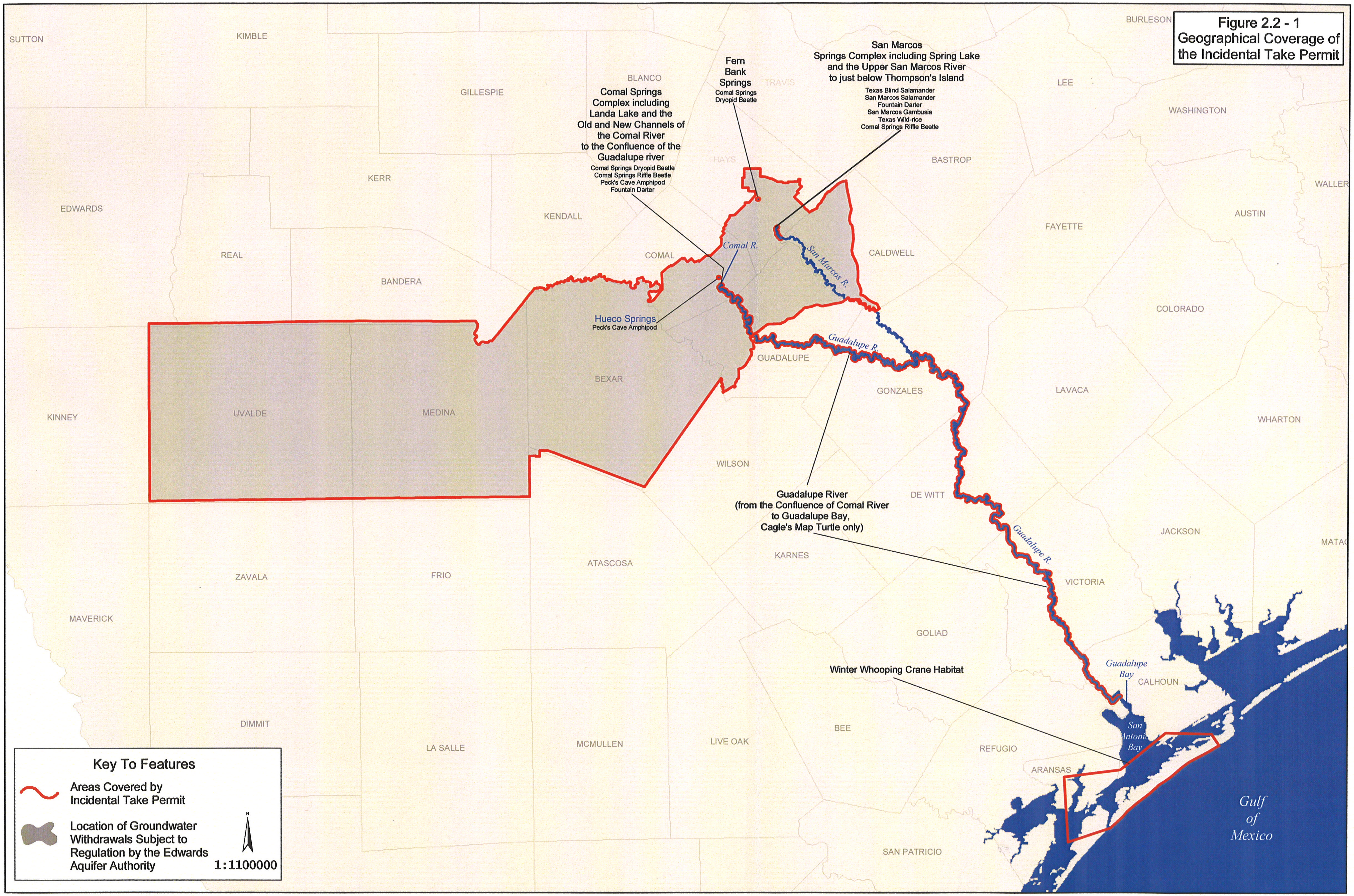

Figure 2.2 - 1
Geographical Coverage of
the Incidental Take Permit