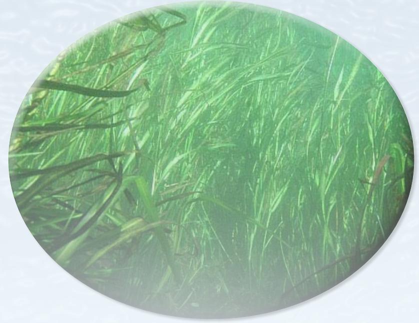
DES #12-29

DRAFT ENVIRONMENTAL IMPACT STATEMENT

Edwards Aquifer Recovery Implementation Program Habitat Conservation Plan

U.S. Department of the Interior
Fish and Wildlife Service

June 2012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Habitat Conservation Plan

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COVER SHEET

Draft Environmental Impact Statement (DEIS) for Authorization of Incidental Take and Implementation of the Habitat Conservation Plan Developed by the Edwards Aquifer Recovery Implementation Program

Lead Agency: U.S. Department of the Interior
United States Fish and Wildlife Service

Type of Statement: Draft Environmental Impact Statement

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The U.S. Fish and Wildlife Service (Service) received an application from the Edwards Aquifer Authority (EAA), San Antonio Water System, City of New Braunfels, City of San Marcos, and Texas State University for a permit to take certain federally protected species incidental to otherwise lawful activities pursuant to Section 10(a)(1)(B) of the Endangered Species Act of 1973, as amended (ESA). This Draft Environmental Impact Statement (DEIS) addresses the potential environmental consequences that may occur if the application is approved and the HCP is implemented. The Service is the lead agency under the National Environmental Policy Act (NEPA).

The incidental take permit (ITP) would authorize incidental take of covered species associated with aquatic habitats within the EAA's jurisdictional boundary; including the San Marcos Springs Complex, Spring Lake, and the San Marcos River (in Hays County); the Comal Springs Complex, and the Comal River (in Comal County); and the Guadalupe River (from the confluence with the Comal River downstream to the EAA jurisdictional boundary).

Species proposed for coverage under the ITP include the endangered fountain darter (*Etheostoma fonticola*), San Marcos gambusia (*Gambusia georgei*), Comal Springs riffle beetle (*Heterelmis comalensis*), Comal Springs dryopid beetle (*Stygoparnus comalensis*), Peck's Cave amphipod

(*Stygobromus pecki*), Texas blind salamander (*Eurycea rathbuni*), Texas wild-rice (*Zizania texana*); the threatened San Marcos salamander (*Eurycea nana*); and three species that have been petitioned for listing, the Comal Springs salamander (*Eurycea* sp.), Edwards Aquifer diving beetle (*Haideoporus texanus*), and Texas troglobitic water slater (*Lirceolus smithii*).

As part of the ITP process, the Edwards Aquifer Recovery Implementation Program has prepared a Habitat Conservation Plan (HCP) that specifies what biological impacts are likely to result from the taking of the covered species and the measures the Applicants will undertake to avoid, minimize, and mitigate such impacts; how the HCP will be funded; and what alternatives to the taking were considered by the Applicants. The proposed term of the permit is 15 years.

The DEIS examines the environmental effects of the Service's approval of the proposed permit and implementation of the HCP (the Proposed Action), and the environmental effects of three alternatives to the proposed action. These alternatives include No Action, a regional permit incorporating an expanded Aquifer Storage and Recovery System in conjunction with more restrictions on authorized pumping, and an alternative that ensures recommended minimum springflows solely through aquifer pumping restrictions.

The No Action alternative would potentially have the lowest economic impacts to the region but the greatest adverse environmental effects to the covered species of the alternatives considered. The Proposed Action addresses the needs of the covered species while minimizing impacts to the regional economy and is the preferred alternative. Alternatives 3 and 4 would conserve the covered species but would result in greater impacts to the regional economy.

Comments on the DEIS are due 90 days from the date the notice of availability is published in the Federal Register. They should be sent to the Service at the address listed above.

EXECUTIVE SUMMARY

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
AM – Adaptive Management
AMP – Adaptive Management Program
ASR – aquifer storage and recovery
BMP(s) – best management practice(s)
BWL – Bad Water Line
CAA – Clean Air Act
CCSP – U.S. Climate Change Science Program
CEQ – Council on Environmental Quality
CFR – Code of Federal Regulations
CFU – colony-forming units
CNB – City of New Braunfels
CPM – Critical Period Management
CSM – City of San Marcos
DEIS – Draft Environmental Impact Statement
DHHS – Department of Health and Human Services
DOR – drought of record
EAA – Edwards Aquifer Authority (the Authority)
EARIP – Edwards Aquifer Recovery Implementation Program
EDF – Environmental Defense Fund
EIS – environmental impact statement
ERPA – Environmental Restoration and Protection Area
ESA – Endangered Species Act
FR – Federal Register
GBRA – Guadalupe-Blanco River Authority
GCSNA – Government Canyon State Natural Area
GHG – Green House Gas
HCP – Habitat Conservation Plan
IA – Implementing Agreement
IH – Interstate Highway
IPCC – Intergovernmental Panel on Climate Change
IPM – Integrated Pest Management
ISD – Independent School District
ITP – Incidental Take Permit
LID – Low Impact Development
MCLs – maximum contaminant levels
MSA – Metropolitan Statistical Area
msl – mean sea level
NAAQS – National Ambient Air Quality Standards
NCDC – U.S. Historical Climate Network of the National Climatic Data Center
NEPA – National Environmental Policy Act
NGOs – non-governmental organizations
NHPA – National Historic Preservation Act
NRHP – National Register of Historic Places
NOI – Notice of Intent
NRI – Nationwide Rivers Inventory
OCR – off-channel reservoir
PCBs – Polychlorinated Biphenyls
PCE – tetrachloroethene
RM – Ranch to Market Road
RWCP – Regional Water Conservation Program
SALs – State Archeological Landmarks
SAWS – San Antonio Water System
SB 3 – Senate Bill 3
SCTRWPG – South Central Texas Regional Water Planning Group
SCUBA – Self-contained Underwater Breathing Apparatus
Service – U.S. Fish and Wildlife Service
SH –Texas State Highway
SHPO – State Historic Preservation Officer
SSA – Sole Source Aquifer
STIR – State of Texas Integrated Report
SVOCs – Semi-Volatile Organic Compounds
TAG – Technical Advisory Group
TCE – trichloroethene
TCEQ – Texas Commission on Environmental Quality
TDS – total dissolved solids
THC – Texas Historic Commission
TPWD – Texas Parks and Wildlife Department
TSDC – Texas State Data Center
TSU – Texas State University
TSWQS – Texas Surface Water Quality Standards
TWC – Texas Workforce Commission
TWDB – Texas Water Development Board
TxDOT – Texas Department of Transportation
US – U.S. Route
USACE – U.S. Army Corps of Engineers
USDI – U.S. Department of the Interior
USEPA – U.S. Environmental Protection Agency
VISPO – Voluntary Irrigation Suspension Program Option
VOCs – Volatile Organic Compounds
WORD – Water Oriented Recreation District of Comal County
WRIP – Water Resources Integrated Pipeline

EXECUTIVE SUMMARY

ES.1 INTRODUCTION

On January 6, 2012, the U.S. Fish and Wildlife Service (Service) received an Incidental Take Permit (ITP) application from the Edwards Aquifer Authority (EAA), San Antonio Water System (SAWS), City of New Braunfels (CNB), City of San Marcos (CSM), and Texas State University (TSU) at San Marcos, hereinafter referred to as the "Applicants," in accordance with Section 10(a)(1)(B) of the Endangered Species Act (ESA) of 1973, as amended. The Applicants seek issuance of an ITP that would permit the incidental take of covered species resulting from otherwise lawful activities including the regulation and production of groundwater in accordance with state law for irrigation, industrial, municipal, domestic, and livestock purposes; the use of instream flows in the Comal River and San Marcos River for recreational uses; and other operational and maintenance activities that could affect Comal Springs, San Marcos Springs, and the associated river systems. The requested term of the ITP is 15 years.

A stakeholder-driven collaborative effort known as the Edwards Aquifer Recovery Implementation Program (EARIP) prepared a Habitat Conservation Plan (HCP) that describes the impacts likely to result from the taking; the steps the Applicants will take to minimize and mitigate such impacts including how these actions will be funded; and alternatives to the taking that the Applicants considered. The HCP proposes actions to manage the Edwards Aquifer and conserve the spring ecosystems and associated habitats for eleven species listed as threatened or endangered, or that could be listed in the future. These species, collectively referred to as the "covered species," include the endangered fountain darter (*Etheostoma fonticola*), San Marcos gambusia (*Gambusia georgei*), Texas blind salamander (*Eurycea rathbuni*), Peck's Cave amphipod (*Stygobromus pecki*), Comal Springs dryopid beetle (*Stygoparnus comalensis*), Comal Springs riffle beetle (*Heterelmis comalensis*), Texas wild-rice (*Zizania texana*), and the threatened San Marcos salamander (*Eurycea nana*). Covered species that are not currently listed include the Edwards Aquifer diving beetle (*Haideoporus texanus*), Comal Springs salamander (*Eurycea* sp.), and Texas troglobitic water slater (*Lirceolus smithii*).

This Draft Environmental Impact Statement (DEIS) addresses the potential environmental consequences that may occur if the application is approved. The Service is the lead agency under the National Environmental Policy Act (NEPA).

ES.2 PURPOSE AND NEED FOR THE PROPOSED ACTION

The Edwards Aquifer is a unique groundwater resource, extending 180 miles (290 kilometers) from Brackettville in Kinney County, Texas, to Kyle, in Hays County Texas. It is the primary source of drinking water for over 2 million people in south-central Texas and serves the domestic, livestock, irrigation, industrial, municipal, and recreational needs of the area. The Edwards Aquifer is also the source of the two largest springs remaining in Texas, Comal Springs and San Marcos Springs. These springs and the rivers they form provide the only known habitats for a number of the covered species.

During the 1950s, Central Texas experienced the most severe drought event since record-keeping began in the area. This event, referred to as the "drought of record" (DOR), resulted in the cessation of springflow at Comal Springs for more than 4 months and significantly reduced flows at San Marcos Springs. At current pumping levels, withdrawals from the Edwards Aquifer under a repeat of DOR-like conditions could result in cessation of flow at Comal Springs for more than 3 years and flow rates approaching zero at San Marcos Springs. These conditions would be expected to result in take and significant negative impacts to the covered species and their habitats associated with Comal and San Marcos Springs.

The purpose of the proposed federal action is to authorize the Applicants to engage in covered activities that could result in some take of listed species incidental to otherwise legal actions as provided for under Section 10(a)(1)(B) of the ESA. The Applicants have developed and propose to implement a conservation plan intended to conserve and contribute to the recovery of the covered species. The Service needs to ensure compliance with the ESA and continue to protect and conserve the covered species and their habitats.

ES.3 THE PROPOSED ACTION AND ALTERNATIVES

This DEIS considers four alternatives: a "No Action" alternative (Alternative 1); the proposed EARIP HCP (Alternative 2); an expanded Aquifer Storage and Recovery (ASR) facility with associated infrastructure (Alternative 3); and a single-stage Critical Period Management (CPM) regulatory pumping restriction alternative (Alternative 4). The Alternatives are described in detail in Chapter 2.

ES.3.1 Alternative 1: No Action

Under Alternative 1, no region-wide ITP would be issued and no mechanisms would be in place to ensure springflows at Comal and San Marcos Springs during severe drought conditions. Aquifer models that considered current pumping volumes during a repeat of the regional precipitation and recharge conditions experienced during the 1950s project that all springflow would cease at Comal Springs for more than 3 years under this alternative. Flows at San Marcos under these conditions are modeled to approach zero for approximately 1 month.

ES.3.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 contemplates issuance of a 15-year ITP by the Service and implementation of the actions proposed in the EARIP HCP (EARIP 2011). This alternative incorporates measures addressing both human water use and conservation needs of the covered species. Under this alternative, the Applicants would implement actions to minimize and mitigate the effects of pumping, and conserve and contribute to the recovery of the covered species associated with the Aquifer-dependent spring ecosystems.

ES.3.3 Alternative 3: Expanded ASR with Associated Infrastructure

Aquifer management under Alternative 3 would focus on a combination of pumping restrictions and establishment of an expanded ASR facility and its associated infrastructure. This alternative contemplates issuance of an ITP that would cover the Applicants for the incidental take of covered species, as well as implementation of an HCP incorporating many of the minimization and mitigation measures identified in Alternative 2. Under this alternative up to 66,700 acre-feet of Aquifer water would be stored in an ASR facility that would be transported and injected into wells during drought conditions to support springflow at Comal and San Marcos Springs.

ES.3.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 contemplates pumping restrictions that would be implemented under relatively minor drought conditions. Modeling of Aquifer conditions predicts that an 85 percent reduction in region-wide pumping would maintain Comal and San Marcos springflows at levels believed to be protective of the covered species during a repeat of the severe drought conditions experienced during the 1950s.

ES.4 SCOPING

On March 5, 2010, the Service initiated the scoping process by publishing a Notice of Intent (NOI) to prepare a DEIS in the Federal Register and requesting suggestions on the scope and issues to be addressed in the environmental document. The Service then conducted seven scoping meetings in April 2010 to ensure that all public issues and concerns had been identified and addressed in preparation of this DEIS. Comments received during the public scoping meetings, collected from an internet website established for this purpose, and delivered by mail have been addressed in this DEIS. The Scoping process and a summary of comments received are described in Chapter 1.

ES.5 ENVIRONMENTAL EFFECTS OF THE PROPOSED ACTION AND ALTERNATIVES

Each of the alternatives considered would be expected to have impacts on the environment within the study area. The direct, indirect, and cumulative environmental effects of the alternatives are described in Chapter 4.

Alternative 1 would not be expected to significantly affect the environment during normal precipitation and recharge conditions. Because no measures are contemplated to minimize or mitigate actions, there are no costs associated with implementing this alternative. During periods of severe drought, this alternative would be expected to have significant negative effects to covered species and their habitats, up to and including ecosystem-level adverse effects. The negative socioeconomic effects of a multi-year drought event such as that experienced in the 1950s would be expected to affect agricultural production, employment, and regional demographics.

Alternative 2 (the proposed action) includes a number of mitigation and minimization measures intended to conserve the covered species and their spring ecosystems. During normal rainfall and recharge conditions, the proposed habitat restoration measures are expected to benefit the Comal and San Marcos Springs ecosystems. Though the activities covered under this alternative could generate impacts to covered species, implementation of the proposed HCP is expected to contribute to recovery of the listed species and ensure their survival during conditions equivalent to those experienced during the DOR. The anticipated cost of implementing Alternative 2 has been estimated to total $261.2 million over the 15-year life of the permit. Funding obligations associated with implementing the proposed HCP could have some negative economic impacts, though the certainty provided by an ITP ensuring continued use of the Edwards Aquifer is expected to be an overall benefit to the regional economy. The EARIP HCP is the alternative that minimizes negative effects to both the natural and human environment to the greatest extent, and is the Service's preferred alternative.

Alternative 3 relies on regulatory changes such as increased pumping restrictions and the construction of an ASR facility and its associated infrastructure to minimize and mitigate potential impacts to covered species and their habitats. This alternative incorporates many of the HCP measures and would provide similar springflow protections as expected under Alternative 2. Estimated costs of implementing Alternative 3 range from $439 million to $1.16 billion over the 15-year term of the associated permit. This alternative could result in adverse environmental and socioeconomic impacts associated with the construction, operation and maintenance of required infrastructure and the significantly increased financial obligations associated with implementing these actions.

Alternative 4 would impose regulatory pumping restrictions to achieve habitat protection goals, and no direct costs would be associated with implementing these regulatory changes. Though this alternative may maintain springflows that are most protective of the covered species during DOR conditions, the indirect and cumulative effects resulting from the proposed pumping restrictions and developing alternative water sources for human use under Alternative 4 would be expected to have significant negative economic impacts throughout the region.

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PURPOSE AND NEED FOR THE ACTION

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1.0 PURPOSE AND NEED FOR THE ACTION

1.1 INTRODUCTION

In 2006, the U.S. Fish and Wildlife Service (Service) invited stakeholders from throughout south-central Texas to collaborate in a voluntary effort established to contribute to the recovery of threatened or endangered species dependent on the Edwards Aquifer. This collaborative stakeholder-driven effort is referred to as the Edwards Aquifer Recovery Implementation Program (EARIP). Recovery Implementation Programs are voluntary, multi-stakeholder initiatives that strive to balance human resource needs with the recovery of threatened and endangered species.

In May 2007, the Texas Legislature directed certain state agencies, local units of government, and other stakeholders to participate in the EARIP and to prepare a plan for managing the Edwards Aquifer that would conserve federally-listed species. The Legislature directed that a Program Document describing a regional management plan for the Edwards Aquifer be delivered no later than September, 2012. The Program Document was to be protective of listed species in the event of drought conditions equal to the most severe on record, referred to as the drought of record (DOR).

On January 6, 2012, the Service received an application from the Edwards Aquifer Authority (EAA), San Antonio Water System (SAWS), City of New Braunfels, Texas (CNB), City of San Marcos, Texas (CSM), and Texas State University (TSU) (collectively hereafter referred to as Applicants) seeking an Incidental Take Permit (ITP) under Section 10(a)(1)(B) of the Endangered Species Act (ESA) of 1973, as amended, to take certain federally protected species incidental to otherwise lawful activities. This Draft Environmental Impact Statement (DEIS) addresses the potential environmental consequences that may occur if the application is approved.

The EARIP Program Document is in the form of a Habitat Conservation Plan (HCP) hereafter incorporated by reference and referred to as the EARIP HCP (EARIP 2011). The EARIP HCP proposes incidental take coverage for eight species listed as threatened or endangered under the ESA and three additional species that are not currently listed, but which have been petitioned for listing or which may be listed in the future. These species are collectively referred to as the “covered species.” The Applicants seek issuance of an ITP, which would permit the incidental take of covered species resulting from the otherwise lawful activities which include, but are not limited to, the regulation and production of groundwater from the Edwards Aquifer in accordance with state law for irrigation, industrial, municipal, domestic and livestock uses; the use of instream flows in the Comal River and San Marcos River for recreational uses; and other operational and maintenance activities that could affect Comal Springs, San Marcos Springs, and the associated river systems.

The EARIP HCP specifies, among other things; 1) the impacts likely to result from the taking of the covered species; 2) the conservation measures the Applicants will undertake to minimize and mitigate such impacts; 3) how these conservation measures will be funded; and 4) alternatives to the taking considered by the Applicants. The proposed permit term is 15 years.

1.2 COVERED SPECIES

A total of eight listed species depend directly on the spring-fed waters of the southern segment of the Edwards Aquifer (Figure 1-1). Several other species dependent on the spring ecosystems have been petitioned for listing, and three of these non-listed species are included as covered species under the EARIP HCP. The proposed conservation actions described in the HCP will be implemented for all covered species upon issuance of the permit, regardless of listing status. The covered species are listed in Table 1-1 below.

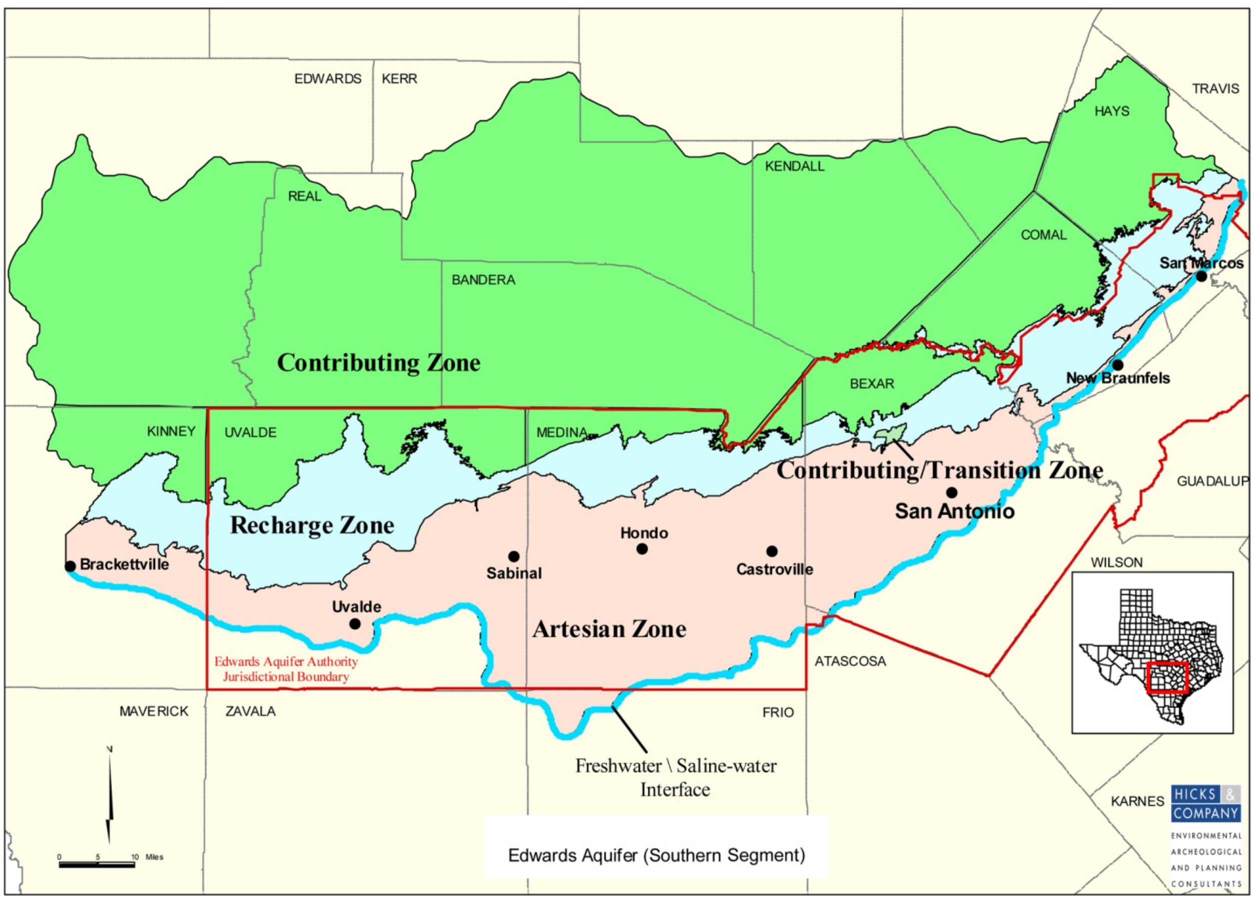


Figure 1-1. Edwards Aquifer (Southern Segment).

Table 1-1. Species Identified for Coverage under the EARIP HCP.

COMMON NAME	SCIENTIFIC NAME	ESA STATUS
Fountain Darter	*Etheostoma fonticola*	Endangered
Comal Springs Riffle Beetle	*Heterelmis comalensis*	Endangered
San Marcos Gambusia	*Gambusia georgei*	Endangered
Comal Springs Dryopid Beetle	*Stygoparnus comalensis*	Endangered
Peck's Cave Amphipod	*Stygobromus pecki*	Endangered
Texas Wild-Rice	*Zizania texana*	Endangered
Texas Blind Salamander	*Eurycea rathbuni*	Endangered
San Marcos Salamander	*Eurycea nana*	Threatened
Edwards Aquifer Diving Beetle	*Haideoporus texanus*	Petitioned
Comal Springs Salamander	*Eurycea* sp.	Petitioned
Texas Troglobitic Water Slater	*Lirceolus smithii*	Petitioned

Among the listed species, the Comal Springs dryopid beetle (*Stygoparnus comalensis*) is known to occur in the Edwards Aquifer near Comal Springs and Fern Bank Springs. Peck's cave amphipod (*Stygobromus pecki*) is known to occur in the Edwards Aquifer near Comal Springs and Hueco Springs. The fountain darter (*Etheostoma fonticola*) and Comal Springs riffle beetle (*Heterelmis comalensis*) occur in the spring-fed aquatic ecosystems of both Comal and San Marcos Springs, while the San Marcos salamander (*Eurycea nana*) and Texas wild-rice (*Zizania texana*) only occur in the aquatic ecosystems associated with San Marcos Springs. The Texas blind salamander (*Eurycea rathbuni*) is a subterranean species, occurring in the Edwards Aquifer near San Marcos Springs. The San Marcos gambusia (*Gambusia georgei*) is endemic to the San Marcos Springs ecosystem, but has not been observed since 1983 and may be extinct.

The Edwards Aquifer diving beetle (*Haideoporus texanus*), Comal Springs salamander (*Eurycea* sp.), and Texas troglobitic water slater (*Lirceolus smithii*) have been petitioned for listing and are proposed to be covered in the HCP. The Edwards Aquifer diving beetle is a subterranean species known from Comal Springs and from an artesian well near San Marcos Springs. The Comal Springs salamander is the common name referring to a population of salamanders from Comal Springs. The Texas troglobitic water slater is known from San Marcos Springs and an artesian well on the TSU campus.

The primary threat to these species is the intermittent loss of habitat from reduced springflows. Springflow loss is the combined result of naturally fluctuating rainfall patterns, regional pumping, and the resulting intermittent drawdown of the Edwards Aquifer. Other threats include invasive and non-native species, impacts associated with recreational activities in the river and springs systems, 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 affect water quality (USFWS 1996a).

1.3 PROPOSED ACTION AND DECISIONS NEEDED

The proposed federal action is the issuance of a Section 10(a)(1)(B) permit by the Service for a term of 15 years to allow incidental take of covered species. The permit area includes subterranean, inter-connected, water-filled caves and conduits within the EAA jurisdictional boundary, the San Marcos Springs Complex, Spring Lake, San Marcos River, and Fern Bank Springs (in Hays County); the Comal Springs Complex, the Comal River including old and new channels, and Hueco Springs (in Comal County). Areas around and including Comal Springs and San Marcos Springs under the jurisdiction of the cities of New Braunfels and San Marcos, respectively, are also included in the permit area.

1.4 PURPOSE AND NEED FOR THE PROPOSED ACTION

The Edwards Aquifer is a unique groundwater resource, extending 180 miles (mi) (290 kilometers [km]) from Brackettville in Kinney County, Texas, to Kyle, in Hays County Texas. It is the primary source of drinking water for over 2 million people in south-central Texas and serves the domestic, livestock, irrigation, industrial, municipal, and recreational needs of the area. The human population in the study area (Figure 1-2) 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). The Edwards Aquifer is also the source of the two largest springs remaining in Texas—the San Marcos and the Comal Springs, which are the headwaters of the San Marcos and Comal Rivers, respectively.

The Edwards Aquifer is totally dependent on rainfall for recharge. Discharge from the Edwards Aquifer is through springflow and wells; only the discharge from wells is controllable. At current pumping levels, withdrawals from the Edwards Aquifer under extended and severe drought conditions could adversely impact covered species associated with the Edwards Aquifer. The Applicants need a long-term, comprehensive solution to allow normal, otherwise lawful operations that could result in take of covered species while assuring compliance with the ESA.

The Service needs to conserve the covered species and the ecosystems upon which they depend and to ensure ESA compliance. The purpose of the proposed federal action is to enable the Applicants to perform the otherwise lawful covered activities in conjunction with the protection and conservation of covered species while allowing some take of these species as provided for under Section 10(a)(1)(B) of the ESA.

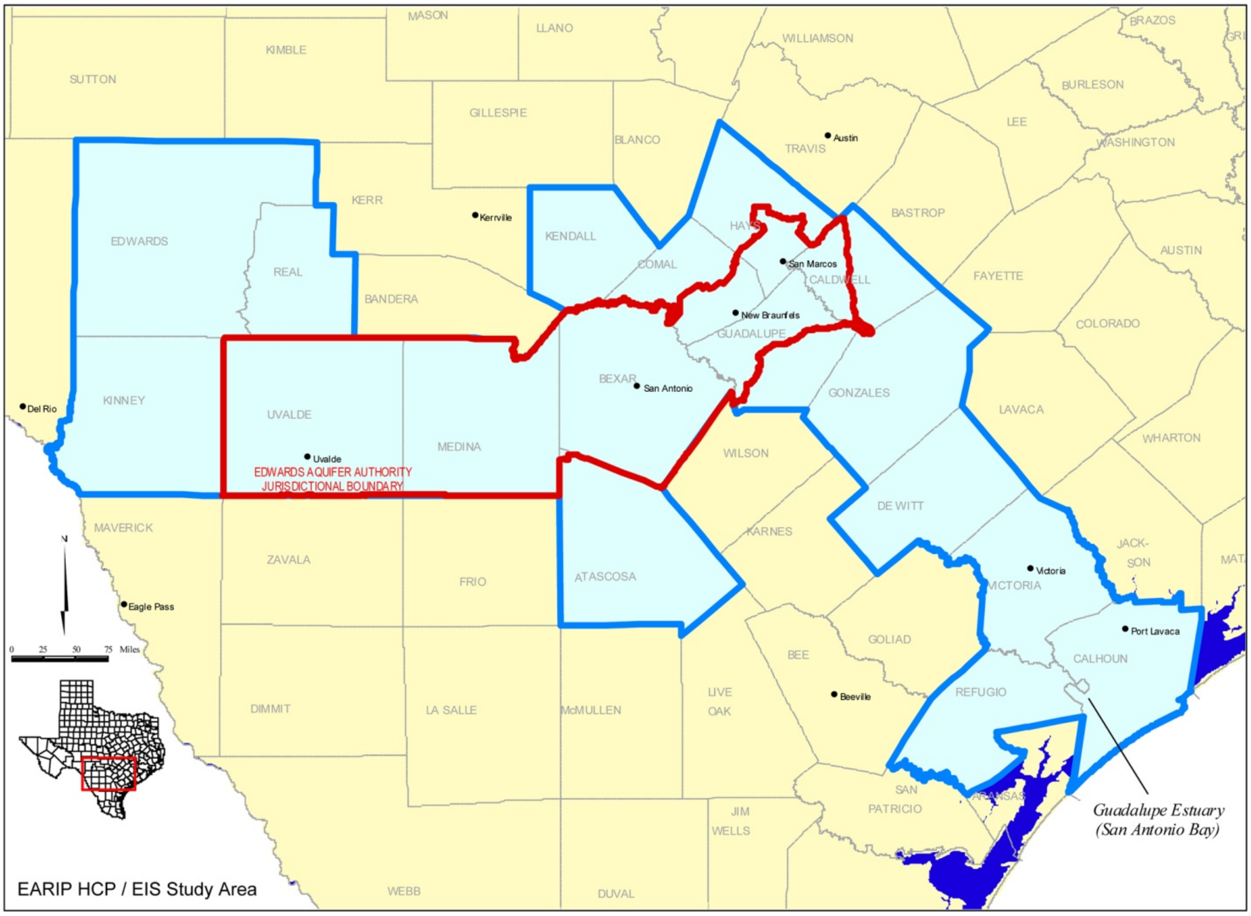


Figure 1-2. The EIS Study Area.

1.5 REGULATORY CONTEXT

1.5.1 National Environmental Policy Act

The National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. 4321 et seq.), requires that federal agencies proposing major actions that could result in significant effects on the quality of the human environment prepare a detailed statement of environmental effects. The Service has concluded that an environmental impact statement (EIS) is the appropriate level of review for this proposed action. An EIS must provide a detailed statement of the environmental impacts of the action, possible alternatives, and measures to mitigate adverse effects of the proposed action (42 U.S.C. § 4332(C)). While NEPA does not mandate any particular result, it requires the agency to follow particular procedures in its decision-making process. The purpose of these procedures is to ensure that the agency has the best possible information to make an "intelligent, optimally beneficial decision" and to ensure that the public is fully apprised of any environmental risks that may be associated with the proposed action.

1.5.2 The Endangered Species Act

Section 9 of the ESA prohibits “take” of species that are listed as endangered, and Section 4 provides the Service with the discretion to extend all or some of those protections deemed necessary and advisable to provide for the conservation of threatened species. Take includes harassment, harm, pursuit, hunting, shooting, wounding, killing, trapping, capturing, or collecting a listed species, or attempting to engage in any such conduct (16 USC §1538(19)). Harm is further defined in ESA implementing regulations as an act which actually kills or injures fish or wildlife, including significant habitat modification or degradation which actually kills or injures fish or wildlife by significantly impairing essential behavioral patterns, including breeding, spawning, rearing, migrating, feeding or sheltering (50 C.F.R. §17.3, and §222.102).

Non-federal entities can apply for “incidental take” authorization when a project or activity does not involve a federal action and the take is incidental to, and not the purpose of, an otherwise lawful activity (16 USC §1539(a)(1)(A-B)). Section 10 of the ESA and the Services’ implementing regulations define the circumstances under which an ITP can be issued.

Section 10(a)(2)(A)(i-iv) of the Act requires that an applicant must submit a conservation plan that specifies:

- The impact that will likely result from such taking; and,
- What steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps; and,
- What alternative actions to such taking the applicant considered and the reasons why such alternatives are not being utilized; and,
- Such other measures that the Service may require as being necessary or appropriate for purposes of the plan.

Section 10(a)(2)(B), provides that the Service shall issue an ITP if the Service finds, after opportunity for public comment, that:

- The taking will be incidental; and,
- The applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking; and,
- The applicant will ensure that adequate funding for the plan will be provided; and,
- The taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; the measures, if any, required by the Service as being necessary or appropriate for purposes of the plan will be met; and,

- The Service has received such other assurances as may be required that the plan will be implemented.

In 2000, the Service adopted policies intended to clarify certain HCP elements (65 FR 35242–35257). These policies became known as "The Five-Point Policy", and require that:

- An HCP include specific, measurable biological goals and objectives based on the best available scientific information; and,
- An HCP include an adaptive management provision; and,
- An HCP include a monitoring program to gauge the effectiveness of the plan in meeting the biological goals and objectives and the permittees compliance with the plan; and,
- The Service consider several factors to determine the appropriate duration of an ITP, including the duration of the covered activities and the expected effects on the covered species; and,
- The Service expand public participation by providing a 90-day comment period for most HCPs.

The ESA provides "no surprises" assurances through the Service's implementing regulations (50 CFR Part 17.22(b)(5), 17.32(b)(5); 50 CFR 222.307(g)). These regulations assure applicants that if "unforeseen circumstances" arise, the Service 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 beyond what is required by the ITP and the associated HCP and Implementing Agreement (IA) without the permittees' consent. The Service will honor these assurances as long as a permittee is implementing the terms and conditions of the HCP, permit, and other associated documents.

1.5.3 State of Texas Legislative Requirements

In 1993, in response to a lawsuit and resulting Aquifer pumping limitations proposed by a U.S. District Court, the Texas Legislature passed the Edwards Aquifer Authority Act (EAA Act) which, among other things, created the EAA. The EAA Act created a new regional entity to "manage, conserve, preserve, and protect the Edwards Aquifer and to increase the recharge of, and prevent pollution of water in, the [Edwards] [A]quifer" (EAA Act 1993).

The following are among the major functions of the EAA as established by the EAA Act:

- Manage and control withdrawals of water from the Edwards Aquifer through the issuance of permits and the registration of wells.
- Protect the water quality of the Edwards Aquifer.

- Protect the water quality of the surface streams to which the Edwards Aquifer provides stream flow.
- Achieve water conservation.
- Maximize the beneficial use of water available for withdrawal from the Edwards 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 Edwards Aquifer.
- Increase recharge of water to the Edwards Aquifer.
- Enforce compliance with the EAA Act.

The EAA Act authorizes the EAA to conduct research on topics relevant to regional water resources management, including water quality, water resources management, the augmentation of springflow, and the development of additional water supplies. The EAA's powers only apply to the use and management of the Edwards Aquifer within the Authority's boundaries. Except for water quality as described below, the EAA has no regulatory powers over surface water resources, portions of the Edwards Aquifer outside of its boundaries, or over other groundwater within its boundaries.

The EAA may assert water quantity management authority within its general jurisdiction extending to all or part of Atascosa, Bexar, Caldwell, Comal, Guadalupe, Hays, Medina, and Uvalde Counties. The EAA Act further established a 5-mi (8-km) buffer zone beyond the general jurisdictional boundary wherein the EAA may assert authority to manage water quality. Although the EAA's regulatory jurisdiction is contained within the counties within its jurisdictional boundaries and the 5-mi (8-km) buffer zone, the use and management of the Edwards Aquifer affects a much larger area. In addition to being the primary water source for over 2 million users within the EAA's boundaries, discharges from the Edwards Aquifer also supply a significant portion of the flow in the Guadalupe River Basin downstream of Comal and San Marcos Springs. Consequently, the EIS study area includes the eight counties within the Authority's general jurisdiction, four counties within the 5-mi (8-km) water quality buffer, and five counties affected by the discharge of springflow that is carried downstream by the

Guadalupe River to the Guadalupe River Estuary and San Antonio Bay. This 17-county EIS study area is shown in Figure 1-2, along with the approximate extent of the EAA's jurisdiction.

In 2007, the Texas Legislature amended the EAA Act by passage of Senate Bill 3 (SB 3). The legislation directed the EAA, among other things, to permit aquifer withdrawals up to 572,000 acre-feet (ac-ft) per calendar year (hereafter, ac-ft/yr) subject to adoption and enforcement of a Critical Period Management (CPM) plan with specified withdrawal reduction percentages triggered by specified aquifer and springflow levels. The legislation also stipulated that "beginning September 1, 2007, the EAA may not require the volume of permitted withdrawals to be less than an annualized rate of 340,000 ac-ft, under critical period Stage IV." Further, "after January 1, 2013, the EAA may not require the volume of permitted withdrawals to be less than an annualized rate of 320,000 ac-ft, under critical period Stage IV unless, after review … the EAA determines that a different volume of withdrawals is consistent with … maintaining protection for federally-listed threatened and endangered species associated with the aquifer to the extent required by federal law."

By 2008, the EAA had issued 1,598 regular permits authorizing aquifer withdrawals of up to 571,549.8 ac-ft/yr in accordance with SB 3 (see Table 1-2).

Table 1-2. Aquifer Withdrawals Authorized by Regular Permits in 2008.

CATEGORY OF USE	NUMBER OF PERMITS	2008 AUTHORIZED WITHDRAWAL (ac-ft/yr)
Municipal	417	277,218.9
Industrial	330	50,431.5
Irrigation	851	243,899.4
TOTAL	**1,598**	**571,549.8**

1.6 SCOPING THE ISSUES AND CONCERNS

1.6.1 The Scoping Process

The purpose of project scoping is to allow an early and open process to:

1. Determine the scope of issues to be addressed; and,
2. Identify specific issues related to a proposed action that need to be evaluated in the EIS; and,
3. Identify and eliminate from detailed study the issues which are not significant or which have been covered by prior environmental review.

The scoping process was formally initiated on March 5, 2010, with publication in the *Federal Register* of a Notice of Intent (NOI) to prepare a DEIS, announce the initiation of a public scoping period, and seek suggestions on the scope and issues to be included in the environmental document (75 FR 10305). The NOI provided information on the background and purpose of the proposed action and provided details for the public scoping meetings and comment period. Public input was collected through a series of scheduled scoping meetings, establishment of an Internet link to the "Edwards Aquifer Public Comments Forum" of the EARIP web page, and direct solicitation of public comments by the Service's Ecological Services Office in Austin, Texas.

1.6.2 Public Involvement

Public scoping meetings were held at seven locations selected to allow representation by various stakeholder interests (e.g., geographical regions, types of water uses, major spring locations, recreational areas, and downstream interests). A summary of the location and dates of these public scoping meetings is listed below in Table 1-3.

Table 1-3. Location and Date of Public Scoping Meetings.

VENUE	LOCATION	DATE
Victoria Community Center	Victoria, Texas	Thursday, April 1, 2010
New Braunfels Civic Center	New Braunfels, Texas	Monday, April 12, 2010
Texas AgriLife Research and Extension Center	Uvalde, Texas	Wednesday, April 14, 2010
San Marcos Activity Center	San Marcos, Texas	Monday, April 19, 2010
San Antonio Water System Customer Service	San Antonio, Texas	Monday, April 26, 2010
Harte Research Institute	Corpus Christi, Texas	Wednesday, April 28, 2010
Schreiner University	Kerrville, Texas	Thursday, April 29, 2010

A total of 156 people attended the seven scoping meetings. Eight categories of issues and concerns emerged from verbal and written statements received at the scoping meetings; from comment letters transmitted to the Service; and from statements received through the EARIP website. Categories and associated subtopics of these comments are listed in Table 1-4.

Table 1-4. Comment Categories and Associated Subtopics.

CATEGORY	COMMENT NO.	COMMENT
Science and Methodology (1)	1.1	Use the best science and technology available to make decisions.
	1.2	A lack of understanding exists about the HCP process and the meaning of incidental take.
	1.3	Public awareness should be increased.
	1.4	Continue aquifer modeling studies to provide more information concerning aquifer management strategies.
	1.5	Control of predators and eradication of noxious species within managed ecosystems should be carefully planned, implemented, and evaluated to ensure that the balance of the ecosystem can be maintained.
Regulations (2)	2.1	A concern exists that real protection for the Aquifer, springs, and endangered species will not be implemented in spite of best intentions.
	2.2	There is difficulty and economic hardship for farmers and ranchers in reducing irrigation pumping after crops have been planted.
	2.3	Water as a property right may be increasingly infringed upon through increased government intervention and regulations.
	2.4	New urban and residential development should require new sources of water as a condition for approval and permitting.
	2.5	All new construction should require rainfall capture.
	2.6	Water conservation should be based on uniform standards.
	2.7	Regulations should balance protection of endangered species with needs of water for other uses.
	2.8	Use of aquifer water should be optimized during wet periods, with reductions during periods when habitats are the most threatened.
	2.9	There are few regulations limiting impervious cover over the Aquifer; greater planning and implementation of impervious cover restrictions are needed.
Water Supply and Conservation (3)	3.1	Balancing water supply against growing future demand including downstream use is a growing concern and priority issue.
	3.2	Alternative sources of water including desalination need be developed to reduce demand on the Aquifer.
	3.3	There is a need for greater public stewardship of water resources.
	3.4	There is a need for greater emphasis on water conservation measures to protect water supply for both municipal water uses and irrigators.
	3.5	Future tax breaks and other financial incentives are needed for farming operations to reduce water consumption and engage in conservation efforts.
	3.6	Future building design should incorporate water conservation measures.
	3.7	Water rates should be structured to encourage water conservation and discourage high use.
	3.8	Water rates should be increased to generate funding to pay for alternative sources of water.
	3.9	Water conservation efforts should include implementation of more water reuse projects.
	3.10	Transport of aquifer water from Kinney County to the San Antonio metropolitan area via a water transmission pipeline will benefit larger western cities at the expense of the smaller western communities.
	3.11	Include construction of Atmospheric Water Generators over the recharge zone and as a requirement for each newly constructed home as an alternative water source.

Table 1-4. (Cont.).

CATEGORY	COMMENT NO.	COMMENT
Water Quality (4)	4.1	Evaluations are needed on the effects of future highway building such as the New Braunfels Outer Loop and other associated development on water quality of streams, rivers, springs, and the Edwards Aquifer Recharge Zone.
	4.2	TxDOT should be included as a stakeholder in the EARIP process due to proposed road construction over the Aquifer; there should be up-to-date demographics and evaluation of environmental effects associated with proposed road development.
	4.3	There is concern with a lack of coordination of environmental agencies with TxDOT in future road building.
	4.4	Maintenance of water quality in Lake Dunlap is a concern.
	4.5	Increase water quality protection over the Edwards Aquifer Recharge Zone including purchasing preserve land and limiting development.
	4.6	Urban and residential developers and ranchers should increase use of detention ponds to increase water quality from runoff.
Springs (5)	5.1	Greater protection of San Marcos Springs and Comal Springs can be provided through more closely controlled public access.
	5.2	Maintenance of springflow during DOR conditions implies drastic pumping reductions that would likely devastate the regional economy; the economic impacts of reduced pumping should be described in detail.
	5.3	Augmentation of springflow would assure more water supply from the Aquifer.
	5.4	Management strategies of the Aquifer should include maintenance of flow at Las Moras (Fort Clark) Springs.
Rivers (6)	6.1	Water should not be taken from the lower Guadalupe River for transport back to the upper basin for water supply.
	6.2	The lower Guadalupe River Basin is subject to greater flooding from increased development upstream and more impervious cover.
	6.3	The City of Victoria is highly dependent on flows of the Guadalupe River.
	6.4	The Guadalupe River Estuary needs to be maintained by instream flows.
	6.5	There is growing concern for impacts of proposed road development on the Guadalupe River and associated ecosystems.
	6.6	There is a need to address growing pollution and trash in the rivers and streams within the Aquifer region.
	6.7	Limited free public access to the Guadalupe River below Canyon Dam as well as limited public parking and need for standardized signage are growing problems associated with recreation in the region.
Aquifer Recharge (7)	7.1	There is a need for more knowledge concerning recharge of the Aquifer.
	7.2	There should be more emphasis and attention on recharge and flow to those portions of the Aquifer closest to locations of the endangered species.
	7.3	Aquifer recharge can be increased through dam construction on rivers and streams running across the recharge zone.
	7.4	There are concerns and resulting opposition to specific proposed locations of aquifer recharge structures (e.g., Lower Blanco River Dam) because such structures would reduce downstream flows.
	7.5	Cumulative effects of development over the Edwards Aquifer Recharge Zone should be evaluated.
	7.6	A recharge and recirculation program would increase water supply while maintaining springflow.
	7.7	All reasonable options for recharging the Aquifer should be evaluated as well as source water alternatives.
	7.8	Recharge to the Aquifer from creeks is likely being retarded by erosion and sediment that is blocking recharge features; water passing over the recharge features will contribute to downstream flooding.

Table 1-4. (Cont.).

CATEGORY	COMMENT NO.	COMMENT
Endangered Species (8)	8.1	There should be greater protection of endangered species at both Comal Springs and San Marcos Springs.
	8.2	The best implementation plan to protect endangered species is one that also allows the region maximum access to aquifer water while minimizing costs to area communities.
	8.3	Protection of endangered species should be focused on development of refugia, supplementing springflow, and other habitat improvements.
	8.4	The whooping crane should not be included as a covered species because it occurs outside the jurisdiction of the likely ITP Applicants.

1.7 COLLABORATION WITH OTHER JURISDICTIONS, REGIONAL PLANNING EFFORTS, OTHER ENTITIES

The EARIP is comprised of the thirty-nine individuals, entities, groups, and agencies signatory to a Memorandum of Agreement with the Service dated December 13, 2007 (see EARIP HCP Appendix A [EARIP 2011]). The EARIP created a Steering Committee, and various Subcommittees and Work Groups to carry out its required functions. The EARIP operated in an open and transparent manner. Meetings and work sessions of each of the Committees and Work Groups were posted and the public was encouraged to attend and participate. The EARIP Steering Committee sought to achieve consensus on all decisions, which they defined as the absence of opposition. For more about the EARIP Committees and decision-making process, please see the EARIP HCP Chapter 1, Section 7 (EARIP 2011).

The Applicants have acknowledged that ongoing and proposed water infrastructure projects may require future collaboration with EARIP stakeholders, other jurisdictions, and planning entities. Consultation with other federal, state, and local agencies with natural and cultural resource protection responsibilities may also be required, and will be addressed before such projects are initiated or approved.

1.8 SCOPE OF THE DEIS

Issues and concerns identified through the public involvement and scoping process contributed to the development of the overall scope of this DEIS. This DEIS analyzes the potential direct, indirect, and cumulative effects of authorizing take of the covered species through issuance of the requested ITP and implementation of the EARIP HCP. Direct effects are caused by the action and occur at the same time and place. Indirect actions are caused by the action and are later in time or farther removed in distance, but are reasonably foreseeable. Cumulative effects on the environment result from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what entity undertakes such other actions. The DEIS considers the physical, biological and socioeconomic effects of the proposed action and the alternatives in the study area (Figure 1-2).

The DEIS addresses four alternatives:

1. The No Action alternative; and,
2. The proposed action that represents the EARIP HCP; and,
3. An alternative involving restricted pumping to 286,000 ac-ft/yr in association with an expanded aquifer storage and recovery (ASR) program; and,
4. An alternative that relies on aquifer pumping restrictions to ensure minimum springflow during drought conditions.

After analyzing the potential for significant impacts (described in Chapter 4 of this DEIS), the Service has determined that the following issues could be affected by the proposed action: biological resources; water quantity/quality resources; agricultural resources; cultural resources; land use; recreation; and socioeconomic resources. Each of these issues is described in this DEIS.

1.9 OTHER REQUIRED ACTIONS

Before a decision can be made regarding the issuance of an ITP, the Service must comply with the consultation requirements stipulated in Section 7 of the ESA for any federal action (i.e., issuance of the ITP by the Service) on the environment. Actions by the Service must also comply with other federal regulations including the National Historic Preservation Act (NHPA), Clean Water Act, and applicable Presidential Executive Orders, Secretarial Orders, and guidance provided by the Council on Environmental Quality (CEQ).

CHAPTER 2

ALTERNATIVES INCLUDING THE PROPOSED ACTION

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
AM – Adaptive Management
AMP – Adaptive Management Program
ASR – aquifer storage and recovery
BMP(s) – best management practice(s)
BWL – Bad Water Line
CAA – Clean Air Act
CCSP – U.S. Climate Change Science Program
CEQ – Council on Environmental Quality
CFR – Code of Federal Regulations
CFU – colony-forming units
CNB – City of New Braunfels
CPM – Critical Period Management
CSM – City of San Marcos
DEIS – Draft Environmental Impact Statement
DHHS – Department of Health and Human Services
DOR – drought of record
EAA – Edwards Aquifer Authority (the Authority)
EARIP – Edwards Aquifer Recovery Implementation Program
EDF – Environmental Defense Fund
EIS – environmental impact statement
ERPA – Environmental Restoration and Protection Area
ESA – Endangered Species Act
FR – Federal Register
GBRA – Guadalupe-Blanco River Authority
GCSNA – Government Canyon State Natural Area
GHG – Green House Gas
HCP – Habitat Conservation Plan
IA – Implementing Agreement
IH – Interstate Highway
IPCC – Intergovernmental Panel on Climate Change
IPM – Integrated Pest Management
ISD – Independent School District
ITP – Incidental Take Permit
LID – Low Impact Development
MCLs – maximum contaminant levels
MSA – Metropolitan Statistical Area
msl – mean sea level
NAAQS – National Ambient Air Quality Standards
NCDC – U.S. Historical Climate Network of the National Climatic Data Center
NEPA – National Environmental Policy Act
NGOs – non-governmental organizations
NHPA – National Historic Preservation Act
NRHP – National Register of Historic Places
NOI – Notice of Intent
NRI – Nationwide Rivers Inventory
OCR – off-channel reservoir
PCBs – Polychlorinated Biphenyls
PCE – tetrachloroethene
RM – Ranch to Market Road
RWCP – Regional Water Conservation Program
SALs – State Archeological Landmarks
SAWS – San Antonio Water System
SB 3 – Senate Bill 3
SCTRWPG – South Central Texas Regional Water Planning Group
SCUBA – Self-contained Underwater Breathing Apparatus
Service – U.S. Fish and Wildlife Service
SH –Texas State Highway
SHPO – State Historic Preservation Officer
SSA – Sole Source Aquifer
STIR – State of Texas Integrated Report
SVOCs – Semi-Volatile Organic Compounds
TAG – Technical Advisory Group
TCE – trichloroethene
TCEQ – Texas Commission on Environmental Quality
TDS – total dissolved solids
THC – Texas Historic Commission
TPWD – Texas Parks and Wildlife Department
TSDC – Texas State Data Center
TSU – Texas State University
TSWQS – Texas Surface Water Quality Standards
TWC – Texas Workforce Commission
TWDB – Texas Water Development Board
TxDOT – Texas Department of Transportation
US – U.S. Route
USACE – U.S. Army Corps of Engineers
USDI – U.S. Department of the Interior
USEPA – U.S. Environmental Protection Agency
VISPO – Voluntary Irrigation Suspension Program Option
VOCs – Volatile Organic Compounds
WORD – Water Oriented Recreation District of Comal County
WRIP – Water Resources Integrated Pipeline

2.0 ALTERNATIVES INCLUDING THE PROPOSED ACTION

This chapter describes the proposed action and alternatives to the proposed action including the No Action Alternative.

2.1 ALTERNATIVES CONSIDERED

This DEIS describes four alternatives and the various measures identified to meet project objectives:

- Alternative 1: No Action – no ITP would be issued by the Service

- Alternative 2: Proposed Action that represents implementation of the EARIP HCP and issuance of an ITP (the preferred alternative)

- Alternative 3: Expanded ASR program with associated infrastructure which includes issuance of an ITP and implementation of an HCP incorporating expanded aquifer storage and recharge actions and CPM pumping restrictions (limited to 286,000 ac-ft/yr) to achieve springflow and covered species protections

- Alternative 4: Highest CPM pumping restriction which relies solely on pumping regulations (limited to 85,800 ac-ft/yr) to maintain spring flows at levels protective of the covered species

2.1.1 EIS Study Area

The affected area is the same for each of the four alternatives and encompasses all or part of 17 south central Texas counties. The study area, illustrated in Figure 1-2 includes eight counties within the EAA's general jurisdiction (Atascosa, Bexar, Caldwell, Comal, Guadalupe, Hays, Medina, and Uvalde), and four counties within the EAA's 5-mi (8-km) water quality buffer (Edwards, Kendall, Kinney, and Real). Five counties affected by springflow carried downstream by the Guadalupe River (Calhoun, Dewitt, Gonzales, Refugio, and Victoria) are also within the study area.

The study area for all alternatives, illustrated in Figure 1-2, includes subterranean water-filled caverns and pools within the EAA's jurisdictional boundary; the San Marcos Springs Complex, Spring Lake, San Marcos River, and Fern Bank Springs (in Hays County); the Comal Springs Complex, Comal River, and Hueco Springs (in Comal County); and the Guadalupe River downstream of its confluence with the Comal River.

2.1.2 Covered Species

Under Alternatives 1 and 4, no ITP will be issued by the Service, and no species would therefore be covered. Alternatives 2 and 3 contemplate implementation of an HCP and issuance of an ITP, and propose coverage of both listed and non-listed species, see Table 1-1.

Texas wild-rice, San Marcos salamander, Texas blind salamander, and the San Marcos gambusia are only known to occur in the vicinity of San Marcos Springs. The Comal Springs riffle beetle and the fountain darter are known from San Marcos and Comal Springs. Peck's Cave amphipod has been found at Comal Springs and at Hueco Springs. The Comal Springs dryopid beetle is known to occur at Comal Springs and Fern Bank Springs.

The Comal Springs salamander is found in Comal Springs. The Texas troglobitic water slater is known from San Marcos Springs and an artesian well located on the TSU campus. The Edwards Aquifer diving beetle is found at Comal Springs and from a well on the TSU campus. For more detailed descriptions of these species, please see Chapter 3, Section 3.3.3 of the EARIP HCP (EARIP 2011).

2.1.3 Activities Common to Each Alternative

Several measures will be implemented regardless of which alternative, including the no action alternative and preferred alternative, is selected as each of the Applicants works to fulfill their respective public service responsibilities. These measures are described in detail in Chapter 2 of the EARIP HCP (EARIP 2011) and summarized in Table 2-1.

Table 2-1. Summary of Implementation Measures Common to All Alternatives.

APPLICANT	IMPLEMENTATION MEASURE
EAA	Groundwater Withdrawal Program (Aquifer Management)
	Permit Administration
CNB	Golf Course Diversions and Operation
	Spring-Fed Pool Diversions and Operation
	Boat Operations on the Comal River and Landa Lake
	Infrastructure Maintenance and Repair
	Litter Collection and Floating Vegetation Management
CSM	Boat Operations on San Marcos River
	Infrastructure Maintenance and Repair

2.1.4 Distinguishing Components of the Alternatives

Components of the alternatives are organized into four categories:

- Category A – Flow Protection Measures Affecting the Edwards Aquifer, Comal and San Marcos Springs, and the Comal and San Marcos River;
- Category B – Minimization and Mitigation Measures;
- Category C – Adaptive Management; and
- Category D – Phase II Implementation.

Activities common to all of the alternatives are anticipated to have similar impacts, and do not therefore differentiate among the alternatives. Distinguishing components of the various alternatives that would result in different impacts are listed in Table 2-2 and are discussed below.

2.1.5 Alternative 1: No Action

The No Action Alternative describes reasonably foreseeable actions that would result if this alternative is adopted and provides an environmental baseline against which the impacts of the other alternatives may be compared (Mandelker et al. 2011). The environmental baseline is the current and future condition of the environment without the proposed action or other alternative actions.

Under the No Action Alternative, no ITP would be issued and the Applicants would therefore not be covered under the ESA if their actions resulted in take of listed species. Each of the Applicants has public service responsibilities that could result in future actions affecting the Edwards Aquifer and its associated springs and river systems. These obligations may require actions that could result in incidental take of listed species associated with these ecosystems. However, none of these actions would be covered under an ITP and consequently would not be afforded protection from violation under the ESA unless future individual HCPs were developed and submitted by separate entities, and approved by the Service. Nothing in this alternative requires or presupposes that project proponents seeking future ITPs would coordinate their activities.

Under the No Action Alternative, the Edwards Aquifer would be managed in accordance with Texas SB 3, the existing EAA 2010–2012 Strategic Plan and Groundwater Management Plan, and the South Central Texas Regional Water Plan (SCTRWPG 2009). The No Action Alternative considers pumping totals ranging from the average annual amount recorded between the years 2000–2010 (381,000 ac-ft/yr) to the SB 3 mandated permitted withdrawal of 572,000 ac-ft/yr (EAA 2010b). These pumping totals are in addition to domestic and livestock pumping (averaging 13,600 ac-ft/yr from 2000 through 2009) (EAA 2010b), and federal withdrawals from the Edwards Aquifer (authorized for up to 10,000 ac-ft/yr).

Table 2-2. Comparison of the Distinguishing Components of the Four Alternatives.

COMPONENT	ALTERNATIVE			
	1: No Action	2: Proposed EARIP HCP	3: Expanded ASR with Associated Infrastructure	4: Highest CPM Pumping Restriction
A. FLOW PROTECTION MEASURES AFFECTING THE AQUIFER, COMAL AND SAN MARCOS SPRINGS, AND THE COMAL AND SAN MARCOS RIVER				
A.1 CPM Program–CPM stage reductions from regular permitted 572,000 ac-ft/yr according to SB 3 for the San Antonio Pool: (20%, 30%, 35%, 40%) at J-17 Levels below 660, 650, 640, and 630 feet msl, respectively; or Comal Springs flow below 225, 200, 150 and 100 cfs, respectively, or San Marcos Springs flow below 96 and 80 for CPM Stages 1 and 2, respectively. Reductions for the Uvalde Pool would be 5%, 20%, and 35% at J-27 levels below 850, 845, and 842 feet msl during Stages II, III, and IV, respectively. Total aquifer wide withdrawals would not be less than 320,000 ac-ft/yr at Stage IV by 2013. (**Note Addition of Emergency Stage V pumping reduction to 320,000 ac-ft/yr occurring for Alternative 2**– See Minimization and Mitigation Measure B.1.4 below). **(EAA)**	X	X		
A.2 CPM–CPM four stage reductions: (20%, 30%, 35%, 50% at J-17 Levels below 660, 650, 640, and 630 feet msl, respectively; or Comal Springs flow below 225, 200, 150 and 100 cfs, respectively, or San Marcos Springs flow below 96 and 80 cfs for CPM Stages 1 and 2, respectively, with **total aquifer wide withdrawals restricted to 286,000 ac-ft/yr during Stage IV**. **(EAA)**			X	
A.3 CPM–A single stage CPM reduction in pumpage to 85,800 ac-ft/yr (85% reduction) triggered under any of the following conditions; Comal Springs flow <225 cfs; San Marcos Springs flow <96 cfs; J-17 level <665 feet msl; J-27 level <865 feet msl. **(EAA)**				X
A.4 Use of the SAWS ASR for Springflow Protection–Includes activities associated with operating and maintaining the infrastructure associated with the Twin Oaks Aquifer Recharge, Storage, and Recovery Facility. **(SAWS)**		X	X	
B. MINIMIZATION AND MITIGATION MEASURES				
B.1 Measures to Protect and Manage Springflow at Comal Springs and San Marcos Springs				
B.1.1 VISPO–Voluntary suspension of irrigation pumping through economic incentives if the J-17 index well in Bexar County is at or below 635 feet msl or less on the annual trigger date of October 1. **(EAA) (Phase 1 Flow Protection Measure)**		X		
B.1.2 RWCP–Reduction of water consumption through installation of high-efficiency plumbing fixtures and economic incentive programs encouraging reduction of lost water, large-scale retro-fit, landscape irrigation using treated wastewater, and rain water harvesting. **(EAA) (Phase 1 Flow Protection Measure)**		X		
B.1.3 Use of the SAWS ASR for Springflow Protection– Through the use of leased irrigation permits and/or using water management practices under Section 1.14(h) of the Act**,** 50,000 ac-ft of the Aquifer water would be stored in the Carrizo Wilcox Aquifer for subsequent use to increase springflow during severe drought conditions. **(SAWS) (Phase 1 Flow Protection Measure)**		X		

Table 2-2. (Cont.).

COMPONENT	ALTERNATIVE			
	1: No Action	2: Proposed EARIP HCP	3: Expanded ASR with Associated Infrastructure	4: Highest CPM Pumping Restriction
B.1.4 Emergency Stage V Critical Period–Addition of a fifth stage in CPM reductions (**Activity A.1** above) when the monthly average at the J-17 Index well declines below 625 feet msl or 45/40 cfs (based on a 10- and 3-day rolling average, respectively) at Comal Springs, and when the J-27 Index well declines below 840 feet msl. **(EAA) (Phase 1 Flow Protection Measure)**		X		
B.1.5 Large ASR Constructed to Support Springflow–Up to 66,700 ac-ft of Edwards water would be pumped and stored in a newly constructed ASR facility in Wilson County to be pumped back to the Aquifer and injected southwest of New Braunfels to support springflow during drought conditions. (**SAWS)**			X	
B.2 Measures to Minimize and Mitigate Impacts to the Spring Ecosystems				
B.2.1 Measures to Reduce Impacts of Drought and Enhance Viability of the Covered Species at Comal Springs				
B.2.1.1 Native Aquatic Vegetation Restoration and Maintenance (CNB)		X	X	
B.2.1.2 Flow-Split Management in the Old and New Channels of the Comal River (CNB)		X	X	
B.2.1.3 Decaying Vegetation Removal and Dissolved Oxygen Management (CNB)		X	X	
B.2.1.4 Old Channel ERPA (CNB)		X	X	
B.2.1.5 Control of Harmful Non-Native Animal Species (CNB)		X	X	
B.2.1.6 Monitoring and Reduction of Gill Parasites (CNB)		X	X	
B.2.1.7 Native Riparian Habitat Restoration (CNB, CSM, TSU)		X	X	
B.2.1.8 Management of Public Recreational Use of the Comal Springs and the Comal River (CNB)		X	X	
B.2.2 Measures to Reduce Impacts of Drought and Enhance Viability of the Covered Species at San Marcos Springs				
B.2.2.1 Texas Wild-Rice Enhancement and Restoration (CSM, TSU)		X	X	
B.2.2.2 Management of Public Recreation at San Marcos Springs and the San Marcos River (CSM, TSU)		X	X	
B.2.2.3 Management of Aquatic Vegetation and Litter Below Sewell Park (CSM)		X	X	
B.2.2.4 Control of Non-Native Plant Species (CSM, TSU)		X	X	
B.2.2.5 Control of Harmful Non-Native and Predator Species (CSM, TSU)		X	X	
B.2.2.6 Sediment Removal Below Sewell Park (CSM)		X	X	
B.2.2.7 Designation of Permanent Access Points/Bank Stabilization (CSM)		X	X	

Table 2-2. (Cont.).

COMPONENT	ALTERNATIVE			
	1: No Action	2: Proposed EARIP HCP	3: Expanded ASR with Associated Infrastructure	4: Highest CPM Pumping Restriction
B.2.2.8 Management of Vegetation (TSU)		X	X	
B.2.2.9 Sediment Removal in Spring Lake and Sewell Park (Upper and Lower) (TSU)		X	X	
B.2.2.10 Sessom Creek Sand Bar Removal (TSU, CSM)		X	X	
B.2.2.11 Diving Classes in Spring Lake (TSU)		X	X	
B.2.2.12 Research Programs in Spring Lake (TSU)		X	X	
B.2.2.13 Management of Golf Course and Grounds (TSU)		X	X	
B.2.2.14 Boating Operations in Spring Lake and Sewell Park (TSU)		X	X	
B.2.2.15 Diversion of Surface Water–Reduction of diversions during low flows and monitoring of intake screens. (**TSU**)		X	X	
B.2.2.16 State Scientific Areas (TPWD)		X	X	
B.2.3 Additional Measures that Contribute to Recovery				
B.2.3.1 Expanded Water Quality Monitoring (EAA, CNB, CSM)		X	X	
B.2.3.2 Prohibition of Hazardous Materials Transport Across the Comal River and its Tributaries (CNB) the and San Marcos River and its Tributaries (CSM)		X	X	
B.2.3.3 Management of Household Hazardous Wastes (CNB, CSM)		X	X	
B.2.3.4 Septic System Registration and Permitting Program (CSM)		X	X	
B.2.3.5 Impervious Cover/Water Quality Protection (CNB, CSM)		X	X	
B.2.3.6 Minimizing Impacts of Contaminated Runoff (CSM)		X	X	
B.2.3.7 Reduction of Non-Native Species Introduction (CNB, CSM, TSU)		X	X	
B.2.3.8 San Marcos National Fish Hatchery and Technology Center, Uvalde National Fish Hatchery, and Inks Dam National Fish Hatchery–Refugia (EAA and the Service)		X	X	
C. ADAPTIVE MANAGEMENT				
C.1 AM Program Structure and Procedures		X	X	
C.2 Monitoring		X	X	
C.3 Core Adaptive Management Strategies		X	X	
D. PHASE II IMPLEMENTATION BASED ON PHASE I ADAPTIVE MANAGEMENT				
D.1 Research and Modeling for Phase II AMP		X		
D.2 SAWS Presumptive Action Utilizing the WRIP		X		

The No Action Alternative represents current and reasonably foreseeable future actions. Comparisons with the other alternatives are based on maximum permitted withdrawals during a repeat of the DOR conditions. Under this alternative, continuous minimum springflows protective of the listed species at Comal and San Marcos Springs would not be assured.

2.1.5.1 Alternative 1 Measures that May Have Impacts

Activity A.1: CPM Program

In 2007, Texas SB 3 directed that the EAA authorize pumping of up to 572,000 ac-ft/yr subject to adoption and enforcement of a CPM plan requiring withdrawal reductions triggered by specified aquifer and springflow levels. The resulting CPM program consists of four stepwise pumping reductions (referred to as "Stages") triggered by Comal and San Marcos springflows and aquifer levels recorded at specified "index wells" located in Bexar and Uvalde Counties. The EAA's CPM plan recognizes two interconnected but separate "pools" located at different elevations within the Edwards Aquifer, and established separate trigger levels and pumping restrictions in these distinct areas. These subdivisions within the Edwards Aquifer are generally referred to as the "San Antonio" and "Uvalde" pools. The trigger levels and pumping reductions specified by SB 3 are summarized in Table 2-3.

Table 2-3. Critical Period Triggers, Stages, and Withdrawal Reductions.[a]

COMAL SPRINGS FLOW (cfs)	SAN MARCOS SPRINGS FLOW (cfs)	INDEX WELL J-17 LEVEL (feet msl)	CRITICAL PERIOD STAGE	WITHDRAWAL REDUCTION
San Antonio Pool				
<225	<96	<660	I	20%
<200	<80	<650	II	30%
<150	N/A	<640	III	35%
<100	N/A	<630	IV	40%
Uvalde Pool				
N/A	N/A	N/A	I	N/A
N/A	N/A	<850	II	5%
N/A	N/A	<845	III	20%
N/A	N/A	<842	IV	35%

[a] A change to a critical period stage with higher withdrawal reduction percentages, including initially into Stage I for the San Antonio Pool and Stage II for the Uvalde Pool, is triggered if the 10-day average of daily springflows at the Comal Springs or the San Marcos Springs or the 10-day average of daily aquifer levels at the J-17 or J-27 Index Wells, as applicable, drop below the lowest number of any of the trigger levels for that stage. A change from any critical period stage to a critical period stage with lower withdrawal reduction percentages, including exiting from Stage I for the San Antonio Pool and Stage II for the Uvalde Pool, is triggered only when the 10-day average of daily springflows at the Comal Springs and the San Marcos Springs and the 10-day average of daily aquifer levels at the J-17 or J-27 Index Wells, as applicable, are all above the same stage trigger level.

The No Action Alternative follows the EAA's current CPM program as described above. Under SB 3, the EAA cannot currently require permitted withdrawals to total less than 340,000 ac-ft/yr. This legislation also mandates that beginning January 1, 2013, CPM reductions cannot restrict pumping to less than 320,000 ac-ft/yr unless further reductions are needed to protect federally listed threatened or endangered species to the extent required by federal law.

2.1.5.2 Measures to Minimize and Mitigate Potential Impacts

Under the No Action Alternative no ITP would be issued, and no HCP with minimization and mitigation measures would be implemented.

2.1.6 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Under Alternative 2, the Service would issue an ITP based on approval of the EARIP HCP according to the ITP issuance criteria described in Chapter 1. This alternative includes implementation of multiple measures intended to balance human water use with the conservation of listed species. Under this alternative, the Edwards Aquifer would be managed in accordance with SB 3 and associated water management programs set out in EAA's rules and associated groundwater management and strategic plans. The Applicants will implement actions to minimize and mitigate the effects of pumping, to conserve the Aquifer–dependent spring ecosystems, and contribute to the recovery of the covered species. The Applicants have committed to achieving the demand reductions necessary to reach the springflow results described in the HCP.

Alternative 2 will be implemented in two phases with specific actions occurring in each phase as described below. Phase 1 Minimization and Mitigation Measures (Category B, Table 2-2) include actions to restore and protect spring ecosystem habitats and will continue throughout the proposed permit term (Category D, Table 2-2). Phase I also prescribes actions that will be implemented during periods of severe drought. Adaptive Management Measures (Category C) will evaluate the performance of minimization and mitigation actions and adjust or modify the measures as needed to achieve the stated goals and objectives.

The Applicants identified significant uncertainty regarding the capacity of current models to determine the need for additional springflow protection measures at extremely low flow conditions for extended periods. Phase I Adaptive Management Measures include development and testing of additional hydrologic modeling to further refine the Applicants' understanding of the potential need for additional flow protections during severe drought conditions.

To demonstrate the Applicants' commitment to achieve modeled flow objectives while recognizing the uncertainty associated with the necessity of implementing additional measures, a "presumptive Phase II" action was developed. The "presumptive Phase II" measure consists of incorporating operations and management of the SAWS Water Resources Integrated Pipeline (WRIP) in conjunction with the ASR and additional CPM pumping restrictions to achieve the identified flow objectives (see Section 5.8.2 of the EARIP HCP [EARIP 2011]). The necessity for and any adjustments to the presumptive Phase II measure and will be identified and implemented through the Adaptive Management Plan (AMP) (Category C, Table 2-2) as described in the HCP (Section 5.5.2 of the EARIP HCP [EARIP 2011]).

2.1.6.1 Measures to Minimize and Mitigate Potential Impacts

Minimization and mitigation measures under Alternative 2 are listed under Category B, Table 2-2. These measures protect, enhance, or manage springflow (Category B.1) and minimize and mitigate impacts to the spring ecosystems (Category B.2) and are described below. Detailed descriptions of the measures summarized below are provided in Chapter 5 of the EARIP HCP (EARIP 2011).

Category B.1: Measures to Protect and Manage Springflow at Comal Springs and San Marcos Springs

B.1.1: Voluntary Irrigation Suspension Program Option

The Voluntary Irrigation Suspension Program Option (VISPO) will reduce Aquifer withdrawals by limiting pumping during drought conditions. Enrolled VISPO participants agree to suspend Aquifer withdrawals when identified flow and aquifer index well thresholds are triggered in exchange for annual payments. When activated during drought conditions, the VISPO program will reduce Aquifer demand by 40,000 ac-ft/yr.

B.1.2: Regional Water Conservation Program

A Regional Water Conservation Program (RWCP) will focus on improving municipal water system efficiencies throughout the region to reduce demand on the Edwards Aquifer. The RWCP consists of measures including but not limited to installation or retrofit of efficient plumbing fixtures, landscape irrigation improvement and retrofit options employing gray water, rain water harvest, and condensate collection and re-use technologies. The RWCP will reduce the need for 20,000 ac-ft/yr of pumped Aquifer water.

B.1.3: Use of the SAWS ASR for Springflow Protection

Under Alternative 2, 50,000 ac-ft of Aquifer water, secured though irrigation permit leases and/or by exercising water management practices authorized under Section 1.14(h) of the EAA Act, would be used to fill and maintain a portion of the capacity of the SAWS ASR facility. During drought periods SAWS would stop pumping Aquifer water from wells closest to the spring ecosystems and offset these reduced volumes with water stored in the ASR. This measure has the effect of maintaining consistent public water supplies while eliminating the draw-down effect of wells most proximate to the covered species and their habitats.

B.1.4: Emergency Stage V Critical Period

Under Alternative 2 the EAA will require additional CPM pumping restrictions (“Stage V”) during drought conditions. For wells within the San Antonio Pool, Stage V will be triggered by a J-17 index well monthly average below 625 feet mean sea level (msl) and springflows of 45/40 cubic feet per second (cfs) (based on a 10- and 3-day rolling averages, respectively) at Comal Springs. Areas within the Uvalde Pool will enter Stage V when the J-27 Uvalde County Index Well water level declines to 840 feet msl. Stage V will require a reduction of 44 percent of permitted pumping in both the San Antonio and Uvalde pools. The proposed CPM trigger levels and required pumping reductions under Alternative 2 are summarized in Table 2-4.

Table 2-4. New Critical Period Withdrawal Reduction Stages for the San Antonio Pool.

COMAL SPRINGS FLOW (cfs)	SAN MARCOS SPRINGS FLOW (cfs)	INDEX WELL J-17 LEVEL (feet msl)	CRITICAL PERIOD STAGE	WITHDRAWAL REDUCTION (SAN ANTONIO POOL)
<225	<96	<660	I	20%
<200	<80	<650	II	30%
<150	N/A	<640	III	35%
<100	N/A	<630	IV	40%
< 45/40	N/A	<625	V	44%

Category B.2: Measures to Minimize and Mitigate Impacts to the Spring Ecosystems

B.2.1: Measures to Reduce Impacts of Drought and Enhance Viability of the Covered Species at Comal Springs

B.2.1.1: Aquatic Habitat Restoration and Maintenance
Non-native plant species will be managed and native aquatic vegetation will be reestablished to restore aquatic habitats in the Comal River.

B.2.1.2: Flow-Split Management in the Old and New Channels of the Comal River
Flow in the Old and New Channels of the Comal River will be managed to complement ecological restoration efforts. Valves and culverts diverting flows between the two channels will be actively managed to mimic more natural flow patterns and increased seasonal variability.

B.2.1.3: Decaying Vegetation Removal and Dissolved Oxygen Management
Dissolved oxygen levels in the system will be enhanced through artificial aeration of portions of Landa Lake and removal of decaying vegetation during periods of reduced flows.

B.2.1.4: Environmental Restoration and Protection Area
A portion of the Old Channel will be designated an Environmental Restoration and Protection Area (ERPA), and will be the focus of habitat restoration actions including sediment management, non-native plant management, and reestablishment of native vegetation.

B.2.1.5: Non-Native Species Management
Non-native species will be managed to reduce the threats that they pose to the covered species or their habitats. Targeted species include, but may not be limited to, suckermouth catfishes, tilapia (*Tilapia* sp.), nutria (*Myocastor coypus*), and ramshorn snails.

B.2.1.6: Gill Parasite Monitoring and Control
Gill parasite monitoring and control measures including but not limited to non-native snail removal will be implemented.

B.2.1.7: Riparian Habitat Restoration

Riparian habitat restoration efforts to increase habitat and food sources for the Comal Springs riffle beetle will be employed. Non-native vegetation will be removed and native species representative of a healthy, functioning riparian zone will be reestablished. Riparian zones will be expanded on public lands between City Park and IH-35.

B.2.1.8: Management of Public Recreational Use of the Comal Springs and River Ecosystems

The effects of recreational use of the Comal River system will be minimized by limiting recreation on Landa Lake; restricting access to spring runs in Landa Park (with the exception of the historic wading pool area in Spring Run 2); prohibiting recreation from public lands within the Old Channel (not including Schlitterbahn operations arising from private property); and reducing litter throughout the river.

B.2.2: Measures to Reduce Impacts of Drought and Enhance Viability of the Covered Species at San Marcos Springs

B.2.2.1: Texas Wild-Rice Enhancement and Restoration

Texas wild-rice population enhancement and restoration efforts, including but not limited to propagation and public education objectives will be implemented.

B.2.2.2: Management of Public Recreation at San Marcos Springs and the San Marcos River

Recreation activities in the San Marcos River system will be managed to avoid, or minimize and mitigate impacts to the listed species and their habitats.

B.2.2.3: Management of Aquatic Vegetation and Litter below Sewell Park

To minimize and mitigate impacts on Texas wild-rice during reduced flows, stands will be monitored and drifting debris and floating vegetation will be removed when necessary. Efforts to reduce and remove litter from the San Marcos River will be implemented.

B.2.2.4: Aquatic Habitat Restoration and Maintenance

San Marcos River aquatic habitats from Spring Lake downstream to the city limits will be the focus of restoration efforts including removal of non-native plants and reestablishment of native aquatic vegetation.

B.2.2.5: Control of Harmful Non-Native and Predator Species

Non-native species will be managed to reduce the threats that they pose to listed species or their habitats in the San Marcos River system. Targeted species include, but may not be limited to, domestic ducks, geese, nutria, suckermouth catfishes, and tilapia.

B.2.2.6: Sediment Removal

Sediment removal downstream of Sewell Park will focus on restoring habitat for Texas wild-rice.

B.2.2.7: Designation of Permanent Access Point/Bank Stabilization

Permanent access points to facilitate recreational access to the river and minimize negative impacts will be established at Dog Beach, Lion's Club Tube Rental, Bicentennial Park, Wildlife Annex, and other areas as necessary. Bank stabilization projects within the city limits will reduce erosion at City Park, Hopkins Street Underpass, Bicentennial Park, Rio Vista Park, Ramon Lucio Park, and at the Cheatham Street underpass.

B.2.2.8: Vegetation Management
Submerged and floating vegetation in Spring Lake and in the San Marcos River from Sewell Park to City Park will be managed to minimize impacts to stands of Texas wild-rice.

B.2.2.9: Sediment Removal in Spring Lake and Sewell Park
Sediment will be removed from Spring Lake and upper and lower Sewell Park to improve Texas wild-rice habitat.

B.2.2.10: Sand Bar Removal at Sessom Creek
The Applicants will develop a proposal to remove the sand bar at the confluence of Sessom Creek and the San Marcos River that will minimize and mitigate impacts to listed species. The Applicants will submit the proposal for review though the Adaptive Management Process and implement the approved plan.

B.2.2.11: Diving Classes in Spring Lake
Specific locations within Spring Lake identified to minimize impacts on listed species will be designated for limited diving classes and training. Access to the designated “Dive Training Area” will require training and authorization as described in the HCP.

B.2.2.12: Research Programs in Spring Lake
All proposals to conduct research in Spring Lake will be reviewed by the TSU River Systems Institute to ensure that listed species or their habitat will not be affected. The TSU River Systems Institute will consult with the Service regarding any projects that may affect species or designated critical habitats covered under the HCP.

B.2.2.13: Management of Golf Course and Grounds
An Integrated Pest Management (IPM) plan created to avoid or minimize and mitigate impacts to aquatic species will be incorporated into the TSU Golf Course management plan, and will address use of pesticides, herbicides, and fertilizers. Any pesticides must be applied by licensed applicators in accordance with label instructions. A riparian buffer zone will be maintained along the banks of Spring Lake and the slough to minimize runoff, erosion, and litter impacts in the waterway. Landscaping on the golf course and the facility grounds will utilize native plant species. Chemicals will be stored in compliance with Texas Structural Pesticide regulations at a location that minimizes the risk of environmental contamination.

B.2.2.14: Boating Activities in Spring Lake and Sewell Park
Boating activities will minimize impacts to covered species habitat in Spring Lake and Sewell Park through restricted access and use limitations. All boating activities at Spring Lake are restricted to eclectic powered or human-powered craft.

B.2.2.15: Surface Water Diversion
Surface water diversion intake pump screens will be monitored to detect entrapment or harm to covered species. Screens or intake pumps may be modified to avoid or minimize any incidental take from the operation of the diversions. Diversion of surface water will be reduced or

suspended during low flow periods by TSU, as described in Section 5.4.6 of the EARIP HCP (EARIP 2011).

B.2.2.16: State Scientific Areas

To reduce the impacts of recreational activities on habitat for covered species, the Texas Parks and Wildlife Department (TPWD) has proposed creation of a State Scientific Area in the San Marcos River. This designation would allow the TPWD to limit recreation during low flow conditions in river stretches identified as habitat for covered species.

B.2.3: Additional Measures that Contribute to Recovery

B.2.3.1: Expanded Water Quality Monitoring

Water quality monitoring efforts will be expanded to include storm water, groundwater, and surface water sites near Landa Lake and the Comal River, and Spring Lake and the San Marcos River. Focus areas include, but are not limited to, areas of impervious cover, golf courses, pool operations, and industrial runoff areas.

B.2.3.2: Prohibition of Hazardous Materials Transport across the Comal River and Its Tributaries and the San Marcos River and its Tributaries

The Applicants will coordinate with and support Texas Department of Transportation (TxDOT) efforts to prohibit or minimize the transport of hazardous materials on routes that cross the Comal and San Marcos Rivers and their tributaries.

B.2.3.3: Management of Household Hazardous Wastes

Expanded hazardous household waste collection and disposal programs will be implemented and maintained by CNB and CSM to reduce the potential for negative water quality impacts from these sources.

B.2.3.4: Septic System Registration and Permitting Program

The CSM will implement aerobic and anaerobic septic system registration, evaluation, and permitting programs to address nutrients and pollutants and minimize the potential of entering the San Marcos Springs ecosystem.

B.2.3.5: Impervious Cover/Water Quality Protection

The CNB will establish a program to limit impervious cover and provide incentives to reduce existing impervious cover on public and private property. The CSM will establish a program to protect water quality and reduce the impacts of impervious cover (such as through Low Impact Development [LID] practices). Both CNB and CSM will also establish criteria and incentives for participation in these programs.

B.2.3.6: Minimizing Impacts of Contaminated Runoff

The CSM will construct sedimentation ponds to reduce contaminated runoff entering the river.

B.2.3.7: Reduction of Non-Native Species Introduction

The Applicants will initiate efforts to reduce or eliminate introductions of non-native species to the Comal and San Marcos River systems. The CNB will prohibit by ordinance introductions of aquatic organisms and prohibited bait species into the Comal River, while the CSM will similarly work to reduce the introductions due to the practice of dumping unwanted aquarium specimens. Efforts may include, but are not limited to partnering with the River Systems Institute, TSU, and local citizen groups to distribute educational materials.

B.2.3.8: San Marcos National Fish Hatchery and Training Center, Uvalde National Fish Hatchery, and Inks Dam National Fish Hatchery

The Applicants will support and contribute to the operation and maintenance of a series of off-site refugia at the Service's San Marcos National Fish Hatchery and Technology Center, Uvalde National Fish Hatchery, and Inks Dam National Fish Hatchery facilities.

2.1.6.2 Adaptive Management and Phase II Implementation

The Adaptive Management (AM) Program (Category C, Table 2-2) will play a major role in Alternative 2. Key components of the AM Program include: AM Program Structure and Procedures (Category C.1); Monitoring (Category C.2); and Core Adaptive Management Strategies (Category C.3). Complete and detailed AMP measures are fully described in Chapter 6 of the EARIP HCP (EARIP 2011). The AM Program will be administered by a Program Manager employed by the EAA to direct the program with guidance and oversight provided by several committees: 1) the Adaptive Management Steering Committee; 2) Adaptive Management Stakeholder Committee; and 3) Adaptive Management Science Committee.

Alternative 2 describes initiation of Phase II activities, should they be deemed necessary, no later than year 8 of the proposed 15-year permit term (described in Section 5.5.2 of the EARIP HCP [EARIP 2011]). The AM Program (described in Chapter 6 of the EARIP HCP [EARIP 2011]) will guide Phase II activities (Category D, Table 2-2) intended to improve or maintain springflows at Comal and San Marcos Springs.

The presumptive Phase II action incorporates use of the SAWS WRIP, scheduled to be completed by 2020, in conjunction with ASR operations and an additional 3 percent pumping reduction under CPM Stage V to achieve flow objectives during severe drought conditions (see Section 5.8.2 of the EARIP HCP [EARIP 2011]). The WRIP consists of water transmission pipelines and pump stations that link brackish desalination and ASR facilities in southern Bexar County with western and northwestern portions of the county. When needed during drought conditions, up to 40 percent of the WRIP distribution system capacity will be made available to meet SAWS customer water needs in exchange for equivalent northwest Bexar County Edwards Aquifer well field pumping reductions. This offset will allow Edwards Aquifer water in northwest Bexar County to continue to flow to Comal and San Marcos, thereby supporting springflows at these locations while eliminating conflicts with customer water demand.

In the event that additional springflow protection measures are required that cannot be met by management of the WRIP phase II actions, additional Stage V CPM pumping cuts or similarly protective measures will be implemented by the Applicants (see Section 5.5.2 of the EARIP HCP [EARIP 2011]).

2.1.6.3 Implementing Roles of the EARIP HCP Participants

The Applicants are each a responsible party to an IA that will contractually obligate the performance of activities as specified in the HCP and the ITP.

2.1.6.4 EARIP HCP Funding

Implementation of Alternative 2 over the 15-year life of the proposed HCP is estimated to total about $261.2 million. Funding will be secured from a number of sources including EAA aquifer management fees and direct contributions from various parties. The Applicants may choose to pursue legislative authority to seek a regional sales tax to further distribute costs throughout the affected region. Detailed descriptions of costs and funding strategies are provided in Chapter 7 of the EARIP HCP (EARIP 2011).

2.1.7 Alternative 3: Expanded ASR with Associated Infrastructure

Under Alternative 3, the Service would issue an ITP based on submission and approval of an HCP. This alternative relies on expanded ASR capacity in combination with additional CPM reductions to maintain springflow during drought conditions (Measures A.2, A.4, and A.5, Table 2-2).

The distinguishing components of Alternative 3 include (see Table 2-2):

- Activity A.2 - CPM restrictions requiring pumping reductions of 50 percent to no more than 286,000 ac-ft/yr; and,

- Activity A.4 - Development and operation of an ASR facility and associated infrastructure for maintenance of springflows.

The large ASR would provide up to 66,700 ac-ft/yr of Aquifer water from the lease or purchase of Edwards irrigation rights in Uvalde, Medina, and Bexar Counties. Water would be pumped from existing Aquifer wells in northeastern Bexar County. Pumping for the ASR would be subject to CPM rules allowing the water supply to range from 40,000 (if pumped during Stage IV CPM) to 66,700 ac-ft/yr (if pumped without CPM reductions). The pumped water would be conveyed by a newly constructed water transmission pipeline to be stored in an ASR facility in the vicinity of Cibolo Creek in northwest Wilson County. When needed for springflow maintenance, the stored water would be conveyed through the constructed water transmission pipeline to recharge facilities located between Cibolo Creek and Comal Springs. Modeling simulations conducted by HDR indicate injection wells located southwest of New Braunfels in Comal County would be required to maintain springflow at Comal Springs.

2.1.7.1 Measures to Minimize and Mitigate Potential Impacts

Hydrologic modeling indicates that Alternative 3 would maintain springflows at Comal and San Marcos during a repeat of DOR-like conditions. Minimization and mitigation measures (listed in Table 2-2) similar to those described in Alternative 2 include strategies to reduce impacts to the spring ecosystems as aquifer levels decline; actions to protect water quality in the contributing, recharge, and artesian zones of the Edwards Aquifer; and direct restoration, enhancement, and protection of endangered species habitats within and near the spring ecosystems. In contrast to Alternative 2, Alternative 3 substitutes measures B.1.1 through B.1.4 with the construction and use of a large ASR (Measure B.1.5, Table 2-2). Alternative 3 would secure additional irrigation rights from pumpers in Bexar, Medina, and Uvalde Counties to be stored in the new ASR facility. Bexar County wells would also contribute between 40,000 and 66,700 ac-ft/yr (if pumped during CPM Stage IV drought conditions, or during non-drought periods, respectively) for storage in the ASR facility. Transmission pipelines would convey stored water during drought conditions to recharge facilities to increase the volume of water available as springflow.

2.1.7.2 Phase II Implementation

Phase II Implementation Measures identified for Alternative 3 are the same as those described for Alternative 2 (see Category D, Table 2-2).

2.1.7.3 Implementing Roles of the HCP Participants

For Alternative 3, the roles of the plan participants would be the same as those described for Alternative 2.

2.1.7.4 HCP Funding

Estimated costs for implementation of measures under Alternative 3 are given in Table 2-5.

Table 2-5. Costs for Implementation Measures under Alternative 3.

ANNUAL COSTS	15-YEAR COSTS
Annual Costs If Water Is Purchased for the ASR	
$56.2 to $72.8 Million (HDR 2011) x 15 Years	$843 Million to $1.09 Billion
15-Year Cost for Minimization and Mitigation Category B.2 Measures	$71.6 Million
TOTAL ESTIMATED COST	**$914.6 MILLION TO $1.16 BILLION**
Annual Costs If Water Is Leased for the ASR	
$24.5 to $41.7 Million (HDR 2011) x 15 Years	$367.5 Million to $625.5 Million
15-Year Cost for Minimization and Mitigation Category B.2 Measures	$71.6 Million
TOTAL ESTIMATED COST	**$439 MILLION TO $697 MILLION**

Funding associated with Alternative 3 would be secured through a combination of contributions from permit Applicants and increases in aquifer pumping fees. The Applicants might choose to seek legislative permission to pursue a regional sales tax as noted above for Alternative 2.

2.1.8 Alternative 4: Highest CPM Pumping Restriction

Under Alternative 4, an ITP would not be necessary because springflows would be assured at Comal and San Marcos Springs, thus avoiding take of covered species during drought conditions. This alternative would limit the amount of water pumped from the Edwards Aquifer in order to assure the long-term survival of the covered species. Under this alternative a single CPM stage requiring an 85 percent reduction in pumping year to a maximum 85,800 ac-ft/yr would be implemented during drought conditions (Activity A.3, Table 2-2).

Under Alternative 4, substantially less groundwater would be available for human use as pumping reductions during CPM would be driven by the requirement to maintain springflow levels at Comal and San Marcos Springs to prevent harm to the covered species. Modeling indicates that this alternative would assure recommended minimum flows for Comal and San Marcos Springs (EARIP EAA 2009) during a repeat of DOR conditions.

2.1.8.1 Measures to Minimize and Mitigate Potential Impacts

Alternative 4 achieves springflow protection through region-wide reduction in aquifer pumping. Because springflows at Comal and San Marcos Springs would be assured during drought conditions under this alternative, the risk of adverse impacts constituting take would be reduced. This alternative incorporates the fewest minimization and mitigation measures (Table 2-2) resulting in the lowest initial implementation costs.

Alternative 4, Activity A.3 (CPM) would rely on a single stage CPM reduction of 85 percent that would be triggered if: flows at Comal Springs fall below 225 cfs; San Marcos Springs flow declines below 96 cfs; J-17 Index well drops below 665 feet msl; or J-27 Index Well falls below 865 feet msl.

2.1.8.2 Funding

Funding would be limited to operational and administrative costs to regulate and enforce pumping restrictions as a part of the operational budget of the EAA, and would be provided through EAA pumping fee collections.

2.2 ALTERNATIVES SUMMARY

A summary of the four alternatives is provided in Table 2-6. Impacts from each of the four alternatives are discussed in Chapter 4.

Table 2-6. Summary of EIS Alternatives.

ISSUE	ALTERNATIVE 1: NO ACTION	ALTERNATIVE 2: PROPOSED EARIP HCP	ALTERNATIVE 3: EXPANDED ASR WITH ASSOCIATED INFRASTRUCTURE	ALTERNATIVE 4: HIGHEST CPM PUMPING RESTRICTION
Plan (Permit) Boundaries	No Regional ITP would be issued therefore no regional ITP boundaries would be created.	See Figure 2-1.	Same as Alternative 2.	No Regional ITP would be issued resulting in no regional ITP boundaries.
Management Structure	No regional EARIP HCP; the Applicants and individual pumpers subject to violation of the ESA; pumpers could seek individual ITPs; no mitigation measures to improve the likelihood for species survival in the event of reduced or no springflows.	The Applicants would pursue operations and activities under coverage and protection of a regional ITP; a maximum number of minimization and mitigation measures would be implemented under an Implementation Agreement with the Service to assure species protection.	The EAA would issue individual pumping permits under a regional ITP; fewer mitigation measures needed than Alternative 2 due to higher CPM reduction.	Pumping would be reduced during single stage CPM by 85% to assure minimum springflows established by the EARIP Science Subcommittee.
Funding	Funding not required as there would be no protection measures directed to a regional HCP.	$261.2 million over the life of the HCP.	$439 million to $1.16 billion over the life of the HCP based on variables in leasing vs. purchasing water rights for the large ASR.	Funding would be limited to operational and administrative costs to regulate and enforce pumping restrictions as a part of the operational budget of the EAA. No ITP would be issued, and no HCP funding would be required.
Pumping Levels and CPM Percent Reductions	Aquifer withdrawals up to 572,000 ac-ft/yr allowed under regular permits with four stage CPM (20%, 30%, 35%, 40%) pumping reductions implemented during each declared drought stage to a withdrawal limit of 320,000 ac-ft/yr at Stage IV by 2013.	Aquifer withdrawals up to 572,000 ac-ft/yr allowed under regular permits with a five stage CPM (20%, 30%, 35%, 40%, 44–47%) pumping reductions implemented during each declared drought stage to a withdrawal limit of 320,000 ac-ft/yr.	Aquifer withdrawals up to 572,000 ac-ft/yr allowed under regular permits with four stage CPM (20%, 30%, 35%, 50%) pumping reductions implemented during each declared drought stage to a withdrawal limit of 286,000 ac-ft/yr.	Aquifer withdrawals up to 572,000 ac-ft/yr allowed under regular permits but with an 85% single stage CPM reduction implemented during Stage I of a declared drought resulting in withdrawals limit of 85,800 ac-ft/yr.

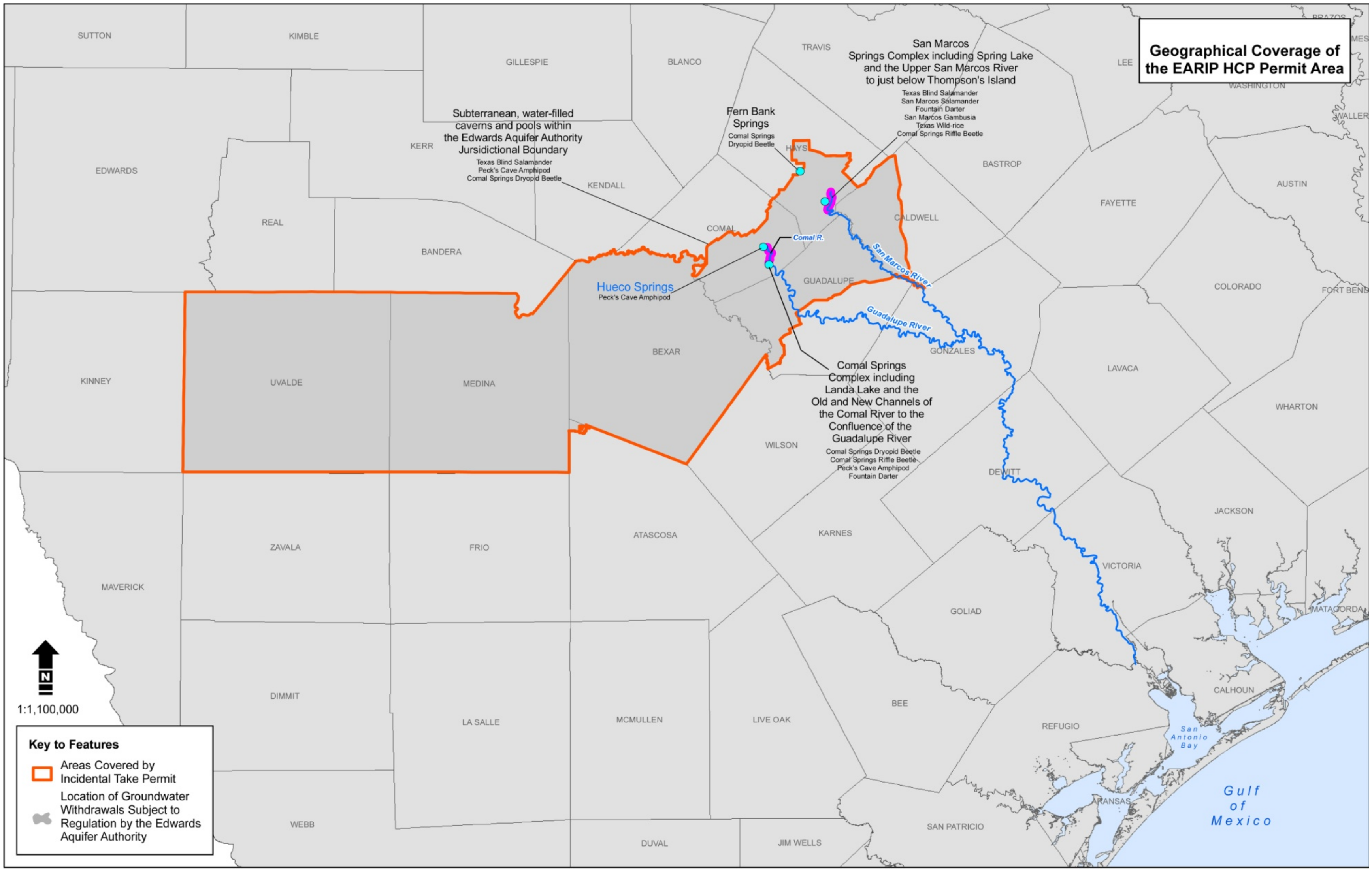


Figure 2-1. Geographical Coverage of the EARIP HCP Permit Area (Not to Scale).

CHAPTER 3

AFFECTED ENVIRONMENT

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
AM – Adaptive Management
AMP – Adaptive Management Program
ASR – aquifer storage and recovery
BMP(s) – best management practice(s)
BWL – Bad Water Line
CAA – Clean Air Act
CCSP – U.S. Climate Change Science Program
CEQ – Council on Environmental Quality
CFR – Code of Federal Regulations
CFU – colony-forming units
CNB – City of New Braunfels
CPM – Critical Period Management
CSM – City of San Marcos
DEIS – Draft Environmental Impact Statement
DHHS – Department of Health and Human Services
DOR – drought of record
EAA – Edwards Aquifer Authority (the Authority)
EARIP – Edwards Aquifer Recovery Implementation Program
EDF – Environmental Defense Fund
EIS – environmental impact statement
ERPA – Environmental Restoration and Protection Area
ESA – Endangered Species Act
FR – Federal Register
GBRA – Guadalupe-Blanco River Authority
GCSNA – Government Canyon State Natural Area
GHG – Green House Gas
HCP – Habitat Conservation Plan
IA – Implementing Agreement
IH – Interstate Highway
IPCC – Intergovernmental Panel on Climate Change
IPM – Integrated Pest Management
ISD – Independent School District
ITP – Incidental Take Permit
LID – Low Impact Development
MCLs – maximum contaminant levels
MSA – Metropolitan Statistical Area
msl – mean sea level
NAAQS – National Ambient Air Quality Standards
NCDC – U.S. Historical Climate Network of the National Climatic Data Center
NEPA – National Environmental Policy Act
NGOs – non-governmental organizations
NHPA – National Historic Preservation Act
NRHP – National Register of Historic Places
NOI – Notice of Intent
NRI – Nationwide Rivers Inventory
OCR – off-channel reservoir
PCBs – Polychlorinated Biphenyls
PCE – tetrachloroethene
RM – Ranch to Market Road
RWCP – Regional Water Conservation Program
SALs – State Archeological Landmarks
SAWS – San Antonio Water System
SB 3 – Senate Bill 3
SCTRWPG – South Central Texas Regional Water Planning Group
SCUBA – Self-contained Underwater Breathing Apparatus
Service – U.S. Fish and Wildlife Service
SH –Texas State Highway
SHPO – State Historic Preservation Officer
SSA – Sole Source Aquifer
STIR – State of Texas Integrated Report
SVOCs – Semi-Volatile Organic Compounds
TAG – Technical Advisory Group
TCE – trichloroethene
TCEQ – Texas Commission on Environmental Quality
TDS – total dissolved solids
THC – Texas Historic Commission
TPWD – Texas Parks and Wildlife Department
TSDC – Texas State Data Center
TSU – Texas State University
TSWQS – Texas Surface Water Quality Standards
TWC – Texas Workforce Commission
TWDB – Texas Water Development Board
TxDOT – Texas Department of Transportation
US – U.S. Route
USACE – U.S. Army Corps of Engineers
USDI – U.S. Department of the Interior
USEPA – U.S. Environmental Protection Agency
VISPO – Voluntary Irrigation Suspension Program Option
VOCs – Volatile Organic Compounds
WORD – Water Oriented Recreation District of Comal County
WRIP – Water Resources Integrated Pipeline

3.0 AFFECTED ENVIRONMENT

3.1 PHYSICAL ENVIRONMENT

3.1.1 Climate

3.1.1.1 Regional Description

The prevailing climate ranges from subtropical steppe in the westernmost portions of the study area through subtropical sub-humid to subtropical humid in the easternmost portions of the region (Figure 3-1) (Larkin and Bomar 1983). Latitude, elevation, and proximity to the Gulf of Mexico influence the climate of the region.

The average annual temperature in the study area is about 68° F (20° C), with average annual high temperatures of 78–84° F (26–29° C) (Figure 3-2). Summertime temperatures commonly exceed 100° F (38° C) with average monthly high temperatures ranging from 90° F (32° C) to 97° F (36° C) (Larkin and Bomar 1983). Winters are generally mild with average monthly low temperatures ranging from about 36° F (2° C) to 60° F (16° C). Temperatures fall below freezing about 20 days each year (NOAA 2010).

Average annual precipitation within the region varies from about 20 inches (51 centimeters [cm]) in western Kinney County to about 40 inches (102 cm) in Calhoun County (Figure 3-3). May and September typically record the highest rainfall amounts each year.

The flooding potential within study area is among the highest in the United States. This is due to the area's high runoff rates and proximity to a barometric convergence zone where high and low pressure air masses collide (Caran and Baker 1986).

Rainfall runoff and absorption rates are a function of landscape physiography and soil type. Narrow valleys with sparsely vegetated slopes along the Balcones Escarpment are typically overlain with thin upland soils or exposed bedrock resulting in rapid runoff and low absorption rates (see Figure 3-4). Gently sloping landforms south and east of the escarpment reduce rainfall and stormwater runoff velocities, though soils with low-infiltration capacities in this area limit absorption rates (Patton and Baker 1976, Caran and Baker 1986).

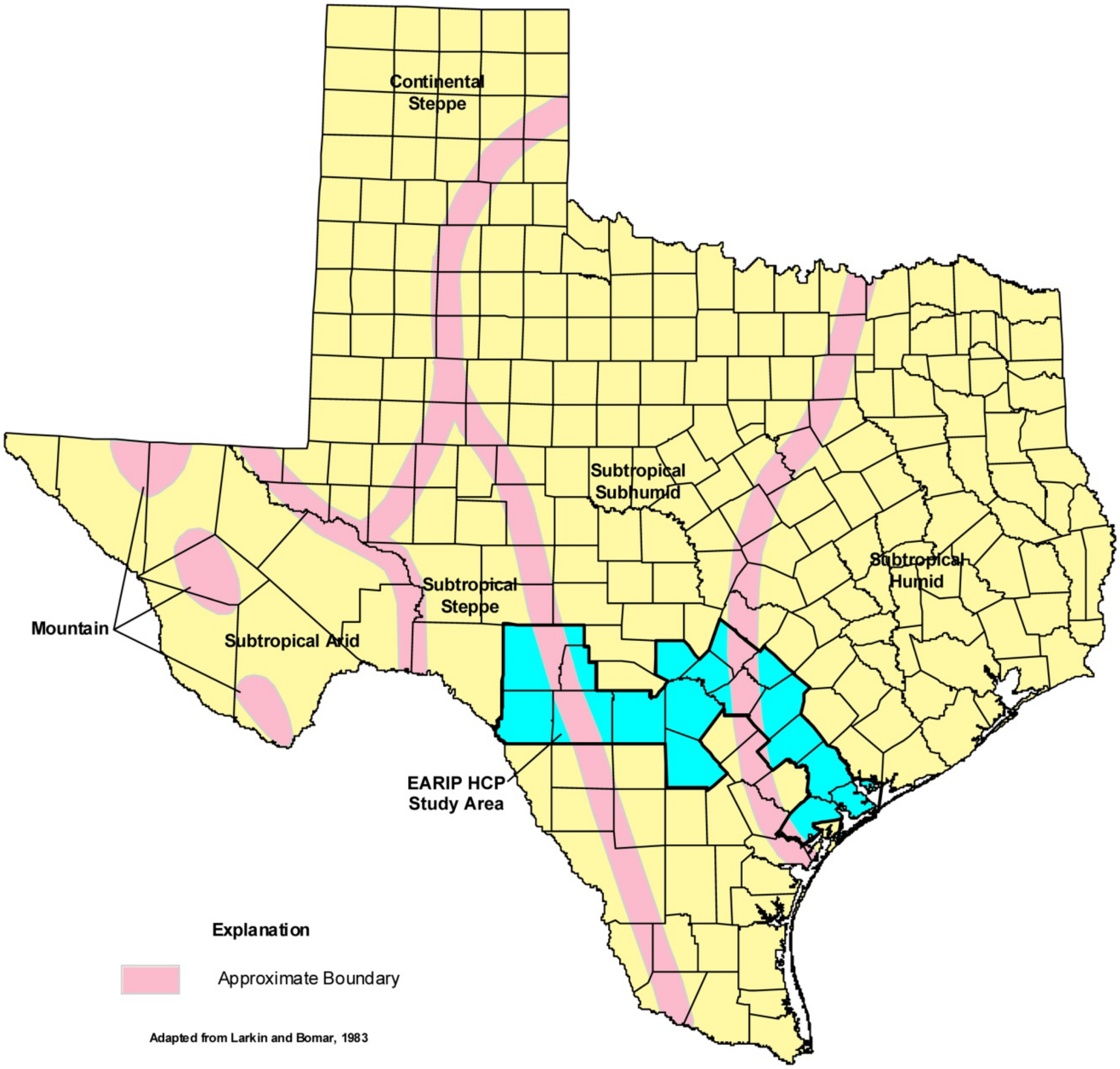


Figure 3-1. Climatic Regions of Texas (Not to Scale).

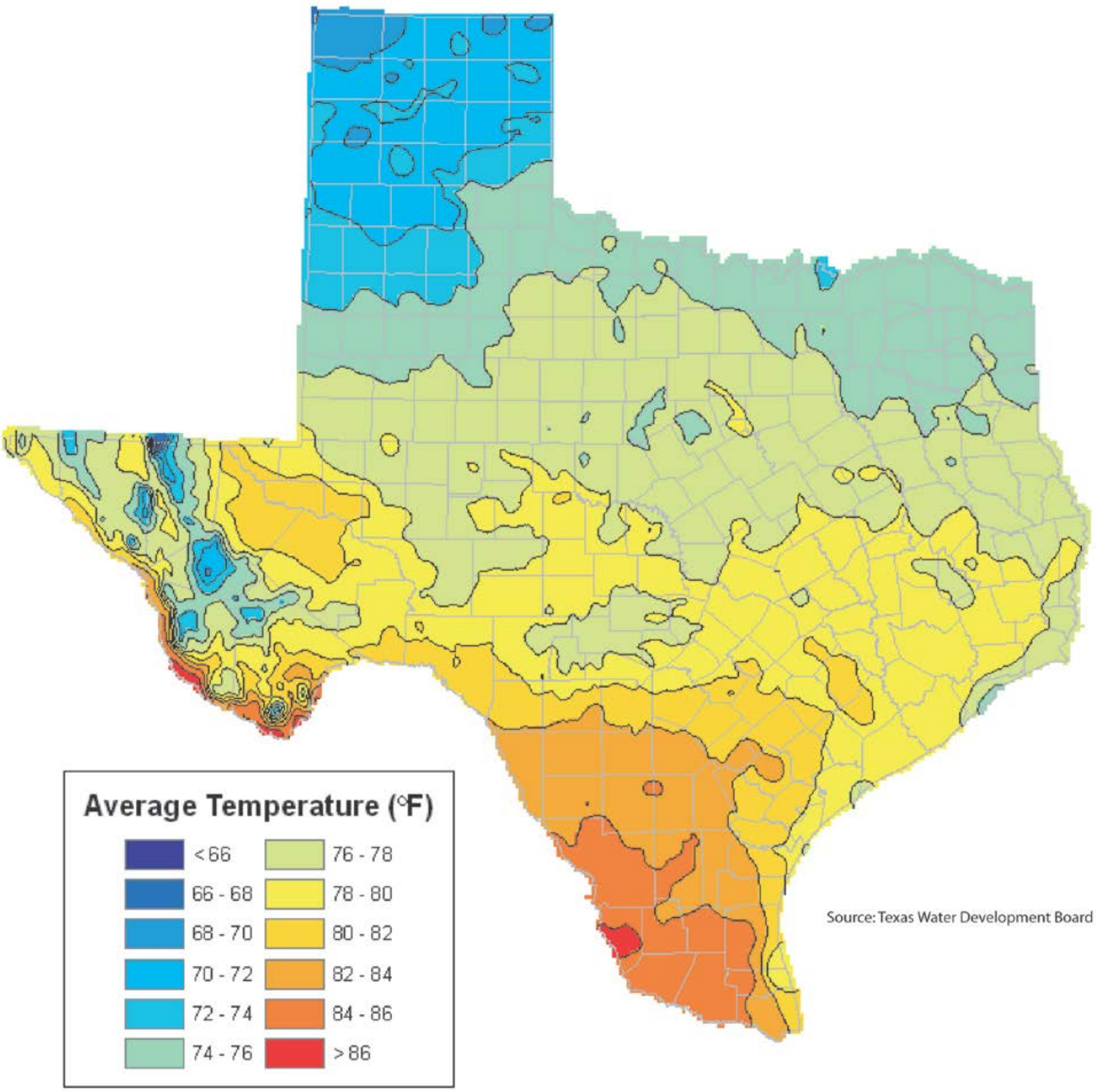


Figure 3-2. Average Annual High Temperature, 1971–2000 (Not to Scale).

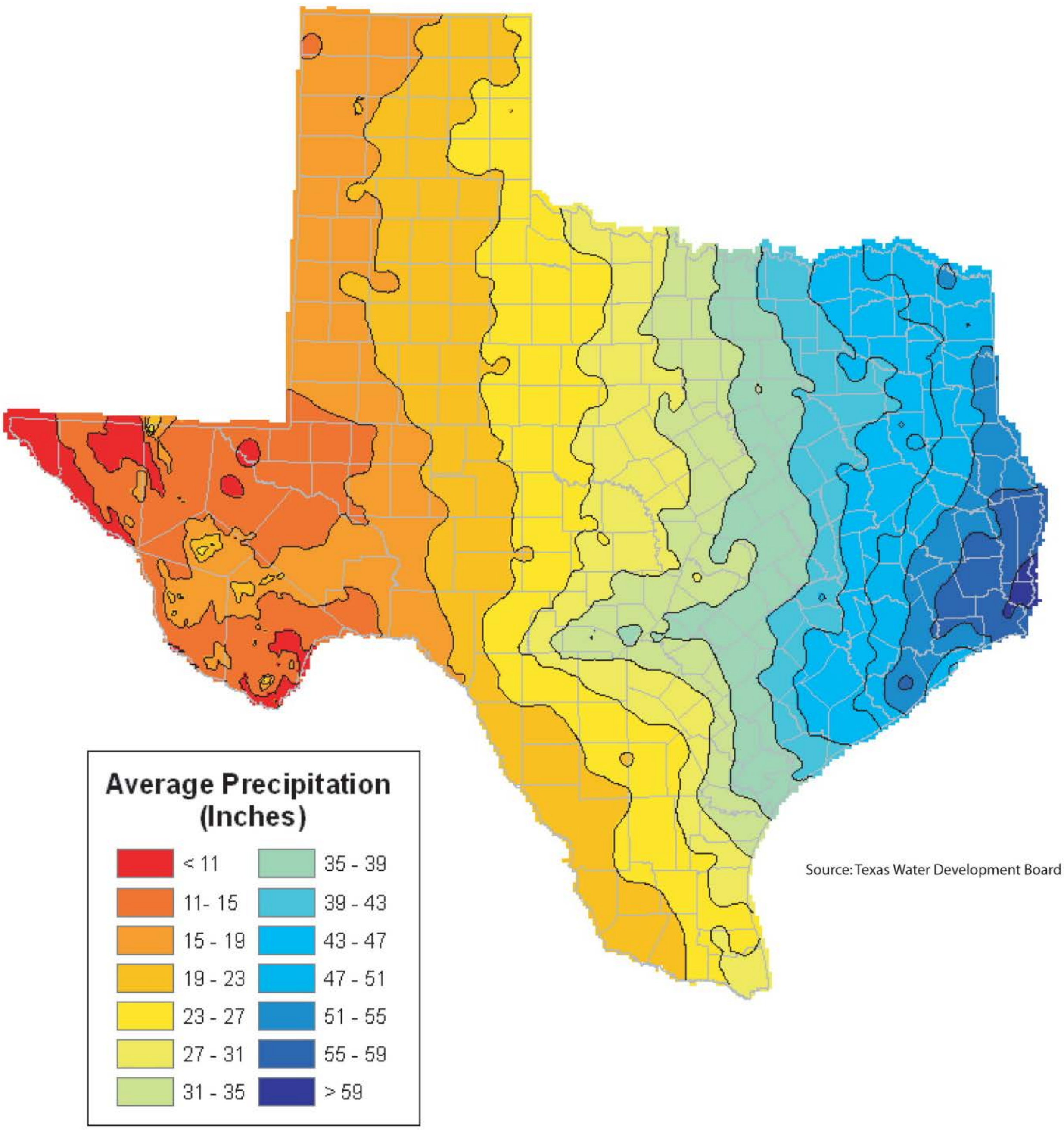


Figure 3-3. Average Annual Precipitation in Inches, 1971–2000 (Not to Scale).

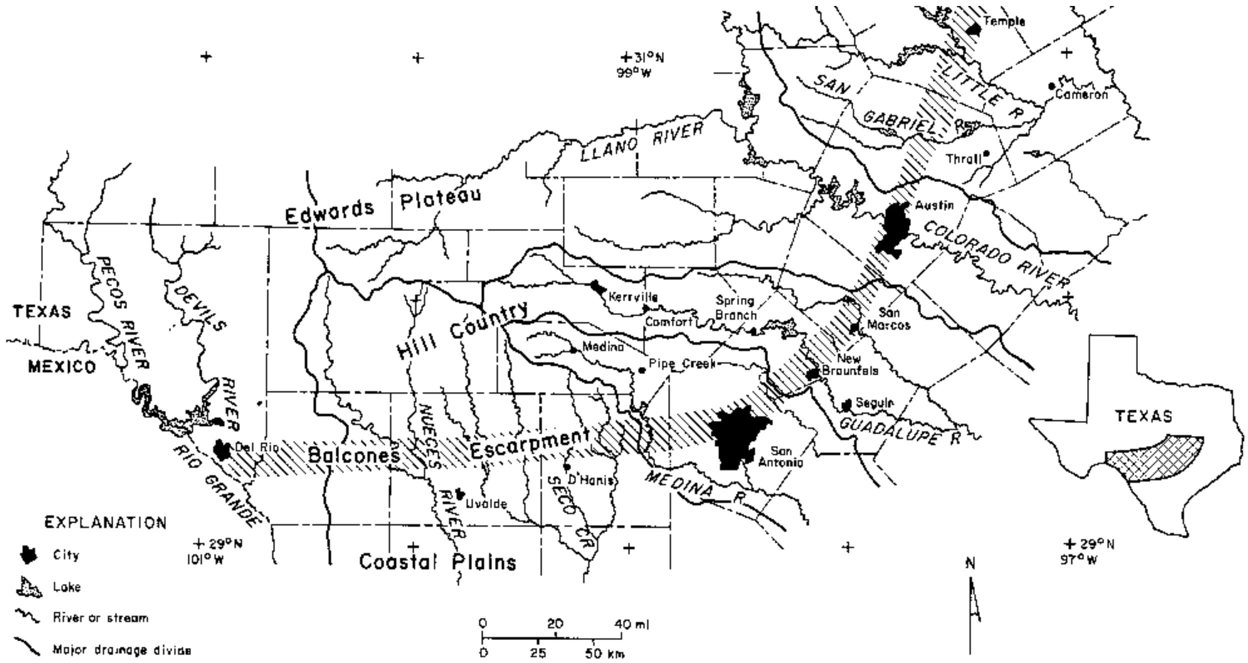


Figure 3-4. Regional Map of the Balcones Escarpment in Central Texas (Abbott and Woodruff 1986).

Tropical storms and hurricanes impact the Texas coastline an average of 0.67 times per year and can produce heavy rainfall events throughout the region as they move inland from the Gulf of Mexico (Brown et al. 1974, Patton and Baker 1976). As these moisture-laden tropical air masses move inland and are forced to rise at the Balcones Escarpment, they often mix with low pressure fronts from the north or west. The resulting severe storms often generate high winds, rainfall, hail, and tornadoes. Thunderstorms in the region often generate flash flooding events (Caran and Baker 1986).

3.1.1.2 Frequency of Droughts

Droughts result from lower than normal rainfall. Drought-like conditions may continue during average or above average rainfall periods if water use limits water availability. Average annual rainfall totals are therefore a poor measure of drought occurrence and tend to mask the duration and intensity of drought conditions.

Though droughts are common in the region they are usually short in duration and intensity (Riggio et al. 1987). The most severe drought in the study area since precipitation record keeping began is the 6-year DOR event that occurred from 1951 through 1956.

Researchers have attempted to determine precipitation patterns prior to the historic record in order to compare the severity and frequency of DOR-like events with previous droughts. One researcher found that droughts of various lengths occurred 40 times between the years 1700 and 1979 (Mauldin 2003). Most droughts lasted for less than 1 year, and the average drought lasted for 1.8 years. Of the four droughts that lasted for 3 years or more, three occurred in the 1700s and the fourth was the 6-year-long DOR. Though six droughts were found to be more intense for shorter durations, the DOR was determined to be the most intense long-term drought during the studied period (Mauldin 2003). Other research concluded that the DOR was the most prolonged period of sustained drought for a 347-year study period (Therrell 2000).

3.1.1.3 Climate Change

The CEQ provided draft guidance regarding consideration of climate change in NEPA documents (CEQ 2010). This section describes the possible effects of climate change on the study area. The summaries below represent reasonably foreseeable climate change impacts that could be expected to occur within the study area over the duration of the alternatives considered.

The Intergovernmental Panel on Climate Change (IPCC) stated that "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level" (IPCC 2007a). The U.S. Climate Change Science Program (CCSP) also concluded that the global climate is changing and that temperature increases, increasing carbon dioxide (CO_2) levels, and altered patterns of precipitation are very likely already affecting U.S. water resources, agriculture, land resources, biodiversity, and human health, among other things (Backlund et al. 2008, NSTC 2008). The CCSP also concluded that it is very likely that climate change will continue to have significant effects on these resources over the next few decades and beyond.

Regional data for North America confirm that warming has occurred throughout most of the United States. The U.S. Historical Climate Network of the National Climatic Data Center (NCDC) found that for 8 of 11 climate regions, average temperatures increased more than 1.1° F (0.6° C) between 1901 and 2005 (NOAA 2007). Though data for 1895 to 2011 indicate that Texas temperatures have remained stable, this timeframe includes periods of anomalously cold temperatures and steadily climbing temperatures since the 1980s (NCDC 2010). In the past 10–15 years temperatures have regularly reached and exceeded those recorded for the same periods in the early twentieth century.

Data from the NCDC indicate a precipitation trend of -0.02 inch (-0.05 cm) per decade from 1895 through 2011 (NCDC 2010). The Texas State Climatologist, however, has reported regionally variable but generally increasing precipitation trends throughout the state from 1900 to 2008 with increasing seasonal precipitation during the December–March and August–November periods over the last 30 years (Nielson-Gammon 2011).

Temperature Projections

The IPCC *Special Report on Emission Scenarios* describes temperature increases that vary by emissions scenario of 3.2 to 7.2° F (1.8 to 4.0° C) in years 2090 to 2099 over 1980 to 1999 recorded data (IPCC 2000). Mid-century climactic change projections (for years 2046 to 2065) also vary by emissions scenario, with average warming of 2.3, 3.2, and 3.1° F (1.3, 1.8, and 1.7° C) for low, medium, and high emissions, respectively (Meehl et al. 2007). Projected temperature trends for Texas based on the medium emissions scenario show an increase of about 1.0° F (0.5° C) for the period 2000–2019, 2.0° F (1.1° C) for 2020–2093, and 4° F (2.2° C) for 2040–2059 (Nielson-Gammon 2011).

Precipitation Projections

Modeling projects global mean precipitation increases with a warming climate, but with spatial and seasonal variations (Meehl et al. 2007). Other conclusions provided by recent climate studies include:

- A widespread increase in annual precipitation is projected over most of the North American continent except the southern and southwestern part of the United States and over Mexico (NSTC 2008).

- Increased precipitation will not necessarily result in more water availability for biological and ecological processes; as higher temperatures will increase evaporative loss and possible reductions in soil moisture and stream flows (Backlund et al. 2008).

- One analysis of projected changes in annual runoff shows a great deal of variability over Texas (Milly et al. 2005). About two thirds of the atmosphere–ocean general circulation models project 5 to 10 percent precipitation decreases in much of the state. Remaining models project runoff increases. Reliance on annual averages, however, may mask important seasonal trends such as reduced summer runoff during periods of high temperature and evapotranspiration rates.

Climate Wizard (www.climatechange.org) is an on-line tool that allows users to access climate change information and visualize potential impacts. The site uses IPCC model results to project future changes over low, medium and high emissions scenarios. Projected mid-century (2050s) precipitation trends were examined for Texas using the ensemble average (median prediction) of all the models under medium and high emission scenarios (Figure 3-5). For South Central Texas the medium emission scenario projects small precipitation decreases while the high emission scenario indicates small precipitation increases (Maurer et al. 2007). It has been pointed out that most future climate projections of Texas precipitation changes by mid-century are lower than observed variations over the past century (Nielson-Gammon 2011). Though climate science is improving rapidly, conflicting models and the complexity of global climate influences make it difficult to project future precipitation regimes over the Edwards Aquifer with any certainty at this time.

Sea Level Rise Projections

Sea level rise could affect portions of the study area along the Gulf of Mexico. The projected rate of sea level rise off the Gulf Coast is anticipated to be higher than the global average (NSTC 2008). During the twentieth century, sea level rose at a rate of 0.1 inch (1.8 millimeters) per year at Galveston, Texas (CCSP 2008). Galveston is located about 140 mi (225 km) northeast of the nearest coastal town in the study area, Port Lavaca. Changes due to sea level rise at Port Lavaca can reasonably be expected to be similar to those projected for Galveston. Projected sea level rise at Galveston ranges from 0.44 to 1.05 feet (0.13 to 0.32 meters [m]) by 2050 depending on the model and the emission scenario tested. By 2100, the projections range from 0.80 to 1.79 feet (0.24 to 0.55 m). These modeling results do not include rapid changes in ice loss from Greenland or Antarctica that could more than double the rate of sea level rise recorded over the past century.

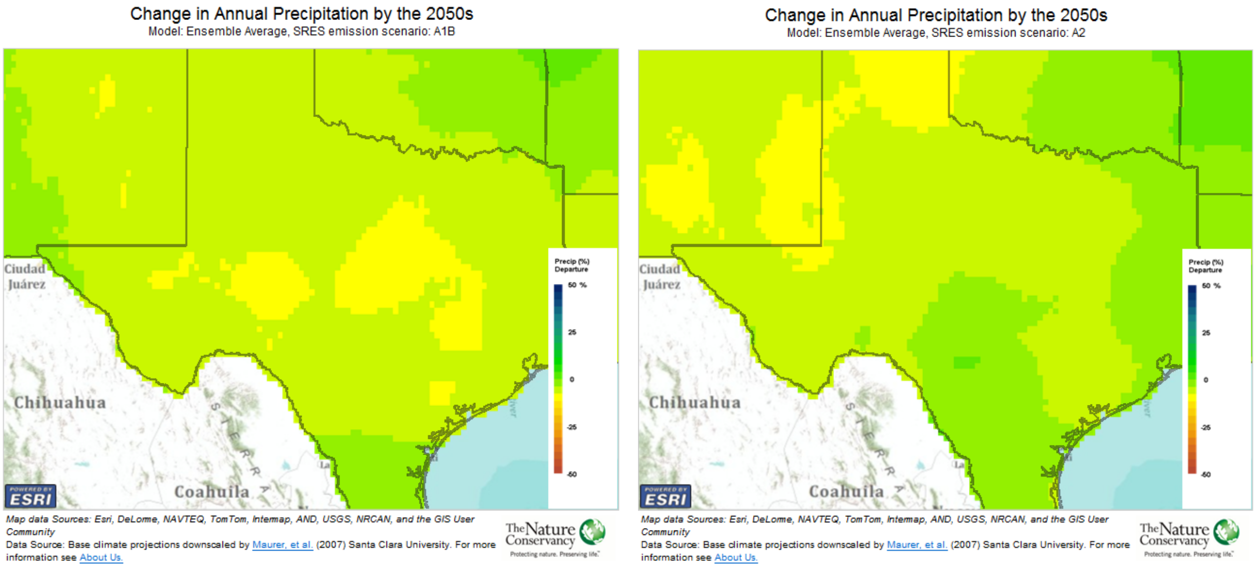


Figure 3-5. Change in Annual Precipitation Projected over Texas by Mid-Century Based on the Ensemble Average (Median Value) of Models Used in the IPCC Fourth Assessment and the A1B Emissions Scenario (Medium) on the Left and the A2 (High) on the Right. Areas in Darker Shades of Green Are Projected to Increase by Half the Models and Areas in Yellow and Lighter Shades of Green Are Projected to Decrease by Half the Models (Maurer et al. 2007) (Not to Scale).

Projections of Extreme Events

Models suggest that climate change may alter the frequency and severity of extreme events such as heat waves, cold waves, storms, floods, and droughts. Projections of global temperature from the IPCC suggest more intense, frequent, and longer lasting heat waves in a future warm climate, whereas the frequency of cold episodes are projected to decrease (Meehl et al. 2007). One recent analysis suggests that extreme cold events that do occur may be more intense than the twentieth-century average (Kodra et al. 2011).

Extreme precipitation episodes have become more frequent and more intense in recent decades over most of North America and now account for a larger percentage of total precipitation. Intense precipitation in the continental United States increased by over 20 percent over the past century while total precipitation increased by 7 percent. Precipitation is likely to be less frequent but more intense and precipitation extremes are likely to increase in the future (Karl et al. 2008).

3.1.1.4 Climate Change Impacts

Global Implications

The IPCC (Kundzewicz et al. 2007) reached several conclusions concerning the effects of global climate change on water resources:

- All IPCC regions show an overall net negative impact of climate change on water resources and freshwater ecosystems.
- Semi-arid and arid areas are particularly sensitive to the impacts of climate change on freshwater.
- Climate change affects the function and operation of existing water infrastructure as well as water management practices.
- Adverse effects of climate on freshwater systems aggravate the impacts of other stresses, such as population growth, changing economic activity, land use change, and urbanization.
- Large regional changes in irrigation water demand as a result of climate change are likely.
- Current water management practices are very likely to be inadequate to reduce the negative impacts of climate change on water supply reliability, flood risk, health, energy, and aquatic ecosystems.
- In the United States, many competing water uses will be adversely affected by climate change impacts on water supply and quality. Climate change will affect agricultural practices, including increasing irrigation demand in dry regions and nonpoint source water pollution (e.g., pollution from urban areas, roads, or agricultural fields) concerns in areas susceptible to intense rainfall events and flooding (Field et al. 2007).
- Climate change will constrain water resources in North America, increasing competition among agricultural, municipal, industrial, and ecological uses (Field et al. 2007).
- Climate change has the potential not only to affect communities directly, but also to affect them through impacts on other areas linked to their economies at regional, national, and international scales. Communities based on agriculture, forestry, water resources, or tourism may be especially affected by climate change related economic impacts (IPCC 2007b).
- The most vulnerable areas in the United States are likely to be Alaska, coastal and river basin locations susceptible to flooding, arid areas where water scarcity is a pressing issue, and areas whose economic bases are climate-sensitive (Field et al. 2007).

Regional Implications

Climate change could impact Texas groundwater resources by affecting recharge, pumping, natural discharge, and saline intrusion (Mace and Wade 2008). Climate change may adversely affect karstic aquifers (like the Edwards Aquifer) that recharge locally from streams and rivers to a greater degree than dripping aquifers. It is reasonable to conclude that a warmer climate will increase demand for water to support agriculture, municipal, and industrial uses and therefore greater demand for both surface and groundwater. Decreases in surface water supply due to climate change may also increase demand for groundwater use (Kundzewicz et al. 2007, Mace and Wade 2008). Natural aquifer discharge to springs and seeps is affected by recharge to the aquifer, withdrawals due to pumping, and changes in groundwater gradients. In coastal areas, groundwater and dependent resources may be affected by rising sea levels. As sea level rises, saline waters move inland, decreasing the areal extent of freshwater aquifers and possibly affecting water quality (Mace and Wade 2008).

Potential Climate Change Impacts to the Edwards Aquifer

Some research has attempted to assess the Edwards Aquifer’s vulnerability to climate change impacts. A study of climate change effects on regional economies estimated that a warmer, dryer climate would reduce the annual flow of Comal Springs by 10 to16 percent by 2030, and 20 to 24 percent by 2090; while San Marcos Springs would decline by 5 to 8 percent by 2030, and 10 to 12 percent by 2090 (Chen et al. 2001).

One study estimated climate change variability by calculating a range of 70 to 130 percent of monthly recharge values for the period of record. Pumping restrictions mandated by SB 3 failed to maintain springflow at Comal Springs during a modeled repeat of DOR-like conditions when projected recharge variability was considered. Further testing suggested that a 30 percent decline in recharge would require regional pumping reductions of about 40,000 ac-ft/yr to maintain springflows at Comal Springs (Mace and Wade 2008).

3.1.2 Geology

The geology and geologic history of an area influences the surrounding topography, hydrology, and environment. The study area encompasses a wide range of geologic settings and landforms. A brief discussion of regional geologic history of the study area is provided here, followed by a more in-depth discussion of the Edwards Aquifer, Comal, and San Marcos Springs.

3.1.2.1 Regional Physiography and Geologic History

The study area incorporates a large portion of the Balcones Escarpment and the associated Balcones Fault Zone. The escarpment, running northeast to southwest, bisects central Texas and represents a physical and ecological boundary between the Edwards Plateau to the north and west, and the Texas Blackland Prairie, to the south and east (TPWD 2011) (Figure 3-6). A diversity of climate, surface water availability, groundwater, soils, flora, and fauna are apparent throughout the varied landforms and habitats of the study area. The prevailing terrain is generally level to gently rolling and cut through by meandering, low gradient streams. Groundwater is usually deep and often tepid and brackish. Relief within the study area is considerably varied, dropping from 2,000 feet (610 m) above msl in northern Uvalde County to mean sea level in Calhoun County.

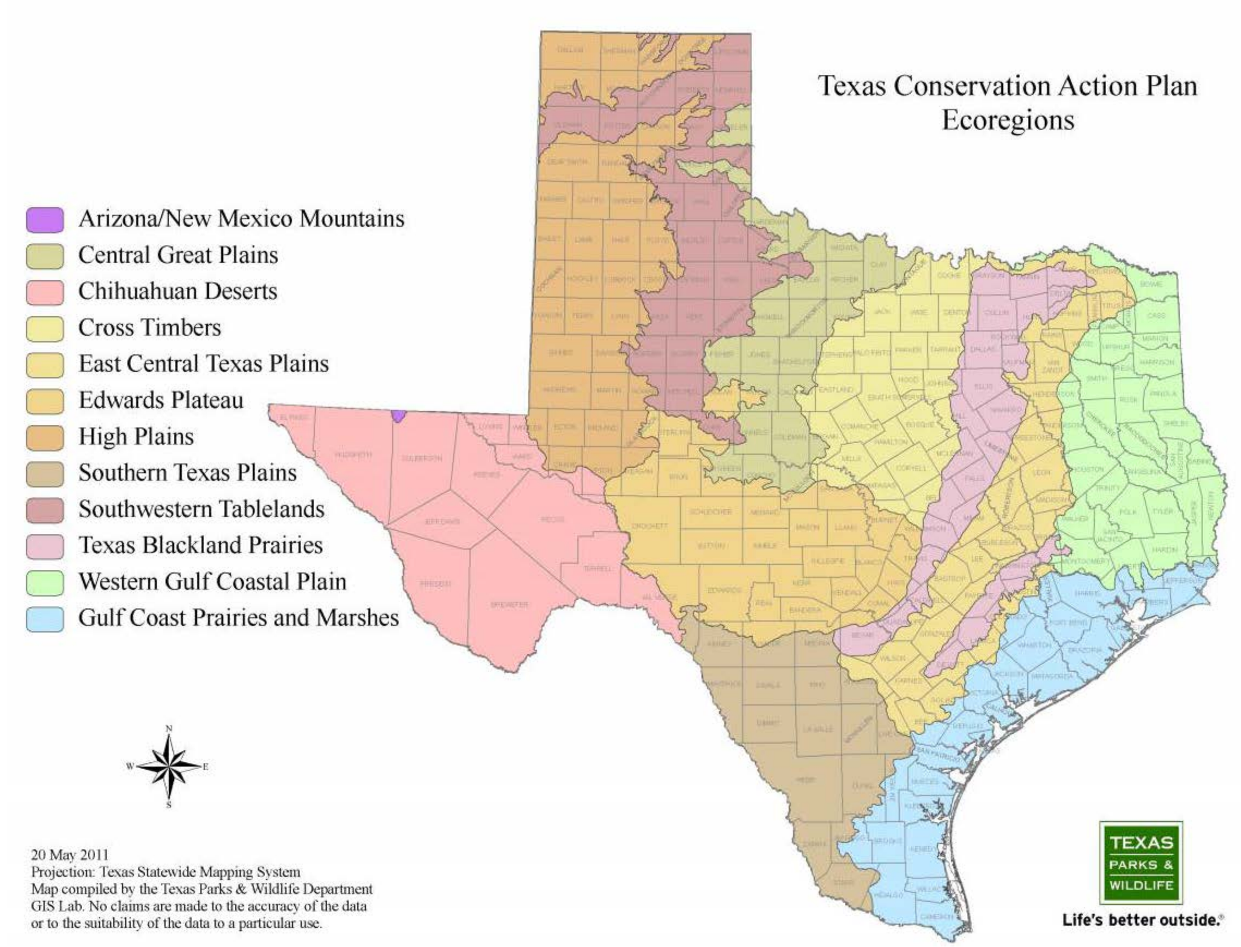


Figure 3-6. Ecoregions of Texas (TPWD 2012) (Not to Scale).

The Edwards Plateau is an uplifted and dissected expanse of Cretaceous sedimentary rock formations (BEG 1981, Riskind and Diamond 1988). The topography along the Edwards Plateau is mapped as flat to light rolling upland plains with rounded hills and wide east to southeast oriented stream divides. The Texas Blackland Prairies region is a low relief unit comprised of sedimentary deposits formed through episodes of transgression and regression of a Cretaceous sea (Fenneman 1931, 1938; TPWD 2011).

3.1.2.2 Geology of the Edwards Aquifer

The Edwards Aquifer is a karstic limestone system that reaches over 249 mi (400 km) from Val Verde County near the Mexican border north and east to Bell County in central Texas. The Edwards Aquifer extends along the Balcones Fault Zone in a relatively narrow band beginning near the city of Brackettville and running north and east through the cities of Uvalde, Sabinal, Hondo, San Antonio, New Braunfels, San Marcos, Austin, and north of Georgetown (Guyton and Associates 1979).

Various geologic strata make up the Edwards Aquifer, and a cross section of a representative portion along the Balcones Fault Zone north of San Antonio is illustrated in Figure 3-7 (Maclay and Small 1986, Crowe 1994). The lower portion is confined by the Glen Rose Formation, composed of an upper unit of alternating resistant and recessive beds of limestone, dolomite, and marl that overlie a lower unit of limestones and marl (see Figure 3-7). Above the Glen Rose Formation is the Walnut Formation, a relatively impenetrable nodular limestone (Abbott 1973).

SYSTEM	SERIES	GROUP	FORMATION	MEMBER	THICKNESS (feet)	LITHOLOGY
Quarter-nary			Alluvium		45	Gravel, Sand, and Silt
			Terrace Deposits		30	Coarse Gravel, Sand, and Silt
Tertiary	Eocene	Claiborne	Reklaw		200	Sand, Sandstone, and Clay
			Carrizo Sand		200–800	Sandstone, Medium to Coarse
	Eocene and Paleo-cene	Wilcox and Midway			500–1,000	Clay, Siltstone, and Fine Sandstone
				Wills Point	500	Clay and Sand
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, Milioloidgrainstone
				Dolomitic	150–200	Limestone, Calcified Dolomite, Kirshbergevaporites
				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 3-7. Stratigraphy of the Confined Edwards Aquifer along the Balcones Fault Zone between Austin and San Antonio, Texas (after Maclay and Small 1986, Crowe 1994).

The Balcones Fault Zone is the major structural feature of the Edwards Aquifer system. Fractures associated with the fault zone cross through various strata, creating porosity and permeability. Displacement in some areas has offset the Edwards Aquifer considerably, such as in areas along the Comal Springs Fault (Figure 3-8). Edwards Group layers undergo a process termed karstification when limestone is dissolved through solution, creating an extensive honeycombed system of voids, pores, and caverns. This process began in the Edwards Group during the Cretaceous Period (which began about 145 million years ago) and continues today.

3.1.2.3 San Marcos Springs

The San Marcos Springs are located near the base of the Balcones escarpment at the head of the San Marcos River in Hays County, Texas. A map showing the local surface geology is included as Figure 3-9, and a stratigraphic cross section of San Marcos Springs is included as Figure 3-10. A list of local surface formations and their properties is included in Table 3-1. San Marcos Springs issue from Edwards Group limestones along the San Marcos Springs Fault (see Figure 3-9) (Guyton and Associates 1979).

3.1.2.4 Comal Springs

The seven outlets comprising Comal Springs make up the largest remaining spring system in the state of Texas, and provide the source of the Comal River in New Braunfels, Comal County, Texas. An illustration of local surface geology is included in Figure 3-11, and a stratigraphic cross section of Comal Springs is included in Figure 3-12. A list of local surface formations and their properties is included in Table 3-2. Comal Springs lie at the base of the Balcones Escarpment, within the Balcones Fault Zone, and issue from Edwards Group limestones along the Comal Springs Fault.

3.1.2.5 Hueco Springs

The Hueco Springs system is located on private property near the junction of Elm Creek and the Guadalupe River approximately 3 mi (5 km) north of New Braunfels, Comal County, Texas. The springs comprise two main groups which are bisected by a paved roadway. The springs rise from the Hueco Springs Fault and discharge water from the Edwards Aquifer (Guyton and Associates 1979). A list of local surface formations and their properties is included in Table 3-3. Additionally, a map depicting the local surface geology is included in Figure 3-13 and a stratigraphic cross section of Hueco Springs is included in Figure 3-14.

3.1.2.6 Fern Bank Springs

Fern Bank Springs, also known as Little Arkansas and Krueger Springs, lie approximately 5 mi (8 km) east of the City of Wimberley on the south bank of Blanco River, in Hays County, Texas. Fern Bank Springs issue from the base of a bluff where the Hidden Valley Fault crosses the Blanco River. A list of local surface formations and their properties is included in Table 3-4.

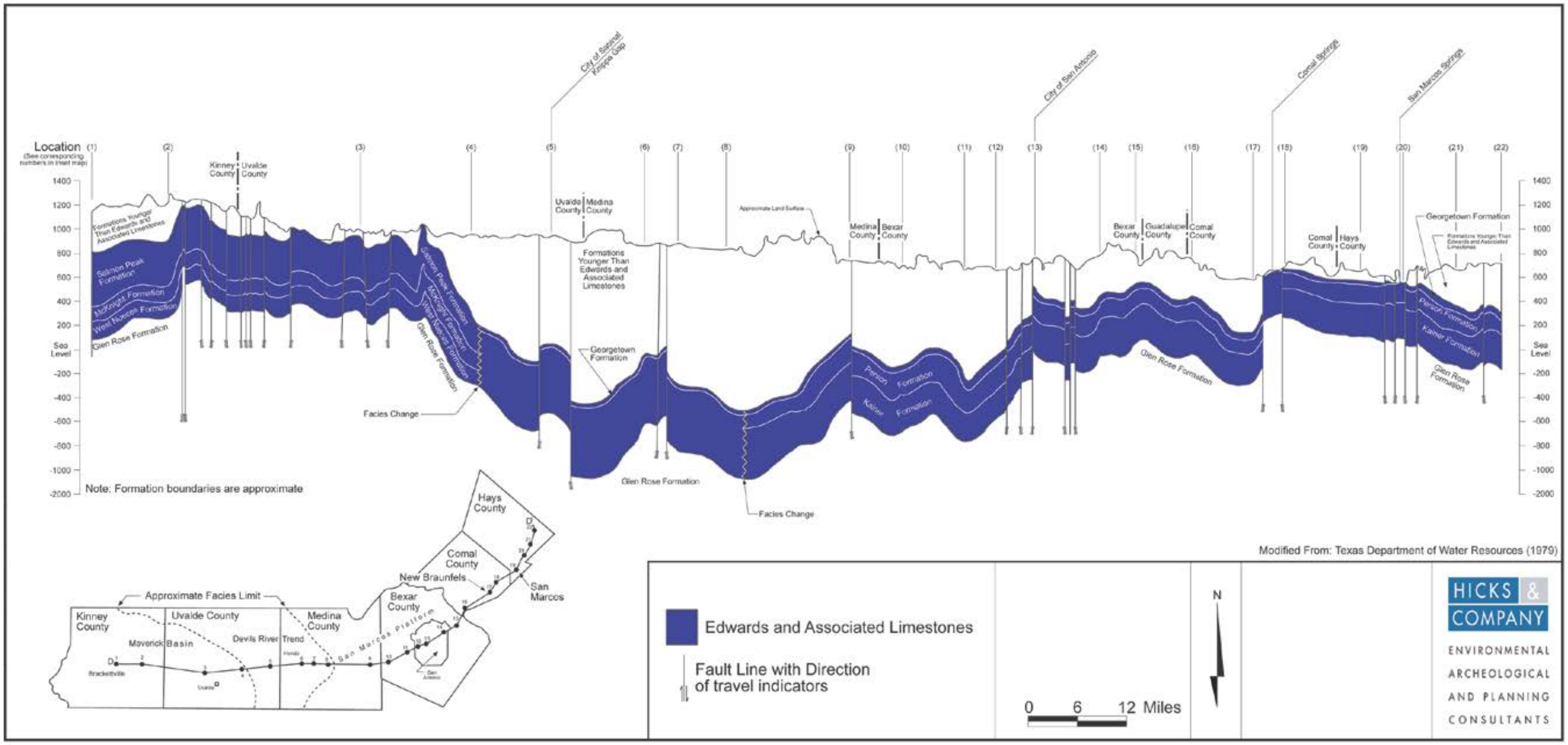
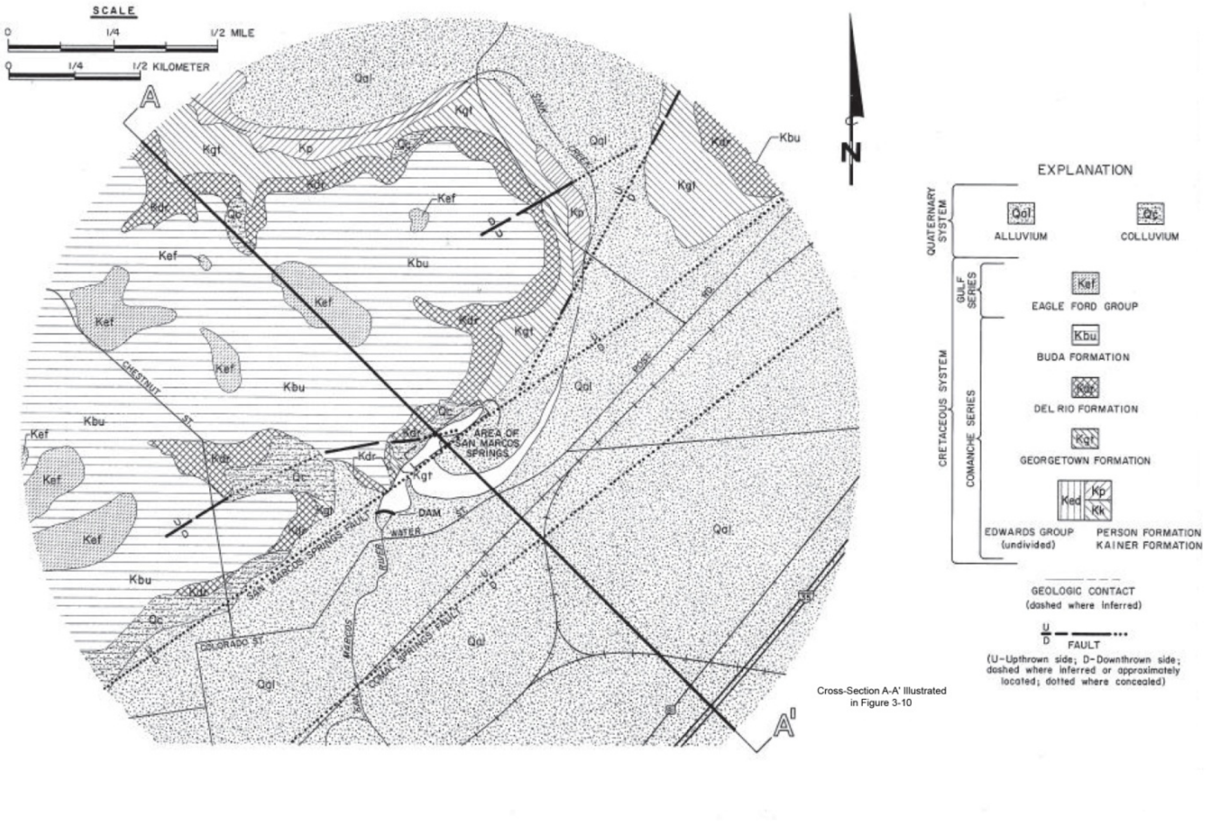


Figure 3-8. Hydrological Cross Section of the Southern Edwards Aquifer.



Source: Wm. F. Guyton and Associates, 1979

Figure 3-9. Surface Geology of San Marcos Springs and Vicinity.

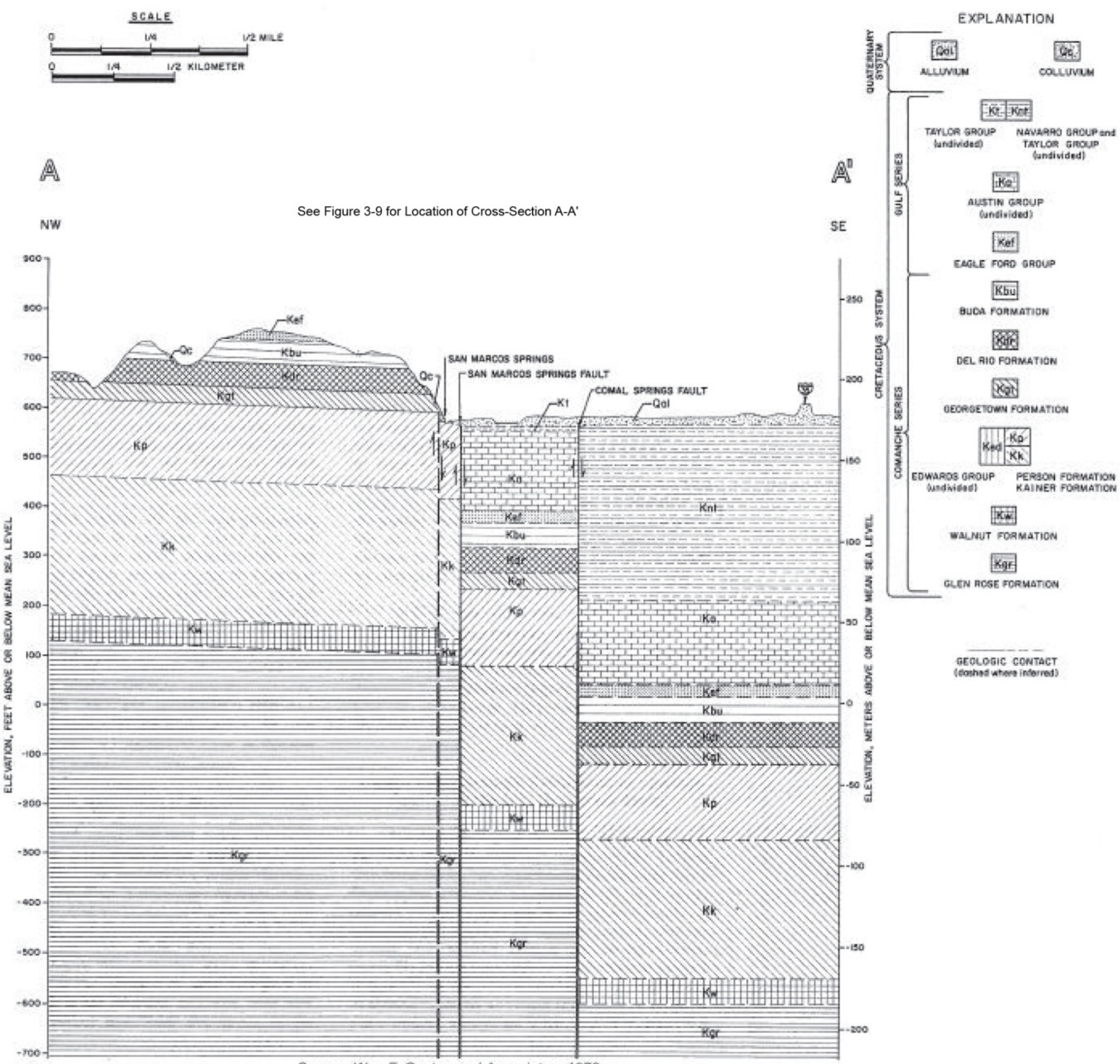
3.2 WATER RESOURCES

The availability, location, and quality of surface water and groundwater within the study area are discussed in this section.

3.2.1 Surface Water

3.2.1.1 River Basins

The southern segment of the Edwards Aquifer lies beneath portions of the Guadalupe, Nueces, and San Antonio River basins. A brief discussion of these features is provided below. These drainage basins are composed of smaller watersheds (illustrated in Figure 3-15) that contribute recharge to the Edwards Aquifer (described in Section 3.2.2.12) (EAA 2010a).



Source: Wm. F. Guyton and Associates, 1979

Figure 3-10. Stratigraphic Cross Section through San Marcos Springs and Vicinity.

Guadalupe River Basin

The Guadalupe River Basin originates in northwestern Kerr County and drains southeasterly to San Antonio Bay and the Guadalupe Estuary (see Figure 3-16). 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 (TNRCC 1998). The drainage area for the Guadalupe River Basin encompasses 6,070 square miles (mi^2) (15,721 square kilometers [km^2]). The main tributaries include the North and South Forks of the Guadalupe, and the Blanco and San Marcos Rivers (TSHA 2010a). Major reservoirs in this basin include Canyon Lake and Coleto Creek Reservoir (see Figure 3-15).

Table 3-1. Surface Geology of 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 Group	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.

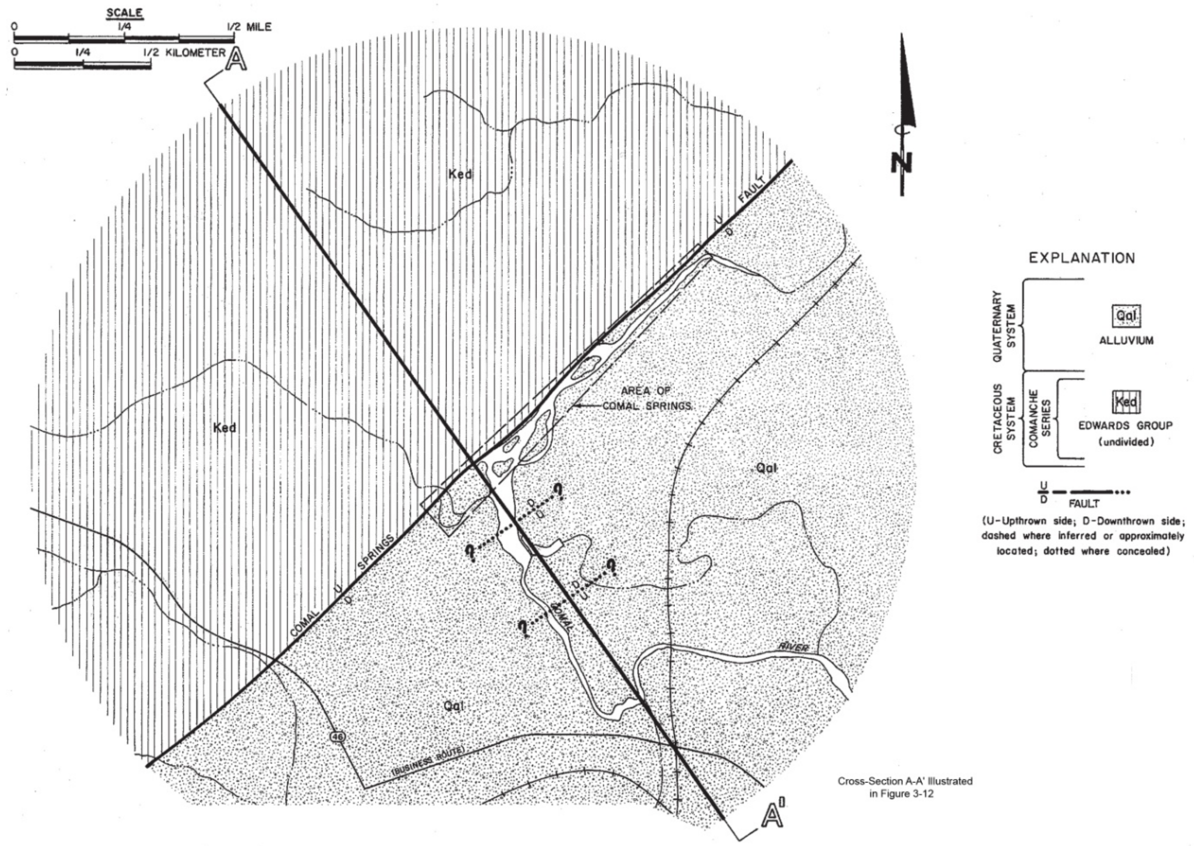
Source: Modified from BEG (1974, 1981, 1982).

Guadalupe River flows are affected by Texas Commission on Environmental Quality (TCEQ [Texas Natural Resources Conservation Commission, or TNRCC, prior to September 1, 2002]) and Guadalupe-Blanco River Authority (GBRA) management and regulations, discharges from Canyon Lake (as managed by the U.S. Army Corps of Engineers [USACE]), and flows of the Comal and San Marcos Rivers originating from their respective springs.

The San Marcos River begins at San Marcos Springs in San Marcos and flows southeast for about 75 mi (121 km), before reaching its mouth on the Guadalupe River near Gonzales in Gonzales County (TSHA 2011).

The Comal River originates at Comal Springs in the City of New Braunfels and runs just 3.1 mi (4.9 km) before emptying into the Guadalupe River. The Comal River holds the distinction of being the shortest river not only in Texas, but in the United States (TSHA 2010b).

Though the cities of New Braunfels and San Marcos have historically relied on pumping from the Edwards Aquifer for municipal water supplies, both cities have strived to diversify water supplies in recent years (SCTRWPG 2000). The City of San Marcos developed a regional surface water supply project with GBRA, including the construction a water transmission pipeline from the Guadalupe River. The City of New Braunfels developed additional water supplies relying on purchased surface water rights drawn from Canyon Reservoir.



Source: Wm. F. Guyton and Associates, 1979

Figure 3-11. Surface Geology of Comal Springs and Vicinity.

Contribution of Aquifer Springflow to the Lower Guadalupe River and the Guadalupe Estuary System

The Edwards Aquifer contributes significant inflow to the Guadalupe River via Comal and San Marcos Springs. Both the quantity and quality of Guadalupe River flows affect biological productivity of the Guadalupe Estuary System including Mission Lake, Guadalupe, Ayres, San Antonio, Mesquite, and Espiritu Santo Bays (see Figure 3-17).

Freshwater contributions to the Guadalupe Estuary System have been estimated by a number of investigators. Average annual freshwater inflow to the Guadalupe Estuary System from various sources is provided in Table 3-5 (CH2M Hill 1986). Another effort determined that Edwards Aquifer springflow has historically represented an average of 14.2 percent of the freshwater inflows to the Guadalupe Estuary (HDR 2009).

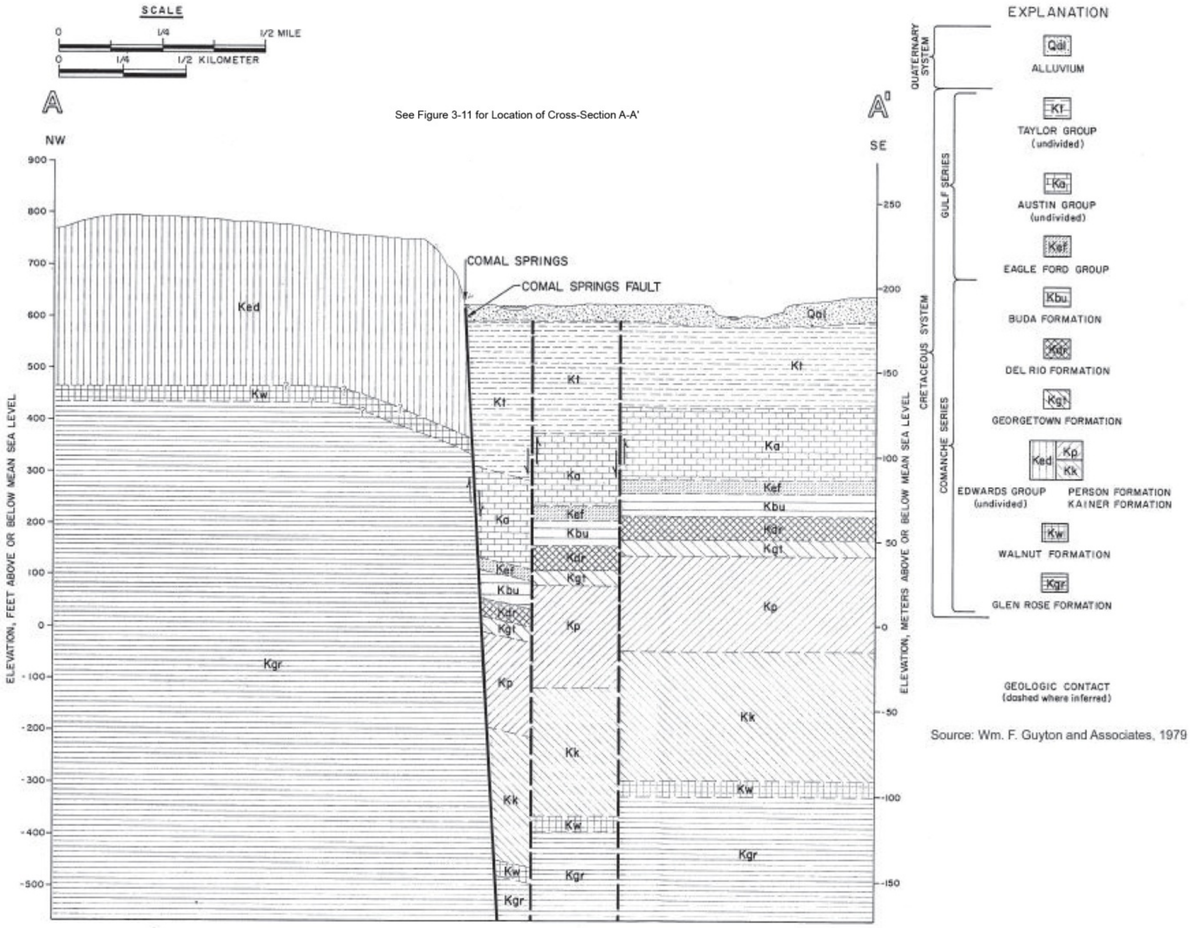


Figure 3-12. Stratigraphic Cross Section through Comal Springs and Vicinity.

Table 3-2. Surface Geology of 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 BEG (1974, 1981, 1982).

Table 3-3. Surface Geology of Hueco Springs and Vicinity.

FORMATION/GROUP	GENERAL DESCRIPTION
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.
Walnut Formation	Limestone and claystone interbedded. Limestone, in upper part- argillaceous, nudlar, thin to medium bedded, iron stained, burrowed; in lower part- fine to coarse grained, hard, in part nodular, ripple marked on bedding surface. Claystone, calcareous, limestone nodules in upper part, sandy in lower part, light brown to gray.

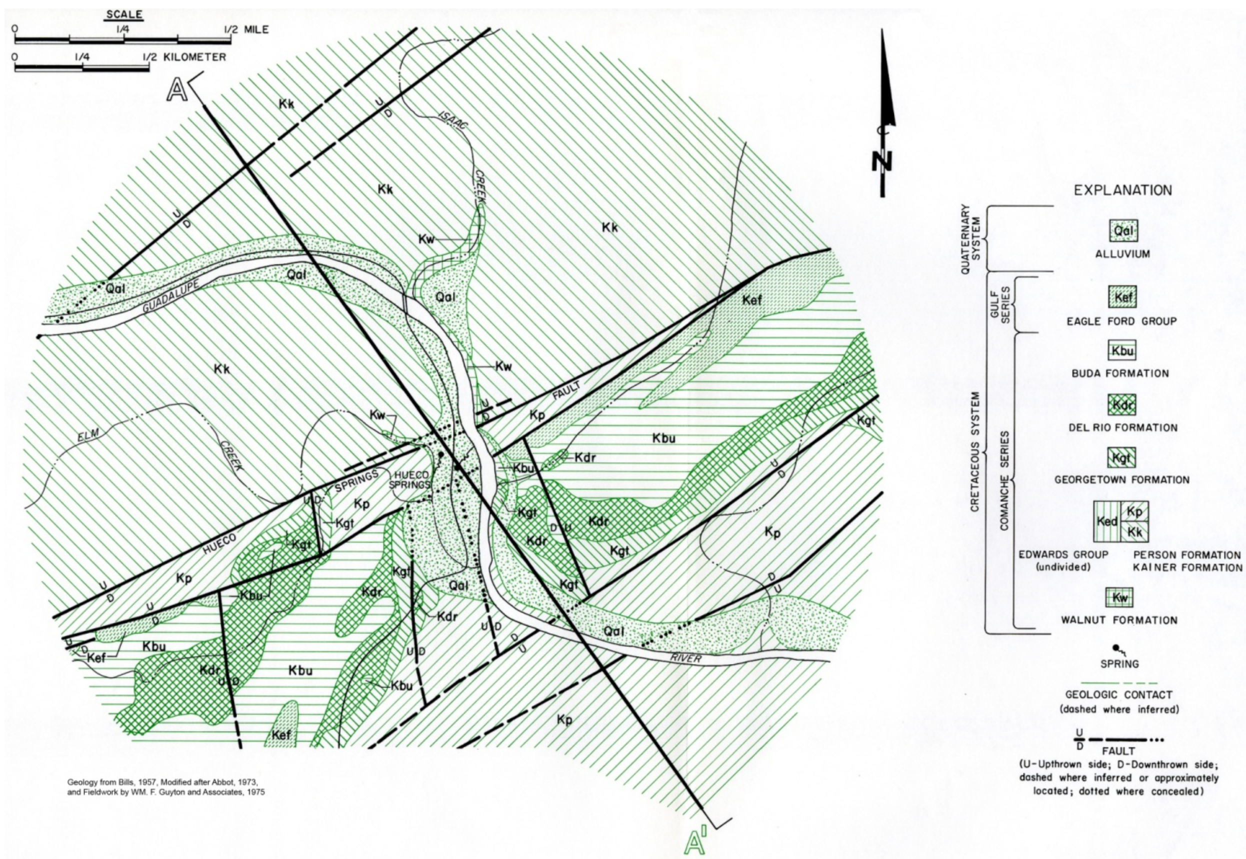


Figure 3-13. Surface Geology of Hueco Springs Locality.

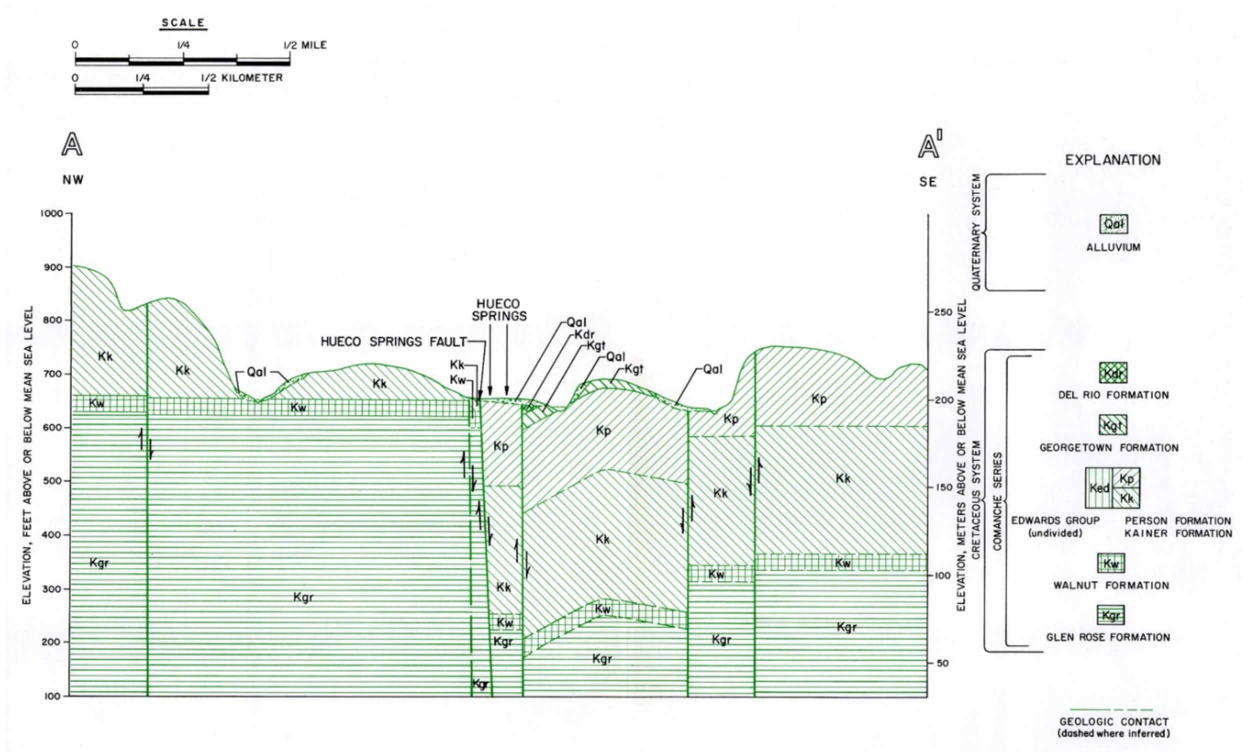


Figure 3-14. Stratigraphic Cross Section through Hueco Springs and Vicinity.

Table 3-4. Surface Geology of Fern Bank Springs and Vicinity.

FORMATION/GROUP	GENERAL DESCRIPTION
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.
Glen Rose Formation	Lower Cretaceous-aged limestone, dolomite, and clay; limestone, fine grained, chalky to hard, white to light gray; alternating with units of dolomite, fine to very fine grained, porous, medium gray to brownish gray; and clay, marly, silty, laminated, dark gray.

Source: Modified from BEG (1974, 1981).

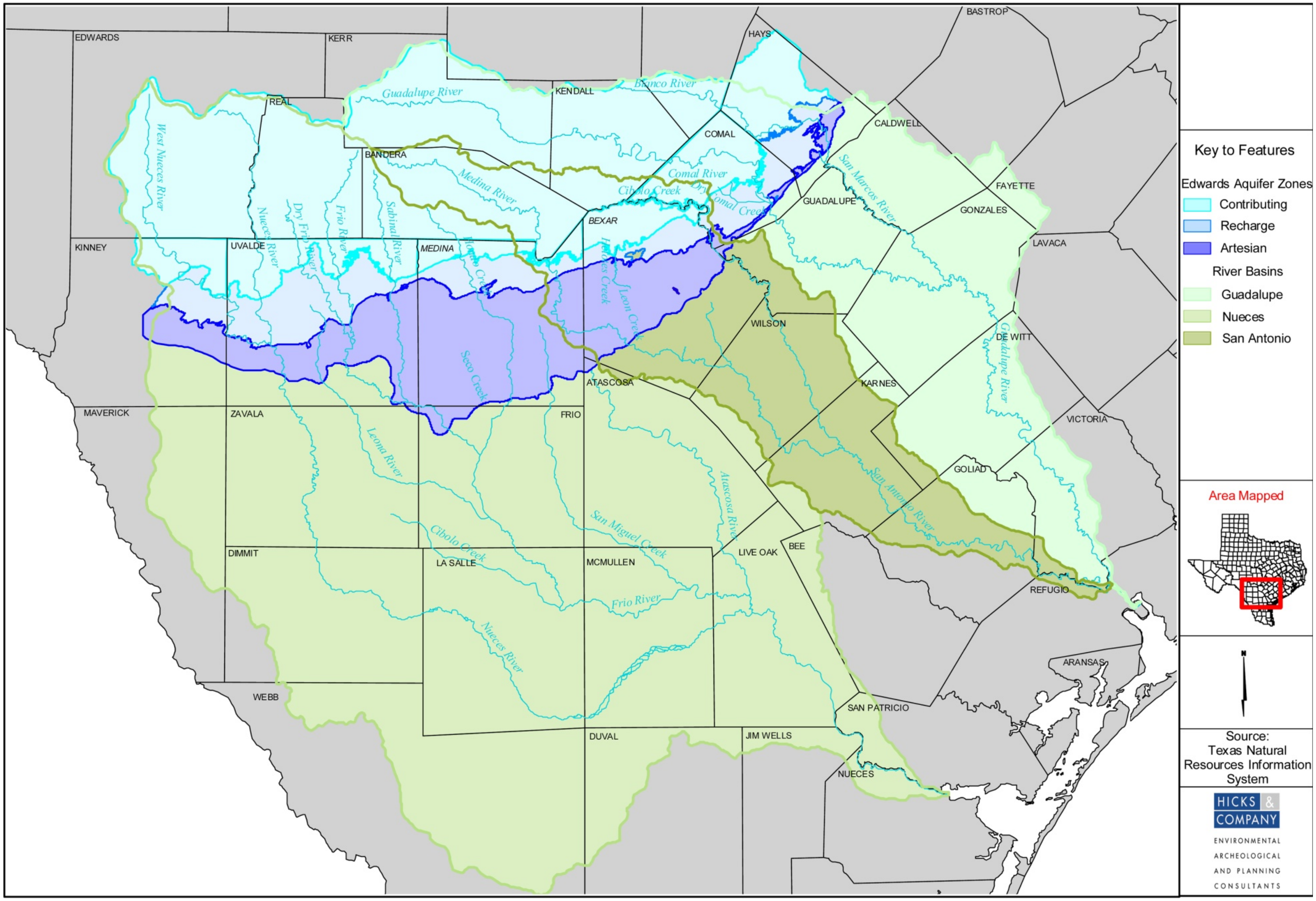


Figure 3-15. Surface Water Located in the Southern Edwards Aquifer Region.

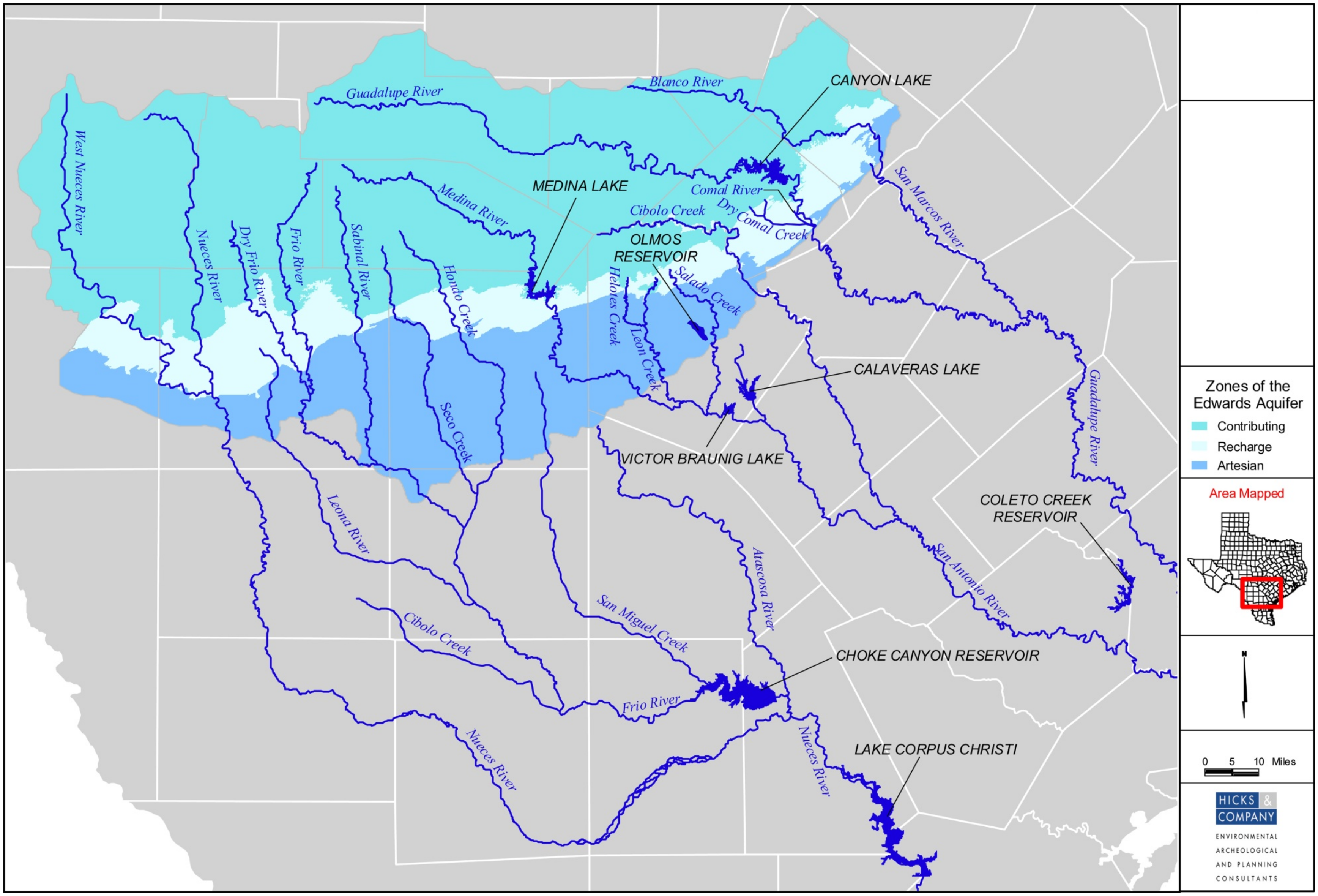


Figure 3-16. River Basins Associated with the Southern Segment of the Edwards Aquifer (Not to Scale).

Figure 3-17. Map of the Guadalupe Estuary (San Antonio Bay), which Receives Freshwater from the Guadalupe and San Antonio Rivers (Guthrie et al. 2010) (Not to Scale).

Table 3-5. Average Annual Freshwater Inflow to Guadalupe Estuary System.

SOURCE	INFLOW (ac-ft/yr)	PERCENTAGE OF TOTAL INFLOW
Guadalupe River	1,304,000	43
San Antonio River	485,400	16
Precipitation	440,000	14
Local Runoff	460,000	15
Edwards Aquifer	360,000	12
TOTAL	**3,049,400**	**100.0**

Source: CH2M Hill (1986).

Surface water management and weather conditions change the proportion of springflow to total freshwater inflow during normal and dry years. Freshwater contributions to the Guadalupe Estuary for an average year (1994) and drought year (1996) have been estimated and are provided in Table 3-6 (HDR 2009). Other researchers reached drought year annual springflow estimations of 33 and 37 percent for this same time period (Votteler 2002). These calculations demonstrate the greater contribution of Aquifer springflow to total freshwater inflow during drought years.

Table 3-6. Average Annual Freshwater Inflow to Guadalupe Estuary System in an Average and Dry Year.

SOURCE	PERCENTAGE OF TOTAL INFLOW DURING AN AVERAGE YEAR (1994)	PERCENTAGE OF TOTAL INFLOW DURING A DRY YEAR (1996)
Guadalupe River	49	37
San Antonio River	20	11
SAWS Effluent	5	14
Ungaged Runoff	13	14
Edwards Aquifer Springflow	13	24
TOTAL	**100**	**100**

Source: HDR (2009).

Springflow contributions to the Guadalupe Estuary during the DOR have also been estimated. Springflow was estimated to have provided 30 percent of the freshwater inflows into the estuary in 1956 (McKinney and Watkins 1993). Monthly springflow contributions for the most severe portion of the DOR have been estimated as: May (9 percent), June (53 percent), July (35 percent), August (32 percent), September (15 percent), and October (5 percent) (Votteler 2002).

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 mi (507 km) (TNRCC 1996) (see Figure 3-15). 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. The Nueces River and its tributaries cross the fractured limestones of the recharge zone and a substantial amount of surface flows are recharged into the Edwards Aquifer. Downstream of the recharge zone much of the Nueces River Basin surface flows consist primarily of stormwater.

San Antonio River Basin

The San Antonio River originates from several springs in north central San Antonio and converges with the Guadalupe River in Victoria County (see Figure 3-15). The San Antonio River Basin drains an area of about 4,180 mi^2 (10,826 km^2) (TNRCC 1996), and is bounded by the Guadalupe River to the north and east and by the San Antonio-Nueces Coastal Basin and Nueces on the west and south.

3.2.1.2 Edwards Aquifer-Fed Springs

Of the 281 major freshwater springs recorded in Texas, only four are known to have had flows greater than 100 cfs. Just two of these largest springs remain today, the San Marcos and Comal Springs, both supported by the Edwards Aquifer (Brune 1975) (see Figure 3-18). Other significant spring outlets include Hueco Springs, Leona Springs, San Antonio Springs, and San Pedro Springs. Total annual discharge from these six springs during the period of record (1934 to 2009) has varied from 69,800 ac-ft in 1956 to 802,800 ac-ft in 1992, with an average annual discharge of 384,360 ac-ft (Table 3-7) (EAA 2010a).

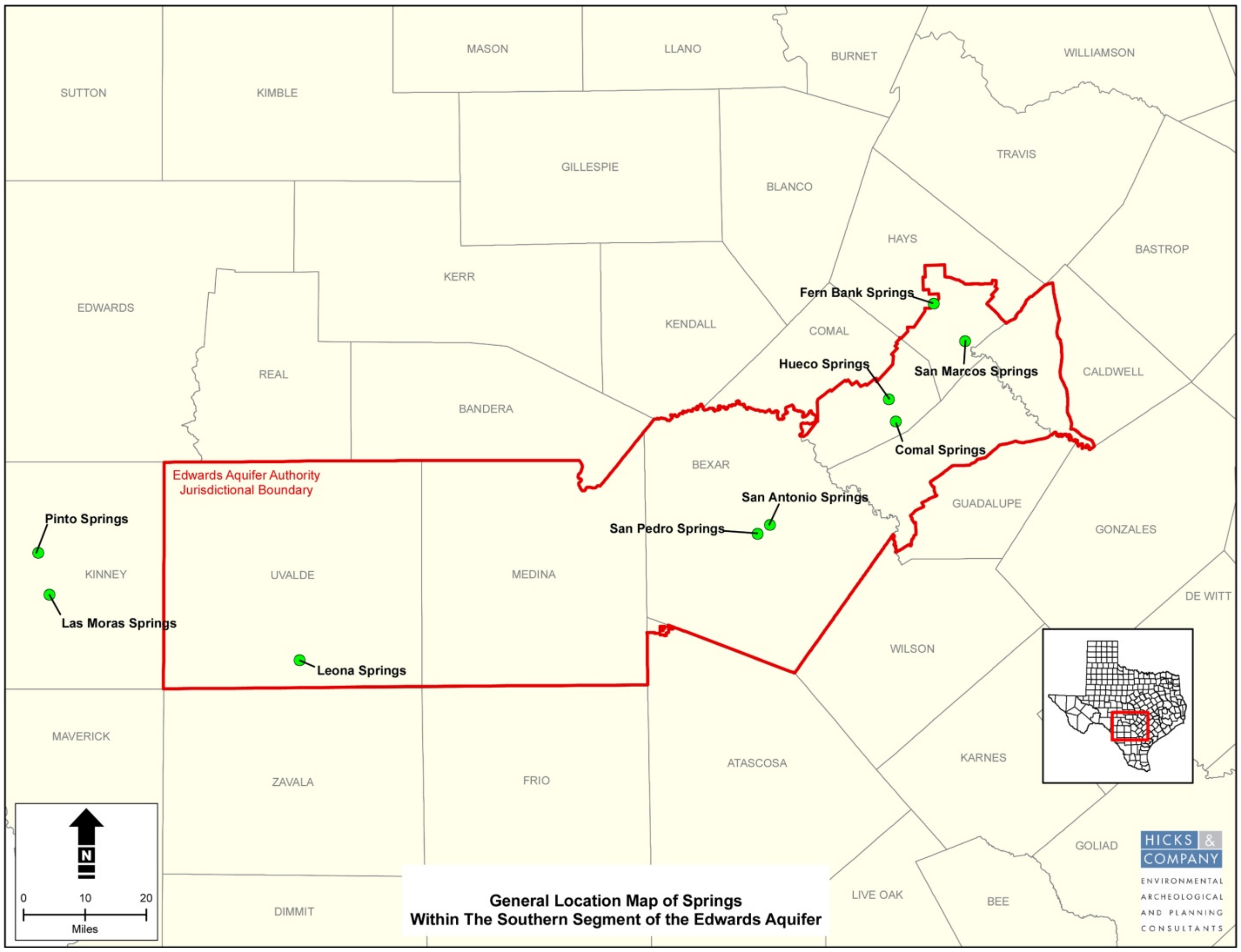


Figure 3-18. General Location of Springs within the Southern Segment of the Edwards Aquifer.

Table 3-7. Estimated Spring Discharge from the Edwards Aquifer, 2009 (Measured in Acre-Feet).

MONTH	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	1,970	270	322	17,910	358	6,000	26,830
February	1,406	180	16	15,570	364	5,480	23,016
March	1,487	195	0.16	16,610	505	6,140	24,937
April	1,574	110	0	15,630	405	5,680	23,399
May	764	30	0	14,210	494	5,680	21,178
June	396	10	0	11,850	338	5,340	17,934
July	366	0.65	0	10,180	194	5,420	16,161
August	415	0	0	10,290	270	5,330	16,305
September	471	3.23	0	11,610	1,880	5,550	19,514
October	549	167	7.41	16,390	5,200	9,080	31,393
November	552	277	68.3	17,590	4,130	10,670	33,287
December	584	295	91.2	19,180	2,590	11,280	34,020
TOTAL	**10,534**	**1,538**	**505**	**177,020**	**16,728**	**81,650**	**287,975**

Data source: EAA (2010a). Differences in totals may occur as a result of rounding.

Comal Springs

At 623 feet (190 m) above msl, Comal Springs is one of the lowest elevation springs fed by the Edwards Aquifer (see Figure 3-18). Comal Springs consists of four major outlets that flow into Landa Lake (Abbott and Woodruff 1986). The average springflow for the period of record (1933 to 2009) was 291 cfs (EAA 2010a). Though precipitation events and resulting stormwater can generate Comal River flows of thousands of cubic feet per second, the highest springflow recorded at Comal Springs was 534 cfs in 1973. Flow completely ceased at Comal Springs for 144 days from June 13 to November 4 of 1956 during the most severe conditions of the DOR (Longley 1995, USFWS 1996a).

San Marcos Springs

San Marcos Springs, at 574 feet (175 m) above msl, is the lowest elevation major springs system in the southern segment of the Edwards Aquifer (Figure 3-18). San Marcos Springs includes six major and several minor orifices at the bottom of the man-made Spring Lake. The average flow from San Marcos Springs for the period of record (1957 to 2009) is 175 cfs (EAA 2010a). The highest springflow recorded at San Marcos Springs was 316 cfs in 1975 (Brune 1981). San Marcos Springs have never ceased flowing in recorded history, and the lowest recoded discharge of 46 cfs occurred during the DOR in 1956.

Other Springs

Fern Bank, Hueco, Leona, San Antonio, and San Pedro Springs are lesser spring outlets of the Edwards Aquifer within the study area (see Figure 3-18). These springs generally have declining or erratic flow due in part to their elevation, seasonal fluctuations during dry years, and pumping.

The elevation of Fern Bank Springs is approximately 670 feet (204 m) above msl. The source of the water for Fern Bank Springs is unclear. It may originate from the upper member of the Glen Rose Formation, from drainage from the Edwards Aquifer recharge zone, from water lost from the Blanco River, or from some combination of those sources (72 FR 39247–39283). Recent dye traces confirm that under some conditions groundwater recharged south of the Blanco River feed the spring (Johnson et al. 2011). Though few records are available for this site, Fern Bank springflow has been recorded at less than 1 cfs (Brune 1981).

Hueco Springs consist of two outlets at an elevation of approximately 658 feet (201 m) above msl. Springflow at Hueco Springs averages about 35 cfs, and the maximum discharge recorded was 131 cfs in 1968 (Brune 1975). Hueco Springs are known to experience long periods of low flow or cessation of flow during drought conditions (Abbott and Woodruff 1986). Hueco Springs recharge has local and regional components originating from the nearby Dry Comal Creek and Guadalupe River basins and from longer flowpaths from San Antonio (Otero 2007).

Leona Springs are found in four groupings along or beneath the surface of the Leona River in Uvalde County. At 860 feet (262 m) above msl, Leona Springs are recharged by the Nueces River and its tributaries to the northwest (Brune 1981). Leona Springs are not monitored by the U.S. Geological Survey and no regular flow records are available for this springs complex.

Originally a complex of over 100 springs (Brune 1981), the remaining outlets of the San Antonio Springs complex are located principally on property of the University of the Incarnate Word near Brackenridge Park in north central San Antonio in Bexar County. Most of the springs are at an elevation of about 672 feet (205 m) above msl. The largest spring is called Head of the River or Blue Hole, implying that it was believed to be the source of the San Antonio River. Many of the individual springs within the complex flow during wet years (such as in 1973 and 1992), but are now frequently intermittent with little or no springflow.

San Pedro Springs are located at 663 feet (202 m) above msl in San Pedro Park in San Antonio. Both San Antonio and San Pedro Springs are recharged by waters over 62 mi (100 km) to the west where the Frio, Sabinal, and Medina Rivers and Hondo and Leon Creeks cross the Balcones Fault Zone. San Pedro Springs today have erratic or no springflow, and waters near the springs used for recreation are piped in from other locations (Brune 1975).

3.2.1.3 Surface Water Quality

Surface water quality is monitored and regulated by the U.S. Environmental Protection Agency (USEPA) and TCEQ. The State of Texas Integrated Report (STIR, formerly known as the Texas Water Quality Inventory) is prepared by TCEQ and submitted to USEPA to meet the requirements of the Clean Water Act. The STIR reports status and trends in statewide water quality and describes the degree to which each water body segment supports its designated uses as established by the Texas Surface Water Quality Standards (TSWQS).

The TCEQ defines surface waters classifications 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 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 do not support designated uses or water quality criteria are listed on the 2010 State of Texas Clean Water Act Section 303(d) List. Stream segments over or partially over the Edwards Aquifer that are categorized as impaired are shown in Table 3-8 (TCEQ 2010a). Section 314 of the Clean Water Act 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 3-8 through 3-11 and discussed below.

Table 3-8. Stream Segments Located (at Least Partially) over the Edwards Aquifer and on the Draft 2010 Texas Clean Water Act Section 303(d) List.

SEGMENT NAME	SEGMENT	SEGMENT SUMMARY
Canyon Lake	1805	Mercury in Edible Tissue
Camp Meeting Creek	1806A	Dissolved Oxygen Concentration Occasionally Lower than Criterion for Aquatic Life
Quinlan Creek	1806D	Bacteria Levels Exceed Criterion
Town Creek	1806E	Bacterial Levels Exceed Criterion
Upper San Marcos River	1814	Total Dissolved Solids
Lower Leon Creek	1906	Bacteria Levels Exceed Criterion, Dissolved Oxygen Concentration Occasionally Lower than Criterion, PCBs in Edible Tissue
Upper Cibolo Creek	1908	Bacteria Levels Exceed Criterion
Salado Creek	1910	Impaired Fish Community, Impaired Macrobenthic Community
Upper San Antonio River	1911	Impaired Fish Community; Bacteria Levels Exceed Criterion
Mid Cibolo Creek	1913	Bacteria Levels Exceed Criterion
Upper Frio River	2113	Impaired Fish Community, Impaired Macrobenthic Community
Frio River above Choke Canyon Reservoir	2117	Bacteria Levels Exceed Criterion

Source: TCEQ (2010a).

Table 3-9. The TCEQ Surface Water Quality Inventory Summary for the Stream Segments in the Guadalupe River Basin Located (at Least Partially) over the Edwards Aquifer.

SEGMENT NAME	NUMBER	DESIGNATED WATER USES	WATER QUALITY CONCERNS WITHIN STREAM SEGMENT
Canyon Lake	1805	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	Mercury in Edible Tissue; First Listed in 2006
Camp Meeting, Quinlan, and Town Creeks	1806	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use	Depressed Dissolved Oxygen, Bacteria; First Listed in 1999 (Camp Meeting Creek) and 2010 (Other Creeks)
Lower Blanco River	1809	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Comal River	1811	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Guadalupe River below Canyon Dam	1812	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Upper Blanco River	1813	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Upper San Marcos River	1814	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	Total Dissolved Solids; First Listed 2010
Cypress Creek	1815	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed

Source: TCEQ (2010a).

The EAA maintains water quality data collection sites within the eight major stream basins that contribute significant groundwater recharge to the Edwards Aquifer. The data is collected at U.S. Geological Survey gauging stations located upstream of the Edwards Aquifer Recharge Zone. The collected data are used to evaluate water quality recharging the Edwards Aquifer and the sensitivity of water quality to land use changes in the region.

Selected stream sites were tested in 2009 for organic compounds related to Volatile Organic Compounds (VOCs), Semi-Volatile Organic Compounds (SVOCs), Polychlorinated Biphenyls (PCBs), herbicides and pesticides. There were no detections of VOCs at San Geronimo and Lorence Creeks. Lorence Creek was also tested for SVOCs with no detections. Remaining stream samples were tested for organic compounds related to PCBs, herbicides and pesticides, with one positive herbicide detection at San Geronimo Creek for pentachlorophenol at 0.25 micrograms per liter (µg/L), (maximum contaminant level (MCL) = 1.0 µg/L) (EAA 2010a).

Springs outflows were also analyzed for VOCs, SVOCs, PCBs, herbicides, and pesticides, and no positive results were noted for these compounds (EAA 2010a).

Table 3-10. The TCEQ Surface Water Quality Inventory Summary for Stream Segments in the San Antonio River Basin Located (at Least Partially) over the Edwards Aquifer.

SEGMENT NAME	NUMBER	DESIGNATED WATER USES	WATER QUALITY CONCERNS WITHIN STREAM SEGMENT
Medina River below Medina Diversion Lake	1903	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Medina Lake	1904	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Medina River above Medina Lake	1905	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use	None Listed
Lower Leon Creek	1906	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use	Depressed Dissolved Oxygen, PCBs in Edible Tissue
Upper Leon Creek	1907	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Upper Cibolo Creek	1908	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	Elevated Levels of Bacteria
Medina Diversion Lake	1909	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Salado Creek	1910	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	Impaired Fish Community, Impaired Macrobenthic Community
Upper San Antonio River	1911	Contact Recreation Use, Aquatic Life Use	Impaired Fish community, Elevated Level of Bacteria
Mid Cibolo Creek	1913	Contact Recreation Use, Aquatic Life Use	Elevated Level of Bacteria

Source: TCEQ (2010a).

Water quality data is summarized for the Guadalupe, San Antonio, and Nueces River Basins below.

Guadalupe River Basin Water Quality

A summary of TCEQ stream segments designated as impaired within the Guadalupe River Basin is provided in Table 3-9 (TCEQ 2010a). Rivers and creeks flowing through the contributing and recharge zones provide a measure of the quality of the waters recharging the Edwards Aquifer. Other water entering the Edwards Aquifer in this river basin is from precipitation that falls over the recharge zone and groundwater from subsurface flow among the various geologic formations.

Table 3-11. The TCEQ Surface Water Quality Inventory Summary for Stream Segments in the Nueces River Basin that Provide Recharge to the Edwards Aquifer.

SEGMENT NAME	NUMBER	DESIGNATED WATER USES	WATER QUALITY CONCERNS WITHIN STREAM SEGMENT
Upper Sabinal River	2111	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Upper Nueces River	2112	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Upper Frio River	2113	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	Impaired Fish Community, Impaired Macrobenthic Community
Hondo Creek	2114	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed
Seco Creek	2115	Contact Recreation Use, Aquatic Life Use, Public Water Supply Use, General Use, Fish Consumption Use	None Listed

Source: TCEQ (2010a).

In 1986, the chlorinated hydrocarbons tetrachloroethene (PCE), trichloroethene (TCE), and 1,2-dichloroethene were detected in groundwater seeping into Willow Springs Creek, east of Interstate Highway 35 (IH-35) in San Marcos. Traces of these compounds were also found in fish, prompting the TCEQ to consider adding the site to the state Superfund list (San Antonio Express News 2001). Willow Springs Creek empties into the San Marcos River east of IH-35. No traces of these chemicals were found in the San Marcos River.

San Antonio River Basin Water Quality

The State of Texas Water Quality Inventory characterizes the San Antonio River as having historically poor water quality. The San Antonio River flows 240 mi (386 km) through the study area to its confluence with the Guadalupe River. The San Antonio 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 after treatment (CH2M Hill 1986). Pollutants in the San Antonio River Basin are derived primarily from urban runoff and municipal wastewater discharges. A summary of stream segment water quality is provided in Table 3-10 (TCEQ 2010a).

Nueces River Basin Water Quality

During low-flow conditions, water quality in the Nueces River Basin can be substantially degraded by natural and human activities. Stream segment water quality is summarized in Table 3-11 (TCEQ 2010a).

3.2.1.4 Nationwide Rivers Inventory

The National Park Service's Nationwide Rivers Inventory (NRI) lists more than 3,400 free-flowing river segments in the United States defined as possessing one or more "outstandingly remarkable" natural or cultural values judged to be of more than local or regional significance. Under a 1979 Presidential Directive and related CEQ procedures, all federal agencies are directed to avoid or mitigate actions that would adversely affect one or more NRI segments. The

NRI is a source of information for statewide river assessments and federal agencies involved with stream-related projects (NPS 2010). Four river or stream segments described in the NRI are partially or wholly within the study area.

- Frio River – A 40-mi (64-km) section from Concan upstream to the headwaters within Uvalde and Real Counties; a clear, spring-fed river listed for outstanding scenic, recreation, wildlife, and historic values; very popular recreational river for canoeing and tubing, mostly concentrated near Garner State Park; banks are lined with bald cypress, pecan, and oak, with limestone outcroppings and bluffs.

- Guadalupe River – An 81-mi (130-km) section from the headwaters of Canyon Lake upstream to headwaters near Kerrville; listed for outstanding scenic, recreation, geologic and other values; has been rated as #1 recreational river in the state and #2 scenic river; heavily used by canoeists, kayakers, and tubers; features two major waterfalls and numerous rapids; limestone bluffs and formations line the river.

- Nueces River – A 54-mi (87-km) section from the southernmost SH 55 crossing northwest of Uvalde, Texas, upstream to the headwaters; listed for outstanding scenic, recreation, geologic, fish and wildlife values; included in the top 100 natural areas in the state.

- Sabinal River – A 37-mi (60-km) section from U.S. Highway 90 crossing in Sabinal, Texas, upstream to the headwaters; listed for outstanding scenic, recreation, geologic, wildlife, and other values.

3.2.2 Groundwater

In addition to the Edwards Aquifer, four major aquifers (Carrizo-Wilcox, Edwards-Trinity, Gulf Coast, and Trinity Aquifers) (Figure 3-19) and five minor aquifers (Ellenburger-San Saba, Hickory, Queen City, Sparta, and Yegua Jackson Aquifers) are located in the study area (Figure 3-20) (TWDB 2006a, 2006b). Each is described briefly here, followed by an in-depth discussion of the Edwards Aquifer.

3.2.2.1 Carrizo-Wilcox Aquifer

The Carrizo-Wilcox Aquifer extends from the Rio Grande in South Texas northeastward into Arkansas and Louisiana (TWDB 2010a) (Figure 3-19). The outcrop proceeds through the study area in Medina and Bexar Counties. The Carrizo-Wilcox Aquifer is predominantly composed of sand locally interbedded with gravel, silt, clay, and lignite deposited during the Tertiary Period (TWDB 2010a).

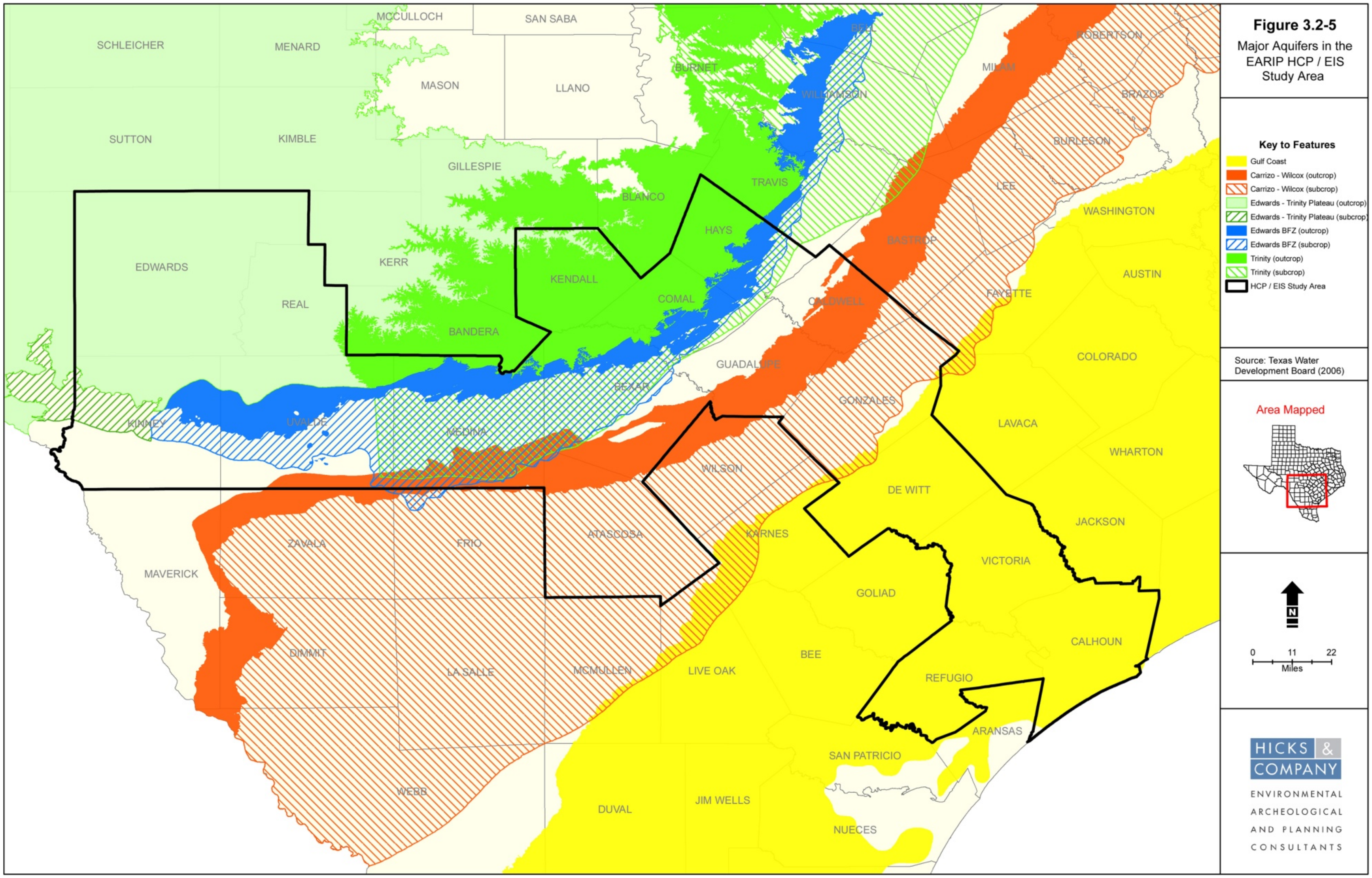


Figure 3.19. Major Aquifers in the EIS Study Area.

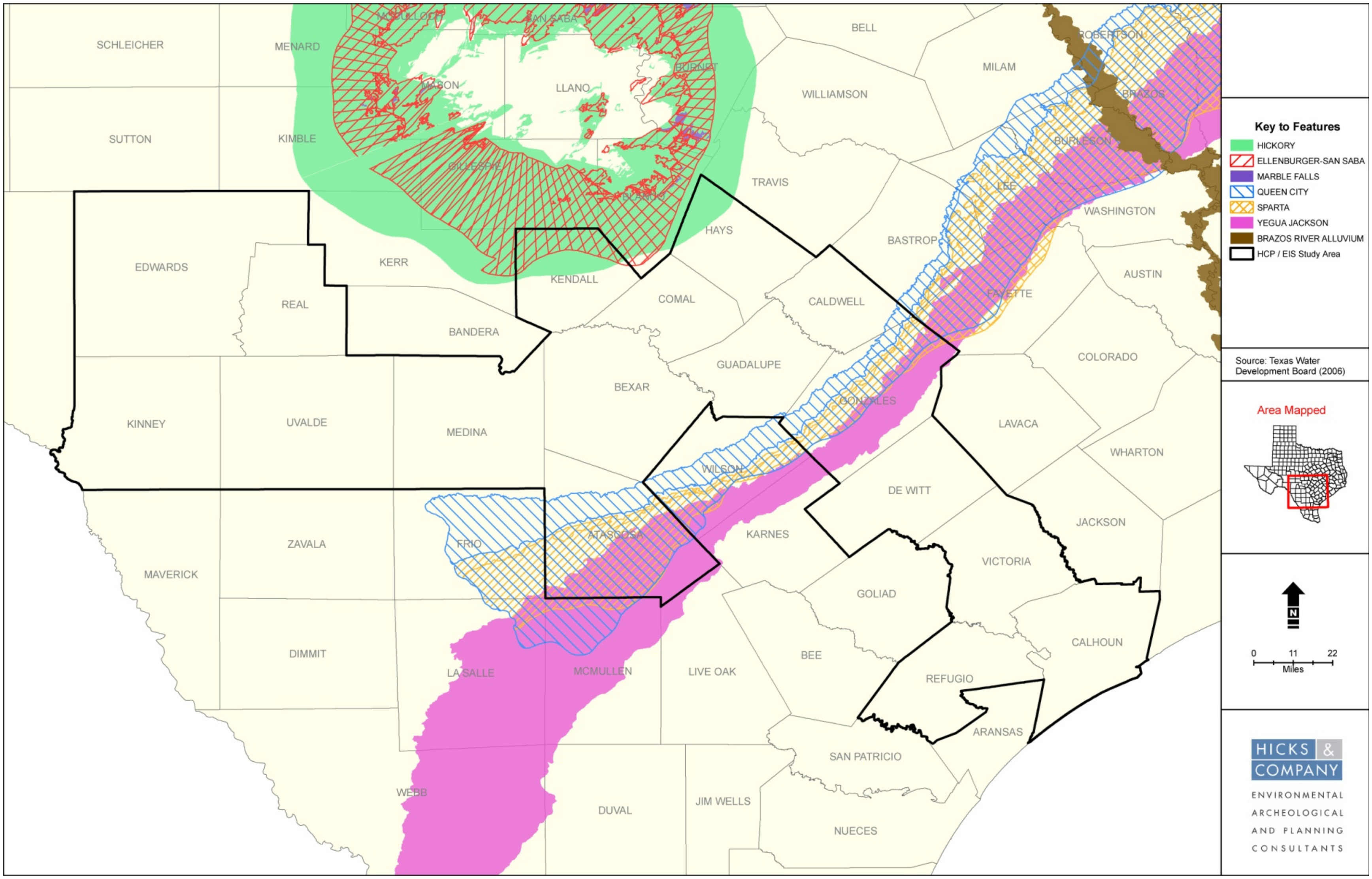


Figure 3.20. Minor Aquifers in the EIS Study Area.

3.2.2.2 Edwards-Trinity Aquifer

The Edwards-Trinity, also known as the Edwards-Trinity (Plateau) Aquifer, is a sandstone and carbonate-rock aquifer extending from the Edwards Plateau into west Texas (Figure 3-19). This aquifer is generally recharged by direct precipitation on the land surface (USGS 1999). Primary demand for groundwater pumped from this aquifer comes principally from agricultural use, followed by municipal and industrial use, and thermo-electric power (USGS 1999). The water is generally a hard, calcium bicarbonate type and typically has concentrations of dissolved solids that range from 400 to 1,000 milligrams per liter (mg/L) (USGS 1999).

3.2.2.3 Gulf Coast Aquifer

The Gulf Coast Aquifer extends from the Lower Rio Grande Valley in south Texas following the Texas Gulf Coast to the Louisiana-Texas border and underlies Calhoun, DeWitt, Refugio and Victoria counties and a small portion of Gonzales County within the study area (Figure 3-19). This aquifer consists of complex interbedded clays, silts, sands, and gravels, which are hydrologically connected to form a large, leaky artesian aquifer system. Water quality is generally good in the shallower portion of this aquifer. Municipal and irrigation uses account for 90 percent of the total pumping from this aquifer (TWDB 2010b).

3.2.2.4 Trinity Aquifer

The Trinity Aquifer is associated with lower Cretaceous rocks underlying the Edwards Group (Figure 3-19) (Ashworth 1983). The Trinity Aquifer is divided into three units (Upper, Middle, and Lower Trinity) that form a leaky, primarily confined aquifer system (Ashworth 1983). Groundwater in the Middle Trinity Aquifer discharges through springs, pumping, and directly into the Edwards Aquifer to the south and east. Waters from the Trinity generally contain higher concentrations of sulfate, chloride and total dissolved solids (TDS) but fewer detections of nitrate, pesticides, and volatile organics than waters from the Edwards Aquifer (Bush et al. 2000).

The Upper Trinity Aquifer occurs in the upper member of the Glen Rose Formation and forms part of the contributing zone for the Edwards Aquifer. Much of the Upper Trinity groundwater emerges in seeps and springs. Some of this discharge flows overland and is recharged into the Edwards Aquifer. Recent dye-trace studies find that the amount of Trinity Aquifer groundwater migrating to the Edwards Aquifer may be greater than was previously understood (Green 2011). The Lower Trinity is not believed to contribute water to the Edwards Aquifer.

3.2.2.5 Hickory Aquifer

The Hickory Aquifer extends into the study area in portions of Kendall and Hays Counties. Groundwater from this aquifer is generally fresh and most of the water pumped is used for irrigation. In some areas, this aquifer produces water with radium concentrations that exceed drinking water standards, and the water can contain radon gas. Waters from the upper unit of the Hickory contain iron concentrations that exceed drinking water standards (TWDB 2010c).

3.2.2.6 Ellenburger-San Saba Aquifer

The Ellenburger-San Saba Aquifer extends into the study area in northern Kendall County (TWDB 2010d). About 75 percent of the water pumped from this aquifer is used for municipal water supplies in the communities of Bertram, Fredericksburg, Johnson City, and Richland Springs. Water produced from this aquifer is inherently hard and usually has less than 1,000 mg/L dissolved solids (TWDB 2010d).

3.2.2.7 Queen City Aquifer

The Queen City Aquifer occurs in portions of Atascosa, Gonzales, and Caldwell Counties within the study area. This aquifer is composed of sand, loosely cemented sandstone, and interbedded clay. Water pumped from this aquifer is used for municipal and industrial water supply as well as agricultural irrigation. Water of excellent quality is generally found within the outcrop but deteriorates with depth. Relatively high iron concentrations occur in some locations (TWDB 2010e).

3.2.2.8 Sparta Aquifer

Portions of Atascosa and Gonzales Counties overlay the Sparta Aquifer. The Sparta Aquifer occurs within sand and interbedded clay and provides water for domestic, livestock, municipal, industrial, and irrigation uses. The water quality is excellent within the outcrop area but deteriorates with depth. Water within some areas may contain iron concentrations in excess of drinking water standards (TWDB 2010f).

3.2.2.9 Yegua Jackson Aquifer

The Yegua Jackson Aquifer occurs within the study area in portions of Atascosa and Gonzales Counties. This aquifer is composed of complex associations of sand, silt, and clay. Water pumped from the Yegua Jackson Aquifer is used for municipal, industrial, and irrigation purposes. Water quality varies greatly within this aquifer. Small to moderate amounts of usable quality water can be found within shallow sands (less than 300 feet [91 m] deep) over much of this aquifer, though, localized occurrences of poor-quality water are not uncommon (TWDB 2010g).

3.2.2.10 Edwards Aquifer

The Edwards Aquifer (referred to as the Edwards Balcones Fault Zone Aquifer by the Texas Water Development Board [TWDB]) covers approximately 4,350 mi^2 (11,266 km^2) across parts of 11 Texas counties (Figure 3-19) (TWDB 2006a). The Edwards Aquifer has focused recharge zones, enhanced secondary porosity, and excellent water quality. These factors make the Edwards Aquifer one of the most productive groundwater reservoirs in the country (Sharp and Banner 1997). The Edwards Aquifer is the primary water source for almost 2 million people and supports cities, towns, rural communities, farms, and ranches (EAA 2010a, U.S. Census Bureau 2010a). The water is used for a range of purposes, including municipal, industrial, manufacturing, power generation, irrigation, mining, livestock, and recreation. The Edwards

Aquifer also supports several major springs which provide habitat for a number of threatened and endangered species.

Groundwater movement through the Edwards 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 geologic strata causes juxtaposition of permeable and impermeable layers across the region. Water moves more freely through the Edwards Aquifer when this displacement is minimal. Groundwater divides hydrogeologically separate the central portion of the Edwards Aquifer from Edwards limestones on either side (see Figure 3-21). The Edwards Aquifer is usually described therefore as being composed of three segments: the southern (sometimes referred to as the San Antonio) segment; the Barton Springs (or Austin) segment; and the northern segment.

One such groundwater divide runs west-northwest from the city of Kyle, in Hays County, hydrologically separating the southern and Barton Springs segments under normal conditions. Generally, groundwater north of this divide flows north, while groundwater south of the divide flows south. Groundwater from the San Antonio and Austin segments do not normally mix, though the groundwater divide may be diminished during drought conditions. A recent study suggests that as water levels in the Edwards Aquifer decline during major droughts and current levels of pumping, some southern segment groundwater bypasses San Marcos Springs and flows north into the Barton Springs Segment of the Edwards Aquifer (HDR 2010). The northern segment of the Edwards Aquifer is hydrologically separated from the Barton Springs Segment by the Colorado River. The study area is primarily concerned with the southern segment of the Edwards Aquifer.

The southern segment of the Edwards Aquifer (illustrated in Figures 1-1, 3-19, and 3-21) varies in width from 5 to 40 mi (8 to 64 km) and extends through six counties: Kinney, Uvalde, Medina, Bexar, Comal, and Hays. The water-bearing body of the Edwards Aquifer underlies approximately 3,600 mi^2 (9,324 km^2) in eight counties and holds water that drains from approximately 8,000 mi^2 (20,720 km^2) in 12 counties. The total volume of freshwater in the Edwards Aquifer is estimated at 173 million ac-ft (BEG 1993), although the amount of recoverable groundwater is not known. The Edwards Aquifer, which historically has been the sole source of water for the city of San Antonio (USGS 1995, EAA 2010a), provides base flow to the Guadalupe, Nueces and San Antonio River basins, and is utilized for municipal, industrial and agricultural needs throughout the region (USGS 1999).

The Edwards Aquifer is a karst aquifer that displays complex flow patterns typical of these systems (USGS 1995). Water flow through the Edwards Aquifer occurs across a range of hydraulic conductivities, from flow through the rock matrix (least conductive), to flow through planar fractures and bedding planes, to turbulent flow through integrated conduit systems (most conductive). Most storage occurs in the matrix zones, while flow typically occurs in the fractures, faults, and conduits. Groundwater in some components of the Edwards Aquifer may have long residence times and remain relatively resistant to contamination, while other portions of the Edwards Aquifer may have extremely rapid travel times and may be easily contaminated. The most easily contaminated portions of the Edwards Aquifer are also the most productive, feeding major springs and wells.

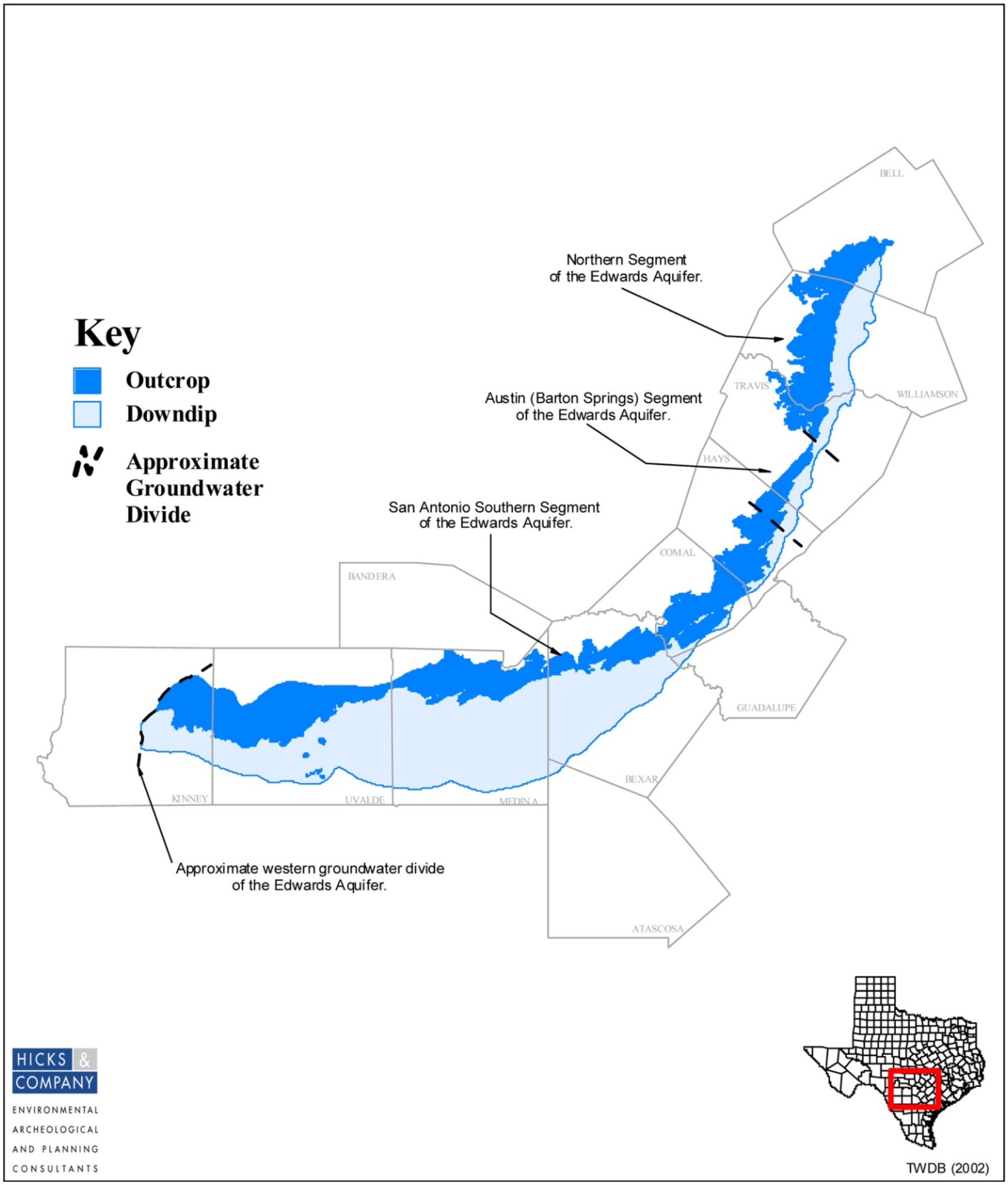


Figure 3-21. Edwards Aquifer (Not to Scale).

Flow pathways are also very dynamic in karst aquifer systems. Flow direction may be influenced by local or regional hydraulic gradients, and constrained by the location and orientation of conduit systems. Flow paths may be influenced by geologic formations that occurred under previous water flow regimes and may not therefore follow local topography or surface watersheds. Water flow in karst aquifers may cross watershed boundaries that would serve as groundwater divides in other aquifer systems. The pattern and direction of flow in karst is often water-level dependent, as differing water levels can utilize flow paths and travel through conduits formed under differing groundwater regimes. The southern section of the Edwards Aquifer consists of distinct contributing, recharge, and artesian zones described below (see Figures 1-1, 3-19, and 3-21).

Contributing Zone

The contributing zone is composed of drainage areas and catchments of surface streams, creeks, and rivers that flow over the Edwards Aquifer's recharge zone in the Guadalupe, Nueces, and San Antonio River Basins. The contributing zone encompasses some 4,400 mi^2 (11,396 km^2) in all or part of Bandera, Bexar, Blanco, Comal, Edwards, Gillespie, Hays, Kendall, Kerr, Kinney, Medina, Real, and Uvalde Counties (see Figures 1-1, 3-19, and 3-21).

Recharge Zone

The recharge zone (also known as the unconfined region) of the Edwards Aquifer comprises about 1,500 mi^2 (3,885 km^2) of heavily faulted and fractured Edwards limestone exposed at the land surface. This highly permeable zone intercepts and allows large quantities of surface water to flow into the Edwards Aquifer. The recharge zone stretches from north and west of San Marcos and New Braunfels extending southwesterly north of San Antonio, then westerly through portions of Bexar, Medina, Uvalde and Kinney Counties (see Figure 3-21). Under normal conditions most Edwards Aquifer recharge occurs in the basins west of Bexar County where the Edwards limestone outcrop is very wide at the surface (USGS 1995).

Recharge occurs where streams and rivers cross permeable Edwards limestones and flows go underground, or when precipitation or runoff falls directly on the exposed permeable outcrop. Each river and stream that crosses the outcrop loses significant portions of their flow to the Edwards Aquifer through joints, faults, sink holes, and other karst features, except the Guadalupe River (USGS 1995). Unlike most creeks and streams in the recharge zone, water levels in the Guadalupe River are near the groundwater table. The Guadalupe, therefore, may either gain or lose water to the Edwards Aquifer where it crosses the recharge zone, depending on Aquifer levels. Surface water reservoirs on the recharge zone, such as Medina Lake, also contribute water to the Edwards Aquifer.

Recharge to the Edwards Aquifer is typically intermittent because most streams in south-central Texas are ephemeral. The karstic nature of the system, however, allows for extremely efficient recharge. Water passing over the contributing zone and into faults and fractures of the recharge zone is rapidly transferred directly to the Edwards Aquifer with little or no filtration.

Artesian Zone

The artesian zone (also known as the confined region) is located between two relatively impermeable formations, the Glen Rose formation below, and the Del Rio clay above (Ferrill et al. 2004). The weight of water entering the Edwards Aquifer from the recharge zone creates tremendous pressure on water 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. This zone is where the highest capacity wells and largest springs, including Comal and San Marcos Springs, are found (Collins and Hovorka 1997).

Freshwater/Saline Water Interface

The freshwater/saline water interface (also referred to as the "Bad Water Line" or BWL) delineates the Edwards Aquifer's eastern and southern boundaries. The BWL is not a well-defined boundary but rather a transition zone extending from west of Kinney County through Bexar County and northward beyond the southern segment of the Edwards Aquifer. Wells to the south and southeast of this line typically have 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 BWL coincides with geologic features such as faults in some areas, while there are no apparent geologic controls in other areas. The presence of saline water in this zone appears to be associated with relative permeabilities of various strata within the Edwards Aquifer rather than a density boundary between different water types as is common in coastal sand aquifers. Wells in the transition zone locate freshwater between layers of brackish water, suggesting that geologic characteristics and porosity may influence salinities in this zone.

Though it has been suggested that increased pumping of freshwater from the Edwards Aquifer might result in expansion or migration of the BWL, testing has not detected any significant changes at water quality test well sites in the fresh/saline interface area. Researchers concluded that normal fluctuations in aquifer water levels have little effect on water quality near the interface (EAA 1997).

Hydraulic Properties

Transmissivity (the ability of water to pass through an aquifer, as measured by hydraulic conductivity and thickness) varies by location in the Edwards Aquifer. Rates of 130 square feet (ft^2) (12 square meters [m^2]) per day are found on the saline side of the BWL, while totals of 1,000,000 to 2,000,000 ft^2 (92,903 to 185,806 m^2) per day are possible on the freshwater side of the BWL near San Antonio (Maclay and Small 1986, Maclay and Land 1988). The highest transmissivity in the Edwards Aquifer exceeds 4,300,000 ft^2 (399,483 m^2) per day in Comal County near Comal Springs (Maclay and Land 1988).

The linear distance that water may travel through the Edwards Aquifer also varies by location. Studies have documented travel ranging from a few feet per day up to 1,000 feet (305 m) per day (Ogden et al. 1986a). Recent testing revealed discrete groundwater flowpaths near Panther Springs Creek with apparent groundwater velocities ranging from 43 to 17,490 feet (13 to 5,331 m) per day from the recharge zone to the transition/artesian zone (EAA 2010b). The high porosity of the Edwards Aquifer allows water levels to quickly respond to rainfall and recharge events; and for groundwater pumping to rapidly draw down water levels over large areas.

The Knippa Gap is a geological restriction within the Edwards Aquifer near Sabinal in eastern Uvalde County (Figure 1-1) that restricts the rate of easterly groundwater flow, thereby maintaining higher groundwater levels in portions of the Edwards Aquifer west of the gap (referred to as the Uvalde pool) than in the Edwards Aquifer east of the gap (sometimes called the San Antonio pool) (Green et al. 2008). Wells west of the Knippa Gap display less water level variability than wells to the east.

Flow models for the Edwards Aquifer show groundwater flowing from Uvalde and Medina Counties east-northeast eventually discharging at Comal, Hueco, and San Marcos Springs, numerous small springs, or extracted by groundwater pumping from wells (Kuniansky et al. 2001). Recent studies in northern Bexar County found some water flowing in a southerly direction at very rapid flow velocities (Johnson et al. 2009). These observations reinforce the understanding that flow paths within the Edwards Aquifer are complex and imperfectly understood, and that rapid groundwater transport within the Edwards Aquifer is dominated by karstic conduit flow.

3.2.2.11 Inter-Formational Flow into the Edwards Aquifer

Though the Edwards Aquifer receives most of its recharge directly from surface outcrops of the Person and Kainer limestone formations, some contributions occur through inter-formational flows from the Trinity Aquifer. A recent TWDB Groundwater Availability Model estimates that approximately 2,400 ac-ft/yr flows from the Hill Country Portion of the Trinity Aquifer to the Edwards Aquifer for each linear mile of Edwards-Trinity boundary in Bexar and Comal Counties (Jones et al. 2011). This model estimates that this flow in Medina and Uvalde Counties totals about 660 ac-ft/yr per mile, and contributes about 350 ac-ft/yr per mile in Hays and Travis Counties. Other recent research has demonstrated that streams in the Upper Glen Rose outcrop of the contributing zone are connected more directly with the Edwards Aquifer than previously understood (Green et al. 2011). Studies in northern Bexar County support significant connectivity between the two aquifers, and have documented rapid groundwater flow across faults that juxtapose the Edwards and Trinity Aquifers.

3.2.2.12 Groundwater Quality of the Edwards Aquifer

The Federal Safe Drinking Water Act of 1974 was created to protect public drinking water and was later amended to require establishment of national safe drinking water standards. The TCEQ is the Texas state agency charged with water quality protection and promulgates statewide criteria intended to meet or exceed USEPA national drinking water requirements.

The TCEQ regulates public water supply systems by enforcing primary drinking water standards. These standards identify specific contaminants that can adversely affect public health and are known or anticipated to occur in public water systems. Primary standards are based on concentrations estimated to be protective of human health and the environment and are described in relation to their MCLs (see Texas Administrative Code, Title 30, Chapter 290, Subchapter F, and Texas Administrative Code, Chapter 350). Secondary drinking water standards affect aesthetic qualities of drinking water, such as odor or appearance, but are not regulated and are therefore non-enforceable.

Approximately 80 wells selected to provide representative samples of the recharge and artesian zones are tested by the EAA on an annual basis to monitor water quality across the region. Testing program results for 2009 are summarized below (EAA 2010a).

No metals regulated under the primary drinking-water standards were detected at concentrations exceeding their respective MCLs in any of the 79 wells tested. Strontium, regulated under the TCEQ's Texas Risk Reduction Program, was detected at concentrations exceeding the state criteria in one Medina County well near the saline water zone. Iron and manganese were detected in several wells above their respective secondary drinking water standards of 300 μg/L and 50 μg/L. Iron was detected in wells in Medina and Hays Counties, while manganese was detected in Medina County near the saline water zone (EAA 2010a).

The presence of fecal coliform or fecal streptococcus bacteria indicates fecal matter contamination in groundwater and surface water. Of the 74 wells sampled for these bacteria, most detected less than 2 colony-forming units (CFU)/100 milliliters (mL) in concentration. Fecal coliform bacteria levels above 2 CFU/100 mL were detected in 12 wells and fecal streptococcus were detected in three wells at concentrations of 2, 3, and 6 CFU/100 mL (EAA 2010a).

Of 79 wells sampled for nitrates, none exceeded the MCL of 10 mg/L. One well indicated a concentration between 5 and 10 mg/L, and 16 wells contained concentrations at or above 2.0 mg/L. Three VOCs—toluene, chloroform, and chloromethane—were detected among the samples from 78 wells tested, though no detections exceeded the MCLs for these compounds. No detections of SVOCs were found in the wells sampled, and no pesticides, herbicides, and PCBs were detected in the 59 wells tested for these substances (EAA 2010a).

A TCEQ investigation identified contaminated groundwater near Leon Valley in northwestern San Antonio in 2004. This area, now designated the Bandera Road Ground Water Plume Superfund site, is located in a mostly commercial area near Bandera Road between Poss Road and Grissom Road. Some homes are also located nearby. Groundwater contaminants from the site include toluene and chlorinated solvents such as PCE, TCE, and cis-1,2-dichloroethene. The site was placed on the final National Priorities List in 2007, and the USEPA is investigating the pollution source and monitoring the contaminants (EAA 2010a).

In order to protect groundwater in the area, TCEQ established rules regulating development activity over the different zones of the Edwards Aquifer in eight counties including: Bexar, Comal, Hays, Kinney, Medina, Travis, Uvalde, and Williamson. The TCEQ regulations commonly referred to as Subchapter A (referring to Section 30 of the Texas Administrative Code, Chapter 213) apply to all construction-related or post-construction activities within the recharge zone, to certain activities within the transition zone along the eastern and southern boundary of the recharge zone, and to other activities that may potentially contaminate the Edwards Aquifer and hydrologically connected surface streams. Subchapter A prohibits various types of facilities such as municipal solid waste landfills and waste disposal wells in the recharge and transition zones and prescribes that aquifer protection plans be created prior to authorizing various regulated activities in these areas.

Subchapter B applies to regulated activities in the Edwards Aquifer contributing zone. Activities that disturb the ground or alter a site's topographic, geologic, or existing recharge characteristics are required to implement sediment and erosion controls or a Contributing Zone Plan to protect water quality during and after construction.

The EAA protects water quality by implementing rules concerning well construction, operation and maintenance, abandonment, and closure (see EAA Rules Chapter 713, Subchapters B, C, and D). The EAA also regulates the reporting of spills, storage of certain regulated substances on the recharge and the contributing zones of the Edwards Aquifer, and the installation of tanks on the recharge zone (Subchapters E, F, and G, respectively).

Local municipalities have also established Edwards Aquifer protection regulations, such as City of San Marcos requirements addressing water quality concerns over the Edwards Aquifer recharge zone.

3.2.2.13 The Edwards Aquifer Water Budget

Water levels in the Edwards Aquifer and the resulting outflows at 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 is the result of water entering the Edwards Aquifer from streams, natural catchments, recharge structures, localized runoff from precipitation events, and from subsurface flow from adjacent aquifers. Seasonal rainfall over the region ultimately controls the rate of recharge. Discharge occurs from natural springs and seeps, and pumping from wells drilled into the Edwards Aquifer. An unquantified amount is also discharged to the saline water zone (USGS 1995). Discharge is greatly affected by water demand and rate of pumping. If recharge rates are high, the Edwards Aquifer can sustain higher levels of pumping while maintaining springflows. Low recharge and high rates of pumping cause aquifer levels to decline, thereby reducing flows at the springs. Historic recharge and discharge of the Edwards Aquifer and effects to springflow are discussed below.

Groundwater Recharge

Estimates of the average annual Edwards Aquifer recharge vary from approximately 635,000 to 651,000 ac-ft (Klemt et al. 1979, USGS 1995). Data from the EAA's 2009 Hydrogeologic Data Report indicate an average annual groundwater recharge of 717,500 ac-ft for the period of record 1934–2009, and an even higher annual average of 965,400 ac-ft during the last 10-year period 2000–2009 (EAA 2010a). Contributions of the major river basins to the average annual recharge during the period of record 1934–2009 are listed in Table 3-12.

Table 3-12. Contributions of Major River Basins to Average Annual Recharge of the Edwards Aquifer, 1934–2009.

AREA	AVERAGE ANNUAL RECHARGE (ac-ft)
Frio River–Dry Frio River Basin	139,700
Nueces River–West Nueces River Basin	127,400
Area between Sabinal River and Medina River Basins	112,700
Cibolo Creek–Dry Comal Creek Basin	112,100
Area between Medina River and Cibolo Creek–Dry Comal Creek Basins	72,800
Medina River Basin	63,000
Blanco River Basin	46,900
Sabinal River Basin	42,900
TOTAL	**717,500**

Source: EAA (2010a).

Recharge to the Edwards Aquifer varied greatly during the years 1934–2009 (Figure 3-22). Variability is associated with precipitation and corresponding runoff into the major river and creek basins. Lowest annual recharge (44,000 ac-ft) occurred during 1956 at the peak of the drought of record. Highest recharge (2,486,000 ac-ft) occurred in 1992. Infiltration rates for water carried by the streams across the recharge zone have been estimated to range from 500 to greater than 1,000 cfs (USACE 1965). Recent EAA Hydrologic Simulation Program Fortran modeling indicates that land-based recharge outside of stream channels varies from two to 76 percent (EAA 2010a), whereas 24 to 98 percent of recharge occurs in stream channels as channel loss (LBG-Guyton Associates 2005). As described above, some recharge is now understood to arise from inter-formational flow from adjacent aquifers. Estimates of the contribution from adjacent hydraulically connected aquifers have been estimated to vary from 5,000 to 60,000 ac-ft/yr (EAA 2009).

Groundwater Discharge

Water exits the Edwards Aquifer from pumped wells and from natural springs and seeps occurring near geological faults. Wells are the principal source of water for agricultural, municipal, and industrial uses in the region. Well depths range from less than 500 feet (152 m) in the unconfined Aquifer to more than 3,000 feet (914 m) in the confined Aquifer in the western region (USGS 1995). Wells in the area can be very large, with casing diameters ranging from 10 to 30 inches (25 to 76 cm) and capable of pumping in excess of 35,000 gallons (132,489 liters) per minute. Average annual discharge from wells over the period of record 1934–2009 was 311,400 ac-ft (44.7 percent), in comparison to 384,400 ac-ft (55.3 percent) from springflow (EAA 2010a). During droughts, the proportion of well discharge to spring discharge changes considerably. During 1956 at the height of the DOR, wells contributed an estimated 82 percent of the discharge in comparison to 18 percent for springs. During the drought of 2008, wells contributed 51 percent of the total discharge, while spring discharge comprised 49 percent.

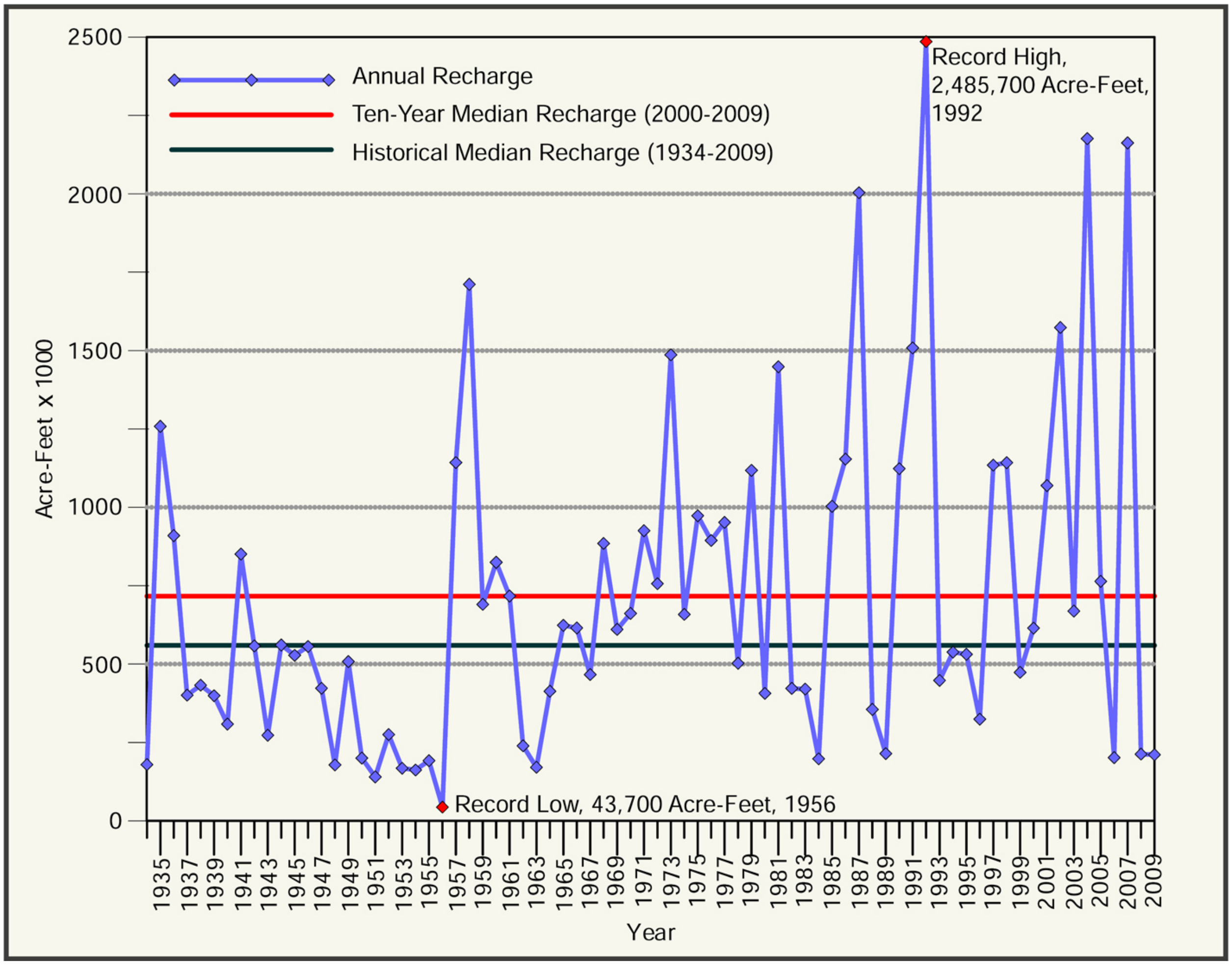


Figure 3-22. Estimated Annual Recharge and 10-year Floating Average Recharge for the San Antonio Segment of the Edwards Aquifer, 1934–2009 (EAA 2010b).

Well discharge generally increased over the period of record. From 1968 through 1989 annual discharge consistently exceeded the average annual recharge (USGS 1995), and pumping peaked in 1989 at an estimated 542,000 ac-ft. Springflow fluctuation has been recorded since 1980 as a result of increased pumping and varying recharge. Figure 3-23 illustrates pumping increases in 1982, 1987, and 1996, and resulting springflow fluctuations.

Dynamics of the Edwards Aquifer during Critical Periods

The EAA formed a Technical Advisory Group (TAG) to study Edwards Aquifer relationships during periods when discharge exceeds recharge. The work group developed trigger level and demand reduction recommendations intended to reduce springflow declines by managing groundwater pumping during critical conditions. The work group evaluated precipitation, recharge, groundwater withdrawal, Aquifer levels and spring discharge.

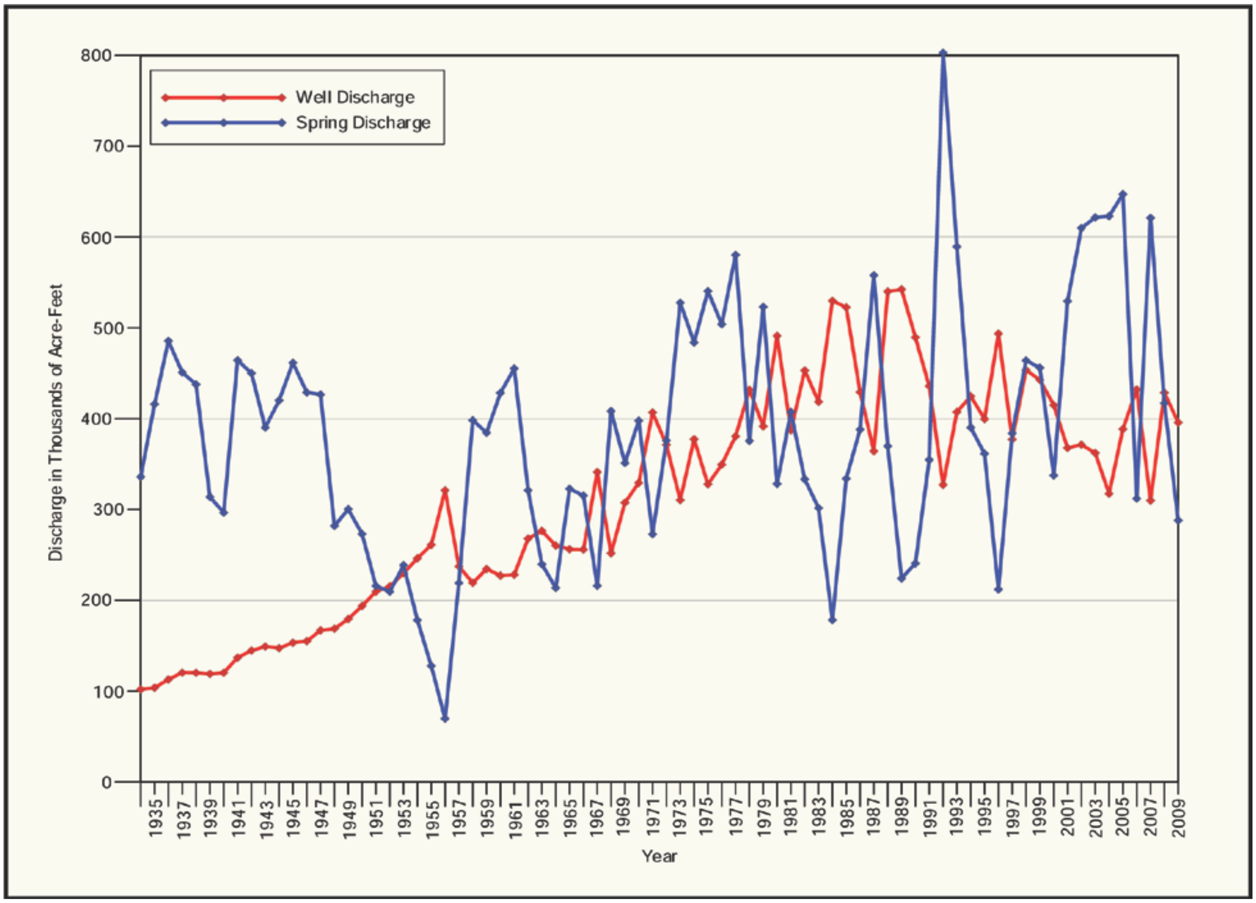


Figure 3-23. Groundwater Pumping Compared with Springflow from the Edwards Aquifer, 1934–2009 (EAA 2010b).

Findings of the TAG are summarized below:

1. Edwards 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 Edwards Aquifer levels measured by the Index Well J-17.

4. All pumping throughout the region contributes to Edwards Aquifer water levels.

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 transmissivity, groundwater levels respond simultaneously to pumping throughout large areas of the Edwards Aquifer region.

9. Moderate pumping reductions are preferred early in the year rather than deep reductions in summer.

Recommendations developed by the TAG include:

1. A CPM 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 Edwards Aquifer during critical periods.

2. Edwards Aquifer conditions should be evaluated using 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/CPM reductions.

3.3 BIOLOGICAL RESOURCES

3.3.1 Regional Ecology

The study area includes portions of five ecoregions, including the Edwards Plateau, Southern Texas Plains, Texas Blackland Prairies, East Central Texas Plains, and Gulf Coast Prairies and Marshes. Descriptions of each of these ecoregions and their characteristic plant and animal communities are found in TPWD's 2012 Texas Conservation Action Plan, and are hereby fully incorporated by reference (TPWD 2012, also available online at **http://www.tpwd.state.tx.us/landwater/land/tcap/**).

The portions of the study area that may be impacted by the actions under consideration are the Edwards Aquifer associated ecosystems such as the aquifer-fed springs and the river ecosystems they support and downstream flora and fauna that rely on the waters flowing from these sources. These systems will therefore be the focus of discussion.

<u>3.3.1.1 Edwards Aquifer Ecosystem</u>

The Edwards Aquifer and its associated springs host distinct but connected aquatic ecosystems containing some of the greatest groundwater and spring-associated species diversity in the world

(Holsinger and Longley 1980, Longley 1981, Reddell 1994, Sharp and Banner 1997, Culver and Sket 2000). The Edwards Aquifer supports a unique ecosystem that contains a number of subterranean aquatic species adapted to deep-water environments (greater than 985 feet [300 m] below the surface) such as the toothless blindcat (*Satan eurystomus*) and the widemouth blindcat (*Trogloglandis pattersoni*), while the springs host a different assemblage of flora and fauna adapted to the distinctive conditions associated with these near-surface environments (Longley 1986, 63 FR No. 174 48166–48167).

The subterranean portions of the Edwards Aquifer support a highly adapted biological community that may be adversely impacted by many of the same threats as species at the springs, such as water quality contamination or degradation. Because the actions contemplated within the study area are not anticipated to impact the deep Edwards Aquifer ecosystem or change the likelihood of exposing deep-water aquatic species to such threats, these species are unlikely to be adversely impacted by the considered alternatives, and are not considered further in this DEIS. The ecosystems at or near the surface of the Edwards Aquifer and the associated springs and organisms that otherwise rely on springflows and that may be affected by the actions being considered will therefore be the focus of the discussion.

3.3.1.2 Comal Springs Ecosystem

The Comal Springs system is comprised of four major springs and several smaller spring runs that feed into Landa Lake. The spring runs and Landa Lake form the headwaters of the Comal River, which spans 3.1 mi (4.9 km) before its confluence with the Guadalupe River.

Water flows from Landa Lake into the natural watercourse referred to as the “old channel” and into a man-made “new channel” created to power a hydropower facility in the mid-1800s. The two channels rejoin 1.6 mi (2.6 km) downstream (McKinney and Sharp 1995). The old channel retains many of its natural characteristics even though there are some small dams and channelization. The new channel is uniform in width with a limestone stream bottom in some stretches. Several dams within both the new and old channels of the Comal River now serve primarily to provide for recreation accessed from the adjacent parklands and privately owned water recreation facilities (McKinney and Sharp 1995). Bankside construction and development, channel modification, and the natural variability of the springs have had an effect on the aquatic environment of the Comal Springs system over time (BIO-WEST 2007). Some effects such as securing the water level in Landa Lake via the reconstructed dam and new culvert installation have probably benefitted native species, while others such as operation of the culvert in the old channel during periods of high springflow have probably been detrimental to these species. Some effects of these modifications are well known and minor, such as the placement of the fishing pier in Landa Lake, which displaced a small amount of aquatic vegetation due to shading and also contributes to catching floating debris during low flow periods which expands the area of shading. Some are well known and significant, such as the upgrade and operation of the culvert system in the old channel of the Comal River that led to several quantifiable negative effects as documented by the loss of native vegetation and subsequent reduction of high quality fountain darter habitat (BIO-WEST 2007).

The severity of the DOR 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 stopped flowing. Landa Lake went from being “full” in early June, to ceasing flow over the dam in August of that year.

The response of Comal Springs to dropping water levels has been described by LBG-Guyton Associates (2004) and is incorporated here by reference and briefly summarized below.

Springflow at spring runs #1 and #2 ceases when flow at Comal Springs drops to about 130 cfs and Landa Park Well (a 320–foot-deep [98-m-deep] 6-inch-diameter [15-cm-diameter] observation well adjacent to Panther Creek above Comal Springs) water elevation is approximately 622 feet (190 m) msl. Spring run #3 stops flowing when Comal Springs flow declines to about 50 cfs and Landa Park Well water level falls to 620 feet (189 m) above msl. This elevation corresponds to the dam-controlled pool level of Landa Lake.

Spring runs #1 and #2 ceased flowing during the summer of 1953 and from the summer of 1954 until January 1957. Spring run #3 stopped flowing during the summer of 1955, and again from May until December 1956. Although flow from spring runs #1, #2 and #3 stops at a Landa Park well level of 620 feet (189 m) msl, some water continued to flow from Landa Lake due to discharge from other spring runs into the lake.

When the water elevation at the Landa Park well declined to about 619 feet (189 m) msl, total spring discharge fell to zero. During 1956, spring discharge was zero for 144 consecutive days, from June 13 to November 3. Flow at the New Channel dam had stopped at this level, though some water continued to flow through the culvert to the Old Channel.

Large portions of the lake bottom emerged at a lake elevation of 618 feet (188 m) msl. The north end of the lake, north of Spring Island, also emerged at about 618 feet (188 m) msl. Although there were some deeper pools at the north end, flow from north to south was probably cut off. Figures 3-24 and 3-25 are photographs of the southern end of Landa Lake that were taken in the summer of 1956. The water level in the individual pools within the lake appeared to be about 617–618 feet (approximately 188 m) msl. The lowest level of Landa Park well (613.34 feet [186.95 m] msl) was reached August 21, 1956. The deepest pool, just south of Spring Island had a bottom elevation of 613 feet (187 m) msl, and newspaper clippings describe 6 inches (15 cm) of water in the deepest pools.

Lake bottom elevations prevent water from reaching the Old Channel culvert at Landa Park Well water levels of approximately 618 feet (188 m) msl. Spring discharge could presumably still occur at water levels as low as the lowest lake-bottom elevation of 613 feet (187 m) msl, though no natural outlets are known from this elevation.

Figure 3-24. Summer 1956 Photograph of Southern End of Landa Lake, on Western Shore Looking North toward the Escarpment. Photograph Date Unknown. Water Level Elevation in Pools Is About 617 to 618 Feet. Photograph Provided by George Ozuna of the U.S. Geological Survey (LBG-Guyton Associates 2004).

3.3.1.3 San Marcos Springs Ecosystem

San Marcos Springs have been described as the most environmentally stabile and reliable spring system in the southwestern United States and flows have never been known to stop at this location in recorded history (Figures 3-26a, 3-26b, and 3-26c) (USFWS 1996a). Spring Lake constitutes the headwaters of the San Marcos River that extends approximately 75 mi (121 km) to its confluence with the Guadalupe River. Temperatures remain nearly constant year-round at 71.1° F (21.7° C) (USFWS 1996a). The average discharge from the San Marcos Spring system from 1994 through 2001 was 180 cfs (EAA 2002) though flows dropped to approximately 46 cfs during the height of the DOR. 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).

Figure 3-25. Summer 1956 Photograph of Southern End of Landa Lake, on Western Shore Looking Southeast toward the Flow-through Pool. Photograph Date Unknown. Water Level Elevation in Pools Is about 617 to 618 Feet. Photograph Provided by George Ozuna of the U.S. Geological Survey (LBG-Guyton Associates 2004).

The San Marcos system, like the Comal, reflects more than a century of intensive use and management. Flood control dams upstream of the San Marcos River reduce the magnitude of scouring flood events thereby increasing sedimentation in the system. These structures also capture stormwater flows that allow some recharge to the Edwards Aquifer system. The river is a destination for water-related recreational activities and riverside parks provide ready access for the local community and tourists. Increasing competition with exotic species and resulting displacement of native species has been noted in association with many of these man-made changes to the San Marcos Springs system (Lemke 1989).

A description of San Marcos Springs response to changing water levels has been described by LBG-Guyton Associates (2004) and is incorporated here by reference and briefly summarized below.

San Marcos Springs is the terminus of an Edwards Aquifer flow path that includes most of the outcrop, streams, and the Blanco River in Hays County. The springs receive recharge from this area, and respond rapidly to storm events in the region. San Marcos Springs also receives a base flow of about 50 to 100 cfs from the southern segment of the Edwards Aquifer that bypasses Comal Springs.

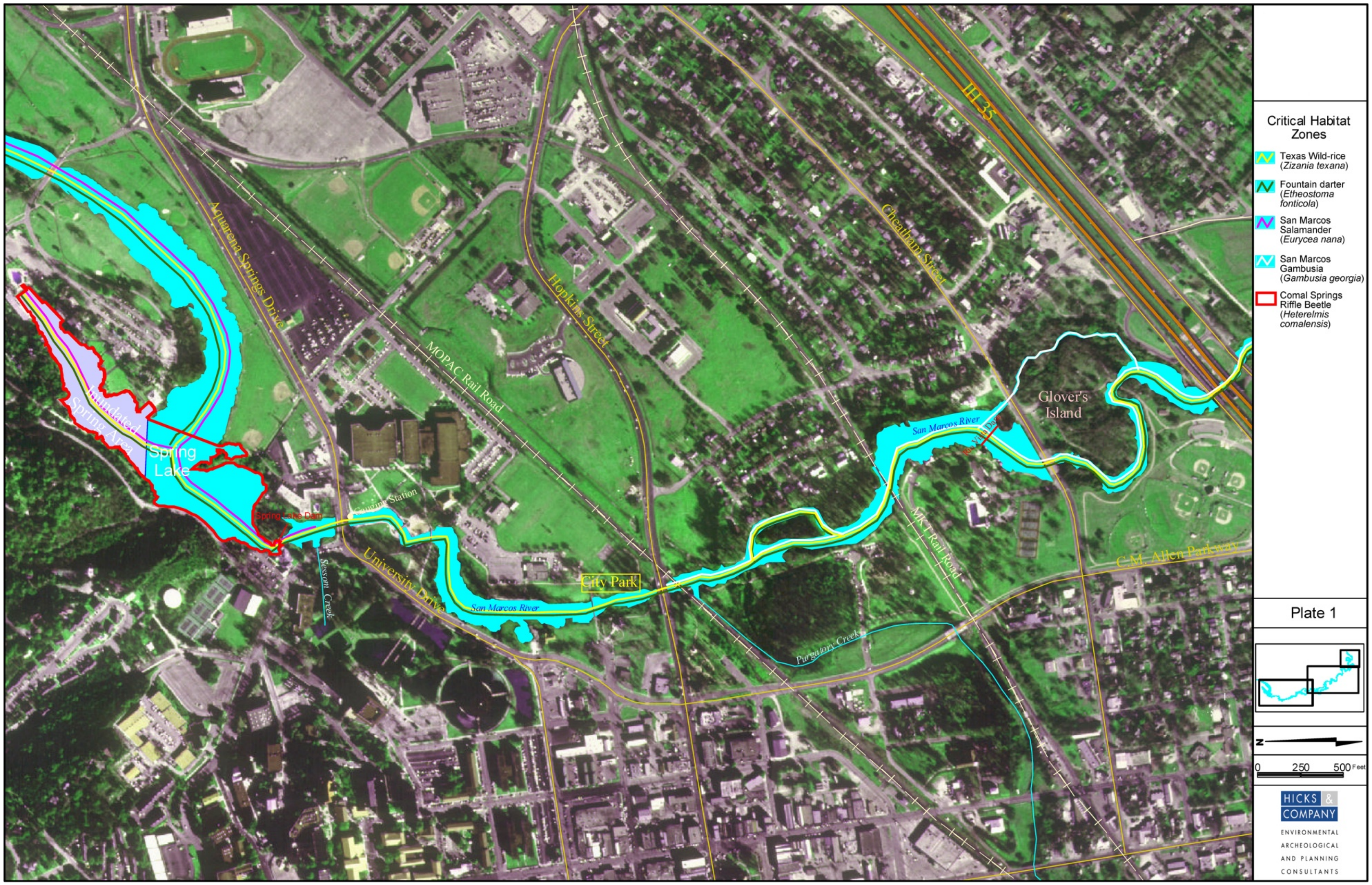


Figure 3-26a. San Marcos Springs Ecosystem Vicinity.

Figure 3-26b. San Marcos Springs Ecosystem Vicinity.

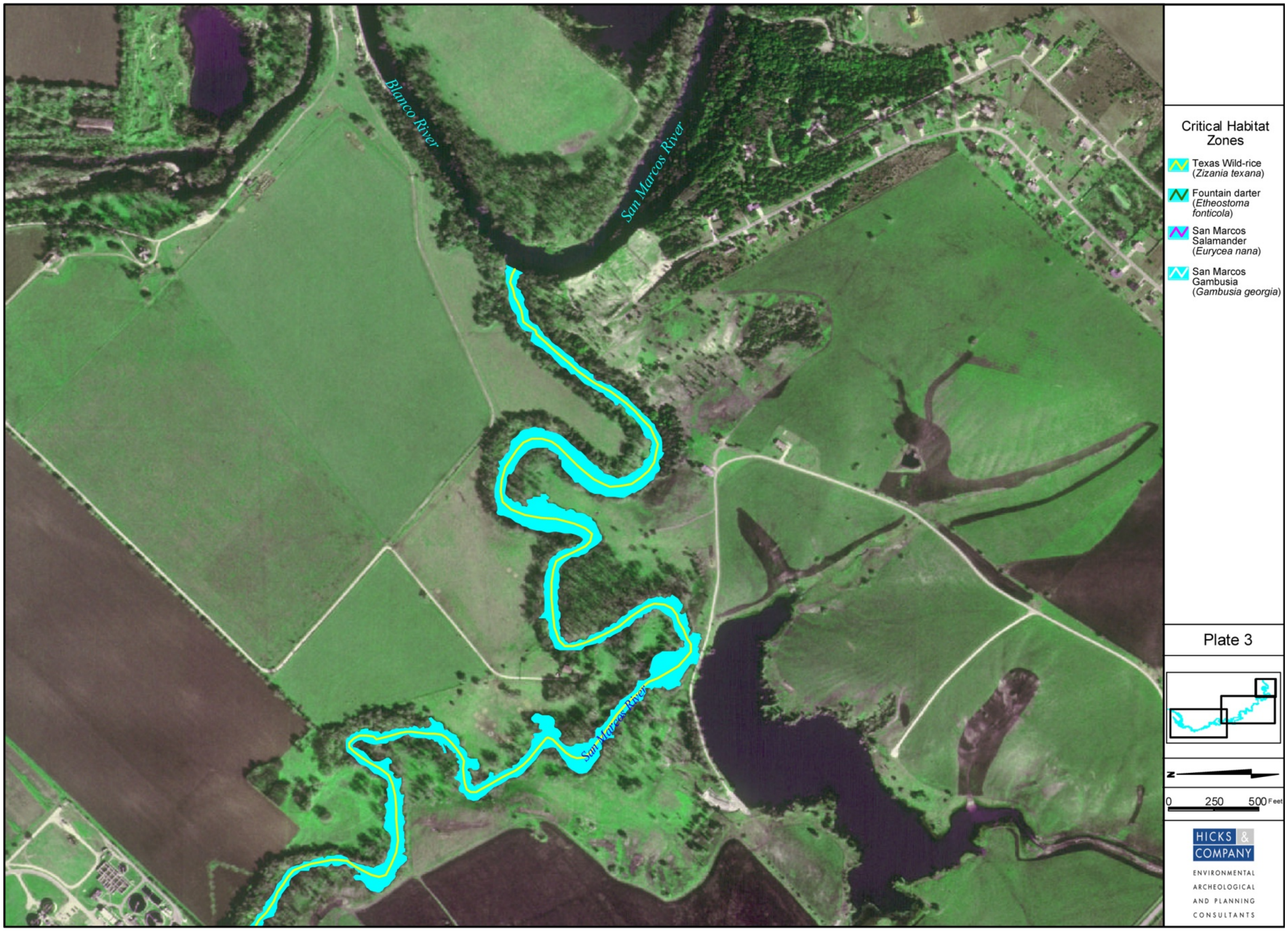


Figure 3-26c. San Marcos Springs Ecosystem Vicinity.

Discharge at San Marcos is through spring complexes in the bottom of Spring Lake. 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 Hays County recharge. Discharge rates in the southern springs are generally more stable under varying flow conditions than the northern springs, which are more variable in proportion to total spring discharge values.

3.3.1.4 Hueco Springs Ecosystem

Hueco Springs is located in Comal County approximately 4 mi (6 km) north of Comal Springs (Figures 2-1 and 3-27). This spring complex consists of two main groups of springs issuing from the floodplain of the Guadalupe River. Hueco I (Hueco A) is a large, typically perennial spring on the west side of River Road in an undeveloped area and Hueco II (Hueco B) is an intermittent spring on the east side of River Road. Aquifer flow paths to both Comal Springs and Hueco Springs are illustrated in Figure 3-27.

Following Barr (1993), only recent drought/springflow data is presented here. The larger of the two springs, Hueco I, typically exhibits constant flow but has been documented to stop flowing during severe droughts such as in 1984 (Ogden et al. 1986b). However, Hueco I did not stop flowing during the drought occurring in 1989–1991. Hueco II is an intermittent spring that typically stops flowing during the driest months of the year (Barr 1993).

3.3.1.5 Fern Bank Springs Ecosystem

Fern Bank Springs is a series of small perennial springs and seeps that flow from the base of a bluff on the south bank of the Blanco River in Hays County (Figure 3-28). While the source of the water for Fern Bank Springs is undetermined (72 FR 39247–39283), it may originate from the upper member of the Glen Rose Formation, from drainage from the Edwards Aquifer Recharge Zone, from water lost from the Blanco River, or from some combination of those sources (72 FR 39247–39283). The springs themselves have been minimally altered, except for the installation of water collection containers below the spring orifices and an intake box and pipes near the uppermost orifice where a pool was once tapped for drinking water.

3.3.1.6 Candidate, Threatened and Endangered Species

The approximately 16,648-mi^2 (43,118-km^2) study area encompasses a range of terrestrial and aquatic habitats that may be occupied by candidate, threatened or endangered species (see Table 3-13, modified from TPWD 2012). This table includes all such species known or believed to occur within the 17-county area. Species within the study area that may be affected by proposed alternatives are further described in Chapter 4.

Other plant and animal species found within the study area that lack federal regulatory status but which may merit conservation concern are identified in the Texas Conservation Action Plan (TPWD 2012).

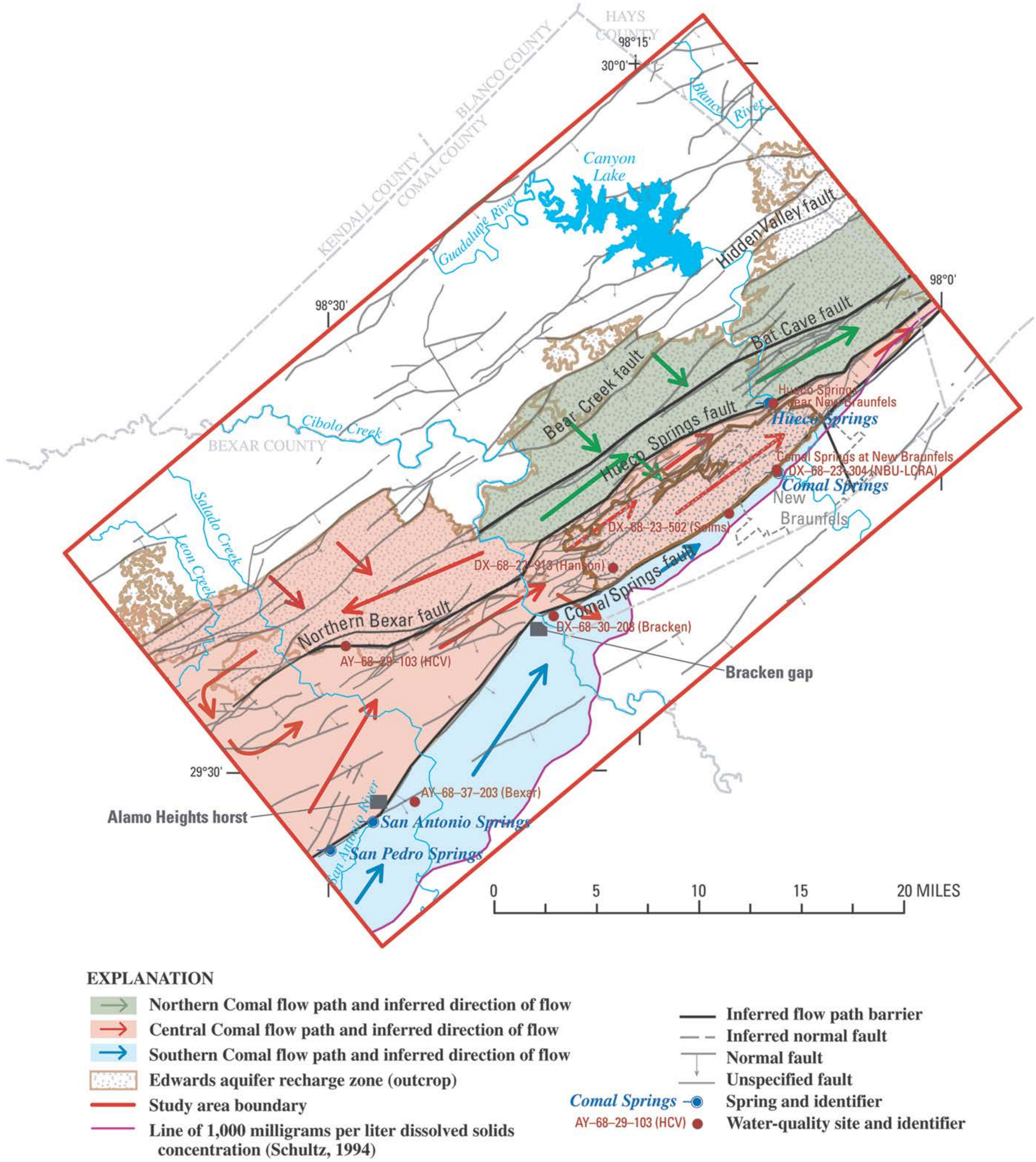
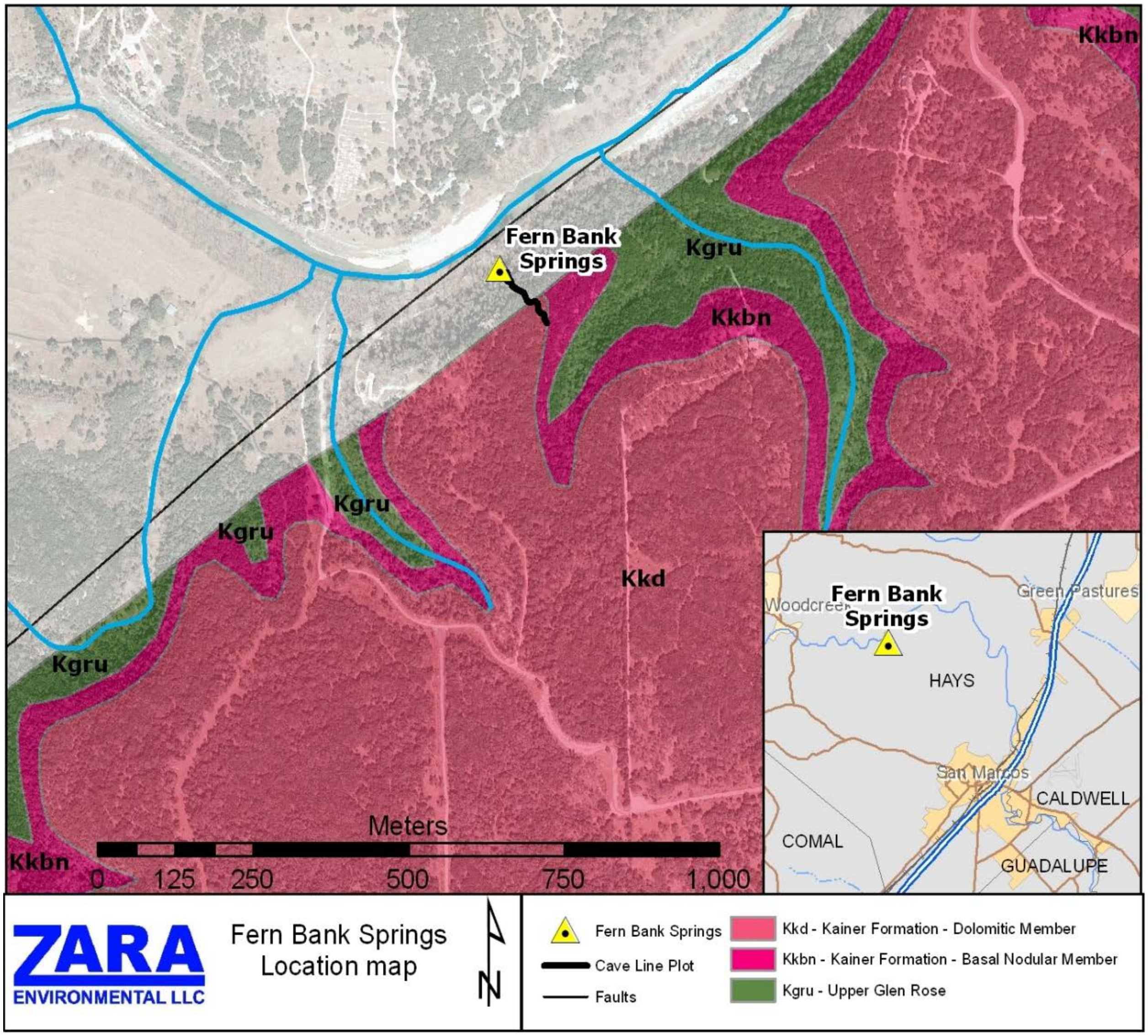


Figure 3-27. Major Faults and Interpreted Groundwater Flowpaths to Comal and Hueco Springs (Otero 2007).



Basemap: U.S. geological Survey (USGS) Geologic Map of the recgarge Zone (Blome et al., 2005); USGS 1:24,000 National Hydrography dataset; CAPCOG Aerial Imagery 2008

Figure 3-28. Local Geologic Map Showing the Plotted Location of Fern Bank Springs Cave and Edwards (Kainer Formation) Limestone Outcrop near the Blanco River.

Table 3-13. Candidate, Threatened, and Endangered Species Known from the EIS Study Area.

SCIENTIFIC NAME	COMMON NAME	STATUS[a]	TCAP ECOREGIONS[b]					GENERAL HABITAT TYPE(S) IN TEXAS
		Federal	TBPR	ECPL	EDPT	GCPM-MID	STPL	
MAMMALS								
Herpailurus yaguarondi calomitli	Jaguarundi Gulf Coast	LE					X	Shrubland
Leopardus pardalis	Ocelot	LE					X	Shrubland
Ursus americanus	Black Bear	SAT	X	X	X			Forest, Woodland, Savanna/Open Woodland, Desert Scrub, Shrubland
BIRDS								
Tympanuchus cupido attwateri	Greater Prairie-Chicken (Attwater's)	LE				X		Grassland
Falco femoralis	Aplomado Falcon	E				X		Grassland, Shrubland
Grus americana	Whooping Crane	LE				X		Saltwater Wetland, Estuary
Charadrius melodus	Piping Plover	LT				X		Estuary/Estuarine, Coastal
Charadrius montanus	Mountain Plover	PT	X			X	X	Agricultural, Grassland
Sternula antillarum	Least Tern	LE	X	X			X	Riverine, Lacustrine, Freshwater Wetland, Saltwater Wetland, Estuary, Coastal, Marine, Developed: Industrial
Vireo atricapilla	Black-Capped Vireo	LE			X			Shrubland
Anthus spragueii	Sprague's Pipit	C	X	X	X	X	X	Barren/Sparse Vegetation, Grassland, Shrubland, Agricultural
Dendroica chrysoparia	Golden-Cheeked Warbler	LE			X			Woodland
REPTILES AND AMPHIBIANS								
Eurycea nana	San Marcos Salamander	LT			X			Freshwater Wetland (Springs)
Eurycea rathbuni	Texas Blind Salamander	LE			X			Aquifer, Caves, and Karst, Freshwater Wetland (Springs)

Table 3-13. (Cont.).

SCIENTIFIC NAME	COMMON NAME	STATUS[a]	TCAP ECOREGIONS[b]					GENERAL HABITAT TYPE(S) IN TEXAS
		Federal	TBPR	ECPL	EDPT	GCPM-MID	STPL	
FRESHWATER FISHES								
Dionda diaboli	Devils River Minnow	LT			X		X	Flowing Spring-Fed Waters near but Not in Spring Outflow, Typically near Spring Run Confluences with Creek/River over Gravel-Cobble Substrate, Usually Associated with Aquatic Macrophytes
Etheostoma fonticola	Fountain Darter	LE	X					Thermally Constant (70–75° F [21–24° C]) Springs and the upper San Marcos (Hays County) and Comal (Comal County) Rivers, Usually in Dense Beds of *Vallisneria*, *Elodia, Ludwigia* and Other Aquatic Plants; Substrate Normally Mucky
INVERTEBRATES								
Batrisodes texanus	Coffin Cave Mold Beetle	LE			X			Caves/Karst
Batrisodes venyivi	Helotes Mold Beetle	LE			X			Caves/Karst
Cicurina baronia	Robber Baron Cave Meshweaver	LE			X			Caves/Karst
Cicurina madla	Madla's Cave Meshweaver	LE			X			Caves/Karst
Cicurina venii	Braken Bat Cave Meshweaver	LE			X			Caves/Karst
Cicurina vespera	Government Canyon Bat Cave Meshweaver	LE			X			Caves/Karst
Heterelmis comalensis	Comal Springs Riffle Beetle	LE			X			Aquifer, Freshwater Wetland
Lampsilis bracteata	Texas Fatmucket	C		X	X	X		Riverine
Neoleptoneta microps	Government Canyon Bat Cave Spider	LE			X			Caves/Karst
Popenaias popeii	Texas Hornshell	C					X	Riverine
Quadrula aurea	Golden Orb	C		X	X	X	X	Riverine

Table 3-13. (Cont.).

SCIENTIFIC NAME	COMMON NAME	STATUS[a]	TCAP ECOREGIONS[b]					GENERAL HABITAT TYPE(S) IN TEXAS
		Federal	TBPR	ECPL	EDPT	GCPM-MID	STPL	
INVERTEBRATES (CONT.)								
Quadrula houstonensis	Smooth Pimpleback	C		X	X			Riverine
Quadrula petrina	Texas Pimpleback	C			X			Riverine
Rhadine exilis	A Cave Obligate Beetle	LE			X			Caves/Karst
Rhadine infernalis	A Cave Obligate Beetle	LE			X			Caves/Karst
Stygobromus pecki	Peck's Cave Amphipod	LE			X			Caves/Karst
Stygoparnus comalensis	Comal Springs Dryopid Beetle	LE			X			Caves/Karst
Texella cokendolpheri	Cokendolpher Cave Harvestman	LE			X			Caves/Karst
Truncilla macrodon	Texas Fawnsfoot	C		X	X	X		Riverine
PLANTS								
Echinocereus reichenbachii var. albertii	Black Lace Cactus	LE				X	X	Grassland; Shrubland; Woodland
Ancistrocactus tobuschii	Tobusch Fishhook Cactus	LE			X			Savanna/Open Woodland
Styrax platanifolius subsp. *texanus*	Texas Snowbells	LE			X			Barren/Sparse Vegetation (Limestone Cliffs and Ledges); Riparian; with Woodland or Shrubland Matrix
Zizania texana	Texas Wild-Rice	LE	X		X			Riverine (Spring-Fed, Clear, Thermally Constant, Moderate Current, Sand to Gravel Substrate)

[a] Status: LE = Federally endangered species or population; LT = Federally threatened species or population; C = Federal Candidate; SAT = Treated as threatened due to similarity of appearance; PT = Proposed Threatened; PDL = Proposed Downlisting/ Proposed Delisting.
[b] TCAP Ecoregions: TBPR = Texas Blackland Prairies; ECPL = East Central Texas Plains; EDPT = Edwards Plateau; GCPM Mid = Gulf Coast Prairies and Marshes - Mid; STPL = Southern Texas Plains.

3.4 AGRICULTURE

3.4.1 Production

A wide range of agricultural enterprises operate within the study area. Data describing regional cropland and livestock trends from 1987 through 2007 are included in Appendix A of this DEIS.

For the purposes of this section, the study area has been divided into four sub-regions to briefly describe the relative importance of various agricultural activities across the diverse 17-county area (Figure 3-29). The Western Region includes Edwards, Kinney, Real, and Uvalde Counties. The Central Region includes Atascosa and Medina Counties. The Eastern Region includes the large urban centers along the IH-35 corridor and contains Bexar, Caldwell, Comal, Guadalupe, Hays and Kendall Counties. The Downstream Region includes counties adjacent to the Guadalupe River, and includes Calhoun, DeWitt, Gonzales, Refugio, and Victoria Counties.

Ranching and both dry land and irrigated farming are the primary agricultural activities in the Western and Central regions. Livestock activities in the region are focused primarily on cattle, sheep and goat production. Many of the crops in this region rely on irrigation, including onions, spinach, beets, cantaloupe, strawberries, and watermelons. Other important crops in the area include citrus, corn, cotton, nursery crops, peanuts, sorghum, tree nuts, and wheat (Odintz 1999).

Agriculture in the Eastern Region is focused on livestock and crop production. Cotton, grain sorghum, and hay are important crops, and much of the cropland in this region relies on irrigation. The Eastern Region is dominated by urban and suburban population centers; and many small farms are part-time or retirement operations.

The Downstream Region also supports extensive agricultural production. Comparatively higher rainfall rates and temperatures moderated by Texas gulf coast weather patterns result in less reliance on irrigation in this portion of the study area. Livestock operations in the area produce cattle, sheep, hogs, and poultry. Row crops are varied and include corn, cotton, nursery crops, peanuts, rice, sorghum, soybeans, and sunflowers. Substantial acreage is allocated for livestock grazing and hay production.

Agricultural operations throughout the study area are impacted by equipment and energy costs for planting, irrigation, and harvest, and livestock and crop returns. These economic pressures have resulted in an increase in large operations and a decrease in the size of family-owned farms and ranches.

3.4.2 Irrigation

Most agricultural production in the study area has historically been dependent on irrigation (see Appendix A, Table A-6 of this DEIS) and irrigation water use varies annually with seasonal rainfall patterns. Other factors such as irrigation efficiency, energy costs, and fluctuations in crop prices also affect the total acreage under irrigation in any given year.

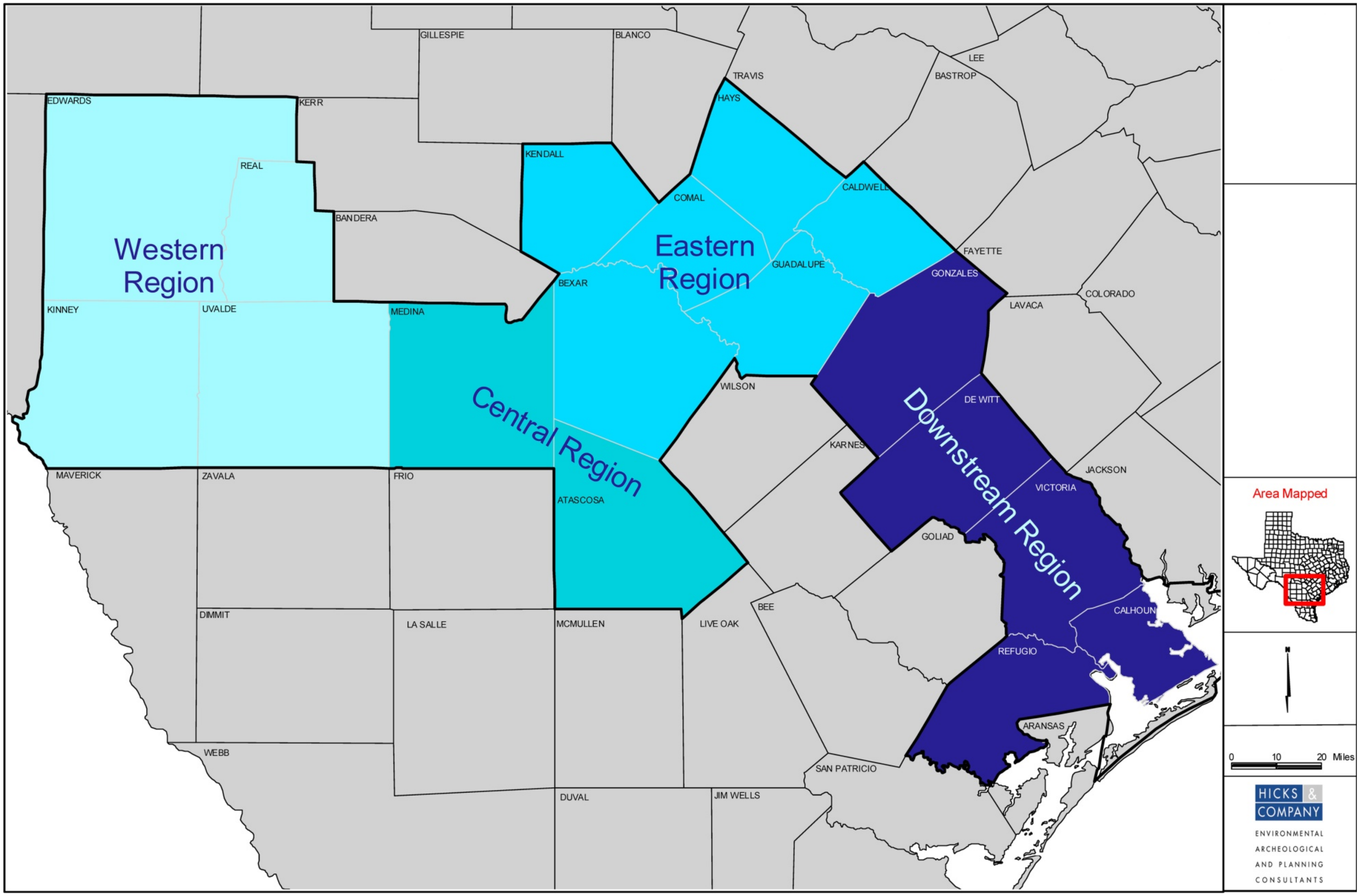


Figure 3-29. Region of the EIS Study Area Evaluated for Agricultural Production, Water Use, Economic, Resources, and Land Use.

The TWDB reports annual groundwater and surface water volumes used by municipal and industrial entities including agricultural producers throughout the state (TWDB 2002, 2012). Long-term regional trends regarding groundwater and surface water use for irrigation are provided here by the sub-regions described above.

Groundwater use for irrigation in the Western Region increased from 19,352 ac-ft in 1958 to a peak of 162,351 ac-ft in 1989. Groundwater use then declined to 66,261 ac-ft in 1997 before increasing to 71,305 in 2004. Surface water use for irrigation in the Western Region increased from 2,400 ac-ft in 1958 to 6,278 ac-ft in 1974. Surface water use then dropped to 163 ac-ft in 1997, before increasing to 537 ac-ft in 2004 (TWDB 2002, 2012).

Groundwater use in the Central Region increased from 1958 totals of 42,147 ac-ft to160,482 ac-ft in 1989. Irrigation groundwater use then declined to 76,285 ac-ft in 1997, and had declined further to 57,583 ac-ft by 2004. Surface water use in the Central Region climbed from 10,661 ac-ft in 1958 to a peak of 43,828 ac-ft in 1989 before declining to 11,105 ac-ft in 1997. The most recent reported total in this category was 16,467 ac-ft in 2004 (TWDB 2002, 2012).

Eastern Region groundwater use in 1958 amounted to 27,036 ac-ft. Groundwater use peaked at 35,569 ac-ft in 1964 before declining to 26,648 ac-ft in 1997 and to 9,723 ac-ft in 2004. Eastern Region counties used 17,641 ac-ft of surface water for irrigation in 1958 (TWDB 2002). Surface water use peaked in 1964 at 32,030 ac-ft and fell off to 13,296 ac-ft by 1997, and had declined to 1,959 ac-ft in 2004 (TWDB 2002, 2012).

The use of groundwater and surface water for irrigation in the Downstream Region has declined over the period for which records are available. Groundwater irrigation use in the region in 1958 totaled 17,081 ac-ft, and had declined to 9,352 ac-ft by 1997 and to 4,729 ac-ft by 2004 (TWDB 2002, 2012). Similarly, irrigation relying on surface water sources declined from 17,327 ac-ft in 1958 to 12,222 ac-ft in 1997, and to 15,869 ac-ft by 2004 (TWDB 2012).

3.4.3 Other Agricultural Enterprises

3.4.3.1 Aquaculture

In 2010, Texas aquaculture operations produced approximately 30 million pounds (13,607,771 kilograms) of products—including finfish, shrimp, aquatic plants, and ornamental fishes—worth an estimated $60 million (Texas Aquaculture Association 2006). Though many of these operations rely on groundwater, it is unclear how many of these facilities use water from the Edwards Aquifer.

3.4.3.2 Hunting Leases

Many agricultural producers throughout the study area generate some portion of their income by offering hunting lease opportunities on their property. The Texas Agricultural Extension Service summarized hunting lease information and concluded that income from hunting leases on private land will likely continue to increase due to projected higher demand (Thomas et al. 1990).

3.4.4 Effect of Climate Change on Agriculture in the United States and the Study Area

This section addresses how observed and projected climate change may affect agriculture, including crop yields, irrigation requirements, effects from extreme events, pests and weeds, livestock production (e.g., milk and meat), and fisheries in the United States and within the study area. Though these effects are described at the national level, they can provide an indication of effects likely in the study area. The study area includes a large agricultural sector, primarily dependent on groundwater for irrigation requirements.

Agricultural commodities are produced in a variety of climates, regions, and soils. However, regardless of where they are grown, crops and livestock are affected by temperature, precipitation, CO_2, and water availability. Annual variability in yields are strongly correlated with growing season weather effects (Hatfield et al. 2008). These variations also affect crops and livestock through their effects on insects, disease, and weeds. Agriculture has substantial economic impacts on national and regional economies (an estimated $200 billion in 2002). Just over half of this value (52 percent) is derived from livestock, with the rest generated by crops (21 percent from fruit and nuts, 20 percent from grain and oilseed, 2 percent from cotton, and 5 percent from production of other commodities).

The agricultural sector within the United States, and the study area, is sensitive to both short-term climate variability and long-term climate change. Productivity is driven by the interaction of a variety of variables including temperature, radiation, precipitation, humidity, and wind speed (Easterling et al. 2007). The productivity of most agricultural enterprises has increased dramatically over recent decades due to advances in technology, fertilizers, innovations in seed stocks and management techniques, irrigation, and changing climate influences. Weather events are a major factor in annual crop yield variation.

3.5 DEMOGRAPHICS

3.5.1 Regions

Demographic data are presented by region to clarify differences within the 17 county study area (see Figure 3-29).

- **Western Region** (Edwards, Kinney, Real and Uvalde Counties). There are no Metropolitan Statistical Areas (MSAs) within this region (TSDC SD 2004).

- **Central Region** (Atascosa and Medina Counties). Medina County is within the 2004 San Antonio MSA within this region.

- **Eastern Region** (Bexar, Caldwell, Comal, Guadalupe, Hays, and Kendall Counties). This region includes four counties within the 2004 San Antonio MSA. When San Antonio MSA data is discussed in this section, please note that the MSA includes Wilson, and Bandera Counties that are not within the study area. Though Caldwell and Hays Counties are part of the Austin-San Marcos MSA, no data have been included from this MSA because demographic data from the much more urban Travis and Williamson Counties dominates the information for these more rural counties.

- **Downstream Region** (Calhoun, DeWitt, Gonzales, Refugio, and Victoria Counties). Victoria and Calhoun Counties are within the Victoria MSA.

3.5.2 Recent Trends in Population Growth

The U.S. Census Bureau estimated the population of the State of Texas in 2010 to be 20,851,820, an increase of almost 21 percent since 2000 (U.S. Census Bureau 2010a). In the past few decades, population growth has occurred primarily along the Texas-Mexico border and in the major urban centers of Houston, San Antonio, Austin, and Dallas (Murdock et al. 1996). The 2000 Census reports approximately 83 percent of Texans reside in urban areas. The study area experienced a growth rate of an estimated 24.7 percent between 2000 and 2010 (Table 3-14), with the largest share of this growth occurring within the Eastern Region of the study area that includes the San Antonio MSA and the Comal and San Marcos Springs ecosystems. The 2010 Census reports an increase of almost 0.5 million people between 2000 and 2010, with an estimated 2010 population of 2,465,053 within the study area. The greatest growth occurred in Hays, Comal, Kendall, and Guadalupe Counties, where each county’s growth exceeded 38 percent between 2000 and 2010.

3.5.2.1 Western Region

The Western Region experienced an estimated average growth of 2.3 percent from 2000 to 2010, the lowest total reported within the study area (U.S. Census Bureau 2010a). The most significant decline in population occurred in Edwards County, where the population declined by 7.4 percent between 2000 and 2010. Of the four counties within the Western Region, Real County posted the strongest gain in population, with an increase of 8.6 percent. The Western Region supports 35,314 persons, or 1.5 percent of the study area’s total population (U.S. Census Bureau 2010a).

3.5.2.2 Central Region

The Central Region population increased by 16.7 percent between 2000 and 2010. This Region makes up 3.7 percent of the total study area population, with a population of 90,917 persons.

3.5.2.3 Eastern Region

The Eastern Region is the most populated region within the study area with a total estimated population of 2,151,940 people. Bexar County supports 1,714,773 persons, making up approximately 70 percent of the region’s population. This region has historically been the most populated and the fastest growing region in the study area and continues to lead the rest of the regions through 2010. The U.S. Census Bureau found Hays County to be among the 25 fastest growing counties in the nation between 2000 and 2009.

Table 3-14. Population Growth in the EIS Study Area, by Region and County, 1960–2010.

COUNTY	1960	1970	1980	1990	2000	2010	PERCENTAGE CHANGE 2000–2010
WESTERN REGION							
Edwards	2,317	2,107	2,033	2,266	2,162	2,002	-7.4
Kinney	2,452	2,006	2,279	3,119	3,379	3,598	6.5
Real	2,079	2,013	2,469	2,412	3,047	3,309	8.6
Uvalde	16,814	17,348	22,441	23,340	25,926	26,405	1.8
Subtotal	23,662	23,474	29,222	31,137	34,514	35,314	2.3
CENTRAL REGION							
Atascosa	18,828	18,696	25,055	30,533	38,628	44,911	16.3
Medina	18,904	20,249	23,164	27,312	39,304	46,006	17.1
Subtotal	37,732	38,945	48,219	57,845	77,932	90,917	16.7
EASTERN REGION							
Bexar	687,151	830,460	988,800	1,185,394	1,392,931	1,714,773	23.1
Caldwell	17,222	21,178	23,637	26,392	32,194	38,066	18.2
Comal	19,844	24,165	36,446	51,832	78,021	108,472	39.0
Guadalupe	29,017	33,554	46,708	64,873	89,023	131,533	47.8
Hays (part)[a]	15,947	22,114	32,475	52,491	78,071	125,686	61.0
Kendall	5,889	6,964	10,635	14,589	23,743	33,410	40.7
Subtotal	775,070	938,435	1,138,701	1,395,571	1,693,983	2,151,940	27.0
DOWNSTREAM REGION							
Calhoun	16,592	17,831	19,574	19,053	20,647	21,381	3.6
DeWitt	20,683	18,660	18,903	18,840	20,013	20,097	0.4
Gonzales	17,845	16,375	16,883	17,205	18,628	19,807	6.3
Refugio	10,975	9,494	9,289	8,828	7,828	7,383	-5.7
Victoria	46,475	53,766	68,807	74,361	84,088	86,793	3.2
Subtotal	112,570	116,126	133,456	137,435	151,204	155,461	2.8
TOTAL	**949,034**	**737,098**	**949,034**	**1,621,988**	**1,957,633**	**2,433,632**	**24.3**

Source: U.S. Census Bureau (2010a).
[a] Estimated that 80 percent of the total county population resides in the EIS study area.

3.5.2.4 Downstream Region

The Downstream Region grew by about 10 percent between 1990 and 2000. This rate slowed to approximately 3 percent between 2000 and 2010. Refugio County saw the greatest declines in the region at 5.7 percent between 2000 and 2010 while Gonzales County saw the largest increases of over 6 percent during this period.

3.5.3 Population Projections

Recent projections by the Texas State Data Center (TSDC) for the year 2040 estimate that the study area will reach 3,004,934 people, just under 10 percent of the projected statewide population of 35,761,165 (Table 3-15) (TSDC 2010). These projections indicate that the population within the study area will grow by about 22 percent over the next 30 years. The counties of the study area are projected to comprise a slightly declining share of the state's population, representing about 8 percent of Texas's population by 2040.

3.5.3.1 Western Region

The population in the Western Region is expected to increase to 46,424 people by the year 2040 (TSDC 2010), an increase of 31 percent from the estimated 2010 population. Real County is projected to see population declines beginning this decade, and is projected to see an almost 20 percent decline in population over the next 30 years. While experiencing an increase over the next 10 years, Edwards County is expected to see its population return to its 2010 level by 2040, while Kinney County is expected to see a decrease of approximately 1 percent between 2010 and 2040. Uvalde County posted the strongest gains in population in the Western Region between 2000 and 2010, and is projected to grow by 31 percent over the next 30 years.

3.5.3.2 Central Region

The Central Region of the study area is expected to experience significant population growth over the next 30 years, with Atascosa County adding 57 percent to its population and Medina County adding 58 percent. The TSDC projects the Central Region will reach a population of 143,371 persons by 2040.

3.5.3.3 Eastern Region

The Eastern Region is projected to experience population growth totaling 20 percent between 2010 and 2040. Caldwell and Hays Counties are projected to experience 85 and 76 percent increases in population, respectively, over the next 30 years. Kendall and Comal Counties are projected to grow by greater than 50 percent and Guadalupe County is expected to grow by 25 percent. Bexar County, the most populous county in the region today, is projected to grow by 10 percent by 2040.

Table 3-15. Population Projections for Regions and Counties in the EIS Study Area, 2000–2040.

COUNTY	2010	2020	2030	2040
WESTERN REGION				
Edwards	2,002	2,320	2,173	2,001
Kinney	3,598	3,513	3,515	3,564
Real	3,309	3,030	2,850	2,666
Uvalde	26,405	32,944	35,872	38,193
Subtotal	**35,314**	**41,807**	**44,410**	**46,424**
CENTRAL REGION				
Atascosa	44,911	55,443	63,613	70,599
Medina	46,006	56,528	65,157	72,772
Subtotal	**90,917**	**111,971**	**128,770**	**143,371**
EASTERN REGION				
Bexar	1,714,773	1,704,153	1,813,101	1,884,509
Caldwell	38,066	49,975	60,127	70,593
Comal	108,472	121,424	145,471	167,774
Guadalupe	131,533	127,944	147,476	164,202
Hays	157,107	181,508	227,912	276,103
Kendall	33,410	37,307	44,411	50,744
Subtotal	**2,183,361**	**2,222,311**	**2,438,498**	**2,613,925**
DOWNSTREAM REGION				
Calhoun	21,381	24,427	25,724	26,569
DeWitt	20,097	21,536	21,896	21,987
Gonzales	19,807	22,079	23,465	24,538
Refugio	7,383	8,661	8,792	8,784
Victoria	86,793	104,269	112,417	119,336
Subtotal	**155,461**	**180,972**	**192,294**	**201,214**
TOTAL	**2,465,053**	**2,557,061**	**2,803,972**	**3,004,934**

Source: TSDC (2010) (0.5 Scenario).

3.5.3.4 Downstream Region

The Downstream Region is also projected to experience continued growth. Victoria County is projected to see the largest population increase in the region at 37 percent, while both Gonzales and Calhoun Counties are predicted to see populations increase by 24 percent. The projected increase in DeWitt County is 9 percent.

3.5.4 Race and Ethnicity

The study area includes a large minority population (see Table 3-16). All four regions, as well as 12 of the 17 counties within the study area, report that more than half of residents are non-white. The study area as a whole has a 62 percent non-white population. The Hispanic/Latino group is the largest minority represented. Residents identifying with this category represent at least 20 percent of the population in all of the counties, and constitute a majority in nine of the 17 counties. Compared to Census 2000 data, the minority (non-white) share of the population has increased in every county during the past decade.

3.5.4.1 Western Region

The Western Region has the largest percentage of non-whites of the four regions. The region’s population is primarily Hispanic/Latino or White. Blacks, Asians, and Other races each represent less than 1 percent of the population. All of the counties except Real County report a larger Hispanic/Latino population than Whites. Edwards and Kinney Counties approach a 50/50 split between the two races, while the division in Real and Uvalde Counties approximate a 70/30 split.

3.5.4.2 Central Region

The Central Region has Hispanic/Latino populations of 50 percent or more, with Whites representing the second largest percentage. Medina County reported a population of almost 1,000 Blacks, representing 2 percent of the population.

3.5.4.3 Eastern Region

The Eastern Region has a total non-white minority population of 62 percent. Comal, Guadalupe, Hays, and Kendall Counties all have a White majority, while Caldwell and Bexar Counties have a Hispanic/Latino majority. The Eastern Region has Black and Asian populations totaling 6 percent and 2 percent of the population total, respectively.

3.5.4.4 Downstream Region

All but one of the counties within the Downstream region (DeWitt County) have a non-white majority. Among the counties of the study area, the Downstream Region includes the county with the largest minority population growth since 2000 (Gonzales County).

Table 3-16. 2010 Population by Race.

COUNTY	TOTAL	HISPANIC OR LATINO	PERCENT HISPANIC OR LATINO	NOT HISPANIC OR LATINO: WHITE ALONE	PERCENT NOT HISPANIC OR LATINO: WHITE ALONE	NOT HISPANIC OR LATINO: BLACK OR AFRICAN AMERICAN ALONE	PERCENT NOT HISPANIC OR LATINO: BLACK OR AFRICAN AMERICAN ALONE	NOT HISPANIC OR LATINO: ASIAN ALONE	PERCENT NOT HISPANIC OR LATINO: ASIAN ALONE	NOT HISPANIC OR LATINO: OTHER RACE[a]	PERCENT NOT HISPANIC OR LATINO: OTHER RACE[a]	NOT HISPANIC OR LATINO: TWO OR MORE RACES	PERCENT NOT HISPANIC OR LATINO: TWO OR MORE RACES	MINORITY (NON-WHITE)	PERCENT MINORITY
WESTERN REGION															
Edwards	2,002	1,027	51%	947	47%	10	0%	3	0%	11	1%	4	0%	1,055	53%
Kinney	3,598	2,004	56%	1,496	42%	39	1%	10	0%	25	1%	24	1%	2,102	58%
Real	3,309	814	25%	2,398	72%	20	1%	2	0%	36	1%	39	1%	911	28%
Uvalde	26,405	18,299	69%	7,666	29%	110	0%	116	0%	103	0%	111	0%	18,739	71%
Subtotal	**35,314**	**22,144**	**63%**	**12,507**	**35%**	**179**	**1%**	**131**	**0%**	**175**	**0%**	**178**	**1%**	**22,807**	**65%**
CENTRAL REGION															
Atascosa	44,911	27,785	62%	16,295	36%	256	1%	130	0%	200	0%	245	1%	28,616	64%
Medina	46,006	22,871	50%	21,408	47%	913	2%	272	1%	198	0%	344	1%	24,598	53%
Subtotal	**90,917**	**50,656**	**56%**	**37,703**	**41%**	**1,169**	**1%**	**402**	**0%**	**398**	**0%**	**589**	**1%**	**53,214**	**59%**
EASTERN REGION															
Bexar	1,714,773	1,006,958	59%	519,123	30%	118,460	7%	39,561	2%	8,496	0%	22,175	1%	1,195,650	70%
Caldwell	38,066	17,922	47%	16,841	44%	2,456	6%	344	1%	152	0%	351	1%	21,225	56%
Comal	108,472	26,989	25%	77,387	71%	1,606	1%	813	1%	505	0%	1,172	1%	31,085	29%
Guadalupe	131,533	46,889	36%	72,086	55%	7,963	6%	1,748	1%	759	1%	2,088	2%	59,447	45%
Hays	157,107	55,401	35%	92,062	59%	4,970	3%	1,699	1%	832	1%	2,143	1%	65,045	41%
Kendall	33,410	6,829	20%	25,746	77%	138	0%	202	1%	168	1%	327	1%	7,664	23%
Subtotal	**2,183,361**	**1,160,988**	**53%**	**803,245**	**37%**	**135,593**	**6%**	**44,367**	**2%**	**10,912**	**0%**	**28,256**	**1%**	**1,380,116**	**63%**
DOWNSTREAM REGION															
Calhoun	21,381	9,922	46%	9,794	46%	519	2%	943	4%	55	0%	148	1%	11,587	54%
DeWitt	20,097	6,502	32%	11,482	57%	1,781	9%	44	0%	139	1%	149	1%	8,615	43%
Gonzales	19,807	9,353	47%	8,836	45%	1,353	7%	73	0%	63	0%	129	1%	10,971	55%
Refugio	7,383	3,487	47%	3,337	45%	445	6%	27	0%	34	0%	53	1%	4,046	55%
Victoria	86,793	38,113	44%	41,564	48%	5,190	6%	860	1%	324	0%	742	1%	45,229	52%
Subtotal	**155,461**	**67,377**	**43%**	**75,013**	**48%**	**9,288**	**6%**	**1,947**	**1%**	**615**	**0%**	**1,221**	**1%**	**80,448**	**52%**
TOTAL	**2,465,053**	**1,301,165**	**53%**	**928,468**	**38%**	**146,229**	**6%**	**46,847**	**2%**	**12,100**	**0%**	**30,244**	**1%**	**1,536,585**	**62%**

Source: U.S. Census 2010 PL94-171 Redistricting Data for Texas.
[a] Other Race category is the aggregate of the Not Hispanic or Latino tabulations of Some Other Race Alone, American Indian.

3.5.5 Income

Data on income and poverty level for the study area was collected from the U.S. Census Bureau's Small Area Income and Poverty Estimates program (see Table 3-17). These estimates are created for school districts, counties, and states, and combine data from administrative records, population estimates, and the decennial census with direct estimates from the American Community Survey to provide consistent and reliable single-year estimates. These model-based single-year estimates reflect current conditions more closely than multi-year survey estimates.

The Department of Health and Human Services (DHHS) also publishes a measure of poverty (called the Poverty Guideline), which considers the number of members of the household. In 2009, the DHHS Poverty Guideline was $22,050 for a family of four. Median incomes do not fall below this guideline for any of the counties in the study area, though there may be smaller geographies (census tract, block groups, etc.) with median incomes below this level. The weighted average of the median incomes for the counties of the study area is slightly below that for the state of Texas ($47,055 and $48,286, respectively).

3.5.5.1 Western Region

The Western Region has significantly lower incomes than the other regions, with a weighted average median income more than $16,000 lower than the weighted average of the study area as a whole. The percent of the population in poverty was higher in the counties of the Western Region than in any of the other study area counties, ranging from 21 percent in Kinney County, to 32 percent in Uvalde County.

3.5.5.2 Central Region

Median incomes in the Central Region fall between those of the Western and Eastern regions. Medina County has a higher median income than Atascosa County, though the percentage of families in poverty is only slightly smaller (18 percent compared to 19 percent).

3.5.5.3 Eastern Region

The Eastern Region has the highest weighted average median income of the four regions of the study area, and includes the counties with four of the highest median incomes, Kendall, Comal, Guadalupe, and Hays Counties, respectively. Comal and Kendall Counties have the lowest percentage of the population in poverty, each with less than 9 percent. Hays County has the highest percentage in poverty in the region, with 19 percent.

3.5.5.4 Downstream Region

The Downstream Region has second highest weighted average of county median incomes in the study area. Victoria County has the highest median income as well as the lowest percentage in poverty. With the lowest median income in the region, Gonzales County has the highest percentage in poverty.

Table 3-17. Median Income and Poverty Estimates.

COUNTY	MEDIAN INCOME (2009 $)	PERCENT OF POPULATION IN POVERTY
WESTERN REGION		
Edwards	$30,517	25
Kinney	$34,777	20.7
Real	$28,823	22
Uvalde	$30,465	31.5
Weighted Average	**$30,753**	
CENTRAL REGION		
Atascosa	$39,190	18.5
Medina	$45,278	17.6
Weighted Average	**$42,271**	
EASTERN REGION		
Bexar	$45,315	17.7
Caldwell	$40,218	16.8
Comal	$62,642	8.8
Guadalupe	$57,817	11.2
Hays	$53,113	19.2
Kendall	$72,094	8.6
Weighted Average	**$47,811**	
DOWNSTREAM REGION		
Calhoun	$42,463	16
DeWitt	$36,273	19.3
Gonzales	$33,123	19.8
Refugio	$36,920	17.2
Victoria	$47,345	14
Weighted Average	**$42,935**	

Source: U.S. Census Bureau (2010b).

3.5.6 Population Density

Population density is measured by dividing a given population by its area. The most current county population estimates from the 2010 Census were combined with area data to yield the density of persons per square mile (Table 3-18). The Eastern Region is the densest at an average of 496 persons per square mile, while the Western Region has approximately six persons per square mile. Overall, 65 percent of the population in the study area resides in the largest cities in each county. The aggregate population density for the study area is 104 persons per square mile, compared to 94.7 persons per square mile for the State of Texas (U.S. Census Bureau 2010a).

Table 3-18. Population Density in the EIS Study Area, 2010.

COUNTY	TOTAL AREA (mi^2)	2010 POPULATION	DENSITY (persons per square mile)	LARGEST CITY IN COUNTY	2010 POPULATION	PERCENT OF COUNTY
WESTERN REGION						
Edwards	2,120	2,002	1	Rocksprings	1,182	59%
Kinney	1,363	3,598	3	Brackettville	1,688	47%
Real	700	3,309	5	Sabinal	1,695	51%
Uvalde	1,557	26,405	17	Uvalde	15,751	60%
Subtotal	**5,740**	**35,314**	**6**		**20,316**	**58%**
CENTRAL REGION						
Atascosa	1,232	44,911	36	Pleasanton	8,934	20%
Medina	1,328	46,006	35	Hondo	8,803	19%
Subtotal	**2,560**	**90,917**	**36**		**17,737**	**19.5%**
EASTERN REGION						
Bexar	1,247	1,714,773	1375	San Antonio	1,327,407	77%
Caldwell	546	38,066	70	Lockhart	12,698	33%
Comal	561	108,472	193	New Braunfels	57,740	53%
Guadalupe	711	131,533	185	Seguin	25,175	19%
Hays	678	157,107	232	San Marcos	44,894	29%
Kendall	662	33,410	50	Boerne	10,471	31%
Subtotal	**4,405**	**2,183,361**	**496**		**1,478,385**	**68%**
DOWNSTREAM REGION						
Calhoun	512	21,381	42	Port Lavaca	12,248	57%
DeWitt	909	20,097	22	Cuero	6,841	34%
Gonzales	1,068	19,807	19	Gonzales	7,237	37%
Refugio	770	7,383	10	Refugio	2,890	39%
Victoria	883	86,793	98	Victoria	62,592	72%
Subtotal	**4,142**	**155,461**	**38**		**91,808**	**59%**
STUDY AREA TOTAL	**16,847**	**2,465,053**	**104**	**LARGEST CITIES**	**1,608,246**	**65%**

Source: U.S. Census Bureau (2010a).

3.5.6.1 Western Region

The Western Region is the least dense of the four regions with approximately six persons per square mile. Almost 60 percent of the population within the region resides in the counties' largest cities, the largest of which is the city of Uvalde at 15,751 people.

3.5.6.2 Central Region

The Central Region has a density of 35.5 persons per square mile and is relatively rural, with less than 20 percent of the overall population residing in the region's biggest cities, Pleasanton and Hondo.

3.5.6.3 Eastern Region

With an aggregate density of 496 persons per square mile, the Eastern Region is the most densely populated region in the study area. Approximately 68 percent of the population in the region resides in the largest cities, of which four have populations of greater than 25,000 people. The city of San Antonio is much larger than any other city in the study area, representing not only 77 percent of the population of Bexar County but also comprising more than 60 percent of the Eastern Region population as a whole.

3.5.6.4 Downstream Region

The Downstream Region is the second densest in the study area with 38 persons per square mile. Victoria is the largest city within the region with a population of 62,592 persons. A total of 59 percent of the people residing within the five counties in the Downstream Region live in the largest cities in the counties.

3.5.7 Water Demand

3.5.7.1 Water Demand in the Study Area

The study area includes counties that fall within three water planning regions established by Texas Senate Bill 1, including 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) (75th Texas Legislature, Section 357.3 of the Texas Water Code, Chapter 16).

The projected quantity of water needed for municipal purposes depends upon the size of the population of the service area, climatic conditions, and water conservation measures. In addition to these factors, per capita water use (gallons per person per day of water use) is a key municipal water planning parameter. Population and per capita water use are used to make projections of municipal water demand for each of the 213 municipal water user groups of the South Central Texas Water Planning Region.

The South Central Texas Regional Water Planning Area includes all of the counties within the EAA boundaries and Calhoun, DeWitt, Gonzales, Kendall, Refugio, and Victoria Counties. The 2011 South Texas Regional Water Plan estimates that 705,661 ac-ft of water was obtained from aquifers of the region (see Section 3.2.2 for a discussion of major and minor aquifers in the study area) in 2000. Of this total, 55.6 percent was from the Edwards Aquifer (TWDB 2010h).

The EAA estimates that 377,255 ac-ft of water was withdrawn from the Edwards Aquifer by permit holders within its jurisdiction in 2009 (EAA 2010a). Approximately 64 percent was withdrawn for municipal purposes, 7 percent for commercial use, and 29 percent for irrigation use (Table 3-19). The 11-year average and median permitted withdrawals for 1999–2009 reflect similar figures: 369,330 and 366,404 ac-ft, respectively.

Table 3-19. Withdrawals from the Edwards Aquifer by Use.

YEAR	MUNICIPAL	INDUSTRIAL/ COMMERCIAL	IRRIGATION	TOTAL	MUNICIPAL	INDUSTRIAL/ COMMERCIAL	IRRIGATION
1999	277,101	42,933	109,156	429,190	65%	10%	25%
2000	260,291	33,473	104,970	398,734	65%	8%	26%
2001	250,781	30,307	78,088	359,176	70%	8%	22%
2002	227,362	32,328	96,445	356,135	64%	9%	27%
2003	229,455	31,688	79,015	340,158	67%	9%	23%
2004	212,630	28,072	54,793	295,495	72%	9%	19%
2005	247,344	34,327	84,733	366,404	68%	9%	23%
2006	251,390	34,472	148,480	434,342	58%	8%	34%
2007	228,121	27,575	41,864	297,559	77%	9%	14%
2008	266,655	28,815	112,708	408,178	65%	7%	28%
2009	243,043	25,326	108,886	377,255	64%	7%	29%
Average	244,925	31,756	92,649	369,330			
Median	247,344	31,688	96,445	366,404			

Source: EAA (2010a).

Due to projected population growth between 2010 and 2030, municipal water demand in the EIS study area counties is projected to increase from 384,257 ac-ft/yr in 2010 to 492,181 ac-ft/yr in 2030. The projected municipal, industrial, steam-electric, mining, irrigation, and livestock water demand for individual counties in the study area is shown in Table 3-19, along with total water demand projections for the years 2010 and 2030.

Future water demand (not limited to Edwards Aquifer water) has been estimated for each county in the study area by the TWDB (TWDB 2010h). The projected demand for the years 2010 through 2030 are shown by decade in Tables 3-20a and 3-20b. Steam electric demand in the Eastern Region is expected to grow by the greatest percentage (33.8) between 2000 and 2030, followed by municipal (30.3), whereas livestock demand is projected to remain static. Irrigation demand is projected to decrease throughout the study area due to increased irrigation efficiency, economic factors, and changes in government programs affecting the profitability of irrigated agriculture (TWDB 2010h). Total water demand within the study area (Table 3-21) is projected to increase by approximately 125,500 ac-ft/yr, or 16 percent over the next 20 years.

Table 3-20a. Regional Water Demand Projections in Acre-Feet per Year, 2010 and 2030.

COUNTY	MUNICIPAL DEMAND			INDUSTRIAL DEMAND			STEAM ELECTRIC DEMAND		
	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	1,009	949	-5.9
Hays (Reg. K)	7,202	13,446	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	**333,394**	**434,341**	**30.3**	**37,236**	**46,572**	**25.1**	**28,383**	**37,989**	**33.8**
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	**384,257**	**492,181**	**28.1**	**118,835**	**144,437**	**21.5**	**36,862**	**47,516**	**34.7**

Source: TWDB (2003, 2010h).

Table 3-20b. Regional Water Demand Projections in Acre-Feet per Year, 2010 and 2030.

COUNTY	IRRIGATION DEMAND			MINING DEMAND			LIVESTOCK DEMAND		
	2010	2030	% Change	2010	2030	% Change	2010	2030	% Change
WESTERN REGION									
Edwards	153	141	-7.8	89	89	0	562	562	0.0
Kinney	13,507	12,373	-8.4	0	0	0	445	445	0.0
Real	392	361	-7.9	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	**69,843**	**64,388**	**-7.8**	**407**	**458**	**12.5**	**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**	**4,075**	**5,044**	**23.7**	**9,192**	**9,192**	**0.0**
STUDY AREA TOTAL	**210,883**	**190,114**	**-9.9**	**12,650**	**14,734**	**16.6**	**19,240**	**19,240**	**0.0**

Source: TWDB (2003, 2010h).

Table 3-21. Projected Water Demand by Use Sector for the EIS Study Area, 2010–2030 (Ac-Ft/Yr).

TYPE OF USE	YEAR 2010	YEAR 2030
Municipal	384,257	492,181
Industrial	118,835	144,437
Steam Electric	36,862	47,516
Irrigation	210,883	190,114
Mining	12,650	14,734
Livestock	19,240	19,240
TOTAL	**782,727**	**908,222**

Source: TWDB (2003, 2010h).

EARIP Counties within Other Regions

The EARIP counties within the Region J – Edwards Plateau Regional Water Planning Area include: Edwards, Kinney, and Real Counties. The EARIP counties within the Region K – Regional Water Planning Area include only a part of Hays County.

Unlike municipal water demand, which tends to be relatively consistent from year to year, irrigation demands can vary considerably. The wide variation in estimates of irrigation water use are the result of local weather conditions, economic factors that influence the amount of irrigated acreage, and water supply constraints. It is important to note that historic irrigation water use data was estimated rather than based on measured use.

3.6 ECONOMY

The counties within the study area are supported by strong trade, service and tourism sectors. Agriculture, biotechnology, higher education, technology, medical research, and military bases all contribute to the diverse economy within the area.

According to the Texas Workforce Commission (TWC), 9.2 percent of the total employment in the State of Texas was located in the study area as of the fourth quarter of 2009. The Eastern Region comprised 90.5 percent of the total employment for the study area, with the highest concentration of employment in Bexar County. Employment in the San Antonio MSA comprised the majority of the study area's average employment of 940,477. The Downstream Region contained the second-highest average employment at 60,857, with the Victoria urban area accounting for 59.4 percent of the employment in this region. The Central Region contributed 1.8 percent of the study area employment, while the Western Region added 1.2 percent (TWC 2010).

Growth in the technology industry was responsible for substantial economic growth and prosperity in the study area during the 1990s and early 2000s. Economic downturn in the mid-2000s, though, drastically affected employment on a county, state, and national level, with unemployment in the beginning of 2010 estimated at 14,837,000 for the United States, compared with 7,784,000 just 5 years earlier (TWC 2010). The State of Texas saw unemployment reach

997,099 in the beginning of 2010, an increase of over 63 percent over 2005. Education and health services provide the highest number of jobs in the State of Texas (2,465,111), followed by trade, transportation and utilities (2,154,130) and professional and business services (1,254,019).

A brief summary of the economic resources within the study area is included below. Table 3-22 shows employment data for each region. These data do not represent the number of actual employees in each region, but rather the number of jobs in each county, compiled by region. These data differ from the labor force estimated in Table 3-23, which track the number of people in a county considered eligible to participate in the labor force along with whether or not they are employed. Differences in the number of jobs and the number of employees within a region are likely a result of workers commuting to other areas. This is especially common in the counties surrounding metropolitan areas such as the San Antonio MSA.

Table 3-22. Employment for the EIS Study Area, 4th Quarter, 2009.

NAICS CATEGORY	WESTERN REGION		CENTRAL REGION		EASTERN REGION		DOWNSTREAM REGION		STUDY AREA		STATE OF TEXAS	
	Total Emp	% of Total	Total Emp	% of Total	Total Emp	% of Total	Total Emp	% of Total	Total Emp	% of Total	Total Emp	% of Total
Natural Resources and Mining	757	7.0%	1,165	6.7%	4,652	0.6%	3,424	6.7%	9,998	1.1%	255,523	2.5%
Construction	415	3.9%	1,050	6.0%	48,096	5.7%	3,030	5.9%	52,591	5.7%	602,061	5.9%
Manufacturing	405	3.8%	527	3.0%	45,262	5.4%	4,663	9.1%	50,857	5.6%	817,645	8.1%
Trade	2560	23.8%	3,764	21.7%	168,799	20.2%	10,900	21.3%	186,023	20.3%	2,154,130	21.3%
Information	165	1.5%	144	0.8%	19,984	2.4%	686	1.3%	20,979	2.3%	208,661	2.1%
Financial Activities	320	3.0%	757	4.4%	65,789	7.9%	2,509	4.9%	69,375	7.6%	622,791	6.1%
Professional and Business Services	385	3.6%	777	4.5%	104,275	12.5%	2,616	5.1%	108,053	11.8%	1,254,019	12.4%
Education and Health Services	3,304	30.8%	5,710	32.9%	208,554	24.9%	15,087	29.5%	232,655	25.4%	2,465,111	24.3%
Leisure and Hospitality Services	1.022	9.5%	1,470	8.4%	103,744	12.4%	4,251	8.3%	109,466	12.0%	1,007,015	9.9%
Other Services	276	2.6%	590	3.4%	26,999	3.2%	1,540	3.0%	29,405	3.2%	291,149	2.9%
Public Administration	1,129	10.5%	1,402	8.1%	40,358	4.8%	2,505	4.9%	45,394	5.0%	447,239	4.4%
Unclassified	0	0%	10	0.1%	189	0.0%	7	0.0%	206	0.0%	5,279	0.1%
TOTAL EMPLOYMENT	**10,738**	**100.0%**	**17,366**	**100.0%**	**836,701**	**100.0%**	**51,218**	**100.0%**	**915,002**	**100.0%**	**10,130,623**	**100.0%**

Table 3-23. Labor Force and Unemployment in the EIS Study Area, 2000 and 2010.

COUNTY	CIVILIAN LABOR FORCE		EMPLOYED		UNEMPLOYED		UNEMPLOYMENT RATE	
	2000	2010	2000	2010	2000	2010	2000	2010
WESTERN REGION								
Edwards	770	1,049	735	959	35	90	4.5	8.6
Kinney	1,135	1,513	1,050	1,355	85	158	7.5	10.4
Real	1,301	1,552	1,260	1,447	41	105	3.2	6.8
Uvalde	11,024	11,446	10,239	10,375	785	1,071	7.1	9.4
Subtotal/Average	**14,230**	**15,560**	**13,284**	**14,136**	**946**	**1,424**	**5.6**	**8.8**
CENTRAL REGION								
Atascosa	18,406	19,661	17,696	17,948	710	1,713	3.9	8.7
Medina	15,919	20,227	15,350	18,651	569	1,576	3.6	7.8
Subtotal/Average	**34,325**	**39,888**	**33,046**	**36,599**	**1,279**	**3,289**	**3.8**	**8.25**
EASTERN REGION								
Bexar	676,590	771,373	652,687	710,990	23,903	60,383	3.5	7.8
Caldwell	16,890	16,137	16,342	14,692	548	1,445	3.2	9
Comal	39,947	56,195	38,947	52,262	1,000	3,933	2.5	7
Guadalupe	43,472	59,422	42,384	55,053	1,088	4,369	2.5	7.4
Hays	55,058	79,831	53,764	73,951	1,294	5,880	2.4	7.4
Kendall	14,265	16,517	13,971	15,463	294	1,054	2.1	6.4
Subtotal/Average	**846,222**	**999,475**	**818,095**	**922,411**	**28,127**	**77,064**	**2.7**	**7.5**
DOWNSTREAM REGION								
Calhoun	10,044	9,496	9,579	8,570	465	926	4.6	9.8
DeWitt	8,450	9,184	8,151	8,380	299	804	3.5	8.8
Gonzales	7,580	10,148	7,349	9,492	231	656	3.0	6.5
Refugio	2,811	4,206	2,684	3,884	127	322	4.5	7.7
Victoria	43,165	45,396	41,634	41,729	1,531	3,664	3.5	8.1
Subtotal/Average	**72,050**	**78,430**	**69,397**	**72,055**	**2,653**	**6,372**	**3.8**	**8.18**
STUDY AREA TOTAL	**966,827**	**1,133,353**	**933,822**	**1,045,201**	**33,005**	**88,149**	**4.0**	**8.1**
STATE OF TEXAS	**10,324,527**	**12,091,623**	**9,887,039**	**11,094,524**	**437,488**	**997,099**	**4.2**	**8.2**

Source: TWC (2010).

The agricultural segment includes jobs in agricultural production, forestry, commercial fishing, hunting and trapping, and related services including reported farm and ranch workers, according to the TWC. The TWC acknowledges that their records underestimate total agricultural employment because only reported farm and ranch workers are included (TWC 2002). In contrast, the U.S. Agricultural Census provides considerably higher farm employment estimates. Table 3-24 provides both agricultural employment (TWC) and farm employment (U.S. Agricultural Census) for the most recent year of data available (2007). Although these data rely on different methodologies, they each provide an estimate of farm workers within the study area.

Table 3-24. The EIS Study Area Farm Labor, 2007.

COUNTY/REGION	4TH QUARTER AGRICULTURAL EMPLOYMENT[a]	HIRED FARM LABOR—WORKERS[b]
WESTERN REGION		
Edwards	44	348
Kinney	33	145
Real	13	95
Uvalde	561	653
Total	**651**	**1,241**
CENTRAL REGION		
Atascosa	312	909
Medina	206	884
Total	**518**	**1,793**
EASTERN REGION		
Bexar	1,056	1,154
Caldwell	99	573
Comal	91	341
Hays	126	355
Guadalupe	229	934
Kendall	64	370
Total	**1,665**	**3,730**
DOWNSTREAM REGION		
Calhoun	75	213
DeWitt	27	789
Gonzales	962	1,761
Refugio	65	300
Victoria	201	837
Total	**1,330**	**3,900**

[a] Source: TWC (2009) Covered Employment and Wages.
[b] Source: U.S. Agricultural Census, Hired Farm Labor-Workers.

Unemployment within the study area has followed statewide unemployment trends. The TWC reports an unemployment rate of 8.6 in January of 2010, a 2.6 increase from 2005. Every county within the study area reported an unemployment rate of no less than 6.4 percent.

3.6.1 Western Region

The Western Region had the lowest total employment within study area in the fourth quarter of 2009 (Tables 3-22 and 3-25). Education and health services comprise nearly one-third of all the employment in the Western Region, followed by trade, transportation, and utilities at approximately 24 percent. The majority of employment within the Western Region is concentrated in Uvalde County, where education and health services and trade, transportation, and utilities are the largest employer categories.

Table 3-25. Employment and Average Quarterly Wages for the Western Region, 4th Quarter, 2009.

CATEGORY	TOTAL EMPLOYMENT				WESTERN REGION	
	Edwards County	Kinney County	Real County	Uvalde County	Total Employment	Percent of Total
Natural Resources and Mining	44	33	16	664	757	7.0%
Construction	39	16	49	311	415	3.9%
Manufacturing	0	0	15	390	405	3.8%
Trade, Transportation, and Utilities	78	139	93	2,250	2,560	23.8%
Information	37	0	0	128	165	1.5%
Financial Activities	0	0	22	298	320	3.0%
Professional and Business Services	14	4	20	347	385	3.6%
Education and Health Services	0	0	314	2,990	3,304	30.8%
Leisure and Hospitality Services	15	80	101	826	1,022	9.5%
Other Services	4	12	4	256	276	2.6%
Public Administration	93	244	76	716	1,129	10.5%
Unclassified	0	0	0	0	0	0.0%
TOTAL EMPLOYMENT	**324**	**528**	**710**	**9,176**	**10,738**	**100.0%**
AVERAGE TOTAL WAGES	**$3,373,655**	**$7,285,663**	**$4,296,885**	**$74,464,018**	**---**	**---**

Source: TWC (2010). Labor Market Information-Covered Employment and Wages.

Though unemployment gradually declined in the Western Region during the 1990s and early 2000s, the national economic downturn has caused unemployment to rise in all counties within the study area. The average unemployment rate for the Western Region of the study area jumped from 5.6 percent in 2000 to 8.8 percent in 2009. Kinney County saw the highest unemployment rate of any county in the study area, while Real County saw the second-lowest unemployment rate of any county in the study area.

3.6.1.1 Government

Federal, state, and local governments employ approximately 35 percent of the Western Region workforce. School districts are one of the major employers in the region; Uvalde Consolidated Independent School District (ISD) alone employs 721 individuals as of 2000 (Uvalde Community Profile 2010). Southwest Texas Junior College in Uvalde is the largest employer in the region with a total of 1,766 employees. The City of Uvalde reported 140 employees in 2000, and Uvalde County employed a workforce of 95 (Uvalde Community Profile 2010).

3.6.1.2 Services

Professional and business services, education and health services, leisure and hospitality, and other services compose a significant part of the region's overall employment. Approximately 4,987 persons were employed in service industries in the Western Region during the fourth quarter of 2009, for a total of 46.4 percent of employment across the region. Amistad Nursing Home and Southwood Nursing employ a total of 97 individuals and are one of the largest employers in the industry in the Western Region.

3.6.1.3 Trade, Transportation, and Utilities

Trade, transportation, and utilities employed 2,560 persons in the Western Region during the fourth quarter of 2009. The local HEB Food Store employs 210 in the Uvalde area, making it one of the largest employers in the industry (Uvalde County Community Profile 2010).

The Western Region depends heavily on trucking between the United States and Mexico via the Eagle Pass-Piedras Negras International Bridge and the Del Rio-Ciudad Acuna International Bridge. Implementation of the North American Free Trade Agreement in 1994 contributed to growth in the Western Region, especially upon full implementation in 2008. Vulcan Materials, an asphalt mining company, employed 200 in 2000, and General Tire Proving Grounds, a tire testing company, employed 94 (Uvalde County Community Profile).

3.6.1.4 Manufacturing

Major manufacturing companies in the Western Region include AgriLink Foods (packaged frozen foods) and Williamson-Dickie Manufacturing (clothing), and three aircraft-related companies: Sierra Industries (aircraft modification), South Star Aircraft Interiors, and Miller Aircraft Painting (Uvalde County Community Profile 2010). The region's temperate climate provides a suitable environment for a variety of crops and associated processing plants and activities. Several cattle feedlots and meat packing plants are located within the area (Table 3-26).

Table 3-26. Major Manufacturing Employers in the Western Region, 2010.

COMPANY	NUMBER OF LOCAL EMPLOYEES	TYPE OF BUSINESS
AgriLink Foods	400	Packaged Frozen Foods
Williamson-Dickies	320	Work Clothes
Sierra Industries	104	Aircraft Modification
South Star Aircraft Interiors	65	Aircraft Interiors
Miller Aircraft Painting	20	Aircraft Painting
TOTAL	**909**	

Source: Uvalde County website 2010.

3.6.1.5 Natural Resources and Mining

Natural resources and mining includes agriculture, forestry, fishing, hunting, and mining. During the fourth quarter of 2009, approximately 7 percent of the Western Region was employed within these industries. Uvalde County had the highest number of employees in mining and supporting activities at 135 people. In Edwards, Kinney, and Real Counties animal production is the strongest element of the industry. Uvalde County provides more employment in crop production and in agriculture and forestry support activities. 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 Atascosa and Medina Counties. This region makes up less than 2 percent of overall employment in the study area (Table 3-22). Education and health services are the primary employers in the Central Region, followed by trade, transportation, and utilities. The disparity between the number of individuals within the work force residing in the Central Region and the relative scarcity of jobs in the area reflects the significant numbers of workers who commute into the San Antonio MSA (TWC 2010).

Unemployment rates in the Central Region increased from 3.9 to 8.7 in Atascosa County and 3.6 to 7.8 in Medina County between 2000 and 2010. Approximately 17.5 percent of the regional population fell below the poverty line in 2008, and the estimated median household income averaged approximately $43,257. Employment and average quarterly wages are provided by county for the fourth quarter of 2009 (Table 3-27).

3.6.2.1 Government

Local governments employ a total of 4,619, providing about 26 percent of all employment in the Central Region.

Table 3-27. Employment and Average Quarterly Wages for the Central Region, 4th Quarter, 2009.

CATEGORY	TOTAL EMPLOYMENT		CENTRAL REGION	
	Atascosa County	Medina County	Total Employment	Percent of Total
Natural Resources and Mining	863	302	1,165	6.6%
Construction	558	492	1,050	5.9%
Manufacturing	597	230	827	4.7%
Trade, Transportation, and Utilities	2,131	1,633	3,764	21.3%
Information	69	75	144	0.8%
Financial Activities	361	396	757	4.3%
Professional and Business Services	368	409	777	4.4%
Education and Health Services	3,134	2,576	5,710	32.3%
Leisure and Hospitality Services	650	820	1,470	8.3%
Other Services	372	218	590	3.3%
Public Administration	518	884	1,402	7.9%
Unclassified	10	0	10	0.0%
TOTAL EMPLOYMENT	**9,631**	**8,035**	**17,666**	**99.8%**
AVERAGE TOTAL WAGES	**$82,529,821**	**$57,688,937**	**---**	**---**

Source: TWC (2010), Labor Market Information-Covered Employment and Wages.

3.6.2.2 Services

Service industry employment makes up approximately 48.4 percent of the Central Region economy. Tri-City Community Hospital, a major medical facility, is located in Atascosa County, while Medina County hosts recreation and tourism destinations including TPWD's Hill County State Natural Area and the Medina Diversion Reservoir.

3.6.2.3 Manufacturing

Several manufacturing industries including fabricated metal, food, and concrete and cement manufacturing employ workers in the Central Region.

3.6.2.4 Agriculture

Agriculture provides the primary economic base in the Central Region. Important agricultural commodities produced in the region include cattle, peanuts, and strawberries. Atascosa County has been dubbed the "Strawberry Capital of Texas." See Section 3.4 for more information regarding the agricultural resources in these counties.

3.6.2.5 Trade, Transportation, and Utilities

Trade, transportation, and utilities comprise 21.3 percent of employment in the Central Region. The area is intersected by major highways including IH-35 and Texas State Highway 132 and numerous railways. The United Parcel Service operates a regional parcel distribution and drop-off center in Atascosa County.

3.6.3 Eastern Region

The Eastern Region is the most populated and most highly employed region within the study area. This region encompasses the San Antonio MSA and a portion of the Austin-San Marcos MSA. In the fourth quarter of 2009, the San Antonio MSA provided over 89 percent of the total employment in the Eastern Region (TWC 2010). Current and planned transportation improvement projects leading into the San Antonio MSA will likely continue to spur urban growth in the area and its surroundings. Table 3-23 and describe the Eastern Region's relatively low unemployment and poverty rates when compared to the rest of the study area and the state. Employment and total wage data is shown in Table 3-28 for the Eastern Region.

The Eastern Region is the most urban economy within the study area and is characterized by large government, education, trade and service, and transportation and utility employers, as well as a few large manufacturers. Export sectors, or products and services purchased with money from outside the region, are a critical part of the region's economy. These sectors include large corporate headquarters which direct operations that occur primarily outside of the region. Table 3-29 shows large employers in the San Antonio area that provide substantial export impact.

Much of the employment in the export sector in the San Antonio MSA is either labor intensive or related to 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 18.7 percent of the overall employment for the Eastern Region. In San Antonio, Fort Sam Houston of the U.S. Army and Lackland Air Force Base are the largest single employers in the area. Five military installations are located within the San Antonio MSA. Local governments employ far more individuals than the federal government within the Eastern Region (SAEDF 2010b).

3.6.3.2 Trade

HEB Food Stores is the second-largest private employer in the San Antonio region, employing 14,588 persons (SAEDF 2010a).

Table 3-28. Employment and Average Quarterly Wages for the Eastern Region, 4th Quarter, 2009.

CATEGORY	TOTAL EMPLOYMENT						CENTRAL REGION	
	Bexar County	Caldwell County	Comal County	Guadalupe County	Hays County	Kendall County	Total Employment	Percent of Total
Natural Resources and Mining	3,341	293	380	285	270	83	4,652	0.6%
Construction	37,818	272	3,804	2,447	2,752	1,003	48,096	5.7%
Manufacturing	32,728	260	2,664	4,938	3,816	856	45,262	5.3%
Trade, Transportation, and Utilities	136,060	1,533	11,031	5,529	12,330	2,316	168,799	19.8%
Information	18,572	31	427	215	608	131	19,984	2.3%
Financial Activities	61,069	272	1,211	997	1,608	632	65,789	7.7%
Professional and Business Services	95,295	342	2,789	1,908	3,071	870	104,275	12.3%
Education and Health Services	187,505	2,409	8,511	7,399	14,460	2,716	223,000	26.2%
Leisure and Hospitality Services	86,842	639	5,775	2,939	6,292	1,257	103,744	12.2%
Other Services	22,492	151	1,192	959	1,707	498	26,999	3.2%
Public Administration	35,534	520	1,008	1,138	1,692	466	40,358	4.7%
Unclassified	128	6	11	8	30	6	189	0.0%
TOTAL EMPLOYMENT	**717,384**	**6,728**	**38,803**	**28,762**	**48,636**	**10,834**	**851,147**	**100.0%**
AVERAGE TOTAL WAGES	**$7,860,522,706**	**$52,149,553**	**$363,344,191**	**$269,849,430**	**$405,319,008**	**$104,130,881**	**---**	**---**

Source: TWC (2010), Labor Market Information-Covered Employment and Wages.

3.6.3.3 Services

Service employment represents the majority of employment in the Eastern Region, composing 53.8 percent of region-wide employment. Accommodation and food services make up a large part of the service industry along with a strong tourism industry (see Section 3.6.3.8 Recreation and Tourism). Bill Miller Bar-B-Q employs 4,190 individuals. Direct economic impact of the Alamodome sports arena since opening in 1993 is estimated at over $250 million (SAEDF 2010a).

3.6.3.4 Manufacturing

The largest manufacturers within the Eastern Region include Harland Clarke check printing, Cardell Cabinetry wood cabinets, and Toyota Motor Manufacturing. The manufacturing sector provides just over 5 percent of the region's employment (see Table 3-30).

Table 3-29. Major Corporate Headquarters and Regional/Divisional Offices Located in San Antonio, 2010.

EMPLOYER	TYPE OF BUSINESS	SAN ANTONIO EMPLOYMENT
United Services Automobile Association	Financial Services and Insurance	14,852
HEB Food Stores	Supermarket Chain	14,588
Bill Miller Bar-B-Q	Fast Food Chain	4,190
Cullen/Frost Bakers	Financial Services	3,082
Valero Energy	Oil Refinery and Gasoline Marketing	3,777
Southwest Research Institute	Applied Research	3,300
Harland Clarke	Check Printing	3,100
Clear Channel Communications, Inc.	TV and Radio Stations, Outdoor Advertisements	2,800
Cardell Cabinetry	Custom Wood Cabinets	2,429
Rackspace	IT Managed Hosting Solutions	2,412
Kinetic Concepts, Inc.	Specialty Medical Products	2,156
Zachry Holding, Inc.	General Contractors	2,000
NuStar Energy L.P.	Petroleum Pipeline and Terminal Operators	1,600
American Funds	Mutual Funds and Investments	1,500
Taco Cabana	Fast Food Chain	1,500
CCC Group, Inc.	General Contractors	900
DPT Laboratories	Pharmaceutical and Cosmetic Products	800
Tesoro	Petroleum Exploration, Extraction, and Refining	800
Whataburger	Fast Food Headquarters	700
Southwest Business	Financial Services and Insurance	675
Broadway Bank	Financial Services	630

Source: SAEDF (2010a).

3.6.3.5 Financial Activities

United Services Automobile Association is the largest private employer in the Eastern Region, employing 14,853 persons. Several large export employers (see Table 3-29) exist within the Eastern Region, making intensive use of clerical labor, which has historically been in ample supply in the San Antonio workforce.

3.6.3.6 Information

Transportation, communication, utilities, manufacturing, and the services sector are all included within the NAICS information sector. Southwestern Bell added 2,000 jobs to the city in the 1990s, while companies like World Savings, CitiCorp, and QVC helped to make San Antonio a national telecommunications center (SAEDF 2010b). Southwest Research Institute, an applied research company, employs 3,300 individuals, while Rackspace, an IT Managed Hosting Solutions company, employs 2,412 individuals.

Table 3-30. San Antonio's Leading Manufacturers, 2010.

COMPANY	PRODUCT	SAN ANTONIO EMPLOYMENT
Harland Clarke	Check Printing	3,100
Cardell Cabinetry	Custom Wood Cabinets	2,429
Toyota Motor Manufacturing, Texas	Truck Manufacturing Plaint	2,200
Kinetic Concepts, Inc.	Specialty Medical Products	2,156
The Boeing Company	Aircraft Maintenance Facility	1,540
Caterpillar	Construction and Mining Equipment	1,400
Miller Curtain Company	Curtains and Draperies	1,100
Lockheed Martin	Aircraft Engine Overhaul	1,000
San Antonio Aerospace	Aircraft Maintenance	1,000
CMC Steel Texas	Steel Manufacturing	1,000
Coca-Cola/Dr. Pepper Bottling	Soft Drink Bottling	800
DPT Laboratories	Pharmaceutical and Cosmetic Products	800
Tyson Foods, Inc.	Poultry Production	800
L&H Packing Company	Boned Beef and Ground Beef Patties	625
Maxim	Semi-Conductor Manufacturers	575
C.H. Guenther & Sons, Inc.	Flour, Baking Mixes, and Other Food	500
SAS Shoemakers	Shoes, Handbags	500
Standard Aero	Small Gas Turbine Engine and Accessory Repair	500
Sterling Foods	Production of Specialty Bakery Products	500

Source: SAEDF (2010c).

3.6.3.7 Natural Resources and Mining

The TWC reports 1,665 persons employed in agriculture in the Eastern Region, while the U.S. Agricultural Census estimates a total of 3,730 hired farm labor workers. Caldwell County had the highest number of estimated farm labor workers relative to its employment with a total of 8.5 percent of individuals reported by the U.S. Agricultural Census working on farms. See Section 3.4 for more detailed information about the agricultural economy in these counties. Ranchers have seen an increase in the importance of recreational hunting use as a source of income, as opposed to leasing of grazing rights.

3.6.3.8 Recreation and Tourism

Tourism is a multibillion-dollar industry in the San Antonio metropolitan area and millions of tourists visit the area each year. The unique blend of cultures, historical sites, and attractions make San Antonio one of the top tourist destinations in Texas, according to TxDOT.

Recreation and tourism has a significant, unique impact on the trade and service employment sectors within the study area. Attractions such as the Tanger Outlet Mall in San Marcos and the Alamo in San Antonio make the area a popular visitor destination and a large convention industry exists in the area. Many attractions that support tourism within the area rely heavily on water supply from the Edwards Aquifer. Attractions such as San Marcos Springs, the Comal and Guadalupe Rivers, Sea World–San Antonio, the San Antonio River Walk, Schlitterbahn Water Park, and Six Flags-Fiesta Texas all rely on and use significant amounts of Edwards Aquifer water.

Tourism attractions are affected directly and indirectly by the issues surrounding the Edwards Aquifer springflows. Reported recreational activities directly associated with Comal and San Marcos Springs and their flows downstream include: swimming, picnicking, paddle boats, swift water rescue training, tubing, fishing, wading, rope swings, lounging, playing, RV campgrounds, snorkeling, SCUBA, kayaking, and canoeing (Halff Associates 2010).

San Antonio attractions that use Edwards Aquifer water could 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 Aquifer water for its needs. Withdrawal restrictions could affect these attractions. However, these facilities incorporate the use of water recycling and have remained operational through recent droughts by having the capability to mitigate impacts of more highly restricted groundwater use by augmenting water supplies with recycled water.

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. Data for 2009 indicate an increase of 36,500 (47 percent) to 114,500 since 2000. In general, population is expected to double every 20 years (Canyon Lake Chamber of Commerce 2000).

The normal lake level is 909 feet (277 m) msl, and the lake is usually maintained between 909 and 911 feet (278 m) msl during the summer, which insures a steady release rate for downstream river recreation and agriculture (GBRA [W.E. West, Jr.] Letter to Greg Ellis, July 28, 2000). Should the lake level rise above or drop below these levels, adjustments are made, as directed by USACE.

In 1987, the Texas Legislature authorized the creation of the Water Oriented Recreation District of Comal County (WORD) to conserve the natural resources, improve public health, safety and welfare, and operate public parks located in the district. The district begins at the New Braunfels city limits on the east and ends at the boundary of the Guadalupe State Park on the west. It includes Canyon Lake and about 30 mi (48 km) of the Guadalupe River above and below Canyon Lake, but does not include the City of New Braunfels as the city did not choose to participate. Therefore, WORD encompasses about two-thirds of the county (WORD 2010a).

As a part of its mandate, WORD issues permits to water-related business owners allowing them to collect user fees from customers visiting the district and renting equipment or lodging within the district. The majority of the collected fees are expended on environmental protection of the river and safety of recreationalists on both the district area of the Guadalupe River and Canyon Lake.

The WORD collects tax revenues for a number of water-oriented recreational activities including marinas, camping, fishing guides, and lodging. A summary of the tax rates and revenue generated during 2008 and 2009 are provided in Table 3-31.

Table 3-31. Tax Receipts Collected by WORD.

ACTIVITY	2008			2009		
	Total Taxable Receipts	Tax Rate	Total Tax	Total Taxable Receipts	Tax Rate	Total Tax
Dry Boat	$485,247.00	3.00%	$14,557.41	$539,127.00	3.00%	$16,173.81
Wet Slip	$2,090,156.75	4.00%	$83,606.27	$2,173,783.50	4.00%	$86,951.34
Camping	$2,768,446.60	5.00%	$138,422.33	$2,677,951.20	5.00%	$133,897.56
Fishing Guide	$24,207.80	5.00%	$1,210.39	$25,703.20	5.00%	$1,285.16
Lodging	$6,993,263.83	4.00%	$279,730.55	$6,738,713.50	4.00%	$269,548.54
Lake Equipment	$922,632.00	5.00%	$46,131.60	$641,976.00	5.00%	$32,098.80
River Equipment	$3,814,452.77	6.67%	$254,424.00	$2,181,784.11	6.67%	$145,525.00
Shuttles	$21,199.40	6.67%	$1,414.00	$26,671.66	6.67%	$1,779.00
Ingress	$29,835.08	6.67%	$1,990.00	$16,776.61	6.67%	$1,119.00
TOTALS	**$17,149,441.23**		**$847,726.12**	**$15,022,486.78**		**$698,642.76**

Source: WORD (2010b).

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 study 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 Tourism and Dean Runyan Associates 2011). This compares with total direct projected spending in 2009 of $260,630,000, which generated $5,440,000 in local sales tax receipts and $16,110,000 in state sales tax receipts (Texas Department of Economic Tourism and Dean Runyan Associates 2011, Texas Comptroller of Public Accounts 2010). Water-based recreation was 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 (Mike Meek, New Braunfels Chamber of Commerce, 2002, pers. comm.).

For the year 2006, sales taxes from tourism generated approximately $5 million for the City of New Braunfels; with Comal River recreation accounting for about 20 percent of the total. (TXP 2007, Halff Associates 2010). During that year, it was estimated that river recreation contributed about $630,270 to lodging taxes and $230,435 in sales taxes (TXP 2007, Halff Associates 2010).

Total direct travel spending in Hays County for 2009 was projected to be $205,420,000 with local sales tax receipts generating $3,670,000 and state sales tax generating $12,930,000 (Texas Department of Economic Tourism and Dean Runyan Associates 2011).

Employment in the leisure and hospitality industry ranged from 11 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 typically increases during the water season from May through September, then declines during winter months. 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 (TWC 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. Recreational use of the upper San Marcos River in the summer time period described was lower in 1984 than 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). It is important to note that while a relationship between increased recreation and higher river flows appear evident during average or reduced flow conditions, higher flows from dam releases associated with flood flows and high rainfall periods would deter recreation use perhaps as much or more than low flows due to increased danger and reduced opportunities for conducting river-oriented recreational activities.

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 Tourism and Dean Runyan Associates 2011). Unlike Comal County, employment in the leisure and hospitality industry remained relatively stable throughout the year in Hays County, ranging from 10.8 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 (TWC 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.

By 2002, approximately 500,000 people visited the San Marcos River for water based recreation and civic activities adjacent to its banks (Earl and Wood 2002). Approximately 375,000 recreationists were attracted to the San Marcos River for tubing and other water-related activities in 2005 (Halff and Associates 2010), with revenue generated during the years 2005 to 2008 estimated at $12.9 million.

3.6.4 Downstream Region

The urbanized area of Victoria, a single-county MSA, is the dominant area within the Downstream Region economy. Nearly 60 percent of employment within the region is attributed to employment within Victoria County (Table 3-32). The region has evolved from an originally agricultural-based economy, with education and health services, trade, transportation and utilities, and manufacturing currently driving the Downstream Region's economy (Table 3-33).

Table 3-32. Employment and Average Quarterly Wages for the Downstream Region, 4th Quarter, 2009.

CATEGORY	TOTAL EMPLOYMENT					CENTRAL REGION	
	Calhoun County	**DeWitt County**	**Gonzales County**	**Refugio County**	**Victoria County**	**Total Employment**	**Percent of Total**
Natural Resources and Mining	304	153	1,105	296	1,870	3,728	6.1%
Construction	1,957	396	150	187	2,297	4,987	8.2%
Manufacturing	2,795	898	1,069	0	2,696	7,458	12.3%
Trade, Transportation, and Utilities	1,180	986	1,348	295	8,271	12,080	19.9%
Information	49	24	49	8	503	633	1.0%
Financial Activities	278	430	215	169	1,695	2,787	4.6%
Professional and Business Services	580	203	190	35	2,188	3,196	5.3%
Education and Health Services	1,497	2,001	1,557	650	10,879	16,584	27.3%
Leisure and Hospitality Services	623	441	321	235	3,254	4,874	8.0%
Other Services	123	176	137	104	1,126	1,666	2.7%
Public Administration	332	628	263	196	1,418	2,837	4.6%
Unclassified	9	0	0	0	7	16	0.0%
TOTAL EMPLOYMENT	**9,727**	**6,336**	**6,404**	**2,175**	**36,204**	**60,846**	**100.00%**
AVERAGE TOTAL WAGES	**$124,729,177**	**$51,229,208**	**$54,510,536**	**$19,383,389**	**$354,058,425**	**---**	**---**

Source: TWC (2010), Labor Market Information-Covered Employment and Wages.

3.6.4.1 Government

The local, state, and federal governments of the Downstream Region of the EIS study area make up a significant portion of employment in comparison to other industries. The Victoria area encompasses six ISDs, the largest of which, Victoria ISD, employs 2,100. Calhoun ISD employs 654, and Cuero ISD employs 423. Other educational employment in the Downstream Region includes Victoria College, which employs 432 individuals, and the University of Houston-Victoria, which employs 456 individuals. A total of 620 persons are employed by Victoria County, while 609 persons are employed with the City of Victoria. The Texas Department of Justice in Victoria employs 319 people at its state prison facility.

Table 3-33. Major Manufacturing Employers in the Victoria MSA, 2009.

COMPANY	TYPE OF BUSINESS	EMPLOYEES
Formosa Plastic	Petrochemical/Plastics	1,500
The Inteplast Group	Plastic Products	1,200
Dow-Seadrift Operations	Petrochemical	700
Invista	Petrochemical	600
Alcoa	Aluminum/Alumina	550
Kasper Wireworks	Metalworks/Plating	490
Berry Plastics	Plastics	455
Tandy Brands	Leather Products	300
Mount Vernon Textiles	Textiles	240
Texas Concrete	Concrete	200
Seadrift Coke	Needle Coke	162
Ineos Nitriles	Petrochemical	130
Fordyce	Sand and Gravel	108
Safety Steel Services	Steel Fabrication	100

Source: VEDC (2010).

3.6.4.2 Manufacturing

Manufacturing in the Downstream Region provides 12.3 percent of total employment in the area. Petrochemical, plastics, and chemical production are all significant contributors to the manufacturing industry in the region, with plants located in Victoria and Calhoun Counties. Due to its location, the area also relies on coastal development like port and water transportation facilities to bolster the economy.

An over $1 billion-expansion of Formosa Plastic's Point Comfort plant from the late-1980s to the mid-1990s increased petrochemical processing capacity to over 5 million tons per year. Expansion and renovation in 1989 of Port Lavaca-Point Comfort to accommodate the increased capacity of Formosa Plastic was completed in December 1994. Since only a small percentage of the increased capacity is necessary for the shipping requirements for which it was built, port officials plan to attempt to increase other petrochemical plants to use the new facilities in place of Houston's port. Economic development in the Downstream Region has been enhanced by the expansion of the Victoria Barge Canal connecting Victoria to the Gulf Intracoastal Waterway, the deep-water port of Port Lavaca-Point Comfort, and the increase in petrochemical plants.

Formosa Plastic is the largest manufacturer in the region employing 1,500, followed by The Inteplast Group with 1,200 employees (VEDC 2010). Plastics, petrochemicals, metalworks, and other products are manufactured in this diverse sector within the region.

The major manufacturing employers in the Victoria MSA as of 2009 are shown in Table 3-33.

3.6.4.3 Services

The service sector provides the majority of employment for the Victoria economy. Altogether, industries within the service sector provide 43.3 percent of the employment for the Downstream Region. Major employers include the Citizen's Medical Center, employing 1,382 individuals, as well as DeTar Healthcare System, which has 1,014 employees. Refugio County also includes a portion of a top Texas tourist destination: Aransas National Wildlife Refuge, home to the whooping crane (*Grus americana*).

3.6.4.4 Trade, Transportation, and Utilities

This sector comprises 19.9 percent of the Downstream Region's overall employment. Major employers include HEB Food Stores with 579 employees, Wal-Mart Supercenter with 410 employees, and department stores like J.C. Penney (150), Dillard's (120), and Target (120).

3.6.4.5 Natural Resources and Mining

Natural resources and mining provided 6.1 percent of employment region-wide during the fourth quarter of 2009. The U.S. Agricultural Census reports hired farm labor workers at 3,900, the highest amount estimated for the entire study area. The TWC estimates 1,330 jobs in the agricultural sector for the fourth quarter of 2009. With 1,762 estimated hired farm labor workers, Gonzales County had the highest amount of workers estimated of any county within the study area.

3.6.4.6 Information

Information contributes just 1 percent of employment to the region, with the *Victoria Advocate* employing 164 individuals.

3.6.4.7 Construction

King Fisher Marine and H.B. Zachry are the largest construction companies within the region, employing 324 and 232 persons, respectively.

3.6.4.8 Recreation

The Downstream Region contains the only two reservoirs in the GBRA system that operates as public recreation areas: Coleto Creek Reservoir in Victoria County and Lake Wood southwest of Gonzales in Gonzales County. 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, 2000, pers. comm.). Coleto Creek Park sees hundreds of thousands of visitors each year, the majority coming from a range within 140 mi (225 km). The park generates revenue of approximately $400,000 per year from park entry fees for camping, picnicking, and bass fishing. The Lake Wood Recreation Area is slightly less busy than Coleto Creek Park but generates revenue of approximately $90,000 per year from park entry for camping, fishing, yearly island lease rentals, and park store sales.

3.7 LAND USE

According to the U.S. Department of Agriculture's 1997 Natural Resources Inventory, (USDA 1997) the study area includes lands dedicated to a wide range of uses including rangeland, cultivated and non-cultivated cropland, pastureland, urban uses, transportation (including roadways and railroads), surface water features, federal lands (such as military bases) and miscellaneous other uses (Table 3-34).

The largest total acreage of lands within the study area, totaling about 68.8 percent, are used as rangeland. Croplands, making up about 10.1 percent, and pasturelands, comprising about 9.3 percent, also make up a significant portion of the study area. Urban uses comprise about 5.1 percent of the study area. The remaining land use categories, including surface water (3.3 percent), transportation (1.3 percent), miscellaneous other uses (1.3 percent), and federal land (0.8 percent), account for less than 5 percent of the total acreage in the study area (USDA 1997).

3.7.1 Western Region

The Western Region of the study area includes Edwards, Kinney, Real, and Uvalde counties. Rangeland accounts for most of the land area in the region (93.5 percent) (see Table 3-34). Cropland makes up about 4 percent, followed by transportation at less than 1 percent. All other categories (pasture, urban, surface water, federal land, and miscellaneous) comprise less than 1.1 percent of the approximately 3,676,400 acres (1,487,792 hectares) in the region.

3.7.2 Central Region

The Central Region includes Atascosa and Medina counties. Rangeland is the predominant land use in this area. This region has, at about 17 percent, the highest relative amount of cropland of any region within the study area (see Table 3-34).

3.7.3 Eastern Region

The Eastern Region includes Bexar, Caldwell, Comal, Guadalupe, Hays, and Kendall counties. Rangeland is the predominant land use making up about 48 percent of the total land area, followed by urban and transportation making up a combined 17 percent, about 16 percent in pastureland, and cropland at about 13 percent. Remaining land use categories account for about 6 percent of the total area (see Table 3-34).

3.7.4 Downstream Region

The Downstream region includes Calhoun, DeWitt, Gonzales, Refugio, and Victoria Counties. At about 61 percent, rangeland makes up the predominant land use within the region, followed by pasture at about 12 percent, surface water at 10 percent, croplands at 10 percent, and urban and transportation at a combined 4 percent. The remaining land use categories account for the remaining 3 percent (see Table 3-34).

Table 3-34. Estimated Land Use in the EIS Study Area, 1997 (Thousands of Acres).

COUNTY	CROPS	% TOTAL	PASTURE	% TOTAL	RANGE	% TOTAL	MISC.[a]	% TOTAL	URBAN	% TOTAL	TRANS.[b]	% TOTAL	SURFACE WATER	% TOTAL	FEDERAL LAND	% TOTAL	CONSERV.[c]	% 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**
STUDY 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**

Source: USDA (1997).
[a] Misc. = Miscellaneous minor land count uses.
[b] Trans. = Rural transportation including roads and railroads.
[c] Conserv. = Lands in the Conservation Reserve Program.

3.8 CULTURAL RESOURCES

This section describes cultural resources including locations listed or potentially eligible to be listed on the National Register of Historic Places (NRHP), State Archeological Landmarks (SALs), Texas Historical Markers, recorded archeological sites, and other historic properties within the Area of Potential Effect. These resources were identified from Texas Historical Commission (THC) records and other archival information.

3.8.1 Regulatory Compliance

Under 36 CFR 800, a Federal Agency with jurisdiction over a federal undertaking, or one that is federally assisted or federally licensed, must take into account the effect that the undertaking will have on properties included in or eligible for listing on the NRHP. Section 106 of the NHPA governs the process in which agencies assess those impacts. The Section 106 process requires the federal agency 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 or minimize those impacts to the fullest possible extent.

This project also falls under the purview of the Antiquities Code of Texas (ACT) because it may involve archeological sites located "on land owned or controlled by the State of Texas or any city, county, or local municipality thereof." The ACT considers all such properties potential SALs and requires that each be examined for potential significance. Chapter 26 of the THC's Rules of Practice and Procedure for the ACT outlines the standards for determining significance.

3.8.1.1 Cultural Resources Identified within the Area of Potential Effect

The following cultural resource sites have been designated as NRHP or SALs.

- 41CM25 – At this site, human burials, heat-altered rock, chert tools, and pre-historic ceramics have been found. The site measures approximately 330 feet (101 m) by 165 feet (50 m) and may have deposits as deep as 7 feet (2 m) 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 (110 m) north-south by 130 feet (40 m) 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 (330 m) east-west and approximately 200 feet (61 m) north-south.

- 41CM175 – This site is located on the east bank of Spring Lake. The site, which measures 165 feet (50 m) east-west and 50 feet (15 m) 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 (20 to 30 cm). 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 (149 m) by 165 feet (50 m). 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 (1 m) below ground surface. The site measured approximately 400 feet (122 m) north-south by 175 feet (53 m) east-west. The site is adjacent to Spring Lake.

- 41CM205 – Located adjacent to the Comal River, this site measures 1,315 feet (401 m) by 985 feet (300 m). A survey of the site recorded lithic debris, diagnostic artifacts and a possible burned rock midden to a depth of 20 inches (50 cm) below ground surface.

- The following archeological sites 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 (10 m) west of Comal Springs, and it measures roughly 115 feet (35 m) north-south and 33 feet (10 m) east-west. It was recommended that this site be protected from future disturbance or mitigated before any disturbance.

- 41CM90 – This site is eroding out of the east bank of the Comal River. The site is estimated to be about 300 feet (91 m) long and possibly 3 feet (1 m) deep. A surface collection included chert flakes, heat-altered limestone, chertbifaces, scrapers, and cores. No recommendations were made for this site.

- 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 (40 m) by 131 feet (40 m). Despite the disturbance, intact cultural resources may still exist as deposits have been found more than 6 feet (2 m) below ground surface. The original site recorders recommended this site for further testing and excavation.

- 41HY160 – The Tee Box 6 site, which is immediately adjacent to Spring Lake, measures about 820 feet (250 m) north-south by 490 feet (149 m) 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 9 feet (3 m) 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 (250 m) east-west by 820 feet (250 m) 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 could potentially 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 (564 m) 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.

- 41HY166 – This site, which measures roughly 330 feet (101 m) by 1,000 feet (305 m), 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.

3.9 AIR QUALITY

This section describes air quality within the study area.

3.9.1 Pollutant Dispersal Characteristics

Topography varies from generally flat in the easternmost portions of the study area to rolling terrain in the central and western portions of the study area. No topographic features significantly limit dispersal or channel the flow of airborne pollutants within the study area.

Thermal and mechanical turbulence in the atmosphere affect the dispersal of air pollutants. The height and wind speed within the mixing layer nearest the earth's surface determine the volume of air into which pollutants will eventually be mixed. Low mixing heights and wind speeds decrease dilution of regional pollutant emissions and can trap pollutants near the surface. Higher mixing heights and stronger wind speeds generally increase dilution and dispersal of emissions and result in reduced air quality impacts. Central and southeast Texas experience better than average annual morning mixing height conditions and about average annual afternoon mixing height conditions throughout the year (Holzworth 1972).

3.9.2 Regional Compliance Standards

The Clean Air Act (CAA) of 1970 required development of federal and state regulations limiting emissions for both stationary (industrial) and mobile sources. The CAA required the USEPA to establish National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment. The NAAQS considers six principal pollutants, including carbon monoxide, nitrogen dioxide, lead, ozone (O_3), particulate matter, and sulfur dioxide.

Ground-level O_3 is the primary pollutant of concern for each of the TCEQ air quality regions in Central Texas (CAMPO 2010). Ozone is not directly emitted, but is formed by the interaction of VOCs and nitrogen oxides in the presence of sunlight.

Air quality regions meeting USEPA NAAQS for principal pollutants are considered to be in attainment. Air quality regions found to exceed the NAAQS are designated as nonattainment areas. Near nonattainment areas currently meet federal standards but are at risk of violating standards. Maintenance areas are areas that were once designated in nonattainment of federal standards, but which have since been redesignated in attainment. An additional designation termed “unclassifiable” 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 a pollutant. An unclassifiable designation implies attainment and therefore no restrictions are applied.

All of the air quality regions within the study area are currently in attainment with respect to each of the NAAQS (TCEQ 2010b). Though USEPA has recently proposed new nonattainment designations for ground-level O_3 in Texas, no part of the study area falls within the affected areas (USEPA Letter to Rick Perry, Governor, State of Texas, December 9, 2011).

3.9.2.1 Greenhouse Gasses

General scientific consensus is that the earth is experiencing a warming trend predominantly caused by human-induced increases in atmospheric Greenhouse Gases (GHG). The CCSP has concluded that the global climate is changing and that it is very likely that the temperature increases, increasing CO_2 levels, and altered patterns of precipitation are already affecting U.S. water resources, agriculture, land resources, biodiversity, and human health, among other things (IPCC 2007a, NSTC 2008). According to CCSP’s Synthesis and Assessment Product 4.3, it is very likely that climate change will continue to have significant effects on these resources over the next few decades and beyond (Backlund et al. 2008).

A widespread increase in annual precipitation is projected over most of the North American continent except the southern and southwestern part of the United States including central Texas by the IPCC, and more than 90 percent of the models project drying of the northern and particularly western parts of Mexico (IPCC 2007b).

Climate-change scenarios were modeled from scaling factors derived from historical data obtained during above-average recharge, near-average recharge, and extreme water shortage periods to assess the likely impacts of pumping on the water resources of the Edwards Aquifer. Results project that climate change conditions that double CO_2 in the air could exacerbate negative impacts and water shortages in the Edwards Aquifer. Researchers suggested that the water resources of the Edwards Aquifer could be severely impacted under a warmer climate without proper consideration to variations in recharge and sound pumping strategies (Loáiciga et al. 2000).

Mace and Wade (2008) modeled groundwater in the region to investigate the possible range of effects of climate change on the San Antonio segment of the Edwards Aquifer. Their global climate models project a warmer Texas with probable changes in long-term precipitation with a preference toward drier conditions, which can affect changes in water resources. For aquifers, climate change can affect recharge, the amount of pumping, and natural discharge with highly responsive aquifers being the most affected. There has only been limited research on how climate change may affect Texas's groundwater resources with most of the existing work focused on the Edwards Aquifer.

Mace and Wade further concluded that the Edwards, the upper part of the Hill Country portion and outcrop areas of the Trinity, the upper parts of the Edwards-Trinity (Plateau), the Seymour, and several responsive minor aquifers are expected to be susceptible directly to climate change. Groundwater resources from the other aquifers are expected to be affected minimally by climate change because of their lower responsiveness, dipping geology, and/or the amount of pumping as compared to recharge. However, many of the aquifers not directly affected by climate change may be indirectly affected if cities that rely primarily on surface water resources are forced to find other sources of water.

The Edwards Aquifer may be particularly susceptible to climate change because it recharges so quickly and is closely tied to surface water runoff. The modeling work conducted for the San Antonio segment of the Edwards Aquifer suggests that pumping may have to be reduced by about 40,000 ac-ft/yr to maintain minimum springflows if recharge declines 30 percent. Additional research is needed on summarizing downscaled climate models for Texas, better representing the flow of water through the unsaturated zone to the water table, quantifying how the intensity and duration of droughts may change, and better characterizing surface water and groundwater interactions (Mace and Wade 2008).

CHAPTER 4

ENVIRONMENTAL CONSEQUENCES

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
AM – Adaptive Management
AMP – Adaptive Management Program
ASR – aquifer storage and recovery
BMP(s) – best management practice(s)
BWL – Bad Water Line
CAA – Clean Air Act
CCSP – U.S. Climate Change Science Program
CEQ – Council on Environmental Quality
CFR – Code of Federal Regulations
CFU – colony-forming units
CNB – City of New Braunfels
CPM – Critical Period Management
CSM – City of San Marcos
DEIS – Draft Environmental Impact Statement
DHHS – Department of Health and Human Services
DOR – drought of record
EAA – Edwards Aquifer Authority (the Authority)
EARIP – Edwards Aquifer Recovery Implementation Program
EDF – Environmental Defense Fund
EIS – environmental impact statement
ERPA – Environmental Restoration and Protection Area
ESA – Endangered Species Act
FR – Federal Register
GBRA – Guadalupe-Blanco River Authority
GCSNA – Government Canyon State Natural Area
GHG – Green House Gas
HCP – Habitat Conservation Plan
IA – Implementing Agreement
IH – Interstate Highway
IPCC – Intergovernmental Panel on Climate Change
IPM – Integrated Pest Management
ISD – Independent School District
ITP – Incidental Take Permit
LID – Low Impact Development
MCLs – maximum contaminant levels
MSA – Metropolitan Statistical Area
msl – mean sea level
NAAQS – National Ambient Air Quality Standards
NCDC – U.S. Historical Climate Network of the National Climatic Data Center
NEPA – National Environmental Policy Act
NGOs – non-governmental organizations
NHPA – National Historic Preservation Act
NRHP – National Register of Historic Places
NOI – Notice of Intent
NRI – Nationwide Rivers Inventory
OCR – off-channel reservoir
PCBs – Polychlorinated Biphenyls
PCE – tetrachloroethene
RM – Ranch to Market Road
RWCP – Regional Water Conservation Program
SALs – State Archeological Landmarks
SAWS – San Antonio Water System
SB 3 – Senate Bill 3
SCTRWPG – South Central Texas Regional Water Planning Group
SCUBA – Self-contained Underwater Breathing Apparatus
Service – U.S. Fish and Wildlife Service
SH –Texas State Highway
SHPO – State Historic Preservation Officer
SSA – Sole Source Aquifer
STIR – State of Texas Integrated Report
SVOCs – Semi-Volatile Organic Compounds
TAG – Technical Advisory Group
TCE – trichloroethene
TCEQ – Texas Commission on Environmental Quality
TDS – total dissolved solids
THC – Texas Historic Commission
TPWD – Texas Parks and Wildlife Department
TSDC – Texas State Data Center
TSU – Texas State University
TSWQS – Texas Surface Water Quality Standards
TWC – Texas Workforce Commission
TWDB – Texas Water Development Board
TxDOT – Texas Department of Transportation
US – U.S. Route
USACE – U.S. Army Corps of Engineers
USDI – U.S. Department of the Interior
USEPA – U.S. Environmental Protection Agency
VISPO – Voluntary Irrigation Suspension Program Option
VOCs – Volatile Organic Compounds
WORD – Water Oriented Recreation District of Comal County
WRIP – Water Resources Integrated Pipeline

4.0 ENVIRONMENTAL CONSEQUENCES

This chapter compares the effects of each of the four alternatives on specific elements of the natural and human environment. Effects and impacts are considered synonymous for the purposes of NEPA analyses, and "include(s) ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historical, cultural, economic, social, or heath, whether direct, indirect, or cumulative. Effects may also include those resulting from actions which may have both beneficial and detrimental effects" (40 CFR 1508.8).

Direct effects are "those that are caused by the action and occur at the same time and place" (40 CFR 1508.8(a)). The CEQ defines indirect effects as those "which are caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect effects may include growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems" (40 CFR 1508.8(b)).

The direct and indirect effects of the actions considered under the proposed alternatives are closely associated, and in many instances difficult or impossible to separate. Actions such as CPM pumping limitations, for example, may have direct effects to the Edwards Aquifer ("occur(-ring) at the same time and place" where the pumping restrictions will be implemented) that result in indirect effects to the springflows ("later in time or farther removed in distance") that impact the covered species. Though an action may be implemented specifically to generate a beneficial effect to the covered species, the effect of that action is by CEQ definition indirect. Direct and indirect effects are therefore considered together for the purposes of this analysis.

Cumulative effects are those "which result(s) from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of the agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7). Cumulative effects are described in Section 4.7 below.

To analyze the effects of each of the alternatives, springflow simulations were generated using precipitation data recorded from January 1947 through December 2000 (which includes the DOR period). Simulations for Alternatives 1, 2, and 3 were developed using a standardized set of model parameters and are therefore directly comparable (HDR 2011). Alternative 4 springflow approximations were simulated under somewhat different model parameters and results are therefore not directly comparable to those of the other alternatives. The springflow simulations provided for Alternative 4 can be compared to the recorded (i.e., historic) conditions, but should be understood to represent an approximation when considered against the other alternatives (EARIP EAAESS 2009).

For the purposes of this analysis, the full extent of all water rights authorized under state-mandated SB 3 allocations (i.e., 572,000 ac-ft/yr) are presumed to be pumped in accordance with the restrictions or management activities that comprise each of the respective considered actions. Presuming that all allocated permits will be pumped to the fullest extent possible ensures that the results among considered alternatives can be compared. The "No Action" Alternative 1 presumes that pumping is managed in accordance with regulations and management activities (such as CPM restrictions) currently in place. This assumption generates a baseline condition against which the remaining alternatives are compared. It should be noted that the highest annual level of pumping actually recorded was 542,000 ac-ft in 1989, and that recent median estimated well production (1998–2007) has declined to approximately 380,000 ac-ft/yr (EAA 2003).

Though the EAA has the ability to adopt emergency rules to meet statutorily mandated obligations to ensure that "continuous minimum springflows of the Comal Springs and San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law…" (EAA Act §1.14(h)), the EAA has not described its course of action in the event of a severe drought such that experienced during the DOR (see Section 5.9 of the EARIP HCP [EARIP 2011]). The effects of any such potential actions cannot therefore be assessed, and are not considered further for the purposes of this analysis.

4.1 PHYSICAL ENVIRONMENT

This section describes the direct and indirect impacts of each of the alternatives on the climate, geology and soils within the study area.

4.1.1 Climate

None of the Alternatives are expected to result in direct or indirect impacts to the climate in the study area. For more on alternative-related emissions, please see Section 4.6.2 below.

4.1.2 Geology

None of the alternatives considered are anticipated to affect the geology in the study area.

4.1.3 Soils

4.1.3.1 Alternative 1: No Action

The "No Action" Alternative 1 describes direct and indirect effects expected under a continuation of the management activities and regulations currently in place. The actions proposed under this alternative are not expected to affect soils during normal or above normal precipitation and recharge conditions.

Simulations of springflows over the period of record given current conditions, however, indicate that Alternative 1 could result in reduction and loss of flows in the Comal River system during severe drought conditions such as those experienced during the DOR. These springflow losses could result in the drying of springs, streamside soils, and some riverbeds. Springflow simulations for San Marcos Springs over the period of record under current conditions approach zero during the DOR period, which could also result in drying of streamside soils and some riverbeds. Subsequent rainfall events could result in erosion of soils and stream sediments that do not experience drying under normal conditions. Pumping restrictions and reduced irrigation during drought conditions could result in decreased upland soil moisture that could make these soils more prone to erosion.

Recent trends in agricultural production indicate that irrigated agriculture in the study area is shifting toward livestock production and dryland farming techniques. Shifts from irrigated agriculture to livestock production can increase compaction and erosion of some soil types. Changes in crop types may result in altered soil moisture regimes on some lands, and changes in fertilizer and pesticide use may result in indirect effects on soil productivity. These trends may be accelerated during periods of drought given the proposed actions considered Alternative 1.

4.1.3.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 includes streamside restoration activities at the Comal and San Marcos Rivers that could have beneficial effects to soils. These actions include removing and replacing non-native vegetation with native trees and stream-side vegetation to reestablish healthy functioning riparian zones. Riparian zones provide natural sediment and bank stabilization benefits that could reduce erosion of streamside soils. While short-term soil disturbance and erosion could result during implementation of these actions, adherence to best management practices (BMPs) and local and state water quality protection measures (such as TCEQ regulations) should minimize negative impacts. Restored riparian zones could improve ecosystem function including reduced future soil erosion potential during normal and above normal precipitation conditions.

Springflow simulations over the period of record with Alternative 2 actions indicate that springflows at both Comal and San Marcos Springs would be maintained throughout a repeat of DOR-like conditions. These continual flows would therefore benefit spring and riverbed associated soils by preventing the drying conditions and increased erosion risk possible under Alternative 1. Erosion effects to streamside soils are expected to be minimal because soils in the area exhibit only a slight to moderate potential for water erosion (Batte 1984). Some actions such as the VISPO and the greater CPM restrictions proposed under this alternative could result in lower soil moistures in upland soils and increased erosion risk during drought conditions when compared to Alternative 1.

4.1.3.3 Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 incorporates many of the same actions and would therefore be expected to have similar effects to soils within the study area as those described for Alternative 2. Alternative 3 does not include the VISPO described in Alternative 2, but achieves similar results through more restrictive CPM limitations. These increased pumping reductions and resulting indirect irrigation limitations could be expected to have similar upland soil moisture effects as those described under Alternative 2.

4.1.3.4 Alternative 4: Highest CPM Pumping Restriction

Direct and indirect effects to soils resulting from Alternative 4 actions during normal or above normal precipitation and recharge conditions are expected to be similar to those described for Alternative 1. The CPM plan under this alternative would require a single step 85 percent reduction in region-wide pumping if Comal or San Marcos springflows fall below 225 or 96 cfs, respectively; or if the J-17 or J-27 index wells drop below 665 or 865 msl, respectively. These thresholds are equivalent to the first stage CPM pumping restrictions contemplated under Alternatives 2 and 3. The pumping restriction considered under this alternative could indirectly affect upland soils by reducing soil moistures with greater frequency and for longer periods. These reduced upland area soil moistures could expose these soils to the highest risk of erosion of the considered alternatives.

4.2 WATER RESOURCES

4.2.1 Aquifer-Fed Springflow Quantity

Hydrograph plots illustrating simulated springflows resulting from the direct and indirect effects of the actions associated with each Alternative over the period of record are found in Figures 4-1 through 4-4. The springflow simulation values presented here are not absolute and reflect the assumptions, limitations, and accuracy of the Edwards Aquifer models and the quality of available input data. Analyses of simulated springflows are therefore limited to the evaluation and comparison of the alternatives.

Figure 4-1 illustrates recorded springflows at Comal Springs from 1947 through 2000 (“historical”) with the simulated results for each alternative over this same period; and Figure 4-3 illustrates the same information for San Marcos Springs. To simulate daily springflow conditions, the simulated monthly values were converted to daily average flows. Note that converting Comal and San Marcos Springs monthly average to daily average flows requires 15 cfs and 7 cfs correction factors, respectively, at discharges below 100 cfs to adjust for model calibration assumptions (HDR 2011). Because the two phases proposed under Alternative 2 yield the same results over the simulated period except during the DOR, the scale of this illustration makes differentiating these results difficult. The two Alternative 2 phases are therefore not depicted in Figures 4-1 and 4-3. Figures 4-2 and 4-4 illustrate at a finer scale the historically observed and simulated springflows at Comal and San Marcos Springs during the DOR period. These figures differentiate the two phases of Alternative 2 to clarify the simulated effects of both the initial and the presumed Phase 2 actions. These figures refer to Alternative 2 Phase 1 as “2a”, and the presumed Phase 2 action as “2b”. Tables 4-1 and 4-2 provide the simulated numerical flow results for each alternative at Comal and San Marcos Springs, respectively.

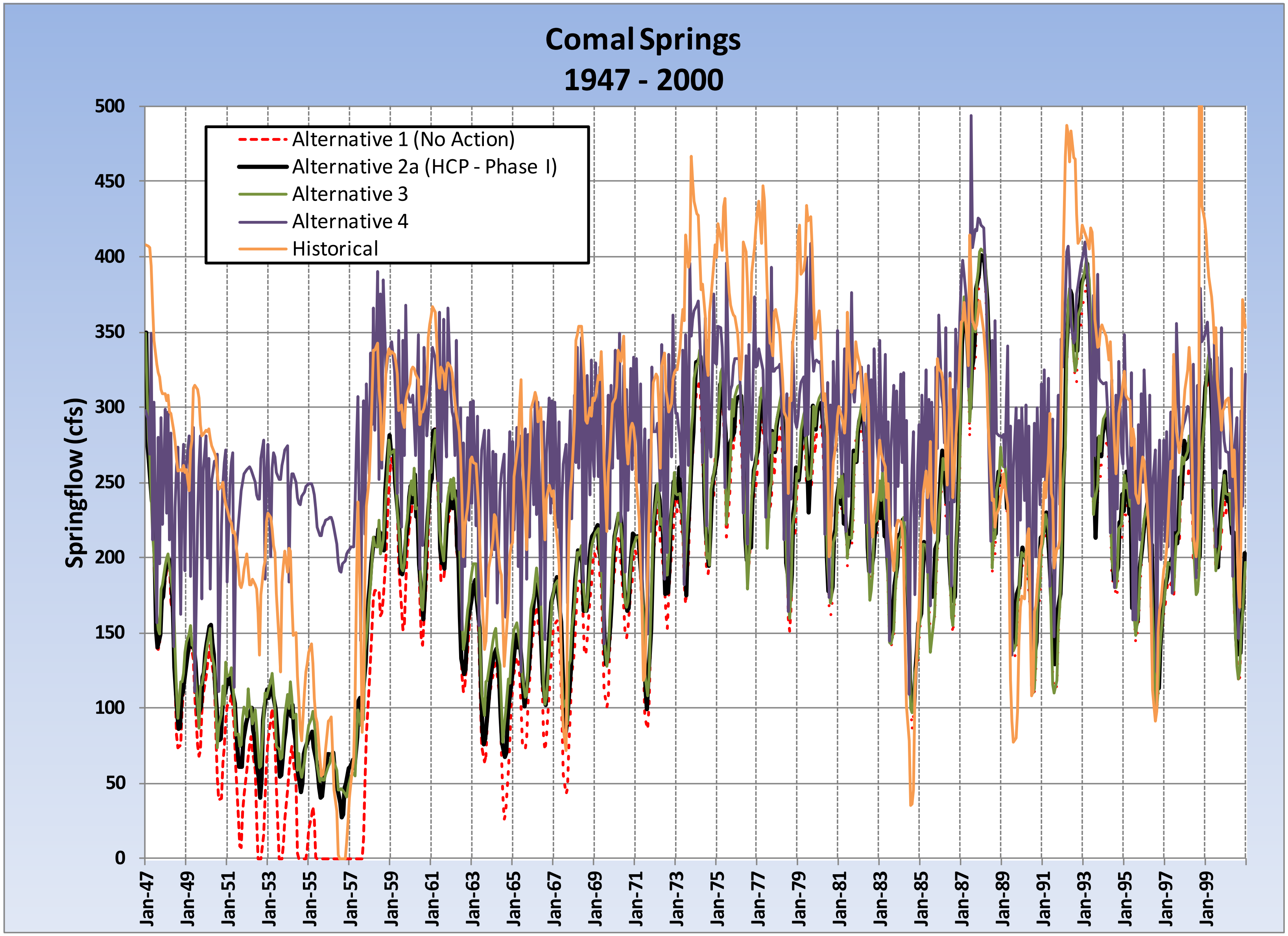


Figure 4-1. Modeled Comal Springs Total Springflow for Alternatives 1, 2a, 3, and 4 for the 1947–2000 Model Period.

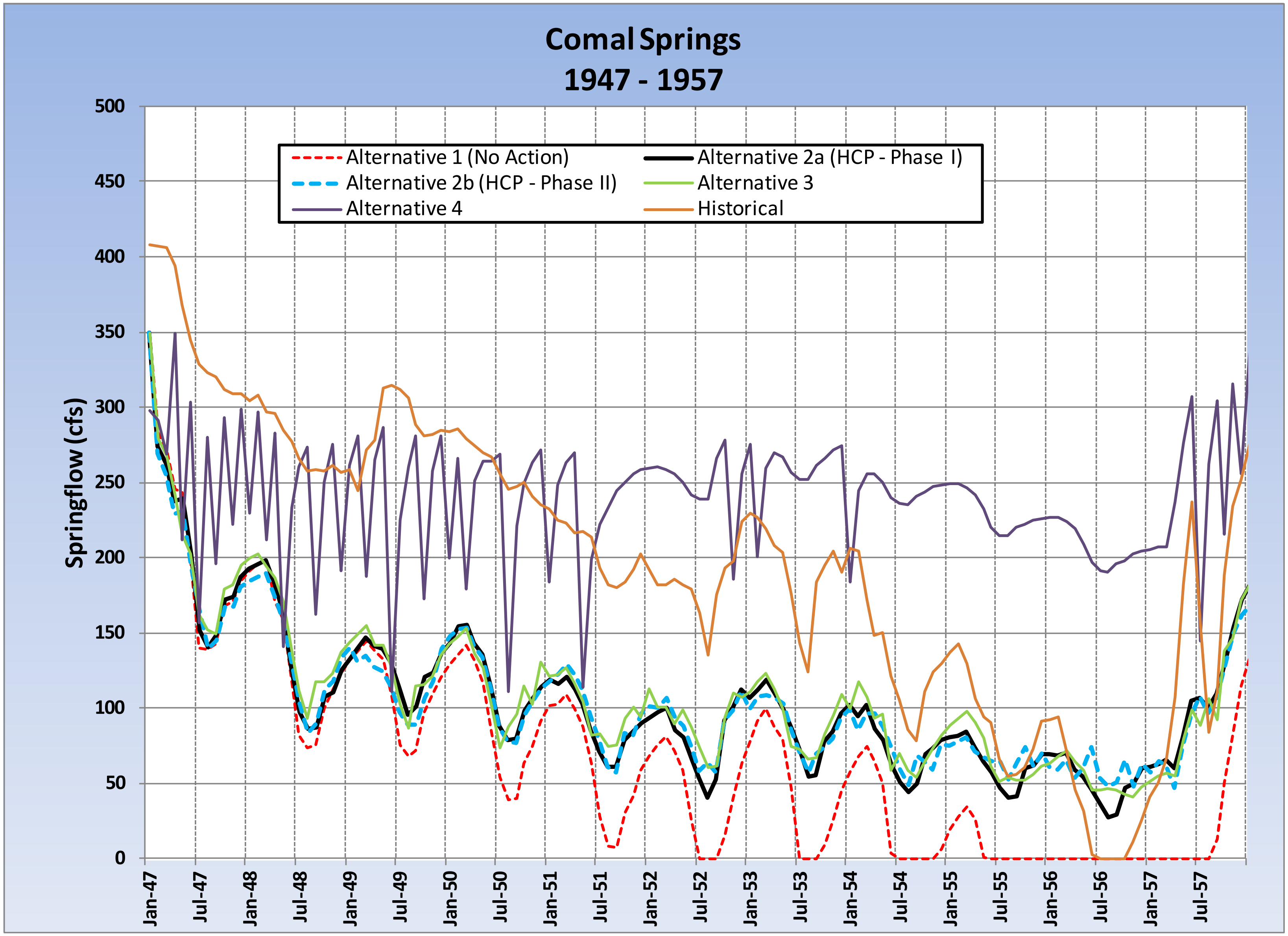


Figure 4-2. Modeled Comal Springs Total Springflow for Alternatives 1, 2a, 2b, 3, and 4 for the 1947–1957 Model Period.

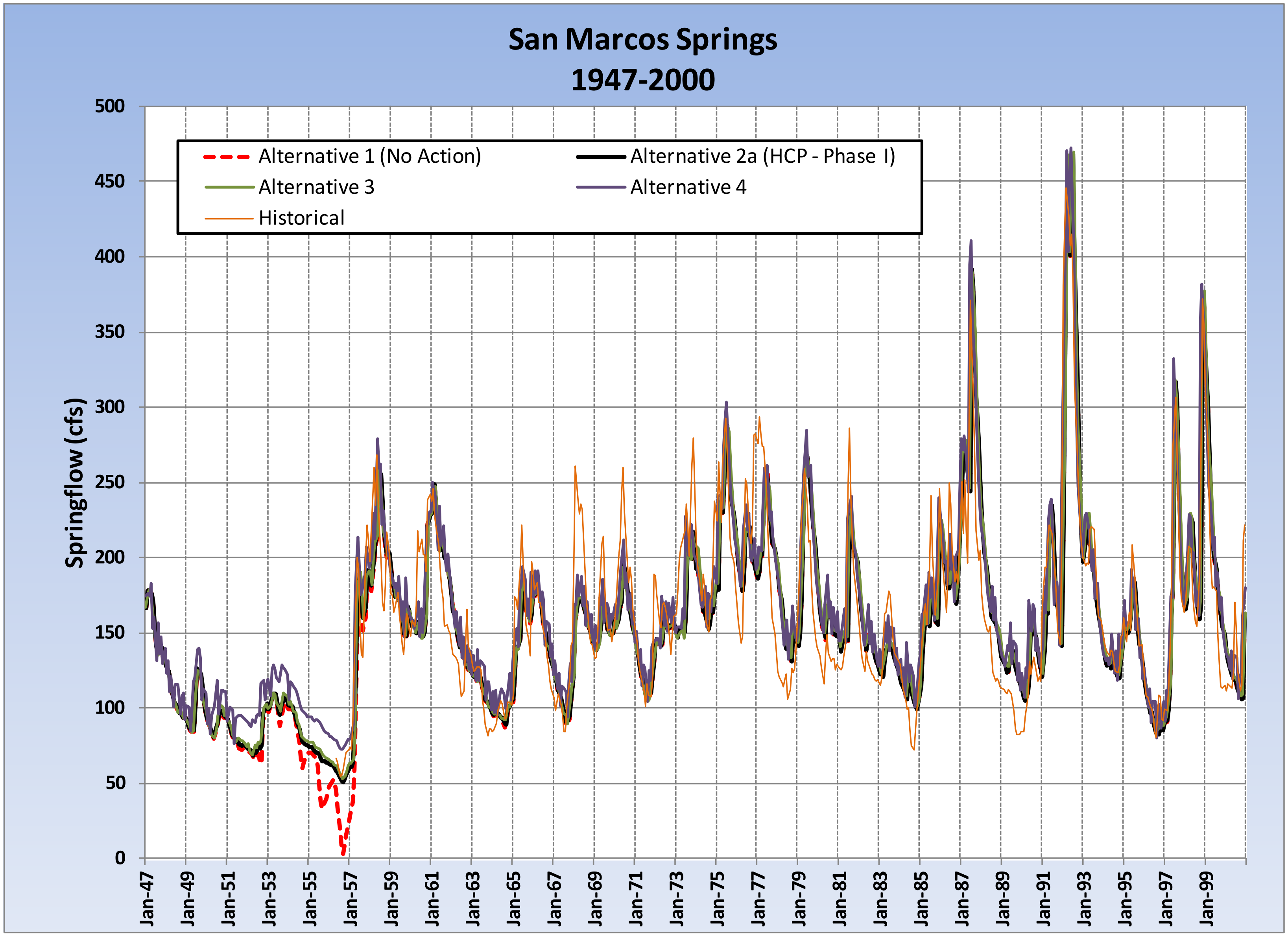


Figure 4-3. Modeled San Marcos Total Springflow for Alternatives 1, 2a, 3, and 4 for the 1947–2000 Model Period.

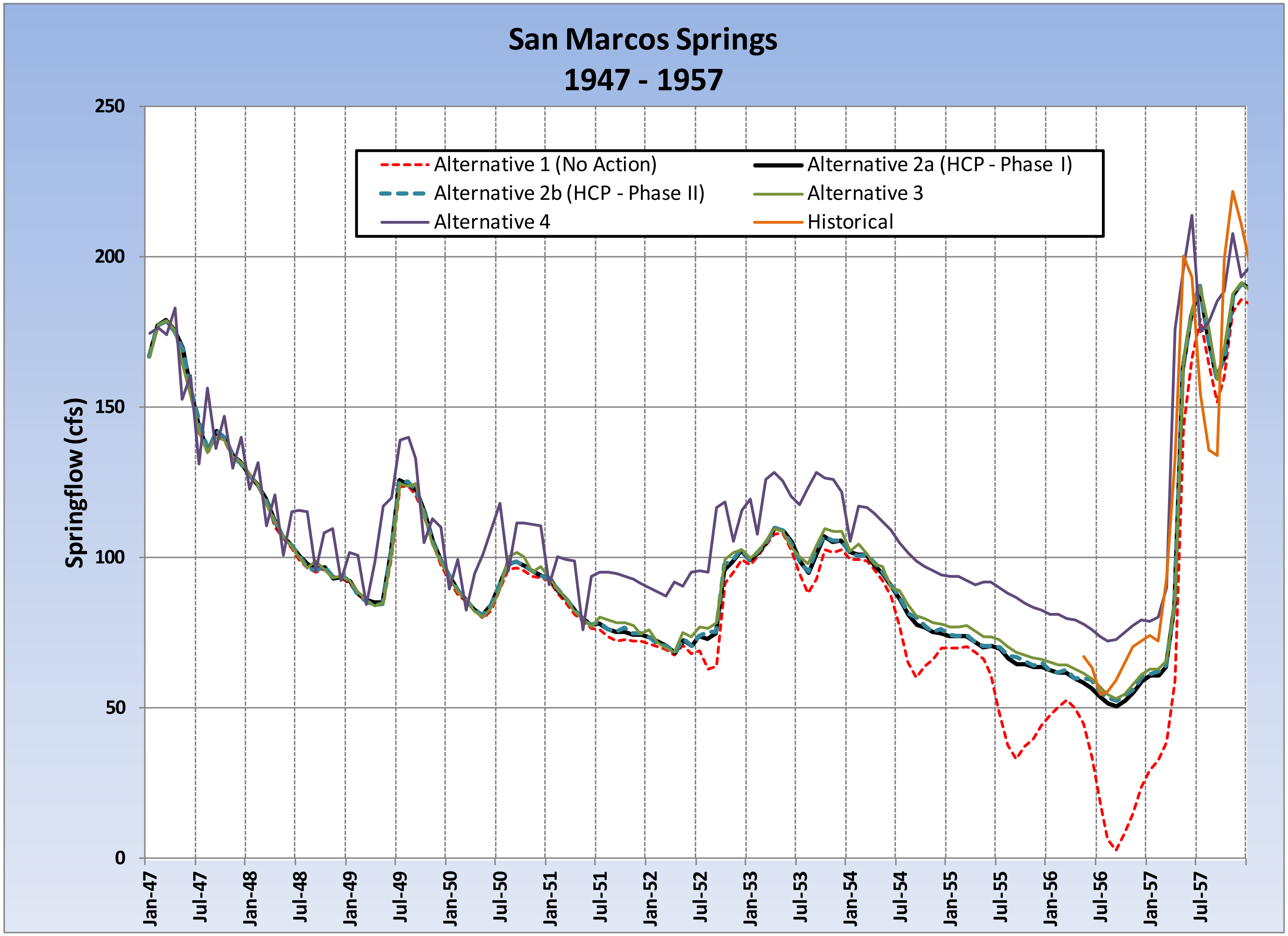


Figure 4-4. **Modeled San Marcos Total Springflow for Alternatives 1, 2a, 2b, 3, and 4 for the 1947–1957 Model Period. Historical Record Starts in Summer 1956 following Gauge Installation.**

Table 4-1. Comal Springs Total Discharge Statistics for Alternatives 1, 2a, 2b, 3, and 4 along with the Historically Observed Discharge from 1947–2000.

SPRINGFLOW STATISTICS (Evaluated for 1947–2000)		ALTERNATIVE					HISTORICAL
		1: No Action	2: Proposed EARIP HCP		3: Expanded ASR with Associated Infrastructure	4: Highest CPM Pumping Restriction	
			(a) Phase I	(b) Phase II			
Minimum Monthly (cfs)		0	27	47	40	109	0
Minimum Rolling 6-Month Average (cfs)		0	39	54	44	196	2
Long-Term Average (cfs)		178	196	196	198	278	274
Number of Months Below	150 cfs	221	185	185	186	17	69
	120 cfs	157	127	125	123	5	51
	80 cfs	99	53	53	42	2	26
	45 cfs	62	7	0	2	0	12
	30 cfs	54	2	0	0	0	7
	0 cfs	38	0	0	0	0	4
Largest Consecutive Number of Days Below (Approximated for Modeled Monthly Flows)	150 cfs	3,510	2,760	2,760	2,775	30	1,063
	120 cfs	2,790	2,370	2,340	1,635	30	750
	80 cfs	1,650	780	795	765	0	384
	45 cfs	1,230	150	30	90	0	265
	30 cfs	930	75	0	15	0	213
	10 cfs	870	0	0	0	0	164
	0 cfs	855	0	0	0	0	144

4.2.1.1 Alternative 1: No Action

Alternative 1 describes current management strategies that rely on restricting Edwards Aquifer withdrawals through step wise CPM reductions, and forms the baseline against which other alternatives can be measured. Alternative 1 represents current conditions and is not expected to have any direct or indirect effects to springflow at Comal or San Marcos Springs during normal precipitation and recharge conditions.

Springflow simulations over the period of record, however, indicate that flows at Comal Springs would cease to flow for a total of 38 months under the actions proposed under Alternative 1. The historic record documents that Comal Springs stopped flowing for 144 days (or 4.8 months) during the DOR in 1956. The long-term average of simulated springflows under Alternative 1 management totals 178 cfs, which is significantly lower than the historic average of 274 cfs (Figures 4-1 and 4-2 and Table 4-1).

Table 4-2. San Marcos Springs Total Discharge Statistics for the Modeled Alternatives 1, 2a, 2b, 3 and 4 along with the Historically Observed Discharge from 1947–2000.

SPRINGFLOW STATISTICS (Evaluated for 1947–2000)		ALTERNATIVE					HISTORICAL[a]
		1: No Action	2: Proposed EARIP HCP		3: Expanded ASR with Associated Infrastructure	4: Highest CPM Pumping Restriction	
			(a) Phase I	(b) Phase II			
Minimum Monthly (cfs)		2	51	52	53	72	54
Minimum Rolling 6-Month Average (cfs)		12	53	55	56	75	60
Long-Term Average (cfs)		153	155	155	156	164	168
Number of Months Below	100 cfs	121	114	114	106	68	-
	80 cfs	52	48	47	46	12	-
	50 cfs	19	0	0	0	0	-
	30 cfs	7	0	0	0	0	-
	10 cfs	3	0	0	0	0	-
Largest Consecutive Number of Days Below (Approximated for Modeled Monthly Flows)	100 cfs	1,215	1,125	1,125	1,125	945	-
	80 cfs	1,020	960	945	930	330	-
	50 cfs	375	30	15	15	0	-
	30 cfs	240	0	0	0	0	-
	10 cfs	120	0	0	0	0	-
	0 cfs	30	0	0	0	0	-

[a] Cells with dashes were not given values because there was no equal comparison to calculate the number of months below or longest consecutive days for the observed springflows as the gauge was not active until May 1956 when the greatest number of months below and longest consecutive days for all modeled runs occurs from 1954 through 1956.

Springflow simulations over the period of record indicate that actions under this alternative would yield minimum flows of 2 cfs for 1 month at San Marcos Springs. This is significantly lower than the estimated 54 cfs minimum springflow at San Marcos Springs during the DOR. Note that because the San Marcos River flow gauge was installed in 1956, flows prior to this date represent modeled results. Long-term Alternative 1 springflow simulated over the period of record averages 153 cfs, which is somewhat lower than the recorded average for this period of 168 cfs (Figures 4-3 and 4-4 and Table 4-2).

4.2.1.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Simulated springflow at Comal Springs over the period of record under Alternative 2 actions result in a minimum average springflow of 27 cfs for 1 month under Phase 1 actions and 47 cfs under Phase 2. The long-term springflow average over the simulated period at Comal Springs under both Phases 1 and 2 is 196 cfs, compared to the historic average of 274 cfs (Figures 4-1 and 4-2 and Table 4-1).

At San Marcos Springs, Alternative 2 generates a simulated minimum monthly average springflow of 51 cfs and 52 cfs under Phase 1 and Phase 2 actions, respectively. The minimum monthly average during the DOR was modeled to be 54 cfs. The Alternative 2 long-term average springflow under both Phases 1 and 2 totals 155 cfs, compared to the historical average of 168 cfs (Figures 4-3 and 4-4 and Table 4-2).

Simulated springflow increases over the period of record are the combined result of the multiple elements of the Alternative 2 measures such as the VISPO, the contributions of municipalities and industries participating in the RWCP, the effects of the management of the SAWS ASR, and the addition of Stage V CPM pumping cutbacks. Note that under this alternative up to 50,000 ac-ft currently pumped for agriculture and irrigation purposes will be leased or purchased for use in maintaining water volumes in the SAWS ASR facility for use as needed. This could have the effect of shifting the location (from various irrigated landscapes to SAWS pumping facilities) and the timing (from planting and growing seasons for agricultural production to an as needed basis to maintain ASR volumes) of this pumping. Fewer months of reduced springflows are simulated during mild drought conditions under Alternative 2 actions when compared to Alternative 1. This is apparent, for example, in the simulated number of months with springflows below 150 cfs at Comal Springs (185) when compared to the simulated number of months below this flow rate for Alternative 1 (221 months). Because most drought events in the study area are short in duration and intensity (see Section 3.1.1.2), maintaining flows at or above 150 cfs for an additional 36 months represents a significant decrease in exposure to drought effects over current management practices (Alternative 1).

4.2.1.3 Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 measures simulated over the period of record maintain minimum monthly springflows of 40 cfs at Comal Springs. The simulated Alternative 3 long-term average is 198 cfs, compared to the historic 274 cfs (Figures 4-1 and 4-2 and Table 4-1).

Simulated springflows associated with Alternative 3 actions at San Marcos Springs generate minimum monthly springflow of 53 cfs, which is comparable to the modeled minimum of 54 cfs during the DOR. The long-term simulated average under this alternative would be 156 cfs at San Marcos Springs, as opposed to the historic average of 168 cfs (Figures 4-3 and 4-4 and Table 4-2).

Effects at Comal or San Marcos Springs under Alternative 3 during normal precipitation and recharge conditions could be similar to those expected under Alternative 2. Though this option lacks the VISPO described above, more stringent CPM pumping restrictions limiting Edwards Aquifer withdrawals to 286,000 ac-ft/yr coupled with expanded use of ASR facilities (including up to 66,000 ac-ft of Aquifer pumping for ASR maintenance) are simulated to generate very similar reductions in the number of months at lowered flows over the period of record at both Comal and San Marcos as Alternative 2.

4.2.1.4 Alternative 4: Highest CPM Pumping Restriction

Springflow simulations over the period of record show that Comal Springs would maintain minimum monthly springflows of 109 cfs under Alternative 4 actions. The simulated long-term flows at Comal Springs would exceed the historic average of 274 cfs to achieve an average of 278 cfs (Figures 4-1 and 4-2 and Table 4-1).

Alternative 4 activities generate simulated minimum springflows of 72 cfs which exceed the modeled DOR minimum of 54 cfs at San Marcos Springs. Simulated long-term average flows of 164 cfs are similar to historic 168 cfs totals (Figures 4-3 and 4-4 and Table 4-2).

Simulated springflows over the period of record under Alternative 4 actions would exceed those of the other alternatives under most conditions at both Comal and San Marcos Springs.

4.2.2 Surface Water Quantity

State law in Texas does not recognize any relationship between groundwater and surface water, and assigns ownership and regulatory authority over the resource based solely on where water is located at a particular time (i.e., water is considered a property right managed under statues and regulations pertaining to groundwater such as the EAA Act when below the surface, and belonging to the citizens of the state and managed under separate and distinct statutes and regulations such as those promulgated by the TCEQ when on the surface).

The Applicants do not control and have no responsibility for water once it is discharged from the Edwards Aquifer though the various springs and becomes surface water beyond the responsibilities and jurisdictions associated with each Applicant and whatever the rights they may have to divert or use such surface waters granted by the State of Texas thorough the TCEQ. Surface water generated by springflows affected by the actions of the Applicants that flow into the Comal, San Marcos and then into the Guadalupe Rivers may be available for downstream uses or diverted in accordance with applicable statutes or regulations.

For the purposes of this analysis, the effects to surface water quantity are therefore limited to a discussion of the volumes of water expected to result from the actions associated with the proposed alternatives.

The following discussion focuses on the effects of proposed alternatives on the Comal, San Marcos, and Guadalupe Rivers. The Comal and San Marcos Rivers originate with the springflows at Comal and San Marcos Springs. Both the Comal and San Marcos Rivers flow into the Guadalupe River, which is a source of freshwater inflows into the Guadalupe Estuary (see Section 3.2.1.1). Tables 4-1 and 4-2 quantify the number of months for which the Comal and San Marcos Springs, respectively, remain below various flows with correspondingly limited inflows to the Comal and San Marcos Rivers when simulated over the period of record for each of the alternatives.

Though portions of the Nueces and San Antonio River basins are found within the study area, only the Comal, San Marcos, and the Guadalupe River are directly influenced by flows at Comal and San Marcos Springs. While some effect to the Nueces and San Antonio Rivers could be associated with the considered alternatives, no effects were simulated and no data has been identified to quantify or qualify the results of implementing any of the alternative actions on these systems.

4.2.2.1 Alternative 1: No Action

Alternative 1 represents the current regulations and management directed under SB 3 and EAA CPM regulations. The current quantity of surface water in the Comal, San Marcos, and Guadalupe Rivers, therefore, constitute the baseline against which the remaining alternatives are compared.

As described in Section 4.2.1.1, simulated springflows over the period of record indicate that flows cease at Comal Springs for approximately 38 months and flows at San Marcos Springs drop to near zero under this alternative. Loss of these springflows would reduce surface water quantity within the Comal and San Marcos Rivers and therefore reduce the quantity available to flow into the Guadalupe River during these conditions.

4.2.2.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

The simulated springflows resulting from Alternative 2 activities over the period of record at both Comal and San Marcos Springs result in increased water volumes in the Comal and San Marcos Rivers and could therefore result in greater inflows into the Guadalupe River. These simulated springflows and resulting increased surface water quantities exceed those simulated over the period of record under Alternative 1.

4.2.2.3 Alternative 3: Expanded ASR with Associated Infrastructure

Simulated springflows over the period of record when managed according to actions considered under Alternative 3 show increased flows, and therefore increased surface water volumes over Alternative 1 activities especially during low flow conditions, and are described in Tables 4-1 and 4-2 for Comal and San Marcos Springs, respectively.

Simulated springflows under this alternative are generally similar to those described under Alternative 2. These springflows could therefore be anticipated to result in comparable increases to Comal, San Marcos, and Guadalupe River surface water volumes.

4.2.2.4 Alternative 4: Highest CPM Pumping Restriction

Springflow simulations of Alternative 4 actions find the highest springflows of the alternatives considered over the period of record. The resulting surface water quantities in the Comal, San

Marcos, and Guadalupe Rivers would also be expected to be higher than any other alternative. The single stage CPM pumping restriction contemplated under this alternative results in the greatest fluctuation in springflows and therefore in surface water volumes. This is apparent in the illustration representing simulated results presented in Figures 4-1, 4-2, 4-3, and 4-4. The relatively dramatic 85 percent pumping restriction generates a rapid change in springflows when simulated over the period of record, and could be expected to result in similarly rapid springflow and surface water quantity fluctuations if implemented.

4.2.3 Surface Water Quality

Many water quality parameters such as temperature and dissolved oxygen are directly related to springflows in the study area. Water temperatures at Comal and San Marcos Springs are relatively constant and typically increase with distance downstream during warm spring and summer conditions. The warming of surface waters is most pronounced when water volumes and resulting flow rates are low. Dissolved oxygen is directly and inversely correlated with water temperature, and is therefore also related to flow volumes within the river systems. Other concerns such as TDS, chemical contaminants, or bacterial levels may have negative water quality effects at elevated concentrations. Actions associated with the alternatives that directly or indirectly affect springflows influence surface water volumes and may therefore also affect water quality.

Though portions of the Nueces and San Antonio River basins are found within the study area, only the Comal, San Marcos, and the Guadalupe River are directly influenced by flows at Comal and San Marcos Springs, and therefore most likely to be impacted by the considered alternatives. While some effect to the Nueces and San Antonio Rivers could be associated with the considered alternatives, no effects were simulated and no data has been identified to quantify or qualify the results of implementing any of the alternative actions on these systems.

4.2.3.1 Alternative 1: No Action

Reduced springflows resulting from Alternative 1 actions could impact water quality in the Comal and San Marcos Rivers. Simulated springflows over the period of record reflecting management according to the actions considered in this alternative show a total of 38 months with no flow at Comal Springs and 3 months with flows below 10 cfs at San Marcos Springs. These conditions could be expected to result in negative effects to surface water quality measures such as increased water temperature and decreased dissolved oxygen. Other water quality concerns such as contaminant concentrations and bacterial levels could increase under these conditions as springflows and resulting surface water quantities decline. Tables 4-1 and 4-2 provide simulated springflows for Comal and San Marcos Springs, respectively, over the period of record when managed in accordance with the actions considered under each alternative.

4.2.3.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Various measures proposed under Alternative 2 could impact surface water quality. These include actions such as efforts to prohibit transport of hazardous materials over the Comal and

San Marcos Rivers and their tributaries; management of household hazardous wastes; a septic system registration and permitting program; impervious cover and water quality protection measures; and efforts to reduce contaminated runoff (Table 2-2). The goal of these efforts is to reduce or eliminate both point and non-point source contaminants or minimize the risks they may pose to the Edwards Aquifer, thereby maintaining, improving, or protecting resulting surface water quality. Other measures proposed under this alternative such as sediment management and control efforts within the San Marcos River and Comal and San Marcos River riparian area restoration efforts are more directly associated with improving or maintaining surface water quality.

Alternative 2 also includes measures such as the VISPO, the RWCP, and management of the SAWS ASR intended to maintain springflows at Comal and San Marcos Springs. Over the 53-year period including the DOR over which springflows were simulated, Alternative 2 activities maintained greater springflows at these locations at all times over those simulated under Alternative 1 activities. The resulting surface water flows would be therefore expected to maintain or improve water quality in the Comal, San Marcos, and Guadalupe Rivers over the baseline condition represented by Alternative 1. Measures such as water temperature and dissolved oxygen would be affected by the relative flow volumes emerging at the springs, and other factors such as contaminant and bacterial concentrations could be diluted by the increased water volumes expected under this alternative when compared to Alternative 1.

4.2.3.3 Alternative 3: Expanded ASR with Associated Infrastructure

Activities and measures that may affect surface water quantity under Alternative 3 are generally similar to those described for Alternative 2; though this alternative does not include the RWCP and VISPO components. During drought conditions, Alternative 3 employs CPM pumping limits and expanded use of the ASR facility to provide increased water volumes at the springs (Table 2-2). Though simulated springflow quantities over the period of record are similar for these alternatives, Alternative 3 relies on storage of Edwards Aquifer water pumped during normal or above average precipitation conditions in an ASR facility until needed during drought conditions. This water will be pumped through a transmission pipeline to recharge facilities in Comal County sited to allow rapid infiltration into the Edwards Aquifer to supplement springflows at Comal and San Marcos Springs.

Though the source waters under this option would be from the Edwards Aquifer, the storage over time may result in changes to biological or chemical composition of water intended to supplement springflows. There is no available data to determine how storage in such a facility may affect the biological or chemical composition that contribute to Edwards Aquifer water quality.

4.2.3.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 does not incorporate the water quality monitoring or additional enhancement or protection measures proposed in Alternatives 2 and 3. This alternative would be expected to have little effect on surface water quality in the Comal, San Marcos, or Guadalupe Rivers during normal rainfall and recharge conditions. This alternative could be expected to result in water quality conditions similar to those anticipated under Alternative 1.

The CPM pumping limits under Alternative 4 simulated over the 53-year period of record show that springflows are maintained at both Comal and San Marcos Springs at all times. For water quality measures related to water quantity, this alternative would be expected to generate the greatest benefits of the alternatives considered.

4.2.4 Nationwide Rivers Inventory

None of the alternatives is expected to produce appreciable effects to river or stream segments within the study area identified as "outstandingly remarkable" in the NRI.

4.2.5 Groundwater

4.2.5.1 Groundwater Quality

Some variability in groundwater quality has been associated with fluctuations in Edwards Aquifer water level. Testing has documented these changes on the saline side of the BWL and within the transition zone between the fresh and saline portions of the Edwards Aquifer (see Section 3.2.2.10). No groundwater quality changes associated with Edwards Aquifer water level fluctuations have been detected in wells or springs within the freshwater zone (EAA 2010b). Researchers concluded that normal fluctuations in Edwards Aquifer water levels have little effect on water quality near the interface, and there is no indication that salinities at Comal or San Marcos Springs or in nearby wells changed during the DOR. Actions that influence pumping or enhance recharge could affect groundwater quality within the study area, but those changes are expected to be limited to impacts within the transition or saline zones of the Edwards Aquifer.

The southern section of the Edwards Aquifer, referred to as the "Edwards Underground Reservoir" by the USEPA, was designated a Sole Source Aquifer (SSA) by the Administrator of the USEPA under Section 1424(e) of the Safe Drinking Water Act on December 16, 1975 (40 FR 58344). The purpose of the SSA designation is to prevent federal funding of projects that might contaminate an aquifer that provides the sole or principal drinking water source for an area. The USEPA may review projects seeking or utilizing federal funds within designated project review areas and work with project proponents to identify and modify projects that might result in aquifer contamination. None of the proposed alternatives is anticipated to have any effect on the SSA status of the Edwards Aquifer.

Alternative 1: No Action

Actions considered under Alternative 1 are limited to the CPM pumping limitations and Edwards Aquifer management strategies currently in place. Water quality protection regulations throughout the region, such as those implemented by the TCEQ pertaining to construction related activities in the recharge and transition zones (often referred to as the "Subchapter A rules") and regulated activities in the contributing zone ("Subchapter B rules"); by the EAA (EAA Rules Subchapters B through G); and by municipalities throughout the region are presumed to remain in place over the period being considered.

Alternative 1 describes the conditions as they exist today, and represents the groundwater quality against which the other alternatives are compared. No changes within the freshwater zone of the Edwards Aquifer are expected under this alternative. No changes in water quality in the freshwater zone of the Edwards Aquifer as defined by the USEPA's national safe drinking water standards or the TCEQ's primary or secondary drinking water standards are expected to result from these actions. Water quality within the transition and saline zones could be affected during drought conditions as dissolved solid concentrations increase within the reduced volumes of water (see Section 3.2.2.10).

Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 incorporates water quality protection measures such as household hazardous materials management, impervious cover and low impact development provisions, prohibitions against transporting hazardous materials across the Comal and San Marcos Rivers and their tributaries, and a septic system registration and permitting program in San Marcos that may indirectly affect groundwater quality by improving the quality of surface waters that recharge the Edwards Aquifer. Alternative 2 would otherwise be expected to have similar groundwater quality effects as Alternative 1.

Alternative 3: Expanded ASR with Associated Infrastructure

Effects of this alternative on groundwater quality within the freshwater zone of the Edwards Aquifer are expected to be similar to Alternative 2. The greater pumping withdrawal limitations under this alternative could maintain higher aquifer levels that reduce dissolved solid concentrations within the transition and saline zones of the Edwards Aquifer.

Alternative 4: Highest CPM Pumping Restriction

The significantly restricted pumping permitted under Alternative 4 could be expected to maintain the highest water levels within the Edwards Aquifer. This may minimize water quality fluctuations by diluting dissolved solids within the transition and saline zones of the Edwards Aquifer to a greater degree than any of the considered alternatives. Note that this alternative does not incorporate the groundwater protection measures found in Alternatives 2 and 3, and would not therefore provide the associated beneficial effects to surface waters that recharge the Edwards Aquifer.

4.3 BIOLOGICAL RESOURCES

This section compares the direct and indirect effects of the alternatives on biological resources including candidate, threatened, and endangered species within the study area. Most of the species with regulatory status that may be affected by one or more of the considered alternatives are associated with the aquatic ecosystems at Comal and San Marcos Springs or in associated river segments. Species that may be affected are briefly described below with the alternatives expected to result in effects.

The golden orb (*Quadrula aurea*), a freshwater mussel, was historically known to exist in the Nueces River basin. No determination of the actions of various alternatives on Nueces River flows have been completed and it is not possible therefore to determine the potential effects of the alternatives on golden orb populations that may continue to exist in this river basin.

4.3.1 Alternative 1: No Action

4.3.1.1 Comal Springs, Landa Lake, and the Comal River

From the headwater springs flowing into Landa Lake to its confluence with the Guadalupe River, the Comal River provides habitat for a number of threatened or endangered species (see Section 3.3.1.2). Many of these species are adapted to uniform water quality conditions and variable flow regimes. As described previously, water quality parameters such as temperature and dissolved oxygen remain relatively constant throughout the year near the springs. Average flows are punctuated by high flows due to flooding events and low flows from naturally occurring drought conditions. These fluctuations may be seasonal and somewhat moderate in scope or may result from infrequent but more severe events such as tropical storm-related flooding events. Short-term flow variability, such as conditions that would be experienced over a monthly time step, would not be expected to result in adverse effects because variations at this scale are typical of the systems to which these species are adapted. Long-term deviations from historical flows could affect aquatic communities, including species abundance and distribution.

During normal precipitation and recharge conditions, Alternative 1 actions would not be expected to adversely affect biological resources associated with Comal Springs, Landa Lake, or the Comal River. Simulated springflows over the period of record under Alternative 1 actions show that Comal Springs would cease to flow during severe drought periods. The modeled 38-month flow disruption simulated over the period of record could result in negative effects to biological resources and their habitats. Species with regulatory status (i.e., those considered candidate, threatened, or endangered species) that may be affected by this alternative are described briefly below.

Comal Springs Dryopid Beetle

The Comal Springs dryopid beetle is a subterranean-adapted aquatic species that was listed as endangered on December 18, 1997 (62 FR 66295–660304). Comal Springs dryopid beetles have been collected from Comal Spring runs 2, 3, and 4 on the Comal River and at Fern Bank Springs in Hays County (see Figure 3-18) (Barr and Spangler 1992). In 2007, the Service designated critical habitat for this species including 31.8 acres (12.9 hectares) at Comal Springs and 1.4 acres (0.6 hectares) at Fern Bank Springs (Figure 3-18) (72 FR 39248–39283).

The species is translucent, slightly pigmented, has vestigial (non-functioning) eyes, and is about 0.125 inch (0.318 cm) long. This species is incapable of swimming and is believed to be restricted to headwaters of springs and spring runs. The Comal Springs dryopid beetle requires flowing, uncontaminated waters for survival (62 FR 66295–660304). The simulated cessation of flow at Comal Springs during a severe drought event under Alternative 1 could adversely affect Comal Springs dryopid beetles by removing the flowing waters needed for this species' survival (see Section 3.3.1.2).

Top photo courtesy of Randy Gibson; bottom photo courtesy of Texas A&M University.

Comal Springs Riffle Beetle

Photo courtesy of Texas A&M University.

The Comal Springs riffle beetle is a small surface-dwelling aquatic species that was listed as endangered on December 18, 1997 (FR 62 66295–660304). The species was first found at Comal Springs and was subsequently collected at San Marcos Springs and Spring Lake (Bosse et al. 1988, Gibson et al. 2008, Gonzales 2008). Critical habitat incorporating 19.8 acres (8.0 hectares) of the Comal Springs complex and 10.5 acres (4.2 hectares) of the San Marcos Springs complex (Figure 3-26a) were designated for the Comal Springs riffle beetle in 2007 (FR 72 39248–39283).

Comal Springs riffle beetles are flightless and entirely aquatic throughout their lives (FR 62:243). These beetles grow to about 0.125 inch (0.318 cm) and are believed to feed mainly on algae and detritus scraped from submerged weeds and rocks (Brown 1987). Comal Springs riffle beetles are found in the flowing waters of spring runs and submerged upwelling areas (BIO-WEST 2002). This species respires by means of a plastron that requires high quality flowing water with dissolved oxygen levels between 4.0 and 10.0 mg/L. The reduction of water flows or drying of the spring runs as simulated during the DOR period under this alternative could adversely impact the species by affecting the species ability to respire (62 FR 66295–660304).

Edwards Aquifer Diving Beetle

The Edwards Aquifer diving beetle, also known as Texas cave diving beetle, is a small (less than 0.5 inch [1.3 cm]), elongate, oval-shaped and somewhat flattened beetle restricted to the subterranean waters of the Edwards Aquifer in Hays and Comal counties (USFWS 2009). Edwards Aquifer diving beetles have been collected from Comal Springs and from an artesian well in Hays County (Bowles and Stanford 1997, Gibson et al. 2008). This diving beetle is the first blind, de-pigmented (characteristic of subterranean dwelling species), aquifer-adapted water beetle known from North America. They have reduced nonfunctional eyes and well developed sensory setae (hairs) on their wings, legs, and mouth (Young and Longley 1975).

The Service was petitioned to list the species as threatened or endangered, and determined that substantial information was presented in the petition that listing may be warranted. The petition stated that the present or threatened destruction, modification, or curtailment of the species' habitat or range resulting from water drawdown and loss of water quality due to development may imperil the species (USFWS 2009). Water drawdowns resulting during the DOR period when Alternative 1 activities are simulated over the period of record could affect this species by negatively impacting required habitat elements.

Peck's Cave Amphipod

Photo courtesy of Texas A&M University.

Peck's Cave amphipod is an aquatic crustacean that lacks eyes and pigment, indicating that this species subterranean habitat is in permanent darkness. The species was listed as endangered on December 18, 1997 (62 FR 66295–660304). This species was first collected at Comal Springs in 1964 (62 FR 66295–660304). Most specimens collected were netted from gravel substrates near Spring Runs 1, 2, and 3 inflows to Landa Lake in the Comal Springs system (Arsuffi 1993, Barr 1993). This species has subsequently been collected at Comal Springs, Landa Lake, Panther Canyon Well, and Hueco Springs (Krejca 2005, Gibson et al. 2008). Despite extensive collection efforts, none have been found outside the Edwards Aquifer (Barr 1993, 62 FR 66295–660304).

Comal Springs and associated portions of Landa Lake, and the Hueco Spring complex (Figure 3-18) have been designated critical habitat units for Peck's Cave amphipod. The species requires unpolluted, high quality water, water temperatures between 68 and 75° F (20 and 24° C), adequate dissolved oxygen levels and food supplies, and gravel or cobble substrates ranging in size between 0.3–5.0 inches (0.8–12.7 cm). Cessation of flow during severe drought conditions as simulated over the period of record could negatively affect Peck's Cave amphipod under Alternative 1 actions.

Comal Springs Salamander

A population of salamanders found at Comal Springs has been described in a federal listing petition as *Eurycea* sp. 8 (USFWS 2009). The salamanders are commonly referred to as Comal Springs salamanders, though the taxonomy of the species is not yet clear and the species has yet to be officially recognized or named. The morphology and genetics of this species are very similar to the Texas blind salamander, and it has been suggested that these species be synonymized and the population at Comal springs be considered an extension of range (Bendik 2006). The Service determined that substantial information was presented in a petition to indicate that listing of this species may be warranted due to habitat loss or degradation resulting from factors including groundwater withdrawal and contamination (USFWS 2009). Alternative 1 may affect Comal Springs salamanders and their habitat if Comal Springs cease to flow as simulated during the DOR period of the studied timeframe.

Fountain Darter

Photo courtesy of Texas A&M University.

The fountain darter is endemic to the San Marcos and Comal Rivers. This species was first collected in the San Marcos River just below its confluence with the Blanco River in 1884 and in the Comal River in 1891 (Schenck and Whiteside 1976). The fountain darter was listed as endangered on October 13, 1970 (35 FR 16047–16048). The historic range of this species in 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 (Schenck and Whiteside 1976, McKinney and Sharp 1995). Designated critical habitat for the fountain darter includes Spring Lake and the San Marcos River downstream to 0.5 mi (0.8 km) below the IH-35 bridge (see Figures 3-26a, b, and c) (USFWS 1996b).

Fountain darters are small (usually less than 1.0 inch [2.5 cm]), olive-green in color, with dark markings along the lateral line, and dark spots at the base of the tail, gill cover, dorsal fin, and around the eye (Gilbert 1887, Schenck and Whiteside 1976). Fountain darters require clear, clean, flowing, and thermally constant waters, adequate food supply, undisturbed sand and gravel substrates, rock outcrops, and areas of submerged aquatic vegetation for cover (Schenck and Whiteside 1977, McKinney and Sharp 1995, USFWS 1996b). Alternative 1 could negatively affect fountain darters during drought conditions as declining springflows simulated over the period of record result in decreasing wetted areas and therefore habitat, increased water temperatures, and declining dissolved oxygen levels.

The cessation of springflows for 144 days during the DOR may have resulted in the extirpation of the fountain darter in the Comal River. Simulated springflows over the period of record show a total of 38 months without measurable flows at Comal Springs under Alternative 1 actions. A repeat of similar precipitation and recharge conditions under this alternative could result in significant habitat loss and adverse impacts to fountain darter populations in the Comal River system.

4.3.1.2 San Marcos Springs, Spring Lake, and the San Marcos River

The surface-dwelling aquatic flora and fauna endemic to San Marcos Springs, Spring Lake, and San Marcos River are adapted to relatively constant water quality conditions marked by wide variations in flow rates similar to those in the Comal River system (see Section 3.3.1.3).

During periods of average rainfall and subsequent recharge, Alternative 1 would be expected to have negligible or minor direct and indirect effects to listed species and the habitats that support them in the San Marcos River system. During severe drought periods, negative effects could occur and would be expected to increase as stream flows needed to sustain downstream pool, riffle, and run habitats decline. Springflow simulations of the DOR period resulted in flows that could affect the abundance, quality, and distribution of aquatic habitats and the species that depend on them.

Texas Wild-Rice

Texas wild-rice is an aquatic perennial grass endemic to the San Marcos River where it is found submerged in shallow swift moving water. During times of low flow, the upper portions of the culms (stems) and leaves become emergent (Terrell et al. 1978, USFWS 1996a). The leaves are linear, up to 3.3 feet (1.0 m) long and 0.5 inch (1.3 cm) wide (Terrell et al. 1978). Flowering typically occurs in the spring and fall but may be seen throughout the year. Texas wild-rice requires thermally constant temperatures, clear water, undisturbed stream bottom habitat, protection from floods, and protection allowing inflorescence (flower production) during reproduction (McKinney and Sharp 1995).

Photos courtesy of Texas A&M University.

When Texas wild-rice was first described in 1933, it was considered abundant in the San Marcos River, Spring Lake, and irrigation ditches associated with these water bodies (Terrell et al. 1978, Silveus 1933). Within 34 years, its abundance had been significantly reduced. In 1967 only one plant was found in Spring Lake and none were found in the uppermost 0.5 mi (0.8 km) of the San Marcos River. Scattered individual plants were found in the next 1.5 downstream river miles (2.4 km) and none others were found downstream (Emery 1967). Texas wild-rice was listed as an endangered species in 1978, and critical habitat for the species was designated as Spring Lake and its outflow, and the San Marcos River downstream to its confluence with the Blanco River (USFWS 1996a) (see Figures 3-26a, b, and c). After listing, declines in areal coverage of Texas wild-rice continued until a total of just 4,881 ft^2 (453 m^2) remained (Vaughan 1986). Texas wild-rice has increased coverage within the last several decades, and is now found in Spring Lake and in the upper reaches of the San Marcos River.

Environmental disturbances and diminished springflow are considered the primary threats to this plant (USFWS 1996a). Texas wild-rice can be damaged by effects from recreational use of the river, floating debris, shade that reduces photosynthesis and interference with pollination and seed maturation (Beaty 1975, Poole 1990). Competition with non-native aquatic plants and herbivory by non-native plant-eaters including snails, waterfowl, and mammals are believed to reduce the size and vigor of Texas wild-rice stands (McKinney and Sharp 1995). Other threats include water quality degradation, chemical spills, siltation, waterborne contaminants, and genetic erosion of the population (Poole 1990, BMWD 1999).

Alternative 1 could affect Texas wild-rice by diminishing springflows during drought conditions such as those simulated when these actions were modeled over the period of record. Texas wild-rice could also experience effects resulting from habitat loss and increased exposure to recreational impacts in the San Marcos River during periods of reduced springflows (see Section 3.3.1.3).

False Spike

The false spike (*Quincuncina mitchelli*) is a freshwater mussel about 5 inches (13 cm) long with an oval to round light to dark brown or black shell. The Service was petitioned to list this species as threatened or endangered and a 90-day finding was published stating that substantial scientific or commercial information was provided indicating that listing may be warranted (74 FR 66260–66271). At this time the status of this species is currently under review. Little information is available about this species, but it is thought to inhabit medium to large rivers with substrates varying from mud to mixtures of sand, gravel and cobble. It historically occurred in the Brazos, Colorado, and Guadalupe river systems in central Texas and in the Rio Grande system in New Mexico, Texas, and Mexico (NatureServe 2009). The only known population exists in the lower San Marcos River (EARIP CSWG 2010).

Proposed actions contemplated under Alternative 1 are not expected to negatively impact freshwater mussel populations inhabiting the San Marcos River during normal rainfall and recharge conditions. It is reasonable to conclude, however, that decreasing springflows could affect freshwater mussels by degrading available habitat. Drought and flood events in the 1970s and 1980s have been implicated in reducing the abundance and distribution of other freshwater mussels known to occur in the study area (Howells 2010). Population level effects of low flows reportedly impacted Texas pimplebacks (*Quadrula petrina*) in the Concho River as the result of dewatering and increasing temperatures in 1997 and 1999–2000 (Howells 1998, 2000, 2006). Freshwater mussels exposed to similar low flow conditions could experience similar negative effects. Alternative 1 could therefore affect the false spike during drought conditions by negatively impacting habitats and affecting abundance and distribution.

Golden Orb

The golden orb is a freshwater mussel about 3 inches (8 cm) long with an orange, yellow, or yellowish brown rectangular or broadly elliptical shell with green rays. The Service was petitioned to list the golden orb as threatened or endangered and responded with a 90-day finding stating that substantial scientific or commercial information had been presented indicating that a listing action may be warranted (74 FR 66260–66271). The status of this species is currently under review. The habitat for this species is apparently restricted to flowing waters with sand, gravel, and cobble substrates at depths of a few centimeters to over 10 feet (3 m). This mussel appears intolerant of excess mud or silt and impoundment. The golden orb was historically known from the San Antonio, Guadalupe, Colorado, Brazos, Nueces, and Frio River systems (NatureServe 2009), and is currently known from the upper and central Guadalupe River, lower San Marcos River, and Lake Corpus Christi (EARIP CSWG 2010).

Much like the false spike, the golden orb could be negatively affected by low flow conditions during drought conditions associated with Alternative 1 CPM restrictions.

Texas Pimpleback

The Texas pimpleback is a freshwater mussel tan to brown in color with yellow and bright green markings. It occupies large and medium sized rivers with mud, gravel and sand substrates in areas with low flow (NatureServe 2009). A petition to list this species as threatened or endangered was received, and the Service published a 90-day finding stating that the petition presented substantial scientific or commercial information indicating that listing may be warranted (74 FR 66260–66271). The status of this species is currently under review. Although endemic to the Guadalupe and Colorado River systems, the current distribution is restricted to two tributaries of the Colorado River, the lower Concho River, Upper San Saba River, and the upper San Marcos River (EARIP CSWG 2010). The population in the San Marcos River could be impacted by Alternative 1 actions resulting in drought-related low flows.

Texas Troglobitic Water Slater

Texas troglobitic water slater is one of six described species in Texas within the genus *Lirceolus* (Krejca 2005). Several species in the genus are endemic to small areas and a regional HCP in Hays County recognizes the Texas troglobitic water slater as a species that could become listed as threatened or endangered in the future (Loomis Partners, Inc. et al. 2010). This species is known from two localities in Hays County, one site at San Marcos Springs (Diversion Springs) and the Artesian Well on the TSU campus near San Marcos Springs.

The Service determined that substantial information was presented in a petition to indicate that the listing of this species may be warranted due to the present or threatened destruction, modification, or curtailment of its habitat or range resulting from Edwards Aquifer drawdowns and decreasing water quality (USFWS 2009). Alternative 1 actions during droughts could contribute to Edwards Aquifer drawdowns that could negatively affect this species.

Comal Springs Riffle Beetle

The Comal Springs riffle beetle population found in San Marcos Springs and Spring Lake are not expected to be affected by Alternative 1 actions during normal precipitations patterns. There is no data on this species’ responses to DOR-like conditions, though the persistence of the Comal Springs riffle beetle at this location suggests that populations likely survived the DOR and might be able to survive a repeat of similar conditions.

Edwards Aquifer Diving Beetle

Edwards Aquifer diving beetles in the artesian well in Hays County could be impacted during drought conditions under Alternative 1. Water drawdowns resulting during the DOR period when Alternative 1 activities are simulated over the period of record could affect this species by negatively impacting required habitat elements.

San Marcos Salamander

Photo courtesy of U.S. Fish and Wildlife Service.

The San Marcos salamander was first collected from the San Marcos Springs and described in 1938. The species was listed as threatened on July 14, 1980 (45 FR 47355–47364). Critical habitat was designated for the San Marcos salamander at Spring Lake and its outflow and the San Marcos River downstream to 164 feet (50 m) below Spring Lake Dam (USFWS 1996a) (see Figure 3-26a). They are small (2.3 inches [5.8 centimeters]), 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). San Marcos salamanders are found in Spring Lake and downstream of the dam at Spring Lake (Tupa and Davis 1976, Nelson 1993).

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 69.8–71.6° F (21–22° C), an oxygen saturation of 40–50 percent, with little variation in bicarbonate alkalinity (220–232 mg/L) (Tupa and Davis 1976). They require clean, clear waters associated with springs in areas of sand, gravel, large rock, and vegetative cover at a depth of 3.3–6.6 feet (1.0–2.0 m) (Nelson 1993, USFWS 1996a). Low flow conditions simulated over the period of record under Alternative 1 actions could result in negative impacts to the species by impacting the species' need for flowing waters and consistent water quality.

Blanco Blind Salamander

The Blanco blind salamander (*Eurycea robusta*) is known from only four specimens observed in 1951, of which only one specimen was preserved. The species is believed to inhabit subterranean streams beneath the Blanco River in Hays County. The Blanco blind salamander is stout-bodied, about 4 inches (10 cm) long, and has thin, elongate limbs, reduced eyes, and a thick finned tail tapering at the tip. The Service found that substantial information was presented in a recent petition to indicate that listing this species may be warranted due to habitat loss or degradation resulting from numerous human factors including groundwater withdrawal and contamination (USFWS 2009). Though little is known about this species, the groundwater withdrawal contemplated under Alternative 1 actions may affect the Blanco blind salamander.

Texas Blind Salamander

Photo courtesy of U.S. Fish and Wildlife Service.

The first collections of Texas blind salamanders took place in 1895 as they were expelled from an artesian well at the Federal Fish Hatchery in San Marcos, Texas (Longley 1978). The species was listed as endangered on March 11, 1967 (32 FR 4001). The Texas blind salamander is a smooth, unpigmented troglobitic (cave-adapted) species, with a maximum length of 4.7 inches (11.9 cm). 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. The distribution of this species has been described as limited to the Edwards Aquifer beneath and near San Marcos (USFWS 1996a). Though little data is available to project the response of subterranean species such as the Texas blind salamander, declining Edwards Aquifer levels associated with simulated conditions might be expected to adversely affect subterranean aquatic habitats.

Fountain Darter

Fountain darters could be impacted in the San Marcos River during drought conditions under Alternative 1. Simulated springflows over the period of record show decreased flows that could result in decreased wetted areas and habitat, increased water temperatures, and declining dissolved oxygen levels that could negatively affect fountain darters.

San Marcos Gambusia

Photos courtesy of Bob Edwards.

The San Marcos gambusia is endemic in the San Marcos River, and was listed as endangered on March 19, 1980 (45 FR 17888–17891). Despite multiple efforts to locate pure San Marcos gambusia, the last known sighting from the San Marcos River occurred in 1983 (McKinney and Sharp 1995). San Marcos gambusia range in size from 1.0–1.5 inches (2.5–3.8 cm), and are usually plainly marked; though 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 San Marcos gambusia prefers 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 (Hubbs and Peden 1969, Edwards et al. 1980). Designated critical habitat includes the San Marcos River from the Highway 12 Bridge downstream to just below the IH-35 Bridge (USFWS 1996a) (see Figures 3-26a, b, and c). The described habitat requirement of thermally constant waters could be impacted during low flows resulting from Alternative 1 actions. This alternative might, therefore, be expected to affect this species during drought conditions.

4.3.1.3 The Guadalupe River and Estuarine Habitats

The assessment of impacts to biological resources beyond the jurisdictions of the Applicants is based on the water quality and quantity contributions resulting from actions under the alternative considered. Because actions affecting surface water quality or quantity beyond their individual jurisdictions are not within the control of the Applicants, they are not considered for the purposes of this analysis (i.e., actions such as surface water withdrawals under the regulatory authority of the TCEQ are not within the jurisdiction or control of the Applicants or reasonably foreseeable and are not considered here).

Whooping Crane

The whooping crane was listed as endangered in 1967 (32 FR 4001). The 263 individuals (as of 2010) that make up the last historical wild population nest in the wetlands of Wood Buffalo National Park in the Northwest Territories of northern Canada and winter on or near the study area at the Aransas National Wildlife Refuge and nearby estuaries of the Texas Gulf Coast.

Edwards Aquifer springflow originating at Comal and San Marcos springs comprise a proportion of the freshwater inflows to the Guadalupe River estuary during both normal and drought conditions (see Section 3.2.1.1); and a relationship has been hypothesized among freshwater inflows, estuary productivity, and wintering whooping cranes (72 FR 39247–39283, EARIP 2011).

The brackish tidal marshes of the Guadalupe River estuary provide wintering habitat and support the production of whooping crane food items. Studies suggest that Atlantic blue crabs (*Callinectes sapidus*) are the primary energy source for wintering whooping cranes and are a primary food item when abundant (Chavez-Ramirez 1996, Guillory and Elliot 2001, Stehn 2001). Various studies have considered the relative importance of alternative food items such as wolfberry fruit, clams, snails, and insects in the whooping crane diet (Chavez-Ramirez 1996, Slack et al. 2009).

During normal rainfall and recharge conditions Alternative 1 would not be expected to affect biological resources of the middle and lower Guadalupe River, the estuaries supported by the river's freshwater inflows, or whooping cranes that winter in the Guadalupe River estuary. Springflow simulations of Alternative 1 actions over the period of record show declining flows that could result in reduced freshwater inflows to the Guadalupe River and downstream to the Guadalupe River estuary during drought conditions. Elevated estuarine salinities such as those associated with low freshwater inflows have been hypothesized to expose whooping cranes to increased energy expenditures and predation risks as they travel greater distances to locate fresh water to drink (Stehn 2001). The reduction of freshwater inflows could impact salinities in the Guadalupe Estuary that might affect Atlantic blue crab availability, whooping crane energy expenditures, and predation risks.

4.3.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

A number of the proposed Alternative 2 measures are intended to improve habitat conditions for biological resources in the study area. Actions such as riparian restoration efforts, non-native plant and animal control, and sediment removal in the San Marcos River could be beneficial to aquatic and terrestrial species associated with the springs, rivers, and riparian zones of the Comal and San Marcos systems. This alternative incorporates adaptive management principals intended to improve the Applicants' understanding of and management responses to issues such as the effects of low flows on covered species and their habitat and the effectiveness of various non-native plant and animal management techniques. Additional testing of the accuracy and precision of the springflow simulation model and efforts to refine the utility of this tool to enhance springflow protection efforts are proposed to continue throughout the term of the proposed permit.

4.3.2.1 Comal Springs, Landa Lake, and the Comal River

Many of the actions proposed under Alternative 2 are expected to benefit the species of the Comal River system. Activities such as non-native aquatic plant and animal management, riparian habitat restoration efforts, and RWCP water demand reductions (see Section 2.1.6.1) could enhance or restore habitat quality and increase flows in the Comal River system regardless of rainfall or recharge conditions.

During drought conditions, Alternative 2 measures could be more protective of listed species and their habitats than actions considered under Alternative 1. Simulated springflows over the period of record employing the flow-related measures in Alternative 2 show continual Comal Springs flows during conditions that result in 38 months of springflow cessation under Alternative 1. Simulated long-term springflow over the period of record averages 196 cfs under this alternative compared to 178 cfs simulated under Alternative 1 (Table 4-1).

Comal Springs Dryopid Beetle

The Alternative 2 continual springflows at Comal Springs over the simulated period of record could provide the flowing waters required by the Comal Springs dryopid beetle. Alternative 2 therefore represents an improvement over the Alternative 1 actions which result in intermittent flows that could fail to provide the flowing water needed by this species.

This species also requires flowing water of high quality and free of contaminants. Alternative 2 incorporates a number of water quality protection measures including prohibiting transportation of hazardous materials across the Comal River and its tributaries, household hazardous waste programs, an IPM plan covering the city of New Braunfels golf course, expanded EAA water quality monitoring, creation of impervious cover goals and incentive-based impervious cover reduction programs on public and private property, and efforts to promote coal tar sealant bans. Implementation of these actions would reduce the threat of contamination or negative water quality effects that could harm the Comal Springs dryopid beetle.

Comal Springs Riffle Beetle

Alternative 2 incorporates riparian restoration efforts intended to benefit the Comal Springs riffle beetle by increasing available habitat areas and food sources. These actions include establishment of native woody riparian vegetation and removal of fine sediments covering spring areas and exposed root habitats.

Some spring outlets in the Comal system that provide habitat for this species begin to start losing wetted area, and therefore incur negative habitat effects, as springflows drop below 150 and 100 cfs (Hardy 2009). Some negative habitat effects could therefore occur at these spring outlets if springflows decline below this level. Simulations during the most severe period of the DOR under this alternative show springflows dropping below 30 cfs for a total of 75 days under Phase 1 actions. Though Comal Spring runs 2 and 3 would not flow, habitats associated with the western wall of Landa Lake and the upwelling areas near Spring Island will continue to flow under these conditions (Hardy et al. 2010). If the Phase 2 presumed actions are implemented, simulated springflows over the period of record drop below 45 cfs for a total of 30 days, and do not fall below 30 cfs. These outcomes represent an improvement over simulated Alternative 1 actions over the period of record that result in Comal Springflows of 1,230 days below 45 cfs, 930 days below 30 cfs, and 855 days of zero flow (see Table 4-1).

Edwards Aquifer Diving Beetle

The Edwards Aquifer diving beetle is a subterranean species believed to be threatened by water drawdowns. The continual Comal Springflows under Alternative 2 actions simulated over the period of record reduce the likelihood of such drawdowns and are therefore supportive of this species. The simulated springflows associated with Alternative 2 actions represent a reduction of this threat over the simulated springflow results of Alternative 1.

Peck's Cave Amphipod

Peck's Cave amphipod is also a subterranean species reliant on flowing high quality water of the Edwards Aquifer. Much like the Edwards Aquifer diving beetle, this species could benefit from the continual springflow conditions simulated to result from the actions under Alternative 2 over the period of record. These simulated springflows are an improvement over the simulated Alternative 1 springflow conditions during severe drought periods in the studied timeframe.

Comal Springs Salamander

Potential threats to the Comal Springs salamander include habitat loss or degradation resulting from factors including groundwater withdrawal and contamination (USFWS 2009). Alternative 2 actions including habitat restoration efforts and groundwater protection measures that minimize the threat of contamination could benefit this species. Alternative 2 actions such as the RWCP demand reduction program, management of the SAWS ASR facility to maintain springflow, and implementation of the VISPO during drought conditions yield simulated springflow increases that reduce the threat of groundwater withdrawal cited as a possible listing factor for this species. These threat reductions could benefit the Comal Springs salamander beyond the actions proposed under Alternative 1.

Fountain Darter

Alternative 2 proposals including habitat restoration efforts, a gill parasite monitoring and control program, and flow management between the new and old channels of the Comal River could benefit the fountain darter in the Comal system.

Fountain darter habitat includes vegetative cover that can be negatively impacted by non-native species including nutria, suckermouth catfishes, tilapia, and giant ramshorn snails. Non-native plant species within Landa Lake and the Comal River can compete with native vegetation that provides shelter and breeding substrates for fountain darters. Habitat management efforts in the Comal system include control of non-native plants and animals and restoration of submerged native vegetation to improve fountain darter habitat. Efforts to monitor and manage the parasitic gill trematode (*Centrocestus formosanus*) will focus on control of the non-native Malaysian livebearing snail (*Melanoides tuburculatus*) that serves as the parasite's first intermediate host while an AM Program seeks to identify the most effective means to manage this threat. The flow management plan in the new and old channels is intended to increase seasonal variability mimicking more natural flow patterns more supportive of native vegetation thereby improving fountain darter habitat within the Comal River.

The simulated springflows over the period of record show continual flows during periods when flows at Comal Springs cease under Alternative 1 actions. These simulated continual flows under Alternative 2 are therefore more supportive of fountain darter requirements than actions considered under Alternative 1. Simulated Alternative 2 springflows over the period of record maintain fountain darter habitat conditions in Landa Lake and in the Old Channel within water quality thresholds that could support seasonal reproduction of this species (Hardy et al. 2010).

4.3.2.2 San Marcos Springs, Spring Lake, and the San Marcos River

San Marcos Springs have never been known to stop flowing, though the conditions experienced during the DOR period may have negatively impacted a number of species associated with this system. Texas wild-rice, for example, was described as abundant prior to the DOR while records describe the species uncommon and declining after this event (see EARIP HCP Chapter 4, USFWS 1996a).

A number of the Alternative 2 actions that benefit species in the Comal River system could be expected to similarly benefit those associated with San Marcos Springs, Spring Lake, and the San Marcos River. Efforts to manage non-native species, restore riparian habitat areas, and reduce water demand through RWCPs (see Section 2.1.6.1), for example, could enhance or restore habitat quality and increase flows in the San Marcos River system regardless of rainfall or recharge conditions. Additional measures to protect or enhance water quality or habitat conditions in the San Marcos system are described below.

Though little data is available for the San Marcos system during the DOR, Alternative 2 actions simulated over the period of record find minimum monthly flows similar to those modeled to have occurred during this event. Simulated Alternative 2 San Marcos springflows show flows of 51–52 cfs (under Phase 1 and Phase 2 actions, respectively) during conditions that result in 2 cfs under Alternative 1 actions. Simulated long-term springflow over the period of record averages 155 cfs under this alternative (for both Phase 1 and Phase 2 actions) compared to 153 cfs under Alternative 1 (Table 4-2).

Texas Wild-Rice

The flow protection measures and mitigation and minimization measures proposed under Alternative 2 would be expected to be more protective of Texas wild-rice than activities under Alternative 1. Diminished springflow is considered one of the primary threats to this species. Flow protection measures such as demand reductions anticipated from the RWCP, implementation of the VISPO, and management of the SAWS ASR to achieve springflow targets reduce the likelihood of this threat. These efforts combine to yield average simulated springflows that exceed those simulated under Alternative 1 and similar to those believed to have occurred during the DOR. Texas State University has committed to reduce surface water diversions to which they are otherwise entitled during drought conditions in order to allow these spring-fed surface waters to remain in the San Marcos River to support ecosystem needs.

Habitat restoration efforts under this alternative could benefit this species. The proposed HCP includes measures such as reintroduction and establishment of Texas wild-rice, control of competing non-native vegetation, and management of species that directly (such as through herbivory) or indirectly (by burrowing into or disrupting sediments) impact Texas wild-rice or its habitat. Actions such as litter control and submerged and floating vegetation management in the San Marcos River and Spring Lake could reduce the negative impacts to photosynthesis, flowering and reproduction of this species. Proposed changes in public recreational use and access management could reduce the threats of stream bottom disturbance that can be associated with recreational uses of the river. The TPWD has initiated efforts to establish a State Scientific Area in portions of the San Marcos River that would allow for delineation of areas for the protection of this species during low flow periods. This action would reduce impacts to Texas wild-rice by limiting recreational access to designated areas while allowing for continued use and recreation in the river. Sediment and sand bar removal within the San Marcos River could help restore more natural flow patterns and provide additional areas that could be colonized by Texas wild-rice.

Alternative 2 incorporates a number of water quality protection measures including prohibiting transportation of hazardous materials across the San Marcos River and its tributaries, household hazardous waste programs, an IPM plan covering the TSU golf course, expanded EAA water quality monitoring, and efforts to promote coal tar sealant bans. Implementation of these actions would reduce the threats of water quality degradation, chemical spills, and waterborne contaminants to Texas wild-rice.

False Spike

The petition to list the false spike as threatened or endangered identified drought and sediment pollution, among others, as threats to this species (74 FR 66260–66271). Alternative 2 actions including the flow protection measures described above reduce the likelihood of drought impacts to the San Marcos River and could benefit the false spike during these conditions. Sediment and sand bar removal within the San Marcos River are among the actions proposed in the HCP that could reduce the threat of sediment pollution. These measures could be expected to support false spike populations to a greater degree than actions proposed under Alternative 1.

Golden Orb

The Service found substantial information that the golden orb may warrant listing as threatened or endangered due to the present or threatened destruction, modification, or curtailment of its habitat or range. Siltation was listed among the potential threats to the species (74 FR 66260–66271). Alternative 2 actions addressing siltation such as those described above could contribute to the survival of the golden orb in the San Marcos and Guadalupe Rivers. The actions such as silt and sand bar removal proposed under this alternative could provide greater benefits to the golden orb than Alternative 1, which does not address these threats.

Texas Pimpleback

The Texas pimpleback is similarly described as potentially warranted for listing as threatened or endangered due to the present or threatened destruction, modification, or curtailment of its habitat or range. Drought-related dewatering was described among the threats to this species. Springflow protection measures such as the demand reductions associated with the RWCP, implementation of the VISPO, and management of the SAWS ASR to maintain flows during drought conditions combine to reduce the likelihood of this threat. Simulated Alternative 2 springflows at San Marcos Springs show flows of 51–52 cfs (under Phase 1 and Phase 2 actions, respectively) during conditions that result in 2 cfs under Alternative 1 actions. Alternative 2 could therefore be considered more protective of Texas pimpleback populations than the actions proposed under Alternative 1.

Texas Troglobitic Water Slater

Edwards Aquifer drawdown and water quality impacts are identified as potential threats to the Texas troglobitic water slater. Alternative 2 springflow protection measures and actions to protect water quality could benefit this species. Alternative 1 simulated springflows over the period of record indicate low flows that would result from Edwards Aquifer drawdowns. Alternative 1 also lacks the additional water quality protection measures proposed under this alternative such as prohibitions to transportation of hazardous materials across the San Marcos River and its tributaries, household hazardous waste programs, the IPM plan covering the TSU golf course, expanded EAA water quality monitoring, and efforts to promote coal tar sealant bans. Alternative 2 actions could support the Texas troglobitic water slater to a greater degree than activities considered under Alternative 1.

Comal Springs Riffle Beetle

Comal Springs riffle beetles known to occur in San Marcos Springs and Spring Lake are expected to be supported by the continual flows and reduced periods of low flow projected to occur under Alternative 2. This species requires high quality water that could be supported by the water quality protection measures described above. Alternative 2 measures provide a greater degree of protection for the Comal Springs riffle beetle at San Marcos Springs and Spring Lake than those of Alternative 1.

Edwards Aquifer Diving Beetle

The petition to list the Edwards Aquifer diving beetle as threatened or endangered stated that impacts of water drawdown and loss of water quality may imperil the species (USFWS 2009). The Alternative 2 springflow and water quality protection measures described above are intended to address and reduce the risks associated with these threats. This alternative could therefore be more supportive of the Edwards Aquifer diving beetle than Alternative 1.

San Marcos Salamander

Most San Marcos salamander habitat is found in Spring Lake, though these salamanders are known to inhabit areas below Spring Lake Dam and have been collected in the San Marcos River (see EARIP HCP Chapter 4 [EARIP 2011]). Alternative 2 simulated springflows and measures such as habitat maintenance and non-native animal management efforts described above are anticipated to support San Marcos salamander populations to a greater degree than those considered in Alternative 1.

Blanco Blind Salamander

The Service found that substantial information was presented to indicate that listing this species as threatened or endangered may be warranted due to habitat loss or degradation resulting from numerous human factors including groundwater withdrawal and contamination (USFWS 2009).

The flow and water quality protections proposed in the HCP and described above address these issues and could benefit the Blanco blind salamander to a greater extent than the measures proposed in Alternative 1.

Texas Blind Salamander

It is reasonable to conclude that the reduced periods of low flows simulated over the period of record under Alternative 2 would support subterranean species such as the Texas blind salamander during drought conditions to a greater degree than the extended low flows simulated to occur under Alternative 1. Troglobitic species such as the Texas blind salamander are typically adapted to narrow ranges of water quality fluctuations, and the additional water quality protection measures incorporated in this alternative could be supportive of the consistent conditions beneficial to this species.

Fountain Darter

Fountain darter populations within the San Marcos system could benefit from Alternative 2 proposals including habitat restoration efforts, non-native species management efforts, and springflow protection measures in San Marcos Springs, Spring Lake, and the San Marcos River.

Habitat management efforts in the San Marcos system include control of non-native plants and animals and restoration of submerged native vegetation to improve fountain darter habitat. Efforts regarding the parasitic gill trematode will initially focus on monitoring until the adaptive management process described in the HCP identifies the most effective means to manage this threat. If monitoring indicates that numbers of the parasitic gill trematode are increasing, Malaysian livebearing snails will be removed to eliminate the parasite's intermediate host. Springflow protection measures such as the RWCP and VISPO and management of the SAWS ASR to maintain flows during drought conditions would also be expected to reduce threats associated with low flows in Spring Lake and the San Marcos River.

The combined effects of these actions could benefit San Marcos fountain darter populations to a greater degree than the measures comprising Alternative 1.

San Marcos Gambusia

The quiet, shallow, thermally constant, open waters adjacent to areas of moving water cited as the preferred habitat of the San Marcos gambusia could be restored and maintained by the Alternative 2 springflow protection and habitat restoration measures described above. Particularly beneficial may be sediment removal actions that would restore the species' preferred silt-free substrates. Activities under Alternative 1 do not provide these habitat benefits and could therefore be less supportive of this species than the actions considered here.

4.3.2.3 The Guadalupe River and Estuarine Habitats

Measures proposed in the HCP that constitute Alternative 2 could have beneficial effects to the biological resources of the Guadalupe River and Estuary. The springflow and water quality protection measures that could increase the quantity and quality of surface waters flowing into the Guadalupe River could be expected to support native flora and fauna associated with this system to a greater extent than Alternative 1 actions. Riparian restoration and bank stabilization measures on both the Comal and San Marcos Rivers could be expected to reduce the risk of erosion and resulting downstream siltation concerns.

Whooping Crane

Under this alternative the simulated springflows over the period of record at both Comal and San Marcos Springs exceed the minimum monthly average and the long-term averages simulated under Alternative 1. These increased springflows could indirectly affect whooping cranes by generating freshwater inflows into the Guadalupe River and therefore to the Guadalupe River estuary that could support estuary function and whooping crane food item production to a greater degree than the inflows simulated under Alternative 1. Increased freshwater inflows associated with this alternative could also reduce increased energy expenditures and predation risks associated with elevated estuarine salinities that could result from low flows associated with Alternative 1 actions.

4.3.3 Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 incorporates the same habitat protection and water quality measures considered under Alternative 2 and these activities could be expected to have similar direct and indirect effects to the biological resources described under the previous example. Alternative 3 differs from Alternative 2 in the flow protection measures employed to achieve and maintain springflows at Comal and San Marcos Springs.

Alternative 3 lacks the RCWP and VISPO proposed under the previous example and relies on expanded storage and delivery of water from the ASR facilities coupled with more stringent CPM pumping restrictions to maintain springflows. These approaches are simulated to generate very similar springflows when modeled over the period of record at both Comal and San Marcos Springs as Alternative 2.

Though modeled springflows over the period of record are similar for these alternatives, the different mechanisms for achieving these results introduces additional issues to consider when comparing these results. Alternative 3 actions include storage of Edwards Aquifer water pumped during normal or above average precipitation conditions in an ASR facility until needed during drought conditions. This stored water will then be pumped through a transmission pipeline to recharge facilities in Comal County sited to allow rapid infiltration into the Edwards Aquifer. This input is anticipated to supplement naturally occurring recharge resulting in increased flows at Comal and San Marcos Springs.

Though waters placed in the ASR would be sourced from the Edwards Aquifer, storage over time may result in changes to biological or chemical composition of the water intended to supplement springflows. The biological make-up and water quality of the Edwards Aquifer provide the food and nutrient resources for the species associated with these spring-fed ecosystems. There is no available data to determine how storage under ASR conditions may affect the biological or chemical composition of Edwards Aquifer water or how supplementing natural springflow with this water may affect the spring ecosystems.

The construction, operation, and maintenance of the required water storage and delivery infrastructure under this alternative could also result in direct and indirect effects to listed species beyond the spring and river-associated ecosystems within the study area.

4.3.3.1 Comal Springs, Landa Lake, and the Comal River

Simulated Alternative 3 springflows at Comal Springs over the period of record are somewhat greater than Alternative 2 flows anticipated under Phase I actions, and similar to or slightly lower than those expected under Phase II. The resulting flow-associated direct and indirect impacts to biological resources in Comal Springs, Landa Lake, and the Comal River would therefore be expected to be similar to those described for Alternative 2.

At this time, there is no data to determine how using water stored in ASR facilities and pumped for re-use to supplement springflows may affect the water quality or the resulting direct or indirect effects on the biological resources in the Comal Springs, Landa Lake, and Comal River ecosystems.

4.3.3.2 San Marcos Springs, Spring Lake, and the San Marcos River

Alternative 3 measures produce simulated San Marcos springflows over the period of record very similar to those expected under Alternative 2, and biological resources would likewise be expected to be similarly affected by the resulting flow rates.

As described above, it is not possible at this time to determine the direct or indirect effects to water quality that may affect the biological resources in the San Marcos Springs, Spring Lake, and San Marcos River ecosystems that may result from using stored water to supplement springflows.

4.3.3.3 The Guadalupe River and Estuarine Habitats

The Guadalupe River system would be expected to receive very similar quantities of water under this alternative as described in the previous example, and resulting direct and indirect effects to biological resources associated with water quantity could be expected to be similar. The water quality effects of relying on stored water to supplement springflows, however, cannot be determined with available data and the potential effects to downstream biological resources cannot therefore be assessed.

4.3.3.4 Other Species with Regulatory Status

Construction, operation, and maintenance of the proposed ASR facilities, water transmission pipeline, and recharge facilities anticipated under this alternative have the potential to impact terrestrial species such as the golden-cheeked warbler (*Dendroica chrysoparia* [GCWA]) and the black-capped vireo (*Vireo atricapilla* [BCVI]) and subterranean species such as karst-dwelling invertebrates. Habitat for these listed songbirds and karst invertebrates may occur along potential pipeline routes between southern Bexar County and central Comal County and in the vicinity of proposed expanded ASR facilities in Wilson County, and in the vicinity of recharge structure locations in Comal County. As no pipeline route has been selected, additional analysis would be required to determine potential effects to these or other terrestrial species that may be affected by infrastructure-related construction or ongoing operations and maintenance activities. The following brief descriptions identify threatened and endangered species known to occur within the study area that could be directly or indirectly affected based on site selection, construction timing (such as relative to nesting and breeding seasons for the listed songbirds), and other factors.

Black-Capped Vireo

The BCVI is an insectivorous migratory songbird that nests in portions of Mexico, Oklahoma, and Texas, and winters on the Pacific coast of Mexico (USFWS 1991a). This species was listed as endangered on October 6, 1987 (52 FR 37420–37423). Breeding habitat throughout the BCVI's range is highly variable, but is generally described as low, patchy shrubland thickets with vegetation cover that extends to ground level. For more on the BCVI, see the Black-capped Vireo Recovery Plan (USFWS 1991a), the Black-capped Vireo 5-year Review (72 FR 39247–39283), and the Black-capped Vireo Spotlight Species Action Plan (USFWS 2009).

Golden-Cheeked Warbler

The GCWA is a small insectivorous migratory songbird that nests only in the mixed juniper-oak woodlands of the Central Texas, and winters in the highland pine-oak woodlands of southern Mexico and northern Central America (USFWS 1992). The GCWA was listed as endangered on December 27, 1990 (55 FR 53153–53160). The breeding range of the GCWA is restricted to 37 Texas counties on the Lampasas Cut Plain, Edwards Plateau and Llano Uplift regions of the state (USFWS 1991b). For more information on this species, see the Golden-cheeked Warbler Recovery Plan (USFWS 1992), the 5-year Review of 25 Southwestern Species (71 FR 20714–20716), and the Golden-cheeked Warbler Spotlight Species Action Plan (USFWS 2009).

Helotes Mold Beetle

The Helotes mold beetle (*Batrisodes venyivi*) is a small, troglobitic, reddish-brown beetle known from eight caves in the Government Canyon and Helotes Karst Fauna Regions in Bexar County, and was listed as endangered on December 26, 2000 (USFWS 2008a, 65 FR 81419–81433). The Helotes mold beetle was first collected in 1984 and described by Chandler (1992); little is known about the life history of the species (65 FR 81419–81433).

Rhadine exilis

Rhadine exilis (no common name) is one of two species of endangered ground beetles known to occur within the EIS study area. This species is a slender-bodied, essentially eyeless cave-dwelling species found in more than 50 caves in north and northwest Bexar County that was listed as endangered on December 26, 2000 (65 FR 81419–81433). This is one of the most broadly distributed federally listed invertebrate cave species in the county. It ranges in size from 0.28–0.33 inch (0.71–0.84 cm), is reddish brown, and is thought to feed on cave cricket eggs. The species has been recorded on cave walls and other bare substrate as well as from under rocks or from the undersides of rocks or other materials (USFWS 2008a).

Rhadine infernalis

The second listed ground beetle, *Rhadine infernalis* (no common name), is known from more than 35 caves in Bexar County (USFWS 2008a). There is enough variation within this species that three subspecies have been identified: *R. infernalis* ssp., *R. infernalis infernalis*, and *R. infernalis ewersi*. All three subspecies are included under *R. infernalis* and are protected under the December 26, 2000 federal listing as endangered (65 FR 81419–81433). *Rhadine infernalis* is typically found underneath rocks in silt or other areas with a high organic content (Veni and Associates 2006). It is an opportunistic feeder, consuming arthropods and scavenging on dead arthropods (Veni et al. 1999).

Government Canyon Bat Cave Spider

The Government Canyon Bat Cave spider (*Neoleptoneta microps*) is found in two caves in the Government Canyon State Natural Area (GCSNA) in Bexar County, and is suspected from a third locality outside of the GCSNA (USFWS 2008a). 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 desiccate quickly in low humidity environments. Much of their time is spent in their web, but they have also been seen walking on the ground near their web (Veni et al. 1999). The Government Canyon Bat Cave spider was listed as endangered on December 26, 2000 (65 FR 81419–81433).

Madla's Cave Meshweaver

Madla's Cave meshweaver (*Cicurina madla*) is a pale, eyeless spider that lives in webs built under and among rocks known from 11 caves in Bexar County (USFWS 2008a). Authorization for take of Madla's Cave meshweaver was granted to La Cantera under a Section 10(a)(1)(B) permit (USFWS 2001) covering three of these locations, which are not expected to contribute to the species' recovery (USFWS 2008a). This species has a more widespread distribution than other *Cicurina* in Bexar County and is thought to be a more recent troglobite. It can tolerate a wide range of temperatures but is unable to survive long in low humidity (Veni et al. 1999). The species was listed as endangered on December 26, 2000 (65 FR 81419–81433).

Cokendolpher Cave Harvestman

The Cokendolpher Cave harvestman (*Texella cokendolpheri*) is a small, pale-orange, essentially eyeless, troglobitic harvestman known from Bexar County (USFWS 2008a). This large cave is located on private property but has been donated to the Texas Cave Management Association, which is interested in cave conservation and habitat improvement. The Cokendolpher Cave harvestman was listed as endangered on December 26, 2000 (65 FR 81419–81433). This species primarily occurs in caves, although some are found under rocks and logs. 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 their natural environment (Veni et al. 1999).

Robber Baron Cave Meshweaver

Robber Baron Cave also provides habitat for a small, eyeless spider known as the Robber Baron Cave meshweaver (*Cicurina baronia*). This species was listed as endangered on December 26, 2000, and is known only from Bexar County (65 FR 81419–81433, USFWS 2008a).

Government Canyon Bat Cave Meshweaver

The Government Canyon Bat Cave meshweaver (*Cicurina vespera*) is a pale, eyeless troglobitic spider found only in Government Canyon Bat Cave in Bexar County (USFWS 2008a). The Government Canyon Bat Cave meshweaver was listed as endangered on December 26, 2000 (FR 65 81419–81433). A second cave, called "unnamed cave five miles from Helotes," was once thought to also contain the species but was subsequently ruled out as a locality. The individual collected from this unnamed cave was determined to be a new species, *Cicurina neovespera* (Reddell and Cokendolpher 2004). It was formerly known as the Vesper Cave spider (Veni et al. 1999).

Bracken Bat Cave Meshweaver

The Bracken Bat Cave meshweaver (*Cicurina venii*) is a small, eyeless, or essentially eyeless troglobitic spider found in Bracken Bat Cave in Bexar County (USFWS 2008a). This cave is located within a low-density semi-urban neighborhood. The cave was filled in during the building of a home in 1990 and the effects to the cave fauna are unknown at this point. When listed as endangered on December 26, 2000 it was reported that there could be a small opening in the area that may possibly be a source of nutrients for the spider (65 FR 81419–81433).

4.3.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 actions are focused on flow protection measures and result in greater simulated springflows over the period of record than any of the other considered alternatives. Because this alternative does not incorporate the habitat restoration or water quality measures considered under Alternatives 2 and 3, the associated benefits expected under these options would not be realized under this alternative.

4.3.4.1 Comal Springs, Landa Lake, and the Comal River

Over the period of record simulated Comal Springflows flows under Alternative 4 remain higher than under any of the contemplated alternatives. Simulated springflows during the modeled DOR period maintain Comal Springs minimum springflows of 109 cfs, and achieve long-term average flows very near those reported in the historic record. Simulated springflows under this alternative fluctuate when the single-stage CPM restrictions are triggered, but fluctuations during more severe or prolonged droughts are less dramatic than would be expected under any other alternative. Consistent flows such as those simulated during drought conditions over the period of record could be expected to reduce threats to listed species associated with low flows or dropping Edwards Aquifer levels in the Comal system.

Comal Springs Dryopid Beetle

The simulated Alternative 4 springflows at Comal Springs over the period of record exceed those simulated under any of the other alternatives and could be expected to provide the flowing waters required by the Comal Springs dryopid beetle. Alternative 4 does not address water quality concerns beyond the dilution of contaminants that may result from the increased quantities of water emerging at Comal Springs. Alternative 4 may not reduce the threats to high quality contaminant free water required by the Comal Springs dryopid beetle to the same extent as Alternatives 2 and 3.

Comal Springs Riffle Beetle

Alternative 4 does not incorporate the riparian or habitat restoration efforts proposed under Alternatives 2 and 3, and the expected benefits from these measures would not be achieved under this alternative. The simulated springflows at Comal Springs over the period of record, however, provide the greatest volumes of any of the alternatives considered and would be expected to be supportive of the Comal Springs riffle beetle.

Edwards Aquifer Diving Beetle

The simulated Comal Springflows under this alternative could be expected to reduce the potential for water drawdowns cited as a threat to the Edwards Aquifer diving beetle to a greater degree than Alternatives 1, 2, or 3.

Peck's Cave Amphipod

Peck's Cave amphipod could benefit from the springflow conditions simulated over the period of record to result from Alternative 4 measures. The results of these actions exceed the simulated springflows and therefore the associated aquifer levels upon which this species relies more than any of the other alternatives.

Comal Springs Salamander

The Comal Springs salamander may be threatened by habitat loss or degradation associated with groundwater withdrawal and contamination (USFWS 2009). The simulated Alternative 4 springflows at Comal Springs over the period of record exceed those simulated under any of the other alternatives and could most significantly reduce the risks associated with groundwater withdrawal. Alternative 4 does not address water quality concerns beyond the dilution of contaminants that may result from the increased quantities of water emerging at Comal Springs. Alternative 4 may therefore not reduce the threats groundwater contamination to the same extent as Alternatives 2 and 3.

Fountain Darter

As for each of the species described here, the fountain darter could be beneficially impacted by the increase springflows simulated under Alternative 4 actions to a greater degree than under any of the other alternatives considered. Because this alternative does not incorporate the habitat restoration efforts, gill parasite monitoring and control program, and flow management controls between the new and old channels of the Comal River, these benefits would not provide these benefits anticipated under Alternatives 2 and 3.

4.3.4.2 San Marcos Springs, Spring Lake, and the San Marcos River

Flows in the San Marcos River system are similarly elevated during springflow simulations modeling Alternative 4 actions. Simulated springflows over the period of record maintain San Marcos Springs minimum springflows of 72 cfs, which exceed the 54 cfs modeled to have occurred during the DOR. The long-term average flows of 164 cfs under this alternative are also very near the recorded long-term average of 168 cfs. Simulated springflow fluctuations at San Marcos Springs occur when the single-stage CPM restrictions are triggered much as those expected at Comal Springs under this alternative.

Texas Wild-Rice

The simulated springflows under this alternative address the threats associated with diminished springflow to Texas wild-rice to a greater degree than any of the other alternatives.

Alternative 4 does not include the habitat restoration efforts, proposed changes in public recreational use and access management, establishment of State Scientific Areas, or sediment and sand bar removal anticipated to benefit the species as proposed under Alternatives 2 and 3. This alternative does not incorporate the water quality protection measures proposed under Alternatives 2 and 3 that could reduce the identified threats of water quality degradation, chemical spills, and waterborne contaminants to Texas wild-rice.

False Spike

Alternative 4 does not include the sediment and sand bar removal measures proposed under Alternatives 2 and 3 anticipated to address the sediment pollution identified as a threat to this species. The simulated Alternative 4 springflows at San Marcos Springs would reduce the risk of drought impacts also considered a threat to the false spike.

Golden Orb

As described above for the false spike, Alternative 4 does not address siltation within the San Marcos River considered a threat to the golden orb.

Texas Pimpleback

Drought-related dewatering was described among the threats to the Texas pimpleback. Simulated springflows under this alternative yield the greatest minimum and long-term averages modeled and could reduce this threat to the greatest degree of any of the considered alternatives.

Texas Troglobitic Water Slater

Edwards Aquifer drawdowns considered a potential threat to the Texas troglobitic water slater are addressed by simulated Alternative 4 springflows to a greater degree than measures proposed under Alternatives 1, 2, or 3. The water quality impacts also identified as potential threats to this species are not addressed beyond the dilution of contaminants that may result from the increased quantities of water emerging at San Marcos Springs.

Comal Springs Riffle Beetle

Comal Springs riffle beetles require high quality water that is not addressed under Alternative 4 measures. Alternative 4 also lacks the riparian and habitat restoration activities proposed under Alternatives 2 and 3 anticipated to benefit this species.

Edwards Aquifer Diving Beetle

The petition to list the Edwards Aquifer diving beetle as threatened or endangered described Edwards Aquifer drawdowns and impacts to water quality as potential threats to the species Alternative 4 simulated springflows over the period of record could be expected to support Edwards Aquifer levels thereby minimizing the threat of drawdown. Water quality impacts are not addressed under Alternative 4 actions beyond the dilution of contaminants that may result from the increased quantities of water emerging at San Marcos Springs.

San Marcos Salamander

Alternative 4 simulated springflows could be expected to support San Marcos salamander populations, though the habitat protection and restoration measures under Alternatives 2 and 3 are not incorporated in this alternative and the anticipated benefits associated with these actions would not occur.

Blanco Blind Salamander

Groundwater withdrawal and contamination are considered threats to the Blanco blind salamander. Alternative 4 simulated springflows could be expected to address the impacts associated with groundwater withdrawal, though the lack of water quality measures associated with this alternative fail to meet this need to the extent proposed in Alternatives 2 and 3.

Texas Blind Salamander

The Alternative 4 simulated springflows over the period of record suggest similarly elevated Edwards Aquifer levels that could be supportive of Texas blind salamander populations.

Fountain Darter

As described above, fountain darter populations within the San Marcos system could benefit from springflows associated with Alternative 4. The simulated long-term and minimum San Marcos flows modeled over the studied timeframe meet or exceed the measures recorded or modeled to have occurred during the DOR, and could support fountain darter populations to the greatest degree of the alternatives considered. Because this alternative fails to incorporate habitat protection or water quality measures, these threats are not addressed to the extent proposed under Alternatives 2 and 3.

San Marcos Gambusia

Alternative 4 does not provide the habitat restoration or protection benefits described under Alternatives 2 and 3 and could therefore be less supportive of San Marcos gambusia habitat than these alternatives.

4.3.4.3 The Guadalupe River and Estuarine Habitats

Simulated springflows under Alternative 4 could benefit downstream biological by increasing the quantity of surface waters flowing into the Guadalupe River and Estuary.

Whooping Crane

Under this alternative the simulated springflows over the period of record at both Comal and San Marcos Springs exceed the minimum monthly and long-term averages simulated under any of the other alternatives. These increased springflows could indirectly affect whooping cranes by generating freshwater inflows into the Guadalupe River and therefore to the Guadalupe River estuary that could support greater estuary function and whooping crane food item production. Increased freshwater inflows associated with this alternative could also reduce increased energy expenditures and predation risks associated with elevated estuarine salinities that could result from low flows.

4.4 SOCIOECONOMIC RESOURCES

Communities within the study area may experience direct and indirect socioeconomic effects under each of the alternatives. Potential effects are primarily related to agricultural production, employment, and demographic changes.

4.4.1 Agricultural Production

Direct and indirect effects to agricultural production in the study area are presented in this section for each of the alternatives. The sub-regions described in Chapter 3 are referenced to describe the effects that may result from the various alternatives within the study area.

4.4.1.1 Alternative 1: No Action

Alternative 1 describes the current EAA program that relies on four CPM stages to manage pumping during periods of drought. Much of the agricultural production in the Eastern Region is dependent on irrigation and operates under existing CPM limits during drought conditions. The Central and Western Regions are also heavily dependent on irrigation for agricultural production, and also operate under EAA directed CPM pumping regulations. Pumping restrictions do not directly affect the Downstream Region, as this area is not within the EAA regulatory boundary.

Alternative 1 represents current management practices and no substantial effects to agricultural production are expected within the study area. Agricultural production would be expected to continue to follow current trends described in Chapter 3 under this alternative.

4.4.1.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

The CPM program under Alternative 2 incorporates a fifth stage of pumping restrictions. The additional stage would require that pumping be reduced by 44 percent in both the San Antonio and Uvalde pools of the Edwards Aquifer during severe drought conditions under Phase 1, and by 47 percent under Phase 2 measures. This element is not expected to impact agricultural production during periods of normal rainfall, but would be expected to reduce the amount of water available for agriculture during severe drought conditions (described in Section 2.1.6.1). As in Alternative 1, these CPM changes will not directly affect the Downstream Region because this area is not within the EAA regulatory boundary and is therefore not subject to these limitations.

Alternative 2 measures include the VISPO that offers financial incentives to agricultural producers in exchange for suspension of pumping during drought conditions (described in Section 2.1.6.1). This element allows agricultural producers to secure guaranteed annual payments for each acre-foot of water enrolled in the program and elevated payments during drought conditions when pumping is suspended.

Alternative 2 includes storage of 50,000 ac-ft of the Edwards Aquifer as part of the SAWS ASR trade-off program (described in Section 2.1.6.1). Edwards Aquifer water for the ASR program would be obtained through leasing irrigation permits or through the use of water management practices under Section 1.14(h) of the EAA Act. This alternative will provide an additional market for agricultural producers willing to lease or sell water rights to SAWS or the EAA for use in maintaining the storage capacity of the ASR facility.

These Alternative 2 actions could indirectly result in shifts in agricultural production within the study area such as the current trend from irrigated agriculture to dryland farming techniques or livestock operations. These indirect effects could be expected to be most pronounced in the Western Region of the study area, to a lesser extent in the Eastern and Central Regions, and to a lesser extent or not at all in the Downstream Region

4.4.1.3 Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 relies on a four-stage CPM Program in which Aquifer-wide pumping would be restricted by 50 percent to 286,000 ac-ft/yr during severe drought conditions (see Section 2.1.7 for a description of CPM stage triggers under this alternative). The CPM restrictions under Alternative 3 are not expected to impact agricultural production during periods of normal rainfall, but would be expected to reduce the amount of water available for agriculture during drought conditions that meet stage IV initiation triggers. As with the alternatives described above, the Downstream Region will not be directly affected by CPM restrictions because these counties are not within the jurisdiction of the EAA.

Alternative 3 includes expanded use of the SAWS ASR requiring pumping up to 66,700 ac-ft of Edwards Aquifer water obtained through the lease or purchase of irrigation rights from users in Bexar, Medina, and Uvalde Counties. This water would be stored in the ASR facilities until needed, and then transported via a transmission pipeline to recharge facilities in Comal County. This alternative will provide an additional market for agricultural producers willing to lease their water rights to SAWS or the EAA for use in maintaining the expanded storage capacity of the ASR facility.

Indirect effects of Alternative 3 are expected to be similar to those described for Alternative 2, though the increased pumping cutbacks and higher demand for ASR water leases may further accelerate current trends in agricultural production.

4.4.1.4 Alternative 4: Highest CPM Pumping Restriction

The CPM Program under Alternative 4 requires Aquifer-wide pumping restrictions of 85 percent to 85,800 ac-ft/yr once the single stage trigger level is achieved. Alternative 4 would be expected to significantly reduce the amount of water available for agriculture once the single stage CPM restriction is initiated (described in Section 2.1.8). As with the other options, Downstream counties beyond the jurisdiction of the EAA will not be directly affected by the CPM pumping limitations in this alternative.

Alternative 4 actions could be expected to affect agricultural production to the greatest degree of the considered alternatives due to the most significant pumping restrictions during drought conditions.

4.4.2 Employment

An economic analysis of regional Edwards Aquifer pumping restrictions projected that employment and income losses would be associated primarily with agricultural sectors of the economy (Jones et al. 2001). This study applied an input-output model based on TWDB water demand estimates representing the relationship between regulatory changes in one sector of the economy and the resulting effect on economic output, income, or employment in other economic sectors. The study anticipated that municipal and industrial users would likely pay higher water rates within certain limits to meet water needs that could not be met from the Edwards Aquifer. Non-agricultural businesses which would be particularly sensitive to increased water prices and drought-related pumping limitations would include those which require large quantities of water in the manufacture or delivery of goods or services. Water use by the agricultural sector was anticipated to be sensitive to pumping limits because irrigators could more readily respond to incentives to sell or lease water rights (Jones et al. 2001).

Though this study estimated initial economic impacts arising from regulatory changes, it did not address resulting adjustments over time. The estimates of regulation-associated employment changes did not address re-employment of affected individuals or other adaptive responses by impacted sectors of the economy. Other factors that may be affected by regulatory changes such as the flow of goods and services across regional boundaries could also affect the regional economy (IEc 2007).

While some agriculture-related employment effects could result from each of the alternatives, less than 2 percent of total employment in the study area is associated with the this sector of the economy.

Local economies reliant on water-based recreation and tourism may also experience indirect socioeconomic effects associated with the alternatives considered. These effects could be expected to be most significant in the cities of New Braunfels and San Marcos, and to a lesser extent in downstream communities.

Tourism is Comal County's second largest industry during the summer season and the third largest through the rest of the year (TWC 2001). More than half of all sales tax revenues for the city of New Braunfels and Comal County are associated with tourism, and water-based recreation accounts for approximately 70 percent of total tourism spending (Mike Meek, New Braunfels Chamber of Commerce, 2002, pers. comm.). Retail trade in Comal County is also heavily affected by tourism, and businesses with no apparent relationship to Comal Springflows or recreation have been shown to be affected by changes in conditions for water-based recreation (J. Young, Tourism Director, New Braunfels Chamber of Commerce, 2002, pers. comm.).

Indirect socioeconomic effects in San Marcos and Hays County could be expected to be less pronounced because the local economies in these communities are less dependent on water-based recreation than those in Comal County. Some water-based recreation would continue to be feasible during drought conditions at San Marcos Springs under all of the alternatives. Some socioeconomic impacts to recreation and tourism could be anticipated when San Marcos River flows drop below the 200 cfs preferred for river-based activities such as canoeing, kayaking, and rafting (McCord 2007).

Indirect socioeconomic effects could also be expected in downstream areas as a result of actions influencing springflow conditions and subsequent inflows to the Comal, San Marcos and Lower Guadalupe Rivers. These interests could include surface water rights holders in the Guadalupe River Basin, river recreation businesses, the tourism industry, and both recreational and commercial fishing interests dependent on the Guadalupe Estuary ecosystem.

The following discussion focuses primarily on those sectors of the regional economy anticipated to be affected by the alternative actions.

4.4.2.1 Alternative 1: No Action

Impacts associated with Alternative 1 actions could be anticipated during periods of drought when CPM restrictions could affect agricultural production and resulting employment and income. Alternative 1 represents current Edwards Aquifer management practices, and would be expected to result in continuation of existing agricultural practices and responses to pumping limitations now in place. During normal rainfall and recharge conditions agricultural production and related employment would be expected to continue to reflect existing trends. During drought conditions, irrigated agriculture could be affected by CPM restrictions with resulting impacts to agriculture-related employment. These effects could be expected to be correlated with precipitation and recharge patterns.

This alternative would not be expected to significantly impact recreation and tourism during normal precipitation and recharge conditions. These sectors of local economies could be negatively impacted during severe drought conditions when Alternative 1 actions significantly affect springflows. The simulated 38 months of cessation of flow at Comal Springs when Alternative 1 actions are modeled over the period of record, for example, could result in significant recreation and tourism associated employment impacts.

Other sectors of the economy could also be expected to be affected by severe drought conditions, though to a lesser degree than the agricultural and recreation and tourism sectors.

4.4.2.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 includes storage of 50,000 ac-ft of the Edwards Aquifer as part of the SAWS ASR trade-off program (described in Section 2.1.6.1). Edwards Aquifer water for the ASR program would be obtained through leasing irrigation permits or through the use of water management practices under Section 1.14(h) of the EAA Act. This alternative will provide an additional market for agricultural, municipal, and industrial water rights holders willing to lease rights to the EAA for use in maintaining the storage capacity of the ASR facility.

Alternative 2 would not be expected to significantly affect recreation and tourism impacts during normal conditions. Actions under these options would be expected to maintain springflows and therefore continue to support recreation and tourism activities during conditions when these activities would be expected to be negatively impacted under Alternative 1.

4.4.2.3 Alternative 3: Expanded ASR with Associated Infrastructure

The CPM cutbacks under Alternative 3 are more restrictive than those considered under Alternatives 1 or 2. As with the other alternatives, the effects of CPM restrictions on agricultural employment are directly related to the frequency and severity of precipitation conditions. Employment impacts under Alternative 3 would therefore be similar to or slightly greater than those expected under Alternative 2.

The increased ASR volume required under Alternative 3 will create a market for up to 66,700 ac-ft of leased Edwards Aquifer water rights, which could have similar or slightly greater impacts than those described under the previous alternative.

Alternative 3 contemplates the construction, operation, and maintenance of water transmission pipelines, expanded ASR facilities, and recharge facilities to manage water volumes to maintain springflow targets. These measures may generate some temporary construction-related employment and the need for a limited number of ongoing operations and maintenance personnel.

Alternative 3 effects to recreation and tourism could be expected to be similar to those described for Alternative 2.

The higher implementation costs associated with Alternatives 3 measures (ranging from $439 million to $1.16 billion over the 15-year term of the proposed permit) would be expected to have greater region-wide socioeconomic impacts than those expected under Alternative 2 ($261.2 million over the 15-year term of the proposed permit).

4.4.2.4 Alternative 4: Highest CPM Pumping Restriction

The single-stage pumping restriction initiated contemplated under Alternative 4 could significantly impact agricultural employment in the study area. A modeled pumping restriction of 175,000 ac-ft/yr projected that irrigated agriculture could become economically unfeasible in the Eastern and Central Regions and would be significantly reduced in the Western Region (Jones et al. 2001). This study projected that cutbacks of this magnitude could result in the loss of an estimated 2,962 to 6,156 jobs in the agricultural sector of the economy. Alternative 4 calls actions could have more significant impacts to employment in the agricultural sector of the economy than any of the other alternatives.

Alternative 4 would be expected to have the most significant impacts to tourism and recreation associated employment of any considered alternative during both normal and drought conditions. The simulated springflow increases could be benefit recreational river uses during most conditions, and especially during drought conditions. The increased instream flows under this alternative would be expected to provide the most beneficial effects for recreation and tourism such as recreational and commercial fishing associated with downstream communities such as those associated with the Guadalupe Estuary.

The region could not meet currently projected levels of water demand for human uses under this alternative without the development of additional water management strategies. The 2011 SCTRWPG estimated that providing alternative water sources to meet projected water demands would cost $7.6 billion in 2008 dollars, without consideration of the pumping cutbacks considered here. Additional supplies would need to be developed to offset the proposed Alternative 4 cutbacks.

The proposed pumping limitations during drought conditions under this alternative could generate the greatest socioeconomic impacts throughout the region. This Alternative would be expected to affect a much broader cross section of the regional economy than any of the other alternatives considered, as the costs of developing new water supplies could be expected to be felt throughout the regional economy.

4.4.3 Demographics

The study area is projected to undergo continued population growth in the coming decades (see Section 3.5.3). As noted in Section 3.7, major urban population centers are located in Bexar, Comal, Guadalupe, Hays, and Victoria Counties. These urban centers have been growing rapidly over the last 50 years, with cities along the IH-35 corridor experiencing especially high growth rates. Bexar County experienced a 50-year compound annual growth rate of 1.8 percent; Comal County, 3.5 percent; Guadalupe County, 3.1 percent; and Hays County, 4.2 percent (U.S. Census Bureau 2010a). The TWDB 50-year population projections for the counties in the study area project continued growth in these urban centers (TWDB 2011). The direct and indirect effects of the alternatives on demographics in the study area are described below.

4.4.3.1 Alternative 1: No Action

Population trends would be expected to follow current projections under the actions considered in Alternative 1. No significant demographic impacts are anticipated under normal precipitation and recharge conditions under this alternative. Extended drought conditions such as a repeat of DOR-like conditions that limit agricultural production may result in job losses and potential demographic shifts as farm and ranch workers seek employment opportunities in other sectors of the economy or in other areas.

4.4.3.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

During normal rainfall and recharge conditions Alternative 2 actions are not likely to impact study area demographics. Extended drought conditions such as a repeat of DOR-like conditions that limit agricultural production may result in job losses and potential demographic shifts as farm and ranch workers seek employment opportunities in other sectors of the economy or in other areas.

Alternative 2 relies on EAA-levied Edwards Aquifer management fees to fund the proposed actions, though alternate funding sources including a regional sales tax have also been proposed (see EARIP HCP Chapter 7 [EARIP 2011]). For the purposes of this analysis, funding is presumed to be provided through collection of EAA Edwards Aquifer management fees, as alternate funding is not assured at this time. Edwards Aquifer management fees would be assessed for the duration of the proposed permit term, and would therefore have the same impact during normal rainfall and drought conditions. Increased Edwards Aquifer management fees may have differential impacts across the study area.

Users relying on EAA authorized pumping would see fee increases that could impact employment and result in demographic changes. By state law, agricultural producers are capped at $2.00 per acre-foot in EAA Edwards Aquifer management fees, and would therefore not be affected by fee increases. Non-agricultural users in the Western, Central, and Eastern regions would experience fee increases, though the impacts of those fees are difficult to quantify. Municipal and industrial pumpers with large customer bases would be expected to recover the impacts of increased fees through incremental adjustments to end user costs. Other water users such as small municipalities and commercial or industrial enterprises may have less capacity to recover increased fees. Smaller communities and businesses, therefore, may bear a proportionally larger impact of increasing fees and therefore a greater potential to experience resulting employment and demographic changes.

Counties in the Downstream region are not within the jurisdictional boundaries of the EAA and therefore not subject to Edwards Aquifer management fees. Some downstream communities and industries, including the City of Victoria, GBRA, and Union Carbide, have acknowledged that success of the EARIP HCP would benefit their interests and have committed to contribute funding toward plan implementation (see EARIP HCP Chapter 7 [EARIP 2011]). These entities believe that the success of the EARIP HCP will support local communities and businesses and will provide stability to local economies within their region.

4.4.3.3 Alternative 3: Expanded ASR with Associated Infrastructure

During normal rainfall and recharge conditions Alternative 3 actions are not likely to impact economies or demographics in the study area. The more restrictive CPM requirements in Alternative 3 are likely to more significantly impact agricultural producers during drought conditions than those proposed in Alternatives 1 and 2. Extended drought conditions would likely result in more significant economic impacts and increase the likelihood of resulting demographic changes than those expected in Alternatives 1 and 2.

The greater total estimated project costs associated with Alternative 3 actions would require significantly higher Edwards Aquifer management fees than those described for Alternative 2. These fees would be expected to generate economic and resulting demographic impacts throughout the study area similar to, but to a greater degree than those considered in Alternative 2.

4.4.3.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 relies on a single significant reduction of pumping throughout the jurisdictional boundaries of the EAA during drought conditions. The 85 percent pumping reduction contemplated under Alternative 4 is likely to significantly impact regional economies and would be expected to affect a much larger cross section of municipal, industrial, agricultural and individual water users. The potential demographic effects of the economic changes would be more significant than for any of the other alternatives considered.

4.4.4 Environmental Justice

Federal agencies strive to ensure that their actions support environmental justice ideals by identifying and addressing disproportionately high and adverse human health or environmental effects of programs, policies, and activities on low-income and minority populations in the United States (59 FR 7629, 1994 WL 43891 [Pres], Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations) (USEPA 1994).

The CEQ guidance directs that the annual Bureau of the Census statistical poverty thresholds be used to identify low-income populations in an affected area. Minorities are defined as individuals of the following population groups: American Indian or Alaskan Native; Asian or Pacific Islander; Black, not of Hispanic origin; or Hispanic. Minority populations should be identified where either: (a) the minority population of the affected area exceeds 50 percent or (b) the minority population percentage of the affected area is meaningfully greater than the minority population percentage in the general population or other appropriate unit of geographic analysis. A minority population also exists if there is more than one minority group present and the minority percentage, as calculated by aggregating all minority persons, meets one of the above-stated thresholds (CEQ 1997).

The U.S. Department of the Interior's (USDI's) environmental justice policy requires that DOI bureaus "consider the impacts of their actions and inactions on minority and low-income populations and communities, as well as the equity of the distribution of benefits and risks of those decisions in NEPA documents (Secretary of the Interior 1994). The composition and distribution of minority populations within the study area are described in Section 3.5.4.

Agricultural employment in the study area could be affected to differing degrees during drought conditions under each of the alternatives considered, and is described in Section 4.4.2. While the counties within the study area with the highest reported agricultural employment also have minority communities that make up more than half of the overall countywide population (Table 4-3), evaluating the full impacts to minority and low-income populations and the extent to which they would be disproportionately and adversely affected cannot be conclusively determined based on available data. Though employment in this sector of the economy may be most directly impacted by regulations related to water use or restrictions in the study area, agriculture employs a small proportion (less than 2 percent) of the regional population and there is no indication that results of these impacts would disproportionately affect any minority or low-income population.

Table 4-3. Minority Population and Agricultural Employment.

COUNTY	TOTAL 2010 POPULATION[a]	PERCENT MINORITY (NON-WHITE)[a]	4Q 2007 AGRICULTURAL EMPLOYMENT[b]	PERCENT OF TOTAL 4Q 2007 EMPLOYMENT[b]	NUMBER OF FARM WORKERS 2007[c]
WESTERN REGION					
Edwards	2,002	53%	44	9.5%	348
Kinney	3,598	58%	33	4.3%	145
Real	3,309	28%	13	1.9%	95
Uvalde	26,405	71%	561	5.9%	653
Subtotal	**35,314**	**65%**	**651**	**5.7%**	**1,241**
CENTRAL REGION					
Atascosa	44,911	64%	312	3.3%	909
Medina	46,006	53%	206	2.4%	884
Subtotal	**90,917**	**59%**	**518**	**2.9%**	**1,793**
EASTERN REGION					
Bexar	1,714,773	70%	1,056	0.1%	1,154
Caldwell	38,066	56%	99	1.5%	573
Comal	108,472	29%	91	0.2%	341
Guadalupe	131,533	45%	126	0.4%	355
Hays	157,107	41%	229	0.5%	934
Kendall	33,410	23%	64	0.6%	370
Subtotal	**2,183,361**	**63%**	**1,665**	**0.2%**	**3,727**
DOWNSTREAM REGION					
Calhoun	21,381	54%	75	0.8%	213
DeWitt	20,097	43%	27	0.4%	789
Gonzales	19,807	55%	962	14.7%	1,761
Refugio	7,383	55%	65	3.0%	300
Victoria	86,793	52%	201	0.5%	837
Subtotal	**155,461**	**52%**	**1,330**	**2.1%**	**3,900**
TOTAL	**2,465,053**	**62%**	**4,164**	**0.4%**	**10,661**

[a] U.S. Census Bureau (2010a).
[b] TWC (2010).
[c] U.S. Census Bureau (2010b).

4.5 CULTURAL RESOURCES

This section compares potential direct and indirect effects to archeological and historical resources that could be expected to result from each of the alternatives being considered. Sites located immediately adjacent to Comal and San Marcos Springs, Landa Lake, Spring Lake, and the Comal and San Marcos Rivers are most likely to be impacted (see Section 3.8).

Four categories of impact to cultural resources were identified by the National Park Service, and these general categories are used in the following analyses. Human impacts such as artifact collecting or looting can result when cultural sites are exposed or intermittently exposed. Mechanical impacts consist of physical erosion and depositional processes. Biochemical impacts occur when terrestrial cultural resources are inundated. Various other miscellaneous impacts are also recognized as threats (Malof 1999).

The primary anticipated impacts to cultural resource sites are human caused effects such as collecting and looting. Indiscriminate collection of cultural resources results in the loss of artifacts, associated information, and disturbance of the stratigraphic and archeological record (Malof 1999). The public location of sites considered here make them easy targets for professional collectors, amateur archeologists, and unknowing visitors who innocently pick up and walk away with cultural artifacts.

Mechanical impacts vary depending upon the location of the site. In the alternatives considered, stream bankside resource sites would be expected to be most affected by 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 vegetation in the area. Deeply buried sites are less likely to suffer mechanical effects (Malof 1999).

Mechanical impacts on artifact assemblages within a site may occur through repeated exposure to wet and dry conditions. Ceramic artifacts, bone, pollen, and shell will be most adversely impacted during these cycles. Stone artifacts would be expected to better withstand these processes, though mechanical impacts may produce the appearance of use wear or erase legitimate evidence of usage (Malof 1999). Wetting and drying episodes in areas with clay soils can have dramatic effects on buried artifacts (Butzer 1982). Expandable clays swell when wet and contract when dry, with the result that rocks and artifacts are mixed laterally and pushed upward by selective swelling adjacent to solid objects. Over time, swelling and contracting episodes can rearrange entire subsurface archeological horizons.

Biochemical impacts result when water inundates a terrestrial site. Cultural resources most susceptible to biochemical change are those composed of wood, bone, pollen, and seeds. Stone artifacts are expected to be least affected. Without full-scale mitigation of individual sites, it is difficult to minimize the consequences of biochemical processes (Malof 1999).

The Comal and San Marcos River systems are prone to flooding events (see Section 3.1.1.1) that may result in inundation and mechanical impacts to cultural resources. These naturally occurring events are expected to be more severe and to generate more significant impacts to archaeological and historical resources in the area than the effects of any actions associated with the alternatives being considered.

It is important to note that any of the alternatives being considered have the potential to impact undiscovered cultural resources in the area, such as those that may lie in undisturbed river bank deposits. In instances in which new sites or newly discovered impacts are identified, it is expected that an assessment would be necessary to effectively mitigate any adverse effects in compliance with Chapter 26 of the THC’s Rules of Practice and Procedure for the ACT.

4.5.1 Alternative 1: No Action

Under Alternative 1 the probability of direct human impacts including collecting and looting exists because these locations may become exposed or more accessible during periods of drought and low flows. Sites adjacent to Comal Springs, Landa Lake, and the Comal River would be more likely to be impacted than sites associated with the San Marcos system due to the very low or cessation of flow projected to occur at these locations during DOR-like conditions. Mechanical and biochemical impacts are not anticipated to result from Alternative 1 activities.

4.5.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Springflow simulations of Alternative 2 actions over the period of record show continued flows even during the most severe conditions simulated, though at reduced flow rates that may expose or facilitate access to cultural resource sites, especially in the Comal system. Reductions in flow that could expose or provide access to sites would also be expected at San Marcos, but to a lesser extent than expected in the Comal. The frequency and degree of human impacts expected under Alternative 2 would be lower than those expected under Alternative 1. Mechanical and biochemical impacts are not anticipated to result from Alternative 2 activities.

Other human impacts to cultural resource sites could result from riparian restoration activities proposed under Alternative 2. Applicants are required under state law to comply with Texas Historic Commission regulations and comply with the standards of the ACT to protect and mitigate any adverse impacts to cultural resources. In the event that previously unidentified cultural resources are located or unanticipated impacts to archaeological or historical resources occur under Alternative 2, the Applicants would be required address these effects under the Secretary of the Interior’s Standards and Guidelines for Archeology and Historic Preservation in coordination with the Texas SHPO in compliance with Section 106 of the NHPA (1966, as amended) and the ACT.

4.5.3 Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 actions would be expected to result in effects similar to those described for Alternative 2 at the identified sites. The construction, operation, and maintenance of water transmission lines and other associated infrastructure proposed under Alternative 3 could have impacts to other cultural resource sites. Until transmission line site and construction plans are provided, it is not possible to assess potential impacts associated with these activities. If Alternative 3 is selected, additional potential cultural resource impact analyses will be required to ensure compliance with state and federal regulations.

In the event that previously unidentified cultural resources are located or unanticipated impacts to archaeological or historical resources occur under Alternative 3, the Applicants would be required address these effects under the Secretary of the Interior’s Standards and Guidelines for Archeology and Historic Preservation in coordination with the Texas SHPO in compliance with Section 106 of the NHPA (1966, as amended) and the ACT.

4.5.4 Alternative 4: Highest CPM Pumping Restriction

The continual flows at both Comal and San Marcos Springs expected under Alternative 4 reduce the threat of human impacts arising from exposure or facilitated access to cultural sites. The expected increased flow levels in both of these systems may expose cultural resource sites now associated with dry terrace deposits to increased biochemical effects and mechanical effects resulting from inundation and erosion processes.

4.6 AIR QUALITY

4.6.1 Local and Regional Air Quality

No direct or indirect effects on local or regional air quality within the study area are expected from any of the proposed alternatives.

4.6.2 Greenhouse Gas Emissions

4.6.2.1 Alternative 1: No Action

Alternative 1 does not include any construction or other activities that would be expected to produce GHG emissions.

4.6.2.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 actions rely largely on existing infrastructure, though some activities such as riparian restoration efforts or travel to and from spring sites to perform water quality analysis may contribute some GHG emissions. These emissions would likely be limited to the use of hand tools or heavy equipment and would be temporary in duration.

4.6.2.3 Alternative 3: Expanded ASR with Associated Infrastructure

Actions proposed in Alternative 3 include construction and operation of a water transmission pipeline from the SAWS Twin Oaks ASR facility in southern Bexar County to recharge features in central Comal County. These construction-related GHG emissions (such as those anticipated from heavy equipment) would be generated at the construction site and would be temporary in nature because these would be generated only during the initial build-out phase of the project. Operation of the pipeline would be expected to generate GHG emissions throughout the term of the permit as energy is used to pump water from the SAWS ASR facility to the recharge features. These emissions would be generated at power plants supplying the energy needed to operate the system. The interconnected nature of the power grid in Texas makes it difficult to determine which generation source may be associated with operations at any given time. An unquantified amount of GHG emissions would be expected to result from ongoing operations of the activities considered in Alternative 3.

4.6.2.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 does not include any construction or other activities expected to generate GHG emissions in the study area.

4.7 CUMULATIVE EFFECTS

Cumulative effects are defined by the CEQ as "the impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR 1508.7). "Reasonably foreseeable" for the purposes of this document means actions that are likely or probable, rather than merely possible, through approximately 2030 in consideration of the proposed permit term.

A meaningful analysis of cumulative effects describes the area in which the effects of the proposed project will be felt; the impacts that are expected in that area from the proposed project; other actions past, proposed and reasonably foreseeable that have had or are expected to have impacts in the same area; the impacts or expected impacts from these and other actions; and the overall impact that can be expected if the individual impacts are allowed to accumulate.

The considered alternatives would each be anticipated to generate effects within the study area (see Section 2.1.1), and these impacts have been described in Sections 4.1 through 4.6 of this DEIS. The remaining elements constituting a cumulative effects analysis are described for each alternative below.

4.7.1 Identification of Past, Present and Reasonably Foreseeable Future Actions

The potential for transportation projects currently planned or under construction in the study area to generate cumulative effects to the natural and human environment was identified by stakeholders during the scoping process described in Chapter 1. Projects such as the U.S. Route 281 (US-281) north/Loop 1604 Interchange, the New Braunfels Outer Loop, and the Lone Star Rail project; and transportation improvement projects such as US-281 North, Loop 1604, and Interstate 35 North are being developed in response to rapid population growth and accompanying urban and suburban development. It is beyond the scope of this evaluation to analyze each of these transportation projects on an individual basis, but the cumulative effects of transportation projects are considered as for their potential to generate significant effects to the environment.

Table 4-4 identifies recent, ongoing, and reasonably foreseeable transportation projects within the study area. This table is not intended to be an exhaustive or all-inclusive list of actions, but represents projects that may affect resources impacted by the alternatives under consideration.

Table 4-4. Recent, Ongoing and Future Transportation Projects.

PROJECT NAME	DEVELOPMENT ENTITY (OR TRANSPORTATION PLAN)	PROJECT DESCRIPTION	BUILD TIMEFRAME	LOCATION
IH-10 West, Loop 1604 to South of Huebner Road	TxDOT (in San Antonio-Bexar County MPO TIP 2011–2014 Draft)	Expand Six- to Eight-Lane Expressway and Operational Improvements	09/2010 Let Date	Bexar County
IH-10 West at Loop 1604	TxDOT (in San Antonio-Bexar County MPO TIP 2008–2011) Not in 2011–2014 Draft TIP	Reconstruct Interchange and Add Four Toll Lanes from IH-10 to Northwest Military Highway	01/2011 Let Date	Bexar County
US-281 at Loop 1604	Alamo Regional Mobility Authority (RMA) (in San Antonio-Bexar County MPO TIP 2008–2011) Not in 2011–2014 Draft TIP	Reconstruct Interchange with Toll Connectors and Add Four Toll Lanes from Stone Oak to Redland	01/2011 Let Date 2010–2013 Construction	Bexar County
US-281 at Wurzbach Parkway	TxDOT (in San Antonio-Bexar County MPO TIP 2008–2011)	Construct Interchange at New Location	01/2011 Let Date	Bexar County
US-281, 0.2 mi North of Loop 1604 to Bexar / Comal County Line	Alamo RMA (in San Antonio-Bexar County MPO TIP 2011–2014)	Expand to Six-Lane Expressway, with Six New Toll Lanes, Non-Toll Outer Lanes	01/2013 Let Date	Bexar County
Loop 1604, Northwest Military Highway to Redland Road	Alamo RMA (in San Antonio-Bexar County MPO TIP 2011–2014 Draft)	Expand from Four- to Eight-Lane Expressway, with Four New Toll Lanes and Non-Toll Outer Lanes	01/2014 Let Date	Bexar County
Loop 1604, SH-16 to Northwest Military Highway	Alamo RMA (in San Antonio-Bexar County MPO TIP 2011–2014 Draft)	Expand from Four- to Eight-Lane Expressway, with Four New Toll Lanes and Non-Toll Outer Lanes, Including Toll Connectors at IH-10	01/2013 Let Date	Bexar County
Austin-San Antonio Passenger Rail (Lone Star Rail)	ASAICRD / Lone Star Rail District (in San Antonio-Bexar County MPO TIP 2011–2014 Draft)	Final Design, ROW, and Construction (Platforms, Stations, Track)	09/2112 and 09/2013 Let Dates	Williamson, Travis, Hays, Comal, and Bexar Counties
US-281 Transit Facility (Park and Ride)	VIA Metro Transit (in San Antonio-Bexar County MPO TIP 2011–2014 Draft)	Site Acquisition (Future Construction of Park and Ride Facility)	2014 (Apportionment Year for Land Acquisition)	Bexar County
Northeast Transfer Center –Naco Pass	VIA Metro Transit (in San Antonio-Bexar County MPO TIP 2011–2014 Draft)	Site Acquisition (Future Construction of Transit Center)	2011 (Apportionment Year)	Bexar County
Loop 1604 at US-281 Interchange Design-Build	Alamo RMA	Construct Interchange with Non-Toll Direct Connectors	2010–2013 Construction	Bexar County
US-281 Superstreet Project	Alamo RMA	Superstreet Concept Operational Improvements	2010–2011	Bexar County
US-281 in Comal County	Comal County Major Thoroughfare Plan	Controlled Access Freeway	Undetermined	Comal County

Table 4-4. (Cont.).

PROJECT NAME	DEVELOPMENT ENTITY (OR TRANSPORTATION PLAN)	PROJECT DESCRIPTION	BUILD TIMEFRAME	LOCATION
SH-46, from FM 2722 to Comal/ Kendall County Line	Comal County Major Thoroughfare Plan	Upgrade to Super Arterial	Undetermined	Comal County
FM 306, FM 2793, FM 2722, FM 3159, FM 1863 (East of US-281), and FM 3351	Comal County Major Thoroughfare Plan	Upgrades to Primary Arterials	Undetermined	Comal County
FM 32, FM 311, and FM 484	Comal County Major Thoroughfare Plan	Upgrades to Secondary Arterials	Undetermined	Comal County
SH-130 Toll Road, Segments 5 and 6	TxDOT, SH-130 Concession Company, LLC	41-mi Four- to Six-Lane Toll Road, with 17 mi of Untolled Frontage Roads	Late 2012 Expected Operational	Travis, Caldwell, and Guadalupe Counties
New Braunfels Outer Loop	City of New Braunfels (Thoroughfare Plan)	To Be Determined	Routing Studies Underway	Comal and Guadalupe Counties
IH-35 Corridor Expansion	Alamo RMA	Upgrade IH-35 Corridor from Comal County Line to Loop 410 in San Antonio	Undetermined	Comal and Bexar Counties
FM 110	TxDOT/Hays County (in CAMPO 2035 Plan [CAMPO 2010])	New Four-Lane Divided Roadway from IH-35 to SH-123	Late 2012	Hays County
FM 1626, RM 12, US-290, SH-21, SH-123, FM 110, RM 150W, Old Bastrop Highway, FM 2001, FM 2770, RM 967	TxDOT/Hays County (in CAMPO 2035 Plan [CAMPO 2010])	Upgrade to Existing Arterial	Undetermined	Hays County
Arterial Road 30	San Marcos	Construct New Four-Lane Major Divided Arterial from Posey Road to SH-280/ SH-21	2025	Hays County
SH-211	Alamo RMA	Construct Two-Lane Rural Highway from Medina County into San Antonio	2013	Medina and Bexar Counties
FM 471	Alamo RMA	Widen Existing Two-Lane Road to Four Lanes; Kallison Lane to FM 1560	2014	Bexar County

Concerns related to water supplies in the region and the relationship between projected increased demand and limited supplies were identified by the public during the scoping process. A number of water supply projects underway or reasonably foreseeable in the study area may address or contribute to these concerns and are identified in Table 4-5. This table is not exhaustive or all-inclusive, but represents examples of recent, ongoing, and reasonably foreseeable actions within the study area. These projects may impact resources affected by the alternatives considered thereby generating cumulative effects.

Table 4-5. Ongoing and Future Actions – Water Supply Infrastructure Projects.

PROJECT NAME	DEVELOPMENT OR PLANNING ENTITY	PROJECT DESCRIPTION	BUILD TIMEFRAME	LOCATION
Bulverde Regional Water Master Plan	Canyon Lake Water Service Company	Plan to provide domestic water service to numerous parcels in southern Comal County	Undetermined / Ongoing	Between Bexar County Line in South, Kendall County Line in West, FM 3009 in East, and Areas to the North of SH-46
Storage Above Canyon Reservoir	GBRA	An ASR or OCR	Implemented prior to 2020	Unspecified Location above Canyon Reservoir, Comal and Kendall Counties
Western Canyon WTP Expansion	GBRA	Future expansion of the Western Canyon WTP	Implemented prior to 2050 per TWDB Region L plan	Existing Water Treatment Plant Expansion in Comal County
Edwards Aquifer – Carrizo/Wilcox Aquifer Transfers (Twin Oaks ASR)	SAWS	An operational ASR program involving transfers between the two aquifers	Operational, Ongoing	SAWS Service Area
Edwards Aquifer Recharge Initiative - Type 1 and Type 2 Projects	SAWS, with GBRA, SARA, EAA, USACE Nueces RA, City of Corpus Christi also for Nueces Basin	Edwards Aquifer recharge enhancement from upstream runoff detention (Type 1) and temporary channel impoundments (Type 2)	Cibolo: 2010+ Nueces: 2012+	Cibolo Watershed Nueces River Basin
Western Canyon WS for SAWS	SAWS, GBRA, Cities of Boerne, Fair Oaks, Bulverde, and Johnson Ranch, Cordillera Ranch, Tapatio Springs/ Kendall County Utility Co., and Comal Trace Subdivision.	Utilization of water supply from Canyon Lake; includes Winwood Tank and Oliver Ranch water storage facilities	Ongoing	Participating Cities and Developments in Bexar, Comal, and Kendall Counties
Trinity Aquifer WS for SAWS	SAWS, Oliver Ranch, Bulverde Sneckner Ranch	Provides water supply to SAWS from Trinity Aquifer withdrawals; augments water supply for most of the AOI	Contract Terms through 2024	Serves Large Areas North of 1604 and West of US-281, Bexar County
Brackish Ground Water Desalination	SAWS	Treatment of water from the brackish zone of the Wilcox Aquifer	Potential Operations 2011+	SAWS Service Area
Regional Carrizo Water Supply	SAWS	Development of a pipeline to transfer water supply from Gonzales and Wilson Counties	2015	SAWS Service Area

In addition to the projects identified here, the South Central Texas Regional Water Planning Group (SCTRWPG) identified management strategies projected to meet future regional water supply needs (SCTRWPG 2010). Recommendations included reducing demand; irrigation transfers; development of the Carrizo, Simsboro and Trinity Aquifers; recycling; desalination; ASR; Aquifer recharge projects; and others. Implementation of these strategies would require both intra- and inter-basin water diversions, development of diversion structures, pump stations, pipelines, well fields, recharge enhancement structures, water treatment plants, and other related infrastructure. Though these strategies have been proposed, the SCTRWPG does not include funding assurances or mechanisms to secure funds to initiate any projects identified in the plan. These projects are not therefore considered reasonably foreseeable during the term of the proposed permit.

Public concerns were expressed during the scoping process about the potential cumulative effects of development over the Edwards Aquifer Recharge Zone. Private and public land development projects may have the potential to impact resources affected by one or more of the alternatives. Though not all-inclusive, Table 4-6 provides examples of land development projects in the study area that are recent, ongoing, or reasonably foreseeable.

Several existing or pending resource management programs and HCPs may have effects cumulative to the actions associated with the alternatives considered here. Public comments collected throughout the scoping process identified existing and proposed conservation efforts contributing beneficial cumulative effects as important considerations in the analysis of the proposed action. Table 4-7 identifies past, ongoing or reasonably foreseeable resource management programs or conservation efforts within the study area that may have effects cumulative to those resulting from the proposed alternatives.

4.7.1.1 Anticipated Cumulative Effects of Identified Past, Present, or Reasonably Foreseeable Future Actions on Affected Resources

The anticipated impacts to resources affected by the proposed alternatives associated with identified past, present or reasonably foreseeable future actions; and the overall impact that would be expected if these individual impacts accumulated are described by resource category below.

4.7.2 Physical Environment: Climate, Geology and Soils

Climate and geology are not anticipated to be affected in any significant way by the considered alternatives (see Sections 4.1.1 and 4.1.2), or by past, present, or reasonably foreseeable actions. No cumulative effects to climate or geology are therefore expected.

Soils may be affected by actions proposed under the alternatives considered (see Section 4.1.3), and potential cumulative effects are described below by alternative.

Table 4-6. Recent, Ongoing, and Future Private and Public Land Development Projects.

PROJECT NAME	DEVELOPMENT OR PLANNING ENTITY	PROJECT DESCRIPTION	BUILD TIMEFRAME	LOCATION
Bulverde Oaks	Various	Master Plan with greater than 19,000 SF lots total	Ongoing	Bulverde Road, North Bexar County
Four S Ranch	Undetermined	780-acre (316-hectare) Master Plan with 1,800 platted lots	2010+	Smithson Valley Road, Comal County
Johnson Ranch	Undetermined	Master Plan, approximately 500 acres (202 hectares) with 1,025 platted lots with retail center	2010+	East of US-281, North of FM 1863, Comal County
McCarty Ranch	Undetermined	Approximately 400 acres (162 hectares)	To Be Determined	West of US-281, North of FM 1863, Comal County
Unnamed Subdivision	Undetermined	Approximately 3,000 acres (1,214 hectares)	Partially Built/ Ongoing	Northwest of Ammann Road at FM 1863, Comal County
Smithson Valley High	Comal ISD	Extensive renovation and expansion; capacity 2,575 students	2009–2011+	SH-46, West of FM 3159, Comal County
Smithson Valley Middle School	Comal ISD	Expansion; capacity 1,150 students	2010	FM 311 North of SH-46, Comal County
Spring Branch Middle School	Comal ISD	Expansion; capacity 1,150 students	2010	SH-46, West of US-281, Comal County
Rahe Bulverde Elementary	Comal ISD	New school facilities for additional space and to combine two existing schools; capacity 824 students	2010	East Ammann Road, Comal County
New Elementary at Indian Springs	Comal ISD	New school; capacity 824 students	2011	Southeast of Smithson Valley Road at Bulverde Road, Comal County
New High School, New Middle School and New Elementary School at Kinder Tract	Comal ISD	Up to three new schools	2011+	Borgfield at Bulverde Road, Comal County
New Elementary School	Northeast ISD	New school to be developed on 21-acre (8-hectare) tract in Bulverde Oaks	2010+	Near Bulverde Road, Comal County

Table 4-7. Recent, Ongoing, and Future Natural Resource Management Programs.

PROJECT NAME	DEVELOPMENT OR PLANNING ENTITY	PROGRAM DESCRIPTION	IMPLEMENTATION TIMEFRAME
Hays County Regional HCP	Hays County	Protection of habitat for BCVI and GCWA	Ongoing
Comal County Regional HCP	Comal County	Protection of habitat for BCVI and GCWA	Under Development for Future Implementation
Southern Edwards Plateau Regional HCP	Bexar County and City of San Antonio	Protection of BCVI, GCWA, and nine karst species	Under Development for Future Implementation
Project Specific HCPs, Management and Recovery Plans (e.g., Camp Bullis Karst Species Recovery Plan; GCSNA Karst Management and Recovery Plan)	Various entities	Conservation and management of sensitive species and habitats including habitat for endangered and threatened species	Ongoing
Biological Opinion for Bexar County Military Installations	U.S. Department of Defense	Protection of endangered species	Ongoing
Sensitive Land Acquisition	SAWS in Partnership with Nature Conservancy, Trust for Public Land, Bexar Land Trust, Texas Cave Management Association	Water Supply Fee-funded program for protection of geologically sensitive areas, point recharge features, using Conservation Easements and Fee Simple land acquisitions; 9,140 acres (3,699 hectares) preserved at GCSNA, Davis Ranch, Stone Oak Park, Annandale Ranch	Ongoing
City of San Antonio Edwards Aquifer Protection	City of San Antonio	An initiative currently implemented by the City of San Antonio to protect the Aquifer by acquiring sensitive and irreplaceable land located over its recharge and contributing zones. Funding is provided by Proposition 3 (2000) and Proposition 1 (2005). Over 54,000 acres (21,853 hectares) have been acquired and protected.	Ongoing
Recreation Management on Comal River	WORD	Organization to protect river and promote more environmentally sensitive behavior among recreational users	Ongoing
Landscape Conservation Cooperatives	USDI	LCCs are conservation efforts at the landscape level to use management-science partnerships to address climate change and other stressors within and across landscapes	To Be Determined
Property Tax Incentives (Ag and Wildlife Exemptions)	County Appraisal Districts – often in Conjunction with TPWD Biologists	Programs which lower taxes on lands managed for agriculture or wildlife production	Ongoing
Landowner Conservation Assistance and Safe Harbor Programs	Environmental Defense Fund (EDF)	GCWA habitat protection based in counties primarily in Edwards Plateau; EDF program addresses private land, seeks to steadily improve relationships with landowners. EDF has enrolled 80 Central Texas landowners (120,000 acres [48,562 hectares] of ranch)	Ongoing
Edwards Aquifer Protection	SAWS	Development review and regulation over the Edwards Aquifer Recharge and Contributing Zones; wellhead protection program, abandoned well program	Ongoing

Table 4-7. (Cont.).

PROJECT NAME	DEVELOPMENT OR PLANNING ENTITY	PROGRAM DESCRIPTION	IMPLEMENTATION TIMEFRAME
Edwards Aquifer Rules and Protection Program	TCEQ	Includes permitting and requires BMPs; Rules apply to the Edwards Aquifer Contributing, Recharge and Transition Zones	Ongoing
Programs to Acquire Sensitive or Threatened Landscapes	Texas Nature Conservancy, Trust for Public Lands, Bexar Land Trust, Green Spaces Alliance of South Texas, Other NGO and Private Land Trusts	Program based on use of inheritance tax rules or other financial incentives	Ongoing
Species Specific Recovery Plans	The Service	Recovery goals established in GCWA, BCVI and Karst Invertebrate Recovery Plans (for example)	Ongoing
Safe Harbor Program	The Service	Endangered species habitat restoration projects usually on private lands to both assist species and protect landowners from future exposure to non-compliance	Ongoing

4.7.2.1 Alternative 1: No Action

Transportation project-related cumulative impacts to soils would be expected to be minimal or negligible during normal rainfall and precipitation conditions because soils affected by Alternative 1 actions exhibit only slight to moderate potential for water erosion. Impacts to these soils may occur, however, during drought conditions. These impacts may include the effects of increased erosion of soils and stream sediments when declining springflow levels expose these substrates to drying or periods of drying and wetting. Transportation project-related effects to soils could occur during drought conditions during the construction, operations and maintenance phases of projects within the Comal and San Marcos River watersheds. Close adherence to construction and operational BMPs can minimize these impacts, though some residual effects may be expected.

Some water supply infrastructure projects may allow for diversification of water supplies by communities currently addressing municipal or industrial needs with water pumped from the Edwards Aquifer. If these projects result in reductions in demand for water pumped from the Edwards Aquifer, springflow levels may not drop to levels generating negative effects to soils and stream sediments. Construction and maintenance of water infrastructure projects within the Comal and San Marcos River watersheds, however, could generate negative impacts to soils similar to those expected from transportation projects described previously. Use of BMPs during construction, operation, and maintenance of these projects can help minimize adverse effects, though some residual effects may be expected.

Public and private land development activities within the Comal and San Marcos watersheds could impact soils under Alternative 1. The most significant effects would be expected from construction or development most closely associated with riparian areas near the Comal and San Marcos Rivers and their tributaries. Effects would be expected to be similar to those described above, with minimization efforts including BMPs that would be expected to reduce but not completely eliminate negative impacts.

Existing and reasonably foreseeable natural resource management efforts may yield beneficial effects to soils under Alternative 1. Some of these projects limit development and associated impervious cover by acquiring sensitive lands or establishing conservation easements over the recharge zone that ensure that these areas continue to function as inflow areas that serve to recharge the Edwards Aquifer. This additional recharge could support springflows and minimize the effects of drought conditions on soils and stream sediments. Other efforts employ regulatory approaches that could generate similar protective benefits to soils that could be impacted by Alternative 1 actions.

4.7.2.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cumulative effects from past, present, and reasonably foreseeable future actions could result under this alternative, though they would be expected to be less significant than those anticipated under Alternative 1.

Transportation project-related soil impacts could occur from the same sources identified under Alternative 1, though the anticipated effects of these impacts would be reduced by the continual springflows expected under Alternative 2. The continual springflows would not expose soils and stream sediments to the drying or periods of wetting and drying that would leave them most susceptible to erosion. Use of BMPs during construction, operation, and maintenance of these projects can help minimize adverse effects, though some residual effects may be expected.

Cumulative effects to soils from water supply infrastructure projects would be expected to be similar under Alternative 2 as those described for Alternative 1. Projects within the Comal and San Marcos River watersheds may result in negative construction and maintenance related soil impacts similar to those expected from transportation projects described previously. Close adherence to construction and operational BMPs can minimize anticipated impacts, though some residual effects may be expected.

Cumulative soil impacts associated with past, present, and reasonably foreseeable future land development activities and natural resource management efforts for Alternative 2 would be similar to those described under Alternative 1.

4.7.2.3 Alternative 3: Expanded ASR with Associated Infrastructure

Cumulative effects to soils could result under Alternative 3, with impacts expected to be similar to those anticipated under Alternative 2. The springflows expected under the actions associated with this alternative reduce soil drying and resulting potential erosion risks to a greater degree than Alternative 2.

4.7.2.4 Alternative 4: Highest CPM Pumping Restriction

Cumulative effects similar to those expected under Alternatives 2 and 3 could occur, though the higher expected springflow rates remove the erosion risks associated with drying of soils and stream sediments under Alternative 4.

4.7.3 Aquifer-Fed Springs

The discharge of the springs at Comal and San Marcos could be affected by past, present, or reasonably foreseeable future actions associated with transportation projects, water supply infrastructure projects, public and private land development, and natural resource management actions within the study area. The cumulative results of these actions when added to the impacts of effects expected from each of the alternatives considered (see Sections 4.2.1 and 4.2.2) are described below.

4.7.3.1 Alternative 1: No Action

Transportation projects over the contributing and recharge zones of the Edwards Aquifer could impact Aquifer recharge and thereby affect springflow. While the overall area affected by these projects represent a small percentage of the total study area, individual recharge sites that contribute significant recharge capacity can be affected by relatively small changes in surface contours, impervious surfaces, or vegetative cover. Alterations to recharge capacity or function could reduce inflows into the Edwards Aquifer and adversely impact springflows. Under a repeat of DOR-like conditions, Alternative 1 is expected to have significant adverse effects to flows from both Comal and San Marcos Springs. The cumulative effects of reduced recharge capacity could result in further negative effects to springflows. Careful project design that identifies and avoids or provides adequate buffer zones around such recharge features throughout the study area can minimize the effects of these impacts.

Water infrastructure projects may have beneficial effects to Edwards Aquifer springflows. Projects that result in diversified water supplies or reduced demand for Edwards Aquifer water near Comal and San Marcos Springs may allow for increased Aquifer levels that would support springflows. These effects might offset somewhat the adverse effects to springflow expected to result under Alternative 1. Recharge enhancement structures within the contributing zone have been proposed to store surface water runoff for later release into the recharge zone. Proposed reservoirs within the recharge zone would impound surface water runoff to directly recharge the Edwards Aquifer. During periods of normal or high precipitation, these structures could provide some additional recharge that would support the Aquifer-fed springs. Such structures would only be expected to provide these benefits, however, when adequate precipitation provides surface flows to be impounded and stored for these uses. During DOR-like conditions, these structures are anticipated to be of little value to Edwards Aquifer recharge or springflow, and would be expected to have little cumulative effect to Alternative 1 actions.

Past, present, or reasonably foreseeable private and public land development activities could adversely affect springflows through various actions. Development that negatively affects recharge features through such actions as alteration of land contours or increasing impervious cover can result in reduced Edwards Aquifer inflows in much the same way as transportation projects. Development projects that generate additional demand for Edwards Aquifer water could reduce water volumes available for springflow. In combination with Alternative 1 actions that are expected to reduce springflows during drought conditions, these effects would be expected to result in further negative cumulative effects. Private or public land development that does not rely on Edwards Aquifer water would be expected to minimize this negative impact.

Some natural resource management actions within the study area could provide cumulative effects benefitting springflows. Some past, present and reasonably foreseeable projects seek to ensure that recharge features continue to provide Edwards Aquifer inflows through voluntary conservation efforts or by way of municipal, county, or state-mandated regulatory measures. The efforts of non-governmental organizations (NGOs) such as the Bexar Land Trust, the Nature Conservancy, Texas Cave Management Association, and the Trust for Public Land, among others, to acquire or put legal mechanisms in place to conserve lands over the recharge and contributing zones have and are expected to continue to contribute to Edwards Aquifer recharge and springflows. Regulatory approaches such as City of San Antonio impervious cover limitations and TCEQ regulations regarding activities over the Edwards Aquifer further protect recharge and enhance springflows. Public education and outreach programs such as those employed by SAWS and the EAA that reduce demand for pumped Edwards Aquifer water also support increased springflows, though by an unquantifiable amount. These impacts contribute to Edwards Aquifer recharge and springflows that may offset somewhat the adverse effects anticipated during drought conditions under this alternative.

4.7.3.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

The cumulative effects of transportation projects, water infrastructure projects, land development and natural resource management actions to Aquifer-fed springflows under Alternative 2 are expected to be similar to those described under Alternative 1.

4.7.3.3 Alternative 3: Expanded ASR with Associated Infrastructure

Past, present and reasonably foreseeable future actions leading to cumulative effects with actions proposed under Alternative 3 are generally expected to be similar to those under Alternative 2.

4.7.3.4 Alternative 4: Highest CPM Pumping Restriction

The cumulative effects of transportation projects would be expected to have a less adverse effect under Alternative 4 than under the other alternatives considered because springflows under this option are not expected to drop significantly even during the most severe DOR-like conditions. Recharge and infiltration capacities could still be adversely affected by these projects as described for Alternatives 1, 2, and 3, but the cumulative effect to overall springflow when considered with the actions proposed under Alternative 4 reduces the magnitude of the negative effects of these activities. Careful site selection and adherence to relevant BMPs would further reduce the potential of these projects to generate negative cumulative effects in the study area.

Alternative 4 would require development of alternative water sources to meet human needs throughout the study area. Creation of such new supplies and associated infrastructure could have impacts to springflows. The location and type of alternate water supply and where the associated infrastructure is constructed could generate negative cumulative impacts. There are no current plans to develop alternative supplies of the magnitude needed to meet the demand created under this alternative, so the extent of these impacts cannot be determined given information currently available.

Past, present, and reasonably foreseeable future land development and natural resource management actions would be expected to generate cumulative effects similar to those anticipated under the other considered alternatives.

4.7.4 Surface Water Flows in the Guadalupe, San Antonio, and Nueces River Basins

Surface water impacts associated with the various alternatives, including effects to downstream segments of the affected river basins (see Section 4.2.2), may be affected by past, present, or reasonably foreseeable future actions that could result in cumulative effects. The potential effects are described below by alternative.

A detailed assessment of the effects associated with regional water use and management is beyond the scope of this assessment. The Region L Water Plan provides a detailed discussion of these topics and describes the implications of implementing regional water plan proposals, and is hereby incorporated by reference (SCTRWPG 2010).

4.7.4.1 Alternative 1: No Action

Surface waters within the study area could be adversely impacted during construction, operation, and maintenance of transportation projects. Transportation project-related activities can impact surface waters by altering short or long-term stream hydrology or morphology. Projects, for example, that alter degree of channelization through bridge or abutment construction can affect instream water velocities that reduce water residence times in downstream stream segments, thereby adversely affecting surface waters. Such actions could result in cumulative surface water impacts that exceed the effects of the Alternative 1 actions alone. Avoidance of projects that limit or alter stream heterogeneity and adherence to BMPs can help minimize the effects of these actions.

Ongoing and future water infrastructure projects such as the Bulverde Regional Water Master Plan and the SAWS brackish groundwater desalination project may reduce dependence on the Edwards Aquifer for some users. To the extent that reduction in demand for pumped Edwards Aquifer water may result in increased springflows and additional inputs to surface waters, these projects may benefit surface water resources within the affected river basins. Other current or future water supply infrastructure projects including SAWS use of Trinity Aquifer water supplies and GBRA proposals to store water in ASR facilities or in an off-channel reservoir (OCR) upstream of Canyon Reservoir may also benefit surface waters dependent on Edwards Aquifer springflows during drought conditions. These potentially beneficial impacts may help reduce the frequency and magnitude of adverse effects expected to result from Alternative 1 actions during periods of drought.

Public or private land development activities within the study area that generate additional water demand could negatively impact surface waters if this demand is met by drawing on existing surface water supplies or by drawing down Edwards Aquifer levels thereby reducing springflows that support these surface waters. The cumulative effect of these impacts when considered with the anticipated adverse Alternative 1 effects during drought conditions would be expected to generate significant negative effects to surface waters within the affected river basins. The resulting declines in instream flows during DOR-like conditions would be expected to have downstream effects throughout the middle and lower Guadalupe River to the estuaries at the Texas coast. Demonstrating that proposed new land development activities have provisions for alternate non-Aquifer sourced water supplies could reduce this potential impact.

Past, present and reasonably foreseeable future natural resource management activities within the study area could benefit surface waters impacted under Alternative 1 actions. Programs such as the SAWS Sensitive Lands Acquisition Program and the City of San Antonio's Aquifer protection measures; and incentives in state tax code that encourage landowners to manage their property to benefit wildlife could prevent or reduce some demand for pumped Edwards Aquifer water, thereby supporting springflows and surface waters. These impacts could help reduce the adverse effects anticipated during drought conditions under Alternative 1.

4.7.4.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cumulative effects from transportation projects, land development activities and natural resource management activities are generally expected to be similar under Alternative 2 as described under Alternative 1. The cumulative effect of water infrastructure projects that diversify supplies and reduce demand for Edwards Aquifer water could reduce the frequency and length of time under which CPM triggers and pumping restrictions proposed under Alternative 2 are in place, thereby resulting in a reduction of the severity of the effects of Alternative 2 actions alone.

4.7.4.3 Alternative 3: Expanded ASR with Associated Infrastructure

Cumulative effects from identified past, present, and reasonably foreseeable future transportation projects, land development and natural resource management actions would be expected to be similar to those anticipated under Alternative 2. The more restrictive CPM pumping requirements and anticipated increased Edwards Aquifer management fees associated with constructing the infrastructure proposed under this alternative may encourage some Edwards Aquifer water users to seek alternative or diversified supplies such as the water infrastructure projects being considered. The cumulative effects of these actions may reduce demand for Edwards Aquifer water somewhat, thus supporting springflows and receiving surface waters within the affected watersheds.

4.7.4.4 Alternative 4: Highest CPM Pumping Restriction

The additive effect of transportation projects, water infrastructure projects, land development, and natural resource management actions under Alternative 4 are anticipated to be generally similar to those described for Alternative 3. Implementation of this alternative would require development of new water supplies to meet agricultural, industrial, municipal, residential, and other water needs resulting from the 85 percent reduction in allowed Edwards Aquifer pumping during stage 1 CPM throughout the study area. The development of these new supplies and the infrastructure to deliver the needed water volumes is likely to affect surface waters within the study area. The cumulative effects of these impacts to surface waters in the affected river basins cannot be quantified given available information at this time.

4.7.5 Surface Water Quality in the Guadalupe, San Antonio, and Nueces River Basins

Surface water quality within the study area is associated with population growth and adverse effects may result from current, ongoing, or future actions within the study area. Projected population growth throughout the region is expected to result in greater urbanization and includes ongoing or planned transportation, water supply, and other development projects that may affect water quality. Urban and suburban development can increase the risk of water quality degradation associated with point and non-point source pollution. The cumulative effects of these actions with those proposed under the various alternatives considered (see Section 4.2.3) are presented below.

4.7.5.1 Alternative 1: No Action

Surface waters within the study area could be adversely impacted during construction, operation, and maintenance of transportation projects. These impacts could lead to cumulative effects associated with the results of actions considered under Alternative 1. Increased turbidity and siltation of surface streams could occur during the construction of transportation projects. Operation and maintenance activities can generate increased volumes of stormwater runoff from impervious roadway surfaces that may include bacteria, nutrients, heavy metals, petroleum hydrocarbons, and potential hazardous material spills that could degrade water quality. Such projects over the contributing and recharge zones of the Edwards Aquifer or that cross streams and rivers have the greatest potential to negatively affect water quality. Adherence to BMPs can minimize the risks associated with these impacts, though some adverse effects could continue to be expected. The low flows anticipated to result under this alternative during drought conditions could exacerbate adverse impacts resulting from these transportation-related effects. Low flows could permit accumulations and concentrations of runoff materials during drought periods. Conditions similar to those experienced during the DOR could result in stagnation of some segments of the Comal and San Marcos Rivers which would be negatively impacted by the cumulative effects associated with transportation projects.

Cumulative effects to surface water quality associated with water supply infrastructure could be anticipated during construction of these projects. Construction-related effects would be expected to be similar to those described for transportation projects, and would include negative impacts such as siltation, increased turbidity, and runoff. Compliance with regulatory standards and BMPs may reduce the effects of these impacts. To the extent that water supply projects reduce demand on Edwards Aquifer water, these projects may be beneficial to surface water quality within the study area. The additive effects of these actions when considered with those expected from the alternative being considered could yield a mixture of positive and negative effects. It should be noted that some transportation and water infrastructure projects may have the potential to induce additional growth and development.

Public and private land development may contribute to surface water quality impacts. Stream health and water quality are inversely correlated to the amount of impervious cover within a watershed. Water quality generally declines when impervious cover exceeds about 10 percent of a watershed's surface area (Klein 1979, Schueler 2000, Booth et al. 2001, Wang et al. 2001, and Dietz and Clausen 2008). Relationships between impervious cover and human population density suggest that impervious cover levels of about 10 percent are correlated with population densities of 500 to 900 persons per square mile (Exum et al. 2005). Population densities within in the study area therefore enable identification of areas where water quality affects are most likely to occur (see Section 3.5.6).

Urbanized areas associated with the city of Victoria are the only portions of the downstream region with population densities that likely contribute to water quality degradation. In the Eastern Region, adversely impacted surface water quality is associated with the average density of 1,375 persons per square mile in Bexar County. The average densities in Comal and Hays Counties range from 193 to 232 persons per square mile, though some areas exceed densities associated with water quality degradation. It is reasonable to conclude that future land development in areas with high densities today or those that could attain these densities may generate additional negative surface water quality impacts. The low flows anticipated under Alternative 1 during drought conditions combined with the adverse effects associated with population densities facilitated by land development could result in adverse cumulative surface water quality effects.

Cumulative surface water quality effects associated with Alternative 1 would be expected to be similar to those described for surface waters and Aquifer-fed springs. The effects of reducing impacts to recharge features and minimizing population densities over the contributing and recharge zones of the Edwards Aquifer are anticipated to have beneficial effects to surface water quality. These beneficial effects would be expected to support surface water quality anticipated to be negatively affected by the actions considered in Alternative 1.

4.7.5.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cumulative transportation project-related, water supply, land development, and natural resource management effects would be expected to improve surface water quality under Alternative 2 over levels expected under Alternative 1. Alternative 2 incorporates measures intended to monitor and reduce point and non-point sources expected to further reduce negative surface water quality impacts. The continual flows during drought conditions would provide some dilution of pollutants and reduce accumulation and concentration of runoff materials, though some of these effects might still be expected. The combination of active pollution reduction measures with increased flows would be expected to maintain higher surface water quality than anticipated under Alternative 1 actions.

4.7.5.3 Alternative 3: Expanded ASR with Associated Infrastructure

Past, present, and reasonably foreseeable future projects or actions in conjunction with Alternative 3 actions would yield similar surface water quality impacts to those described for Alternative 2. Alternative 3 incorporates active monitoring and point and non-point source measures similar to those described above, and the somewhat higher springflows expected under Alternative 3 actions would provide greater dilution of pollutants. The more restrictive CPM restrictions and anticipated increased costs associated with implementing Alternative 3 actions may increase the viability of alternate water supplies that could reduce demand on Edwards Aquifer supplies, further supporting surface water quality in the study area.

4.7.5.4 Alternative 4: Highest CPM Pumping Restriction

Identified effects would be expected to have a reduced impact to surface water quality due to the high flow volumes anticipated to result under Alternative 4 actions. Though this alternative does not incorporate the pollution control measures proposed under Alternatives 2 and 3, the much higher in-stream flows would be anticipated to minimize residence times of pollutants and runoff materials and provide much greater dilution effects. Meeting the human water needs throughout the region under the restrictions under this alternative, however, would require development of new or alternative water sources that may have adverse impacts to surface water quality. Until plans to provide such alternative water supplies can be reviewed, the total cumulative effects to surface water quality cannot be determined.

4.7.6 Groundwater Quality

Some groundwater quality effects are the result of past transportation, water supply, and land development actions. Existing and ongoing development in some San Antonio, New Braunfels and San Marcos watersheds have the greatest potential to directly affect the quality of recharge waters that could impact groundwater. Ongoing and future development associated with projected population growth could be reasonably expected to contribute to additional water quality impacts.

Groundwater quality could be affected through multiple potential pathways. Pollutants could flow directly into recharge features, or contaminated runoff from the contributing zone could be transported to the recharge zone where they could flow into the Edwards Aquifer. Groundwater quality in the study area is therefore largely dependent on the volume and quality of surface waters that recharge the Edwards Aquifer. The effects of past, present, and foreseeable future actions that may impact surface water volumes and quality are discussed in the sections above, and would be expected to generate similar cumulative impacts to groundwater quality as previously described for surface waters and surface water quality.

Because some inter-formational flow is believed to occur between the Trinity and Edwards Aquifers, similar impacts to water volume and quality in Trinity Aquifer source waters could influence groundwater quality in the Edwards Aquifer. The quantity and conditions under which such inter-formational flow occurs in this system is poorly understood, and the potential effects of this mixing cannot be calculated with any certainty given currently available information.

4.7.6.1 Alternative 1: No Action

Groundwater quality effects are not expected to be substantially influenced by actions proposed under this alternative, and no cumulative effects beyond those described above are anticipated.

4.7.6.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cumulative effects under Alternative 2 are expected to be similar to those described under Alternative 1.

4.7.6.3 Alternative 3: Expanded ASR with Associated Infrastructure

Groundwater quality effects under Alternative 3 would be expected to be similar to those described for Alternative 2.

4.7.6.4 Alternative 4: Highest CPM Pumping Restriction

Cumulative effects to groundwater quality would be moderated somewhat by the highest relative Edwards Aquifer levels and resulting increased dilution capacity expected under Alternative 4 actions. As described above, however, the effects of developing and providing new water supplies to meet regional water needs could result in additional unquantified negative cumulative effects.

4.7.7 Biological Resources

Many of the impacts stemming from past, present, and future actions could affect biological resources within the study area. Population projections within the study area indicate continued growth for the next 30 years and beyond. It is reasonable to conclude that impacts associated with transportation, water, and land development projects associated with this projected population growth could negatively affect native plants and wildlife. Impacts of these actions will likely affect both terrestrial and aquatic ecosystems and could result in habitat fragmentation and loss in the study area. Because the considered alternatives are expected to primarily impact aquatic ecosystems and the organisms that depend on them, the cumulative effects from other actions would likewise be focused on these systems and species. The following cumulative effects discussion, therefore, addresses only the terrestrial habitats and organisms likely to be affected by the effects of both identified potential impact sources and the alternatives.

4.7.7.1 Alternative 1: No Action

Biological resources could be affected by transportation projects, water supply infrastructure, and land development related impacts such as those associated with changes in impervious cover, alteration of stream hydrology and morphology, changes to in-stream flows, surface water quality impacts, and the effects of runoff. The potential adverse effects of these activities to biological resources and the habitats they depend on when combined with actions considered under Alternative 1 result in significant negative effects during severe drought conditions.

To the extent that impact sources may alter flow patterns or water quality parameters such as temperature, dissolved oxygen, or turbidity, surface flow-related species expected to be affected by actions under this alternative such as fountain darters, San Marcos salamanders, and Texas wild-rice, would experience additional adverse cumulative effects during drought conditions. Modeled flows during a repeat of DOR-like conditions at Comal Springs fall to zero for more than 3 years, and San Marcos springflows drop below the lowest ever recorded under Alternative 1. The additional adverse effects to habitats or water quality generated by other sources could significantly impact these species.

Water quality and flow pattern effects resulting from impact source actions could create negative cumulative effects to subterranean adapted species such as the Comal Springs dryopid beetle and the Comal Springs riffle beetle anticipated to experience habitat effects during Alternative 1 low flow or drying events at Comal Springs. Species such as the Texas blind salamander and Peck's Cave amphipod that are wholly aquatic could be affected by cumulative effects of impact source activities and declining Edwards Aquifer levels resulting from Alternative 1.

Populations of freshwater mussels such as the false spike, golden orb, Texas fatmucket (*Lampsilis bracteata*), and Texas pimpleback could experience cumulative effects resulting from impact sources described above and the actions considered under this alternative. Negative effects could result from project-related impacts such as siltation, increased turbidity, and water quality impacts in combination from reduced flows or cessation of flows during drought periods resulting from Alternative 1 actions. These cumulative effects could also impact biological resources associated with the Guadalupe Estuary, elevating potential risks to species affected by freshwater inflows under this alternative.

Because this alternative is anticipated to have little or no effect in the Nueces and San Antonio River systems, no effects from other activities are expected to create cumulative effects to biological resources associated with these ecosystems.

4.7.7.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cumulative effects resulting from impact sources and Alternative 2 activities are less severe for biological resources than those expected under Alternative 1. Edwards Aquifer management actions under this option are expected to ensure that springs continue to flow during a repeat of DOR-like conditions, thereby supporting surface-associated species to a much greater extent than Alternative 1. The continual flows expected under this alternative are expected to be beneficial for subterranean and wholly aquatic species such as Comal Springs dryopid beetle, Comal Springs riffle beetle, Texas blind salamander and Pack's Cave amphipod, as the risks of adverse habitat or water quality impacts associated with other projects are reduced.

Minimization and mitigation activities such as non-native plant and animal management, riparian restoration efforts, and RWCP water demand reductions are anticipated to provide beneficial effects to offset adverse impacts to flows and water quality that may result from other sources. These flows are expected to exceed historic conditions thereby maintaining habitat conditions and providing transport and dilution of potential contaminants that could result from other impact sources.

Though freshwater mussel populations may be affected by inputs from other sources, the continual flows and dilution and transport effects of Alternative 2 actions are anticipated to have offsetting cumulative effects. The enhanced springflows and resulting freshwater inflows into the Guadalupe River and the Guadalupe Estuary are also anticipated to benefit biological resources in these habitats that may be otherwise impacted by past, present, or reasonably foreseeable future actions.

Populations of golden orb that may exist in the Nueces River basin may be negatively affected by transportation projects, water supply infrastructure, or land development actions by alterations in water flows or water quality impacts. Alternative 2 may generate some additional groundwater flows to the Nueces River system during drought conditions that may offset these outside effects to some degree thereby benefitting this species. This alternative is not expected to impact the San Antonio River system and no cumulative effects are therefore expected.

4.7.7.3 Alternative 3: Expanded ASR with Associated Infrastructure

Cumulative effects under Alternative 3 are generally expected to be similar to those described for Alternative 2 for the species considered. The effects associated with construction, operation and maintenance of the expanded ASR facility, water transmission line, and injection facilities could have cumulative effects with other activities that could impact biological resources. Because no pipeline route has been identified, the total cumulative effects expected under this alternative cannot be determined given available information.

4.7.7.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 springflows and water quality would be expected to most closely mimic pre-development conditions presumed to be most beneficial to the species associated with these habitats. The significant pumping reductions required to achieve these flows, however, would likely result in significant environmental impacts associated with providing alternate water supplies to the growing population in the region. Because plans for such alternate water supply and delivery have yet to be developed or reviewed, it is not possible to assess the magnitude of the potential adverse impacts that could occur cumulatively to those proposed under this alternative.

4.7.8 Socioeconomic Resources

Potential cumulative socioeconomic impacts resulting from the impacts or expected impacts from past, present, or expected future actions when combined with the anticipated effects of the various alternatives are presented below. Expected impacts are related primarily to employment and subsequent demographic changes.

4.7.8.1 Agriculture

Alternative 1: No Action

Economic factors such as increasing energy costs, fluctuating crop prices, and other market factors have contributed to trends in the declining number of acres under groundwater irrigation in the study area since the mid-1990s. Agricultural production and land use in the western, central, and eastern regions of the study area have reflected these trends in the conversion of previously irrigated farmland to livestock production and dryland farming techniques. These trends could have effects cumulative to those of Alternative 1 in the study area.

Water supply projects that reduce demand for Edwards Aquifer water or diversify water supplies in portions of the study area could provide supplemental water that is currently unavailable for agricultural uses.

Land development has had and is expected to continue to have an impact on agriculture in the study area. Population growth and resulting development pressures have converted lands from agricultural production to urban and suburban uses. Economic incentives offered to agricultural landowners to sell their lands for development often outweigh the income-generating capacity of individual agricultural enterprises.

Some natural resource management programs such as those operated by SAWS in partnership with NGOs such as the Nature Conservancy provide incentives for agricultural landowners in exchange for limiting some uses on their properties. These programs have primarily targeted lands in the recharge and contributing zones that provide for Edwards Aquifer inflows. These programs have allowed participating landowners to continue agricultural production in exchange for foregoing future development that could adversely impact water quality or quantities available for recharge.

The cumulative effects of the economic factors and land development pressures described above in combination with drought-triggered pumping restrictions under Alternative 1 could adversely impact agricultural production in the western, central, and eastern portions of the study area. These impacts would be expected to be most pronounced during times of drought.

Alternative 2: Proposed EARIP HCP, the Preferred Alternative

The cumulative effects of economic factors and land development pressures to pumping restrictions during drought conditions as described for Alternative 1 could adversely impact agricultural production in the western, central, and eastern regions of the study area under Alternative 2.

Alternative 2 actions such as the VISPO that offer financial incentives for farmers to suspend pumping during drought conditions and the new water market demand created by the Applicants' need to lease or otherwise acquire 50,000 ac-ft for storage in the ASR facility may provide beneficial effects cumulative to those identified for Alternative 1 in the western, central, and eastern regions of the study area. Downstream region agricultural production is beyond the jurisdiction of EAA CPM regulations, and would therefore not experience this effect cumulatively with the other economic and development pressures identified.

Alternative 3: Expanded ASR with Associated Infrastructure

Cumulative effects under Alternative 3 would generally be similar to those described above, though the more restrictive pumping limitations could adversely impact agricultural production during drought to a somewhat greater degree than would be expected under Alternative 2. Under this alternative the Applicants would lease or acquire up to 66,700 ac-ft of water for ASR storage, which would be expected to create additional water market demand that could benefit agricultural producers.

Alternative 4: Highest CPM Pumping Restriction

Cumulative effects from Alternative 4 actions could have significant impacts to agricultural producers. The 85 percent pumping reductions implemented under Stage 1 drought conditions would dramatically reduce the amount of water available for agriculture under these conditions. Economic factors and land development pressures cumulative to these impacts would be expected to have significant adverse effects to agriculture in the western, central, and eastern regions. The development of new alternative water supplies and construction of infrastructure required to meet water demands under this alternative would be expected to further adversely affect agriculture in the study area.

4.7.8.2 Employment and Demographics

Population growth in the study area is projected to continue, and may be facilitated or induced in part by actions such as transportation projects, water supply projects, and public and private land development activities. The effects of this projected growth and the resulting implications for economic and demographic conditions in the study area could, therefore, be cumulative to the effects expected under the alternatives being considered. Though various economic sectors throughout the study area may be expected to be affected by these cumulative impacts, the agricultural sector is anticipated to experience the most significant changes (see Section 4.4.2) and is therefore a focus of the discussion of alternatives below.

Alternative 1: No Action

Current population and associated employment trends would be expected to continue under this alternative during normal rainfall and recharge conditions. Alternative 1 CPM pumping limitations anticipated to affect agricultural production during drought conditions could result in cumulative demographic changes as agri-business workers seek employment in other areas or in other sectors of the economy.

Communities such as New Braunfels and San Marcos that rely on recreation and tourism employment associated with Edwards Aquifer springs may experience adverse cumulative effects during drought when Alternative 1 actions result in reduction or cessation of springs and river flows. These impacts could affect employment and potentially influence demographic patterns in these communities.

Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cumulative economic and resulting demographic impacts could result from increased fees levied to fund HCP implementation activities under this alternative. As described in Section 4.4.3.2 above, non-agricultural pumpers subject to EAA fees would bear the costs of implementing HCP actions. To the extent that increased fees may affect employment for these water users in the study area, resulting demographic responses may occur. Some HCP program elements such as VISPO and the increased market value of water expected to result from efforts to acquire 50,000 ac-ft for storage in the SAWS ASR facility may provide economic offsets that minimize adverse impacts to agriculture interests during drought conditions. These Alternative 2 actions may thereby help maintain some level of economic stability to populations with resulting demographic effects in areas highly dependent on agri-business sectors of the economy. Downstream region EARIP supporters have determined that ITP issuance will support local communities and business interests and have committed to help fund HCP implementation. This commitment demonstrates that these interests believe that economic growth and stability, and likely beneficial demographic changes will result from issuance of an ITP under this alternative.

Spring-related recreation and tourism employment sectors in New Braunfels and San Marcos would be expected to suffer less adverse impacts under Alternative 2 actions that maintain springflows than would be expected under Alternative 1, though some negative impacts during severe droughts might be expected. The cumulative effects of new water source development under Alternative 2 are similar to those expected under Alternative 1

Alternative 3: Expanded ASR with Associated Infrastructure

Employment and associated demographic effects of activities beyond those associated with Alternative 3 are anticipated to generate impacts that may be cumulative to those identified under this alternative. The combined effects of increased populations and actions under this option could be expected to be similar to, but somewhat more extensive than those anticipated under Alternative 2.

The increased CPM restrictions proposed under Alternative 3 would be expected to have a greater adverse impact on pumpers throughout EAA’s jurisdiction during drought conditions. Resulting employment impacts and subsequent demographic changes could be associated with these limitations. The higher anticipated project costs associated with this alternative would require funding assurances significantly greater than those needed under Alternative 2. The increased fees could be expected to adversely impact employment, thereby resulting in demographic changes. Alternative 3 would require acquisition of additional water for storage in an expanded ASR facility that would be expected to provide additional market incentives to sell or lease agricultural water rights that could offset pumping restrictions which support agri-business and associated demographic sectors.

Cumulative employment and demographic effects resulting from impacts to recreation and tourism-based economies and the impacts from developing new water supplies under Alternative 3 are expected to be similar to those described under Alternative 2.

Alternative 4: Highest CPM Pumping Restriction

The effects of an increasing population when combined with anticipated effects associated with Alternative 4 result in significant cumulative effects to employment and demographics in the study area. The single stage pumping restrictions proposed to meet springflow objectives would be expected to have significant impacts to municipal, industrial, agricultural, and individual water users. Resulting employment and demographic impacts would be expected throughout the area affected by the EAA CPM regulations. However, recreation and tourism-based economic sectors may benefit under Alternative 4 actions that maintain springflows at levels that could support recreational activities even through a repeat of DOR-like conditions.

The water demands created by increasing populations in concert with actions proposed under this alternative would likely require development of new water supplies and delivery infrastructure that could also impact study area demographics. The construction of new reservoirs and associated water transmission pipelines to meet increased water demands, for example, could displace communities and alter demographic relationships within the area.

4.7.8.3 Environmental Justice

No actions expected to impact environmental justice in the study area that would generate effects cumulative to those described for any of the alternatives have been identified or are anticipated to occur.

4.7.9 Cultural Resources

4.7.9.1 Alternative 1: No Action

The construction of transportation and water supply projects, as well as and public and private land development activities, could adversely affect cultural resources primarily through mechanical impacts to artifacts or artifact assemblages. The potential impacts associated with Alternative 1 actions are expected to be limited to sites most closely associated with the Comal and San Marcos Springs and the downstream river systems, and cumulative effects would therefore be restricted to these sites.

Alternative 1 impacts are largely associated with collecting and looting resulting from increased access or exposure of cultural resource sites during periods of low flow. The risk of significant adverse effects to cultural resources is increased when combined with potential mechanical impacts or alteration of artifact assemblages that might be expected from construction or development activities throughout the study area.

4.7.9.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Cultural resources would not be accessible or experience exposure under Alternative 2 to the degree expected under Alternative 1. Potential impacts could be associated with riparian restoration activities proposed under this alternative, though any impacts associated with federally permitted actions (in this case, implementation of actions under the ITP) would be subject to compliance with state and federal cultural and antiquity regulations. The mechanical impacts to artifacts and resource assemblages would be expected to be similar under Alternative 2 as described for Alternative 1. The cumulative effects of these separate actions might pose some risk of negative effects to cultural resources, though less than would be expected under Alternative 1.

4.7.9.3 Alternative 3: Expanded ASR with Associated Infrastructure

Cumulative effects could result from the construction, operation, and maintenance of the water transmission pipelines, expanded ASR facilities, and recharge facilities contemplated under this alternative. Other effects would be expected to be similar to those described under Alternative 2.

4.7.9.4 Alternative 4: Highest CPM Pumping Restriction

The mechanical impacts to cultural resources or artifact assemblages described above could be cumulative to the effects of increased flow rates and associated effects anticipated under Alternative 4. While increased flows would be expected to reduce the potential for exposure of or increased access to artifacts, biochemical and mechanical effects associated with increased water tables and greater potential for erosion may occur under this option.

4.7.10 Air Quality

While numerous impacts to air quality throughout the region exist and are expected to continue, the lack of direct or indirect impacts expected from the alternatives being considered results in an absence of cumulative effects in this analysis.

4.7.10.1 Greenhouse Gas Emissions

Alternative 1: No Action

Though emissions contributing to GHG concentrations occur throughout the study area, there are no specific impacts anticipated under Alternative 1 and therefore no cumulative effects under this alternative.

Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 GHG emissions are expected to be limited to the use of hand tools and heavy equipment, and the transportation needs during short-term activities such as the implementation of riparian restoration projects or water quality monitoring. While GHG emissions throughout the study area may be cumulative to the emissions associated with implementation of the proposed action, the small quantity and temporary nature of the emissions associated with these actions make these impacts minor or negligible.

Alternative 3: Expanded ASR with Associated Infrastructure

An unquantified amount of GHG emissions would be expected from the construction and ongoing operations of activities proposed under Alternative 3 that would be cumulative to emissions from other sources within the region. The unquantified amount of GHG emissions from all other point and non-point sources, combined with the interconnected nature of the power grid in Texas makes it impossible to identify or quantify sources with available data at this time.

Alternative 4: Highest CPM Pumping Restriction

Alternative 4 does not contemplate actions resulting in GHG emissions, therefore no cumulative effects are expected under this alternative.

4.7.10.2 Effects of Climate Change

Climate change projections indicate that changing temperatures and precipitation over some or all of the Edwards Aquifer could occur during the next several decades (see Section 3.1.1.3). Though climate change associated sea level rise is expected to continue, the projected rates of increase are not anticipated to significantly affect estuaries in the study area during the 15-year term of the requested permit.

Alternative 1: No Action

No activities anticipated to impact the climate are expected under Alternative 1, and no cumulative impacts are therefore anticipated.

Alternative 2: Proposed EARIP HCP, the Preferred Alternative

A limited number of activities such as riparian restoration efforts and water quality monitoring that could contribute to climate change effects would be associated with Alternative 2 actions. The short duration associated with these activities under this alternative are anticipated to be so minor in relation to the global climate system that the cumulative effects of these actions are expected to be negligible.

Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 contemplates infrastructure construction and ongoing operations that could affect global climate change. The cumulative effects of the unquantified amount of emissions occurring at multiple sources cannot be determined with available information, but are expected to be negligible.

Alternative 4: Highest CPM Pumping Restriction

No activities expected to impact the climate are associated with this alternative and no cumulative effects are therefore anticipated.

4.8 THE RELATIONSHIP BETWEEN SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

An EIS must consider the relationship between short-term uses of the environment and the maintenance and enhancement of long-term productivity (40 CFR 1502.16). For the purposes of this analysis, short-term is defined as the 15-year proposed term of the requested permit, and long-term extends beyond that timeframe into the future. Productivity is considered in terms of the natural and the human environments.

4.8.1 Alternative 1: No Action

Under Alternative 1, little effect is expected to the natural or human environments during periods of normal precipitation and recharge conditions. The significant reductions or cessation of springflow during drought conditions would be expected to adversely impact short and long-term productivity of both the natural and human environment under this alternative.

Short–term impacts could include adverse ecosystem-level effects of periods of low or ceased flow resulting in long-term negative effects to the natural environment. Short-term human environment impacts under Alternative 1 during drought conditions could include the economic effects of temporary loss of agricultural production, employment, recreation and tourism. Long-term negative effects could include permanent impacts to employment, and the wider resulting economic effects from the loss of a stable water supply.

4.8.2 Alternative 2: Proposed EARIP HCP, the Preferred Alternative

Alternative 2 would be expected to protect and enhance productivity of the natural and human environments during normal and drought conditions over those anticipated under Alternative 1. Measures such as ecosystem restoration and the reductions in water demand anticipated from municipal and industrial contributions would be expected to support and enhance habitat sustainability and productivity and support local economies during normal precipitation conditions. During periods of drought, water withdrawal limitations and mitigation actions are expected to maintain springflows thereby supporting both natural resources and the socioeconomic factors affected by those resources. Ensuring springflows and continued water availability for human uses during droughts would support the long-term regional benefits resulting from a stable and usable water resource.

4.8.3 Alternative 3: Expanded ASR with Associated Infrastructure

Alternative 3 would be expected to have effects similar to those described for Alternative 2.

4.8.4 Alternative 4: Highest CPM Pumping Restriction

Alternative 4 would also be expected to be supportive of short and long-term productivity regardless of precipitation or recharge conditions. The significantly increased spring and resulting instream river flows would have the most beneficial effects of the alternatives considered during drought conditions for natural and human environment productivity, though the economic costs associated with providing adequate alternate water supplies to the region would have the most significant adverse impacts on the regional economy.

4.9 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

Implementing regulations for NEPA require a discussion of “any irreversible or irretrievable commitments of resources which would be involved in the proposal should it be implemented” (40 CFR 1502.16). Irreversible commitments of resources result from the use or destruction of non-renewable resources such as energy, minerals, or cultural resources, and to those factors that are renewable only over long time spans, such as soil productivity. Irretrievable resource commitments involve the loss of value of an affected resource that cannot be restored as a result of the action, such as extinction of a threatened or endangered species or disturbance of a cultural resource.

The commitment and funding by the Applicants to implement HCP actions such as mitigation and monitoring activities would be irreversible and irretrievable. These actions could prevent the irreversible and irretrievable loss of biological resources in the Comal Springs and San Marcos Springs ecosystems and the species that rely on them by conserving aquatic habitats during drought conditions. The proposal allows for the consumptive and therefore irreversible use of identified volumes of water from the Edwards Aquifer and an irretrievable commitment of fossil fuels and funding to implement monitoring and mitigation actions.

CHAPTER 5

COORDINATION AND CONSULTATION

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
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USEPA – U.S. Environmental Protection Agency
VISPO – Voluntary Irrigation Suspension Program Option
VOCs – Volatile Organic Compounds
WORD – Water Oriented Recreation District of Comal County
WRIP – Water Resources Integrated Pipeline

5.0 COORDINATION AND CONSULTATION

This chapter is divided into three sections. Section 5.1 summarizes the public involvement in determining the scope of issues addressed in this DEIS. Section 5.2 lists the federal, state, and local agencies and the other interested parties who participated in the process and to whom copies of the DEIS have been sent. Section 5.3 lists agencies, organizations, and persons with whom the Service consulted during the preparation of the DEIS.

5.1 PUBLIC INVOLVEMENT

Public involvement in development and preparation of the proposed action (Alternative 2) is described in Section 1.7 of the EARIP HCP (EARIP 2011).

The Scoping process prescribed under NEPA was described in Section 1.6 of this DEIS, and is briefly summarized below.

The Service published an NOI to prepare a DEIS, announced the availability of a public scoping period, and sought comments regarding the scope and issues to be considered in the *Federal Register* on March 5, 2010 (75 FR 10305). The NOI described the background and purpose of the proposed action and provided details about the public scoping meetings and comment period. Public input was collected from seven scheduled scoping meetings, from comments received on the "Edwards Aquifer Public Comments Forum" of the EARIP internet web page, and from mailed comments received by the Service's Ecological Services Office in Austin, Texas.

Eight general categories of issues and concerns were identified, including science and methodology, regulations, water supply and conservation, water quality, springs, rivers, Edwards Aquifer recharge, and endangered species. The comments received are summarized in Section 1.6 of this DEIS. These issues and concerns contributed to the development of the overall scope of this DEIS, and are reflected in the analysis of the direct, indirect, and cumulative effects of the alternatives considered.

5.2 DISTRIBUTION

Copies of the DEIS have been placed in the following locations for public review:

- U.S. Fish and Wildlife Service
  10711 Burnet Road, Suite 200
  Austin, Texas 78758

- Edwards Aquifer Authority
  1615 N. St. Mary's Street
  San Antonio, Texas 78215

- City of New Braunfels
  City Secretary's Office
  424 South Castell Avenue
  New Braunfels, Texas 78130

- City of San Marcos
  630 East Hopkins
  San Marcos, Texas 78666

- San Antonio Water System
  Water Resources Department
  2800 U.S. Highway 281 N
  Tower 1 Office 247
  San Antonio, Texas 78212

- Texas State University
  Texas Rivers Center
  River Systems Institute
  951 Aquarena Springs Drive
  San Marcos, Texas 78666

Electronic files of the DEIS will be made available to the following federal, state, and local agencies and officials:

- Atascosa County
- Bexar County
- Calhoun County
- Caldwell County
- City of Austin
- Comal County
- DeWitt County
- Edwards Aquifer Authority, Environmental Studies
- Edwards Aquifer Research and Data Center, Texas State University
- Edwards County
- Gonzales County
- Guadalupe-Blanco River Authority
- Guadalupe County
- Hays County
- Kendall County
- Kinney County
- Medina County
- National Park Service, Santa Fe, New Mexico
- Real County
- Refugio County
- San Antonio River Authority

- Texas Commission on Environmental Quality
- Texas Department of Agriculture
- Texas Department of Transportation
- Texas General Land Office
- Texas Parks and Wildlife Department
- Texas Water Development Board
- U.S. Army Corps of Engineers, Fort Worth, Texas
- U.S. Bureau of Reclamation, Austin, Texas
- U.S. Department of Agriculture
- Natural Resources Conservation Service, Temple, Texas
- Rural Utilities Service (RUS), Washington, D.C.
- U.S. Environmental Protection Agency, Region 6, Dallas, Texas
- U.S. Farmers Home Administration, Temple, Texas
- U.S. Geological Survey, Austin, Texas
- Uvalde County
- Victoria County
- City of Uvalde
- City of Victoria
- City of Corpus Christi

State and Federal Congressional Offices:

U.S. Senators

- Senator John Cornyn
- Senator Kay Hutchinson

U.S. Representatives

- Congressman Francisco Canseco
- Congressman Henry Cuellar
- Congressman Lloyd Dogett
- Congressman Blake Farenthold
- Congressman Charles Gonzales
- Congressman Ruben Hinojosa
- Congressman Ron Paul
- Congressman Lamar Smith

State Senators

- Senator Glenn Hegar
- Senator Leticia Van Deputte
- Senator Carlos I. Uresti

- Senator Jeff Wentworth
- Senator Judith Zaffirini

State Representatives

- Representative Jose Aliseda
- Representative Joaquin Castro
- Representative Joe Farias
- Representative Trey Martinez Fischer
- Representative Pete P. Gallego
- Representative John V. Garza
- Representative Roland Gutierrez
- Representative Harvey Hilderbran
- Representative Todd A. Hunter
- Representative Jason Isaac
- Representative Tracy O. King
- Representative John Langston Kuempel
- Representative Lyle Larson
- Representative Ruth Jones McClendon
- Representative Jose Menendez
- Representative Doug Miller
- Representative Geanie Morrison
- Representative Joe Strauss
- Representative Mike Villarreal

Conservation Organizations

- Gulf States National Resource Center
- San Antonio Audubon Society
- San Marcos River Foundation
- Sierra Club
- Sportsmen Conservationists of Texas
- Texas Nature Conservancy
- Texas Farm Bureau

The DEIS is available in PDF format on the EARIP Web site at http://earip.org/ and on the Service's Web site at http://www.fws.gov/southwest/es/AustinTexas/.

5.3 CONSULTATION WITH OTHERS

The following agencies, organizations, and individuals contributed information that was incorporated into the preparation of the DEIS:

- BIO-WEST, Inc.
- Edwards Aquifer Authority
- Hicks & Company
- RECON
- Texas A&M University
- the Service

CHAPTER 6

LIST OF PREPARERS

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
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- Jeremy Webster, Aquatic Ecology

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- Dr. Jean Krejca, Endangered Species
- Rachel Barlow, Endangered Species

CHAPTER 7

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WRIP – Water Resources Integrated Pipeline

7.0 REFERENCES

Abbott, P.L. 1973. The Edwards limestone in the Balcones Fault Zone, south-central Texas. Ph.D. Dissertation, University of Austin, Texas.

Abbott, P.L., and C.M. Woodruff, Jr., eds. 1986. The Balcones Escarpment: geology, hydrology, ecology and social development in central Texas. Geological Society of America Annual Meeting.

Arsuffi, T.L. 1993. Status of the Comal Springs riffle beetle (*Heterelmis comalensis*), Peck's cave amphipod (*Stygobromus pecki*), and the Comal Springs dryopid beetle (*Stygoparnus comalensis*) from Central Texas. Prepared for the U.S. Fish and Wildlife Service.

Ashworth, J.B. 1983. Ground-water availability of the lower Cretaceous formations in the Hill Country of south-central Texas. Texas Department of Water Resources Report 273, 65 pp.

Backlund, P., A. Janetos, and D. Schimel. 2008. The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States. Synthesis and Assessment Product 4.3 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA.

Barr, C.B. 1993. Survey for two Edwards Aquifer invertebrates: Comal Springs dryopid beetle *Stygoparnus comalensis* Barr and Spangler (Coleoptera: Dryopidae) and Peck's Cave amphipod *Stygobromus pecki* Holsinger (Amphipoda: Crangonyctidae). Prepared for U.S. Fish and Wildlife Service, Austin, TX.

Barr, C.B., and P.J. Spangler. 1992. A new genus and species of stygobiontic dryopid beetle, *Stygoparnus comalensis* (Coleoptera, Dryopidae), from Comal Springs, Texas. Proceedings of the Biological Society of Washington 105(1):40–54.

Batte, C.D. 1984. Soil survey of Comal and Hays Counties, Texas. U.S. Department of Agriculture, Soil Conservation Service.

Beaty, H.E. 1975. Texas wild-rice. Texas Horticulturist 2:9–11.

[BEG] Bureau of Economic Geology. 1974. Geologic atlas of Texas. San Antonio sheet. University of Texas at Austin, Bureau of Economic Geology, map.

——. 1981. Geologic atlas of Texas, Austin sheet. University of Texas at Austin, Bureau of Economic Geology, map.

——. 1982. Geologic atlas of Texas, San Antonio sheet. University of Texas at Austin, Bureau of Economic Geology, map.

——. 1993. Edwards Aquifer storage assessment, Kinney County to Hays County, Texas. University of Texas at Austin. Prepared for Edwards Underground Water District.

Bendik, N.F. 2006. Population genetics, systematics, biogeography, and evolution of the southeastern central Texas *Eurycea* clade Blepsimolge. (Plethodontidae). Master's thesis, The University of Texas at Arlington. 127 pp.

[BIO-WEST] BIO-WEST, Inc. 2002. Comal Springs Riffle beetle habitat and population evaluation. Final Report. Prepared for Edwards Aquifer Authority, San Antonio, TX. 11 pp.

——. 2007. Variable Flow Study: seven years of monitoring and applied research. Prepared for Edwards Aquifer Authority, August 2007, 70 p. http://www.edwardsaquifer.org/pdfs/Reports/AS%20Reports/Other%20Completed%20Biologic%20Assessment%20Projects/Summary%20of%20Monitoring%20and%20Research%20for%202000-2007.pdf.

[BMWD] Bexar Metropolitan Water District. 1999. Habitat conservation plan in support of Edwards Aquifer withdrawals affecting Edwards Aquifer dependent species for Endangered Species Act Section 10(a)(1)(B) Permit. Bexar Metropolitan Water District.

Booth, D.B., J.R. Karr, S. Schauman, C.P. Konrad, S.A. Morley, M.G. Larson, P.C. Henshaw, E.J. Nelson, and S.J. Burges. 2001. Urban stream rehabilitation in the Pacific Northwest: final report of EPA Grant no. R82-5284- 010. Center for Urban Water Resources, University of Washington, Seattle, Washington.

Bosse, L.S., D.W. Tuff, and H.P. Brown. 1988. A new species of *Heterelmis* from Texas (Coleoptera, Elmidae). Southwestern Naturalist 33(2):199–203.

Bowles, D.E., and R. Stanford. 1997. A new distributional record for *Haideoporus texanus* (Coleoptera: Dytiscidae), a stygobiontic beetle from the Edwards Aquifer, Texas. Entomological News 108(4):297–299.

Bradsby, D.D. 1994. A recreational use survey of the San Marcos River: San Marcos, Texas. M.S. thesis, Southwest Texas State University, San Marcos, TX. 82 pp.

Brown, H.P. 1987. Biology of riffle beetles. Annual Review of Entomology 32:253–273.

Brown, L.F., Jr., R.A. Morton, J.H. McGowen, C.W. Kreitler, and W.L. Fisher. 1974. Natural hazards of the Texas coastal zone. University of Texas at Austin, Bureau of Economic Geology, Special Publication.

Brune, G. 1975. Major and historical springs of Texas. Texas Water Development Board Report 189. 95 pp.

——. 1981. Springs of Texas. Vol 1. Branch-Smith, Ft. Worth, Texas.

Bush, P.W., A.F. Ardis, L. Fahlquist, P.B. Ging, C.E. Hornig, and J. Lanning-Rush. 2000. Water quality in south-central Texas, Texas, 1996–98, U.S. Geological Survey Circular 1212, 32 pp.

Butzer, K.W. 1982. Archeology as human ecology. Cambridge University Press, Cambridge.

[CAMPO] Capital Area Metropolitan Planning Organization. 2010. CAMPO 2035, Regional Transportation Plan. Adopted May 24, 2010.

Canyon Lake Chamber of Commerce. 2000. Home page. http://www.canyonlakechamber.com Accessed May 5, 2010.

Caran, S.C., and V.R. Baker. 1986. Flooding along the Balcones escarpment, Central Texas. *In* P.L. Abbott and C.M. Woodruff, Jr., eds. The Balcones Escarpment: geology, hydrology, ecology and social development in central Texas. Geological Society of America.

[CCSP] Climate Change Science Program. 2008. Impacts of climate change and variability on transportation systems and infrastructure: Gulf Coast study, Phase I. A report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [M.J. Savonis, V.R. Burkett, and J.r. Potter (eds.)]. Department of Transportation, Washington, D.C., USA.

——. 1997. Environmental Justice: Guidance Under the National Environmental Policy Act. Council on Environmental Quality, Executive Office of the President. 34 pp.

——. 2010. Draft NEPA guidance on consideration of the effects of climate change and greenhouse gas emissions. CEQ Memorandum of February 18, 2010.

Chandler, D.S. 1992. The Pselaphidae (Coleoptera) of Texas caves. Texas Memorial Museum, Speleological Monographs 3:241–253.

Chavez-Ramirez, F. 1996. Food availability, foraging ecology and energetics of whooping cranes wintering in Texas coast. PhD Dissertation. TAMU, College Station, Texas. 105 pp.

Chen, C., D. Gillig, and B.A. McCarl. 2001. Effects of climate change on a water dependent regional economy: a study of the Texas Edwards Aquifer. Climate Change 49:397–409. Kluwer Academic Publishers.

CH2M Hill. 1986. San Antonio regional water resources study. Final completion report prepared for the City of San Antonio and Edwards Underground Water District. San Antonio, Texas.

Collins, E.W. and S.D. Hovorka. 1997. Structure map of the San Antonio segment of the Edwards Aquifer and Balcones Fault Zone, South-Central Texas: structural framework of a major limestone aquifer: Kinney, Uvalde, Medina, Bexar, Comal, and Hays Counties, Texas. The University of Texas, Bureau of Economic Geology. Miscellaneous Map No. 38, 14 pp. + 1 sheet.

Crowe, J.C. 1994. Detailed hydrogeologic maps of the Comal and San Marcos Rivers for endangered species habitat definition, Texas. M.A. dissertation, University of Texas at Austin.

Culver, D.C., and B. Sket. 2000. Hotspots of Subterranean Biodiversity in Caves and Wells. Journal of Cave and Karst Studies 62(1):11–17.

Dietz, M.E. and J.C. Clausen. 2008. Stormwater runoff and export changes with development in a traditional and low impact subdivision. Journal of Environmental Management Vol 87 (4): Pages 560–566.

[EAA] Edwards Aquifer Authority. 2002. Historical water levels and springflow rates. http://www.edwardsaquifer.org/display_technical_m.php?pg=historical_data#. Accessed March 31, 2010.

——. 2003. Edwards Aquifer Authority hydrgeologic data report for 2002. San Antonio: Edwards Aquifer Authority.

——. 2009. Edwards Aquifer Authority hydrologic data report for 2008. Report no. 09-02. San Antonio: Edwards Aquifer Authority.

——. 2010a. Tracing groundwater flowpaths in the Edwards Aquifer Recharge Zone, Panther Springs Creek Basin, Northern Bexar County Texas. Report # 10-01, May 2010.

——. 2010b. Hydrologic data report for 2009. Report #10-02, December, 2010. http://www.edwardsaquifer.org/files/HydroReport2009.pdf. Accessed June 14, 2011.

[EAA Act] Edwards Aquifer Authority Act. 1993. Act of May 30, 1993, 73rd Texas Legislature, R.S., ch 626, 1993 Texas General Laws 2350 as amended by, Act of May 28, 1995, 74th Texas Legislature, ch 3189, 1995 Texas General Laws 2505, and Act of May 16, 1995, 74th Texas Legislature, R.S. ch 361, 1995 Texas General Laws 3280.

[EARIP] Edwards Aquifer Recovery Implementation Program. 2011. Habitat Conservation Plan and Appendices. December 2011.

[EARIP CSWG] Edwards Aquifer Recovery Implementation Program Covered Species Work Group. 2010. Background and recommendations regarding covered species. Memorandum dated December 3, 2010. http://earip.org/EARIPMeetings/Dec0910/12-09-10%20Attachment%202%20Covered%20Species%20Workgroup%20Report.pdf. Accessed January 24, 2011.

[EARIP EAA] Edwards Aquifer Recovery Implementation Program Edwards Aquifer Area Expert Science Subcommittee. 2009. Analysis of species requirements in relation to spring discharge rates and associated withdrawal reductions and stages for critical period management in the Edwards Aquifer. Report to the Steering Committee for the EARIP. December 28, 2009.

Earl, R.A., and C.R. Wood. 2002. Upstream changes and downstream effects of the San Marcos River of Central Texas. The Texas Journal of Science 54(1):69–88.

Easterling, W. et al. 2007. Food, Fibre and Forest Products. *In*: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Edwards, R.J., E. Marsh, and C. Hubbs. 1980. The status of the San Marcos gambusia, *Gambusia georgei*. Endangered Species Report 9. U.S. Fish and Wildlife Service.

Emery, W.H.P. 1967. The decline and threatened extinction of Texas wildrice (*Zizania texana* Hitchcock). Southwestern Naturalist 12:203–204.

Exum, L.R., S.L. Bird, J. Harrison, and C.A. Perkins. 2005. Estimating and projecting impervious cover in the southeastern United States. U.S. Environmental Protection Agency EPA Rep. No EPA/600/R-05/061, May 2005. Washington D.C.

Fenneman, N.M. 1931. Physiography of western United States. McGraw Hill, NewYork.

Fenneman, N.M. 1938. Physiography of eastern United States. McGraw Hill, New York.

Ferrill, D.A., D.W. Sims, D.J. Waiting, A.P. Morris, N.M. Franklin, and A.L. Schultz. 2004. Structural framework of the Edwards Aquifer recharge zone in South-Central Texas. Geological Society of America Bulletin. 116(3/4):407–418.

Field, C.B., L.D. Mortsch,, M. Brklacich, D.L. Forbes, P. Kovacs, J.A. Patz, S.W. Running, and M.J. Scott. 2007. North America. *In*: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 617–652.

[GBRA] Guadalupe-Blanco River Authority. 2000. Letter to Greg Ellis from W.E. West, Jr., July 28, 2000.

Gibson, J.R., S.J. Harden, and J.N. Fries. 2008. Survey and distribution of invertebrates from selected springs of the Edwards Aquifer in Comal and Hays Counties, Texas. The southwestern Naturalist 53(1):74–84.

Gilbert, C.H. 1887. Descriptions of new and little known etheostomoids. Proc. U.S. Nat. Mus. 10:47–64.

Gonzales, T.K. 2008. Conservation genetics of the Comal Springs riffle beetle (*Heterelmis comalensis*) populations in central Texas, with examination of molecular and morphological variation in *Heterelmis* sp. throughout Texas. Theses and Dissertations-Biology, Texas State. Paper 15.

Green, R.T. 2011. Field assessment and analytical assessment of the hydraulic relationship between the Trinity and Edwards. Presented to the Society of American Military Engineers. May 10, 2011. San Antonio, Texas.

Green, R.T., F.P. Bertetti, and M.O. Candelario. 2011. Edwards Aquifer – Upper Glen Rose Aquifer hydraulic interaction. Proceedings of the February 2011 Karst Conservation Initiative. http://www.bseacd.org/publications/reports/.

Green, R.T., P. Bertetti, A. Morris, D. Ferrill, and R. Klar. 2008. Dynamic hydraulic boundaries within the western Edwards Aquifer. Presentation at the AAPG Annual Convention, San Antonio, Tx. April 20–23, 2008. http://www.searchanddiscovery.net/documents/2008/08215green/ndx_green.pdf Accessed June 29, 2010.

Guillory, V. and M. Elliot. 2001. A review of blue crab predators, proceedings of the blue crab mortality symposium 69-83. Gulf State Marine Fisheries Commission Publication Number 90.

Guthrie, C.G., J. Matsumoto, and Q. Lu. 2010. TxBLEND model calibration and validation for the Guadalupe and Mission-Aransas Estuaries. Texas Water Development Board, Austin, Texas. 46 pp.

Guyton, W.F., and Associates. 1979. Geohydrology of Comal, San Marcos, and Hueco Springs. Texas Department of Water Resources, Austin. R-234.

Halff Associates. 2010. Initial study on the recreational impacts to protected species and habitats in the Comal and San Marcos Springs ecosystems. A report prepared for the Edwards Aquifer Implementation Program. November 3, 2010. http://earip.org/Reports/10-0930-Final-Report-b.pdf. Accessed April 18, 2010.

Hardy, T.B. 2009. Technical assessments in support of the Edwards Aquifer Science Committee "J Charge" flow regime evaluation for the Comal and San Marcos River Systems. Prepared for the Edwards Aquifer Recovery and Implementation Program by the Rivers Systems Institute, Texas State University, December 29, 2009. 159 pp.

Hardy, T.B., K. Kollaus, and K. Tower. 2010. Evaluation of the proposed Edwards Aquifer Recovery Implementation Program drought of record minimum flow regimes in the Comal and San Marcos River Systems. December 28, 2010. http://earip.org/Hardy/EARIP_1-6-2010_Draft_03.pdf

Hatfield, J.L., K.J. Boote, B.A. Kimball, D.W. Wolfe, D.R. Ort, R.C. Izaurralde, A.M. Thomson, J.A. Morgan, H.W. Polley, P.A. Fay, T.L. Mader, G.L. Hahn. 2008. Agriculture. *In*: The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity. Synthesis and Assessment Product 4.3 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research, Washington, DC, USA.

[HDR] HDR Engineering, Inc. 2009. Environmental flows in the Guadalupe River Basin. Presentation by Sam Vaugh to the Edwards Aquifer Area Expert Science Subcommittee, Edwards Aquifer Recovery Implementation Program, October 26, 2009. http://earip.tamu.edu/WhoopingCrane/HDR%20Engineering%202009.pdf. Accessed April 27, 2010.

——. 2010. Evaluation of hydrologic connection between San Marcos Springs and Barton Springs through the Edwards Aquifer. Report HDR-007081-1294-10 prepared for Guadalupe-Blanco River Authority, April 2010. http://earip.tamu.edu/Reports/04-29-10%20San%20Marcos%20&%20Barton%20Springs%20Final%20Report_Apr%202010.pdf. Accessed May 5, 2010.

——. 2011. Evaluation of water management programs and alternatives for springflow protection of endangered species at Comal and San Marcos Springs. Prepared for the Edwards Aquifer Recovery Implementation Program (EARIP). http://earip.org/Reports/EARIP--tech%20Evaluations%20Report_Oct%2010%20%202011.pdf

Holsinger, J.R., and G. Longley. 1980. The subterranean amphipod crustacean fauna of an artesian well in Texas. Smithsonian Contributions to Zoology 308:1–62.

Holzworth, G.C. 1972. Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous United States. Bulletin AP-101. U.S. Environmental Protection Agency, Office of Air Programs, Research Triangle Park, NC.

Howells, R.G. 1998. Distributional surveys of freshwater bivalves in Texas: progress report for 1997. Texas Parks and Wildlife Department, Management Data Series 147, Austin.

——. 2000. Distributional surveys of freshwater bivalves in Texas: progress report for 1999. Texas Parks and Wildlife Department, Management Data Series 170, Austin.

——. 2006. Statewide freshwater mussel survey. State Wildlife Grant Final Report T-15-P, Texas Parks and Wildlife Department, Austin.

——. 2010. Rare Mussels: Summary of selected biological and ecological data for Texas. Biostudies, Kerrville, Texas, USA.

Hubbs, C., and A.E. Peden. 1969. *Gambusia georgei* sp. nov. from San Marcos, Texas. Copeia 2:357–364.

[IEc] Industrial Economics, Incorporated. 2007. Economic Analysis of Critical Habitat Designation for the Peck's Cave Amphipod, Comal Springs Dryopid Beetle, and Comal Springs Rifle Beetle. Prepared for Division on Economics, U.S. Fish and Wildlife Service. 64pp.

[IPCC] Intergovernmental Panel on Climate Change. 2000. Special report on emissions scenarios (SRES). A special report of working group III of the Intergovernmental Panel on Climate Change [N. Nakicenovic et al. (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

——. 2007a. Summary for policymakers. *In:* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

——. 2007b. Summary for policymakers. *In:* Climate change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Johnson, M., A. Bolick, M. Alexander, D. Huffman, E. Oborny, and A. Monroe. 2011. Fluctuations in densities of the invasive gill parasite *Centrocestus formosanus* (Trematoda: Heterophyidae) in the Comal River, Comal County, Texas, U.S.A. The Journal of Parasitology 97(4), August 18 2011.

Johnson, S., G.M. Schindel, and G. Veni. 2009. Tracing groundwater flowpaths in the Edwards Aquifer Recharge Zone, Panther Springs Creek Basin, northern Bexar County, Texas. Proceedings of the 15th International Congress of Speleology. p. 1538.

Jones, L., D. Gillig, and B. McCarl. 2001. Economic Impacts of Edwards Aquifer Pumping Restriction Alternatives. Submitted to Hicks & Company for Edwards Aquifer Authority Habitat Conservation Plan. 86pp.

Jones, T.L., V.A. Kelley, T. Yan, A. Singh, D.W. Powers, R.M. Holt, and J.M. Sharp. 2011. Draft conceptual model report for the ruster aquifer: Intera Inc. contract report by Intera Inc., to the Texas Water Development Board, pp. 252.

Karl, T.R., G.A. Meehl, C.D. Miller, S.J. Hassol, A.M. Waple, and W.L. Murray. 2008. eds. Weather and climate extremes in a changing climate; Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. Synthesis and Assessment Product 3.3 by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Washington, DC, USA, 164 pp.

Klein, R.D. 1979. Urbanization and stream quality impairment. Water Resources Bulletin 15(4):948–963.

Klemt, W.B., T.R. Knowles, G.R. Elder, and T.W. Sieh. 1979. Ground-water resources and model applications for the Edwards (Balcones fault zone) aquifer in the San Antonio region. Texas Department of Water Resources Report 239.

Kodra, E., K. Steinhaeuser, and A.R. Ganguly. 2011. Persisting cold extremes under 21st-century warming scenarios. Geophysical Research Letters, 38, L08705, doi:10.1029/2011GL047103.

Krejca, J.K. 2005. Stygobite phylogenetics as a tool for determining aquifer evolution. Dissertation, University of Texas at Austin. 115 pp.

Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen, and I.A. Shiklomanov. 2007. Freshwater resources and their management. *In:* Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 173–210.

Kuniansky, E.L., L. Fahlquist, and A.F. Ardis. 2001. Travel times along selected flowpaths of the Edwards Aquifer, Central Texas. U.S. Geological Survey. Water-Resources Investigation Report 01-4011. p. 69–77.

Larkin, T.J., and G.W. Bomar. 1983. Climatic atlas of Texas. Texas Department of Water Resources LP-192, Austin.

LBG-Guyton Associates. 2004. Evaluation of augmentation methodologies in support of in-situ refugia at Comal and San Marcos Springs, Texas. Draft report prepared for the Edwards Aquifer Authority, May 2004, 194 pp.

——. 2005. HSPF recharge models for the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer. Prepared for Edwards Aquifer Authority. 230 p.

Lemke, D.E. 1989. Aquatic macrophytes of the upper San Marcos River. The Southwestern Naturalist 34(2):289–291.

Loáiciga, H.A., D.R. Maidment, and J.B. Valdes. 2000. Climate change impacts in a regional karst aquifer, Texas, USA. Journal of Hydrology 227:173–194.

Longley, G. 1978. Status of *Typhlomolge* (=*Eurycea*) *rathbuni*, the Texas blind salamander. U.S. Fish and Wildlife Service Endangered Species Report 2.

——. 1981. The Edwards Aquifer: earth's most diverse groundwater ecosystem? International Journal of Speleology 11:123–128.

——. 1986. The Balcones Escarpment: the biota of the Edwards Aquifer and the implications for paleozoogeography. Pp. 51–54 *in* P.L. Abbott and C.M. Woodruff, Jr., eds. The Balcones Escarpment: geology, hydrology, ecology and social development in central Texas. Geological Society of America.

——. 1995. The relationship between long term climate change and Edwards Aquifer levels, with an emphasis on droughts and spring flows. Paper delivered at the 24th Water for Texas Conference, Austin, Texas.

Loomis Partners, Inc.; Smith, Robertson, Elliot, Glen, Klein, & Bell, LLP; Zara Environmental, LLC; Joe Lessard; Texas Perspectives, LLC; Capitol Market Research. 2010. Hays County regional habitat conservation plan. Prepared For: Hays County Commissioners Court, 111 E. San Antonio Street, San Marcos, Texas 78666. 159 pp.

Mace, R.E., and S.C. Wade. 2008. In hot water? How climate change may (or may not) affect the groundwater resources of Texas: Gulf Coast Association of Geological Societies Transactions 58:655–668.

Maclay, R.W., and L.F. Land. 1988. Simulation of flow in the Edwards Aquifer, San Antonio region, Texas, and refinement of storage and flow concepts. U.S. Geological Survey Water Supply Paper 2336-A.

Maclay, R.W., and T.A. Small. 1986. Carbonate geology and hydrology of the Edwards Aquifer in the San Antonio area, Texas. Texas Water Development Board Report # 296. November 1986. 90 pp. http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwreports/R296/R296.pdf. Accessed June 14, 2010.

Malof, A.F. 1999. A summary of processes affecting archeological sites in artificial reservoirs. Bulletin of the Texas Archeological Society 70:563–567.

Mandelker, D.R., R.L. Glicksman, A.M. Aughey, and D. McGillivray. 2011. NEPA Law and Litigation. Thomson Reuters/West, Eagan, MN: 10–75.

Mauldin, R.P. 2003. Exploring drought in the San Antonio area between 1700 and 1979. Special Report 29. Center for Archaeological Research, University of Texas-San Antonio.

Maurer, E.P., L. Brekke, T. Pruitt, and P.B. Duffy. 2007. Fine-resolution climate projections enhance regional climate change impact studies, Eos Trans. AGU, 88(47), 504. http://climatewizard.org. Accessed September 7, 2011.

McCord, M.W. 2007. San Marcos River – Old City Park to Luling. A report on river technical data for canoes, kayaks, and rafts. Southwest Paddler. http://southwestpaddler.com/docs/guad7.html. Accessed September 11, 2011.

McKinney, D.C., and D.W. Watkins, Jr. 1993. Management of the Edwards Aquifer: a critical assessment. Center for Research in Water Resources Technical Report CRWR 244, Bureau of Engineering Research, University of Texas at Austin, TX. 94 pp.

McKinney, D.C., and J.M. Sharp. 1995. Springflow augmentation of Comal Springs and San Marcos Springs, Texas: phase I - feasibility study. Center for Research in Water Resources Technical Report CRWR 247, Bureau of Engineering Research, University of Texas at Austin, TX.

Meehl, G.A., T.F. Stocker, W.D. Collins, P. Friedlingstein, A.T. Gaye, J.M. Gregory, A. Kitoh, R. Knutti, J.M. Murphy,A. Noda, S.C.B. Raper, I.G. Watterson, A.J. Weaver, and Z.-C. Zhao. 2007. Global climate projections. *In* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z.Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 747–846.

Milly, P.C.D., K.A. Dunne, and A.V. Vecchia. 2005. Global pattern of trends in streamflow and water availability in a changing climate. Nature 438:347–350.

Murdock, S.H., M.N. Hoque, M. Michael, S. White, and B. Pecotte. 1996. Texas challenged: the implications of population change for public service demand in Texas. Texas Legislative Council, Austin, TX. February.

NatureServe. 2009. An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://www.natureserve.org/explorer Accessed: June 13, 2010.

[NCDC] National Climatic Data Center. 2010. Texas climate summary - May 2010. U.S. Department of Commerce National Climatic Data Center. http://www.ncdc.noaa.gov/oa/climate/research/cag3/tx.html. Accessed June 14, 2010.

Nelson, J.M. 1993. Population size, distribution, and life history of *Eurycea nana* in the San Marcos River. M.S. thesis, Southwest Texas State University, San Marcos, TX.

Nichols, K.N., and A.P. Goldbloom. 1989. Texans outdoors: an analysis of 1985 participation in outdoor recreation activities. Texas Parks and Wildlife Department.

Nielson-Gammon, J.W. 2011. The changing climate of Texas. *In*: The Impact of Global Warming on Texas: Second Edition. G. North, J. Schmandt and J. Clarkson (eds.), The University of Texas Press.

[NOAA] National Oceanic and Atmospheric Administration. 2007. State of the climate of National Overview Annual 2006. National Oceanic and Atmospheric Administration. www.ncdc.noaa.gov/oa/climate/research/2006/perspectives.html. Accessed April 27, 2010.

——. 2010. San Antonio climate narrative. http://www.srh.noaa.gov/images/ewx/sat/satclisum.pdf.

[NPS] National Park Service. 2010. Nationwide rivers inventory. http://www.nps.gov/ncrc/programs/rtca/nri/index.html. Accessed October 10, 2010.

[NSTC] National Science and Technology Council. 2008. Scientific assessment of the effects of global change on the United States, A Report of the Committee on Environment and Natural Resources. May 2008.

Odintz, M. 1999. Winter garden region. The handbook of Texas online. The Texas State Historical Association. Last updated February 15, 1999. http://www.tshaonline.org/handbook/online/articles/WW/ryw2.html. Accessed May 5, 2010.

Ogden, A.E., R.A. Quick, D.L. Lunsford, S.R. Rothermel. 1986a. Hydrogeological and hydrochemical investigation of the Edwards Aquifer in the San Marcos area, Hays County, Texas: Edwards Aquifer Research and Data Center Report, No. Rl-86, 364 p.

Ogden, A.E., R.A. Quick, and S.R., Rothermel. 1986b. Hydrochemistry of the Comal, Hueco, and San Marcos Springs, Edwards Aquifer, Texas. Pp. 115–130 *in* P.L. Abbott and C. M. Woodruff, Jr., eds. 1986. The Balcones Escarpment: geology, hydrology, ecology and social development in central Texas. Geological Society of America.

Otero, C.L. 2007. Geologic, hydrologic, and geochemical identification of flow paths in the Edwards Aquifer, northeastern Bexar and southern Comal Counties, Texas. United States Geological Survey. Scientific Investigations Report 2007-5285.

Patton, P.C. and Baker, V.R. 1976. Morphometry and floods in small drainage basins subject to diverse hydrogeomorphic controls. Water Resources Research. 12:941–952.

Pena, J.G. 1997. Texas crop enterprise budgets, Southwest Texas District. Uvalde (TX): Texas Agricultural Extension Service, Texas A&M University System.

Poole, J. M. 1990. Conservation of the upper San Marcos River ecosystem. Performance report as required by Endangered Species Act, Section 6, Endangered and Threatened Species Conservation. Texas Project E-1-3, Job No. 2.5.

Reddell, J.R. 1994. The cave fauna of Texas with special reference to the western Edwards Plateau. Pages 31–49 *in* W.R. Elliott and G. Veni, eds. The Caves and Karst of Texas. National Speleological Society, Huntsville, Alabama.

Reddell, J.R., and J.C. Cokendolpher. 2004. The cave spiders of Bexar and Comal Counties, Texas. Texas Memorial Museum, Speleological Monographs 6:75–94.

[Research and Planning Consultants] Research and Planning Consultants, Lee Wilson & Associates, Inc. 2000. Edwards Aquifer Authority programmatic assessment draft report. Austin, TX.

Riggio, R.F., G.W. Bomar, and T.J. Larkin. 1987. Texas drought: its recent history (1931–1985). LP-87-04. Texas Water Commission, Austin.

[SAEDF] San Antonio Economic Development Foundation. 2010a. San Antonio business profile: major employers.

——. 2010b. Major regional employers in San Antonio.

——. 2010c. San Antonio industry clusters: manufacturing. www.sanantonioedf.com/index.php?module=xarpages&func=display&pid=7. Accessed June 12, 2010.

San Antonio Express News. 2001. State considers cleanup of creek. Article by Roger Croteau, February 2, 2001, section 3B.

Schenck, J.R., and B.G. Whiteside. 1976. Distribution, habitat preference, and population size estimate of *Etheostoma fonticola*. Copeia 76(4):697–703.

——. 1977. Food habits and feeding behavior of the fountain darter *Etheostoma fonticola* (Osteichthyes, Percidae). Southwestern Naturalist 21(4):487–492.

Schueler, T.R. 2000. The importance of imperviousness. Watershed Protection Techniques. 1(3): 100–111, *in*: The Practice of Watershed Protection, T.R. Schueler and H.K. Holland, eds. Center for Watershed Protection. Elliott City, Maryland.

[SCTRWPG] South Central Texas Regional Water Planning Group. 2000. South Central Texas Region Water Management Plan, Initially Prepared Plan, August 2000.

——. 2009. South Central Texas Regional Water Plan as amended 2009. http://www.twdb.state.tx.us/RWPG/main-docs/documents/L-Vol.I-AmendedAugust2009.pdf. Accessed May 12, 2010.

——. 2010. 2011 Regional Water Plan. Volume I — Executive Summary and Regional Water Plan, South Central Texas Regional Water Planning Area. http://www.twdb.state.tx.us/wrpi/rwp/3rdRound/2010_IPP/RegionL/Volume%20I%20(separate)/TOC.pdf. Accessed May 13, 2010.

Secretary of the Interior. 1994. Environmental justice policy memorandum. August 17, 1994.

Sharp, J.M., Jr., and J.L. Banner. 1997. The Edwards Aquifer: A resource in conflict. GSA Today 7(8):2–9.

Silveus, W.A. 1933. Texas grasses: classification and description of grasses. The Clegg Co, San Antonio, TX.

Slack, R.D., W.E. Grant, S.E. Davis III, T.M. Swannack, J. Wozniak, D. Greer, and A. Snelgrove. 2009. Linking freshwater inflows and marsh community dynamics in San Antonio Bay to whooping cranes. Final Report. Texas A&M AgriLIFE. August 2009. Also known as the San Antonio-Guadalupe Estuarine System (SAGES) study. http://earip.tamu.edu/WhoopingCrane/Slack%20et%20al%202009%20(SAGES%20Final).pdf. Accessed November 1, 2010.

Stehn, T. 2001. Relationship between inflows, crabs, salinities, and whooping cranes. Journey North: U.S. Fish and Wildlife Service file document dated November 26, 2001. http://www.learner.org/jnorth/tm/crane/Stehn_CrabDocument.html. Accessed December 30, 2009.

——. 2010a. Draft 2010 Texas integrated report for Clean Water Act sections 305(b) and 303(d). http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/305_303.html#fy2010. Accessed November 15, 2010.

——. 2010b. Air monitoring site information. http://www.tceq.state.tx.us/cgi-bin/compliance/monops/site_info.pl. Accessed June 21, 2010.

Terrell, E.E., W.H.P. Emery, and H.E. Beaty. 1978. Observations on *Zizania texana* Texas wildrice, an endangered species. Bulletin of the Torrey Botanical Club 105(1):50–57.

Texas Aquaculture Association. 2006. The Texas aquaculture industry 2006. http://www.thefishsite.com/articles/183/the-texas-aquaculture-industry-2006. Accessed July 6, 2010.

Texas Comptroller of Public Accounts. 2010. State sales and use tax analysis quarterly report. http://www.window.state.tx.us/taxinfo/staxqtr/stxqtr_hist.html. Accessed August 24, 2010.

Texas Department of Economic Tourism and Dean Runyan Associates. 2011. The economic impact of travel on Texas 1990–2010. A report prepared for Texas Tourism, Office of the Governor, Texas Economic Development & Tourism.

[TNRCC] Texas Natural Resources Conservation Commission. 1996. The State of Texas water quality inventory. Vols. 3 and 4.

——. 1998. State of Texas water quality inventory for planning basin groups B and C.

——. 2011. Texas Conservation Action Plan.

——. 2012. Texas Conservation Action Plan.

[TSDC] Texas State Data Center. 2010. Estimates of the total populations of counties and places in Texas for July 1, 2008 and January 1, 2009 - Table 1 race/ethnicity total population by migration scenario for 2000–2040 in 5 year increments. http://txsdc.utsa.edu/tpepp/2008projections/2008_txpopprj_cntytotnum.php. Accessed June 5, 2010.

[TSDC SD] Texas State Data Center and Office of the State Demographer. 2004. Metropolitan statistical areas. http://txsdc.utsa.edu/maps/reference/txmsa04_ref.php.

[TSHA] Texas State Historical Association. 2010a. Handbook of Texas Online, s.v. “Guadalupe River”. http://www.tshaonline.org/handbook/online/articles/GG/rng1.html. Accessed November 15, 2010.

——. 2010b. Handbook of Texas Online, s.v. “Comal River”. http://www.tshaonline.org/handbook/online/articles/rnc11. Accessed November 15, 2010.

——. 2011. Handbook of Texas Online s.v. “San Marcos River” http://www.tshaonline.org/handbook/online/articles/rns10. Accessed April 18, 2011.

[TWC] Texas Workforce Commission. 2000. Labor market information. Covered employment and wages by industry and county.

——. 2001. Labor market information. Covered employment and wages by industry and county, 2000.

——. 2002. Labor market information. Covered employment and wages by industry and county, 2001.

——. 2009. Labor market information. http://www.twc.state.tx.us/. Accessed January 19, 2011.

——. 2010. Labor market information. http://www.twc.state.tx.us/. Accessed January 19, 2011.

[TWDB] Texas Water Development Board. 2002. 2002 state water plan, population projections by county. http://www.twdb.state.tx.us/data/popwaterdevelop/countypopulation.htm. Accessed April 2010.

——. 2003. Revised population and water demand projections for development of 2006 regional water plans. http://www.twdb.state.tx.us/data/popwaterdemand/2003Projections/DemandProjections.htm. Accessed April 2010.

——. 2006a. Major aquifers of Texas. A map. http://www.twdb.state.tx.us/mapping/maps/pdf/aqu_maj_8x11.pdf. Accessed May 4, 2010.

——. 2006b. Minor aquifers of Texas. A map. http://www.twdb.state.tx.us/mapping/maps/pdf/aqu_min_8x11.pdf. Accessed May 4, 2010.

——. 2010a. Carrizo-Wilcox aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R345%20Aquifers%20of%20Texas/Majors/carrizo.pdf. Accessed May 4, 2010.

——. 2010b. Gulf coast aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwreports/r345%20aquifers%20of%20texas/Majors/gulf.pdf. Accessed May 4, 2010.

——. 2010c. Hickory aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwreports/r345%20aquifers%20of%20texas/Minors/hickory.pdf. Accessed May 5, 2010.

——. 2010d. Ellenburger –San Saba aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwreports/R345%20Aquifers%20of%20Texas/Minors/ellenbur.pdf. Accessed May 5, 2010.

——. 2010e. Queen City aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R345%20Aquifers%20of%20Texas/Minors/queen.pdf. Accessed May 5, 2010.

——. 2010f. Sparta aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwreports/R345%20Aquifers%20of%20Texas/Minors/sparta.pdf. Accessed May 5, 2010.

——. 2010g. Yegua Jackson aquifer. Texas Water Development Board On-line Description. http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwreports/R345%20Aquifers%20of%20Texas/Minors/YeguaJackson.pdf. Accessed May 5, 2010.

——. 2010h. Population and water demand projections for regional water planning. http://www.twdb.state.tx.us/wrpi/data/pop.asp. Accessed July 6, 2010.

——. 2011. Groundwater Conservation Districts confirmed and pending confirmation. Texas Water Development Board, updated September 2011. http://www.twdb.state.tx.us/mapping/maps/pdf/gcd_only_8x11.pdf. Accessed September 2011.

——. 2012. Summary of South-Central Texas (L) region *in* Water for Texas 2012 State Water Plan. Available http://www.twdb.state.tx.us/wrpi/swp/swp.asp.

Therrell, M.D. 2000. The historic and paleoclimatic significance of log buildings in south-central Texas. Historical Archaeology 34(2):25–37.

Thomas, J.K., C.E. Adams, and J. Thigpen. 1990. Texas hunting leases: Statewide and regional summary. Texas A&M University. Texas Agricultural Experiment Station – Department of Rural Sociology Technical Report. 90-4. College Station, TX.

Tupa, D.D., and W.K. Davis. 1976. Population dynamics of the San Marcos, Texas salamander *Eurycea nana*. Texas Journal of Science 27(1):179–195.

[TXP] TXP, Inc. 2007. The impact of tourism in Comal County. City of New Braunfels and the New Braunfels Economic Development Foundation. December 2007.

[USACE] U.S. Army Corps of Engineers. 1965. Survey report on Edwards underground reservoir, Guadalupe, San Antonio, and Nueces Rivers and tributaries, Texas. U.S. Army Corps of Engineers, Fort Worth District and San Antonio, Texas, Edwards Underground Water District, 2 Vols.

U.S. Census Bureau. 2010a. Decadal censuses of 1960, 1970, 1980, 1990, 2000 and estimates for 2009.

——. 2010b. Small area income and poverty estimates, 2006–2009. http://www.census.gov/population/www/metroareas/aboutmetro.html. Accessed August 24, 2010.

[USDA] U.S. Department of Agriculture. 1992. Census of Agriculture Texas State and County highlights. http://www.agcensus.usda.gov/Publications/1992/State_and_County_Highlights/Texas/index.asp. Accessed December 7, 2011.

——. 1997. Census of Agriculture Texas State and County data, National Agricultural Statistics Service. http://www.agcensus.usda.gov/Publications/1997/Vol_1_National,_State_and_County_Tables/Texas/index.asp. Accessed December 7, 2011.

——. 2002. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/index.asp.

——. 2007. http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_County_Level/Texas/index.asp.

[USEPA] U.S. Environmental Protection Agency. 1994. Presidential Executive Order 12898, environmental justice. http://www.epa.gov/fedrgstr/eo/eo12898.htm. Accessed August 24, 2010.

——. Letter to Rick Perry, Governor, State of Texas, December 9, 2011.

[USFWS] U.S. Fish and Wildlife Service. 1991a. Black-capped vireo recovery plan. Austin, TX.

——. 1991b. Golden-cheeked warbler recovery plan. Austin, TX.

——. 1992. Attwater's prairie chicken (*Tympanuchus cupido attwateri*) recovery plan, second revision. Albuquerque, NM.

——. 1996a. San Marcos and Comal Springs and associated aquatic ecosystems (revised) recovery plan. U.S. Fish and Wildlife Service. 121 pp.

——. 1996b. San Marcos/Comal/Edwards Aquifer rare, threatened, and endangered species contingency plan. Revised version dated May 1996. 59 pp.

——. 2001. Environmental assessment/habitat conservation plan for issuance of an Endangered Species Act Section 10(a)(1)(B) permit for the incidental take of two troglobitic ground beetles (*Rhadine exilis* and *Rhadine infernalis*) and Madla Cave meshweaver (*Cicurina madla*) during the construction and operation of commercial development on approximately 1,000-acre La Cantera property, San Antonio, Bexar County, Texas. 196 pp.

——. 2008a. Draft Bexar County karst invertebrate recovery plan. U.S. Fish and Wildlife Service, Albuquerque, NM. 125 pp.

——. 2009. Part III: Endangered and threatened wildlife and plants; partial 90-day finding on a petition to list 475 species in the southwestern United States as threatened or endangered with critical habitat; proposed rule. Federal Register Vol. 74, No. 240. December 16, 2009.

[USGS] U.S. Geological Survey. 1995. Geology and hydrology of the Edwards Aquifer in the San Antonio area, Texas. Water-Resources Investigations Report 95-4186. U.S. Department of the Interior, Austin.

——. 1999. Recharge to and discharge from the Edwards Aquifer in the San Antonio area, Texas, 1998. http://tx.usgs.gov/reports/dist/dist-1999-01/. Accessed April 27, 2010.

Uvalde County Community Profile. 2010. Central and Southwest Economic Development Department. 2010. Community profile of Uvalde, TX. http://www.csw.com/ed/. Accessed June, 2010.

Vaughan, J.E. 1986. Population and autoecological assessment of *Zizania texana* Hitchcock (Poaceae) in the San Marcos River. M.S. thesis, Southwest Texas State University, San Marcos, TX. Veni, G. 1997. Geomorphology, hydrogeology, geochemistry and evolution of the karstic Lower Glen Rose Aquifer, South-Central Texas. Texas Speleological Survey Monographs No. 1: 1, 409 pp.

[VEDC] Victoria Economic Development Corporation. 2010. Community profile: major employers. http://www.victoriaedc.com/community-profile/major-employers/. Accessed June 10, 2010.

Veni, G., and Associates. 2006. Hydrological, biological, archeological, and paleontological karst investigations, Camp Bullis, Texas 1993–2006. Report for Natural and Cultural Resources, Environmental Division, Fort Sam Houston, TX.

Veni, G., J.R. Reddell, and J.C. Cokendolpher. 1999. Management plan for the conservation of rare and endangered karst species, Camp Bullis, Bexar and Comal Counties, Texas. Report for Garrison Public Works, Environmental Division, Fort Sam Houston, TX.

Votteler, T.H. 2002. Raiders of the lost aquifer? Or the beginning of the end to fifty years of conflict over the Texas Edwards Aquifer. Tulane Environmental Law Journal 15(2):257–334.

Wang, L., J. Lyons, P. Kanehl, R.T. Bannerman. 2001. Impacts of urbanization on stream habitat and fish across multiple scales. Environmental Management 28(2):255–266.

Whiteside, B.G. 1976. *Gambusia georgei* Hubbs and Peden, 1969: San Marcos gambusia. Report to U.S. Fish and Wildlife Service, Endangered Species Division.

[WORD] Water Oriented Recreation District of Comal County. 2010a. About WORD: organization and mission. Website at http://www.wordcc.com/aboutus.htm. Accessed August 24, 2010.

——. 2010b. Tax receipt summary statistics for 2008 and 2009. Data provided by Mike Dussere, Director on August 23, 2010.

Young, F.N., and G. Longley. 1975. A new subterranean aquatic beetle from Texas (Coleoptera: Dytiscidae-Hydroporinae). Annals of the Entomological Society of America 69(5):787–792.

APPENDIX A

TABULAR DATA FOR AGRICULTURAL PRODUCTION AND IRRIGATION WATER USE WITHIN THE EIS STUDY AREA

TERMS AND ACRONYMS

ACT – Antiquities Code of Texas
AM – Adaptive Management
AMP – Adaptive Management Program
ASR – aquifer storage and recovery
BMP(s) – best management practice(s)
BWL – Bad Water Line
CAA – Clean Air Act
CCSP – U.S. Climate Change Science Program
CEQ – Council on Environmental Quality
CFR – Code of Federal Regulations
CFU – colony-forming units
CNB – City of New Braunfels
CPM – Critical Period Management
CSM – City of San Marcos
DEIS – Draft Environmental Impact Statement
DHHS – Department of Health and Human Services
DOR – drought of record
EAA – Edwards Aquifer Authority (the Authority)
EARIP – Edwards Aquifer Recovery Implementation Program
EDF – Environmental Defense Fund
EIS – environmental impact statement
ERPA – Environmental Restoration and Protection Area
ESA – Endangered Species Act
FR – Federal Register
GBRA – Guadalupe-Blanco River Authority
GCSNA – Government Canyon State Natural Area
GHG – Green House Gas
HCP – Habitat Conservation Plan
IA – Implementing Agreement
IH – Interstate Highway
IPCC – Intergovernmental Panel on Climate Change
IPM – Integrated Pest Management
ISD – Independent School District
ITP – Incidental Take Permit
LID – Low Impact Development
MCLs – maximum contaminant levels
MSA – Metropolitan Statistical Area
msl – mean sea level
NAAQS – National Ambient Air Quality Standards
NCDC – U.S. Historical Climate Network of the National Climatic Data Center
NEPA – National Environmental Policy Act
NGOs – non-governmental organizations
NHPA – National Historic Preservation Act
NRHP – National Register of Historic Places
NOI – Notice of Intent
NRI – Nationwide Rivers Inventory
OCR – off-channel reservoir
PCBs – Polychlorinated Biphenyls
PCE – tetrachloroethene
RM – Ranch to Market Road
RWCP – Regional Water Conservation Program
SALs – State Archeological Landmarks
SAWS – San Antonio Water System
SB 3 – Senate Bill 3
SCTRWPG – South Central Texas Regional Water Planning Group
SCUBA – Self-contained Underwater Breathing Apparatus
Service – U.S. Fish and Wildlife Service
SH –Texas State Highway
SHPO – State Historic Preservation Officer
SSA – Sole Source Aquifer
STIR – State of Texas Integrated Report
SVOCs – Semi-Volatile Organic Compounds
TAG – Technical Advisory Group
TCE – trichloroethene
TCEQ – Texas Commission on Environmental Quality
TDS – total dissolved solids
THC – Texas Historic Commission
TPWD – Texas Parks and Wildlife Department
TSDC – Texas State Data Center
TSU – Texas State University
TSWQS – Texas Surface Water Quality Standards
TWC – Texas Workforce Commission
TWDB – Texas Water Development Board
TxDOT – Texas Department of Transportation
US – U.S. Route
USACE – U.S. Army Corps of Engineers
USDI – U.S. Department of the Interior
USEPA – U.S. Environmental Protection Agency
VISPO – Voluntary Irrigation Suspension Program Option
VOCs – Volatile Organic Compounds
WORD – Water Oriented Recreation District of Comal County
WRIP – Water Resources Integrated Pipeline

Table A-1. Agricultural Production in the EIS Study Area, 2007.

COUNTY	TOTAL CROPLAND (acres)	IRRIGATED CROPLAND (acres)[a]	HARVESTED CROPLAND (acres)	CATTLE AND CALVES (num)	HOGS AND PIGS (num)[a]	SHEEP AND LAMBS (num)[a]	POULTRY (LAYERS) (num)[a]
Western Region							
Edwards	24,872	630	3,420	22,247	D	27,832	313
Kinney	11,632	2,019	2,636	11,672	D	9,052	D
Real	26,097	231	1,354	4,830	352	2522	182
Uvalde	131,420	36,855	66,273	52,366	120	10,050	846
Subtotal	**194,021**	**39,735**	**73,683**	**91,115**	**472**	**49,456**	**1,341**
Central Region							
Atascosa	139,080	16,618	52,418	94,266	208	1,049	1,584
Medina	173,541	34,380	95,022	55,759	360	2,981	2,488
Subtotal	**312,621**	**50,998**	**147,440**	**150,025**	**568**	**4,030**	**4,072**
Eastern Region							
Bexar	124,952	9,999	59,827	35,820	1,241	3,403	11,118
Caldwell	71,459	681	43,862	45,291	93	516	D
Comal	37,467	208	13,468	12,868	137	3,512	2,946
Guadalupe	125,959	893	83,517	52,045	1,118	2,676	140,828
Hays	39,265	287	15,557	16,309	256	1,570	31,136
Kendall	34,071	281	10,069	15,485	442	9,491	1,819
Subtotal	**433,173**	**12,349**	**226,300**	**177,818**	**3,287**	**21,168**	**187,847**
Downstream							
Calhoun	88,885	3065	61,537	19,057	10	254	453
DeWitt	78,581	510	42,802	108,324	491	356	61,229
Gonzales	99,016	2,965	50,836	160,799	606	889	4,909,610
Refugio	94,329	D	75,615	33,197	47	D	154
Victoria	134,085	2,304	79,299	59,059	149	303	878
Subtotal	**494,896**	**8,844**	**310,089**	**380,436**	**1,303**	**1,802**	**4,972,324**
TOTAL	**1,434,711**	**111,926**	**757,512**	**799,394**	**5,630**	**76,456**	**5,165,584**

Source: USDA (2007).
[a] D = Withheld by the U.S. Department of Agriculture to avoid disclosing data for individual farms.

Table A-2. Agricultural Production in the EIS Study Area, 2002.

COUNTY	TOTAL CROPLAND (acres)	IRRIGATED CROPLAND (acres)[a]	HARVESTED CROPLAND (acres)	CATTLE AND CALVES (num)	HOGS AND PIGS (num)[a]	SHEEP AND LAMBS (num)	POULTRY (LAYERS) (num)[a]
Western Region							
Edwards	19,144	191	1,843	17,256	55	35,240	786
Kinney	21,611	D	1,573	10,738	D	22,286	72
Real	12,528	250	1,565	7,297	226	3,992	105
Uvalde	154,086	44,762	77,882	64,325	314	22,243	948
Subtotal	**207,369**	**45,203**	**82,863**	**99,616**	**595**	**83,761**	**1,911**
Central Region							
Atascosa	222,603	13,821	55,452	95,693	629	846	D
Medina	236,096	48,931	123,848	73,794	454	2,043	2,570
Subtotal	**458,699**	**62,752**	**179,300**	**169,487**	**1,083**	**2,889**	**2,570**
Eastern Region							
Bexar	155,900	11,469	74,204	52,988	3,412	2,778	2,519
Caldwell	107,126	757	43,961	50,022	1,182	945	D
Comal	37,231	246	12,495	14,582	505	3,379	1,148
Guadalupe	183,601	2,288	101,367	60,032	1,498	3,673	88,660
Hays	57,922	291	16,344	26,165	391	3,239	2,235
Kendall	41,507	541	10,381	13,962	764	13,483	1,095
Subtotal	**583,287**	**15,592**	**258,752**	**217,751**	**7,752**	**27,497**	**95,657**
Downstream							
Calhoun	94,647	2,752	48,600	23,892	10	96	175
DeWitt	166,017	1,411	47,628	117,113	2,253	448	D
Gonzales	183,539	2,171	53,768	161,794	1,540	1,157	3,988,343
Refugio	106,678	750	15,535	41,239	22	71	63
Victoria	166,089	2,509	85,578	69,544	236	305	731
Subtotal	**716,970**	**9,593**	**251,109**	**413,582**	**4,061**	**2,077**	**3,989,312**
TOTAL	**1,966,325**	**133,140**	**772,024**	**900,436**	**13,491**	**116,224**	**4,089,450**

Source: USDA (2002).
[a] D = Withheld by the U.S. Department of Agriculture to avoid disclosing data for individual farms.

Table A-3. Agricultural Production in the EIS Study Area, 1997.

COUNTY	TOTAL CROPLAND (acres)	IRRIGATED CROPLAND (acres)[a]	HARVESTED CROPLAND (acres)	CATTLE AND CALVES (num)	HOGS AND PIGS (num)[a]	SHEEP AND LAMBS (num)[a]	POULTRY (3 MONTHS OR OLDER) (num)[a]
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: USDA (1997).
[a] D = Withheld by the U.S. Department of Agriculture to avoid disclosing data for individual farms.

Table A-4. Agricultural Production in the EIS Study Area, 1992.

COUNTY	TOTAL CROPLAND (acres)	IRRIGATED CROPLAND (acres)	HARVESTED CROPLAND (acres)	CATTLE AND CALVES (num)	HOGS AND PIGS (num)[a]	SHEEP AND LAMBS (num)[a]	POULTRY (3 MONTHS OR OLDER) (num)[a]
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: USDA (1992).
[a] D = Withheld by the U.S. Department of Agriculture A to avoid disclosing data for individual farms.

Table A-5. Agricultural Production in the EIS Study Area, 1987.

COUNTY	TOTAL CROPLAND (acres)	IRRIGATED CROPLAND (acres)[a]	HARVESTED CROPLAND (acres)	CATTLE AND CALVES (num)	HOGS AND PIGS (num)[a]	SHEEP AND LAMBS (num)[a]	POULTRY (3 MONTHS OR OLDER) (num)[a]
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: USDA (1992).
[a] D = Withheld by the U.S. Department of Agriculture to avoid disclosing data for individual farms.

Table A-6. Non-Irrigated and Irrigated Land Crop Yields[a] in Bexar, Medina and Uvalde Counties, South Central Texas Region.

CROP		NON-IRRIGATED LAND[b]	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		NP	3,500 lbs/acre
Sesame		NP	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		NP	14 tons/acre
Cabbage		NP	16 tons/acre
Cantaloupe		NP	300 cartons/acre
Carrots/Fresh		NP	12 tons/acre
Carrots/Processing		NP	14 tons/acre
Cucumbers/Fresh		NP	6.25 tons/acre
Cucumbers/Pickles		NP	8 tons/acre
Lettuce		NP	12.5 tons/acre
Onions		NP	18.75 tons/acre
Spinach/Fresh		NP	450 bushels/acre
Spinach/Processing		NP	11 tons/acre
Forage	Coastal Bermuda/Pasture	200 days/acre	600 days/acre[c]
	Coastal Bermuda/Hay	NP	10 tons/acre
	Forage Sorghum/Grazing	NP	600 days/acre[c]
	Forage Sorghum/Hay	4.5 tons/acre	10 tons/acre

[a] Source: Pena (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.
[b] NP = Not produced on non-irrigated land.
[c] May stock more than one animal unit per acre.

Special Note:

The Texas Blind Salamander is listed under the scientific name *Typhlomolge rathbuni* in the EIS.

However, it has been reclassified as *Eureycea rathbuni* by the scientific community in Petranka, 1998, Chippindale et al., 2000, and Crothers et. al. 2000 and 2008.

The U.S. Fish and Wildlife Service follows the name under which a species was listed, though we recognize the scientific change in name that has not been recorded in the FR.

Therefore, the standard notation should be:

Typhlomolge* [=*Eureycea*] *rathbuni

This both recognizes the regulatory and scientific naming conventions until a change notice published.

This change will be reflected in the final version of the EIS.