DRAFT
ENVIRONMENTAL IMPACT STATEMENT

AUTHORIZATION OF INCIDENTAL TAKE AND IMPLEMENTATION OF THE BARTON SPRINGS/ EDWARDS AQUIFER CONSERVATION DISTRICT HABITAT CONSERVATION PLAN

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

June 2017

Austin Blind Salamander
Photo courtesy David M. Hillis.

Barton Springs Salamander
Photo courtesy Dee Ann Chamberlain.

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Prepared for:

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

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June 2017

Cover Sheet

Draft Environmental Impact Statement (dEIS) for Authorization of Incidental Take and Implementation of the Barton Springs/Edwards Aquifer Conservation District Habitat Conservation Plan (HCP) for the Barton Springs salamander (*Eurycea sosorum*) and the Austin blind salamander (*Eurycea waterlooensis*).

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

Type of Statement:Draft Environmental Impact Statement

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The U.S. Fish and Wildlife Service (the Service) received an application from the Barton Springs/Edwards Aquifer Conservation District (District) 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 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 provide exceptions to the prohibitions of take for two Covered Species, the Barton Springs salamander and Austin blind salamander, arising from permitted pumping authorized by the District throughout the District's jurisdictional area that in turn reduces springflow at the natural outlets of the Barton Springs system.

As part of the ITP process, the District prepared an HCP that specifies what biological impacts are likely to result from the taking of the Covered Species and the measures that the District will undertake to avoid, minimize, and mitigate such impacts; how the HCP will be funded; and what alternatives to the taking were considered. The proposed term of the permit is 20 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 other alternatives to the proposed action. The alternatives are: 1) No Action; 2) issuance of an ITP for permitted pumping under the District HCP (proposed action); 3) water demand reduction; and 4) water supply augmentation and substitution.

The Proposed Action (Alternative 2) would have the lowest economic impacts to the region, but would have potentially higher biological impacts to the Covered Species during Drought of Record (DOR) conditions than Alternative 1 (No Action), Alternative 3 (Water Demand Reduction), and Alternative 4 (Water Supply Augmentation and Substitution). Alternatives 1, 3, and 4 would provide greater protection to the Covered Species, but would result in high impacts to the regional economy. The proposed action would provide mitigation measures for the Covered Species, afford coverage under an ITP, and is the most balanced alternative in consideration of biological benefits, economic costs, and the existing regulatory and political environment. Therefore, it was selected as the preferred alternative.

Executive Summary

ES 1.0 Background

This Draft Environmental Impact Statement (dEIS) describes the potential impacts of the issuance of a proposed Incidental Take Permit (Permit, ITP) to the Barton Springs/Edwards Aquifer Conservation District (District). The District created a Habitat Conservation Plan (HCP) that proposes actions to minimize and mitigate unavoidable incidental take of the endangered Barton Springs salamander (*Eurycea sosorum*) and Austin blind salamander (*Eurycea waterlooensis*) (the "Covered Species"). The District submitted the HCP to the U.S. Fish and Wildlife Service (Service) as part of an application for a Permit under Section 10(a)(1)(B) of the Endangered Species Act of 1973, as amended, 16 U.S.C. § 1531, et seq. (ESA). The requested Permit would provide exceptions to the prohibitions of take of the Covered Species that may result from specific otherwise lawful activities (the "Covered Activities") for a period of 20 years. The Covered Activities include pumping withdrawals from the Barton Springs segment of the Edwards Aquifer (Aquifer) implemented, authorized, or permitted by the District in portions of Travis and Hays Counties in central Texas.

ES 2.0 Purpose and Need for Action

The purpose of providing the requested Permit to the District is to authorize incidental take of the Barton Springs salamander and Austin blind salamander that may occur from District-permitted Aquifer pumping under implementation of the HCP. The need for this action is for the Service to provide a mechanism for the District to avoid violations of the ESA, to minimize and mitigate the effects of its actions to the maximum extent practicable, while providing adequate funding to protect the two covered salamander species. Approval of the HCP by the Service and the District's assurance that the HCP will be implemented as written are among several requisites that must be met for issuance of the Permit. The purposes of the HCP are to avoid, minimize, and mitigate any incidental take that occurs from Aquifer pumping under Aquifer management strategies implemented by the District pursuant to its statutory mandate to provide for the conservation, preservation, and protection of groundwater resources of all aquifers in its jurisdictional area.

ES 3.0 dEIS Alternatives Evaluated

Four alternatives were selected for analysis in this dEIS. Each of the four alternatives are described below and summarized in **Table ES-1**.

ES 3.1 Alternative 1: No Action

Under the No Action Alternative, the District would not implement its HCP and the Service would not issue an ITP. The District would pursue its legislatively mandated Aquifer management responsibilities, but the management and regulation of pumping would be limited to non-drought conditions. Maximum allowable pumping during non-drought desired future conditions (including water for aquifer storage and retrieval projects) would be limited to 16 cubic feet per second (cfs). The District would notify permittees of approaching drought and issue notices to stop pumping once drought is declared and “take” of the Barton Springs and Austin Blind salamanders is imminent. Protection of listed species would depend on expected compliance by the District’s permittees. Under the No Action Alternative, each permittee would be expected to comply with pumping cessation notices issued by the District, or would need to seek an individual ITP for the two species in order to continue pumping.

Under Alternative 1, during DOR conditions, compliance by all permittees could reduce total Aquifer pumping to less than 1 cfs, (assumes nearly complete cessation of pumping), with resulting projected lowest average monthly springflow at Barton Springs of 11 cfs reached during the 1950’s DOR that the Covered Species are known to have survived. However, if Aquifer pumping reductions were not realized during any drought conditions that resulted in take of the two species, there would not be any protection provided to the District from violations under the ESA or to permitted pumpers that did not reduce pumping and were not covered by an individual ITP.

Under Alternative 1, in the absence of a District ITP, pumpers could seek individual ITPs from the Service. Within the affected area many pumping entities could apply for separate ITPs, each with its own permit area.

ES 3.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District HCP (Preferred Action)

Alternative 2 would involve approval of the District’s HCP addressing authorized pumping of the Barton Springs Segment of the Edwards Aquifer and the issuance of an ITP by the Service. Alternative 2 measures could meet state-mandated Desired Future Conditions (DFC).

Table ES-1. Comparison of dEIS Alternatives

Characteristics of Alternatives	**Alternative 1** No Action[1]	Alternative 2 Issuance of ITP and Implementation of HCP by BSEACD	Alternative 3 Water Demand Reduction[2] (Complete Curtailment of Pumping)	Alternative 4 Water Supply Augmentation and Substitution[3]
Coverage Under an ITP for Barton Springs and Austin Blind Salamanders	No	Yes	Not Required, provided regulated pumping of Aquifer completely ceases during drought as defined.	Yes, until alternative water supplies completely substitute for groundwater pumping.
ITP Permit Holders	None, BSEACD permittees that choose to continue pumping the Aquifer during drought would need to apply for individual ITPs.	BSEACD	None	BSEACD
Terms of ITP	N/A	20 years	N/A	5 years
Maximum Allowable Pumping (cfs) During Non-drought Conditions Including ASR Requirements	16	16	16	16
Total Aquifer Pumping Allowed During DOR Conditions (cfs)	<1[4]	≤5.2	<1	≤5.2, but decreasing stepwise to < 1 as alternative supplies become available and are required to be used.
Lowest projected Springflow During DOR conditions (cfs)	11	6.5	11	6.5 initially, until complete substitution is achieved, then becomes 11

Table 1, cont'd

Characteristics of Alternatives	**Alternative 1** No Action[1]	Alternative 2 Issuance of ITP and Implementation of HCP by BSEACD	Alternative 3 Water Demand Reduction[2] (Complete Curtailment of Pumping)	Alternative 4 Water Supply Augmentation and Substitution[3]
Required Change in Groundwater Management Policy and Strategy	BSEACD would notify permittees of the need to cease pumping during declared drought when take may occur.	None; current phased regulatory-based Aquifer drought management program continues.	Would require the BSEACD to modify permits unilaterally to require permittees to cease pumping during declared drought when take may occur.	Would require BSEACD to begin immediate development of alternative water supplies for substitution, then modify to-be-substituted permits unilaterally to use alternate supplies during declared drought when take may occur.
Ability to offset Effects of Increased Exempt Pumpage on Springflow during Drought	No	Yes	Yes	Yes
Mitigation and Conservation Measures	Conservation and mitigation measures limited only to individual ITPs.	Minimization measures throughout; maximum benefit of mitigation during extreme drought.	None	Minimization measures throughout, but only during shortened permit term. Maximum benefit achieved by complete supply substitution during drought.
Planned Research Studies	None	Yes	None	Only those that can be implemented under the shortened permit term
Biological Impacts	Low	Low to Moderate	Low	Low
Socioeconomic Impacts	Moderate to High	Low	High	High
Mitigation or Conservation Measures	Minimum Benefit	Maximum Benefit	None	Limited to Interim HCP until alternative water supplies supersede groundwater pumping.

Table 1, cont'd

Characteristics of Alternatives	**Alternative 1** No Action[1]	Alternative 2 Issuance of ITP and Implementation of HCP by BSEACD	Alternative 3 Water Demand Reduction[2] (Complete Curtailment of Pumping)	Alternative 4 Water Supply Augmentation and Substitution[3]
Annual Costs to BSEACD[5]	< $300,000	≥$900,000	< $300,000	Costs would range between $3,200,000 and $14,300,000, depending on the source of augmented/substitute water supplied to permittees.
Annual New Costs to BSEACD's Permittees and Other Parties	Potentially moderate/high as entities with pumping permits may choose to apply for an ITP.	Low/None	Potentially high depending on requirements for and source(s) of any augmented substitute water.	Potentially very high depending on the source(s) of augmented/substitute water developed by BSEACD and supplied to permittees, and on cost-recovery by BSEACD.

[1] The BSEACD groundwater management activities would change to not directly regulate groundwater once drought occurs; rather, BSEACD would issue notices to permittees to completely curtail Aquifer pumping upon any drought declaration by BSEACD. Protection of listed species would hinge on expected compliance by its permittees.

[2] BSEACD regulatory program would change to include permit requirements and enforcement of mandatory complete curtailment of all Aquifer pumping once in declared drought, and the ceiling on aggregate Aquifer pumping would be adjusted downward to assure effective cessation of such pumping during drought. Permittees would control how cessation in Aquifer pumping is achieved and could include a variable combination of enforced conservation, drought demand reduction, and supply substitution at the individual permittees' behest and discretion.

[3] BSEACD would develop or cause to be developed and then provide alternative water supplies that would allow complete substitution of Aquifer pumpage during drought, and its regulatory program would change, to include permit requirements and enforcement of mandatory complete substitution of all Aquifer pumping once in declared drought, and the ceiling on authorized Aquifer pumping would be adjusted downward to assure effective substitution for such pumping during drought.

[4] Pumping by BSEACD permittees is restricted without individual ITP.

[5] Annual costs except for Alternative 2 are rough estimates, rounded to nearest $100,000. Costs for Alternatives 1 and 2 are based on costs specified in the HCP (BSEACD 2017); costs for Alternative 4 are based on estimated costs per ac-ft of water produced by the cheapest (water reuse) and most expensive (ASR) water strategies identified in the Region K Regional Water Plan (LCRWPG 2010) to replace a lower limit of up to 5.2 cfs of groundwater withdrawals during DOR conditions; costs to BSEACD for Alternative 3, not including legal defense costs, are similar to those of Alternative 1.

These actions would limit Aquifer pumping during Drought of Record (DOR)-like conditions to no more than 5.2 cfs, thereby maintaining a minimum average Barton Springs monthly springflow of 6.5 cfs. The District's HCP incorporates actions to minimize and mitigate unavoidable incidental take and, includes demand reduction measures, programs encouraging the development and use of new water supplies, greater enforcement capabilities, cooperative efforts with other entities, and mechanisms to adapt management strategies and respond to emergencies. Among the four alternatives evaluated in this EIS, Alternative 2 provides the most technically feasible and economically acceptable measures available for Aquifer management and conservation of the Covered Species (**Table ES-1**) and is, therefore, the preferred Alternative.

ES 3.3 Alternative 3: Water Demand Reduction

Under Alternative 3, the District's permitting program would control Aquifer pumping, both in absolute-use terms and during drought conditions. Alternative 3 would require mandated pumping reductions during DOR conditions to less than 1 cfs to maintain minimum average monthly Barton Springs springflow of 11 cfs. Similar to Alternative 1, this level of springflow would approximate the lowest recorded instantaneous level of springflow reached (10 cfs) during the 1950's DOR that the Covered Species are known to have survived. These regulatory curtailments, backed with effective enforcement to ensure compliance, would protect springflow for the Covered Species. Minimum required springflows equivalent to historical conditions would be ensured under Alternative 3. However, this alternative would employ the most severe regulatory measures to achieve the level of pumping reductions needed and would require one or more sources of replacement water for some indeterminate fraction of the amount curtailed to meet residual demand. Recent rulings by the Texas Supreme Court upheld the rights of groundwater districts to regulate the withdrawal of groundwater, but also upheld the rights of property owners to pump water from their property. This ruling in effect established an undefined legal and financial limit on how much curtailment is "reasonable" and "fair" before a regulatory takings exists in which compensable loss of the amount of water prohibited from pumping must be considered.

ES 3.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would involve the development of other alternative water supplies that would augment the amount of water pumped from the Aquifer, substitute for Aquifer withdrawals, or involve a combination of both to achieve the goal of substantially reducing Aquifer pumping to a level below 1 cfs in order to provide for a minimum average monthly springflow of 11 cfs during drought of record conditions. As additional water supplies become available, the amount of Aquifer pumping would be reduced in direct proportion to the amount of water augmented or substituted. Until enough alternative water supplies could be developed to offset pumping withdrawals to ensure minimum springflows, a short-term ITP and associated HCP would be required. The HCP would identify alternative water sources and other mitigation measures to be implemented until groundwater withdrawals were sufficiently reduced to maintain minimum springflows during drought of record conditions. The District currently does not have the regulatory authority to develop alternative water supplies. Use of augmented or substituted water supplies would have to be implemented voluntarily as is currently being done by some users within the study area. There are also current limitations on the amount of alternative water supplies that could economically be made available to groundwater users within the region.

ES 4.0 Scoping

An updated environmental evaluation was initiated on March 5, 2014, with a Notice of Intent to prepare an environmental document and HCP in the *Federal Register* (79 FR 12522).

A public scoping meeting was held on April 3, 2014, to identify the scope of issues and concerns concerning the proposed action. Comments received during this scoping process have been addressed in this dEIS. The scoping process is described in **Section 1.6** and comments received are included in **Appendix A, Public Involvement**.

ES 5.0 Summary of Impacts

Direct impacts of the four alternatives with respect to the affected resources, as presented in **Sections 4.1** through **4.6**, are summarized for comparison in **Table ES-1**.

The most substantial impacts to the Barton Springs ecosystem are driven by measures that affect Aquifer pumping. The greatest positive impacts to the Covered Species are associated with Alternative 3, Water Demand Reduction, and Alternative 4, Water Supply Augmentation and Substitution. These alternatives provide the greatest level of protection to the Barton Springs ecosystem and the Barton Springs and Austin blind salamanders by sustaining a higher level of water flow through the spring ecosystems during drought, including conditions that would correspond to the drought of record. At the same time, these alternatives would result in the most severe pumping reductions and, consequently, would provide the greatest uncertainty in the establishment of future water management policy. These alternatives would either greatly reduce water available to support existing economic activities and could preclude further economic growth, or they would require greater reliance on higher cost water supplies that would be reflected in higher development costs that could affect many economic sectors.

Under Alternative 1, No Action, there would be no implementation of an HCP and no District ITP. During non-drought conditions, this alternative would allow Aquifer withdrawals that would be higher than current rates (future pumpage estimated at 13–16 cfs), with the least number of measures to avoid or mitigate impacts to the Covered Species. Economic impacts under Alternative 1 would be moderate to high, but would have low biological impacts assuming pumping reductions were implemented during drought conditions. Under Alternative 1, pumpers could apply for individual ITPs to obtain protection from violation of the ESA in the event species take occurs.

Under Alternative 2, Issuance of an ITP for Permitted Pumping under the District HCP, a mandatory pumpage withdrawal limit would be implemented with mitigation measures to reduce groundwater demand, encourage development of alternative water sources, and adapt management strategies to future changing conditions. These HCP measures and the protection provided by the ITP would provide the District's permitted pumpers with protection under the ESA. Although the combination of pumping and low Aquifer recharge could result in monthly springflow as low as 6.5 cfs, any incidental take resulting from this springflow would be covered under the ITP, Alternative 2 would result in low to moderate biological impacts and have low economic impacts.

Under Alternative 3, Water Demand Reduction restricts pumping withdrawal limits (<1 cfs) to ensure monthly springflow equivalent to the lowest historical flow that occurred during the DOR (11 cfs). This alternative would result in low biological impacts but with potentially high economic impacts, would require regulatory and policy actions from the District Board, and may require action on the part of other governmental entities including the Texas Legislature.

Alternative 4, Water Supply Augmentation and Substitution, considers provision of additional water supplies to reduce water demand and subsequent groundwater pumping. Under Alternative 4, augmented or substituted water supplies sufficient to reduce groundwater pumping to less than 1 cfs would be required to ensure monthly springflow equivalent to the lowest historical flow (11 cfs), similar to Alternative 3. While this alternative would provide ecological benefits similar to Alternative 3, the water supplies needed to offset Aquifer pumping would require substantial lead time to develop and would require high economic investment costs. Due to the long development horizon for this alternative, an ITP would likely be needed to provide take coverage under the ESA until pumping could be reduced enough to ensure minimum springflow during droughts. This would require additional costs for the development and implementation of an HCP until sufficient alternative water supplies could be developed and brought online. The lead time requirements and development costs associated with this alternative substantially reduce its overall feasibility.

In summary, the overall impact evaluation of the four dEIS alternatives indicates Alternative 2 is the most balanced alternative in consideration of biological benefits, economic costs, and the existing regulatory and political environment

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Acronyms and Abbreviations

AACOG	Alamo Area Council of Governments
AMP	Adaptive Management Plan
amsl	Above mean sea level
APA	Administrative Procedures Act
APE	Area of Potential Effect
ARR	Austin-Round Rock MSA
ASR	Aquifer Storage and Recovery
BAT	Biological Advisory Team
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
BSEACD	Barton Springs/Edwards Aquifer Conservation District (District)
BWL	Bad Water Line
CAC	Citizens Advisory Committee
CAMPO	Capital Area Metropolitan Planning Organization
CAPCOG	Capital Area Council of Governments
CCTP	Climate Change Technology Program
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	cubic feet per second
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CWO	Comprehensive Watersheds Ordinance
DCP	Drought Contingency Plan
dEIS	Draft Environmental Impact Study
DFC	Desired Future Conditions
District (the)	Barton Springs/Edwards Aquifer Conservation District (BSEACD)
DO	Dissolved Oxygen
DOR	Drought of Record occurring during the years 1950 -1956
EAA	Edwards Aquifer Authority
EIS	Environmental Impact Study
USEPA	Environmental Protection Agency
ERP	Emergency Response Period
ESA	Endangered Species Act
ETJ	extra-territorial jurisdiction
°F	degrees Fahrenheit

FR	*Federal Register*
FY	Fiscal Year
GAM	Groundwater Availability Model
GBRA	Guadalupe-Blanco River Authority
GCD	Groundwater Conservation District
GCP	Groundwater Conservation Plan
GMA	groundwater management area
GMP	Groundwater Management Plan
gpm	gallons per minute
HB	House Bill
HCP	Habitat Conservation Plan
HFC	Hydrofluorocarbons
IA	Implementing Agreement
IH	Interstate Highway
ILA	Interlocal Agreement
IPCC	Intergovernmental Panel on Climate Change
ITP	Incidental Take Permit
LCRA	Lower Colorado River Authority
LCRWPA	Lower Colorado Regional Water Planning Area
LCRWPG	Lower Colorado Regional Water Planning Group
LDC	Land Development Code
µg/L	micrograms per liter.
µS/cm	microsiemen per centimeter
mg/L	milligrams per liter
MAC	Management Advisory Committee
MAG	Managed Available Groundwater
mgd	million gallons per day
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPN	Most probable number
MRLC	Multi-Resolution Land Characteristics
MSA	Metropolitan Statistical Area
msl	Mean sea level
NAAQS	National Ambient Air Quality Standards
NDU	non-exempt domestic use
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NH_3	Ammonia

NRHP	National Register of Historic Places
NOAA	National Oceanic and Atmospheric Administration
NO_x	Nitrogen Oxides
NRCS	Natural Resource Conservation Service
NRI	National Resource Institute
N_2O	Nitrous oxide
O_3	Ozone
PDSI	Palmer Drought Severity Index
PFC	Perfluorocarbons
Pb	Lead
PM_{10}	Particulate matter (10 micrograms)
$PM_{2.5}$	Particulate matter (2.5 micrograms)
POR	Period of Record
R&D	Research and development
RFPs	Request for Proposals
SA	San Antonio-New Braunfels MSA
SAL	State Archeological Landmark
SB	Senate Bill
SC	Specific Conductance
SF_6	Sulfur hexafluoride
SH	State Highway
SHPO	State Historic Preservation Officer
SO_2	Sulfur Dioxide
SOS	Save Our Springs Alliance
TAC	Texas Administrative Code
TAG	Technical Advisory Group
TARL	Texas Archeological Research Laboratory
TCEQ	Texas Commission on Environmental Quality
TDA	Texas Department of Agriculture
TDS	Total Dissolved Solids
TGWA	Texas Groundwater Association
THC	Texas Historical Commission
TNRCC	Texas Natural Resource Conservation Commission (now TCEQ)
TPWD	Texas Parks and Wildlife Department
TSDC	Texas State Data Center
TSWQS	Texas State Water Quality Standards
TWC	Texas Workforce Commission
TWDB	Texas Water Development Board

TxDOT	Texas Department of Transportation
UCP	User Conservation Plans required by the BSEACD
UDCP	User Drought Contingency Plans required by the BSEACD
UNFC	United Nations Framework Convention
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service (Service)
USGCRP	United States Global Climate Change Research Program
USGS	United States Geological Survey
WCWO	Williamson Creek Watershed Ordinance
WORD	Water-oriented Recreation District
WRI	Water Reclamation Initiative
WSC	Water Supply Corporation
WUG	water user groups

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1.0 PURPOSE AND NEED FOR THE ACTION

1.1 INTRODUCTION

This Draft Environmental Impact Statement (dEIS) has been prepared in accordance with the requirements of the National Environmental Policy Act (NEPA) (42 United States Code [U.S.C.] 4321–4327) regarding the proposed issuance of an Incidental Take Permit (ITP) under Section 10(a)(1)(B) of the Endangered Species Act of 1973, as amended (ESA) for authorized pumping of the Barton Springs segment of the Edwards Aquifer (Aquifer) (**Figure 1-1**) by the Barton Springs/Edwards Aquifer Conservation District (the District [also BSEACD in documentation]) throughout its jurisdictional area (**Figure 1-2**). The District seeks an ITP for incidental "take" of two federally protected species, the Barton Springs salamander (*Eurycea sosorum*), and the Austin blind salamander (*Eurycea waterlooensis*).

Section 9 of the ESA prohibits "take" of federally listed species and take means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect such a species or attempt to engage in any such conduct." The ESA defines "incidental" take as take that is incidental to, and not the purpose of, carrying out of an otherwise lawful activity, and Section 10(a)(2)(B) provides for the issuance of ITPs to authorize such take. Under Section 10(a)(2)(A), any application for an ITP must include a "conservation plan" that details, among other things, the impacts of the incidental take allowed by the ITP on affected species and how the impacts of the incidental take will be minimized and mitigated.

The District has prepared a Habitat Conservation Plan (HCP) in support of issuance of an ITP for authorized pumping of the Barton Springs segment of the Edwards Aquifer that may result in incidental take of the Barton Springs salamander and Austin blind salamander.

1.2 COVERED SPECIES

There are two species that will be covered under the proposed action: the Barton Springs salamander and the Austin blind salamander. The Barton Springs salamander was listed as endangered on April 30, 1997 (62 FR 23377), and the Austin blind salamander was listed as endangered on August 20, 2013 (78 FR 51277). These are hereafter referred to as Covered Species.

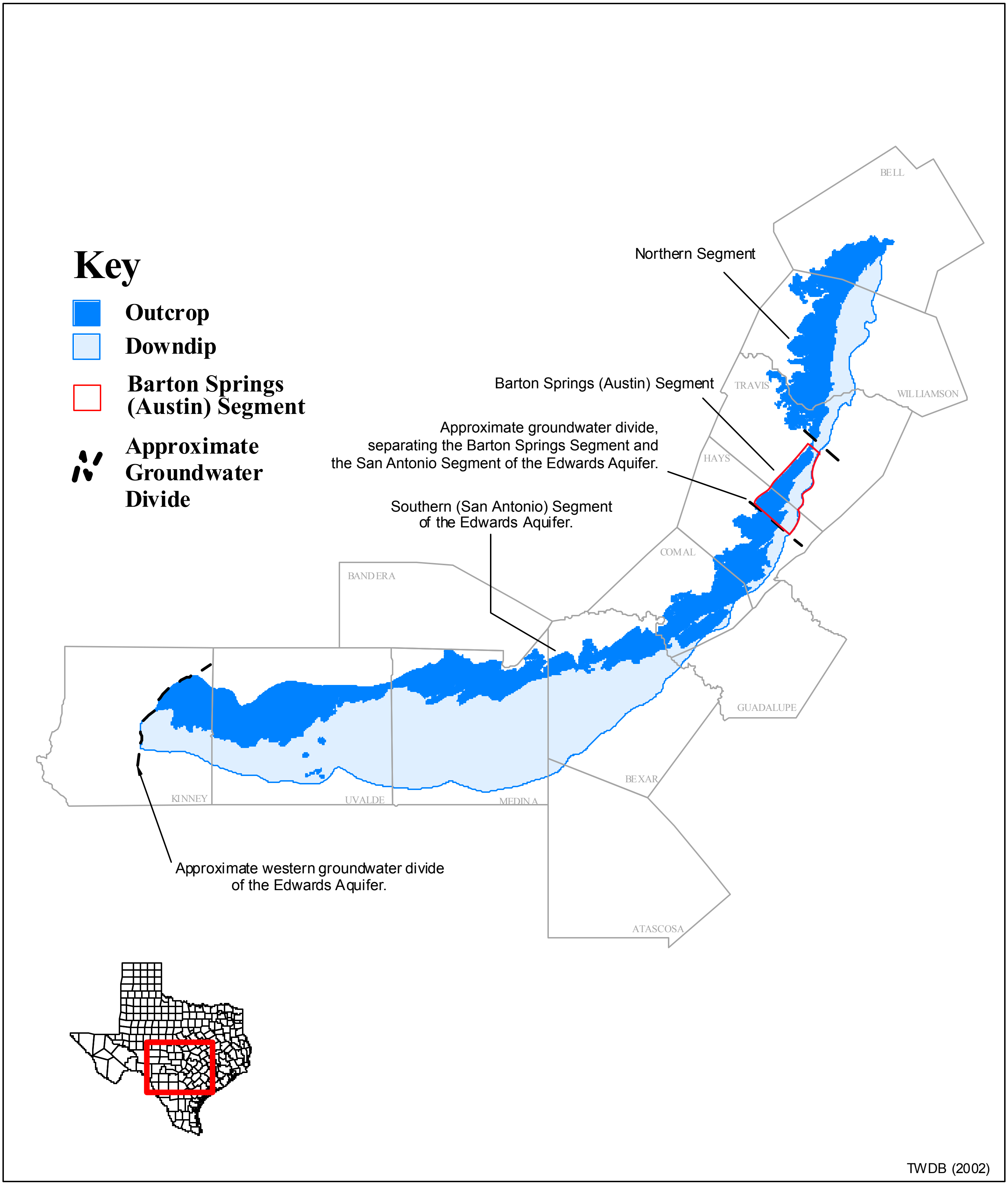

FIGURE 1-1
Map of the Edwards Aquifer and
Barton Springs Segment

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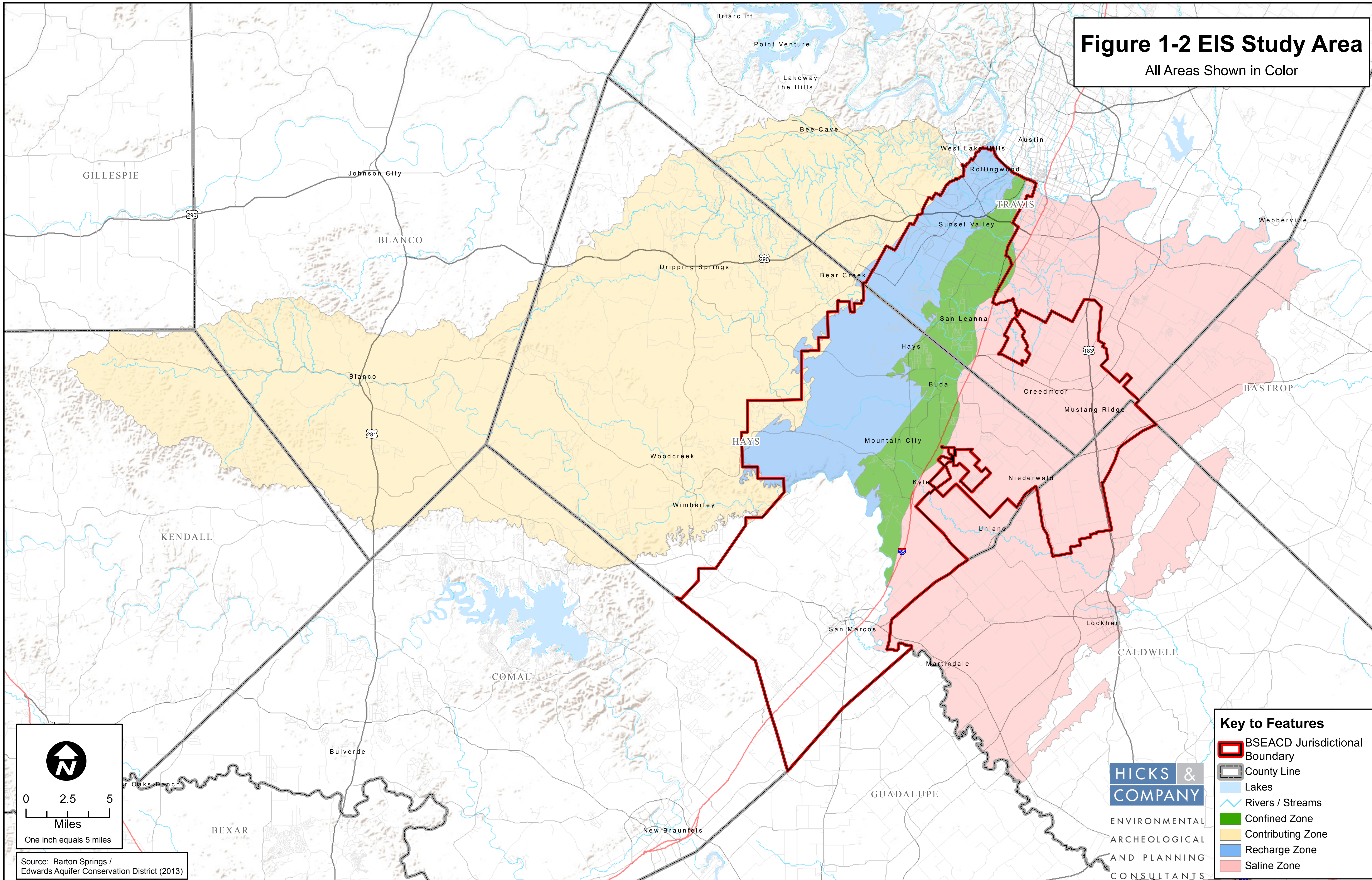

Figure 1-2 EIS Study Area
All Areas Shown in Color
Briarcliff
Point Venture
Lakeway
The Hills
Bee Cave
West Lake Hills
Austin
Rollingwood
TRAVIS
Sunset Valley
Webberville
GILLESPIE
Johnson City
BLANCO
Dripping Springs
Bear Creek
San Leanna
Hays
Buda
Creedmoor
Mustang Ridge
BASTROP
Blanco
HAYS
Mountain City
Woodcreek
Kyle
Niederwald
Wimberley
Uhland
KENDALL
San Marcos
Lockhart
CALDWELL
Martindale
COMAL
Bulverde
GUADALUPE
BEXAR
New Braunfels
0 2.5 5
Miles
One inch equals 5 miles
Source: Barton Springs / Edwards Aquifer Conservation District (2013)
Key to Features
BSEACD Jurisdictional Boundary
County Line
Lakes
Rivers / Streams
Confined Zone
Contributing Zone
Recharge Zone
Saline Zone
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1.3 PROPOSED ACTION AND DECISIONS NEEDED

The proposed action is the approval of the District's HCP and issuance of the requested ITP pursuant to Section 10(a)(1)(B) of the ESA (Preferred Alternative). The proposed ITP term would be 20 years, and renewable thereafter. Before an ITP can be issued, the U.S. Fish and Wildlife Service (the Service) must decide whether the statutory requirements for issuing an ITP under the ESA have been met. In addition, a NEPA analysis as contained in this dEIS must be completed to determine the environmental consequences of the proposed Federal action, alternatives to this action, and whether issuance of an ITP and resulting implementation of the HCP will result in any significant impacts to the human environment.

1.4 PURPOSE AND NEED FOR THE PROPOSED ACTION

The purpose of the proposed action is for the Service to address an application from the District for an ITP to allow for take of the two covered salamander species in the course of conducting otherwise lawful activities as provided for by the ESA. Covered actions include regulated water withdrawals from the Aquifer under an approved HCP. The HCP includes a range of conservation measures and programs designed to minimize and mitigate the effects of take on the two Covered Species, monitor the biological effectiveness of the HCP over time, and allow modification of those measures and programs if necessary. These are described in Section 6.0 of the HCP.

The purpose of this dEIS is to evaluate the effects of HCP implementation and its alternatives on the environment pursuant to requirements of NEPA. The dEIS evaluates environmental consequences of the Preferred Alternative, two other Action Alternatives, and a No Action Alternative.

The need for the action is for the Service to provide a mechanism for the District to avoid violations of the ESA in the course of fulfilling its statutory responsibilities and implementing measures to protect the two covered salamander species. The Barton Springs segment of the Edwards Aquifer is dependent on rainfall for recharge, especially creek flow in streams that cross the recharge zone. Discharge from the Aquifer is through springflow and wells. Only the discharge from wells is controllable. At current pumping levels and future levels anticipated by the District, withdrawals from the Edwards Aquifer under extended and severe drought conditions could adversely impact the Covered Species. Without the proposed action, the District could face significant difficulty in balancing its state-mandated management functions and goals of regulating the water resources of the Barton Springs segment of the Edwards Aquifer while complying with the ESA.

1.5 REGULATORY CONTEXT

1.5.1 Texas Statutes/Regulations

1.5.1.1 Rights to Withdraw Groundwater in Texas

Since 1904, administration of groundwater has basically occurred in Texas under the common law "Rule of Capture." Under this rule, an owner of land may drill a well to seek groundwater, withdraw any groundwater that may be encountered, and place the water to beneficial use without limitation as to amount, place, or purpose of use without incurring any liability to the owner of an adjacent well. Passage of Senate Bill 332 in 2011 by the 82nd Texas Legislature reaffirmed the Rule of Capture, while upholding the authority of groundwater conservation districts to regulate groundwater withdrawals.

Although the Rule of Capture remains in effect, groundwater conservation districts may through rulemaking modify the operation of the Rule of Capture within their boundaries. Districts may limit aquifer withdrawals under the specific authorities provided by Chapter 36, Subsection 36.101 of the Texas Water Code in order to conserve, preserve, and protect groundwater or groundwater recharge.

The Texas Supreme Court, in *Edwards Aquifer Authority v. Day* (369 S.W. 3d 814 [Tex. 2012]), found that landowners might be able to assert a regulatory takings claim against groundwater conservation districts and other government entities in some circumstances. The court reiterated that a landowner's right to groundwater prior to capture is entitled to protection under the takings clause of the Texas Constitution. The court left open the point at which regulation limits or prohibits access to, or production of, groundwater that constitutes a compensable taking.

1.5.1.2 Function of the Barton Springs/Edwards Aquifer Conservation District

The District was created in 1987 by the 70th Texas Legislature as a groundwater conservation district under Chapter 36, with a directive to conserve, protect, and enhance the groundwater resources within its jurisdictional area, including the Aquifer, which currently serves as either a sole source or a primary source of drinking water for more than 70,000 people (BSEACD 2013). It also provides water for Barton Springs, Barton Springs Pool, and their associated spring-dependent species.

Under its enabling legislation, the general jurisdiction of the District wherein it asserts its water management authority for the Aquifer extends to the unconfined (recharge) zone and the confined zone of the Aquifer. The District's jurisdictional area is bounded on the west by the approximate western edge of the Edwards Aquifer outcrop and on the north by the Colorado River (see **Figure 1-2).** The eastern boundary is generally formed by the easternmost service area limits of the Creedmoor-Maha, Aqua-Texas Water Services, and Goforth Water Supply

Corporations. The District's southern boundary reflects additional "shared" territory annexed as a result of legislation passed in 2015, but excludes the Barton Springs segment of the Edwards Aquifer, for which the District regulates groundwater exclusively. This is a multicounty jurisdiction and includes parts of Caldwell, Hays, and Travis Counties; most Barton Springs segment groundwater production is in northern Hays and southern Travis Counties. The dEIS study area includes all areas shown in color on **Figure 1-2**.

The District has the authority to regulate water wells drilled inside its regulatory boundaries, restrict Aquifer withdrawals, build structural facilities, implement non-structural programs, and undertake various studies to develop and implement Aquifer management strategies to achieve its statutory mandate. The District has rule-making authority under Chapter 36 of the Texas Water Code as specified above to implement its policies and procedures and to help ensure the management of the groundwater resources.

A five-member Board of Directors, elected by the population in the jurisdictional area, for staggered 4-year terms, oversees the District's work. All board and advisory committee meetings are open to the public. Directors hire a general manager, who acts as the chief operating officer. The general manager employs a technical staff to administer programs, monitor and manage the Aquifer, and carry out research in support of the District's programs. The Board sets policies and adopts rules and bylaws to operate the District. The Board also appoints *ad hoc* advisory committees to review various activities and procedures and make recommendations to the District. These committees are made up of local citizens who are knowledgeable about environmental and economic concerns within the District as well as technical specialists in various fields.

1.5.1.3 Desired Future Conditions for Springflow

The District Management Plan (BSEACD 2013) adopted by Board resolution on September 27, 2012, and approved by the Texas Water Development Board (TWDB) on January 7, 2013, included the following Desired Future Conditions (DFCs) for the Edwards Balcones Fault Zone Aquifer previously adopted by the member Groundwater Conservation Districts (GCDs) of Groundwater Management Area (GMA) 10 through a joint planning process required by the Texas Water Code 36.108:

- Springflow of Barton Springs during average recharge conditions shall be no less than 49.7 cfs averaged over an 84-month (7-year) period.
- During extreme drought conditions, including those as severe as a recurrence of the 1950s drought of record (DOR), springflow of Barton Springs shall be no less than 6.5 cfs, averaged on a monthly basis. This would require the limit of pumping withdrawals of no more than 5.2 cfs.

1.6 SCOPING

1.6.1 Scoping Process

The purpose of project scoping is to allow an early and open process to determine the scope of issues to be addressed, and identify and eliminate from detailed study the issues which are not significant or which have been covered by prior environmental review.

1.6.2 Public Involvement

1.6.2.1 Scoping History

The process to identify HCP alternatives and contents of a draft environmental document was initiated on August 9, 2005, with publication of a Notice of Intent to prepare an EIS and HCP in the *Federal Register* (70 FR 46186). A scoping meeting was held in Austin, Texas, on August 23, 2005. Issues identified during this scoping meeting were incorporated into a combined Draft HCP and Environmental Impact Study dated August 2007. Subsequent to preparation of this document, the Austin blind salamander became listed as an endangered species and new information became available for the Barton Springs salamander that supersedes some previous concerns and issues. The Service therefore initiated a process to update the scope of issues and concerns concerning the proposed action. An updated environmental evaluation was initiated on March 5, 2014, with a Notice of Intent to prepare an environmental document and HCP in the *Federal Register* (79 FR 12522).

1.6.2.2 Scoping Meeting

A public scoping meeting was held on April 3, 2014, to update the scope of issues and concerns regarding the proposed action. A record of public comments received was posted at the website: ***http://www.regulations.gov***, and also appears as **Appendix A, Public Involvement**.

1.6.2.3 Advisory Groups

The District utilized several advisory groups to assist in the preparation of the HCP. A Citizens Advisory Committee and a Biological Advisory Team were initially established for guidance and oversight. A third committee, the Management Advisory Committee (MAC), was later established to coordinate activities associated with the Covered Species and to monitor implementation of the District HCP. The committees are more fully described below.

Citizens Advisory Committee

The Citizens Advisory Committee (CAC) was created to provide periodic input and critical review of the HCP as it was being prepared. The CAC was created in conformance with Texas Parks and Wildlife Code §§ 83.015–83.016. At least 30 percent of the CAC were owners of unimproved land in the District. The recommendations of the CAC were advisory only, but it had an essential role as a forum for critical review of the HCP. As the District prepared the HCP with the help of a consultant team and other participants, it asked the CAC to provide feedback and advice at various times during the process. The CAC is no longer required and has been replaced by the MAC.

Biological Advisory Team

The Biological Advisory Team (BAT) was created to provide biological and other scientific input and critical review of the HCP as it was being prepared, and to evaluate the HCP once completed in draft form. The BAT was created in conformance with Texas Parks and Wildlife Code §§ 83.015–83.016. The recommendations of the BAT were advisory only, but it had a role in interpreting the results, findings, and conclusions of scientific studies conducted as a part of the HCP and in influencing the outcome of the permit application to the Service. The BAT is no longer required and has been replaced by the MAC.

Management Advisory Committee

On November 15, 2012, the District Board of Directors established an HCP Management Advisory Committee (MAC). The MAC was initially convened during the development of the Draft HCP in 2013-2014 to review the initial versions of documentation and provide input to the Board. The purpose of the MAC is to advise and assist in the coordination of conservation activities affecting Covered Species at Barton Springs, and to monitor the implementation of the District HCP if it is approved. The MAC was created as an additional measure of ensuring continued implementation of the HCP and compliance with the ITP.

More specifically, the MAC is charged with:

- Providing a forum for exchange of information relative to Covered Species;
- Providing advice on Covered Species management activities;
- Advising the District on budgetary issues relating to the management of Covered Species;
- Advising the District on priorities for conservation actions;
- Reviewing the District’s HCP annual report and providing comments to the District; and
- Guiding the development and implementation of the adaptive management program.

If the HCP is approved, the MAC will meet periodically as needed or required to address the responsibilities stated above. Membership of the MAC is more-fully described in **Appendix A, Public Involvement**.

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

The District has acknowledged that ongoing and proposed Aquifer management strategies may require future collaboration with stakeholders, and other jurisdictions and planning entities.

Consultation with other Federal, state, and local agencies with mandated natural and cultural resource protection responsibilities will also be required. Because the Service recently issued an amendment to an existing ITP for the Barton Springs salamander and Austin blind salamander covering city management, operation and maintenance of Barton Springs pool, and approved an associated HCP (COA 2013a) for the ITP amendment, close coordination will be required between the District and the City of Austin (COA) to ensure that the District's HCP measures are compatible with the COA's HCP measures. Consultation between the District and the Texas State Historic Preservation Officer (SHPO) will be necessary for Covered Activities and conservation measures, if any, affecting Barton Springs and the archeological sites near Barton Springs pool and lower Barton Creek. Additionally, coordination with the TPWD will be needed concerning its regulatory responsibilities for state listed species and fish and wildlife conservation and management.

1.8 SCOPE OF THE ENVIRONMENTAL IMPACT STATEMENT

The level of environmental impact evaluation for the proposed action was elevated from an Environmental Assessment (EA) to an Environmental Impact Statement (EIS). The Service's decision was based on issues and concerns identified through the public involvement and scoping process and the subsequent availability of technical information that indicated an EIS was warranted. This dEIS analyzes the potential direct, indirect, and cumulative effects of authorizing take of the Covered Species through issuance of an ITP and implementation of the District HCP. Direct effects are caused by an action and occur at the same time and place. Indirect actions are caused by an action and are later in time or farther removed in distance, but are still reasonably foreseeable. Cumulative effects on the environment result from the incremental impact of an 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**).

This dEIS addresses four alternatives:

1. No Action;
2. Issuance of an Incidental Take Permit for Permitted Pumping under the District HCP (the preferred alternative);
3. Water Demand Reduction; and

4. Water Supply Augmentation and Substitution.

After analyzing the potential for significant impacts to federally listed species and other environmental resources (described in **Section 4** of this document), the Service has determined that several major environmental components, including water resources, wildlife resources, socioeconomic resources, land use, and cultural resources, could be affected by HCP implementation. Each of these components is analyzed in this dEIS.

1.9 OTHER REQUIRED ACTION

The Service must comply with the consultation requirements stipulated in Section 7 of the ESA for any Federal action (in this case, issuance of the ITP by the Service) before a decision can be made regarding the issuance of an ITP. 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).

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2.0 ALTERNATIVES ANALYSIS

This section includes a description of the four major alternatives considered in the development of this dEIS, a description of the study area included in each of the four alternatives, and Covered Species evaluated under each of the four alternatives. This section also contains a discussion of alternatives considered, but eliminated from future evaluations.

2.1 ALTERNATIVES CONSIDERED

A number of alternatives were considered for this dEIS evaluation. Several evaluated alternatives were dismissed from further consideration because they 1) overlapped or were redundant with existing alternatives identified and evaluated in this dEIS; 2) did not address identified scoping issues; or 3) did not meet the purpose and need identified in **Section 1**. Alternatives initially considered but eliminated from further consideration are listed below:

2.1.1 Extending the Regional Water Quality Plan for the Barton Springs Segment of the Edwards Aquifer and its Contributing Zone

A water quality protection plan for the Aquifer was developed in 2005 by a consulting team led by Naismith Engineering Inc. for a number of local governmental entities (Naismith Engineering 2005), in cooperation with a citizen committee. These included the cities of Dripping Springs, Austin, Buda, Kyle, Rollingwood, Sunset Valley, Village of Bee Cave; counties of Blanco, Hays, and Travis; and the Barton Springs/Edwards Aquifer Conservation District, Hays Trinity Groundwater Conservation District, and Blanco-Pedernales Groundwater Conservation District. This regional plan was not carried forward as an alternative because water quantity was not a major focus of the plan and many of the water quality protection measures either were beyond the legal authority of the District or were redundant with alternative measures that are evaluated in this dEIS.

2.1.2 Extending the Existing City of Austin Habitat Conservation Plan to Cover Actions of the District

The COA implemented an HCP for the City's management of the Barton Springs Pool as part of the conditions for obtaining a Section 10(a)(1)(B) ITP for the Barton Springs salamander (COA 1998) and obtained a recent amendment to the current ITP (COA 2013a). The goal of this plan is to improve salamander habitat, increase population size, and increase life history information over the term of the permit. The COA HCP was not included in the alternatives to be evaluated in this dEIS because many of the factors creating the incidental take (from the City's operation of Barton Springs Pool) are different from the District's activities. The City's activities under this ITP are more direct and localized in nature, are beyond the legal authority of the District to implement, and require mitigation measures to lessen impacts that are outside the purview of the

District's activities affecting management of the Barton Springs segment of the Edwards Aquifer. Additionally, the City does not have the statutory authority to implement the groundwater regulatory program of the Covered Activities and the proposed conservation measures of the District. These differences in Covered Activities and authorities effectively preclude combining the ITPs and HCPs for these entities.

2.1.3 Previous Alternatives Evaluated in the Draft EIS for the District Draft Habitat Conservation Plan dated August 2007

In the previous draft environmental impact study, dated August 2007 (BSEACD 2007), two action alternatives were evaluated in comparison to a no action alternative. One of these alternatives was an earlier proposed District HCP that was superseded by the current proposed HCP (Alternative 2 in this dEIS) that was developed as a result of changed water management policies and procedures and also new legal findings and opinions. The other alternative focused on springflow protection incorporating stricter pumping limits. This alternative was superseded by the current dEIS Alternative 3 to reflect an alternative that would provide springflow equivalent to historical conditions existing during the DOR by restricting pumping to similar levels existing during the DOR.

2.2 STUDY AREA

The study area designated for each of the four alternatives is the same for each (see **Figure 1-2**) and includes the Barton Springs segment of the Edwards Aquifer Contributing Zone, Recharge Zone, Confined Zone, and Saline Water Zone in parts of Travis, Hays, Blanco, Kendall, Comal, Caldwell, and Bastrop Counties. The bulk of the study area is in southwestern Travis County and northern Hays County, but includes portions of the five other counties. The jurisdictional boundary of the District is also included in the study area and shown on **Figure 1-2**.

2.3 COVERED SPECIES

There are two Covered Species that will be addressed under each of the four alternatives. The Barton Springs salamander (*Eurycea sosorum*) and the Austin blind salamander (*Eurycea waterlooensis*) have been proposed for incidental take coverage under Section 10(a)(1)(B) of the ESA of 1973, as amended (16 U.S.C. 1531 et seq.). The Barton Springs salamander was federally listed as endangered on April 30, 1997 (62 FR 23377), and the Austin blind salamander was listed as endangered on August 20, 2013 (78 FR 51277).

2.4 DESCRIPTION OF ALTERNATIVES EVALUATED

2.4.1 Alternative 1: No Action

Under the No Action Alternative, the District would not implement its HCP and the Service would not issue an ITP. The District would pursue its legislatively mandated aquifer management responsibilities, but the management and regulation of pumping would be limited to non-drought conditions. Maximum allowable pumping during non-drought desired future conditions (including water for aquifer storage and retrieval projects) would be limited to 16 cfs. The District would notify permittees of approaching drought and issue notices to stop pumping once drought is declared and "take" of the Barton Springs and Austin blind salamanders is imminent. Protection of listed species would depend on expected compliance by the District's permittees. Under the No Action Alternative, each permittee would be expected to comply with pumping cessation notices issued by the District or would need to seek an individual ITP for the two species in order to continue pumping.

Under Alternative 1, during DOR conditions, compliance by all permittees could reduce total aquifer pumping to less than 1 cfs (assumes nearly complete cessation of pumping), with resulting projected springflow at Barton Springs of 11 cfs. However, if aquifer pumping reductions were not realized during any drought conditions that resulted in take of the two species, there would not be any protection provided to the District from violations under the ESA or to permitted pumpers that did not reduce pumping and were not covered by an individual ITP.

Under Alternative 1, in the absence of a District ITP, pumpers could seek individual ITPs from the Service. Within the affected area many pumping entities could apply for separate ITPs, each with its own permit area. Nothing in this alternative requires or presupposes that permitted pumpers seeking ITPs or consultations would coordinate their activities. Under this alternative, there would be an increased burden on the Service to closely monitor reduced springflows and effects of reduced springflows on the species and to enforce provisions of the ESA should any take occur. Aquifer management strategies that would be included under Alternative 1 are listed in **Table 2-1**.

2.4.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

Alternative 2 would involve the approval of the District's HCP and issuance of an ITP for District-authorized pumping of water from the Barton Springs segment of the Edwards Aquifer. Alternative 2 consists of the District's proposed plan that addresses state-mandated DFCs. The District proposes to limit Aquifer pumping during DOR conditions to no more than 5.2 cfs, which would ensure a minimum average monthly Barton Springs springflow of 6.5 cfs. Measures that minimize and mitigate take of the Covered Species include a combination of demand reduction measures, programs encouraging the development and use of new water supplies, greater enforcement capabilities, cooperative efforts with other entities, and mechanisms to adapt management strategies and respond to emergencies. Among the four alternatives evaluated in this dEIS, Alternative 2 provides the most technically feasible and economically acceptable measures available for Aquifer management and conservation of the Covered Species (**Table 2-1**) and is, therefore, the preferred Alternative.

2.4.3 Alternative 3: Water Demand Reduction

Under Alternative 3, the District would control pumping in absolute-use terms and during drought conditions. Alternative 3 would mandate pumping reductions to ensure a minimum average monthly springflow of 11 cfs, allowing the lowest instantaneous level of springflow reached (10 cfs) during the DOR occurring in the 1950s under which the Covered Species survived.

Table 2-1. Comparison of dEIS Alternative Measures

Alternative Measures	Alternative 1 No Action	2 HCP	3 Water Demand Reduction	4 Water Augmentation/ Substitution
1.0 Providing the Most Efficient Use of Groundwater (HCP Measures 6.2.1.1)				
1.1 Provide and maintain on an ongoing basis a sound statutory, regulatory, financial, and policy framework for continued District operations and programmatic needs.	X	X	X	X
1.2 Monitor aggregated use of various types of water wells in the District, as feasible and appropriate, to assess overall groundwater use and trends on a continuing basis.	X	X	X	X
1.3 Evaluate quantitatively at least every 5 years the amount of groundwater withdrawals by exempt wells in the District to ensure an accurate accounting of total pumping in a water budget that includes both regulated and non-regulated withdrawals so that appropriate groundwater management actions are taken.	X	X	X	X
1.4 Develop and maintain programs that inform and educate citizens of all ages about groundwater and springflow-related matters, which affect both water supplies and salamander ecology.		X		
2.0 Controlling and Preventing Waste of Groundwater (HCP Measures 6.2.1.2)				
2.1 Require all newly drilled exempt and non-exempt wells and all plugged wells to be registered and to comply with applicable District Rules, including Well Construction Standards.	X	X	X	X
2.2 Ensure permitted wells and well systems are operated as intended by requiring reporting of monthly meter readings, making periodic inspections of wells, and reviewing pumpage compliance at regular intervals that are meaningful with respect to the existing aquifer conditions.	X	X	X	
3.0 Addressing Conjunctive Surface Water Management Issues (HCP Measures 6.2.1.3)				
3.1 Assess the physical and institutional availability of existing regional surface-water and alternative groundwater supplies and the feasibility of those sources as viable supplemental or substitute supplies for groundwater users.		X		X
3.2 Encourage and assist District permittees to diversify their water supplies by assessing the feasibility of alternative water supplies and fostering arrangements with currently available alternative water suppliers.		X		X
3.3 Demonstrate the importance of the relationship between surface water and groundwater, and the need for implementing prudent conjunctive use, through educational programs with permittees and public outreach programs.		X		X

Table 2-1, cont'd

Alternative Measures	Alternative			
	1 No Action	**2 HCP**	**3 Water Demand Reduction**	**4 Water Augmentation/ Substitution**
4.0 Address Natural Resource Management Issues (HCP Measures 6.2.1.4)				
4.1 Assess ambient conditions in District aquifers on a recurring basis by (a) sampling and collecting groundwater data from selected wells and springs monthly, (b) conducting scientific investigations as indicated bynew data and models to better determine groundwater availability for the District aquifers; and (c) conducting studies as warranted to help increase understanding of the aquifer and, to the extent feasible, detect possible threats to water quality and evaluate their consequences.	X	X	X	X
4.2 Evaluate site-specific hydrogeological data from applicable production permits to assess potential impact of withdrawals to groundwater quantity and quality, public health and welfare, contribution to waste, and unreasonable well interference.	X	X	X	X
4.3 Implement separate management zones and as warranted different management strategies to address more effectively the groundwater management needs for the various aquifers in the District, particularly the Barton Springs Aquifer.		X		X
4.4 Actively participate in the joint planning processes for the relevant aquifers in the District to establish and refine Desired Future Conditions (DFCs) that protect the Aquifer and other aquifers, and the Covered Species.	X	X	X	X
5.0 Addressing Drought Conditions (HCP Measures 6.2.1.5)				
5.1 Adopt and keep updated a science-based drought trigger methodology and frequently monitor drought stages for the Aquifer on the basis of actual Aquifer conditions, and declare drought conditions as determined by analyzing data from the District's defined drought triggers and from the existing and such other, new drought-declaration factors, especially the prevailing DO concentration trends at the spring outlets, as warranted.	X	X	X	X[1]
5.2 Implement a drought management program that step-wise curtails Aquifer use to at least 50% by volume of currently (2014) authorized aggregate monthly use during Extreme Drought , and that designs/uses other programs that provide an incentive for additional curtailments where possible (for example, cap-and-retire of historical production permits, accelerated and/or larger drought curtailments in exchange for additional authorized use during non-drought periods).		X		X[1]
5.3 Inform and educate permittees and other Edwards Aquifer well owners about the significance of declared drought stages and the severity of drought and encourage practices and behaviors that reduce water use by a stage-appropriate amount.	X	X	X	X[1]

Table 2-1, cont'd

Alternative Measures	Alternative: 1 No Action	2 HCP	3 Water Demand Reduction	4 Water Augmentation/ Substitution
5.4 Assist and, where feasible, incentivize individual historical-production permittees in developing drought planning strategies that foster compliance with implemented District drought rules, including step-wise demand curtailment by drought stage to at least 50% of currently (2014) authorized use on a 3-month rolling average basis, during Extreme Drought; "right sizing" authorized use over the long term to reconcile actual water demands and permitted levels; and as necessary and with appropriate conditions, the substitution by surface water, reclaimed water, and/or other groundwater resources such as the Trinity Aquifer to achieve curtailments.		X	X	X[1]
5.5 Implement a Conservation Permit that is held by the District and accumulates and preserves withdrawals from the Aquifer that were previously authorized with historic-use status and that is retired or otherwise additionally curtailed during severe drought for use as ecological flow at Barton Springs during Extreme Drought and thereby increase springflow for a given set of hydrological conditions.		X		
6.0 Addressing Demand Reduction through Conservation (HCP Measures 6.2.1.6)				
6.1 Develop and maintain programs that inform, educate, and support District permittees in their efforts to educate their end-user customers about water conservation and its benefits and about drought-period temporary demand reduction measures.	X	X	X	X
6.2 Encourage use of conservation-oriented rate structures by water utility permittees to discourage egregious water demand by individual end-users during declared drought.	X	X	X	X
6.3 Develop and maintain programs that educate and inform District groundwater users and constituents of all ages about water conservation practices and resources.	X	X	X	X
7.0 Addressing Supply through Structural Enhancement (HCP Measures 6.2.1.7)				
7.1 Improve recharge to the Aquifer by conducting studies as engineering feasibility is established and as allowed by law (subject to rules and /or approval by TCEQ or City of Austin if within certain locations within the study area), physically altering (cleaning, enlarging, protecting, diverting surface water to) discrete recharge features that will lead to an increase in recharge and water in storage beyond what otherwise would exist naturally.		X		
7.2 Conduct technical investigations and, as engineering feasibility is established, assist water supply providers in implementing engineered enhancements to the regional supply strategies, including desalination, Aquifer storage and recovery, and effluent reclamation and re-use, to increase the options for water-supply substitution and reduce dependence on the Aquifer.		X		X

Table 2-1, cont'd

Alternative Measures	Alternative 1 No Action	2 HCP	3 Water Demand Reduction	4 Water Augmentation/ Substitution
8.0 Quantitatively Addressing Established Desired Future Conditions (HCP Measures 6.2.1.8)				
8.1 Adopt rules that restrict, to the greatest extent practicable, the total amount of groundwater authorized to be withdrawn annually from the Aquifer to an amount that will not substantially accelerate the onset of drought conditions in the Aquifer; this established as a running 7-year average springflow at Barton Springs of no less than 49.7 cfs during average recharge conditions.		X		X
8.2 Adopt rules that restrict to the greatest extent practicable and as legally possible, the total amount of groundwater withdrawn monthly from the Aquifer during Extreme Drought conditions in order to minimize take and avoid jeopardy of the Covered Species as a result of the Covered Activities, as established by the best science available. This is established as a limitation on actual withdrawals from the Aquifer to a total of no more than 5.2 cfs on an average annual (curtailed) basis during Extreme Drought, which will produce a minimum springflow of not less than 6.5 cfs during a recurrence of the drought of record (DOR).		X		
Research Supporting the Adaptive Management Process of the HCP (HCP subsection 6.4.1)				
R-1 During the term of the ITP the District commits to collaborating with universities, the COA, and other qualified parties on projects to better inform and determine the level of risk associated with springflow-related changes in water chemistry affecting the viability and recovery of the Covered Species' population by supporting: a) surveys of the temporal and spatial DO variability of the Aquifer and the surface environments around the Barton Springs complex; b) investigations of salamander habitat in the Aquifer in the vicinity of existing active monitor wells and future monitor wells close to Barton Springs; c) continued support of laboratory stressor-response studies of salamander species; and/or d) efforts to restore the spring-run habitat to allow improved re-aeration at the spring outlets.		X		
R-2 During the term of the ITP the District commits to collaborating with the USGS, the TWDB, universities, the COA, Edwards Aquifer Authority (EAA), and other qualified parties to: a) develop a refined conceptual model to improve the numerical models for the District Aquifers; and b) improve hydrologeologic characterization of Aquifer function during extreme low flows, including assessments of new potential recharge sources from urban recharge and bypasses from the San Antonio segment, and their changes over the term of the ITP.		X		
Additional Mitigation Measures Specific Only to the HCP (HCP subsection 6.2.2.2)				

Table 2-1, cont'd

Alternative Measures	Alternative: 1 No Action	2 HCP	3 Water Demand Reduction	4 Water Augmentation/ Substitution
M-1: The District commits to supporting the operations of an existing refugium with facilities capable of maintaining backup populations of the Covered Species to preserve the capacity to re-establish the species in the event of the loss of population due to a catastrophic event such as an unexpected cessation of springflow or a hazardous materials spill that decimates the species habitat. Such supplemental support would be provided through a commitment of in-kind, contracted support, and/or cash contributions or other appropriate means of support that would contribute to: a) continuing the study of salamander physiology and/or behavior, and/or b) conserving field and captive populations.		X		
M-2: The District, in cooperation with the COA, commits to participating in conducting feasibility studies and, as warranted, pilot and implementation projects to evaluate the potential for beneficial subsurface DO augmentation of flow in the immediate vicinity of the spring outlets and improved surface DO augmentation in the outlets (only) of the Aquifer during Extreme Drought conditions. This measure will involve assessing and utilizing injection of oxygenated or aerated water into the Aquifer throughthe monitor well installed as part of the Research Measure R-1, and/or improving devices and methods for aerating subsurface water in the immediate vicinity of the outlets. In-kind, contracted support, and/or cash contributions, phased during the term of the permit, may be authorized for feasibility studies and, if a project is feasible, for the pilot study and implementation of the augmentation project. Measure M-2 will be informed by the results of Measure R-1, and will be authorized and specified in the to-be-negotiated MOU/ILA with the COA. The District is currently planning to commit cash contributions, in-kind labor, and contracted support in an aggregate amount of up to $147,000 to this measure over the ITP term.		X		
M-3: The District commits to extending the time period to maintain and operate the Antioch Recharge Enhancement Facility for the term of the ITP thereby improving recharge water quality and reducing non-point source pollution at the outlets from runoff events during that time. This will include maintaining the existing equipment, replacing damaged equipment, and purchasing better quality equipment.		X		
M-4: The District commits to establishing a fund for plugging abandoned wells to eliminate high risk abandoned wells as potential conduits for contaminants from the surface or adjacent formations into the Aquifer with priority given to problematic wells close to the Barton Springs outlets. The fund would be established within the first year after issuance of the ITP with repurposed seed money currently held in the Drought Reserve Account which would be re-designated as a new Aquifer Protection Reserve Account. The new account would exist solely to fund plugging of abandoned wells and would be replenished with any collected enforcement penalties and an annual budgeted supplement at the discretion of the Board.		X		

Table 2-1, cont'd

Alternative Measures	Alternative 1 No Action	 2 HCP	 3 Water Demand Reduction	 4 Water Augmentation/ Substitution
M-5: For the term of the ITP, the District commits to provide leadership and technical assistance to other government entities, organizations, and individuals when prospective land-use and groundwater management activities in those entities' purview will, in the District's assessment, significantly affect the quantity or quality of groundwater in the Aquifer. The District will respond actively and appropriately to legislative initiatives or projects that affect Aquifer characteristics, provided such actions are consistent with established District rules, ongoing initiatives, or existing agreements. (Examples include contesting unsustainable wastewater management or actions that contravene the District's consent decree(s) that are projected to adversely affect the Aquifer, and providing technical support to GMA 9 and other GCDs whose practices may affect the Aquifer).		X		

[1] Implementation of Measures 5.1, 5.2, 5.3, 5.4, and 8.1 would be required under Alternative 4 until additional water supplies needed to augment or substitute for pumping withdrawals become available to users.

To achieve this minimum springflow during conditions similar to the DOR, pumping under all District permits would need to be completely curtailed, where the only pumping allowable is for exempt use, which is now less than 1 cfs and approximately the level occurring during the actual DOR (Hunt et al. 2010; Brune and Duffin 1983). These regulatory curtailments, backed with effective enforcement to ensure compliance, would provide the highest springflow protection for the Covered Species. Minimum required springflows equivalent to measured conditions in the historical record would be ensured under Alternative 3. This alternative would require significant pumping cutbacks to ensure springflow protection, employ the most severe regulatory measures to achieve the level of pumping reductions needed and would require one or more sources of replacement water for some indeterminate fraction of the amount curtailed to meet residual demand.

2.4.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would involve the development of alternative water supplies to augment the amount of water pumped from the Barton Springs segment of the Edwards Aquifer, substitute for the water pumped with the end result of substantially reduced Aquifer pumping, or some combination. The goal under this alternative would be augmentation and substitution sufficient to reduce Aquifer pumping below 1 cfs to provide minimum average monthly springflow of 11 cfs during DOR conditions, similar to Alternative 3. As these water supplies become available, the amount of Aquifer pumping would be reduced in direct proportion to the amount of water augmented or substituted. Until enough alternative water supplies could be developed on a dedicated standby basis to offset pumping withdrawals to ensure minimum springflows, a short-term ITP and associated HCP would be required. The HCP would identify alternative water sources and other mitigation measures to be implemented until the amount of groundwater withdrawals were sufficiently reduced to maintain minimum springflows during DOR conditions. The District currently does not have the regulatory authority or financial resources to develop or mandate the use of alternative water supplies. Under existing regulatory authorities, the development and use of augmented or substituted water supplies would have to be implemented voluntarily as is currently being done by some users within the study area.

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3.0 AFFECTED ENVIRONMENT

3.1 PHYSICAL ENVIRONMENT

3.1.1 Geology

This section describes the geology of the study area, including regional physiography, geological history, and structure. The section also includes a description of the geology of the Barton Springs segment of the Edwards Aquifer, including recharge and groundwater movement, and hydrology.

3.1.1.1 Regional Physiography

The study area lies along a physiographic borderland formed by the Balcones Escarpment. This boundary between two major physiographic regions is evident in the change from the Blackland Prairies on the east to the Edwards Plateau/Hill Country to the west. Across this geographic boundary are changes in almost all the natural attributes of the land: climate, surface water, groundwater, soils, flora, and fauna. Limestone plateaus, predominant oak-juniper woodland and savannah, thin soils, and narrow watercourses in steep canyons characterize the Edwards Plateau region west of the Balcones Escarpment. Terrain in the plateau region is typically steep and rugged, resulting from different rock types offset by the Balcones Fault zone, as well as the numerous streams that dissect the plateau. Groundwater is relatively shallow and occurs in several strata. In contrast, areas east of the escarpment are overlain by deep, fertile soils of the Blackland Prairie. These clay soils are highly productive and support intensive agriculture. The prevailing terrain is generally level to gently rolling and cut by meandering, low-gradient streams. Groundwater may be found at depths much greater than in the Edwards Plateau region, although it is also found at shallow depths in outcrop areas, and is generally fresh to brackish in quality. Elevation within the study area varies considerably, increasing from east to west from about 400 feet above mean sea level (amsl) in Caldwell County to as high as 2,000 feet amsl in Kendall County.

3.1.1.2 Geological History and Structure

Geologically, the various landforms found in any given area reflect the underlying lithology. A locale's lithology significantly influences the surrounding topography, hydrology, and enviro-nment. The Central Texas area encompasses a number of geologic settings and landforms that resulted from a long history of sedimentary activity (Grunig 1996). Traveling west to east over this varied topography, the age of bedrock formations becomes younger. Predominantly, the bedrock of the region is limestone although other sedimentary rock types such as dolostone, marl, chalk, siltstone, sandstone, and shale are also present. In isolated areas there are occurrences of igneous (granite, basalt) and metamorphic (schist, gneiss, and quartzite) rock.

The Balcones Escarpment is a geologic fault zone several miles wide consisting of numerous individual faults, most of which both dip and are downthrown to the east. It extends in a line across Texas from Del Rio to the Red River and is visible eastward from Del Rio, where its elevation is about 1,000 feet amsl, and northeastward from San Antonio to Austin, where it is about 300 feet amsl (*Handbook of Texas Online* 2005). The escarpment lies within a region that has a rich geological history. During the Paleozoic Era, approximately 300 million years ago, tectonic upheavals associated with the collision of North America with parts of South or Central America formed the Ouachita Mountain belt bisecting Texas from north to south, the remnants of which may be seen in Oklahoma, Arkansas, and the Trans-Pecos region of Texas. Within the study area, they are in the deep subsurface. Later, during the Mesozoic Era, the mountains eroded and subsided as rifting occurred, and the Gulf of Mexico began to form. Strata of limestone, sandstone, and shale were deposited in the newly formed Gulf of Mexico burying the roots of this mountain belt.

During the Cretaceous Period, a shallow sea covered much of the region (Grunig 1996). A large barrier reef, the Stuart City Reef, paralleled the coastline, forming a large interior sea that was separate from the Gulf of Mexico. Sediments were slowly deposited in this interior sea, eventually forming the strata of limestones, dolomite, and marls that are present today. These strata of limestones form the Edwards Group, which makes up the bedrock of the Edwards Aquifer. The Georgetown Formation, overlying the Edwards Group (but also part of the Edwards Aquifer), was deposited in a more openly circulated, shallow-marine environment (Rose 1972).

After the Cretaceous sea retreated, rivers and streams draining the land surface brought sand and mud towards the coast, forming a system of deltas. The deltas began to fill in the coastline until they eventually extended over 250 miles into the Gulf of Mexico. Tertiary-aged clastic (made up of fragments of preexisting rocks) sediments were deposited and formed the Gulf Coastal Plains. Later, during the mid-Cenozoic Era, faulting along the buried Ouachita Mountain belt resulted in the dislocation of overlying strata, forming the Balcones Fault Zone.

The Balcones Fault Zone marks the eastern boundary of the Edwards Plateau. The extensive faulting along the fault zone trends mainly to the northeast, and in aggregate has displaced strata as much as 1,000 feet. Younger units were displaced downward toward the Gulf of Mexico while older units remained higher west of the fault zone, forming the plateau and escarpment present today. Present-day rivers and streams in the plateau are dissecting the plateau area, causing the varied topography evident throughout this region. The faulting has also significantly fractured the limestone bedrock in the region, in particular near the major faults, although jointing occurs throughout the Edwards region. This faulting and jointing affect how groundwater flows through, and is stored in, these strata.

3.1.1.3 Stratigraphy

The geologic formations of interest in the study area include, from oldest to youngest; the Glen Rose Formation comprising the upper portion of the Trinity Aquifer; the Edwards Group and Georgetown Formation, together comprising the Edwards Aquifer; the Buda Limestone and Del Rio Clay; the Eagle Ford; and the Austin Group. These units are all lower to upper Cretaceous strata, which are overlain by Quaternary terrace deposits. The generalized stratigraphic relationship of these formations is shown on **Figure 3-1**.

System	Series	Group	Formation	Member	Thickness (ft)	Description
Quaternary			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 Paleocene	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	Upper: Buda Lower: Del Rio		100–200	Upper: dense, hard, nodular limestone Lower: clay
			Georgetown		20–60	Dense argillaceous limestone with pyrite (Edwards Aquifer)
		Edwards	Person	Marine/ Cyclic	90–150	Limestone and dolomite chalky and recrystallized mix (Edwards Aquifer)
				Leached/ Collapsed	60–90	Recrystallized dolomite, limestone (Edwards Aquifer)
				Regional Dense	20–30	Dense, argillaceous limestone (Edwards Aquifer)
			Kainer	Grainstone	50–60	Limestone, hard, milioloid grainstone (Edwards Aquifer)
				Dolomitic	150–200	Limestone, calcified dolomite, Kirshberg evaporates (Edwards Aquifer)
				Basal Nodular	40–70	Limestone: hard, dense, nodular, mottled, and stylolitic (Edwards Aquifer)
		Trinity	Glen Rose	Upper Member	300–400	Limestone, dolomite, shale, marl (Trinity Aquifer)
				Lower Member	200–250	Massive limestone with marl beds (Trinity Aquifer)

Source: Maclay and Small 1986; Crowe 1994.

Figure 3-1. Stratigraphy of the Confined Edwards Aquifer (shaded) along the Balcones Fault Zone between Austin and San Antonio, Texas

The Glen Rose Formation – The Glen Rose Formation lies under the Edwards Aquifer and crops out at the land surface primarily in the western portions of the study area, west of the Edwards Aquifer recharge area. The Glen Rose consists of alternating layers of limestone, dolomite, and marl, and is between 500 and 1,000 feet thick in the Austin area. Dolomite limestones within the Glen Rose contain water and are part of the Trinity Aquifer present throughout much of the Texas Hill Country. Alternating resistant and recessive beds of limestone, dolomite, and marl of the upper unit overlie the lower unit, consisting of limestones and marl. The limestone is fine-grained, hard to soft, and is chalky and clayey (Guyton 1979). Both units are fossiliferous and include Molluscan steinkerns, rudistids, oysters, and echinoids. The upper portion of the Glen Rose is thinly bedded and considerably more dolomitic than the lower part. Tracer studies indicate that the uppermost part of the Upper Glen Rose (a part of the Trinity Aquifer) is hydrologically connected to the Edwards Aquifer in the study area (Smith and Hunt 2011; Veni 2004; Schindel et al. 2005).

The Edwards Group – The Edwards Group consists of massive to thin-bedded limestone and dolomite. The outcrop of this unit makes up the recharge zone of the Edwards, and is approximately 400 feet thick in the Austin area. Within the Balcones Fault Zone, the Edwards Group has been divided into the Kainer and Person Formations (Rose 1972; Abbott 1973). The lower portion of the Kainer Formation consists primarily of honeycombed and cavernous limestones, dolomitic limestones, and leached evaporitic rocks, while the upper half is comprised of dense, chalky to hard, medium-grained, bioclastic coarse-grained limestone (Guyton 1979). Chert nodules are common in the dolomitic portions of the Kainer. The Kainer is between 240 and 310 feet thick in the Austin area. The Person Formation is located above the Kainer, and consists of marl and soft limestone in the lower part, and variable carbonate units, including limestone, dolomitic limestone, and dolomite in the upper part. The Person Formation is marked by a dense shaly clayey limestone base with an upper part that is a sequenced hard recrystallized limestone bed that runs dense to very porous. This formation averages from 130 to 180 feet thick.

The Georgetown Formation – The Georgetown Formation consists mostly of fossiliferous limestone with some interbedded marls, and unconformably overlies the Person Formation of the Edwards Group. Occasional sections of the Georgetown are hard, brittle, and thickly bedded and contain numerous fossils of marine oysters and brachiopods. The Georgetown is between 65 and 100 feet thick in the study area. It is the uppermost formation in what is considered the Edwards Aquifer (Maclay and Small 1986; Scanlon et al. 2001).

The Del Rio Formation – The Del Rio Formation, commonly referred to as the Del Rio Clay, is a fossiliferous clay, shale, and marl layer that is approximately 65 to 75 feet thick in the Austin area. The Del Rio is the confining unit for the Edwards Aquifer and outcrops in the eastern portion of the Balcones Fault Zone (Maclay and Small 1986; Scanlon et al. 2001).

Younger Formations – The Buda Formation in the Austin area consists mainly of limestone and is between 3 and 30 feet thick. This unit is overlain by the Eagle Ford Formation, which consists of a lower calcareous shale, a middle silty limestone, and an upper shale, and is between 23 and 65 feet thick in the Austin area. The Austin Group, commonly referred to as the Austin Chalk, consists of thick-bedded chalk, marl, and limestone, and is between 360 and 425 feet thick. The Austin Chalk does contain some amount of groundwater and wells in this formation produce water in some areas. Overlying the Austin Chalk in many areas is the Taylor Clay of the Taylor Group, and Quaternary-age alluvial deposits in stream valleys (Maclay and Small 1986; Scanlon et al. 2001).

The geographical distribution of major geological features throughout the study area is illustrated on **Figure 3-2**.

3.1.1.4 Edwards Aquifer

The Edwards Aquifer is one of nine major aquifers in Texas and is referred to as the Edwards Balcones Fault Zone Aquifer by the TWDB (2014a). This karst aquifer covers approximately 4,350 square miles across parts of 11 Texas counties, from a groundwater divide in Kinney County through the San Antonio area northeast to Bell County (see **Figure 1-1**). The Aquifer is the sole source of drinking water for approximately 2 million people in central Texas (BSEACD 2005a; Smith et al. 2005), and provides habitat for a number of aquatic cave organisms and species dependent on spring ecosystems, about 75 percent of which are endemic (found only in this region) (Abell et al. 2000; Longley 1986).

The Edwards Aquifer is comprised of three segments: the southern (San Antonio) segment which covers 3,600 square miles or 82 percent of the Aquifer’s total area (as defined by the TWDB); the Barton Springs (Austin) segment, covering approximately 155 square miles or 4 percent of the total Aquifer area (Slade et al. 1985); and the northern segment, which covers about 600 square miles or 14 percent of the total Aquifer area (**Figure 1-1**).

Barton Springs Segment of the Edwards Aquifer

The Barton Springs segment of the Edwards Aquifer shown on **Figures 1-1**, **3-3**, and **3-4** is about 25 miles long and 12.5 miles wide, extending over Travis and Hays Counties. This segment of the Aquifer is bounded on the north by the Colorado River, on the east by the interface between the fresh-water zone and the saline-water or “bad-water” zone of the Aquifer, on the west by the western limit of Edwards Aquifer hydrogeologic units and the Balcones Fault Zone (Slagle et al. 1986; Small et al. 1996), and on the south by a groundwater divide that is estimated to occur between Onion Creek and the Blanco River (LBG–Guyton Associates 1994; Hauwert et al. 2004). This Aquifer provides drinking water for approximately 70,000 people (BSEACD 2017). In 2011, the Barton Springs segment supported 6,206 acre-ft/yr (2.02 billion gallons) of actual pumping (BSEACD 2013). Groundwater use was characterized as 82 percent public-supply, 10 percent industrial, and 8 percent irrigation (domestic, commercial, and non-agricultural irrigation).

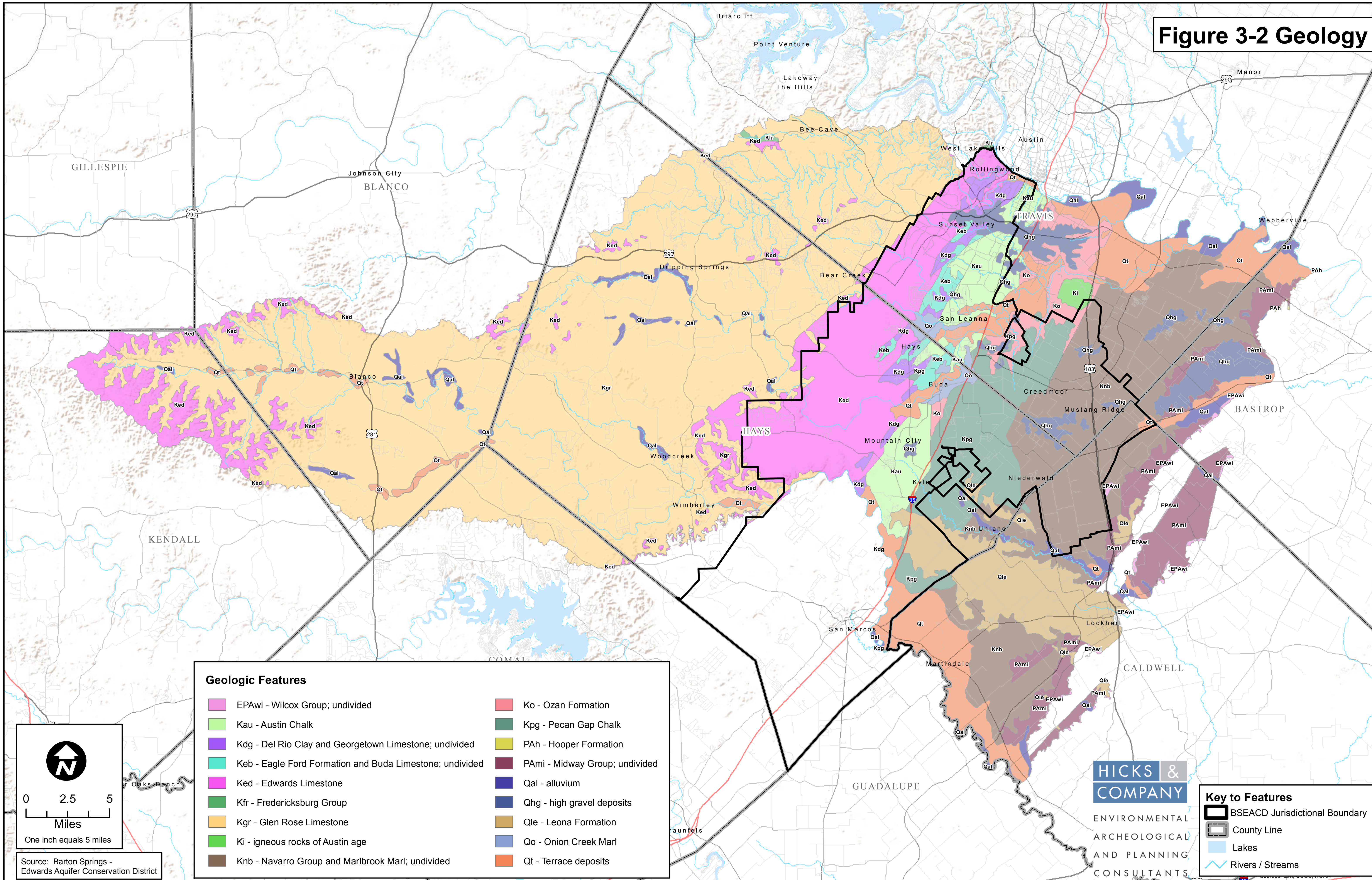
Figure 3-2 Geology
Geologic Features
EPAwi - Wilcox Group; undivided
Kau - Austin Chalk
Kdg - Del Rio Clay and Georgetown Limestone; undivided
Keb - Eagle Ford Formation and Buda Limestone; undivided
Ked - Edwards Limestone
Kfr - Fredericksburg Group
Kgr - Glen Rose Limestone
Ki - igneous rocks of Austin age
Knb - Navarro Group and Marlbrook Marl; undivided
Ko - Ozan Formation
Kpg - Pecan Gap Chalk
PAh - Hooper Formation
PAmi - Midway Group; undivided
Qal - alluvium
Qhg - high gravel deposits
Qle - Leona Formation
Qo - Onion Creek Marl
Qt - Terrace deposits
Key to Features
BSEACD Jurisdictional Boundary
County Line
Lakes
Rivers / Streams
0 2.5 5
Miles
One inch equals 5 miles
Source: Barton Springs - Edwards Aquifer Conservation District
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GILLESPIE
BLANCO
KENDALL
COMAL
HAYS
TRAVIS
BASTROP
CALDWELL
GUADALUPE
Briarcliff
Point Venture
Lakeway
The Hills
Austin
Manor
West Lake Hills
Rollingwood
Bee Cave
Sunset Valley
Webberville
Johnson City
Dripping Springs
Bear Creek
San Leanna
Hays
Buda
Creedmoor
Mustang Ridge
Blanco
Mountain City
Woodcreek
Kyle
Niederwald
Wimberley
Uhland
San Marcos
Lockhart
Martindale

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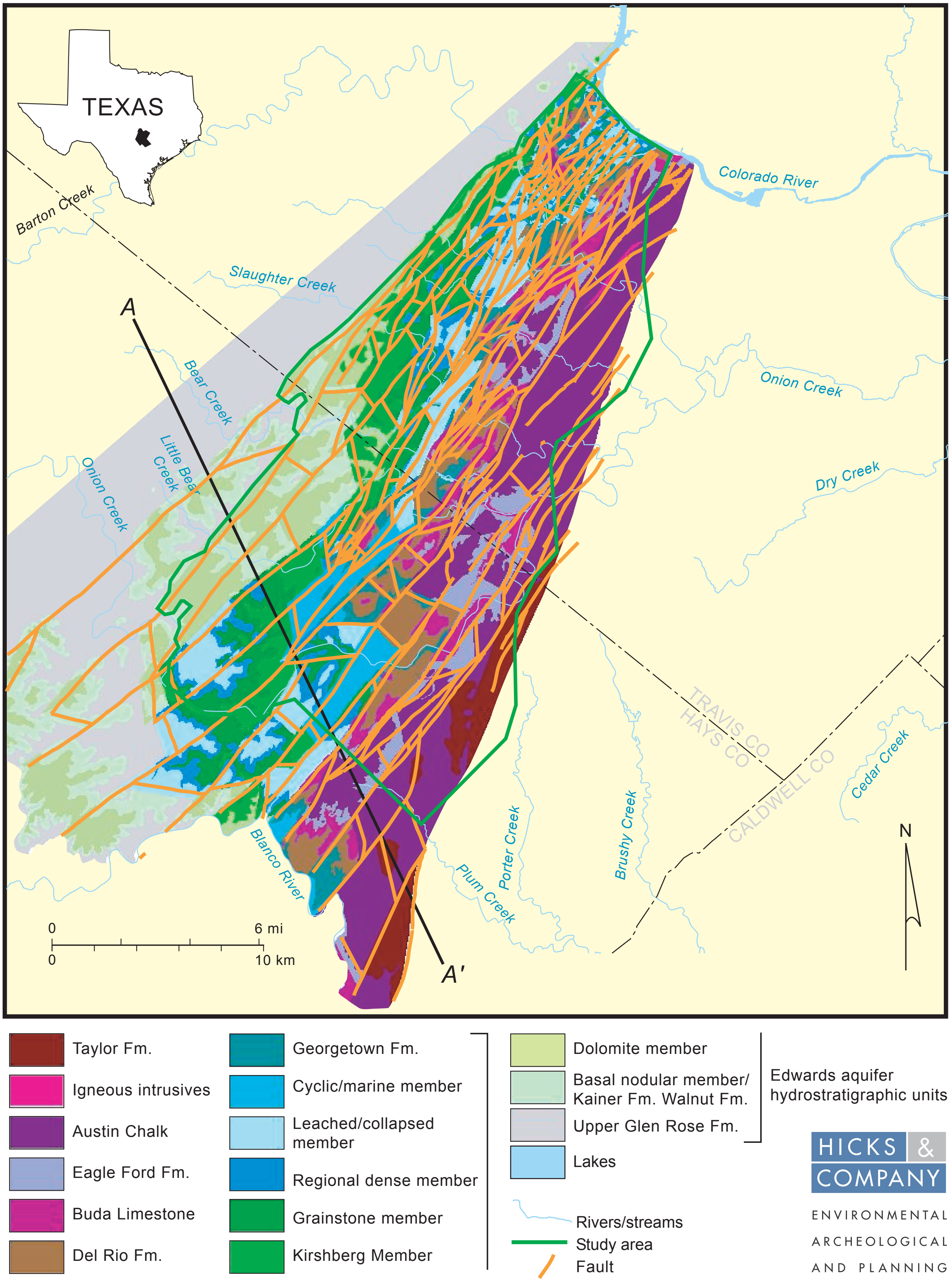

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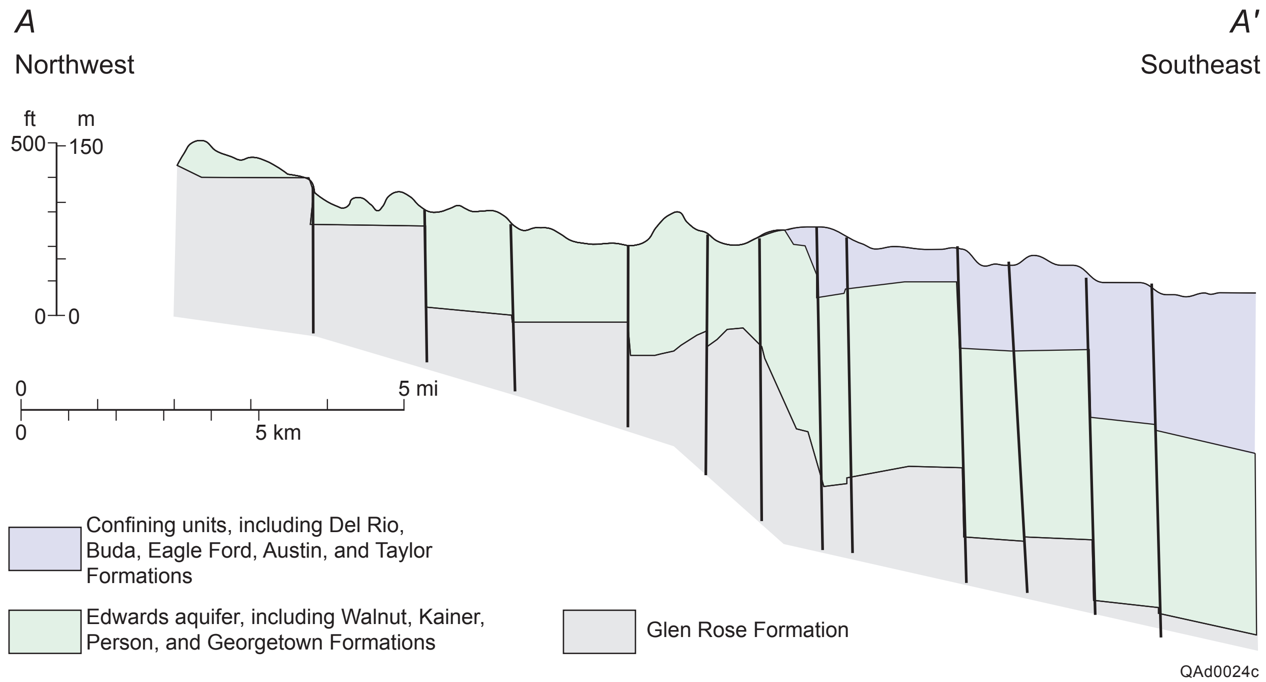
Source: Scanlon et al. (2001)

Figure 3-3 Surface Geology in the Barton Springs Segment, Edwards Aquifer



Source: Scanlon et al. (2001)

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Figure 3-4 Geologic Cross-section of the Barton Springs Segment, Edwards Aquifer. Location of the Cross-section is shownin Figure 3-3

The geologic formations of interest in the Barton Springs segment of the Edwards Aquifer are principally composed of the Georgetown Formation, and the Edwards Group of limestones including the Kainer and Person Formations described above and illustrated on **Figures 3-1** and **3-4.** The units crop out in the recharge zone of the Aquifer and then are present in the subsurface in the transition and artesian zones, and farther downdip beneath the Gulf Coast plain. A significant amount of the porosity and permeability present in the Edwards Group was developed while the Edwards Group was being eroded prior to the deposition of the Georgetown Formation. Once the Georgetown Formation was deposited, the Aquifer system that had developed within the Edwards Group was largely static due to the lack of discharge points to allow groundwater to flow through the system. The formation of the Aquifer was then influenced significantly by fracturing and faulting associated with the Balcones Fault Zone, which created significant topographic relief and stream incision in the region. This faulting also produced a large system of faults and fractures, which allowed groundwater to flow through the formations to discharge points at lower elevations, which increased the dissolution of limestone and dolomite units by the infiltrating meteoric water (Senger and Kreitler 1984; Sharp 1990; Barker et al. 1994; Sharp and Banner 1997). Flow through the Aquifer was also strongly influenced by bedding. Once established, the groundwater flow system matured, developing a continuously circulating groundwater flow system, which enlarged the fractures and faults into a cavern system that controlled groundwater flow characteristic of karst systems and that is present today in the Edwards Aquifer (Senger and Kreitler 1984).

3.1.1.5 Recharge and Groundwater Movement

Groundwater flow within the Edwards Aquifer is complex (Maclay 1995). Generally, groundwater is unconfined in the recharge zone and flows with steep hydraulic gradients. As the water flows into the confined portion of the Aquifer, the flow direction changes toward the east and northeast. The groundwater is then discharged through a number of springs, the largest being Comal, San Marcos, and Barton Springs. Although the Edwards Aquifer contains vast reserves of groundwater, a large volume of water cannot be extracted without affecting springflow because the springs are at a higher elevation than much of the groundwater in storage in the confined artesian zone. A groundwater divide running west-northwest from the City of Kyle in Hays County, hydrologically separates the San Antonio and Barton Springs (Austin) segments. At this location, under most conditions, groundwater from the San Antonio and Barton Springs segments do not mix. Generally, groundwater north of the divide flows north, while groundwater south of the divide flows south. This groundwater divide is diminished substantially during drought conditions and its location is dynamic, with Onion Creek serving as the divide during wet conditions and the Blanco River forming the divide during severe drought (Smith et al, 2012). A recent study conducted by HDR (2010) suggests that as water levels in the Aquifer decline during major droughts and current levels of pumping, this groundwater divide diminishes to allow the potential for some groundwater to bypass San Marcos Springs and flow north into the Barton Springs segment of the Aquifer toward Barton Springs.

The Colorado River separates the Barton Springs segment from the northern segment of the Aquifer.

3.1.1.6 Hydrology of the Barton Springs Segment of the Edwards Aquifer

As with the larger Edwards Aquifer, the Barton Springs segment is divided into several hydrological zones through which water flows. These zones are described below.

Contributing Zone

The contributing zone of the Barton Springs segment of the Edwards Aquifer is not technically part of the Aquifer, consisting mainly of the drainage basins containing streams and creeks that lead to and eventually flow over the Aquifer's recharge zone. The contributing zone in the study area comprises approximately 671 square miles in Travis, Hays, Blanco, Kendall and Comal Counties (BSEACD 2017) (see **Figure 1-2**). This area is important because it affects the quantity and quality of water received, stored, and eventually discharged by the Aquifer.

Recharge Zone

The recharge zone covers approximately 107 square-miles within the study area (BSEACD 2017) where heavily faulted and fractured Edwards limestone crops out at the land surface, allowing water to flow into the Aquifer. Recharge occurs when creeks and streams cross the permeable formation and lose a portion of their flow to the geologic units they are crossing, or when precipitation or runoff falls directly on these outcrop areas. Water reservoirs, including small lakes and ponds located in the recharge zone, may also contribute recharge to the Aquifer. Based on data from streamflow gages, approximately 75 percent of surface recharge occurs from streams that cross the recharge zone (Slade 2014). The remaining portion of recharge (25%) comes from soil infiltration or direct flow into discrete recharge features in upland areas (Slade 2014). Information provided by Hauwert (2014) using data collected from 2003 to 2007 shows the following stream recharge contributions: Barton Creek (less than 11 percent); Williamson Creek (1 percent); Slaughter Creek (7 percent); Bear Creek (6 percent); Little Bear Creek (3 percent); Onion Creek (33 percent); and the Blanco River (6 percent) (**Figure 3-5**). In a more recent study, Hauwert (2016) found less recharge from major streams (56 to 67 percent), with a residual of 33 to 44 percent originating from upland recharge. East of the recharge zone, the Aquifer is overlain by less permeable clay and limestone units, which hydraulically confine the Aquifer farther east in the confined, or artesian, zone.

Artesian Zone

The artesian (confined) zone (see **Figures 1-2** and **3-5**) is located between two relatively impermeable formations, the Glen Rose formation below, and the Del Rio clay above. Approximately 20 percent of the surface extent of the Aquifer is under confined conditions, while the remaining part of the Aquifer is under unconfined or water-table conditions (Slade et al. 1986).

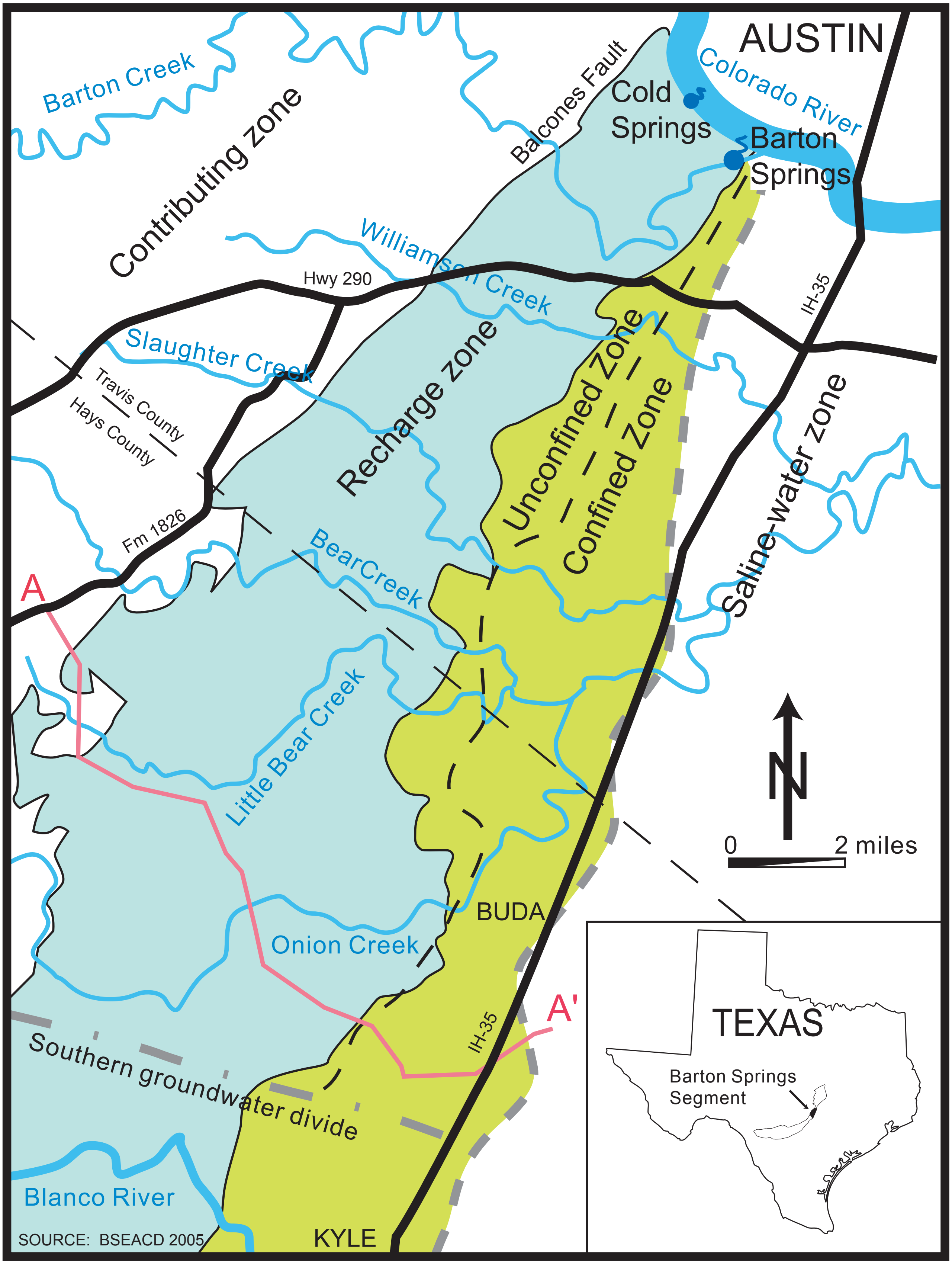

Figure 3-5 Location of Aquifer Cross Section referenced in Figure 3-6

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Water entering the Aquifer from the recharge zone creates tremendous pressure on water that is already present in the formation. Flowing artesian wells exist where this pressure is sufficient to force water to the surface in wells, and springs exist where this pressure is sufficient to force the water to the surface through faults, fractures, bedding planes, or other weak points in the overlying formations, and/or in topographically low areas where the ground surface intersects the formation. Groundwater movement through the Aquifer is generally controlled by a number of faults that disrupt the continuity of the permeable Edwards limestone. This movement tends to be from the higher elevations in the west to discharge areas in the east. The displacement of strata ranges from very large, which causes permeable and impermeable layers to be juxtaposed, to very small. Water moves more freely through the Aquifer when displacement is minimal.

Freshwater/Saline Water Interface

The freshwater/saline water interface (boundary between confined fresh and saline water zones) shown on **Figures 1-2 and 3-5** is not an actual, well-defined boundary but rather a zone of change that generally follows the Interstate 35 corridor through Hays and Travis Counties. The reason why the "bad-water line" exists is not clear; in some places, it is coincident with geologic features such as faults; however, in other places there is no obvious geologic control. The presence of "bad" or more saline water appears to be more associated with relative permeabilities of the Aquifer rather than a density boundary between two different water types, which commonly exists in coastal sand Aquifers. Wells in the transition zone have shown sections of brackish water that overlie freshwater, which in turn overlie brackish water, indicating that the type of rock and porosity influences the salinity of the water.

For the Barton Springs segment of the Edwards Aquifer, there is evidence that during low Aquifer levels, higher salinity water can encroach into the freshwater zone, particularly in the northeastern portion of the Aquifer and near Barton Springs (Slade et al. 1986). Measurements from wells on either side of the bad water line (BWL) indicate that during high recharge conditions, water levels within the freshwater zone can exceed levels within the "bad-water zone," allowing movement of freshwater into the bad-water zone. During low recharge conditions, the process is reversed, allowing the encroachment of bad water into the freshwater zone. While the BWL is often depicted as a line on a map, a substantial component of flows from more saline to less saline strata may be more vertical than horizontal. Measurements of well levels during the DOR in 1956 also indicate the possibility of water movement from the southern segment of the Edwards Aquifer north into the Barton Springs segment, thus affecting changes in the BWL and resulting increased salinities in Barton Springs (Slade et al. 1986, DeCook 1960).

Transition Zone

In addition to the hydrological zones, the Texas Commission on Environmental Quality (TCEQ) has defined a transition zone for implementing Aquifer protection rules. The transition zone is defined by the TCEQ (2008) as containing geologic features such as faults and fractures that present possible avenues for surface water to reach the Aquifer. This zone is adjacent to the recharge zone and is transitional to the artesian zone. It should also be noted that these same faults and fractures may provide conduits for some amount of saline water intrusion into the freshwater parts of the Edwards Aquifer.

Surface and Subsurface Flowpaths

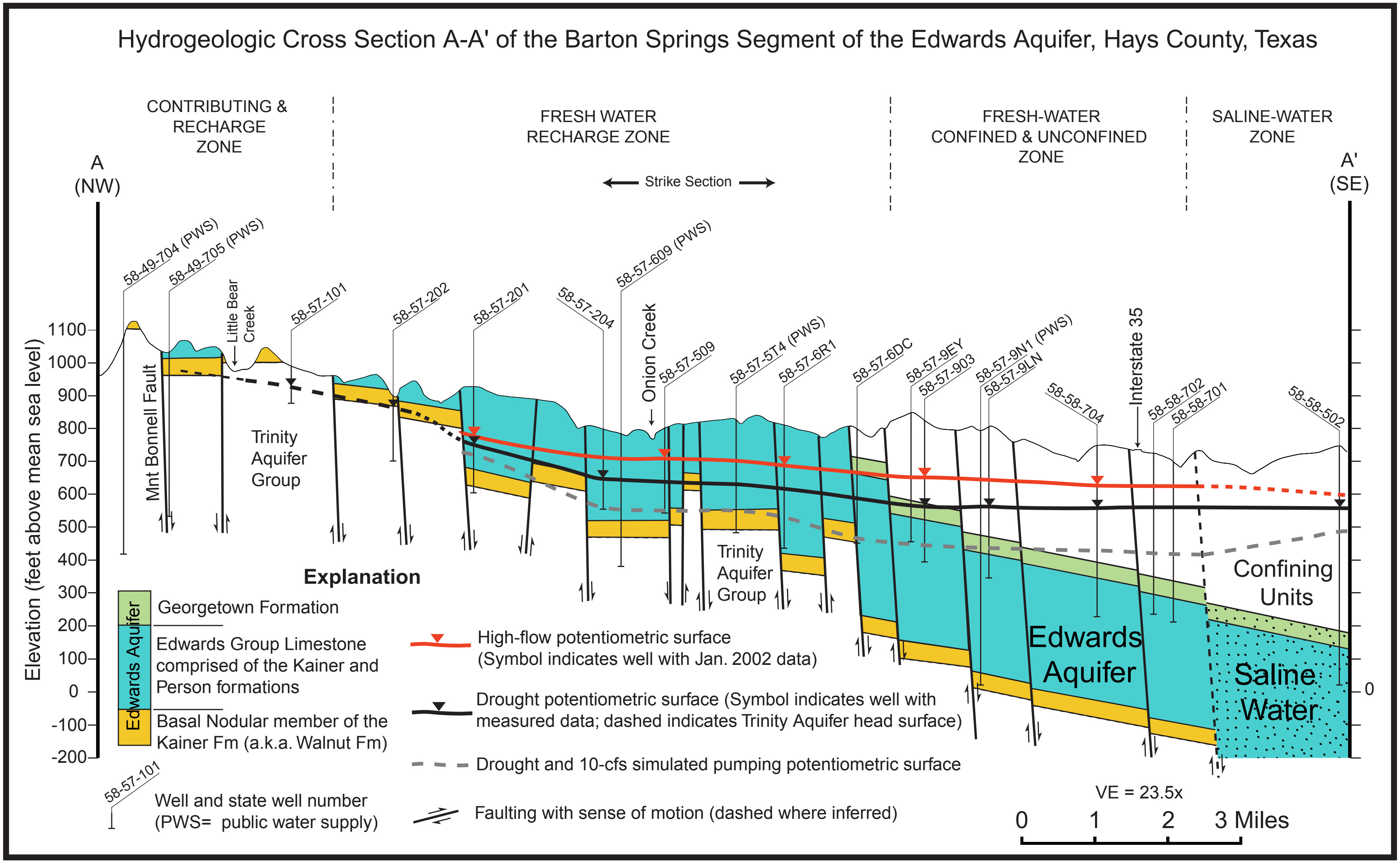
The hydrology of the Barton Springs segment of the Edwards Aquifer is extremely dynamic, with rapid fluctuations in springflow, water levels, and storage, reflecting changes in recharge (climatic conditions) and pumpage (demand). The surface and subsurface hydrology of the Barton Springs segment is portrayed by **Figures 3-5 and 3-6**, respectively. Water-level measurements and groundwater dye-tracing studies provide insight into groundwater flowpaths from source areas (recharge locations) to wells and springs. Groundwater generally flows west to east across the recharge zone, converging with preferential groundwater flowpaths subparallel to major faulting, and then flowing north toward Barton Springs. Although regional groundwater flow in the Aquifer occurs largely under diffuse conditions, preferential flow paths were traced along troughs in the potentiometric surface, indicating zones of high permeability. Rates of groundwater flow along preferential flow paths, determined from dye tracing, can be as fast as 4 to 7 miles per day under high-flow conditions or about one mile per day under low-flow conditions (Hauwert et al. 2004). Heterogeneity of the Aquifer is further expressed in terms of well yields, which range from less than 10 gallons per minute (gpm) to greater than 1,000 gpm. Well yields in the confined part of the Edwards Aquifer are often limited more by pump size than by Aquifer properties (Schindel et al. 2004).

Storage Capacity

The volume of water stored in the Barton Springs segment during average springflow conditions has been estimated to be about 306,000 acre-feet, of which about 31,000 acre-feet represents change in storage occurring between high flow and lowest known flow of Barton Springs (Slade et al. 1986). Characteristics of Aquifer recharge and discharge have been documented in sustainability studies conducted by the District (BSEACD 2004). These characteristics are described below.

Surface Recharge

Recent studies of stream flow data show that as much as 75 percent of the water that recharges the Barton Springs Aquifer comes from streams that cross the recharge zone (Slade 2014). The remaining recharge is attributed to infiltration through upland soils or direct flow into discrete upland recharge features (Slade 2014). (**Figure 3-6**). Recent investigations have demonstrated that most recharge infiltrates via discrete features, such as caves, sinkholes, fractures, and solution cavities within stream channels (BSEACD and COA 2001). Additional flow and



Source: BSEACD 2005

Figure 3-6
Cross Section of the Barton Springs and Trinity Aquifers in Hays County (see Figure 3.5)

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recharge data are currently being collected by the U.S. Geological Survey (USGS), the COA, the District, and the University of Texas at Austin to verify and further refine quantification of sources of recharge to the Barton Springs Aquifer. Long-term (1978–2013) average annual recharge to the Aquifer is currently estimated at about 67 cfs (Hauwert 2014).

Subsurface Recharge

The amount of subsurface recharge occurring from adjacent aquifers is unknown, although it is thought to be relatively small on the basis of water-budget analysis for surface recharge and surface discharge (Slade et al. 1985). Leakage from the saline-water zone is probably minimal, although this leakage does influence water quality at Barton Springs during low springflow conditions (Senger and Kreitler 1984, Slade et al. 1986). On the basis of a geochemical evaluation, Hauwert et al. (2004) found that the contribution to springflow from the saline-water zone to Barton Springs under low flow conditions could be about 3.5 percent of the discharge.

Subsurface flow into the Barton Springs Aquifer from adjacent aquifers such as the San Antonio portion of the Edwards Aquifer and the Trinity Aquifer is limited when compared with surface recharge (Slade et al. 1985; Smith et al. 2012). The uppermost part of the Trinity Aquifer and the Edwards Aquifer are hydrologically connected allowing exchange of water between the aquifers (Wong et. al 2014) and contribution of flows from one aquifer to another would depend on respective water level elevations. Recent studies by Wong et al. (2014) and Smith and Hunt (2011) indicate that the Edwards Aquifer is not hydrologically connected to the deeper units of the Trinity Aquifer.

Discharge

Discharge from the Aquifer is primarily from springflow and pumpage from wells in the study area. The amount of subsurface discharge occurring through adjacent aquifers is unknown, although it is thought to be relatively small on the basis of a water-budget analysis (Slade et al. 1985). Discharge from Barton Springs during the period 1917-2013 which included the drought of record is about 53 cfs or 34 million gallons per day (BSEACD 2017). Slade (2014) estimated average long-term annual discharge from Barton Springs during the period 1917-1982 at 51 cfs or 36,922 acre-feet per year, with Cold Springs and Deep Eddy Springs together contributing an estimated 5.5 cfs or 3,982 acre-feet per year. From this data, total long-term annual spring discharge is estimated to be about 56.5 cfs or 40,904 acre-feet per year. Pumpage estimated over the period of record 1917-1982 was estimated to be 0.8 cfs or 579 acre-feet per year.

The jurisdictional boundary of the District contains about 1,230 operational wells, with the majority producing water from the Edwards (Hunt et al. 2006) for public, domestic, industrial, commercial, irrigation, and agricultural uses. About 10 percent of these wells have annual pumping permits issued by the District. Most permitted pumpage is for public-supply and industrial purposes, and most of the permitted pumping occurs in the southeast part of the

Aquifer. In 2010, permitted (authorized) pumpage was about 2.7 billion gallons (8,434 acre-feet, or 11.65 cfs) (BSEACD 2011b), while actual pumpage was less than 8 cfs (BSEACD 2014).

Scanlon et al. (2001) estimated that pumping would increase linearly from 9.3 cfs in 2000 to 19.6 cfs by the year 2050, without regulatory restriction. Future pumping projections are described in Appendix A of that report (Scanlon et al. 2001). These rates are rough estimates that are based on projections from the Lower Colorado Regional Water Planning Group (LCRWPG) and the Capital Area Metropolitan Planning Organization (CAMPO). None of these projections, however, could be applied directly to the District's jurisdictional area. Therefore, a multiplier of 2.1 was used to estimate pumpage demand in 2050 from pumpage in 2000, as this multiplier is higher than current estimates for Texas rural areas but lower than for towns.

On the basis of results of hydrogeological modeling studies conducted by the District, the effect of pumping on springflow during severe drought approximates a 1:1 relationship, for example, for each additional increase in pumping of 1 cfs, springflow at Barton Springs declines by approximately 1 cfs (BSEACD 2004).

3.1.2 Soils

Soils within the study area vary according to the presence of two major physiographic regions, the Edwards Plateau and the Blackland Prairies.

Soils on the Edwards Plateau are typically shallow on uplands and include very stony, dark, alkaline clays and clay loams. On steep hillsides and valleys, soils are slightly deeper, lighter, and less stony. Soils in bottomlands are typically deep, dark, alkaline loams and clays. Surface drainage on Edwards Plateau soils is rapid. Land historically was agricultural, used primarily for cattle and sheep ranching, with forage crops grown in the deeper bottomland soils.

Edwards Plateau soils generally have low shrink-swell potential, high foundation strength, low compressibility, high slope stability, low plasticity, and potentially moderate to difficult excavation potential (Kier et al. 1977).

Soils on the Blackland Prairies are typically deep, dark alkaline clays. These soils are moderately to well drained and have a high shrink-swell potential. This high shrink-swell potential poses an engineering concern, since it can cause damage to roads and foundations. These soils support grasslands, pasture, and crops, including cotton, grains, and hay.

In contrast to the Edwards Plateau soils, the Blackland Prairie soils generally have high shrink-swell potential, low foundation strength, moderate compressibility, low slope stability, high plasticity, and easy excavation potential.

3.1.3 Air Quality

The study area includes portions of seven Texas counties; Travis, Hays, Blanco, Kendall, Comal, Caldwell, and Bastrop Counties. Four of these counties (Travis, Bastrop, Hays, and Caldwell) are located within Austin-Round Rock (ARR) Metropolitan Statistical Area (MSA) and two of these counties (Kendall and Comal) are within the San Antonio-New Braunfels (SA) MSA. These MSAs have committed to air quality planning to enable a local approach to help control air quality in the areas. The portion of the study area within Blanco County is the only area not included in an MSA.

All counties within the ARR and SA MSAs are considered by the State of Texas and the USEPA to be attainment/unclassifiable with respect to each of the National Ambient Air Quality Standards including the 2008 standard for Ozone [0.075 parts per million (ppm)], effective July 20, 2012 (TCEQ 2015a).

The 2008 attainment status for Austin-Round Rock and San Antonio-New Braunfels MSAs is partly a result of proactive measures taken by the local governments of the area. Concerned about a potential designation of nonattainment with the ozone standard, the local governments in the MSAs entered into a series of voluntary regional ozone reduction plans. The ARR/MSA began with the One-Hour Ozone Flex Plan (2002), followed by the Early Action Compact State Implementation Plan (2004), and the Eight-Hour Ozone Flex Plan (2008). The Central Texas Clean Air Coalition (CAC) of the Capital Area Council of Governments (CAPCOG) recently adopted the Ozone Advance Program (OAP) Action Plan for the Austin-Round Rock MSA. The OAP Action Plan will be in effect from January 1, 2014, through December 31, 2018, and is intended to keep the region in attainment for the 2008 ozone standard of 0.075 ppm, reduce ozone levels enough to remain in attainment of anticipated future standards, and improve public health, particularly for vulnerable populations (CAPCOG 2013).

Since implementation of voluntary ozone reduction plans in 2002, the ARR/MSA has remained in attainment of the 2008 Federal ozone standards and experienced a larger decrease in ozone than any other Texas near-nonattainment area, while also experiencing some of the highest population growth in the country. However in 2015, the U.S. Environmental Protection Agency established a stricter standard for ground level ozone (0.070 ppm). Based on this new standard, both the ARR and SA MSAs could fall out of attainment for ozone. The TCEQ designations for ozone for the ARR and SA MSAs are currently pending (TCEQ 2015a). Federal lawsuits over the new ozone standards filed by Texas as well as other states are also pending (Texas Tribune 2015).

Greenhouse Gases

The Kyoto Protocol to the United Nations Framework Convention (UNFC) obligated participating industrialized nations to reduce atmospheric emissions of six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorcarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). Carbon dioxide results from both natural and man-made processes including plant and animal respiration, volcano eruptions, and the burning of fossil fuels (coal, oil, and natural gas). Methane originates from many sources both natural and man-made including coal mines, oil and gas production, natural gas generating facilities, landfills, and waste treatment facilities. Nitrous oxides are commonly associated with industrial plants and agricultural production. HFCs result from refrigeration and air conditioning systems. PFCs and SF_6 are produced mainly from industrial operations and processes.

The COA Climate Program (COA 2014a) calculates human-caused greenhouse gas emissions in the Travis County area through a community greenhouse gas inventory every 3 years. The inventory takes data from energy, water, transportation, materials and waste emissions sources and converts them to a CO_2 emission equivalent, which is used to monitor emissions levels, reductions and develop reduction strategies. The average Travis County resident was responsible for about 15 metric tons of CO_2 emissions from energy use in 2010. The average U.S. citizen is responsible for roughly 19 metric tons, and the average Texas resident is responsible for about 25 metric tons. Travis County residents' per capita carbon footprints are 21 percent smaller than the U.S. citizen's carbon footprint and 40 percent smaller than the average Texas citizen's carbon footprint (COA 2014a).

3.1.4 Existing Climate

The prevailing climate of the study area is within a transitional zone between a subtropical subhumid region to the west and a subtropical humid region to the east (Larkin and Bomar 1983) (**Figure 3-7**). The subtropical sub-humid climate type is characterized, in general, by long, hot summers and short, mild winters. Western parts of the region are influenced by a subtropical steppe climate, characterized by semi-arid to arid conditions. Eastern parts of the region, influenced by a subtropical humid climate, have higher humidity and experience slightly milder summers. Regional prevailing winds are generally southerly, except during winter, when they are frequently from the north. Latitude, elevation, and proximity to the Gulf of Mexico influence the climate of the region.

The average annual temperature of the region is about 69 degrees Fahrenheit (°F) (National Oceanic and Atmospheric Administration [NOAA] 2011). Winters are generally mild with an average monthly low temperature in January of 42°F. Sub-freezing temperatures occur on average about 25 days each year. North winds with strong cold fronts block any moderating effects from the Gulf of Mexico and occasionally usher in frigid conditions to central Texas. The coldest temperature on record in Austin was –2°F on January 31, 1949. The average occurrence of the last temperature of 32°F in spring is early March and the average first fall occurrence of 32°F is late November. Monthly high temperatures in August average 89°F. Daytime temperatures in summer are hot, with highs over 90°F about 80 percent or more of the time. The highest temperature of record was 112°F on September 5, 2000, and again on August 28, 2011. Average sunshine varies from about 50 percent in the winter to near 75 percent in the summer (NOAA 2011).

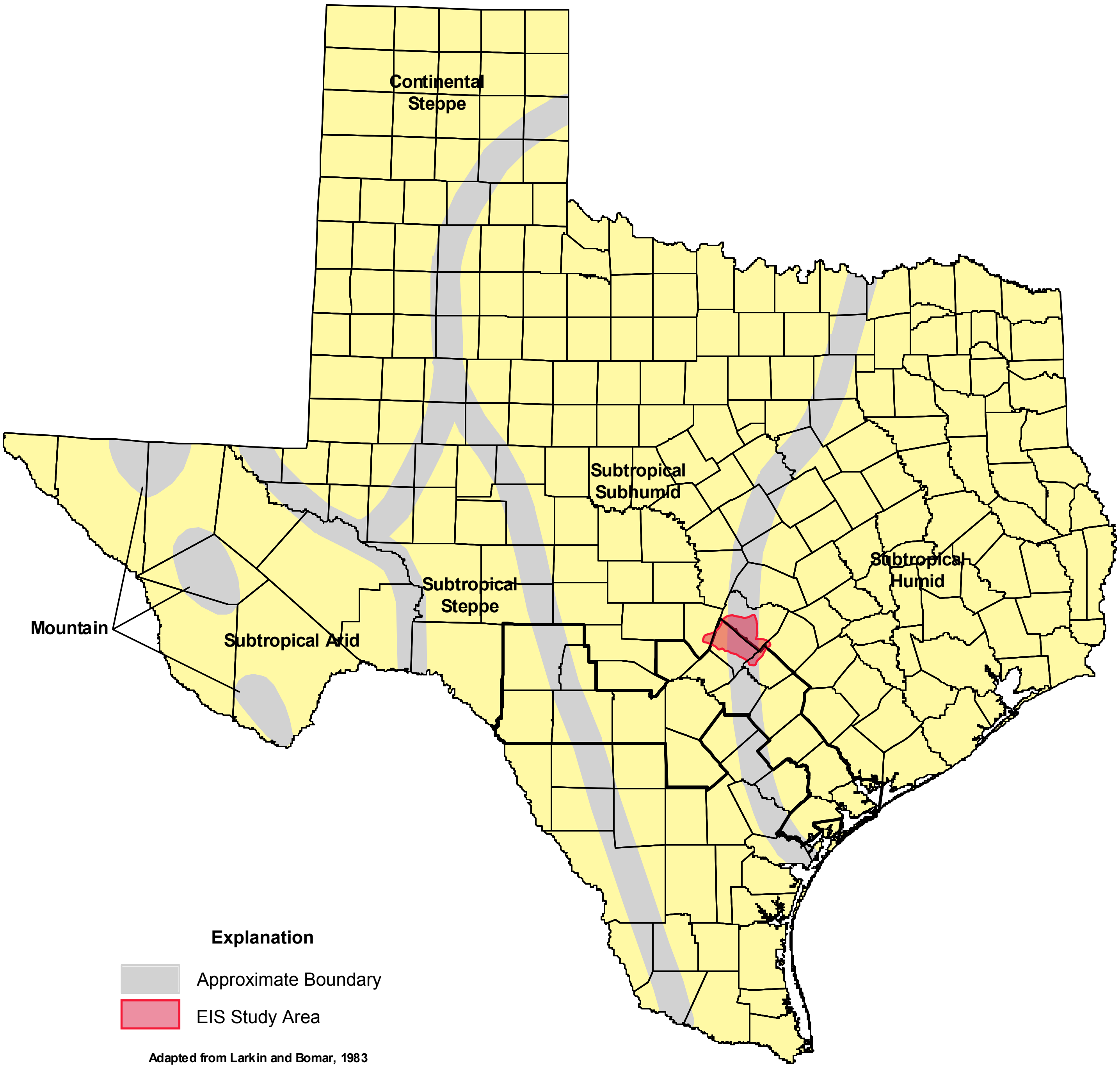

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Figure 3-7
Climatic Regions of Texas

Regional surface water features are subject to evaporation, especially during hot summer months. Average monthly gross lake-surface evaporation in the region ranges from approximately 2.5 inches in January to about 9 inches in August (Larkin and Bomar 1983).

Average annual precipitation within the region is approximately 33 inches but varies greatly from year to year: 11.42 inches in 1954 to 64.68 inches in 1919 (NOAA 2014). Historically, precipitation is highest during May and September. Stalled cold fronts and summer tropical storms may increase precipitation amounts, but an increased frequency of extreme precipitation events appears to be occurring (see **Appendix B** for additional information). For example, more than 12 inches of rainfall was recorded over a 12-hour period starting on October 12, 2013, in the Barton Springs watershed. Just over 2 weeks later, another extreme precipitation event centered over Hays County recorded upwards of 12 inches in less than 24 hours. Tropical storms and droughts are discussed in greater detail below.

3.1.4.1 Historical Frequency of Tropical Storms

Tropical storms, including hurricanes, hit the Texas Gulf Coast at a frequency of about 0.67 storms per year (Brown et al. 1974). Occasionally these storms move inland while dissipating, resulting in severe weather over the region. Moisture-laden air masses moving inland from the Gulf of Mexico are forced to rise at the Balcones Escarpment and Edwards Aquifer Recharge Zone and have generated some of the largest storms ever recorded in the United States. High winds, heavy rainfall, hail, and tornadoes may result from these tropical storms. Flash flooding of Hill Country streams is common after thunderstorms that produce large amounts of precipitation in a relatively short period of time. One such instance of flooding was associated with Hurricane Amelia in August 1978. Between August 1 and August 3, more than 48 inches of rain fell on a ranch in Medina County, the highest 3-day precipitation total ever recorded in the United States (Caran and Baker 1986).

Remnant low-pressure systems associated with dissipating tropical storms and hurricanes moving northeast into central Texas from western Mexico and the Baja Peninsula in late summer and early fall create weather effects that are generally less severe, but retain the capacity for potentially heavy rainfall.

3.1.4.2 Historical Frequency of Droughts

Drought is a condition defined by the lack of water caused by unusual meteorological conditions; severity is a function of intensity and duration. Serious droughts have been recorded in parts of Texas in every decade since 1900. Long-term droughts can be punctuated by episodes of rainfall that may provide temporary relief but do not fully replenish soil moisture or surface water reservoirs or aquifers. For example, the current Texas drought is thought to have begun in fall 2010 and more than 40 percent of the state remains in drought in 2014 despite periods of near-normal precipitation and even above-normal precipitation that has fallen in various localities across Texas since 2010 (John Nielsen-Gammon, pers. comm.).

The current drought includes the driest year ever (2011) in Texas since record keeping began in 1895. The South Central Texas climate division set new record lows for 6-month and 12-month rainfall totals in 2011. For the 2011 water year spanning October 1, 2010, to September 30, 2011, the South Central region recorded 9.6 inches of rain. The second-driest equivalent period was the 1956 water year in which nearly twice as much precipitation fell. To put this in perspective, in 2011 the region received the normal rainfall of the Trans-Pecos (Nielsen-Gammon 2012). From the start of record keeping, the South Central region has experienced 13 droughts including the most recent one (Nielsen-Gammon 2012).

Regional water planning guidelines found in 31 Texas Administrative Code (TAC) § 357.10 define “drought of record” as the period of time when natural hydrological conditions provided the least amount of water supply. The 7-year drought that occurred from 1950 through 1956 is considered the “drought of record” for the Edwards Aquifer region. This drought resulted in the only known cessation of flow of Comal Springs in Comal County in 1956, for 144 days (Longley 1995). During this same period, flow at San Marcos Springs in Hays County declined to a low of 47 cfs in comparison to an average of 187 cfs during the period 1996 through 2001 (Edwards Aquifer Authority [EAA] 2005), while Barton Springs in Travis County declined to the lowest recorded instantaneous flow of 9.6 cfs (within an 11 cfs average monthly flow period) in comparison to an average historical flow of 53 cfs (BSEACD 2004).

To better understand the DOR and how it relates to the long-term climate of the region, studies have been undertaken using tree rings as a proxy for the instrumental record. Dendrochronology, the dating and study of tree-ring growth, is an established method of evaluating historic climate conditions (e.g., Blasing and Fritts 1976; Robinson 1976; Stahle et al. 1985; Stahle and Cleaveland 1988; Cook et al. 1999). Annually produced tree rings often reflect climate conditions, with rings tending to be wider during wet years and narrower during dry ones. Trees are long-lived organisms that are widely distributed and readily available for sampling. Each ring can be dated precisely to a year; hence, the climate information contained in annual rings is relatively easy to extract from properly dated samples.

Previously published drought chronologies based on post oak tree rings collected from Central Texas were updated by Cleaveland et al. (2011) with the inclusion of additional sampling sites and two additional tree species. They were able to extend chronologies from the previous start date of the mid 1600s back to the 1500s. As was the case in prior studies (e.g., Cook 2000), Cleaveland et al. (2011) found a strong correlation between tree-ring width and the Palmer Drought Severity Index (PDSI). The PDSI is a model of soil moisture conditions used to classify drought frequency, intensity, and duration for agricultural purposes. It is centered around zero with an average year falling between –0.5 and 0.5. Droughts are defined as starting at –1.0.

Cleaveland et al. (2011) analyzed tree-ring reconstructions for years of consecutive drought up to 30 years while noting the data suggested there may have been droughts of even longer duration in the past. In their reconstruction of 1–7 and 10-year droughts, the drought spanning 1950–1956 ranked as the third-worst 7-year drought for the South Central climate division and the period of 1947–1956 ranked third for 10-year droughts, suggesting the drought of the 1950s might have started in the late 1940s. The period from 1951–1956 also ranked as the fourth-worst 6-year drought. The worst drought in their analysis of 2–7 and 10-year droughts took place in the early 1700s. The drought of the early 1700s was also the worst of the 15-year droughts identified. The period from 1841–1860 was the driest 20 years in the South Central reconstruction and 1835–1864 represented the driest 30 years. The drought of the 1950s fell within the sixth-driest 15 years in this region, the fifth-driest 20 years, and the second-driest 30 years. While the PDSI associated with the drought of the 1950s was –2.72, the study calculated PDSIs as low as –6.67 for droughts of shorter duration.

One conclusion from the study is that droughts are a recurring phenomenon in Central Texas. Cleaveland et al. (2011) state:

> The reconstruction of the twentieth century seems to have as many long drought episodes as other centuries . . . division 7 [South Central] has 6 [10-year period of drought in the twentieth century]. This, and the results with the 15-, 20-, and 30-year drought intervals, clearly indicates that overall, the twentieth century in these four Texas climate divisions was not anomalously wet or dry and appears typical of the 1500–2008 time period. Therefore, it can be expected that droughts as bad as or worse than the 1950s will occur in the future.

Prolonged and severe droughts are not unique to Central Texas. Cleaveland et al. (2011) pointed out that for several drought episodes, including the sixteenth century megadrought, conditions were much worse in areas west and south of Texas. Likewise, reports from dendrochronological and other investigations have identified considerably more prolonged droughts of equivalent severity as having occurred in the Early and Middle Ages (the Medieval megadroughts) in the desert Southwest (Seager et al. 2007a). More recently in Texas, summer 2011 was both the warmest and driest on record (records dating back to 1895). From a paleoclimatic perspective, again using tree rings as a proxy, the 2011 drought in Texas was approximately equal in intensity to the worst single-year droughts of the past 429 years (NOAA 2013).

Although the nature of future drought remains unclear, for those areas where climate models suggest drying, such as the desert Southwest and including the western half of Texas (Seager et al. 2007b), extreme droughts as or more severe than those encountered in the instrumental record are likely to occur more frequently (Burke et al. 2006). Additional discussion on climate projections follows in the next **subsection 3.1.4.3**.

3.1.4.3 Climate Change

In a February 18, 2010, memorandum, the CEQ provided draft guidance for Federal agencies in analyzing the environmental effects of greenhouse gas (GHG) emissions and climate change as part of the assessment of the effects of a proposed action on the environment in accordance with Section 102 of NEPA and the CEQ Regulations for Implementing the Procedural Provisions of NEPA, 40 CFR parts 1500–1508.

In light of the proposed CEQ guidance, this dEIS will consider the possible effects of climate change on the affected environment and the proposed alternatives, which include a proposed agency action, the issuance of an ITP under Section 10(a)(1)(B) of the Endangered Species Act. A discussion of the findings of current national and international studies on climate change is provided in **Appendix B, Summary of Climate Change Impacts in Texas**. A summary of these findings is presented below. Compounding effects of climate change to impacts of the proposed alternatives on the affected environment of the dEIS study area are discussed in **Section 5**.

Current State of Climate Assessments

Updated climate assessments covering the United States were published in 2013 and early 2014. The most relevant reports for this dEIS are: 1) Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 4, Climate of the U.S. Great Plains (NOAA 2013), 2) Climate Change Impacts in the United States: The Third National Climate Assessment (NCA) Report (Melillo et al. 2014), and 3) the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC 2013). The Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 4, Climate of the U.S. Great Plains (NOAA 2013) was one of a series of regional analyses undertaken to support the Third National Climate Change Assessment Report. Concurrent to the U.S. effort was the 5-year update (AR5) of the global assessment of the IPCC. In preparation for AR5, a new generation of global climate models or general circulation models (GCMs) were built and tested.

Results of the Latest Climate Assessments

Relative to the District’s request for a 20-year permit, climate projections through 2035 are the focus of this dEIS. To the extent that projections could be isolated for Central Texas from larger-scale modeling domains, those results are presented. GCMs operate on grid cells that may be as large as 200 miles on a side and many of the graphics reported in IPCC AR5 or the NCA, for example, do not provide the fine detail to locate Austin, Texas, or the Edwards Aquifer on a map. In some cases, the climate variable of interest shows the same widespread pattern across Texas, negating the need for locational specificity. In other cases, data presented from simulations may show heterogeneity across the state and it becomes challenging to interpolate mottled color patterns. In those instances, a range of values has been reported.

Observed Changes in Temperature

The Third National Climate Assessment reports that U.S. average temperature has increased by 1.3°F to 1.9°F since 1895; most of this increase has occurred since 1970 (Melillo et al. 2014). There is a statistically significant upward trend in temperature for winter (0.14°F/decade) and spring (0.11°F/decade) months in the Southern Great Plains for the period 1895–2011 (NOAA 2013). Since 1991 (1991–2012), temperatures have averaged 1 to 1.5°F higher than the 1901–1960 average over most of the U.S. In Central Texas, that increase has been about 1°F (**Appendix B, Summary of Climate Change Impacts in Texas**, **Figure 1**). Recent climatological evaluations by Hunt et al. (2012) indicate an overall increase in temperature of about 3 degrees Fahrenheit since the 1850s in the Austin area.

Observed Changes in the Hydrologic Cycle

Central Texas has experienced increases in precipitation on the order of 5–15 percent from 1991–2012 compared with the 1901–1960 average (**Appendix B, Figure 2**). This increase reflects, in part, the major droughts of the 1930s and 1950s, which made the early half of the record drier. Nonetheless, it is consistent with the trend of increasing precipitation observed across the Great Plains in recent decades (Georgakakos et al. 2014) and it is consistent with a previous analysis by the U.S. Global Change Research Program (USGCRP 2009) using the slightly different reference period of 1958–2008 that showed very similar results, especially over central Texas (**Appendix B, Figure 3**).

Across most of the U.S., the heaviest rainfall events have become heavier and more frequent (Melillo et al. 2014). Since 1991, the amount of rain falling in very heavy precipitation events has been above average in every region of the country. Warmer air can contain more water vapor than cooler air. Global analyses show that the amount of water vapor in the atmosphere has, in fact, increased over both land and oceans (Melillo et al. 2014). Observed global trends suggest extreme precipitation increases about 4 percent per 1°F of warming (Boucher et al. 2013).

The USGCRP (2009) reported that between 1958 and 2008, the amount of rain falling in very heavy precipitation events (defined as the heaviest of 1 percent of all daily events) increased by about 15 percent across Texas. Other studies have indicated increased precipitation in central Texas since the 1850s and particularly since the 1960s (Hunt et al. 2012). Groisman et al. (2012) examined the frequency of moderately heavy, heavy, very heavy, and extreme precipitation across the U.S. In the past several decades, the frequency of very heavy precipitation events (upper 0.3 percent of daily precipitation, or greater than 4.0 inches of daily rain in the central U.S. including Texas) and extreme precipitation events (greater than 6 inches of daily rain in the central U.S.) began to increase over much of the conterminous U.S. east of the Rockies.

Soil moisture, on a regional scale, has historically been difficult to monitor and has often been inferred from models, but it is well-recognized that soil moisture plays a major role in the water cycle. In the last 20 years, soil moisture appears to have declined in parts of the Southeast, southern Great Plains, and Southwest (Melillo et al. 2014). Increasing temperatures have made droughts more severe and widespread than they would be otherwise (USGCRP 2009). In Texas, summer 2011 was both the warmest on record and the driest on record (records dating back to 1895). From a paleoclimatic perspective using tree rings as a proxy for water availability, the 2011 drought in Texas is approximately equal in intensity to the worst droughts of the past 429 years (NOAA 2013).

Projected Changes in Temperature

The projected change in average air temperature over central Texas for 2016–2035 is an increase of 1.8 to 2.7°F over the 1986–2005 period, with slightly greater warming occurring in the summer months than the winter months (Kirtman et al. 2013). Using data compiled by NASA and the USGS for Travis and Hays Counties, an increase in annual average maximum temperature of about 3°F is projected for the time period of 2025–2049 compared with the historical period of 1980–2004 (Alder and Hostetler 2013) (**Appendix B**). Average minimum temperatures for 2025–2049 are projected to be 2.5°F to 3.0°F higher than those recorded for 1980–2004 (Alder and Hostetler 2013).

Thus, the frequency of warm days and warm nights will likely increase in the next decades, while that of cold days and cold nights will decrease. Models also project increases in the duration, intensity, and spatial extent of heat waves.

Projected Changes to the Hydrologic Cycle

For every 1°F rise in temperature, the water holding capacity of the atmosphere increases by about 4 percent. Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between). Summer droughts are expected to intensify in most regions of the U.S., with longer-term reductions in water availability in response to both rising temperatures and changes in precipitation.

Soil moisture, especially in summer, is expected to decline with higher temperatures and attendant increases in the potential for evapotranspiration (evaporation of water from soil and the release of water to the air from plant leaves) in much of the country, especially across the southern U.S. (Melillo et al. 2014).

Models do not agree concerning whether average precipitation will increase or decrease over central Texas. At the resolution of the climate models, central Texas borders the zone between regions of increasing and decreasing precipitation for much of the year. The models project average precipitation over central Texas for 2016–2035 to be in the range of ±10 percent (Kirtman et al. 2013, **Appendix B, Figure 6**). A factor contributing to the uncertainty in the direction of change is that central Texas is part of a zone known as the humid subtropics and sits adjacent to a semi-arid zone to the west and south (the desert southwest) that is projected to expand northward and eastward. Just how far and how quickly the semi-arid zone expands plays a role in whether central Texas will likely see reduced precipitation. At the global scale, IPCC modeling found that average precipitation will “more likely than not” decrease in the subtropics (Kirtman et al. 2013).

Floods are projected to intensify in most regions of the U.S., even in areas where average annual precipitation is projected to decline (Melillo et al. 2014). The 1-in-20-year heavy downpour (based on 1958–2008 statistics) is projected to occur once every 4 to 15 years depending on location (USGCRP 2009). Average precipitation is expected to increase less than extreme precipitation because of energy constraints in the atmosphere (Bindoff et al. 2013).

Limitations of Climate Change Models in Predicting Water Quantity to Aquifers

Climate models do not, in general, yet include dynamic representations of the groundwater reservoir and its connections to streams, the soil-vegetation system, and the atmosphere, hampering progress in understanding the potential impacts of climate change on groundwater and groundwater-reliant systems (Georgakakos et al. 2014). The Third National Climate Assessment concluded with a high degree of confidence that groundwater aquifers will be influenced by climate change through impacts on recharge and by increased groundwater use, though exactly how these impacts will manifest remains unexplored (Georgakakos et al. 2014). Among the most significant implications of climate change for water resources management is the very real possibility that there will be increasing variability at the tails of the hydrograph – that is, floods and/or droughts will become more frequent, of greater intensity, and of longer duration.

3.1.4.4 Climate Change Impacts

Regional Implications

Climate change could impact groundwater resources by affecting recharge, pumping, natural discharge, and saline intrusion (Mace and Wade 2008). They suggest that climate change will more adversely affect karstic aquifers (like the Edwards Aquifer) that recharge locally from streams and rivers in comparison to dipping aquifers where effective recharge is increased through pumping and the capture of intermediate and local groundwater flow paths. A warmer, drier climate notwithstanding human population growth will increase demand for water to support agriculture, municipal, and industrial use. This will result in 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, discharge by pumping, and changes in groundwater gradients as affected by plants, including phreatophytic species that demand higher amounts of water. In coastal areas, groundwater and dependent resources may be affected by rising sea levels.

Potential Climate Change Impacts to the Edwards Aquifer

Mace and Wade (2008) and Loáiciga et al. (1996) suggest that the Edwards Aquifer is probably Texas's most vulnerable aquifer and groundwater resource with respect to climate change and variability, and if there is a long-term drying of the climate in south-central Texas, area groundwater users can expect to be under more frequent drought restrictions.

Loáiciga et al. (2000) studied the climate change impacts on the Edwards Aquifer. Climate change scenarios were created from scaling factors derived from several general circulation models to assess the likely impacts of Aquifer pumping on the water resources of the San Antonio segment of the Edwards Aquifer. Aquifer simulations using GWSIM IV indicate that, given the predicted growth and water demand in the Edwards Aquifer region, the Aquifer's ground water resources appear threatened under $2\times CO_2$ climate scenarios. Their simulations indicate that $2\times CO_2$ climatic conditions could exacerbate negative impacts and water shortages in the Edwards Aquifer region even if pumping does not increase above its present average level. The historical evidence and the results of this research indicate that without proper consideration to variations in Aquifer recharge and sound pumping strategies, the water resources of the Edwards Aquifer could be severely impacted under a warmer climate.

Impact Summary

As discussed in subs**ection 3.1.4.3**, temperatures across Central Texas are increasing because of climate change and further warming is predicted over the 20-year term of the proposed HCP (Preferred Alternative 2). The degree to which climate change is expected to influence precipitation, and how that would affect groundwater flow, is more uncertain. There is a trend toward more extreme precipitation events, possibly punctuated by longer drought periods. While there is currently insufficient information available to predict the potential for natural resource changes in the study area to be affected by climate change, warmer air temperatures are expected to produce drier soil conditions and less surface runoff, which could potentially result in decreased groundwater and resulting springflow. Warmer water resulting from warmer air temperatures could adversely affect habitat components, food availability, and behavior of the Barton Springs and Austin blind salamanders. Warmer waters contain reduced concentrations of dissolved oxygen critically important to both salamanders. Studies suggest that climate change will more adversely affect karstic aquifers (like the Edwards Aquifer) that recharge locally from streams and rivers in comparison to dripping aquifers where effective recharge is increased through pumping and the capture of intermediate and local groundwater flow paths. A warmer, drier climate will increase demand for water to support agricultural, municipal, and industrial use. This will result in 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).

Even if climate change does not significantly affect Texas over the next 20 years, the threat of multi-year droughts still remains as historical records based on tree-ring data indicate that droughts more severe than the DOR have occurred many times in the past several hundred years (see sub**section 3.1.4.2**). While the Covered Species have lived through significant droughts in the past, the effects of a severe and prolonged drought on the Covered Species in the future are unknown because of changes to the landscape due to human development. Severe drought, in combination with other factors such as changes in water quality, increased impervious cover, and introduction of non-native species, could make it more difficult for the species to survive.

3.2 WATER RESOURCES

The quality and availability of surface and ground water within the study area are discussed in this section. Competition for water resources has increased along with the region's population. A summary of existing conditions related to these resources is provided below.

3.2.1 Surface Water

Surface water within the study area includes rivers, creeks, lakes, and springs discharging from the Barton Springs segment of the Edwards Aquifer. Portions of the study area extend west into the Blanco River drainage in Blanco, Comal, and Kendall Counties, and to the east into the Cedar Creek, Lytton Springs Creek and Plum Creek drainages in Caldwell County. Most of the study area lies within the Colorado River Basin, which covers a drainage area of approximately 42,000 square miles in Texas and the eastern portion of New Mexico (LCRWPG 2005). The basin extends from eastern New Mexico and the western portion of Texas in Dawson County southeast approximately 900 miles to the Gulf of Mexico. The remaining western and eastern portions of the study area are drained by the Guadalupe River Basin.

3.2.1.1 Local Watersheds

Principal watersheds within the study area that most affect surface water interactions with the Barton Springs segment of the Edwards Aquifer are associated with six creek drainages: Barton Creek, Williamson Creek, Slaughter Creek, Bear Creek, Little Bear Creek, and Onion Creek; and also the main stem of the Blanco River (see **Figure 3-5**). The recharge zone stretches across these six watersheds as a band from south of the Colorado River in the COA southwesterly to north of the City of Kyle. The contribution of these watersheds to recharge of the Barton Springs segment of the Edwards Aquifer is described in **subsection 3.1.1.6**.

3.2.1.2 Aquifer-fed Springs

The Barton Springs segment of the Edwards Aquifer naturally discharges principally through the Barton Springs complex, with minor discharge occurring at other ancillary springs (Slade et al. 1986). The spring complex is located in and adjacent to Barton Creek in Zilker Park near downtown Austin, about ¼ mile upstream of the confluence of Barton Creek with an impounded segment of the Colorado River known as Lady Bird Lake (**Figure 3-8**).

Approximately 89 percent of all water that discharges from this segment of the Aquifer emerges at Barton Springs, while the remaining 11 percent discharges at ancillary spring sites or is extracted by wells (Slade 2014). The collective flow of the Barton Springs system is the fourth largest in Texas behind Comal Springs (Comal County), San Marcos Springs (Hays County), and San Felipe Springs (Val Verde County) (Brune 2002). The spring system has not ceased flowing in recorded history. The ultimate driver of the quality of the aquatic surface habitat of the Barton Springs complex and in many aspects of subterranean habitats is the flow regime of Barton Springs and Barton Creek (COA 2013a).

The Barton Springs complex comprises four springs, including the main spring in Barton Springs Pool (Parthenia Spring), Eliza Spring, Old Mill Spring (also called Sunken Garden or Zenobia Spring), and Upper Barton Spring (**Figure 3-8**). Two dams built in the 1920s maintain the current confines of Barton Springs Pool (COA 1998). Many additional structural features surrounding the springs were added during the following decades, including a bypass for Barton Creek that flows under the sidewalk on the north side of the pool (constructed in 1974–1976). Eliza Spring was modified during the early 1900s to include a concrete amphitheater. Subsequently, outflow was confined to an underground culvert pipe and a concrete bottom was installed. The concrete substrate has seven 15-centimeter-diameter (6-inch-diameter) holes and 16 rectangular vents that allow springflow up through the concrete slab to the surface. Old Mill Spring is located downstream and south of Barton Springs Pool. During periods of moderate to high Aquifer levels, water in Old Mill Spring can reach a depth of 2.0 meters (6.6 feet) and there is abundant surface flow along a stream that connects Old Mill Spring to lower Barton Creek. Flow ceases at this spring when total discharge from the Barton Springs complex is approximately 14 cfs (Smith et al. 2013) Public access is currently restricted at Eliza and Old Mill Springs. Upper Barton Spring is located a short distance upstream of Barton Springs Pool abutting the south bank of Barton Creek. Flow ceases at this spring when total discharge from the Barton Springs complex is approximately 40 cfs (Turner 2004).

Long-term mean discharge from Barton Springs during the period 1917-2013 which included the drought of record is about 53 cfs or 34 million gallons per day (BSEACD 2017). Average annual Barton Springs flow from 1917 to 1947 was 45cfs (**Figure 3-9**). After the DOR (1957-2012), average annual springflow has been higher (64 cfs). During the 16 years from 2000 to 2015, average annual discharge has been 62.3 cfs according to the USGS (2016) (**Figure 3-10**).

The hydrostatic pressure of Barton Springs Pool that lies over the Main (Parthenia) Spring appears to affect flow of the other springs. Eliza and Sunken Garden (Old Mill) Springs can cease to flow when the discharge from the Main (Parthenia) Spring drops below 50 cfs and the pool is lowered for routine maintenance and cleaning (COA 1998). Upper Barton Spring flows only when discharge from the Main Spring exceeds 40 cfs and drops slightly when the pool is lowered (COA 1998). Although the collective flow of Barton Springs has never ceased during recorded history, the lowest instantaneous springflow measurement of 9.6 cfs was made during the DOR on March 29, 1956 (Brune 2002). The lowest monthly mean springflow of 11 cfs was reported at the end of the drought-of-record (1950s drought) during July and August 1956 (Slade et al. 1986). Comal Springs in the San Antonio portion of the Aquifer and the largest spring system in Texas ceased flowing for about 4 months in 1956 during the same drought. Recent modeling conducted by the District (BSEACD 2004) indicates that under 1950s drought conditions and 2004 authorized pumping rates of about 10 cfs, flow from Barton Springs would decrease to less than 1 cfs on a monthly basis, and likely cease altogether on some days within that month.

Barton Springs provides good to excellent water quality conditions for its biological assemblage. Water temperature remains within a narrow range from approximately 66ºF (19°C) to 75ºF (24°C) (COA, unpublished data) with an annual average varying between approximately 70ºF (21°C) and 72ºF (22°C) (COA 1997). Values for pH range between 6.6 and 7.1 in the main (Parthenia) spring. Dissolved oxygen is typically undersaturated and varies with springflow; lower flows result in lower dissolved oxygen concentrations (Turner 2004). Citing COA (1998) and Veenhuis and Slade (1990), the Service concludes in its *Barton Springs Salamander Recovery Plan amended to include the Austin Blind Salamander* (USFWS 2016a), that impervious cover, composition and health of the plant community, disturbed surface areas, point source contamination, and operating stormwater treatment facilities can all alter the quality of runoff entering the Aquifer. The relationship between dissolved oxygen and discharge in Barton Springs has changed over time such that dissolved oxygen is currently lower at given discharges than in the past (Turner 2004; USFWS 2016a). Dissolved oxygen is a critical component of habitat suitability for the Barton Springs and Austin blind salamanders as well as the rest of the biological community in the springs, and low values appear to have direct and/or indirect effects on abundance of biological fauna (Turner 2004; Wetzl 2001; Lampert and Sommer 1997). Turbidity in the springs has also increased significantly over time during storm-flow (COA 2000). However, recent analysis of long-term non-storm-flow monitoring data by the City of Austin did not detect any long-term trends in turbidity or total suspended solids (Herrington and Hiers 2010). The sediment transported during these high-flow events in Barton Creek is deposited in Parthenia Spring when the creek overflows the upper dam and bypass structure and enters Barton Springs Pool (COA 1998). Greater sediment loads result in a longer period of time required to clear the springs. Such changes in water quality conditions can have detrimental impacts on the biological communities in these areas

Figure 3-8 Barton Springs Ecosystem Vicinity Map

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Figure 3-9. Mean Annual Barton Springs Flow: 1917-2012

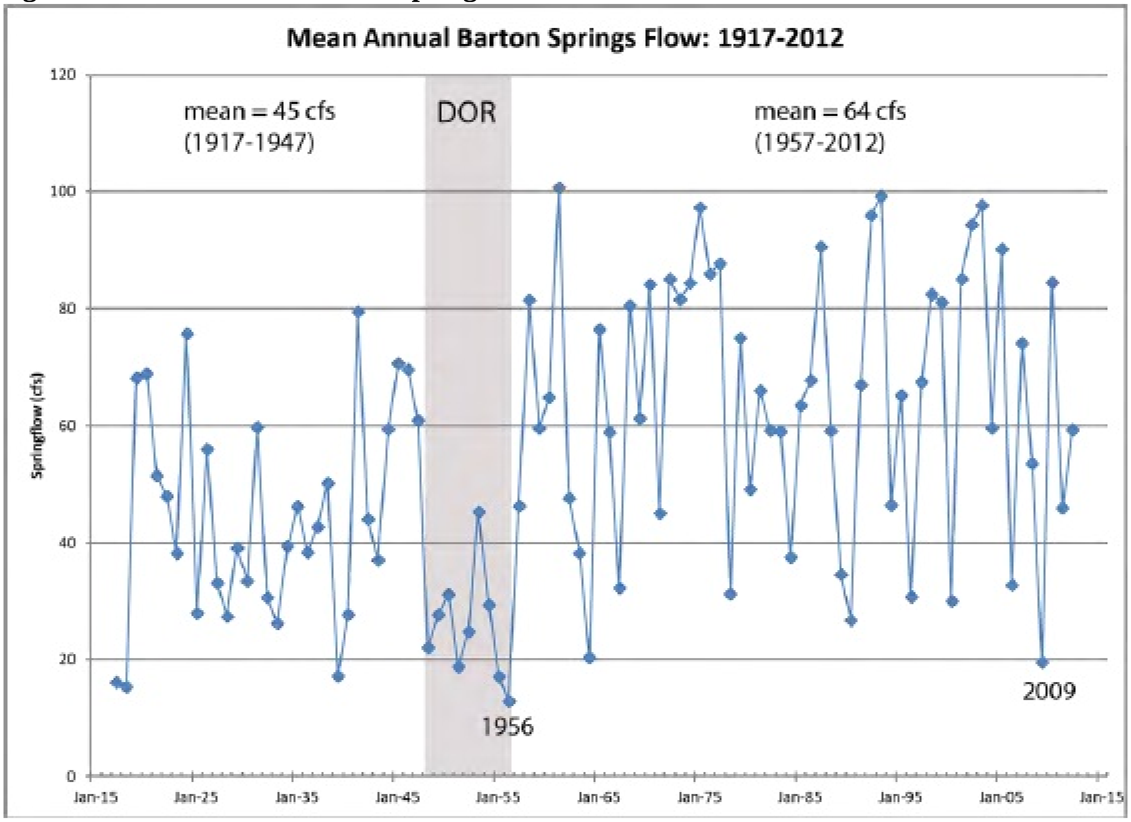
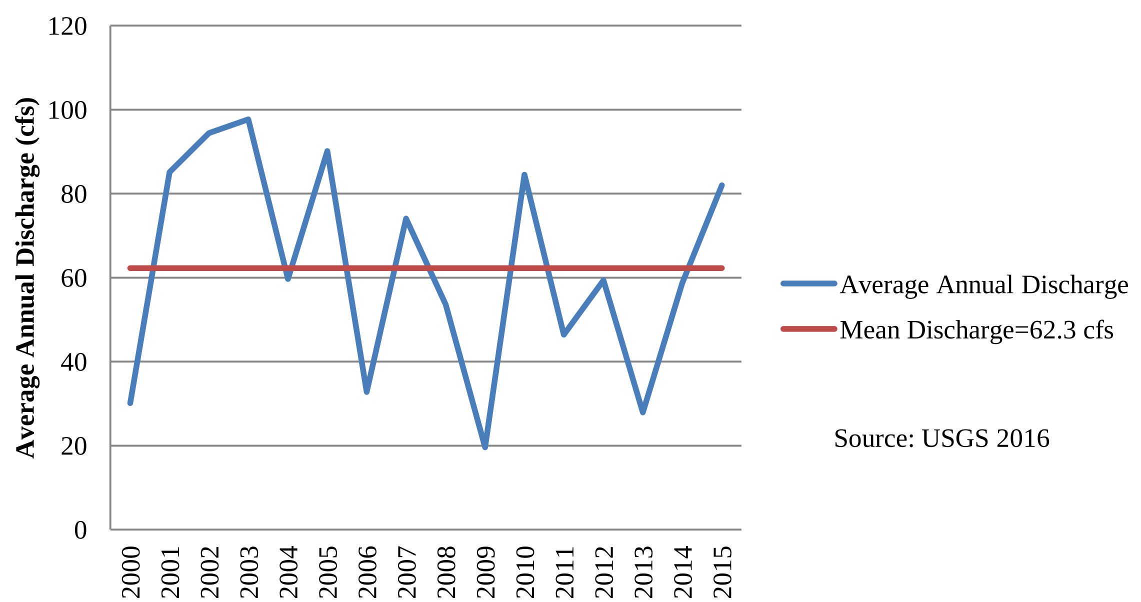


Table from Smith et al (2013). Data from the U.S. Geological Survey.

Figure 3-10. Average Annual Barton Springs Discharge During Years 2000-2015 (cfs)



Other minor springs discharging from the Barton Springs segment of the Edwards Aquifer include Cold Springs and Deep Eddy Springs. These springs form a complex of what was originally seven springs, although only two, located on the south bank of Lady Bird Lake (Colorado River) about 1.5 miles upstream of the mouth of Barton Creek, are now above the normal level of Lady Bird Lake (Brune 1975). Measurements of springflow from Cold Springs are limited and imprecise, but range from 2.6 to 6.8 cfs (Brune 2002; Hauwert et al. 2004b). Several other minor springs have been identified within the Barton Springs segment that provide inconsequential flow and may be more influenced by local conditions than directly affected by the Aquifer (Brune 1975).

3.2.1.3 Surface Water Quality

Rules and Regulations Governing Surface Water Quality

Surface water quality is regulated and monitored by the TCEQ (Texas Natural Resource Conservation Commission [TNRCC] prior to September 1, 2002) and by the USEPA. The State of Texas Integrated Report for Clean Water Act Section 305b and 303d (also known as the Texas Water Quality Inventory) is prepared by the TCEQ (TCEQ 2015b) and submitted to the USEPA. This effort reports on water chemistry information, data on toxic substances in the water, sediments, fish tissue, contaminants, status and trends in water quality statewide and other historical information. The report assesses water by river or coastal basin where all major bodies of water, creeks, rivers, reservoirs, lakes, bays and estuaries, are divided into monitored segments. The report also includes the degree to which each water body segment supports its designated uses as established by the Texas Surface Water Quality Standards.

The TCEQ divides classified surface water body segments into two groups: water quality limited or effluent limited. Water bodies are classified as water quality limited if one or more of the following are applicable: (1) surface water quality monitoring data indicate significant violations of criteria in the Texas State Water Quality Standards (TSWQS) that are protective of aquatic life, contact recreation, public water supply, fish consumption, or oyster waters uses; (2) advanced waste treatment for point source wastewater discharges is required to meet water quality standards; (3) the segment is a public water supply reservoir (requires special wastewater treatment considerations). All other water bodies are classified effluent limited, indicating that water quality standards are being maintained and that conventional wastewater treatment is adequate to protect existing conditions.

Water Quality of Designated Streams in the Study Area

TCEQ stream segments within the study area that undergo water quality monitoring assessments by the TCEQ (2015b) are summarized in **Table 3-1**.

Streams within the study area have been characterized in the State of Texas 2014 Integrated Report for Clean Water Act Section 305b and 303d as having mixed levels of water quality

(TCEQ 2015b). Elevated nutrient levels and fecal coliform (*Escherichia coli*) densities found in many of the tributary streams in the Austin area originate mostly from unidentified non-point source runoff.

Impaired water body segments that did not support designated uses or water quality criteria are listed on the 2014 State of Texas Clean Water Act Section 303(d) List (TCEQ 2015b). These include two impaired stream segments (Onion Creek # 1427-03 and Slaughter Creek #1427A-01) that lie within the study area. Onion Creek was listed because of elevated sulfate, while Slaughter Creek was listed because of an impaired macrobenthic community occurring within the entire water body (**Table 3-1**).

Plum Creek Segments 1810-01 through 1810-03 were listed as Category 4 impaired waters due to elevated levels of bacteria (**Table 3-1**).

Table 3-1
TCEQ Surface Water Quality Inventory Summary
for the Stream Segments Overlying the Study Area

Segment Name	Segment Number	Evaluated Water Uses	Impairment Category[1]
Onion Creek	1427-01 through 02	Aquatic life, recreation, general, public water supply	
Onion Creek From FM 967 upstream To Jackson Branch confluence	1427-03	Aquatic life, recreation, general, public water supply	5
Onion Creek	1427-04	Aquatic life, recreation, general, public water supply	
Slaughter Creek	1427A-01	Aquatic life, recreation, general	5
Williamson Creek	1427B	Aquatic life, general	
Bear Creek	1427C	Aquatic life, recreation, general	
Granada Hills Tributary to Slaughter Creek	1427G	General	
Colorado River Below Town Lake (now Lady Bird Lake)	1428-01 through 03	Aquatic life, recreation, general	
Town (Ladybird) Lake	1429-01 and 02	Aquatic life, recreation, general	
Eanes Creek	1429B	Aquatic life, recreation, general	
East Bouldin Creek	1429D	Aquatic life	
Barton Creek	1430-01 through 05	Aquatic life, recreation, general	
Barton Springs	1430A	Aquatic life, recreation, general, fish consumption	
Tributaries to Barton Creek Upstream to Barton Creek Blvd	1430B-01	Aquatic life, recreation, general	
Tributaries to Barton Creek Upstream to CR 169	1430B-05	Aquatic life, recreation, general	
Lower San Marcos River	1808-01 Through 04	Aquatic life, recreation, general	
Lower Blanco River	1809-01 and 02	Aquatic life, recreation, general	
Plum Creek	1810-01 through 03	Aquatic life, recreation, general	4

Segment Name	Segment Number	Evaluated Water Uses	Impairment Category[1]
Upper Blanco River	1813-01 through 05	Aquatic life, recreation, general	
Cypress Creek	1815-01 and 02	Aquatic life, recreation, general	

[1]Category Definitions:

The 2014 Integrated Report Assigned Categories 4 and 5 to those segments with Impairments. The absence of any designation indicates the stream did not meet Category 4 or 5 Impairment Criteria

Category 4 – Standard is not attained or nonattainment is predicted in the near future due to one or more parameters, but no TMDLs are required.

Category 5 (i.e., Texas 303d List) – Standard is not attained or nonattainment is predicted in the near future for one or more parameters.

Source: (TCEQ 2015b).

3.2.1.4 Floodplains

Floodplains within the study area may be classified according to the Federal Emergency Management (FEMA) zones A, AE, X, and X500, which are relevant to the flood insurance program and are defined based on the probability of flooding. The 100-year flood elevations and flood depths provided on Flood Insurance Rate Maps (FIRMs), where available, establish the minimum regulatory elevations applicable to local floodplain management ordinances. Zones A and AE generally correspond to the areas subject to a 100-year flood event. Zone A is defined by FEMA as areas with a 1 percent annual chance of flooding, which equates to a 26 percent chance of flooding over the life of a 30-year mortgage. Zone A designations are considered approximations where detailed analyses have not been performed, thus no depths or base flood elevations are shown within these zones. Zone AE designates areas with a 1 percent annual chance of flooding where the base flood elevations have been determined. Zone X defines areas of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. Zone X500 generally refers to areas subject to a 500-year flood event. Typical floodplains found along rivers, creeks, and streams are generally classified as Zones A and AE.

3.2.1.5 Unique Ecological Stream Segments

In accordance with 31 TAC § 357.8, regional water planning groups such as the Lower Colorado Regional Water Planning Group (LCRWPG):

> “. . . may include in adopted regional water plans recommendations for all or parts of river and stream segments of unique ecological value located within the regional water planning area by preparing a recommendation package consisting of a physical description giving the location of the stream segment, maps, and photographs of the stream segment, and a site characterization of the stream segment documented by supporting literature and data.”

Guidelines for Designating Unique Ecological Stream Segments

The following criteria were established by TPWD to identify a river or stream segment as being of unique ecological value:

- **Biological Function**: Segments that display significant overall habitat value including both quantity and quality considering the degree of biodiversity, age, and uniqueness observed and including terrestrial, wetland, aquatic, or estuarine habitats;
- **Hydrologic Function**: Segments which are fringed by habitats that perform valuable hydrologic functions relating to water quality, flood attenuation, flow stabilization, or groundwater recharge and discharge;
- **Riparian Conservation Areas**: Segments that are fringed by significant areas in public ownership including state and Federal refuges, wildlife management areas, preserves, parks, mitigation areas, or other areas held by governmental organizations for conservation purposes under a governmentally approved conservation plan;
- **High Water Quality/Exceptional Aquatic Life/High Aesthetic Value**: Segments and spring resources that are significant due to unique or critical habitats and exceptional aquatic life uses dependent on or associated with high water quality; or
- **Threatened or Endangered Species/Unique Communities**: Sites along segments where water development projects would have significant detrimental effects on state or federally listed threatened and endangered species, and sites along segments that are significant due to the presence of unique, exemplary, or unusually extensive natural communities.

Unique Ecological Stream Segments within the Study Area

Although the 2011 Regional Water Plan for the Lower Colorado (Region K) (LCRWPG 2010) did not recommend any sites for the designation of unique ecological stream segments, TPWD did identify six different streams that are located (or partially located) within or adjacent to the study area that fit one or more of the criteria. These stream segments are listed in **Table 3-2** below.

Table 3-2
Unique Stream Segments Identified Within or Adjacent to the Study Area

Stream	Segment #	Location	Criteria Met
Barton Creek	1430	From confluence with Colorado river upstream to RR 12 in Hays County	High water quality; exceptional aquatic life, high esthetic life, threatened & endangered species.
Little Barton Creek		Upstream from confluence with Barton Creek to headwaters	High water quality; exceptional aquatic life, high esthetic life.
Blanco River	1813	From Blanco/Hays County Line to Blanco/Kendall County Line	High water quality; exceptional aquatic life, high esthetic life.
Little Blanco River		From Blanco/Comal County Line upstream to headwaters	High water quality; exceptional aquatic life, high esthetic life.
Colorado River	1428	From Longhorn Dam downstream to FM 969 crossing near Utley	High water quality; exceptional aquatic life, high esthetic life, threatened & endangered species.
Onion Creek	1427	From confluence with Colorado River upstream to upstream crossing of FM 165 in Blanco County	High water quality; exceptional aquatic life, high esthetic life.

Source: TPWD 2014.

3.2.2 Groundwater

Groundwater within the study area originates from the Trinity and Edwards Aquifers, two major Aquifers that are hydrogeologically interrelated. The Edwards Aquifer overlies the Trinity Aquifer. The uppermost part of the Trinity Aquifer and the Edwards Aquifer are hydrologically connected allowing exchange of water between the aquifers (Wong et. al 2014) and contribution of flows from one aquifer to another would depend on respective water level elevations. Influences of the Blanco River on recharge of both the Edwards and Trinity aquifers has also been investigated (Wong et al. 2014; Smith et al. 2014). The Trinity Aquifer outcrops on the western portion of the study area in an area generally corresponding to the contributing zone of the Edwards Aquifer. The stratigraphic relationship of the two aquifers is shown on **Figure 3-1**. A description of the Trinity Aquifer is provided below, while the description of the Edwards Aquifer has been previously provided in **subsections 3.1.1.4** through **3.1.1.6**.

3.2.2.1 Groundwater Quality of the Trinity Aquifer

The Trinity Aquifer is a karst aquifer that underlies an area of about 41,000 square miles that extends from south-central Texas to southeastern Oklahoma (Green et al. 2011; TWDB 2014b, Wierman et al. 2010). This Aquifer lies beneath the Recharge, Confined, and Saline Zones of the Barton Springs segment of the Edwards Aquifer and provides greater variability in yield and water chemistry (BSEACD 2017). Groundwater in the Trinity Aquifer has been described as calcium carbonate in western Travis County, changing to a sodium sulfate or chloride type water as the Aquifer extends deeper into the subsurface to the southeast (i.e., downdip). The water is very hard and the quality tends to decrease downdip. Low permeability, restricted water circulation, and increase in temperature result in higher mineralization downdip (Brune and Duffin 1983).

Through increased water demand from urban and suburban development, the upper, middle, and lower parts of the Trinity Aquifer are locally experiencing declining water levels (Mace et al. 2000) and degraded water quality. This trend has prompted the need for supplemental surface water supplies in southwestern Travis and Northern Hays Counties and largely justified the need for construction of a major distribution pipeline providing surface water supplied by the LCRA (BIO-WEST 2002).

The Trinity Aquifer within the study area is composed of the following formations (from stratigraphically highest to lowest): the Upper Glen Rose Limestone, Lower Glen Rose Limestone, Hensell Sand, Cow Creek Limestone, and the Hammett Shale. The Upper and Lower Glen Rose Limestones consist mostly of limestone, dolomite, shale, and marl. Some units of the Upper and Lower Glen Rose Limestones contain evaporites (Smith et al. 2015). These formations are discussed below.

Upper Glenrose

This formation, also referred to as the Upper Trinity (Mace et al. 2000) dips irregularly toward the southeast and has a thickness ranging from about 230 feet in northwestern Travis County to about 600 feet in the southeast. Depths of wells in the Upper Trinity Aquifer within the Dripping Springs area range from 11 to 169 feet with static water levels of 5 to 91 feet (Muller 1990). Artesian conditions historically existed in the subsurface; however, no flowing wells or springs in the upper Trinity were located within Travis County (Brune and Duffin 1983).

Muller (1990) noted that the quality in the upper Trinity Aquifer was better than the Middle Trinity Aquifer for sulfate, fluoride, and dissolved solids, indicative of shorter flow paths in the upper Aquifer. However, elevated nitrate concentrations were present and believed to be primarily caused by septic tank effluent. Samples from wells also documented fecal coliform and fecal streptococcus above Texas Department of State Health Services standards; however, the results were not conclusive (Muller 1990). The Upper Trinity Aquifer is considered to generally be in hydrological communication with the overlying Edwards Aquifer, although the connection is not well-established and poorly known; the differences in hydraulic heads, which control inter-formational flow direction, are not great and are probably variable in much of the Aquifer.

Lower Glenrose, Hensel Sand, Cow Creek Limestone

In this portion of the aquifer, also referred to as the Middle Trinity Aquifer (Mace 2000), groundwater is unconfined in the outcrop area, but it becomes confined downdip. In the downdip portions of the Aquifer, groundwater was historically found under artesian conditions, and wells flowed due to hydrostatic pressure, particularly those drilled in lower areas along Lake Austin and in the COA (Brune and Duffin 1983).

Most of the deep wells in the Dripping Springs area, west of the District's jurisdiction, produce from this portion of the aquifer. Well depths in the Dripping Springs area range from 99 to 580 feet, with static water levels of 81 to 296 feet (Muller 1990). However, low Aquifer permeability has created rapid drawdowns of the wells and slow recharge rates. Bluntzer (1992) documented wells with water levels declining since 1977. Mace (2000) indicates that over the past 20 years, water levels have declined in many areas within the Middle Trinity and reported one monitoring well near Wimberly in Hays County (Well # 68-08-102) declining by 40 feet since 1980.

Quality of groundwater from this portion of the Trinity Aquifer has been characterized as variable but generally slightly saline and may contain high sulfate that is derived from the gypsum beds of the Cow Creek Limestone (DeCook 1963; Ashworth 1983; Brune and Duffin 1983; Bluntzer 1992). Additional water quality problems involving bad taste and odor have been reported by the LCRA (LCRA 2000). Muller (1990) noted that the groundwater in the Middle Trinity Aquifer could be contaminated at certain locations because of improperly completed wells with open or uncased boreholes.

Hammett Shale and Lower Trinity Group

The Hammett Shale formation generally separates the Middle Trinity from the Lower Trinity Aquifer group (Mace 2000). Units of the Lower Trinity Aquifer, comprising the Hosston and Sligo Formations according to Mace (2000), both outcrop in extreme western and southwestern Travis County. In these areas, these units appear to be largely non-water bearing, but further east in the downdip portions of the aquifer, they appear to be more permeable, with many flowing wells on the Colorado River (Brune and Duffin 1983).

The groundwater quality in the Lower Trinity Aquifer has been described as slightly saline with dissolved solids content often over 1,000 milligrams per liter (DeCook 1963; Brune and Duffin 1983; PBS&J 1999). A portion of the wells in this aquifer could be expected to exceed drinking water maximum contaminant levels for several constituents including nitrate, fluoride, chloride, sulfate, dissolved solids, and sodium (Bluntzer 1992).

3.2.2.2 Groundwater Quality of the Barton Springs Segment of the Edwards Aquifer

Historically, the quality of water in the Barton Springs segment of the Edwards Aquifer has been high. However the results of a number of studies and investigations including Andrews et al. (1984), Slade et al. (1986), Turner (2000), Mahler et al. (2006, 2011), and Mahler and Bourgeais (2013) indicate that the Aquifer and its discharging Barton Springs have experienced varying levels of water quality degradation as a result of human development over the Aquifer and its contributing zone (See **Appendix C**). While the overall water quality of the Aquifer and its springflows remains high, future water quality degradation from increased nutrients and pollutants from urban runoff remains a major concern involving public use of Barton Springs Pool as well as the future health of the Barton Springs ecosystem.

The highly fractured limestone formations and resulting fissures, cavities, and transport conduits typical of karst aquifers, in conjunction with thin soils, make the Barton Springs-Edwards Aquifer susceptible to water quality degradation from land surface erosion and runoff. The Edwards Aquifer has been ranked most vulnerable to degradation from anthropogenic contamination statewide based on its hydrogeological structure (Texas Groundwater Protection Committee 2003). Water quality of the Barton Springs complex is primarily determined by quality of surface waters in the recharge zone as they recharge the Aquifer and mix with groundwater while traveling to downstream springs. The quality of groundwater emanating from Barton Springs is positively related to quality of recharging waters (Mahler et al. 2006). The character of that relationship varies with amount of groundwater discharge and surface conditions (storm vs. base flow).

Mahler et al. (2006) concluded that when Aquifer conditions are low, recharge entering the Aquifer is transported rapidly to the springs with little dilution or loss to storage. In contrast, when Aquifer flow conditions are high, recharge is diluted by mixing with previously stored Aquifer water, and, in turn, some of the recharge water with its associated contaminants is stored within the Aquifer for future discharge.

Years of study have led to the conclusion that water quantity, water chemistry, and water quality of the Barton Springs segment of the Edwards Aquifer are interrelated. During recharge events, the water quality of recharge waters from streams exerts a strong influence on the quality of water discharging at the springs. During non-recharge conditions, Barton Springs discharge is a reflection of the long-term water quality of the Aquifer. Stormwater runoff is generally of poorer quality than base flows and these flows may contain elevated concentrations of suspended solids, nutrients, bacteria, and oxygen-demanding material, while having lower concentrations of total dissolved solids concentrations (salinity) and dissolved oxygen (DO) (Mahler and Bourgeais 2013). Storm conditions, however, tend to be transitory and the quality of discharging spring water returns to antecedent levels as rain events subside. While average flows and typical drought flows of recharge streams tend to be of high quality (i.e., have smaller pollutant loads than stormwater), a prolonged drought that reduces springflows will tend to increase salinity and decease DO in the springs (Herrington and Hiers 2010). These changes appear to be driven by the mixing of older, more-saline water from the eastern part of the Aquifer, also known as the “saline zone,” which has much lower DO (Mahler and Bourgeais 2013). Salinity and DO are the two water quality parameters believed to be of primary importance to the two covered salamander species. Investigations of these and other commonly tracked water quality parameters are summarized below and also discussed in **Appendix C, Water Quality in the Barton Springs Segment of the Edwards Aquifer.**

Nutrients

Nutrients, primarily nitrogen, phosphorous, and potassium are essential for plant growth, although they can become pollutants in certain circumstances. Major sources of nutrients include fertilizer runoff, animal manure, particularly dogs and cats in urban and suburban environments, and domestic and industrial wastewater effluent. Investigations of nutrient loadings into the Barton Springs complex identified only nitrate above a detection threshold under base-flow conditions (Mahler et al. 2006).

Additional sampling conducted by USGS between November 2008 and March 2010 showed a substantial increase in nitrate loadings to the five streams recharging the Barton Springs complex compared to samples collected between 1990 and 2008. Nitrate concentrations from Onion Creek had increased 6- to 10-fold while those at Barton Springs were also higher (Mahler et al. 2011). Median nitrate concentrations in routine samples from all sites were higher during wet periods than dry periods. Increases in nitrate concentrations have coincided with rapid increases in number of septic systems and land applications of treated wastewater associated with wide-spread development over the contributing zone. Moreover, nitrate detected bears the signature of human or animal waste. This 2011 investigation indicates that baseline concentrations of nitrate have shifted upward even without any direct discharges of treated wastewater to the watershed.

Potassium has been found to increase in response to storms. Potassium concentrations increased at all four springs following one storm Mahler et al. (2006) sampled. The study raised the possibility that its source could be fertilizer washed into the Aquifer. However, no long-term trends in potassium concentrations have been detected by the COA (Herrington and Hiers 2010).

Orthophosphates are typically below detection levels at Main Spring, but concentrations in storm samples from two of the creeks were 3 to 5 times greater than those in routine samples during the 2008–2010 study (Mahler et al. 2011). No trends in orthophosphorus or phosphorus have been detected by long-term (non-storm) monitoring by the COA (Herrington and Hiers 2010). Additional information on nutrients is provided in **Appendix C.**

Dissolved Oxygen

DO at all spring orifices decreases as discharge flow from the Barton Springs complex decreases (Mahler et al. 2011). Conversely, higher non-stormflow discharges from the Aquifer generally coincides with higher DO concentrations. DO concentrations vary among the four springs since DO is temperature- and recharge-dependent and each spring demonstrates a unique profile. Following this relationship, USGS data showed a low of 4 mg/L at Main Spring during the drought of 2009 in comparison to a daily average of 6 mg/L measured from October 2006 to June 2012 (Mahler and Bourgeais 2013). Interestingly, 4 mg/L was lower than the 4.4 mg/L estimated by Woods et al. (2010) as the threshold level of No Observable Adverse Effect for captive San Marcos salamanders, indicating some adverse effects could occur to the salamanders if they could not retreat to areas with higher levels of DO.

While long-term DO measurements have been recorded and in some instances suggest decreasing trends at Main Spring (COA 2013a; Herrington and Hiers 2010), these data are controversial because of changes to instrumentation over time and some questionably low DO values from 1996 that have never been recorded since, even during recent drought conditions (Mahler and Bourgeais 2013). The most reliable and consistent measurements emanate from work by the USGS since 2006, which show a very small positive trend (Mahler and Bourgeais 2013). Additional information on dissolved oxygen is provided in **Appendix C.**

Temperature

The average water temperature of Barton Springs is approximately 70°F (21°C) with a small range of variation under normal conditions (Mahler et al. 2006, Gillespie 2011). Mahler et al. (2006) reported a significant correlation between air and water temperature of the Main Spring. Cooler water temperatures coincide with seasonal winter rainfalls. Long-term monitoring by the COA has detected a trend of increasing water temperature (Herrington and Hiers 2010). Water temperature is a key determinant of DO solubility; warm water does not hold as much oxygen as cold water.

Salinity

Salinity refers to inorganic salts in water. Salinity differs from one watershed to another depending on the underlying rock type. Reduced instream flows and high evaporation rates can increase salt levels. Salinity is measured indirectly as specific conductance, which is the ability of water to carry an electric current and is dependent on the amount of dissolved solids in water. Salinity can also be measured by quantifying the amount of chloride, sulfate, and total dissolved solids (TDS) in water.

Salinity in the Barton Springs complex varies within a fairly narrow range, with the difference in conductance between average and lowest flows over 7 years recorded as 75 micro siemens per centimeter (μS/cm), which corresponds to a variation in total dissolved solids (TDS) of less than

50 mg/L (Herrington and Hiers 2010). Even at the lowest flows, the highest TDS concentrations measured at the springs are about 475 mg/L. For comparison, water is considered fresh if TDS is under 1,000 mg/L.

Conductivity varies at the springs, with increasing conductivity as discharge decreases and decreasing conductivity with storm events. Main Spring averages ~650 µS/cm, while Old Mill averages ~700 µS/cm (Mahler et al. 2006, COA 2013a). When Barton Springs discharge is less than approximately 40 cfs, concentrations of sodium, chloride, and sulfate are inversely proportional to discharge, indicating some influx of saline zone water into the springs (Mahler et al. 2006).

Long-term (non-storm) monitoring by the COA has detected increases, decreases and no trend among various ions; however, the City does report an overall increase in conductivity (Herrington and Hiers 2010).

Suspended Solids and Sedimentation

Suspended solids refer to mineral or organic particles suspended in the water column. Those solids reduce the penetration of sunlight into the water column. They may also carry nutrients or other contaminants. High flows are often associated with heavy sediment loads due to surface runoff and also because the force of the water keeps the solids suspended rather than allowing them to settle. Short-term turbidity increases are common during storm conditions as a watershed becomes urbanized. Turbidity, caused by suspended solids, has been significantly increasing during storm-flow conditions for more than 20 years (Mahler et al. 2006).

Solids that are carried into the Aquifer from surface runoff may eventually be discharged through the springs. Mahler and Lynch (1999) found that sediments begin to discharge from Main Spring whenever a rainfall event of 1.5 inches or greater occurs within the Barton Springs watershed. Further, the amount of sediment discharged from Main Spring in a 24-hour period following a 2-inch rainfall event is approximately one metric ton.

Suspended sediments can inhibit the respiratory function of fishes and neotenic salamanders (Garton 1977; Werner 1983); decrease the ability to locate food or escape from predators (USEPA 1986; Schueler 1987); and become a vector for contaminants toxic to aquatic animals (Ford and Williams 1994; Menzer and Nelson 1980; Landrum and Robbins 1990; Medine and McCutcheon 1989).

Stormwater runoff pollutant loads have been found to increase with increasing impervious cover and have been correlated with development intensity in Austin (Soeur et al. 1995).

Additional information on suspended solids is provided in **Appendix C.**

Trace Metals

Edwards water contains trace concentrations of metals, such as copper, nickel, and arsenic, which leach naturally from rocks and soils. USGS sampled sediment in discharging spring water and creeks in the Barton Creek watershed between 2000 and 2002 (USGS 2003). Arsenic, chromium, copper, and nickel in discharging spring sediment was measured at higher concentrations than in surface-water sediments. The converse was true for lead and zinc, two metals strongly related to urban land use. Based on their analysis, USGS concluded that most of the metals in discharging Aquifer sediments seem to be a natural consequence of the geochemistry of the Aquifer rather than pollution. Elevated levels of lead and zinc were associated with the two urbanized sites sampled. There are numerous human sources of metals and in the urban environment these sources might include roadway, parking lot, and roof runoff, landfill leachate, wastewater, and fertilizers. Concentrations of all metals are well below USEPA maximum contaminant levels for drinking water, and no trends have been detected (Herrington and Hiers 2010).

Bacteria

Bacteria have long served as an indicator of water quality. *E. coli*, present in human waste, serves as the indicator bacteria for freshwater bodies in Texas. Densities of *E. coli* were measured between 2008 and 2010 in the creeks of the Barton Springs watershed and at Barton Springs itself. During the dry period, densities were low (<100 Most Probable Number [MPN]/100 milligrams per liter [mL]) in surface waters and in spring discharge. During the rainy period, densities of *E. coli* in routine samples collected from streams contributing to discharge at the springs varied from less than 10 to 4,800 MPN/100 mL (Mahler et al. 2011). Samples taken from Main Spring during the wet period contained 2–450 MPN/100 mL. Previous sampling was based on fecal coliform so comparisons are difficult. While there were indications of fecal coliform increasing over time at Barton Springs, the COA reports that concentrations of indicator bacteria are well below the State of Texas standard for contact recreation (Herrington and Hiers 2010).

Pesticides

Pesticides are used on a variety of landscapes in the study area from residential lawns to ranchland to golf courses. Most pesticides applied to these landscapes are water-soluble and can infiltrate into the subsurface via fractures and sinkholes. These pesticides travel through the Aquifer and discharge at the springs. Water quality monitoring studies conducted at Barton Springs by the USGS during the years 2003–2005 revealed measurable levels of atrazine, diazinon, prometon, carbaryl, and simazine, though pesticides were detected more frequently in Upper Spring than at the other three springs and, in most cases, at higher concentrations (Mahler et al. 2006). Atrazine, a widely used weed killer, was the focus of litigation between the Center for Biological Diversity, SOS Alliance, and the USEPA in August 2005. This prompted a study by the USEPA's Office of Pesticide Programs (2006), which concluded that acute and chronic levels of atrazine were not exceeded and that existing levels of atrazine would have no effect on survival, growth, and reproduction on individuals of the Barton Springs salamander via direct effects. No long-term trends in pesticides have been reported by the COA (Herrington and Hiers 2010).

Volatile Organic Compounds

Volatile organic compounds (VOCs) include constituents of gasoline such as toluene, benzene, and methyl tertiary-butyl ether. Other volatile organic compounds include chloroform, a by-product from the addition of chlorine to water, and tetrachloroethene, a metal degreaser and dry cleaning solvent. VOCs were detected in historical samples from wells and springs in the Barton Springs watershed. Data collected after the mid-1990s continued to show the presence of chloroform, toluene, and tetrachloroethene (Mahler et al. 2006). Between 2003 and 2005, 9 of 85 VOCs were detected: Two drinking-water disinfection by-products (chloroform and bromodichloromethane), one gasoline compound (toluene), four solvents, and two other industrial VOCs (Mahler et al. 2006). Chloroform and tetrachloroethene were detected in all routine samples collected from the four springs; other VOCs were detected less frequently or at specific springs. No long-term trends have been reported by the COA (Herrington and Hiers 2010).

Rules and Regulations Governing Groundwater Quality

State, Federal and local regulations governing the quality of groundwater in Texas have been developed over the last several decades. In 1974, the Federal Safe Drinking Water Act was passed to protect sources of public drinking water. This act, amended in 1996, mandated enforceable drinking water standards established by the USEPA. The TCEQ has assumed responsibility for enforcement of drinking water standards in Texas and has established standards as strict as or more strict than the USEPA's. As part of this responsibility the TCEQ has established by rule an Edwards Aquifer Protection Program, requiring that those who plan to build on the recharge, transition, or contributing zones of the Edwards Aquifer, must first have an application including construction plans approved by the TCEQ. The Service, the District, and several other local jurisdictions have initiated studies, plans, ordinances and programs to address the regulation of groundwater quality in the study area. These regulatory efforts are summarized in **Appendix D, Groundwater Quality Management and Planning Efforts**.

3.3 WILDLIFE RESOURCES

3.3.1 Regional Ecology

The study area occurs within a transition zone of the Edwards Plateau (west of Austin) and the Texas Blackland Prairies (east of Austin) as mapped by Griffith et al. (2004) and USEPA (2003). These vegetation regions were originally described by Gould et al. (1960), Gould (1975), later refined by the Lyndon B. Johnson (LBJ) School of Public Affairs (1978); and were used by the TPWD (McMahan et al. 1984) and Hatch et al. (1990). These general vegetation types have been mapped in more specific detail by TPWD (2011). A brief description of the Edwards Plateau and Texas Blackland Prairies ecological regions follows.

3.3.1.1 Edwards Plateau

This ecological region encompasses approximately 24 million acres, including a large portion of the Hill Country in west-central Texas, as well as the Llano Uplift and Stockton Plateau regions. Average annual precipitation increases from west to east across this region. The surface is rough and well drained, being dissected by several river systems. The shallow, variably textured soils are typically underlain by limestone or caliche, and granitic rock in the Llano Uplift region. Land use in this vegetation area is dominated by cattle, sheep, and goat ranching.

Historically, this region was reportedly once dominated by a grassland or open savannah climax community except in the steep canyons and slopes, where junipers and oaks were dominant. However, with the widespread disturbance associated with livestock grazing and the suppression of fire, brush and tree species have been able to spread widely throughout the grassland and savannah areas.

Grasses that are typical of the Edwards Plateau region include switchgrass (*Panicum virgatum*), indiangrass (*Sorghastrum nutans*), beardgrass (*Bothriochloa* spp.), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), Canada wildrye (*Elymus canadensis*), curly mesquite (*Hilaria belangeri*) and buffalograss (*Buchloe dactyloides*). Other plants commonly found within this vegetational area include Ashe juniper (*Juniperus ashei*), plateau live oak (*Quercus fusiformis*), Texas oak (*Q. texana*), Texas persimmon (*Diospyros texana*), elbowbush (*Forestiera pubescens*), Texas mountain laurel (*Sophora secundiflora*), prickly-pear cactus (*Opuntia* spp.), and pencil cactus (*O. leptocaulis*) (Hatch et al. 1990).

3.3.1.2 Texas Blackland Prairies

The Texas Blackland Prairies ecological region consists of nearly level to gently rolling topography. This area covers approximately 11.5 million acres from Grayson and Red River Counties in northeast Texas to Bexar County in the south-central region of the state, where it merges with the brushland of the South Texas Plains. Annual precipitation averages 30 inches on the west to 45 inches on the east, and elevations range from 300 to 800 feet above sea level. Blackland soils that occur in the region are so named due to the uniform dark-colored calcareous clay component. These soils are interspersed with gray acid sandy loams. This highly fertile region has been widely used for cultivated agriculture, although use of the land for ranching has become increasingly popular (Gould 1975; Schuster and Hatch 1990). It has been estimated that less than 1 percent of the once extensive Blackland Prairies remains in a near natural condition (Smeins and Diamond 1986).

Studies have shown that the native vegetation of the Blackland Prairies should historically be classified as true prairie, typified by medium tall grasslands with scattered deciduous trees, with little bluestem (*Schizachyrium scoparium* var. *frequens*) being a climax dominant species (Gould 1975). Big bluestem (*Andropogon gerardi*), Indiangrass, switchgrass, hairy grama (*Bouteloua hirsuta*), sideoats grama (*B. curtipendula*), tall dropseed (*Sporobolus asper* var. *asper*), silver bluestem (*Bothriochloa saccharoides*), and Texas wintergrass (*Stipa leucotricha*) represent other important grasses in the region. With heavy livestock grazing, invading or increasing species such as buffalograss, hairy grama, sideoats grama, and Texas wintergrass have increased, along with a variety of forbs (Hatch et al. 1990). Non-native pastures with introduced grass species such as dallisgrass (*Paspalum dilatatum*), King Ranch bluestem (*Bothriochloa ischaemum*), and bermudagrass (*Cynodon dactylon*) are common in the area. Asters (*Aster* spp.), prairie bluet (*Hedyotis nigricans* var. *nigricans*), prairie clover (*Dalea* spp.), and late coneflower (*Rudbeckia serotina*) are common forbs of these prairies (Hatch et al. 1990). Disturbed areas are also highly susceptible to invasion of honey mesquite (*Prosopis glandulosa*) and groundsel-tree (*Baccharis* spp.)

Wooded areas along riparian strips in the Blackland Prairies include such species as black willow (*Salix nigra*), oaks (*Quercus* spp.), pecan (*Carya illinoiensis*), Osage orange (*Maclura pomifera*), elms (*Ulmus* spp.), and eastern cottonwood (*Populus deltoides*) (Hatch et al. 1990). Woody invasive species that are commonly found include post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*), and cedar elm (*Ulmus crassifolia*) in the north, with honey mesquite being a common invader in the southern portion of the region (Gould 1975).

3.3.2 Invertebrates

Invertebrates occurring within the two ecological regions described above and within the study area represent five of nine invertebrate phyla within the animal kingdom: 1) arthropods (including crustaceans such as crayfish and pillbugs), insects (including butterflies and beetles), arachnids (spiders and scorpions); 2) annelids (segmented worms, including earthworms); 3) platyhelminthes (flatworms; e.g., tapeworms and flukes); 4) nematodes (roundworms; e.g., whipworms and hookworms); and 5) mollusks (clams). Many different individual species occur within these major groups involving both terrestrial, aquatic, and cave (karst) ecosystems.

The complex subterranean habitat of karst features (caves, sinkholes, fractures) formed by the readily dissolved limestone bedrock within the Edwards Aquifer creates numerous ecological niches that have been exploited by a number of invertebrate species. As many as forty-seven stygobytes (obligate aquatic cave organisms) have been referenced as occurring in the Edwards Aquifer with a majority considered endemic (Hendrickson and Krejca 2000; Abell et al. 2000).

There are many terrestrial invertebrates (troglobites) associated with these karst features, many of which are associated with only a single karst feature such as a particular cave or sinkhole. These organisms spend their entire lives in subterranean habitats and have small or absent eyes, elongated appendages, and other adaptations specific to their environment. These organisms require constant, high humidity environments, with nutrient inputs from the surface and are typically found in areas that have nearly constant temperature and humidity (USFWS 1994). The surface community above the karst is an integral part of the habitat, as it buffers the internal environment from fluctuations in temperature and moisture, and supplies the system with energy and nutrients in the form of detritus, leaf litter, animal droppings, and cave visitors. The surface vegetation is important because as surface water permeates the karst features, the vegetation serves as a potential pollution filter and a supplier of nutrients (USFWS 2001).

The aquatic invertebrate community in the study area and particularly, the Barton Springs complex is diverse. COA biologists have compiled a list of approximately 130 species that have been identified in the four springs and Barton Creek downstream of Barton Springs Pool (COA, unpublished data). This includes several aquatic worms, glossiphoniid leeches, triclad flatworms of the genus *Dugesia*, at least 12 gastropods (snails and clams), several crustaceans (including 2 species of crayfish, 4 species of amphipods, 3 species of ostracods, and blind isopods) and representatives of 10 orders of aquatic insects. The common species of crayfish found in the pool is *Procambarus clarkii*, which has been reported to be extremely abundant at times with an apparent "crayfish bloom" occurring at Barton Springs in 1995 when thousands of crayfish were found throughout the pool (COA 1998). Three blind amphipods have been documented at Barton Springs. These include *Stygobromus flagellatus*, *S. bifurcatus*, and *S. russelli* (DeeAnn Chamberlain, COA, pers. comm.). One apparent endemic species is the Barton cavesnail (*Stygopyrgus bartonensis)* a small, strictly aquatic hydrobiid gastropod (snail), which has only been collected at Barton Springs Pool to date. Common insects include mayfly larvae of the families Baetidae and Heptageniidae, while burrowing nymphs of the genus *Hexagenia* (family Ephemeridae) have been found in the sediments downstream of the main spring discharge. Snail-case caddisflies of the genus *Helicopsyche* have been historically observed in large numbers at Barton Springs Pool, but is not currently common (DeeAnn Chamberlain, COA, pers. comm.). Seven families of aquatic beetles have been collected in Barton Springs Pool.

3.3.3 Fishes

At least 70 fish species have been documented in Travis County (Hendrickson and Cohen 2012), with 35 species documented in the study area (Linam et al. 1999; unpublished data from BIO-WEST). Common species include sport fish such as the largemouth bass (*Micropterus salmoides*), Guadalupe bass (*M. treculii*), spotted bass (*M. punctulatus)*, white bass *Morone chrysops*, channel catfish (*Ictalurus punctatus*), as well as a variety of sunfish (*Lepomis* spp.) darters (*Etheostoma* spp.) and various minnows including *Cyprinus* spp., *Notropis* spp., *Pimephales* spp. and *Fundulus* spp. A number of non-native fish have also been introduced such as the common carp (*Cyprinus carpio*), Rio Grande cichlid (*Cichlasoma cyanoguttatum*), and tilapia (*Oreochromis* spp.) that compete with native species. Fish survey data collected within the Barton Springs watershed in 1993 found 28 species, while a similar survey conducted in 2008 yielded 26 species (Labay et al. 2011). Within this watershed, bluegill sunfish (*Lepomis macrochirus*), redbreast sunfish (*L. auritus*), longear sunfish (*L. megalotis*), largemouth bass (*Micropterus salmoides*), blacktail shiner (*Cyprinella venusta*), mosquitofish (*Gambusia affinis*), and central stoneroller (*Campostoma anomalum*) were most widespread, while blacktail shiner, mosquitofish, central stoneroller, bluegill, and redbreast sunfish were the most abundant.

Within the Barton Springs complex, the COA has identified 23 species of fish (COA 1998). Historically, fish species have ranged from large schools of non-native Mexican tetras (*Astyanax mexicanus*) to single specimens of Asian grass carp (*Ctenopharyngodon idella*) to native species including the American eel (*Anguilla rostrata*). Other large fishes that have been found more frequently in Barton Springs Pool include channel catfish, flathead catfish (*Pylodictus olivaris*), Rio Grande cichlid (*Cichlasoma cyanoguttatum*) and gray redhorse sucker (*Moxostoma congestum*). The most common species are centrarchids, including green sunfish (*Lepomis cyanellus*), spotted sunfish (*L. punctatus*), bluegill sunfish, redbreast sunfish, longear sunfish, largemouth bass, and Guadalupe bass. Smaller-bodied fishes include the central stoneroller, mosquito fish, greenthroat darter (*Etheostoma lepidum*), and the Texas log perch (*Percina carbonaria*).

3.3.4 Reptiles and Amphibians

A relatively high diversity of reptiles and amphibians is represented within the study area. According to Dixon (2013) there are at least 13 species of salamanders and newts, 25 species of frogs and toads, 13 species of turtles, 22 species of lizards and skinks, and 40 species of snakes that inhabit counties within the study area (See **Appendix F**, **Table F-1**).

3.3.5 Birds

A high diversity of avifauna represented by at least 418 species has been documented within the Edwards Plateau Ecological Region (TPWD 2001). Among these species, those that are abundant or fairly common within the study area are listed in **Appendix F**, **Table F-2**.

3.3.6 Mammals

A total of 62 species of mammals have been documented to occur within those counties occurring within the study area (Schmidly 2004). These species are listed in **Appendix F, Table F-3**.

3.3.7 Threatened and Endangered Species and other Species of Greatest Conservation Need

3.3.7.1 Federal and State-listed Species

Federal – U.S. Fish and Wildlife Service Regulatory Oversight

The Service has regulatory authority to list and monitor the status of species listed as threatened or endangered. This authority issues from the Endangered Species Act (ESA) of 1973, and its subsequent amendments. Regulations supporting this act are codified and regularly updated in 50 CFR 17.11 and 17.12. Petitions for Federal protection of species receive an initial review, and if the Service finds that listing may be warranted, then the species will undergo a thorough status review. After the status review is complete, vulnerable species that qualify for listing are either listed as threatened (T) or endangered (E).

State – Texas Parks and Wildlife Department Regulatory Oversight

The Texas Parks & Wildlife Department (TPWD) oversees endangered resources through the Wildlife Division's Wildlife Diversity Program. This program is responsible for maintaining county occurrence records of state and federal endangered and threatened species and also maintains a Natural Diversity Database (NDD) that provides specific site information and other species status tracking information on listed or rare animal and plant species, including unique or declining vegetation communities of concern. State-listed endangered species have limited regulatory protection. While these species cannot be taken, collected, held, or possessed without a permit, their habitat is afforded no regulatory protection, except on tracts managed by state, federal, or private interests for conservation purposes.

Table 3-3 summarizes federally and state-listed endangered and threatened species as well as Federal candidate species for listing according to potential occurrence within the study area. The Service's IPac Trusted Resources Report (2016b) was generated for species that could potentially occur within the study area (a countywide search was not conducted). Although a countywide list was generated by TPWD for state-listed species, only species that could potentially occur within the study area are included in **Table 3-3**. Additionally, species that are only considered for wind energy projects and species that have been considered extirpated are not included in **Table 3-3**.

Table 3-3. Federally and State-listed Endangered, Threatened, and Candidate Species of Potential Occurrence within the Study Area

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
VASCULAR PLANTS								
Bracted twistflower *Streptanthus bracteatus* FC	X	X			X			Shallow, well-drained gravelly clays and clay loams over limestone in oak juniper woodlands and associated openings, on steep to moderate slopes and in canyon bottoms; several known soils include Tarrant, Brackett, or Speck over Edwards, Glen Rose and Walnut geologic formations.
INSECTS								
Comal Springs dryopid beetle *Stygoparnus comalensis* FE, SE		X			X			Inhabits Fern Bank Springs near the southern boundary of the study area; usually clings to objects in the stream; sometimes found crawling on stream bottoms or along shores; adults may leave a stream and fly about, especially at nights; typically larvae are vermiform and live in soil or decaying wood.
Tooth Cave ground beetle *Rhadine persephone* FE	X							Resident, small, cave-adapted beetle found in small Edwards Limestone caves in Travis and Williamson Counties.
Kretschmarr Cave mold beetle *Texamaurops reddelli* FE	X							Small, cave-adapted beetle found under rocks buried in silt; small, Edwards Limestone caves of the Jollyville Plateau, a division of the Edwards Plateau.
ARACHNIDS								
Bee Creek Cave harvestman *Texella reddelli* FE	X							Confirmed within the study area; Small, lined, cave-adapted harvestman endemic to a few caves in Travis and Williamson Counties.
Bone Cave harvestman *Texella reyesi* FE	X							Small, blind, cave-adapted harvestman endemic to a few caves in Travis and Williamson Counties.
Tooth Cave pseudoscorpion *Tartarocreagris texana* FE	X							Small, cave-adapted pseudoscorpion known from small limestone caves of the Edwards Plateau.
Tooth Cave spider *Leptoneta myopica* FE	X							Very small, cave-adapted, sedentary spider
MOLLUSKS								
False Spike Mussel *Quadrula mitchelli* ST	X	X	X	X	X	X	X	While TPWD indicates potential occurrence in all counties, it is known from only two disjunct populations – one in the San Saba River (Randklev et al. 2013), and the other in the Guadalupe River near Gonzales, Gonzales County, Texas (Randklev et al. 2012); probably medium to large rivers; substrates varying from mud through mixtures of sand, gravel and cobble; one study indicated water lilies were present at the site.
Golden Orb *Quadrula aurea* FC, ST		X	X	X	X	X		While TPWD indicates potential occurrence, USFWS does not list this species as occurring in the study area; occurs in Guadalupe, San Antonio, and Nueces-Frio River Basins; sand and gravel in some locations and mud at others; intolerant of impoundments in most instances.

Table 3-3, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Texas Fatmucket *Lampsilis bracteata* FC, ST	X	X		X	X			Historically occurred in moderately flowing streams and rivers on sand, mud, and gravel substrates in the Colorado and Guadalupe basins of Central Texas. In the past 30 years, natural and human-induced stressors have lead to the dramatic decline of this species in both rivers. Remaining populations are at risk from scouring flood, dewatering, and poor land management; intolerant of impoundments.
Texas Fawnsfoot *Truncilla macrodon* FC, ST			X					While TPWD indicates potential occurrence, USFWS does not list this species as potentially occurring in the study area. Historically occurred in the Colorado and Brazos drainages of Central Texas. A recently discovered population in the Brazos River between Possum Kingdom and the mouth of the Navasota River represents the only known surviving population; intolerant of impoundments.
Texas Pimpleback *Quadrula petrina* FC, ST	X	X	X	X		X	X	Current distribution limited to the lower Concho River, upper San Saba River, and San Marcos River; mud, gravel and sand substrates, generally in areas with slow flow rates.
Smooth Pimpleback *Quadrula houstonenisis* FC, ST	X		X				X	While TPWD indicates potential occurrence, USFWS does not list this species as potentially occurring in the study area. Endemic mussel restricted to the Colorado and Brazos River drainages. Surveys conducted from 1980 to 2006 have noted steep declines in the number of extant populations in both river systems; tolerates very slow to moderate flow rates; appears not to tolerate dramatic water-level fluctuations, scoured bedrock substrates, or shifting sand bottoms.
FISHES								
Blue sucker *Cycleptus elongates* ST	X					X	X	In major rivers usually in channels and flowing pools with a moderate current,; bottom type usually of exposed bedrock, perhaps in combination with hard clay, sand, and gravel .
AMPHIBIANS								
Cascade Caverns salamander Eurycea latitans complex ST				X	X			A small, lungless salamander with external gills; endemic; subaquatic; springs and caves in Bexar, Comal, Kendall, and Kerr counties.
Austin blind salamander *Eurycea waterlooensis* FE	X							Mostly restricted to subterranean cavities of the Edwards Aquifer; dependent upon water flow/quality from the Barton springs segment of the Edwards Aquifer; only known from the outlets of Barton springs (Sunken Gardens (old Mill) Spring, Eliza Spring, and Parthenia (Main) Spring which forms Barton Springs Pool).
Blanco blind salamander *Eurycea robusta* ST		X						A small, lungless salamander with external gills inhabiting water-filled underground caverns in the San Marcos Pool of the Balcones (a part of the Edwards) Aquifer to the north and east of the Blanco River.
Barton Springs salamander *Eurycea sosorum* FE, SE	X	X						Dependent upon water flow/quality from the Barton Springs segment of the Edwards Aquifer; only known from the outlets of Barton springs; spring dweller, but ranges into subterranean water-filled caverns; found under rocks, in gravel, or among aquatic vascular plants and algae, as available.
Jollyville Plateau Salamander *Eurycea tonkawae* FT	X							The Jollyville Plateau salamander occurs in the Jollyville Plateau and Brushy Creek areas of the Edwards Plateau in Travis and Williamson Counties, Texas. Critical Habitat designated by the USFWS occurs within the study area.

Table 3-3, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Houston toad *Bufo Houstonensis* FE, SE							X	Endemic; sandy substrate , water in pools, ephemeral pools, stock tanks; breeds in spring especially after rains; burrows in soil of adjacent uplands when inactive; associated with soils of the Sparta, Carrizo, Goliad, Queen City, Recklaw, Weches, and Willis geological formations. Critical Habitat designated by the USFWS occurs within the study area.
REPTILES								
Texas horned lizard *Phrynosoma cornutum* ST	X	X	X	X	X	X	X	Open, arid and semi-arid regions with sparse vegetation, including grass, cactus, scattered brush or scrubby trees; soil may vary in texture from sandy to rocky; burrows in soil, enters rodent burrows, or hides under rock when inactive; breeds March-September.
Timber/Canebrake rattlesnake *Crotalus horridus* ST						X	X	Swamps, floodplains, upland pine and deciduous woodlands, riparian zones, abandoned farmland; limestone bluffs, sandy soil or black clay; prefers dense ground cover, e.g., grapevines or palmetto.
BIRDS								
American Peregrine Falcon *Falco peregrinus anatum* ST	X	X	X	X	X	X	X	Occupies a wide range of habitats during migration including urban, concentrations along the coast and barrier islands; low-altitude migrant, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.
Peregrine Falcon *Falco peregrines* ST	X	X	X	X	X	X	X	Migrate across the state from more northern breeding areas in the U.S. and Canada to winter along coast and farther south.
Bald Eagle Haliaeetus leucocephalus ST	X	X	X	X	X	X	X	Found primarily near rivers and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter; hunts live prey, scavenges, and pirates food from other birds.
Black-capped Vireo Vireo atricapilla FE, SE	X	X	X	X	X			Oak-juniper woodlands with distinctive patchy, two-layered aspect; shrub and tree layer with open, grassy spaces; requires foliage reaching to ground level for nesting cover; return to same territory, or one nearby, year after year; deciduous and broad-leaved shrubs and trees provide insects for feeding; species composition less important than presence of adequate broad-leaved shrubs, foliage to ground level, and required structure; nests mid-April to late summer.
Golden-cheeked Warbler Setophaga chrysoparia FE, SE	X	X	X	X	X			Juniper-oak woodlands; dependent on Ashe juniper for long fine bark strips, only available from mature trees, used in nest construction; nests placed in various trees other than Ashe juniper; only a few mature junipers or nearby cedar brakes can provide the necessary nest material; forage for insects in broad-leaved trees and shrubs; nests late March to early summer.
Whooping Crane Grus americana FE, SE	X	X	X	X	X	X	X	Potential migrant; breeds in the wetlands of Wood Buffalo National Park, Northwest Territory, Canada, and winters in the coastal wetlands of the Aransas National Wildlife Refuge in Aransas, Calhoun, and Refugio Counties, Texas; only remaining natural breeding population of this species .
Wood Stork Mycteria americana ST		X				X	X	Forages in prairie ponds, flooded pastures or fields, ditches, and other shallow standing water, including salt-water; usually roosts communally in tall snags, sometimes in association with other wading birds (active heronries); breeds in Mexico and birds move into Gulf States in search of mud flats and other wetlands, even those associated with forested areas; formerly nested in Texas, but no breeding records since 1960.

Table 3-3, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Zone-tailed Hawk Buteo albonotatus ST		X	X	X	X			Arid open country, including open deciduous or pine-oak woodland, mesa or mountain country, often near watercourses, and wooded canyons and tree-lined rivers; nests in various habitats and sites ranging from small trees in lower desert, giant cottonwoods in riparian areas, to mature conifers in mountain regions.

Note: For some species that are both federal and state-listed, the listing status and/or location occurrence may not be consistent between state and federal databases. Where this situation occurs, U.S. Fish and Wildlife Service information will take precedence.

U.S. Fish and Wildlife Service Listing Status
FE Endangered (in danger of extinction throughout all or a significant portion of its range)
FT Threatened (likely to become endangered within the foreseeable future)
FC Candidate, USFWS has substantial information on the biological vulnerability and threats to support a proposal for listing as threatened or endangered.

Texas Parks and Wildlife Department Listing Status
SE Listed as Endangered in the State of Texas
ST Listed as Threatened in the State of Texas

Sources:

U.S. Fish and Wildlife Service IPaC Trust Resource List Report. Search of Project Area. Generated May 10, 2016. IPaC version 3.0.*7* ***https://ecos.fws.gov/ipac/***

Texas Parks and Wildlife Department Annotated County Lists of Rare Species***: http://www.tpwd.state.tx.us/gis/ris/es/*** accessed May 10, 2016 for Travis County (Revised 2/10/16); Hays County (Revised 2/8/16); Blanco County (Revised 2/10/16); Kendall County (Revised 2/8/16); Comal County (Revised 2/8/16); Caldwell County (Revised 2/7/16); and Bastrop County (Revised 2/10/16).

A total of 20 species are federally listed as endangered, threatened or candidates for listing. This includes one plant [the bracted twistflower (*Streptanthus bracteatus*)]; three insects [the Tooth Cave ground beetle (*Rhadine Persephone*), Kretschmarr Cave mold beetle (*Texamaurops reddelli*), and Comal Springs dryopid beetle (*Stygoparnus comalensis*)]; four arachnids [the Bee Creek Cave harvestman (*Texella reddelli*), Bone Cave harvestman (*Texella reyesi*), Tooth Cave psudoscorpion (*Tartarocreagris texana*), and Tooth Cave spider (*Leptoneta myopica*); five mollusks that are candidates for listing [the golden orb (*Quadrula aurea*), Texas fawnsfoot (*Truncilla macrodon*), Texas Fatmucket (*Lampsilis bracteata*), amooth pimpleback (*Quadrula houstonenisis*), and Texas pimpleback (*Q.petrina*)]; four listed amphibians [the Barton Springs salamander , Jollyville Plateau salamander (*Eurycea tonkawae*), Austin blind salamander and Houston toad (*Bufo houstonensis*)]; and three listed birds [the black-capped vireo (*Vireo atricapilla*), golden-cheeked warbler (*Setophaga chrysoparia*), and whooping crane (*Grus americana*)].

The TPWD lists 11 species as threatened or endangered that are not federally listed as potentially occurring within the study area. This includes one mollusk, the false spike mussel (*Quadrula mitchelli*); one fish, the blue sucker (*Cycleputs elongates*); two amphibians, the Cascade Caverns salamander (*Eurycea latitans*) and Blanco blind salamander (*E. robusta*); two reptiles, the Texas horned lizard (*Phrynosoma cornutum*) and timber/canebrake rattlesnake (*Crotalus horridus*); and five birds, the American peregrine falcon (*Falco peregrinus anatum*), Peregrine peregrine falcon (*Falco peregrines*), bald eagle (*Haliaeetus leucocephalus*), wood stork (*Mycteria americana*), and zone-tailed hawk (*Buteo albonotatus*).

Among the federally and state-listed species, two salamanders are proposed for coverage under the ITP: the Barton Springs salamander, and Austin blind salamander. These two salamanders are syntopic, by occupying the same spring sites but inhabiting different depths of the aquifer (Hillis et al. 2001). The Barton Springs salamander occurs in the epigean (living at the "surface" of the Aquifer at the interface between subterranean and spring habitat) areas, while adult Austin blind salamanders occur predominately in deeper, subterranean areas (COA, unpublished data). These salamanders are more-fully described below.

3.3.7.2 Covered Species

The two endangered species to be covered by the ITP are the Barton Springs salamander and the Austin blind salamander. Both are endemic to the Edwards Aquifer and inhabit the Barton Springs complex, which comprises four discharge locations within 400 to 800 yards of one another along lower Barton Creek. Thus, these species are thought to have two of the smallest ranges of vertebrates in the United States. The Barton Springs salamander is an epigean (aquatic species that was listed as endangered on May 30, 1997 (62 FR 23377). No critical habitat has been designated by the Service for the Barton Springs salamander.

The Austin blind salamander is a primarily subterranean species that was listed as endangered on August 20, 2013 (78 FR 51278). Critical habitat was designated by final rule on August 20, 2013

(78 FR 51327) (see **Figure 3-14**). Details about the species' biology and life history can be found in the *Federal Register* listing notices as well as the City of Austin's *Major Amendment and Extension of the Habitat Conservation Plan for the Barton Springs Salamander and the Austin Blind Salamander to Allow for the Operation and Maintenance of Barton Springs and Adjacent Springs* (COA 2013a). Highlights are summarized below.

Both species are members of the family Plethodontidae (lungless salamanders). The two are generally morphologically and physiologically similar and solely inhabit the Barton Springs segment of the Edwards Aquifer. They are perennibranchiate ("always gilled"), solely aquatic (never metamorphose, meaning they become sexually mature in aquatic form), and long-lived invertebrate predators. Each species is typified by lack of lungs, three external gills on each side of the head, reduced, spindly limbs, and a dorsoventrally flattened fin on the tail. Primary respiration in both species is across their gills, although a substantial amount of gas exchange occurs through the skin as well (Boutilier et al. 1992).

Barton Springs' *Eurycea* live in a highly oxygenated, flowing water environment with a narrow temperature range of 68-71.6°F (20–22°C); captive salamanders show signs of stress when water temperature exceeds 81°F (27.2°C) (COA 2013a) and dissolved oxygen levels fall to approximately 5.0 mg/L (Woods et al. 2010).

Barton Springs Salamander (*Eurycea sosorum*)

The Barton Springs salamander (**Figure 3-11**) was first collected from Parthenia and Eliza Springs in 1946 (Brown 1950), Old Mill Spring in 1993 (Chippindale 1993), and Upper Barton Spring in 1997 (COA 1998). The salamander was formally described by Chippindale et al. (1993).

The species has well-developed, image forming eyes set in a rounded head with a slightly compressed snout and uses visual and bioelectric cues rather than olfaction to avoid predators (Gillespie 2011). These characteristics are consistent with surface-dwelling organisms inhabiting clear water. Newly hatched larvae are about 12 mm (0.5 inch) total length and may lack fully developed limbs or pigment (Chamberlain and O'Donnell 2003). Juveniles closely resemble adults and reach sexual maturity at approximately 43–50 mm (1.69-1.96 inches) total length or starting at about 11 months of age (COA 2013a). Adults reach total lengths greater than 50 mm (1.96 inches) (Gillespie 2011). The presence of melanophores (cells containing brown or black melanin pigments) and silvery white iridiophores in the skin gives individuals a mottled salt-and-pepper color pattern on the upper body surface. The ventral side (underside) of the body is cream-colored and often translucent so that some internal organs, and developing eggs in females, are readily visible. The tail is short relative to other aquatic *Eurycea*, with a well-developed dorsal (upper) fin and narrow ventral (lower) fin (Chippindale et al. 1993).

Figure 3-11
Barton Springs Salamander
Photo courtesy Dee Ann Chamberlain.

Gravid females, eggs, and larvae have been found throughout the year in the wild, suggesting year-round reproduction (USFWS 2016a). Also, because salamander larvae are found year-round but very few eggs (which are white and visible to the human eye) have been observed in the wild (Chamberlain and O'Donnell 2003), oviposition is believed to occur in the Aquifer. On average, a female Barton Springs salamander lays 15 eggs per clutch (COA 2013a). The ova are surrounded by several layers of a clear capsule that is permeable for gas exchange. The capsule protects the embryo and is sticky, which presumably allows the female to lay the eggs on rocks in flowing water. The eggs hatch in 3 to 4 weeks (COA 2013a). Longevity data are currently only available for captive Barton Springs salamanders. In 2010, a wild-caught female that was collected as an adult in 1996 died at a minimum age of 15 years. The oldest captive raised individual is a 15-year-old male that hatched in January 1997 (COA 2013a).

The vast majority of Barton Springs salamanders are found in interstitial spaces beneath rocks in flowing water (COA 2013a). Flowing water is where higher levels of dissolved oxygen are found compared to the undersaturated areas of the karst Aquifer. Flowing water favors growth of periphytic algae that supports benthic invertebrate communities (prey), and also prevents accumulation of sediment within the interstitial spaces. Those spaces provide protection from predators and habitat for prey. There is evidence that Barton Springs salamanders use subterranean habitats during at least some portions of their life history, though the full extent of such use is unknown (Chippindale et al. 2000). These salamanders have been observed following water when it recedes from Upper Barton Spring, and they have been found repeatedly in surface habitat of this spring in as little as a week after flow returns (COA 2013a). The lack of genetic divergence among populations inhabiting the different spring outlets suggests there is gene flow (Bendik 2006). Thus, abundance of Barton Springs salamanders in epigean habitat represents only the proportion of the population at the surface at that moment and is probably not indicative of total population size. This suggests that declines in surface abundance could represent either mortality and/or migration from epigean to subterranean habitat.

Known prey items of *E. sosorum* include ostracods, chironomids, copepods, mayfly larvae, amphipods, oligochaetes, planarians, adult riffle beetles, snails, and leeches (COA 2013a; Chamberlain and O'Donnell 2002; Chippindale et al. 1993; Gillespie 2011). Predators of *E. sosorum* include birds, fish, crayfish, aquatic invertebrates, and possibly other salamanders.

The Barton Springs salamander has been found in the four springs that make up the Barton Springs complex (see **Figure 3-8**), including the largest (Parthenia) spring in Barton Springs Pool, Eliza Spring, Old Mill Spring (also called Sunken Garden or Zenobia Spring), and Upper Barton Spring (COA 1998). The spring complex is located within Zilker Park, near downtown Austin. The COA has conducted monthly surveys since 1993 and has found that salamanders within Barton Springs Pool reside primarily near the outlets of Parthenia Spring and the fissures west of the diving board. They have been found sporadically along the north bank of the pool in flowing water just downstream of Parthenia Spring. Currently, these salamanders are found in all four springs (COA 2003a).

Overall abundance of the salamanders at each of the four individual spring outlets, Upper Barton Spring, Eliza Spring, Parthenia Spring, and Sunken Garden (Old Mill) Spring, from the years 2003 through 2013 as reported by the COA (2014) is shown on **Figure 3-12**.

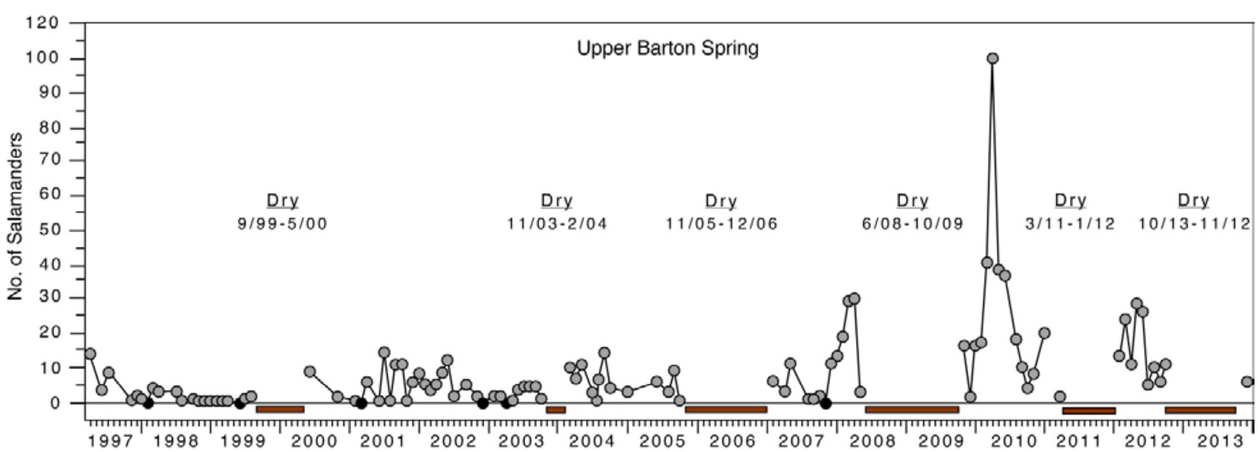


Figure 3-12. Abundance of Barton Springs Salamanders at Each Spring Site (Values from consecutive months are connected by lines) (COA 2014b)

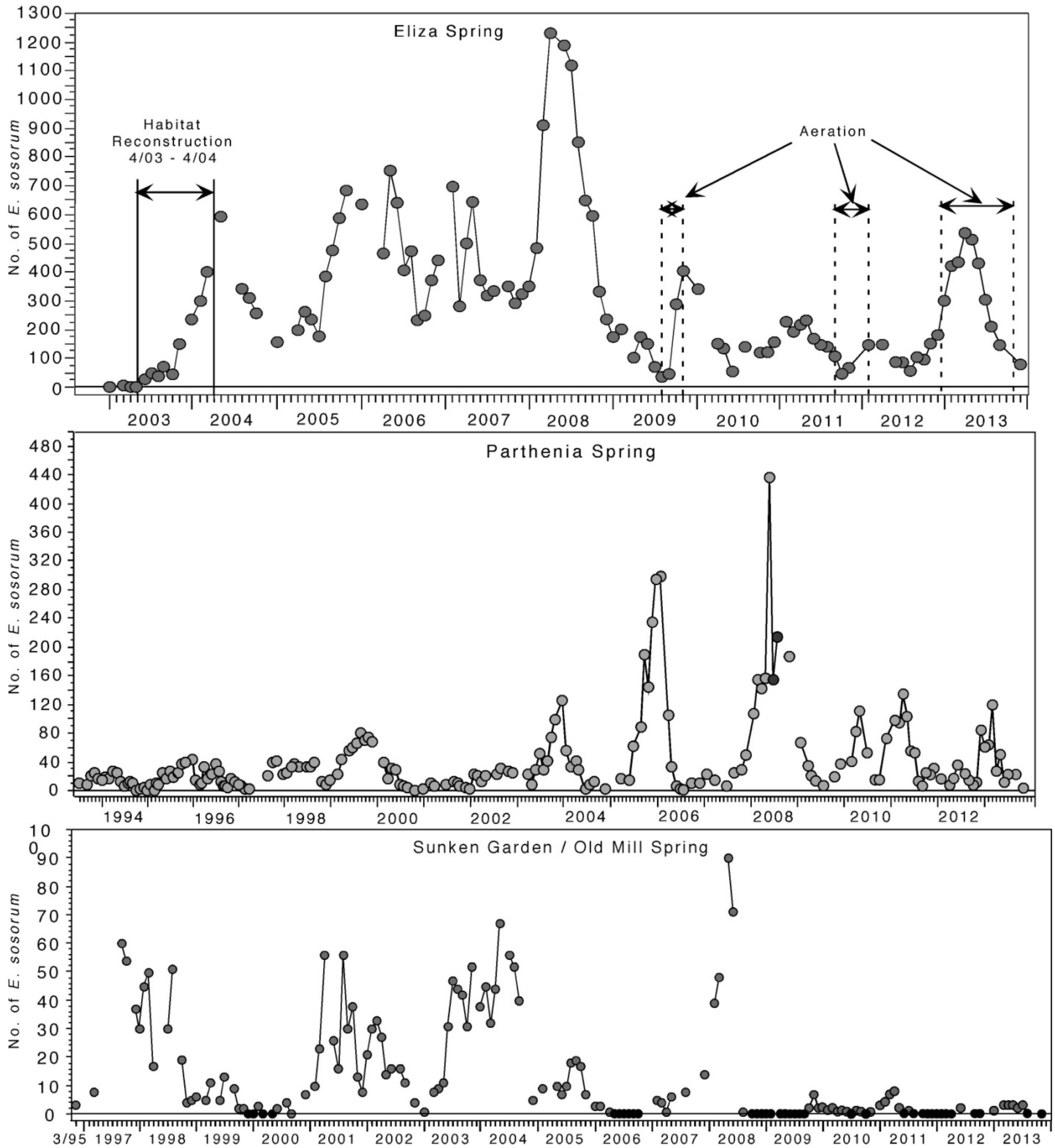


Figure 3-12, cont'd

Barton Springs salamanders are found in the highest abundance and highest density in Eliza Spring (COA 2013a). Anecdotal evidence suggests that Eliza Spring had an abundant population of Barton Springs salamanders in the 1970s (Reddell 1963, referenced in Chippindale et al. 1993); however, surveys between 1997 and 2003 showed a steady decrease of approximately 81percent from an average of 23.6 individuals to 4.5 individuals (COA 2003a). Habitat restoration at Eliza Spring in 2003 dramatically altered these numbers with an average of 191 individuals counted during the years 1995–2011 (COA 2013a).

The second highest abundance of Barton Springs salamanders is in the main (Parthenia) spring. These salamanders are primarily found around spring openings and fissures; they are rarely found in areas of little flow and excess sediment accumulation, such as the deep areas of the pool downstream of the spring openings or the shallow end upstream of the fissures. An average of 45 salamanders per year were counted between 1993 and 2011 (COA 2013a). Salamanders are least abundant at Old Mill Spring and Upper Barton Spring. An average of 15 salamanders were counted per year between 1998 and 2011 at Old Mill Spring, while an average of 8 salamanders were counted at Upper Barton Creek during the years 1997–2011 (COA 2013a). Because Upper Barton Creek Spring stops flowing when the collective flow of the Barton Springs complex is lower than approximately 40 cfs, no aquatic *Eurycea* salamanders are present. However, these salamanders reappear when springflow returns. Juveniles have been found in all spring sites, indicating reproduction occurs in all sites (COA 2013a).

Austin Blind Salamander (*Eurycea waterlooensis*)

The Austin blind salamander (**Figure 3-13**) was described by Hillis et al. (2001) and is more closely related to the Texas blind salamander (*Eurycea rathbuni*), found in the southern portion of the Edwards Aquifer in San Marcos, Texas, than it is to the Barton Springs salamander.

The Austin blind salamander is a predominately subterranean species; it is rarely found in surface habitat. Its head is slightly enlarged with a compressed shovel-like snout and its eyes are reduced to spots beneath the skin without image-forming lenses. Such sensory characteristics are suggestive of subterranean life where absence of light renders prey or predator detection by vision impossible (Hillis et al. 2001). The tailfin of this species is not well developed; the dorsal portion is weakly developed or absent, and the ventral portion is only present on the posterior part of the tail. The largest Austin blind salamander captured at Barton Springs was 66 mm (2.6inches) in total length, but captive individuals have reached lengths up to 81 mm (3.2 inches) (Hillis et al. 2001). The coloration of the Austin blind salamander is pearl with iridiophores found along the body and tail. Melanophores are uniformly distributed on the dorsal side of Austin blind salamanders resulting in almost no visible mottling on the dorsal part of the body. Like the Barton Springs salamander, the light body color of the Austin blind salamander allows internal organs to be easily seen.

Figure 3-13
Austin Blind Salamander
Photo courtesy David M. Hillis.

Due to its recent discovery and the difficulty surveying subterranean populations, very little is known of this salamander's biology and life history. Hillis et al. (2001) reported that individuals appear to feed on small aquatic invertebrates, specifically blind amphipods and isopods, but when they are at the surface of the springs will also consume other small invertebrates. Predators are unknown. Austin blind salamanders become sexually mature at about 18 to 23 months (COA 2013a). On average, females lay 16 eggs per clutch, and like the Barton Springs salamander, it is hypothesized that they lay their eggs in the Aquifer below the surface because only a few eggs have ever been found in the wild (COA 2013a). The ova demonstrate the same characteristics of being a clear, sticky capsule that is permeable for gas exchange and protects the embryo. They also hatch in 3 to 4 weeks. As part of its captive breeding program, the COA (2003b) has observed that juveniles collected in the wild "generally grow rapidly for about 8 months (until they reach a total length of about 2.4 inches or 60 mm), after which growth slows to about 1 mm per month." A wild-caught Austin blind salamander in captivity reproduced to an age of at least 12 years. The oldest Austin blind salamander in captivity was collected from the wild in 1998 and lived 13 years.

As noted above, in 2013 the Service designated critical surface and subsurface habitat components for this species that includes 120 acres in one unit that coincides with city-owned and private land in the City of Austin, Travis County, Texas (78 FR 51328) (**Figure 3-14**). This unit contains Parthenia Spring, Sunken Gardens (Old Mill) Spring, Eliza

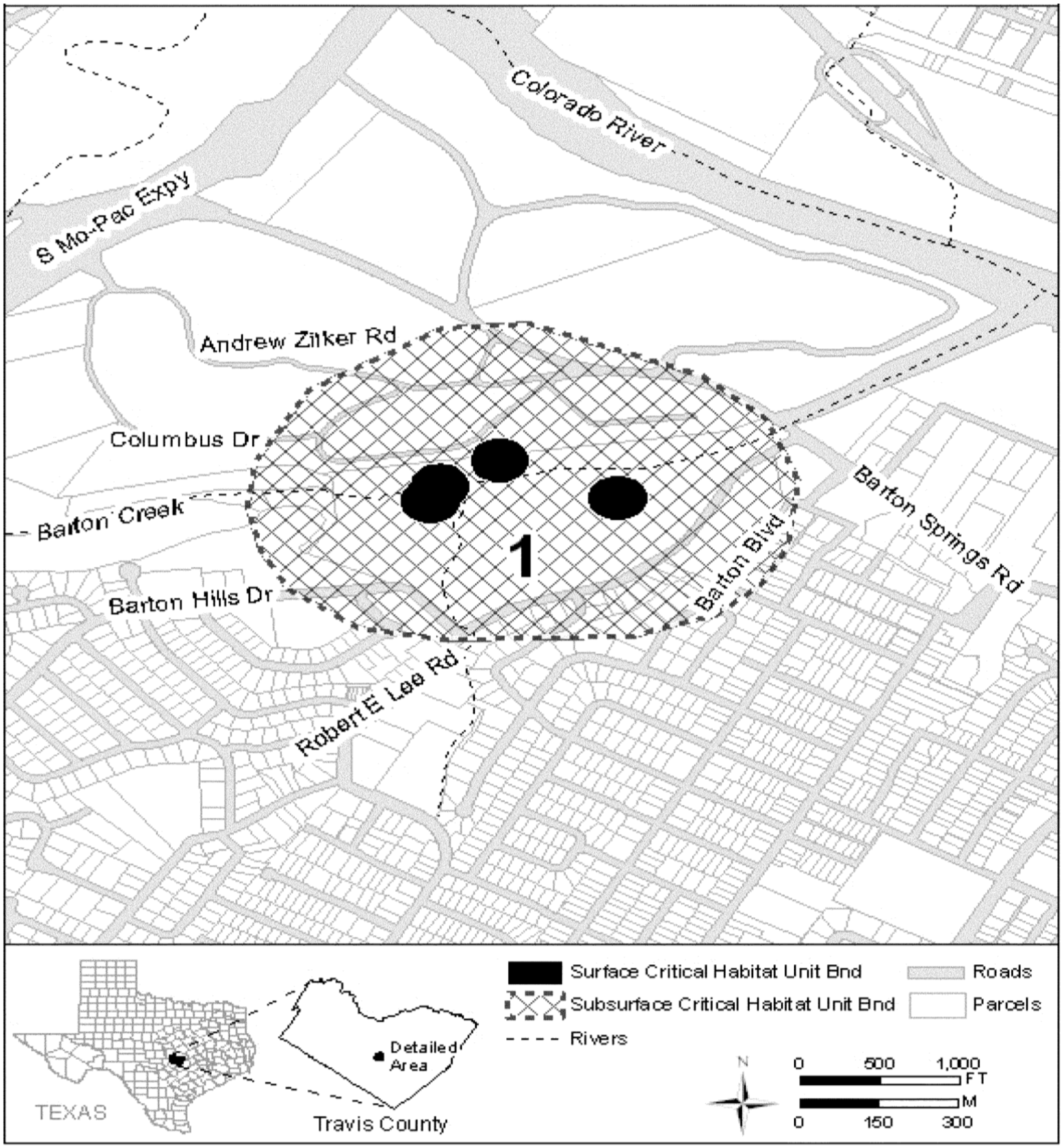


Figure 3-14. Critical Habitat for the Austin Blind Salamander (78 FR 51327–51379)

Spring, and Upper Barton Spring. Austin blind salamanders have been collected regularly from the three perennial springs, Parthenia, Old Mill, and Eliza. However, it has not been regularly observed in the intermittent Upper Barton Spring. It is thought that occurrence of this species in surface habitat is "accidental" (Hillis et al. 2001), possibly related to surges in groundwater flow that may flush them out of sub-surface habitat. At the surface, they have been found in the highest numbers in Old Mill Spring and sporadically in low numbers in Barton Springs Pool and Eliza Spring, but they are likely found in the greatest number in the subterranean areas of Barton Springs (Hillis et al. 2001). Most of the observations of this species have been of the more mobile juveniles. Substantially fewer Austin blind salamanders than Barton Springs salamanders have been observed by COA biologists during regular surveys.

Threats to the Barton Springs Salamander and Austin Blind Salamander

The Service identified several threats that led to the listing of the Barton Springs salamander (62 FR 23377) and the Austin blind salamander (78 FR 51278). These include 1) degradation of the quality and quantity of water that feeds Barton Springs as a result of urban expansion and associated activities in the contributing and recharge zone, 2) direct destruction or modification of the salamanders' habitat, 3) inadequacy of existing regulatory mechanisms to protect the Barton Springs watershed from increasing threats to water quality and quantity degradation, and 4) the salamanders' extreme vulnerability to stochastic events due to their restricted ranges. More than anything, sufficient and reliable springflow of high quality within a narrow range of conditions (e.g., temperature and pH) is critical to meeting the life history requirements for survival, growth, and reproduction of these two species.

Detailed information on the range of threats, based on extensive literature reviews, is contained within the two *Federal Register* final listing rules for the two species and is not repeated here in its entirety. However, a summary is provided below of key factors from 78 FR 51278 and references therein (except where other references are noted) that bear on the evaluation of the proposed alternatives in this dEIS.

Water Quality Conditions

Water quality conditions in the four springs that make up the Barton Springs complex are influenced by both groundwater and surface water. Groundwater recharge occurs through seven stream systems (Barton Creek, Williamson Creek, Slaughter Creek, Little Bear Creek, Bear Creek, Onion Creek, and the Blanco River). Surface water from Barton Creek periodically enters the surface habitat of Upper Barton Spring. This spring lies directly in the Barton Creek floodplain and is subject to high flow of surface water in Barton Creek itself. The principal threats to water quality in the Aquifer are changes in land use that degrade the quality of stormwater runoff and the release of contaminants in the recharge areas of these watersheds that potentially can be transported to Barton Springs.

The main water quality constituents influencing the two salamanders are thought to be dissolved oxygen, temperature, conductivity, salinity, and sediment. Information concerning how water quality changes have affected the salamanders or their habitat is incomplete. Dissolved oxygen appears to be critical for development of eggs, young, and adults; predator avoidance; feeding; reproduction; and basic survival processes in amphibians. Optimal respiration in these salamanders requires oxygenated water moving across their gills and bodies. Oxygenation of salamander eggs is critical to embryonic development since gas exchange and waste elimination occur through semi-permeable membranes surrounding the embryo. In a study of three *Eurycea* species, metabolic rates and oxygen consumption were highest in juveniles and decreased with increasing body size. There are some indications in survey data collected by the COA that the abundance of salamanders at Barton Springs has been influenced by variation in dissolved oxygen.

To support its HCP, the BSEACD funded research on a closely related salamander species, the San Marcos salamander (*E. nana*), as a surrogate for the Barton Springs salamander. The genetics and life history of the San Marcos salamander are similar to those of the Barton Springs salamander (Chippindale et al. 2000). Moreover, in their experiments, Woods et al. (2010) demonstrated that the San Marcos and Barton Springs salamanders show similar metabolic responses to a range of DO concentrations. Neither species habituates to low DO by reducing metabolic rate; metabolic rates increase until salamanders are approaching death.

Additional experiments performed by Woods et al. (2010) determined adult mortality and juvenile growth responses to DO. The testing procedure generated 28-day mortality estimates and also described sub-lethal effects such as metabolic rate variation, growth rate, and behavioral response to various treatment levels under controlled laboratory conditions. In the 28-day adult stressor-response study, groups of salamanders were progressively exposed to several levels of DO exposure: 1.3, 2.4, 3.6, 4.6, and 7.5 mg/L. Some salamander mortality occurred within 28 days in all three of the lowest three treatments (1.3, 2.4, and 3.6 mg/L), and there was 100 percent mortality within 48 hours of the two lowest treatments; no DO related mortalities were observed in either of the two highest treatments (4.6 and 7.5 mg/L). Lethal concentration (LC) values of DO were computed:

LC_5	4.5 $\pm$0.5 mg/L
LC_{10}	4.2 $\pm$0.3 mg/L
LC_{25}	3.7 $\pm$0.1 mg/L
LC_{50}	3.4 $\pm$0.2 mg/L

These values represent levels of DO that would be expected to cause mortality of 5, 10, 25, and 50 percent of adult San Marcos salamanders if exposed continuously to that level over a 28-day period. It should be noted that while no mortality was observed above 4.5 mg/L, termed the No Observed Adverse Effect Level (NOAEL), all San Marcos salamanders did exhibit a clear onset of activity as DO dropped below 5.5 mg/L. Falling DO might trigger salamanders to seek out areas of higher DO. In the Barton Springs complex, counts of the Barton Springs salamander decline when DO falls below 5.0 mg/L and reproduction decreases (Turner 2004).

Woods et al. (2010) also conducted a 60-day study on juvenile San Marcos salamanders, exposing individuals to various DO concentrations. Chronic 60-day exposure to 4.44 mg/L DO compromised growth of juvenile San Marcos salamanders.

The DO water quality criterion of 5.0 mg/L set by TCEQ for the Barton Springs Pool samples coincides with the upper limit of the LC_5 calculated by Woods et al. (2010) and is similar to that recommended previously by the Service to be protective of federally listed salamanders.

Conductivity is a measure of the ability of water to carry an electrical current and can be used to approximate the concentration of dissolved inorganic solids in water that can alter the internal water balance in aquatic organisms that may affect their survival. Conductivity levels in the Edwards Aquifer are naturally low, ranging from approximately 550 to 700 µS/cm. Rainfall serves to dilute ions and lower conductivity while drought has the opposite effect. As ion concentrations such as chlorides, sodium, sulfates, and nitrates rise, conductivity will increase. High conductivity has been associated with detrimental effects on aquatic salamanders (USFWS 2016a).

Specific conductivity levels have been periodically measured above 1,000 µS/cm at Barton Springs. Tests on effects of elevated conductivity on a closely related salamander, the San Marcos salamander, resulted in 100 percent mortality within 24 hours under non-aerated conditions with a conductivity of 1,145 µS/cm and a dissolved oxygen level of 6.8 to 7.6 mg/L (USFWS 2016a). However, another study on the San Marcos salamander did not show any substantial metabolic response to conductivity levels between 600 and 3,000 µS/cm when confined in tanks with DO levels at 6 mg/L (Woods et al. 2010).

As groundwater levels decline, there is evidence of encroachment of water with higher salinity that is typically maintained deeper in the Aquifer but moves upward when the freshwater above it is depleted. Saline water encroachment can be detrimental to freshwater amphibians. In a study using saline well water taken from the "bad water" zone, San Marcos salamanders were found to sustain 100 percent mortality within 24 hours in well water that had a conductivity of 1145 µS/cm and a dissolved oxygen level of 6.8 to 7.6 mg/l (Edwards Aquifer Research and Data Center as reported in City of Austin [2001]) (USFWS 2016a). In comparison, maximum conductivity levels have been measured periodically above 1000 µS/cm at Barton Springs (COA 1997) (USFWS 2016a).

Average temperature at the four spring outlets is about 70°F (21°C) (COA 2013a). There is some seasonal variability reflecting the temperature of recharging rainfall. For example, when recharge events occur in winter, water temperature may drop as low as 65.5°F (18.6°C) and remain below the long-term average for several months (Gillespie 2011). During drought, water temperature increases, which depresses DO concentrations since they are inversely related to water temperature.

Water Quantity

In general, salamander abundance varies with discharge. The higher the total discharge from the Barton Springs complex, the greater the number of salamanders and the greater the amount of reproduction and recruitment (COA 2013a; Gillespie 2011). The timing of increases in abundance of juveniles and adults indicates that the majority of reproduction and recruitment occurs during non-drought periods (COA 2013a).

Springflow declines are considered threats to both salamanders because drying of spring habitats reduces overall habitat availability and can cause salamanders to be stranded, resulting in death of individuals. The salamanders may be able to persist through temporary surface habitat degradation because of their ability to retreat to subsurface habitat. Drought conditions are common to the region, and the ability to retreat underground may be an evolutionary adaptation to such natural conditions. However, although salamanders may survive a drought by retreating underground, this does not necessarily mean they are resilient to long-term drought conditions (particularly because sites may already be affected by other, significant stressors, such as water quality declines). Drought may also adversely affect surface habitats that are important to prey populations. Prey availability for carnivores, such as these salamanders, is low underground due to the lack of sunlight and primary production. Drought reduces dissolved oxygen levels and increases temperature in Barton Springs. Barton Springs salamander counts decline with decreasing discharge.

The long-term average flow at the Barton Springs outlets is approximately 53 cfs. The lowest short-term flow measured at Barton Springs was 9.6 cfs on March 29, 1956 (USGS 1957) under drought of record conditions. Although both salamanders survived this period, pumpage during the 1950s was estimated at 0.66 cfs (Brune and Duffin 1983). With current authorized groundwater production in the Barton Springs segment during a DOR at 4.7 cfs (BSEACD 2017), discharge from the springs would be correspondingly lower during a repeat of similar drought, and pumping accelerates the rate at which groundwater levels decline in the Aquifer. As recently as November 2011, flows at Barton Springs dropped below 17 cfs and no Austin blind salamanders were observed during surveys at any of their three known locations during this time. There were also substantial decreases in the abundance of Barton Springs salamanders of all size classes at all sites (COA 2013a).

Low flows also result in changes in physico-chemical conditions such as dissolved oxygen, conductivity, and siltation that may reduce habitat suitability for the species. Reduced flows may exacerbate the degradation of water quality that appears to be associated with urbanization including reduced dissolved oxygen concentration and increased conductivity. In general, these conditions may lead to reduced habitat suitability for the salamanders. A reduction in surface habitat suitability for Barton Springs salamanders associated with lower flows and reduced water quality conditions may also result in movement of the species deeper into the Aquifer and result in an overlap in habitat occupation (and increased competitive interaction) between the Barton Springs and Austin blind salamanders. Competition for food and space along with other un-known biological interactions may negatively affect one or both species.

The COA has documented long-term increases in water temperature (Herrington and Hiers 2010) while other investigators have measured increases in turbidity caused by suspended solids during storm-flow conditions (Mahler et al. 2006). Lower flows occurring during drought may result in a reduced capability of sediments to be forced out of spring openings and may be a concern for both salamanders. Unobstructed interstitial space is a critical habitat component for the salamanders because it provides cover from predators and habitat for their macroinvertebrate prey items. When the interstitial spaces become compacted or filled with fine sediment, the amount of available foraging habitat and protective cover for salamanders is reduced. Accumulation of sediment may also be associated with increased concentrations of pollutants in the Aquifer.

3.3.7.3 Other Species of Greatest Conservation Need

The TPWD has compiled information on species of greatest conservation need (SGCN). These are species for which there are not enough data to support listing but which have been identified as species considered rare or in decline, that require specialized habitat requirements, or are experiencing widespread habitat alterations. TPWD lists 83 SGCN that occur or potentially occur within counties represented in the study area. This group includes 42 plants, 1 mussel, 10 crustaceans, 2 spiders, 10 insects, 3 fish, 5 amphibians, 2 reptiles, 4 birds, and 4 mammals. **Table 3-4** below lists these species, and counties of potential occurrence within the study area. A brief habitat description for each species is also provided.

Table 3-4. Species of Greatest Conservation Need Potentially Occurring in Counties Represented in the Study Area[1]

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
VASCULAR PLANTS								
Basin bellflower *Campanula reverchonii*	X			X				Texas endemic; among scattered vegetation on loose gravel, gravelly sand, and rock outcrops on open slopes with exposures of igneous and metamorphic rocks; may also occur on sandbars and other alluvial deposits along major rivers; flowering May-July.
Boerne bean *Phaseolus texensis*	X			X				Narrowly endemic to rocky canyons in eastern and southern Edwards Plateau occurring on limestone soils in mixed woodlands, on limestone cliffs and outcrops, frequently along creeks.
Granite spiderwort *Tradescantia pedicellata*			X					Texas endemic; mostly in fractures on outcrops of granite, gneiss, and similar igneous and metamorphic rocks, or in early successional grasslands for forb-dominated assemblages on well-drained, sandy to gravelly soils derived from same; flowers at least April-May.
Llano butterweed *Packera texensis*			X					Endemic to Llano Uplift of Edwards Plateau; granite sands; arises quickly from evergreen winter rosettes during January rains; flowers Feb-Mar.
Green beebalm *Monarda viridissima*						X	X	Endemic perennial herb of the Carrizo Sands; deep, well-drained sandy soils in openings of post oak woodlands; flowers white.
Shinner's sunflower *Helianthus occidentalis* ssp. *plantagineus*						X	X	Mostly in prairies on the Coastal Plain, with several slightly disjunct populations in the Pineywoods and South Texas Brush Country.
Hill Country wild-mercury *Argythamnia aphoroides*		X	X	X	X			Texas endemic; mostly in bluestem-grama grasslands associated with plateau live oak woodlands on shallow to moderately deep clays and clay loams over limestone on rolling uplands, also in partial shade of oak-juniper woodlands in gravelly soils on rocky limestone slopes; flowering April-May with fruit persisting until midsummer.
Correll's false dragon-head *Physostegia correllii*	X							Wet, silty clay loams on streamsides, in creek beds, irrigation channels and roadside drainage ditches; or seepy, mucky, sometimes gravelly soils along riverbanks or small islands in the Rio Grande; or underlain by Austin Chalk limestone along gently flowing spring-fed creek in central Texas; flowering May-September.
Texabama croton *Croton alabamensis* var. *texensis*	X							Texas endemic; in duff-covered loamy clay soils on rocky slopes in forested, mesic limestone canyons; locally abundant on deeper soils on small terraces in canyon bottoms, often dominating the shrub layer; scattered individuals are occasionally on sunny margins of such forests; also found in contrasting habitat of deep, friable soils of limestone uplands, mostly in the shade of evergreen woodland mottes; flowering late February-March; fruit maturing and dehiscing by early June.
Warnock's coral-root *Hexalectris warnockii*	X	X						In leaf litter and humus in oak-juniper woodlands on shaded slopes and intermittent, rocky creekbeds in canyons; in the Trans Pecos in oak-pinyon-juniper woodlands in higher mesic canyons (to 2000 m [6550ft]), primarily on igneous substrates; and the Edwards Plateau in oak-juniper woodlands on limestone slopes; flowering June-September; individual plants do not usually bloom in successive years.
Comal snakewood *Colubrina stricta*					X			In El Paso County, found in a patch of thorny shrubs in colluvial deposits and sandy soils at the base of an igneous rock outcrop; the historic Comal County record does not describe the habitat; in Mexico found in shrublands on calcareous, gravelly, clay soils with woody associates; flowering late spring or early summer.

Table 3-4, cont'd

	Travis	**Hays**	**Blanco**	**Kendall**	**Comal**	**Caldwell**	**Bastrop**	**Habitat Description**
Big red sage *Salvia pentstemonoides*				X				Texas endemic; moist to seasonally wet, steep limestone outcrops on seeps within canyons or along creek banks; occasionally on clayey to silty soils of creek banks and terraces, in partial shade to full sun; basal leaves conspicuous for much of the year; flowering June-October.
Sandhill woollywhite *Hymenopappus carrizoanus*						X	X	Texas endemic; disturbed or open areas in grasslands and post oak woodlands on deep sands derived from the Carrizo Sand and similar Eocene formations; flowering April-June.
Arrowleaf milkvine *Matelea sagittifolia*	X							Most consistently encountered in thornscrub in South Texas; perennial, Flowering March through July and Fruiting April through July and possibly in December.
Buckley tridens *Tridens buckleyanus*	X	X	X	X	X			Occurs in juniper-oak woodlands on rocky limestone slopes; perennial, flowering and fruiting April through November.
Darkstem noseburn *Tragia nigricans*				X	X			Occurs in oak-juniper woodlands on mesic limestone slopes and canyon bottoms; perennial, flowering and fruiting April through October.
Hairy sycamore-leaf snowbell *Styrax platanifolius var. stellatus*				X				Habitat similar to those of *S. var. plantanifolius,* usually in oak-juniper woodlands on steep rocky banks and ledges along intermittent or perennial streams, rarely far from some reliable source of moisture; perennially, flowering April to October and fruiting May to September.
Glass Mountains coral-root *Hexalectris nitida*	X	X	X		X			Apparently rare in mixed woodlands in canyons in the mountains of the Brewster County, but encountered with regularity, albeit in small numbers, under *Juniperus ashei* in woodlands over limestone on the Edwards Plateau, Callahan Divide and Lampasas Cutplain; perennial, flowering June through September and fruiting July through September.
Gravelbar brickellbush *Brickellia dentata*	X	X	X		X			Essentially restricted to frequently-scoured gravelly alluvial beds in creek and river bottoms; Perennial; flowering June through November and Fruiting June through October.
Hall's prairie clover *Dalea hallii*		X		X				In grasslands on eroded limestone or chalk and in oak scrub on rocky hillsides. Perennial, flowering May to September and fruiting June to September.
Heller's marbleseed *Onosmodium helleri*	X	X	X	X	X			Occurs in loamy calcareous soils in oak-juniper woodlands on rocky limestone slopes, often in more mesic portions of canyons; Perennial; flowering March through May.
Low spurge *Euphorbia peplidion*	X							Occurs in a variety of vernally-moist situations in a number of natural regions; Annual; flowering February through April and Fruiting March through April.
Narrowleaf brickellbush *Brickellia eupatoriodes var. gracillima*	X	X	X		X			Moist to dry gravelly alluvial soils along riverbanks but also on limestone slopes; Perennial; flowering and fruiting April through November.
Net-leaf bundleflowe *Desmanthus reticulatus*	X	X			X			Mostly on clay prairies of the coastal plain of central and south Texas; Perennial; flowering April through July and fruiting April through October.
Osage Plains false foxglove *Agalinis densiflora*		X	X		X			Most records are from grasslands on shallow, gravelly, well drained, calcareous soils; prairies, dry limestone soils; annual, flowering August to October.

Table 3-4, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Plateau loosestrife *Lythrum ovalifolium*	X	X	X		X			Banks and gravelly beds of perennial (or strong intermittent) streams on the Edwards Plateau, Llano Uplift and Lampasas Cutplain; Perennial; flowering and fruiting April through November.
Plateau milkvine *Matelea edwardsensis*	X	X	X	X	X			Occurs in various types of juniper-oak and oak-juniper woodlands; Perennial; flowering March through October and fruiting May through June.
Rock grape *Vitis rupestris*	X							Occurs on rocky limestone slopes and in streambeds; Perennial; flowering March through May and fruiting May through July.
Scarlet leather-flower *Clematis texensis*	X	X	X	X	X			Usually in oak-juniper woodlands in mesic rocky limestone canyons or along perennial streams; Perennial; Flowering March through July and fruiting May through July.
Stanfield's beebalm *Monarda punctata var. stanfieldii*	X		X					Largely confined to granite sands along the middle course of the Colorado River and its tributaries; perennial.
Spreading leastdaisy *Chaetopappa effusa*				X				Limestone cliffs, ledges, bluffs, steep hillsides, sometimes in seepy areas, oak-juniper, oak, or mixed deciduous woods, 300 to 500 meters in elevation; perennial, flowering July to October and potentially flowering starting in May.
Sycamore-leaf snowbell *Styrax platanifolius ssp. platanifolius*	X	X	X	X	X	X		Rare throughout range, usually in oak-juniper woodlands on steep rocky banks and ledges along intermittent or perennial streams, rarely far from some reliable source of moisture; Perennial; flowering April through May and fruiting May through August.
Texas milk vetch *Astragalus reflexus*	X							Grasslands, prairies, and roadside on calcareous and clay substrates; annual, flowering February through June and fruiting April through June.
Texas almond *Prunus minutiflora*	X		X		X			Wide-ranging but scarce, in a variety of grassland and shrubland situations, mostly on calcareous soils underlain by limestone but occasionally in sandier neutral soils underlain by granite; Perennial; flowering February through May and fruiting February through September.
Texas amorpha *Amorpha roemeriana*	X	X		X	X			Juniper-oak woodlands or shrublands on rocky limestone slopes, sometimes on dry shelves above creeks; Perennial; flowering May through June and fruiting June through October.
Texas barberry *Berberis swaseyi*	X	X	X		X			Shallow calcareous stony clay of upland grasslands/shrublands over limestone as well as in loamier soils in openly wooded canyons and on creek terraces; Perennial; flowering and fruiting March through June.
Texas fescue *Festuca versuta*	X	X	X	X	X		X	Occurs in mesic woodlands on limestone-derived soils on stream terraces and canyon slopes; Perennial; flowering and fruiting April through June.
Texas peachbush *Prunus texana*							X	Occurs at scattered sites in various well drained sandy situations; deep sand, plains and sand hills, grasslands, oak woods, 0 to 200 meters in elevation; perennial, flowering February to March and fruiting April to June.
Texas seymeria *Seymeria texana*	X	X		X	X			Found primarily in grassy openings in juniper-oak woodlands on dry rocky slopes but sometimes on rock outcrops in shaded canyons; Annual; flowering May through November and fruiting July through November.

Table 3-4, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Tree dodder *Cuscuta exaltata*	X	X		X	X			Parasitic on various Quercus, Juglans, Rhus, Vitis, Ulmus, and Diospyros species as well as Acacia berlandieri and other woody plants; Annual; flowering May through October and fruiting July through October.
Texas sandmint *Rhododon ciliatus*						X	X	Open sandy areas in the Post Oak Belt of east-central Texas; annually, flowering April through August and fruiting May to August.
Texas tauschia *Tauschia texana*						X		Occurs in loamy soils in deciduous forests or woodlands on river and stream terraces; perennial, flowering and fruiting February to April.
MOLLUSKS								
Horseshoe liptooth snail *Daedalochila hippocrepis*					X			Terrestrial snail known only from the steep, wooded hillsides of Landa Park in New Braunfels.
CRUSTACEANS								
An amphipod *Stygobromus russelli*	X							Subterranean waters, usually in caves and limestone aquifers; resident of numerous caves in about 10 counties of the Edwards Plateau.
Long-legged cave amphipod *Stygobromus longipes*				X	X			Subaquatic crustacean; subterranean obligate; found in subterranean streams.
A cave obligate crustacean *Monodella texana*		X						Subaquatic, subterranean obligate; underground freshwater aquifers.
Balcones Cave amphipod *Stygobromus balconis*	X	X						Subaquatic, subterranean obligate amphipod.
Bifurcated cave amphipod *Stygobromus bifurcaus*	X							Found in pools within caves.
Ezell's cave amphipod *Stygobromus flagellatus*		X			X			Known only from artesian wells.
Cascade Cave amphipod *Stygobromus dejectus*				X				Found in pools within caves.
Texas cave shrimp *Palaemonetes antrorum*		X						Subterranean sluggish streams and pools.
Texas troglobitic water slater *Lirceolus smithii*		X						Subaquatic, subterranean obligate, aquifer.
A crayfish *Procambarus texanus*							X	Ponds, lakes, wetlands, and streams.
ARACHNIDS								
Bandit Cave spider *Cicurina bandida*	X	X						A very small, subterrestrial, subterranean obligate.
Warton's cave meshweaver *Cicurina wartoni*	X							Very small, cave-adapted spider.
INSECTS								

Table 3-4, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
A mayfly *Baetodes alleni*				X				Larval stage is aquatic, may be found in shoreline vegetation.
A mayfly *Allenhyphes michaeli*			X	X				Larval stage is aquatic, may be found in shoreline vegetation.
A mayfly *Pseudocentroptiloides morihari*					X			Distinguished by aquatic larval stage; adult stage generally found in shoreline vegetation.
Disjunct crawling water beetle *Haliplus nitens*			X					Habitat components unknown, possibly shallow water.
Tooth Cave blind rove beetle *Cylindropsis* sp. 1	X							Only one specimen collected from Tooth Cave; only known North American collection of this genus.
Comal Springs diving beetle *Comaldessus stygius*					X			Known only from the outflows at Comal Springs and Fern Bank Springs; aquatic; diving beetles generally inhabit the water column. This species does not occur in the study area.
Edwards Aquifer diving beetle *Haideoporus texanus*		X			X			Habitat poorly known; known from an artesian well in Hays County.
Flint's net spinning caddisfly *Cheumatopsyche flinti*		X						Very poorly known species with habitat description limited to "a spring."
San Marcos saddle-case caddisfly *Protoptila arca*		X						Known from an artesian well in Hays County; locally very abundant; swift, well-oxygenated warm water about 1–2 m deep; larvae and pupal cases abundant on rocks.
Texas austrotinodes caddisfly *Austrotinodes texensis*		X						Appears endemic to the karst springs and spring runs of the Edwards Plateau region; flow in type locality swift but may drop significantly during periods of little drought; substrate coarse and ranges from cobble and gravel to limestone bedrock; many limestone outcroppings also found along the streams.
FISHES								
Guadalupe bass *Micropterus treculii*	X	X	X	X	X	X	X	Endemic to perennial streams of the Edwards Plateau region; introduced in the Nueces River system.
Headwater catfish *Ictalurus lupus*			X	X				Originally throughout streams of the Edwards Plateau and the Rio Grande basin; currently limited to Rio Grande drainage, including Pecos River basin; springs and sandy or rocky riffles, runs and pools of clear creeks and small rivers.
Ironcolor shiner *Notropis chalybaeus*		X						Big Cypress Bayou and Sabine River basins, with disjunct populations in the San Marcos River; spawns April-September, eggs sink to bottom of pool; pools and slow runs of low gradient small acidic streams with sandy substrate and clear well vegetated water; feeds mainly on small insects, ingested plant material not digested.
AMPHIBIANS								
Pedernales River springs salamander *Eurycea* sp. 6	X							Endemic; known only from vicinity of Pedernales Springs.

Table 3-4, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Blanco River springs salamander *Eurycea pterophila*		X	X	X				Subaquatic; springs and caves in the Blanco River drainage.
Comal Springs salamander *Eurycea* sp. *8*					X			Endemic to Comal Springs. This species does not occur in the study area.
Edwards Plateau spring salamanders *Eurycea* sp. *7*					X			Endemic, springs and waters of caves within the Edwards Plateau.
Texas salamander *Eurycea neotenes*				X				Endemic; troglobitic; springs, seeps, cave streams, and creek headwaters; often hides under rocks and leaves in water; restricted to Helotes and Leon Creek drainages.
REPTILES								
Spot-tailed earless lizard *Holbrookia lacerata*	X	X	X	X	X	X		Central and southern Texas and adjacent Mexico; moderately open prairie-brushland; fairly flat areas free of vegetation or other obstructions, including disturbed areas; eats small invertebrates; eggs laid underground
Texas garter snake *Thamnophis sirtalis annectens*	X	X	X	X	X	X	X	Wet or moist microhabitats, but not necessarily restricted to them; hibernates underground or in or under surface cover; breeds March-August.
BIRDS								
Arctic Peregrine Falcon *Falco peregrines tundrius*	X	X	X	X	X	X	X	Migrant throughout the state from far northern breeding range, winters along coast and farther south; occupies wide range of habitats during migrations, including urban, concentrations along coast and barrier islands; low-altitude migrants, stopovers at leading landscape edges such as lake shores, coastlines, and barrier islands.
Henslow's Sparrow *Ammodramus henslowii*						X	X	Wintering individuals found in weedy fields or cut-over areas where lots of bunch grasses occur along with vines and brambles; a key component of habitat is bare ground for running/walking.
Mountain Plover *Charadrius montanus*	X	X	X	X	X	X	X	Nests on high plains or shortgrass prairie, on ground in shallow depression; nonbreedng: shortgrass plains and bare, dirt (plowed fields).
Western Burrowing Owl *Athene cunicularia hypugaea*	X	X	X	X	X	X	X	Open grasslands, especially prairie, plains, and savanna, sometimes in open areas such as vacant lots near human habitation or airports; nests and roosts in abandoned burrows.
MAMMALS								
Cave myotis bat *Myotis velifer*	X	X	X	X	X	X	X	Colonial and cave-dwelling; also roosts in rock crevices, old buildings, carports, under bridges, and in abandoned cliff swallow nests; roosts in clusters of up to thousands of individuals; hibernates in limestone caves of the Edwards Plateau and gypsum caves of the Texas panhandle region during winter; opportunistic insectivore.
Elliot's short-tailed shrew *Blarina hylophaga hylophaga*							X	Sandy areas in live oak motts, grassy areas with a loblolly pine (Pinus taeda) overstory, and grassy areas near post oak (Quercus stellata) stands, burrows extensively under leaf litter, logs, and into soil, but ground cover is not required; needs soft damp soils for ease of burrowing.
Llano pocket gopher *Geomys texensis texensis*			X					Found in deep, brown loamy sands or gravelly sandy loams and is isolated from other species of pocket gophers by intervening shallow stony to gravelly clayey soils.

Table 3-4, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
Plains spotted skunk *Spilogale putorius interrupta*	X	X	X	X	X	X	X	Found in open fields, prairies, croplands, fence rows, farmyards, forest edges, and woodlands; prefers wooded, brushy areas and tallgrass prairie.

[1]Species of Conservation Concern are those considered rare or sensitive (but not endangered or threatened) by the Texas Parks and Wildlife Department Annotated County Lists of Rare Species: ***http://www.tpwd.state.tx.us/gis/ris/es/*** accessed May 10, 2016 for Travis County (Revised 2/10/16); Hays County (Revised 2/8/16); Blanco County (Revised 2/10/16); Kendall County (Revised 2/8/16); Comal County (Revised 2/8/16); Caldwell County (Revised 2/7/16); and Bastrop County (Revised 2/10/16).

3.4 SOCIOECONOMIC RESOURCES

3.4.1 Demographics

3.4.1.1 Study Area

Socioeconomic resources evaluated in this dEIS focus on five of the seven counties represented in the dEIS study area: Bastrop, Blanco, Caldwell, Hays, and Travis. The other two counties, Comal and Kendall, represent only a small part of the study area, are outside the regulatory boundary of the BSEACD, and involve only a small portion of the aquifer contributing zone. Consequently, socioeconomic statistical data for these counties are not included in these evaluations. The Austin-Round Rock-San Marcos Metropolitan Statistical Area (MSA) is located within the region, as defined by the U.S. Office of Management and Budget.

3.4.1.2 Population

According to the 2010 Census, the State of Texas' percent change in population was ranked fifth among the 50 states between 2000 and 2010 (20.6 percent). The numerical change in population ranked first, with an increase of 4.3 million people. Most of this growth has occurred along the Texas-Mexico border and in the large urban areas of Houston, San Antonio, Austin, and Dallas. Approximately 83 percent of the state's population lives in urban areas. According to 2010 U.S. Census Bureau data, between 2000 and 2010, the total population within the study area counties grew by an estimated 29.3 percent, more than a quarter million people (295,893) (**Table 3-5**). The largest percent change over the decade was within Hays County at 61 percent, followed by Bastrop County at 28.5 percent, Travis County (26.1 percent) and Caldwell County (18.2 percent).

Table 3-5
Population Study Area Counties, 1950–2010

County	1950	1960	1970	1980	1990	2000	2010	% Change 2000–2010
Bastrop	19,622	16,925	17,297	24,726	38,263	57,733	74,171	28.5
Blanco	3,780	3,657	3,567	4,681	5,972	8,418	10,497	24.7
Caldwell	19,350	17,222	21,178	23,637	26,392	32,194	38,066	18.2
Hays	14,272	15,947	22,114	32,475	52,491	97,589	157,107	61.0
Travis	160,980	212,136	295,516	419,573	576,407	812,280	1,024,266	26.1
TOTAL	**218,004**	**265,887**	**359,672**	**505,092**	**699,525**	**1,008,214**	**1,304,107**	**29.3**

Source: U.S. Census Bureau 1990, 2000, and 2010.

Based on data from the 2010 Census, both Travis County and Caldwell County have a minority (non-White) population of over 50 percent (see **Table 3-6**). Hispanic and Latino persons made up the largest share of any minority group in all of the study area counties.

Table 3-6
Race Characteristics of Study Area Counties, 2010

		Not Hispanic or Latino									
	Total Population	White	Black or African American	American Indian and Alaska Native	Asian	Pacific Islander	Other Race	Two or More Races	Hispanic or Latino of Any Race	Total Minority Population	Total % Minority Population
Caldwell County, Texas	38,066	16,841	2,456	90	344	8	54	351	17,922	21,225	55.8
Bastrop County, Texas	74,171	42,446	5,535	315	449	54	115	1,067	24,190	31,725	42.8
Blanco County, Texas	10,497	8,336	62	47	49	4	5	85	1,909	2,161	20.6
Hays County, Texas	157,107	92,062	4,970	502	1,699	104	226	2,143	55,401	65,045	41.4
Travis County, Texas	1,024,266	517,644	82,805	2,611	58,404	540	1,813	17,683	342,766	506,622	49.5

Source: U.S. Census 2010, P.L. 94-171, Table P-2.

3.4.1.3 Population Projections

Texas Water Development Board Population Projections

The total population within the five counties evaluated for the study area is projected to increase by approximately 105 percent, or by about 1.75 million people, between the years 2020 and 2070, according to population projections developed by the TWDB (2014c). This projected increase is presented in **Table 3-7**.

Table 3-7
Population Projections for Counties in the Study Area, 2020–2070

County	2020	2030	2040	2050	2060	2070	% Change 2020–2070
Bastrop	95,487	125,559	164,648	217,608	289,140	384,244	302
Blanco	13,015	15,475	16,917	17,672	18,175	18,472	42
Caldwell	47,008	57,553	67,955	78,243	88,639	98,754	110
Hays	238,862	313,792	398,384	474,801	593,384	728,344	205
Travis	1,273,260	1,508,642	1,732,860	1,897,769	2,033,120	2,185,909	72
Total	1,667,632	2,021,021	2,380,764	2,686,093	3,022,458	3,415,723	105
State of Texas	29,510,184	33,628,653	37,736,338	41,928,264	46,354,818	51,040,173	73

Source: TWDB 2015.

Texas State Data Center Population Projections

The Texas State Data Center (TSDC 2014) publishes several scenarios of population projections for the state and individual counties based on different assumptions about future migration rates. The projections presented below in **Table 3-8** utilize the “0.5” growth-rate scenario, which assumes rates of net migration to be one-half of those of the 1990s; the TSDC believes that many counties in the state are unlikely to continue to experience the overall levels of relatively extensive growth of the 1990s. The TSDC considers the 0.5 scenario to be the most appropriate scenario for most counties for use in long-term planning.

Table 3-8
Projections of Population in Study Area Counties, 2010–2050

County	2010	2020	2030	2040	2050	% Growth 2020–2050
Bastrop	74,171	89,066	107,906	128,712	153,180	107
Blanco	10,497	11,574	12,522	12,846	13,043	24
Caldwell	38,066	44,538	51,665	58,006	64,014	68
Hays	157,107	216,983	285,920	369,861	474,802	202
Travis	1,024,266	1,200,883	1,348,207	1,484,854	1,630,964	59

Source: TSDC 2014.

Hays County is projected to see the largest growth between 2010 and 2050, with a projected population growth rate of 202 percent over the 40-year period. With the exception of Bastrop County, the decade of 2010 to 2020 is projected to be the period of the highest growth in all of the study area counties. The TSCD 0.5 percent growth rate scenario projections are considerably lower than the estimates produced by the TWDB, which did not apply a 0.5 percent growth rate to all counties.

The TSDC also provides estimates of racial distribution for each geography (**Table 3-9**). In all of the study area counties, the percentage of the population described as Anglo is projected to decline between 2010 and 2050. In Bastrop, Caldwell, Hays, and Travis County, Hispanic persons are anticipated to make up the largest share of the population by 2050.

Table 3-9
Racial distribution of Projected Population in Study Area Counties, 2010–2050

	2010	2020	2030	2040	2050
Bastrop					
Anglo	57%	51%	44%	36%	29%
Black	7%	7%	7%	7%	6%
Hispanic	33%	39%	47%	54%	62%
Other	3%	3%	3%	3%	3%
Blanco					
Anglo	79%	77%	75%	72%	69%
Black	1%	1%	0%	0%	0%
Hispanic	18%	20%	23%	26%	29%
Other	2%	2%	2%	2%	2%
Caldwell					
Anglo	44%	40%	36%	32%	29%
Black	6%	6%	5%	5%	4%
Hispanic	47%	52%	56%	61%	65%
Other	2%	2%	2%	2%	2%
Hays					
Anglo	59%	56%	52%	49%	46%
Black	3%	3%	3%	2%	2%
Hispanic	35%	38%	42%	45%	49%
Other	3%	3%	3%	3%	3%
Travis					
Anglo	51%	47%	43%	38%	33%
Black	8%	8%	7%	7%	6%
Hispanic	33%	37%	40%	45%	49%
Other	8%	9%	10%	11%	12%

Source: TSDC 2014.

3.4.2 Economy

The study area maintains a diversified economy that is supported by strong manufacturing, government, trade and service sectors (including a strong tourism industry). The rapid growth of the region's high-technology sector has boosted the area's economy in the last several decades. **Table 3-10** summarizes employment by major sectors of the economy for the counties evaluated in the study area. These data represent the percentage of jobs in each sector by county. Education and Health Services represents the largest sector in each of the study area counties.

Table 3-10
Employment by Sector, 4Q 2015

Industry Sector	Study Area Total	Bastrop County	Blanco County	Caldwell County	Hays County	Travis County
Natural Resources & Mining	1%	3%	6%	5%	0%	0%
Construction	6%	7%	14%	5%	7%	6%
Manufacturing	6%	8%	7%	6%	7%	6%
Trade, Transport. & Utilities	17%	25%	17%	24%	26%	16%
Information	3%	0%	1%	1%	1%	4%
Financial Activities Group	6%	3%	3%	3%	4%	6%
Prof., Business & Other Svcs.	18%	4%	15%	5%	8%	19%
Education & Health Svcs.	21%	26%	19%	31%	28%	20%
Leisure & Hospitality	13%	15%	11%	10%	14%	13%
Other Services	4%	7%	2%	2%	3%	4%
Public Administration	6%	3%	6%	6%	3%	7%

Source: TWC 2016.

The Leisure & Hospitality Sector was the fourth-largest employment sector in the study area as a whole and represents an important component of the area's economy. Tourism is a multibillion-dollar industry in the Austin–San Marcos region (**Table 3-11**), and, to a lesser extent, in the study area. Millions of tourists who visit the area annually are drawn in by the area's rich southwestern cultural heritage and numerous attractions.

Table 3-11
Travel and Tourism Impact for Travis and Hays Counties, 2014

County	Total Direct Spending ($000)	Visitor Spending ($000)	Earnings ($000)	Employment ($000)	Tax Receipts	
					Local ($000)	State ($000)
Hays County	302,940	300,960	91,170	3,100	5,320	16,060
Travis County	5,636,430	4,688,570	1,504,210	47,900	118,500	209,760

Source: Office of the Governor 2016.

Austin is one of the top tourist destinations in Texas. Located at the center of the state, it is the gateway to the Texas Hill Country and the Highland Lakes, and is the state capital.

Contribution of Aquifer Springflow at Barton Springs to Ecotourism and Water-based Recreation

Austin's temperate year-round climate and 300 days of sunshine a year result in recreation and tourism focused on the outdoors. Attractions like Barton Springs; Zilker and other parks; lakes

Travis, Austin, Walter Long, and Lady Bird; nature and hike-and-bike trails; and wilderness preserves create a strong eco-tourism market for the city.

Although difficult to capture in any single employment sector, the recreation and tourism industry in Travis and Hays counties has an influence on both the trade and service employment sectors of the study area's economy.

Water-based recreation, primarily swimming and canoeing, associated with the Edwards Aquifer, affects the local trade and service sectors. The Barton Springs Pool, located in Zilker Park, is fed by water naturally discharging from the Barton Springs segment of the Edwards Aquifer (Barton Springs is more fully described in **subsection 3.2.1.2**). Three acres in size, the pool's springwater maintains an average 70°F year round. Over the years, Barton Springs Pool has attracted a large and diverse group of patrons, especially during the hot summer months. **Table 3-12** presents annual visitor data for the period 2008 through 2015.

Table 3-12
Annual Barton Springs Pool Visitors, 2008–2015

Year	Visitors
2008	515,099
2009	568,939
2010	505,297
2011	723,335
2012	573,834
2013	594,738
2014	527,770
2015	585,972

Source: COA 2016.

Several golf courses depend upon the Edwards Aquifer for irrigation water, either through direct pumping or the purchase of municipal utility or water supply corporation supplies. Additionally, a large convention industry has developed in the study area, partly as a result of its water-based recreation opportunities, as well as the diversity of other attractions and activities available in the area.

Unemployment and Low Income

As noted in **Table 3-13**, Caldwell County had the highest unemployment rate (4.3 percent) among the study area counties in 2015, while Blanco County had the lowest unemployment rate

(3.2 percent). Following a rise in unemployment caused by the 2007–2009 recession, the unemployment rate has been declining since 2010 in all of the study area counties.

Table 3-13
Unemployment Rates in Study Area Counties, 2009–2015

	2009	2010	2011	2012	2013	2014	2015
Bastrop County	7.9%	8.3%	8.0%	6.7%	6.1%	4.9%	3.9%
Blanco County	5.1%	6.3%	6.1%	5.2%	4.7%	3.7%	3.2%
Caldwell County	8.3%	8.8%	8.7%	7.2%	6.5%	5.2%	4.3%
Hays County	6.5%	6.9%	6.7%	5.8%	5.3%	4.3%	3.5%
Travis County	6.6%	6.9%	6.6%	5.5%	5.0%	4.1%	3.3%

Source: U.S. Bureau of Labor Statistics and Real Estate Center at Texas A&M University, 2016.

Table 3-14 presents the most recent income and poverty estimates for the counties of the dEIS study area. According to data from the 2010–2014 American Community Survey (ACS), Hays County has the highest median household income and Caldwell County has the largest percentage of persons living below poverty level in the study area. Blanco County has the smallest percentage of persons living below the poverty level.

Table 3-14
Income and Poverty Characteristics for Study Area Counties, 2014

	2014 Median Household Income	Percentage of People whose Income in the Past 12 Months is Below the Poverty Level
Bastrop County, Texas	53,382	15.9
Blanco County, Texas	51,740	10.1
Caldwell County, Texas	47,435	18.1
Hays County, Texas	58,878	17.3
Travis County, Texas	59,620	17.5

Source: US Census Bureau, 2010-2014 American Community Survey 5-Year Estimates, Tables B19013 and DP03.

3.5 LAND USE

Digital land cover data from the Multi-Resolution Land Characteristics (MRLC) Consortium National Land Cover Database (MRLC 2014) was analyzed for the study area. This database is produced by a group of Federal agencies who coordinate and generate land cover information at the national scale from satellite imagery and other supplementary datasets. The dataset classifies land cover into several categories, including "developed" land and various types of vegetation. "Developed" land is further classified as open space or high, medium, or low intensity. Results from the 2006 and 2011 (published April 2014) dataset were analyzed. Land cover within the study area based on the 2011 dataset is geographically portrayed on **Figure 3-15** with total acreages summarized in **Table 3-15**.

A comparison between 2006 and 2011 data indicates that approximately 9,500 acres transitioned to “Developed” land cover from other land cover categories, an increase of approximately 9 percent over the 5-year period. Land cover types with reductions in acreage include Forest and Shrubland.

3.5.1 Developed Land Cover Uses

As depicted on Figure 3-15, developed land uses are concentrated in the urbanized areas of the study area, including Austin, Bee Cave, and Sunset Valley in Travis County; Kyle, Buda, Dripping Springs, Woodcreek, and Wimberley in Hays County; Lockhart in Caldwell County; areas along the Travis County line in Bastrop County; and Blanco in Blanco County. Most “high density” developed uses are mapped in Austin and southwest Travis County, along I-35, and in Dripping Springs in Hays County.

“Open space” developed land use cover represents the largest component of the “Developed” land cover category, approximately 8.5 percent of the study area in 2011 (MRLC 2014). Developed open space areas include such uses as municipal or county parks, athletic fields, golf courses, and airports.

3.5.2 Non-Developed Land Cover Areas

According to the MRLC data, undeveloped land comprises approximately 85 percent of the study area (**Table 3-15**). This category includes cultivated land in agricultural use as well as vacant land. “Shrubland” and “Forest” land cover represents the largest non-developed land cover category in the study area, comprising approximately 32 percent and 28 percent of the study area acreage, respectively.

Data from the U.S. Department of Agriculture’s Census of Agriculture, which is published every 5 years, illustrate the decline in acreage in use as farmland (see **Table 3-16**). The number of acres in farms as well as the average size of farms has generally decreased between 2002 and 2012 (a small increase in the percentage of acreage in farms was observed in Caldwell County between 2002 and 2012). Travis County has the smallest percentage of total land acreage in farms.

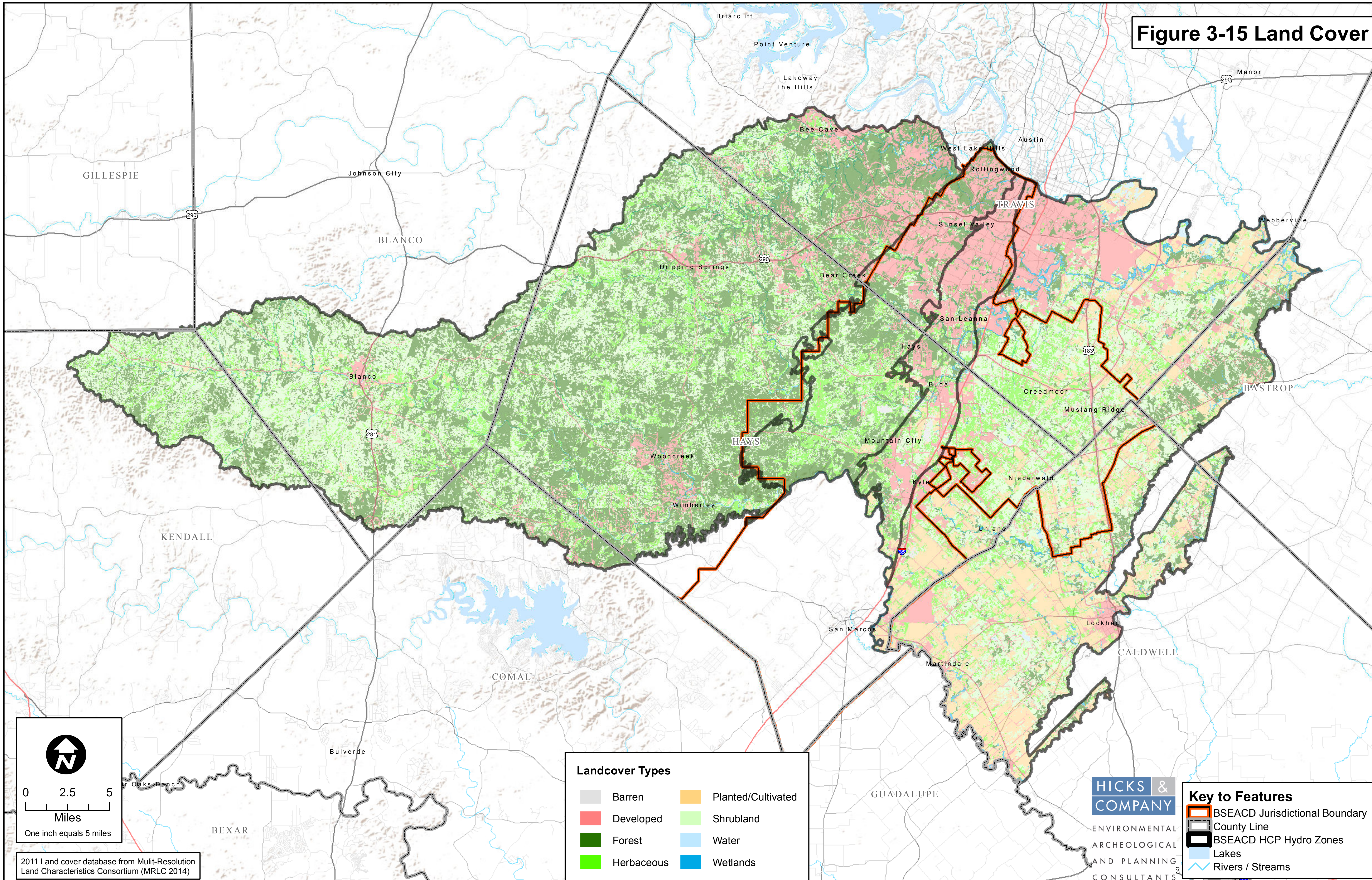


Figure 3-15 Land Cover

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Table 3-15
Summary of 2006 and 2011 Land Cover Within the Study Area

	2006		2011	
Land Cover Type	**Acreage**	**Percent**	**Acreage**	**Percent**
Barren	2,042	0.2	2,446	0.3
Developed	109,429	13.1	118,924	14.3
High Intensity	5,214		6,591	
Medium Intensity	12,713		19,197	
Low Intensity	19,713		22,720	
Open Space	71,790		70,417	
Forest	247,580	29.7	240,248	28.9
Herbaceous	114,668	13.8	114,606	13.8
Planted/Cultivated	73,851	8.9	76,057	9.1
Shrubland	272,767	32.8	268,159	32.2
Water	3,662	0.4	3,688	0.4
Wetlands	8,280	1.0	8,229	1.0
Other Unclassified	79	0.0	-	0.0
Total	**832,357**		**832,357**	

Source: MRLC 2014.

Table 3-16
Farmland in Study Area Counties, 2002–2012

	Acres in Farms						Average Size of Farm (acres)		
	2002		2007		2012				
	Acres	% of County	Acres	% of County	Acres	% of County	2002	2007	2012
Bastrop	422,852	74	402,079	71	387,586	68	193	182	186
Blanco	389,282	86	395,667	87	363,990	80	497	446	460
Caldwell	304,844	87	304,737	87	310,433	89	217	214	191
Hays	278,352	64	235,568	54	245,006	56	252	207	170
Travis	298,426	47	262,481	41	252,686	40	229	216	223

Source: USDA Census of Agriculture 2002, 2007, and 2012.

In the Travis and Hays Counties portion of the study area, there is a substantial amount of acreage in nature and conservation preserves. The Nature Conservancy owns and manages the 4,000-acre Barton Creek Habitat Preserve. Just west of the preserve is another conservation area, the Shield Ranch. Although privately owned, the development rights on this 7,000-acre tract have been purchased by the Nature Conservancy and the COA for the purpose of preserving water quality in Barton Springs (LCRA 2002). In May 1998 Austin voters approved a plan that dedicated $65 million to the purchase of 15,000 acres for the purpose of water-quality protection in the Barton Springs Watershed. In 2012, City of Austin voters approved another $30 million in funding to allow the City to purchase land in the Barton Springs Watershed contributing and recharge zones for water quality protection.

3.6 CULTURAL RESOURCES

Although the study area includes portions of seven counties, the effects of Aquifer management strategies on resulting springflow will be most evident at the spring locations and along the lower portion of Barton Creek. Consequently, background and site study focused on Barton Springs and the lower portion of Barton Creek. Research centered on previously recorded archeological sites, State Archeological Landmarks (SALs) (now State Antiquities Landmarks), properties listed on the National Register of Historic Places (NRHP), Texas Historical Markers, archeological surveys and other historic properties within 500 feet of the waterways (Texas Historical Commission 2014). The designated Area of Potential Effect (APE) for the archeological and historic properties aspect begins at the confluence of Barton Creek and Short Spring Branch and extends to the Creek's confluence with the Colorado River. Properties, sites or districts that lie within 500 feet of the waterway are discussed. Water management strategies that will require infrastructure development such as Aquifer recharge enhancement projects, pipelines, or pump stations may also impact other cultural resource sites outside the vicinity of the springs. These projects would be included in separate investigations as sites become known and commitments for design and construction are made.

Research was conducted through the Texas Historical Commission's (THC) online Texas Archeological Sites Atlas (2011) and the THC library. Reports on archeological investigations consulted include (1) *An Archeological Survey with Shovel Testing Along Existing and Proposed segments of Zilker Loop Trail, Travis County, Texas* in *Texas Archeological Research Laboratory Technical Series 46*, Austin. (Collins 1996); and (2) *Archeological and Geomorphological Testing along the Proposed South Austin Outfall Relief Main, Phase II Tunnel Alignment: The Vara Daniel Site (41TV1364), Zilker Park, Austin, Texas* (Takac et al. 1992) and (3) *Archaeological Excavation of a Deeply Buried Paleoindian Component at the Vara Daniel Site (41TV1364), Travis County, Texas* (Nickels et al. 2010).

Archeological investigations indicate that human occupation in the vicinity of Barton Springs and Barton Creek dates to the Paleoindian period and continue to the modern era. The prehistoric background of Barton Creek and Barton Springs parallels that of the overall Central Texas region as a whole. Paleoindian (10,000–8800 BP) cultures in Central Texas are related to the Great Plains big game hunting traditions in the early phases followed by smaller game during later Paleoindian periods. Artifacts are most often large lanceolate projectile points with minimal plant processing features. Sites attributed to this phase of occupation are relatively rare across the continent but particularly so in this region. One of the earliest known sites along Barton Creek and Barton Springs is the Vara Daniel Site, in Zilker Park along the left (north) bank of Barton Creek. This massive, deeply buried archeological site contains occupational deposits that date to this rare Paleoindian period (10,000 BP) and a substantial Archaic period occupation. Archaic period (8800 BP–AD 600, subdivided into Early, Middle and Late I and II Phases) sites in Central Texas are dramatically more numerous. During this period, subsistence shifted toward an increased reliance on plants and plant processing. Burned rock hearths and middens (stone ovens used for plant processing) are typical of this period. Hunters still relied on large projectile points as the bow and arrow was not in use up to this point. Several of the sites are attributed to the Archaic period. Beyond the Archaic period, the Late Prehistoric (600–1600 AD) period is marked by the replacement of the dart and atlatl with the bow and arrow, reflected in a shift from large dart points to smaller, lighter arrow points. Later technology includes pottery. A number of sites along portions of Barton Creek are attributed to this phase of occupation.

During the Historic Period, the Barton Creek and Barton Springs area underwent dramatic changes. First the Tonkawa and Comanche, who camped along the banks through the eighteenth century, were replaced by Spanish settlers. Shortly thereafter, Anglo-Americans moved into the area and established home sites, mills and ranches. The creek itself was named for one of these settlers, a William Barton, who moved to the area in 1837. Some of the earliest Anglo occupations of the Barton Creek/Springs area are the Gail Rabb House Site and the Andrew Cox Ranch. Barton Springs gained local and regional prominence beginning around the turn of the century, being called “Austin’s Eden” in the 1880s. The famed swimming hole was built into a more modern pool in the 1930s and continues to be a top recreational attraction.

A detailed discussion of archeological surveys and recorded archeological sites in the vicinity of Barton Springs and the lower portion of Barton Creek, including sites that are listed or are candidates for listing on the NRHP or as SALs, is provided in **Appendix E, Cultural Resources in the Vicinity of Lower Barton Creek and Barton Springs**.

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4.0 ENVIRONMENTAL CONSEQUENCES

4.1 PHYSICAL ENVIRONMENT

This section describes direct impacts of each of the four dEIS alternatives on the physical environment including geology, air quality, and climate.

4.1.1 Geology

Long-term processes formed the geologic structure of the Edwards and Trinity Aquifers. Changes to any hydrological processes from any of the alternatives would not affect the physical structure of any of the geological formations. Therefore, there should be no effects to the geology of either of the Aquifers from any of the alternatives. Potential effects to groundwater are discussed in **subsection 4.2.3**, **Groundwater and Springflow.**

4.1.2 Soils

Erosion Potential near Barton Springs

Existing soils exhibit only a slight to moderate potential for erosion by water (USDA, SCS 1974). Erosion near Barton Springs would be much more affected by precipitation runoff during flood events than by changes in springflow resulting from any of the alternative measures. Therefore, effects to soil resources from any changes in springflow under any of the four dEIS alternatives would be minimal.

Changes in Regional Soil Conditions

Flows of creeks and streams in the study area would be much more affected by rainfall events than by any of the measures implemented under any of the four dEIS Alternatives. Although erosion and sediment runoff into creeks is occurring in all of the watersheds within the study area, causes of this erosion and sedimentation are attributed to increased stormwater runoff from urban and suburban development (Naismith Engineering 2005; COA 1990). Consequently, none of the dEIS alternatives are expected to substantially change the rate of erosion or adversely affect soils within the watersheds.

4.1.3 Air Quality

No direct effects on local or regional air quality are expected to occur from any of the proposed alternatives. Air quality within a specific area is determined from a number of source activities including local and regional pollutant emissions combined with large-scale meteorological patterns and dispersal characteristics. Air quality within the study area is primarily influenced by human activity resulting from increased population growth in urban areas. Increased automobile usage and industrial emissions in urban and rural areas contribute to the degradation of air quality, which is subject to regulation by state and Federal agencies. Air quality impacts associated with ongoing development will occur within the study area based on prevailing economic conditions. Air quality impacts associated with such development resulting from market conditions are not a direct or indirect effect of any of the proposed alternatives.

4.1.4 Climate

None of the alternatives are expected to produce any appreciable changes to the climate of the study area. Although regional temperatures are expected to increase over the next 20 years as a result of climate change (see **subsection 3.1.4.3**), none of the measures in the four alternatives are expected to have any influence on the expected temperature increases over the southern Great Plains, which includes the study area. While precipitation events involving both floods and droughts are expected to become more intense, none of the alternatives would be expected to exert any influence on these changes.

4.2 WATER RESOURCES

Environmental consequences to surface water resources occurring within the study area are described in this section for each of the four dEIS alternatives.

4.2.1 Surface Water

4.2.1.1 Alternative 1: No Action

Because Alternative 1 would not have any effect on precipitation and resulting rainfall runoff or streamflow, there would not be any effects to creeks and streams within the study area except lower Barton Creek where flows would largely result from spring discharge.

Impacts of Alternative 1 on springflow are discussed in **subsection 4.2.3.1**. Reduced pumping from voluntary efforts by pumpers during drought conditions would be expected to increase springflow and would contribute to higher surface water flows in Barton Creek below the springs and in the Colorado River below the confluence of Barton Creek, during such drought conditions.

4.2.1.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

Effects of Alternative 2 on surface water within the study area would be similar to effects under Alternative 1. However, mandatory drought management reductions would contribute to higher surface water flows in Barton Creek below the springs and in the Colorado River below the confluence of Barton Creek, particularly during drought conditions.

Effects of recharge enhancement structures under Alternative 2 (Measure 7.1, Table 2-1) could result in reduced flows immediately downstream of these features, depending on the efficiency of the recharge enhancement features. During periods of moderate-to-high runoff, effects of recharge enhancement features on downstream flows would be low due to the higher volume of flows. However, during drier conditions, recharge enhancement features could further reduce downstream flows that could adversely affect the availability of pool, riffle, and stream habitat.

4.2.1.3 Alternative 3: Water Demand Reduction

Effects of Alternative 3 on surface water within the study area would be similar to effects under Alternative 1 and Alternative 2. Reduced pumping from Alternative 3 restrictions would have the effect of making more groundwater available for springflow during drought conditions than Alternative 2, and equivalent to Alternative 1, assuming all pumpers agreed to reduce pumping voluntarily. This would result in potentially more streamflow through Barton Springs Pool, lower Barton Creek, and the Colorado River than Alternative 2 during drought conditions.

In summary, environmental consequences of Alternative 3 to surface water flows within the study area would be similar to Alternatives 1 and 2, except for Barton Springs Pool and lower Barton Creek, where flows (similar to Alternative 1) would be potentially higher during drought conditions than Alternative 2.

4.2.1.4 Alternative 4: Water Supply Augmentation and Substitution

Effects of Alternative 4 on regional surface water within the study area would be similar to effects under Alternatives 1, 2, and 3, but would develop over a longer period of time. Alternative 4 would result in additional water supplies becoming available within the study area (possibly at the expense of reducing water supplies to other areas outside the study area) and eventually reduce water demand, resulting in higher springflow. This would eventually increase streamflow downstream of Barton Springs Pool during drought conditions, with increases in springflow corresponding to the rate at which additional water supplies become available.

4.2.2 Surface Water Quality

Surface water quality is the capacity of surface water to meet standards of use according to established criteria involving levels of suspended or dissolved solids, oxygen demanding substances, nutrients (principally nitrogen and phosphorus), pathogens, petroleum hydrocarbons, synthetic organic compounds, metals, and physical parameters including dissolved oxygen, water temperature, conductivity (a measure of salinity), and pH.

4.2.2.1 Alternative 1: No Action

Lower Barton Creek

Water quality in lower Barton Creek is directly influenced by the amount of flow resulting from runoff contributions in the Barton Creek watershed in combination with Aquifer discharge through Barton Springs.

In years of average to above-average rainfall, effects of measures under Alternative 1 on the quality of water in lower Barton Creek would be determined by the combination of groundwater discharged by Barton Springs in addition to water contributed by Barton Creek and its associated watershed. Resulting water quality would be highly variable depending on the frequency of rainfall events and stormwater pulses. It is likely that water quality will continue to be degraded by nonpoint source contaminants and sedimentation immediately after rainfall events. The generally high-quality groundwater discharged by Barton Springs would be diminished following heavy rainfall events by the additional flows (including flood flows) contributed by upper Barton Creek. In years of below-average rainfall, virtually all of the water in lower Barton Creek originates from springflow and would be subject to adverse impacts by infrequent pulses of stormwater that would be carrying some accumulated surface pollutants from Upper Barton Creek and the immediate area of Zilker Park that surrounds Lower Barton Creek. During low-flow conditions, in the absence of rainfall runoff events, water quality in lower Barton Creek would be expected to be similar to the quality of the groundwater discharged from the springs, with some variation in temperature and DO between Barton Springs Pool and the confluence with Lady Bird Lake (Colorado River).

Other Creeks

Effects of measures under Alternative 1 on water quality in other creeks within the study area are expected to be negligible.

4.2.2.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

Lower Barton Creek

In years of average to above-average rainfall, effects of measures under Alternative 2 on surface water quality in lower Barton Creek would be similar to effects under Alternative 1 as springflow would not be substantially different in comparison to Alternative 1. In years of below-average rainfall, water quality in lower Barton Creek would be expected to be similar to the quality of the groundwater discharged from the springs (similar to Alternative 1), with some variation in temperature and DO between Barton Springs Pool and the confluence with Lady Bird Lake (Colorado River).

Other Creeks

Effects of measures under Alternative 2 on water quality in other creeks within the study area are expected to be negligible, similar to Alternative 1.

4.2.2.3 Alternative 3: Water Demand Reduction

Lower Barton Creek

In years of average to above-average rainfall, effects of Alternative 3 on water quality would not be substantially different than Alternatives 1 and 2. In years of below average rainfall, water quality in lower Barton Creek would be expected to be similar to the quality of the groundwater discharged from Barton Springs (similar to Alternatives 1 and 2) with some variation in temperature and DO between Barton Springs Pool and the confluence with Lady Bird Lake (Colorado River).

Other Creeks

Higher pumping restrictions under Alternative 3 would have negligible effects on water quality in other creeks within the study area, similar to Alternatives 1 and 2.

4.2.2.4 Alternative 4: Water Supply Augmentation and Substitution

Lower Barton Creek

Effects of measures under Alternative 4 would eventually result in similar springflow levels as Alternatives 1 and 3, thus resulting in similar water quality impacts. However, the resulting springflows would not be achieved until alternative water strategies are developed to substitute for the Aquifer withdrawals. In comparison with Alternatives 1 and 3, these benefits would not be immediate, and realized later in time when all of the alternative water strategies needed to replace aquifer pumping are completely developed.

Other Creeks

Higher pumping restrictions under Alternative 4 would have negligible effects on water quality in other creeks within the study area similar to Alternatives 1, 2, and 3.

4.2.3 Groundwater and Springflow

This section describes effects of the four alternatives on groundwater and resulting Aquifer springflow. Alternatives 1 and 2 reflect pumping restrictions according to the District’s current drought management rules, and would allow water withdrawals in accordance with Desired Future Conditions ranging from 16 cfs under normal rainfall patterns to 5.2 cfs during DOR conditions. The frequency of occurrence (percent of time) that springflow would fall below specified levels under the four alternatives based on data compiled over the period of record (POR) 1917–2013 is summarized in **Tables 4-1** and **4-2**.

4.2.3.1 Alternative 1: No Action

With voluntary suspension of pumping under the No Action Alternative, aquifer springflow is predicted to be at or below 53 cfs about 52 percent of the time during the POR (see **Table 4-1**). About 25 percent of the time over the POR, springflow is predicted to be at or below 30 cfs. Springflow levels at or below 20 cfs would occur about 10 percent of the time. Under Alternative 1, minimum average monthly springflow of 11 cfs would occur less than 1 percent of the time, and would never fall below 10 cfs.

Table 4-1
Comparison of Projected Frequency of Springflows at Barton Springs Over the Period of Record 1917–2013

Frequency of Occurrence (Percent of time over the period of record average monthly springflow would have been at or below designated levels)				
Springflow Level (cfs)	Alternative 1 No Action	Alternative 2 District HCP	Alternative 3 Demand Reduction	Alternative 4 Water Supply Augmentation and Substitution
53	52	61	52	52
40	38	48	38	38
38	37	44	37	37
30	25	36	25	25
29	23	35	23	23
26	20	31	20	20
20	10	20	10	10
19	8	19	8	8
14	2	8	2	2
12	<15	5	<1	<1
11[1]	<14	4	<1	<1
10	0	3	0	0
6.5[2]	0	<1	0	0
0	0	0	0	0

Source: BSEACD 2017.

[1] Lowest historical instantaneous flow (9.6 cfs) occurred during DOR on March 29, 1956, when average monthly springflow = 11 cfs.

[2] Minimum springflow established by BSEACD policy to be maintained during DOR conditions.

4.2.3.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

Under Alternative 2, springflow is predicted to be at or below 53 cfs 61 percent of the time during the POR (See **Table 4-1**). During nearly half of the months over the POR, springflow would be at or below 40 cfs. Springflow levels at or below 20 cfs would occur about 20 percent of the time. Under Alternative 2, the lowest monthly springflow recorded during the DOR (11cfs) would be reached about 4 percent of the time. Springflow could fall to 6.5 cfs but the frequency of occurrence would be less than 1 percent over the POR. Complete cessation of springflow during conditions similar to the DOR is not expected under Alternative 2.

Table 4-2 Barton Springs Discharge Thresholds and Predicted Levels of Impact Under Alternatives 1 - 4 (vs 5-11-16)

Total Springflow (cfs)	BSEACD Drought Stage	Percent Occurrence at or Below Springflow Level Over the Period of Record[1]				Predicted Dissolved Oxygen Concentration (mg/l)[2]			Potential Mortality From Laboratory DO Toxicity Study[3]
		ALTERNATIVE 1 No Action	ALTERNATIVE 2 District HCP	ALTERNATIVE 3 Demand Reduction	ALTERNATIVE 4 Water Supply Augmentation & Substitution	Main Spring	Eliza Spring	Old Mill Spring	
53	No Drought	52	61	52	52	6.1	5.8	5.6	No impacts to any springs above 40 cfs
40	No Drought	38	48	38	38	5.7	5.5	5.3	Upper spring ceases to flow at total spring flow ≤ 40 cfs
38	Stage II Alarm ≤ 38 cfs	37	44	37	37	5.6	5.4	5.3	Salamanders occurring at upper spring disappear. Level of impact is unknown.
30	Stage II Alarm ≤ 38 cfs	25	36	25	25	5.2	5.1	5.0	
29	Stage II Alarm ≤ 38 cfs	23	35	23	23	5.2	5.0	5.0	LC_5 (5% mortality) @ DO = 4.5 ± 0.5 mg/l
26	Stage II Alarm ≤ 38 cfs	20	31	20	20	5.0	4.9	4.9	
20	Stage III Critical ≤ 20 cfs	10	20	10	10	4.6	4.5	4.6	
19	Stage III Critical ≤ 20 cfs	8	19	8	8	4.5	4.4	4.5	
14	Stage IV Exceptional ≤ 14 cfs	2	8	2	2	4.1	4.0	4.3	LC_{10} (10% mortality) @ DO = 4.2 ± 0.3 mg/l
12	Stage IV Exceptional ≤ 14 cfs	< 1	5	< 1	< 1	3.8	3.8	4.1	
11[4]	Stage IV Exceptional ≤ 14 cfs	< 1	4	< 1	< 1	3.7	3.7	4.0	LC_{25} (25% mortality) @ DO = 3.7 ± 0.1 mg/l
10	Emergency Response ≤ 10 cfs	0	3	0	0	3.6	3.5	3.9	
6.5[5]	Emergency Response ≤ 10 cfs	0	< 1	0	0	2.9	2.9	3.5	LC_{50} (50% mortality) @ DO = 3.4 ± 0.2 mg/l
0	Emergency Response ≤ 10 cfs	0	0	0	0	-	-	-	50 - 100% mortality @ DO < 3.2 mg/l

1 Predicted frequency of occurrence of average monthly springflow over the period of record (POR) 1917 - 2013 as determined from historical data.

2 Predicted DO derived from summary data provided by BSEACD (12-1-14) using algorithms from Porras (2014).

3 Mortality estimates for the Barton Springs salamander (*Eurycea sosorum*) were determined from dissolved oxygen toxicity studies using captive, surrogate salamanders (*Eurycea nana*) (Woods et al. 2010) that were subjected to low DO.

4 Lowest historical instantaneous flow (9.6 cfs) occurred during drought of record on March 29, 1956 when average monthly springflow = 11 cfs.

5 Minimum springflow established by BSEACD policy to be maintained during drought of record conditions.

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4.2.3.3 Alternative 3: Water Demand Reduction

Alternative 3 eliminates all permittee pumping through mandated reductions, unlike Alternative 1, which relies on voluntary reductions, and therefore, employs the strictest pumping restrictions among all the alternatives. This would result in a minimum monthly springflow of no less than 11 cfs during DOR conditions, allowing instantaneous flow of 10 cfs, similar to conditions occurring during the DOR. Under Alternative 3, springflows at or below specified discharge levels would occur less often than under Alternative 2. For example, springflow at or below 20 cfs would occur about 10 percent of the time over the POR in comparison to 20 percent of the time under Alternative 2. Minimum monthly springflow of 11 cfs would occur less than 1 percent of the time, and would never drop below 10 cfs.

4.2.3.4 Alternative 4: Water Supply Augmentation and Substitution

Water supply strategies developed and implemented under Alternative 4 would be designed to eventually reduce water withdrawals to less than 1 cfs, ensuring a minimum average monthly springflow of no less than 11 cfs during DOR conditions, similar to Alternative 3. However, total withdrawal reductions to less than 1 cfs would not be achieved until all of the required water strategies could be developed and implemented. Because Aquifer withdrawals resulting from Alternatives 3 and 4 would ensure monthly springflow of 11 cfs during DOR conditions, the frequency of occurrence of specified springflows over the POR would eventually be the same for Alternatives 3 and 4, although protection of minimum springflow would be developed over a longer period of time under Alternative 4 than Alternative 3.

4.2.4 Groundwater Quality

Impacts of the four dEIS alternatives on important groundwater quality parameters are discussed in this section. While the quality of water discharged from the Barton Springs segment of the Edwards Aquifer has historically been good, ongoing water sampling studies indicate a long-term gradual decline in water quality (**subsection 3.2.2.2**). The overall decline in water quality is generally attributed to the following anthropogenic influences regarded as continuing future threats (Naismith Engineering 2005): urbanization; long-term groundwater withdrawal exceeding recharge; point source discharges, including domestic wastewater collection, treatment, and discharge; stormwater/nonpoint source pollution; lack of water quality protection measures on existing development; failure to implement/enforce existing regulations of various political subdivisions outside the District; use, storage, and disposal of harmful materials; improper vegetation management; and improper agricultural practices. Additionally, groundwater at Barton Springs may also be affected by inflows from a portion of the Aquifer that contains naturally occurring levels of total dissolved solids that do not meet national drinking water quality standards.

None of the four alternatives discussed below would eliminate continuing water quality threats. As population growth and attendant development continue to occur over the Aquifer, there will likely be greater risk in the study area for point and nonpoint source pollution.

Because the anticipated impacts of each alternative on water quality cannot be precisely measured or projected, each alternative is evaluated for the relative “net effect” that the alternative would have on the quality of groundwater.

Because long-term aquifer withdrawals exceeding recharge have been identified as one source of declining water quality (Naismith Engineering 2005), each of the four dEIS alternatives, by reducing aquifer withdrawals (albiet through different means) would result in positive impacts to water quality. Because it cannot be shown that specific reduction of groundwater withdrawals would have a direct proportional effect on increasing water quality, none of the alternatives can be distinguished by predicted, quantitative changes in water quality parameters. While all of the dEIS alternatives would potentially increase the quality of groundwater by limiting groundwater withdrawals, Alternatives 2 and 4 also include measures that could indirectly reduce further water quality degradation. This would include conducting technical studies and assisting water suppliers in implementing engineered enhancements to water supply strategies, including desalination, aquifer storage and recovery, and effluent reclamation and re-use to increase the options for water supply substitution and reduce dependence on the Aquifer (Measure 7.2, **Table 2-1**).

Alternatives 1, 3, and 4, provide a benefit in reducing the intrusion of saline water into the aquifer by providing for more groundwater flow. However, under Alternative 4, complete substitution will tend to remove a current constraint on development in the recharge and confined zones, which may have deleterious impacts of various types, including water quality.

Alternative 2 contains the most measures that would develop additional information on water quality, inform the public, and implement other operational activities that address water quality and/or could potentially enhance future water quality. These measures include:

1) collaboration with universities, the COA, and other parties to better inform and determine level of risk associated with springflow-related changes in water chemistry affecting the Covered Species (Measure R-1, **Table 2-1**);

2) collaboration with the USGS, Texas Water Development Board, universities, the COA, Edwards Aqufier Authority, and other parties to development improved numerical models for District aquifers, and improve hydrologic characterizations of aquifer function during low flows (Measure R-2, **Table 2-1**);

3) a commitment by the District to extend operation of the Antioch Recharge Enhancement Facility to improve recharge water quality and reduce non-point source pollution (Measure M-3, **Table 2-1**);

4) a commitment by the District to plug abandoned wells to prevent potential conduits for contaminants (Measure M-4, **Table 2-1**); and,

5) a commitment by the District to provide leadership and technical assistance to entities when prospective land-use and groundwater management will significantly affect the quantity or quality of groundwater in the Aquifer (Measure M-5, **Table 2-1**).

In summary, while pumping withdrawals associated with all of the dEIS alternatives have the potential to positively impact groundwater quality, Alternative 2 provides the most measures for groundwater quality protection and enhancement.

4.3 WILDLIFE RESOURCES

This section discusses impacts of each of the four dEIS alternatives on regionally occurring fauna and flora within the study area; **subsection 4.3.1** addresses regional effects of the four alternatives on aquatic communities; **subsection 4.3.2** describes regional effects on terrestrial resources; **subsection 4.3.3** summarizes expected effects of the four alternatives on regional threatened and endangered species; and **subsection 4.3.4** describes effects of the four alternatives on the two endangered species covered by the District HCP.

The primary threat to biological resources in the region is the modification and loss of plant and animal habitat as a consequence of ongoing urbanization in the District's service area. This includes changes in native plant and animal communities through land clearing, introduction of non-native species in urban and suburban landscapes, little or no applied management to increase habitat value on undeveloped lands, degradation of water quality in urban/suburban watersheds by both point source and nonpoint source pollutants, and reduction in water available for wildlife because of increasing demand for water resources by a growing populace.

4.3.1 Aquatic Resources

4.3.1.1 Alternative 1: No Action

Aquatic flora and fauna occurring in streams, creeks, and wetlands within the study area have developed and evolved in response to a variable flow regime. This regime is characterized by variable flows ranging from low flows during drought periods to high flows during periodic flooding events. In fact, most small streams in this region are considered seasonal or intermittent. Long-term deviations from historical flows to either considerably wetter or drier conditions would likely result in gradual as well as episodic changes to the aquatic communities, including the abundance and distribution of species.

Lower Barton Creek

The lower reach of Barton Creek extends a distance of approximately 0.5 mile between Barton Springs Pool and its confluence with the Colorado River; its flow is dominated by the combined discharge of individual springs in the Barton Springs complex. In years of average to above-average rainfall, effects of measures under Alternative 1 (No Action) to fish and aquatic invertebrate communities in the stream channel and to the high-quality riparian corridor would be negligible because the volume of springflow would be sufficient to maintain optimum habitat conditions and stability of the riparian corridor. In years of below-average rainfall or during drought conditions, reduced springflow would decrease the volume of instream flow below Barton Springs Pool. However, under Alternative 1, minimum average monthly springflow of 11 cfs would occur less than 1 percent of the time, and would never drop below 10 cfs. Under these conditions, the habitat of aquatic communities would be reduced but not completely eliminated. However, the extent and duration of reduced downstream flows could adversely affect the spatial coverage of aquatic habitat.

The existing streamside riparian community would not likely change under POR conditions, However, the extent and duration of droughts could result in a reduced water table along the banks of the streambed which could induce stress to established trees and shrubs within the riparian corridor (Stromberg et al. 2010).

Other Creeks

Alternative 1 would have minimal or no effects to aquatic resources in creeks and streams and associated riparian corridors throughout the study area, as flows would be dominated by the combined effects of regional and localized runoff.

4.3.1.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

Lower Barton Creek

In years of average to above-average rainfall, effects of measures under Alternative 2 to fish and aquatic invertebrate communities and to the riparian corridor associated with lower Barton Creek would be similar to Alternative 1. In years of below-average rainfall or during drought conditions, potential adverse effects under Alternative 2 would be slightly greater. Under Alternative 2, the lowest monthly springflow recorded during the DOR (11cfs) would be reached about 4 percent of the time. Springflow could fall to 6.5 cfs but the frequency of occurrence would be less than 1 percent over the POR, while complete cessation of springflow during conditions similar to the DOR would not be expected. Downstream flow would still occur under DOR conditions, but would be substantially diminished in volume and could be lower than what historically occurred during the DOR. The extent and duration of reduced downstream flows could adversely affect the spatial coverage of aquatic habitat. Similar to Alternative 1, a reduced water table along the banks of the streambed could also result in stress to established trees and shrubs within the riparian corridor.

Other Creeks

Similar to Alternative 1, during years of average to above-average rainfall, effects of Alternative 2 on aquatic resources in other creeks, streams, and associated riparian corridor throughout the study area would be minimal as flows would be dominated by the combined effects of regional and localized runoff. Under Alternative 2, during years of low rainfall or during drought conditions, recharge enhancement features to divert streamflow into the Aquifer in the recharge zone (**Measure 7.1**, **Table 2-1**) could affect downstream aquatic communities by reducing flows directly downstream of the structures. This reduced flow would adversely affect aquatic stream communities by reducing the availability of pool, riffle, and stream habitat.

Effects of Alternative 2 on aquatic resources in other creeks and streams not affected by recharge enhancement features would be minimal to low, similar to Alternative 1.

4.3.1.3 Alternative 3: Water Demand Reduction

Lower Barton Creek

In years of average to above-average rainfall, effects of Alternative 3 on fish and aquatic invertebrate communities would be minimal, similar to Alternatives 1 and 2. In years of below-average rainfall or during drought conditions, flow of lower Barton Creek would be sustained by springflow enhanced by mandated pumping reductions, ensuring flows equivalent to those existing during the DOR. Preservation of springflow would also allow flows within lower Barton Creek, providing positive benefits to aquatic vertebrate and invertebrate communities and to the riparian corridor dependent on these flows.

Other Creeks

During years of normal-to-high rainfall, effects of Alternative 3 on aquatic resources in creeks and streams throughout the study area would be minimal, similar to Alternatives 1 and 2. During periods of low rainfall or drought conditions, effects of Alternative 3 on aquatic resources in other creeks and streams would be minimal to low, similar to Alternative 1.

4.3.1.4 Alternative 4: Water Supply Augmentation and Substitution

Lower Barton Creek

In years of average to above-average rainfall, effects of Alternative 4 on fish and aquatic invertebrate communities would be minimal, similar to Alternatives 1, 2 and 3. In years of below-average rainfall, flow of lower Barton Creek would be sustained by springflow resulting from reduced pumping under Alternative 4, ensuring flows equivalent to those existing during the DOR, similar to Alternatives 1, and 3. Preservation of springflow would also allow flows within lower Barton Creek, providing positive benefits to aquatic vertebrate and invertebrate communities and to the riparian corridor dependent on these flows.

Other Creeks

Similar to Alternatives 1, 2, and 3, during years of average to above-average rainfall, effects of Alternative 4 on aquatic resources in creeks and streams throughout the study area would be minimal. During periods of low rainfall or drought conditions, effects of Alternative 4 on aquatic resources in other creeks and streams in the study area would be minimal to low, similar to Alternatives 1, and 3.

4.3.2 Terrestrial Resources

Reductions in pumping and subsequent changes in springflow under each of the four dEIS alternatives would have minimal or no direct affects on terrestrial habitats within the study area. Changes to the terrestrial flora and fauna within the study area are being caused primarily from growth-induced effects related to changes in the pattern of land use, population density and growth rates, all of which could be affected by pumping reductions and/or availability and development of alternative water supplies. Such changes would be considered indirect effects as discussed in **Section 5.1** and **subsection 5.2.5.3**.

4.3.3 Regional Threatened and Endangered Species

Some adverse impacts to regional threatened and endangered species and their habitats could occur under all of the alternatives. Under each of the four alternatives, minimal impacts would be expected to occur to the state-listed Wood Stork, Zone-tailed Hawk, and Bald Eagle, and the federally and state-listed Whooping Crane. These species are highly mobile, and are considered uncommon or rare visitors to the area and would not be directly dependent on any habitat within the study area.

The federally and state-listed black-capped vireo and golden-cheeked warbler are migratory species that nest in the study area during spring and summer. Urban and suburban development supported by all of the alternatives could have potential direct effects on loss of habitat; however, habitat loss covered under an ITP in the principal counties in the study area could be offset by ongoing HCPs that have been implemented to conserve habitat of these species. Over the 20-year ITP term, development outside the study area would not differentiate impacts among the alternatives. Consequently, minimal impacts from all of the alternatives would be expected.

Of the six federally listed karst invertebrates in Travis County, only the Bee Creek Cave harvestman has been confirmed within the study area. However, the other five species could potentially occur. Reduction in groundwater levels under each of the four alternatives (with less reduction in groundwater levels under Alternatives 1, 3, and 4) could indirectly influence habitat conditions (hotter and drier) for these karst species. The extent to which each alternative could impact these species is not known because the influence of Aquifer levels on the life requirements of these species is unknown.

The state-listed Texas horned lizard and timber/canebrake rattlesnake have been reported to occur within counties located in the study area. Increased urban and suburban development supported by all four alternatives could have potential adverse effects on these species through loss of habitat.

Impacts to the state-listed blue sucker (occurring principally in the Colorado River and possibly lower Barton Creek which connects to the Colorado River) are not expected as some flow in Lower Barton Creek would be maintained under any of the alternatives under DOR conditions.

Potential impacts of each of the four alternatives to mussel species would occur only through lower aquifer levels and resulting reduction in springflow at Barton Springs. Based on the current distribution information for mussel species listed as state-threatened or candidates for Federal listing (indicated in **Table 3-3),** only one species, the Texas fat mucket (*Lampsilis bracteata*), could potentially occur near Barton Springs. Potential habitat is within a 0.53-mile segment of Barton Creek, between the dam at Barton Springs Pool and its confluence with the Colorado River (Lady Bird Lake). If the species is present within this segment of Barton Creek, only a small portion of total potential habitat for this species (in comparison to other areas within the Colorado and Guadalupe Rivers where it could occur) is located within this short reach. Consequently, low flows resulting from decreased spring discharge under any of the alternatives would be expected to result in negligible impacts to this species. Further, any low flows and resulting potential impacts would likely be mitigated by releases from Barton Springs Pool during the City of Austin's periodic cleaning activities and backflow influences of Lake Bird Lake, which is managed as a constant level reservoir even during drought periods through regular releases from Lake Travis and Lake Austin.

4.3.4 Covered Species

This section describes effects of the four alternatives on the Covered Species, the Barton Springs salamander and Austin blind salamander.

4.3.4.1 Alternative 1: No Action

Alternative 1 would not be expected to significantly affect the Barton Springs salamander or Austin blind salamander under the normal range of precipitation and recharge conditions. However, during periods of severe drought similar to conditions that occurred during the DOR, this alternative would be expected to result in potentially moderate salamander mortality for short periods of time (**Table 4-2**) and negative impacts on their habitats, up to and including ecosystem-level adverse effects. Flows of clean spring water with a relatively constant, cool temperature are essential to maintaining well-oxygenated water necessary for salamander respiration and survival. The reduction of flow at the Barton Springs complex during a severe drought would adversely affect the salamanders by reducing flowing waters, increasing water temperature, and reducing the amount of dissolved oxygen in the Aquifer and discharging spring water necessary for the species' survival (see **subsection 3.3.7.2**). Increasing concentrations of dissolved solids (salinity) are also associated with decreasing flow. High conductivity (used to approximate salinity in aquatic and terrestrial environments) has been associated with detrimental effects on aquatic salamanders (USFWS 2016a). During severe droughts, the relative contribution of older, more saline and less oxygenated water from other parts of the Aquifer increases compared to surface recharge and alters overall water chemistry (Mahler and Bourgeais 2013) with currently unknown effects to the Covered Species. While such water chemistry changes tied to reductions in flow are natural occurrences, pumping of groundwater by entities authorized by the District accelerates and deepens drawdown of the Aquifer. Pumpage and springflow are related on a 1:1 basis during extreme and exceptional droughts. Discharge at Barton Springs decreases monotonically (always decreases, never remaining constant) as Aquifer water levels drop and the amount of groundwater in storage in the Barton Springs segment of the Edwards Aquifer decreases. Under Alternative 1 during POR conditions, discharge at Barton Springs would never fall below 10 cfs (**Table 4-2**).

DO concentrations differ somewhat among the spring outlets and are directly related to springflow (COA 2013a). At the larger outlets of Barton Springs, DO ranges between 4 and 7 mg/L and averages approximately 6 mg/L (COA 2013a). Average DO is highest in Upper Barton Springs, followed by Main, Eliza, and Old Mill Springs (COA 2013a). Sustained lower DO concentrations occur primarily during periods of moderately low spring discharge. Upper Barton Springs, which provides habitat for the Barton Springs salamander, goes dry when the combined discharge from the Barton Springs complex falls below approximately 40 cfs. At that point, Barton Springs salamanders are no longer found at that location. During droughts, groundwater discharge at Eliza and Old Mill Springs declines to less than 2 cfs and 1 cfs, respectively (COA 2013a). With near no-flow conditions at Old Mill Spring, Barton Springs salamander reproduction appears to cease, food becomes scarce, and seasonal higher temperatures in the surface environment causes mortality from respiratory distress (COA 2013a).

Prior droughts, during which flow at Barton Springs fell below 25 cfs (COA 2013a), have been accompanied by decreases in flow velocity and biologically significant decreases in dissolved oxygen and increases in water temperature (COA 2013a). During these times, Barton Springs salamanders experienced steep reductions in abundance and curtailment of reproduction and recruitment; the Austin blind salamander largely disappeared from surface habitat (COA 2013a). Increases in water temperature have also been associated with detrimental effects on other

Edwards Aquifer perennibranchiate *Eurycea* and it is reasonable to assume that Barton Springs' *Eurycea* could be similarly affected (COA 2013a).

Experimental work appears consistent with observations of the City of Austin. Woods et al. (2010) reported the onset of activity (to seek higher DO levels) in the closely-related San Marcos salamander when DO fell to a range between 5.5 and 2.7 mg/L in their experiments. They reported that the DO at which 50% of the salamanders became active was 4.54 mg/L. That DO threshold corresponds to predicted concentrations of DO below the long-term average discharge at the Barton Springs Complex of 53 cfs (BSEACD 2017). Woods et al. (2010) also calculated the LC_5 (concentration at which 5% mortality occurs) for the San Marcos salamander at a DO concentration of 4.5 ±0.5 mg/L (see **Table 4-2**). DO is predicted to fall to 5.0 mg/L at Old Mill Spring (within the upper range of LC_5) when springflow at the Barton Springs complex is 30 cfs (BSEACD 2017) (see **Table 4-2**). Under Alternative 1 this level would be reached about 25 percent of the time. The upper limit of the LC_{10}, 4.5 mg/L, is predicted to occur at Eliza Spring when discharge at the complex reaches 20 cfs (occurring about 10 percent of the time). The upper limit of the LC_{25}, 3.8 mg/L, is predicted to occur at Main Spring and Eliza Spring when discharge at the complex reaches 12 cfs. This would occur about less than 1 percent of the time during conditions similar to the DOR (see **Table 4-2**). The upper limit of the LC_{50}, 3.6 mg/L, is predicted to occur at Main Spring when discharge at the complex reaches 10 cfs. Under Alternative 1 this level would never be reached (see **Table 4-2**).

4.3.4.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

As described for Alternative 1, the major pathway of stress on the Covered Species is through reduced springflow, increased water temperature, and decreased DO concentration. Similar to Alternative 1, DO under Alternative 2 (the proposed action) is predicted to fall to 5.0 mg/L at Old Mill Spring (within the upper range of $LC_{5)}$ when springflow at the Barton Springs complex is 30 cfs (BSEACD 2017) (see **Table 4-2**). Under Alternative 2 this level would be reached about 36 percent of the time. The upper limit of the LC_{10}, 4.5 mg/L, is predicted to occur at Eliza Spring when discharge at the complex reaches 20 cfs (occurring about 20 percent of the time). The upper limit of the LC_{25}, 3.8 mg/L, is predicted to occur at Main Spring and Eliza Spring when discharge at the complex reaches 12 cfs. This would occur 5 percent of the time during conditions similar to the DOR (see **Table 4-2**). The upper limit of the LC_{50}, 3.6 mg/L, is predicted to occur at Main Spring when discharge at the complex reaches 10 cfs. This would occur about 3 percent of the time during conditions similar to the DOR (**see Table 4-2**). Under a repeat of the drought of record conditons, all three perennial springs are predicted to have DO levels at or below LC_{50}, with potential mortality of 50 percent when springflow reaches 6.5 cfs. However this would occur less than 1 percent of the time (**see Table 4-2**), and the springs would never cease flowing.

The HCP under Alternative 2 identifies 25 direct measures among 8 different categories to minimize take of the Covered Species (See **Table 2-1** in **Section 2.4**). These categories include: 1) methods to maintain efficient use of groundwater; 2) controlling and preventing groundwater waste; 3) promoting conjunctive surface water management; 4) protecting the natural resources of the aquifer; 5) developing and implementing measures to address drought conditions; 6) reducing the demand for groundwater through conservation; 7) enhancing groundwater supply through structural enhancement; and 8) implementing measures to statutorily address Desired Future Conditions. In addition, there are several indirect measures that would be implemented under Alternative 2 that would involve other parties. This includes research to better inform and determine the level of risk associated with springflow-related changes in water chemistry affecting the health of the Covered Species, development of better models to predict changing conditions of the aquifer, supporting operations of existing refugium and studies on physiology and behavior of the Covered Species; conducting feasibility studies of subsurface dissolved oxygen augmentation; extending future operations of the Antioch Recharge Enhancement Facility; establishing a fund for plugging abandoned wells; and providing leadership and guidance to other entities whose actions would significantly affect the quantity or quality of the Aquifer's groundwater. Although the benefits that all of these measures would provide would be very difficult, if not impossible to quantify, taken collectively, implementation of all of the measures would represent a multi-level array of increased protection for the Covered Species. Although Aquifer withdrawals under Alternative 2 could, during brief periods of time, generate the highest level of risk for potentially negative biological impacts among the four alternatives. This risk would occur only rarely (less than 1% of the time) during conditions similar to the period of record (See **Table 4-2**), and any potentially adverse impacts would be mitigated by a variety of protection measures involving more efficient use and management of groundwater, preventing groundwater waste, providing greater Aquifer protection through conjunctive use of surface water, protecting the natural resources of the Aquifer, planning for and addressing drought conditions, reducing groundwater demand, enhancing groundwater supply, and implementing measures to statutorily address Desired Future Conditions (See **Table 2-1** in **Section 2.4**). The commitment for pumping restrictions during drought conditions under Alternative 2 would be firm and reliable, and would be accompanied by other Aquifer protection measures that would minimize impacts to the Covered Species as indicated in **Table 2-1**. Alternative 2 is more practicable and feasible than Alternative 1, which assumes pumpers would voluntarily reduce or even stop aquifer withdrawals during severe drought conditions; and Alternative 3, which requires nearly complete curtailment of Aquifer pumping through regulatory mandate and enforcement; and Alternative 4, which eventually eliminates aquifer withdrawals by assuming development and implementation of future alternative water supplies sufficient to completely offset the aquifer withdrawals. In summary, Alternative 2 appears more feasible than Alternatives 1, 3, and 4, because it contains comprehensive aquifer protection measures that can be reasonably and realistically implemented, including pumping reductions that can be regulated and enforced. Additionally, Alternative 2 does not rely on critical assumptions inherent to the other alternatives (Alternative 1 assumes aquifer pumping reductions will be achieved through voluntary actions of pumpers even during severe drought; Alternative 3 assumes complete curtailment of Aquifer pumping through mandate and enforcement would be politically acceptable; Alternative 4 assumes aquifer pumping can be eventually eliminated by the development and implementation of sufficient substitute water supplies).

4.3.4.3 Alternative 3: Water Demand Reduction

Alternative 3 would restrict permitted pumping through mandated reductions to achieve habitat protection goals, that is, monthly discharge at Barton Springs that would not fall below 11 cfs, the lowest level previously recorded during the DOR. Similar to Alternative 1, this alternative would maintain springflows that are more protective of the Covered Species than Alternative 2 during DOR conditions. Under Alternative 3, predicted lethal concentration limits at springflow threshold levels would occur less often than Alternative 2. As with Alternative 1, predicted mortality of 25 percent at a springflow of 12 cfs would occur less than 1 percent of the time for the Barton Springs salamander in comparison to 5 percent under Alternative 2. Fifty percent mortality would never be reached as springflow would not decline to 10 cfs under Alternatives 1 and 3 as would occur under Alternative 2 (**Table 4-2**). Alternative 3 does not incorporate habitat or water quality measures included under Alternative 2, thus associated mitigation benefits expected under Alternative 2 would not be realized under this alternative. However, Alternative 3 ensures a higher average monthly springflow (11 cfs) during DOR conditions than Alternative 2.

4.3.4.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 is similar to Alternatives 1 and 3 in that it would maintain springflows that are most protective of the salamanders during DOR conditions. This alternative provides for construction of water supply projects that would serve as an alternative to groundwater pumping in order to minimize and mitigate potential impacts to the salamanders and their habitats. This alternative could result in adverse environmental effects associated with the construction, operation and maintenance of required infrastructure. Pumping restrictions to achieve 11 cfs of springflow would be required while water supply projects were being developed. The indirect and cumulative effects to the Covered Species resulting from the proposed pumping restrictions and developing alternative water sources for human use are currently unknown.

4.4 SOCIOECONOMIC RESOURCES

Environmental consequences to the community resources in the study area identified and described in **Section 3.4** are presented in this section for each of the four dEIS alternatives. Accordingly, this section describes the direct impacts related to population trends, minority populations, low-income populations, and community resources.

Several studies were referenced in order to evaluate the socioeconomic impacts of each of the alternatives. These studies are summarized below.

District Habitat Conservation Plan

The District HCP for Managed Groundwater Withdrawals from the Barton Springs Segment of the Edwards Aquifer presents several regulatory and managerial conservation measures to be implemented by the District in support of an application for an ITP for the Barton Springs salamander.

Included in the HCP for proposed Alternative 2 are select measures that attempt to balance human water use with the need to maintain springflow to conserve endangered species habitat. Conservation measures that could potentially impact socioeconomic resources are listed in **Table 4-3**.

Alternative Water Supplies for the Barton Springs Segment of the Edwards Aquifer and for the Region

The Barton Springs/Edwards Aquifer Conservation District (District) published a report in 2012 outlining sources of water which could be used as alternatives to historically permitted withdrawals from the Barton Springs portion of the Edwards Aquifer. The report was a response to the recognition that historical maximum pumping rates occurring during extreme drought conditions, in absence of available alternative supplies for substitution, may not have maintained safe flows at Barton Springs for the Covered Species. Each identified water source was recommended for further feasibility evaluation. Potential sources of alternative supplies in the event of pumping restrictions or limitations include:

- Edwards Aquifer saline zone (desalination)
- Aquifer storage and recovery
- Middle and Lower Trinity Aquifers
- Surface water
- Groundwater from outside of the District
- Reclaimed wastewater
- Rainwater harvesting
- Natural recharge enhancement
- Recharge enhancement with externally sourced water
- Weather modification

The report assessed only the first three of the above listed strategies, as the other sources are mainly alternatives to be pursued by individual water supply providers and well owners (Smith et al. 2012). However, one or more of the above strategies may be evaluated as part of the process of addressing conjunctive surface water management issues included under Alternatives 2 and 4 (Measures 3.1, 3.2, and 3.3 (see **Table 2-1**).

Water Strategies Identified in the 2011 Region K Water Plan

The LCRWPG represents Region K, which is one of 16 regional water planning groups established by the TWDB. Each of the 16 planning groups was tasked with creating a Regional Water Plan, which, among other things, projects future water supply and demand over a 50-year planning window. Each regional plan was analyzed to ensure feasibility and consistency on a statewide level, and eventually consolidated to serve as the foundation of the State Water Plan. Within this framework, Region K's operative planning area is mostly situated in the Lower Colorado River Basin and encompasses all or part of 14 different counties, including: San Saba, Burnet, Llano, Mills, Blanco, Gillespie, Hays (partial), Williamson (partial), Travis, Bastrop, Fayette, Wharton (partial), Colorado, and Matagorda. Currently, there are 25 voting members on the water planning board for Region K representing different interest groups throughout the river basin. Below are four water management strategies and their associated costs as identified in the 2011 Region K Plan (LCRWPG 2010) that appear to be the most feasible under Alternative 4:

- **Aquifer Storage Recovery (ASR)**. Region K estimated a cost of $3,802.48/ac-ft for water from ASR wells located on the Carrizo-Wilcox in Bastrop County. Assumptions used in the cost analysis include: 2 miles of transmission pipeline to convey the raw water from the diversion point to a 20 mgd traditional lime softening water treatment plant; a high service pump station to feed the treated water through a 20-mile, 36-inch pipeline to the ASR well field for storage; and, twelve 16-inch wells spaced one-mile apart and completed to a depth of 652 feet, that store at a rate of 850 gpm and recover at a rate of 1,000 gpm. Total project costs are estimated at $270,627,490 with $168,711,000 of that being capital costs.
- **Edwards-BFZ Aquifer Brackish Groundwater Desalination**. Region K estimated a cost of $978.67/ac-ft for water from brackish groundwater desalination located over the Saline Zone of the Edwards-BFZ Aquifer in eastern Travis County. There are six assumed potential capital expenditures: drilling and installation of the required additional wells (including pump station), installation of a one-mile well collection line(s), a 1-mile distribution pipe, a pump station, a water treatment plant, and a brine disposal system. Additional project costs include: engineering, contingencies and legal services (35%); land acquisition (5 acres per well at $5,000/acre); and, environmental and archeological studies, mitigation, and permitting (assumed equal to the land acquisition cost). There are three water user groups (WUG) associated with this strategy. The WUG specified as "County-Other" in the plan that includes the Barton Springs area has a total project cost of $23,393,343 with $16,693,491 of that being capital costs.
- **Groundwater Importation**. Region K estimated a cost of $1,330/ac-ft for raw water delivered from outside the planning area and Colorado River basin to an area in eastern

Travis County. The basic infrastructure required for this strategy include production wells, collection piping and other well field facilities, as well as an approximately 80-mile conveyance pipeline and pump station. The conceptual well field was assumed to be located in Burleson County and the conceptual delivery point was assumed to be located at approximately SH 130 and the Colorado River. Groundwater acquisition was assumed to be leased and annual payments are included in the operation and maintenance costs. The estimated development cost is approximately $395.9 million.

- **Water Reclamation Initiative: Direct Reuse**. Region K estimated a cost of $851/ac-ft for reclaimed water. The City of Austin has established its central reclaimed water system location to be Walnut Creek Wastewater Treatment Plant (WWTP) and its south system location to be South Austin Regional WWTP. Austin has also evaluated the feasibility of developing reclaimed water facilities in other areas of the City. Capital Costs for the project are $302,250,510 and include: plant pump station, storage, transmission system, system pumping and storage, and miscellaneous improvements. Other project costs include: land acquisition and survey, engineering, contingencies and legal services, environmental and architectural studies, mitigation, and permitting. The total project cost is estimated at $429,195,724.

The District has established state-mandated DFCs, which include the following: (1) an effective upper limit of 16 cfs on all pumping from the Edwards Aquifer, and (2) a lower limit of 5.2 cfs on pumping that would be allowed during DOR conditions. Having a continual flow of 16 cfs equals approximately 11,583.5 acre-feet per year and 5.2 cfs equals approximately 3,764.6 acre-feet per year. Using Region K's above water supply strategies and cost estimates to provide water to offset 16 cfs of pumping would cost approximately: $44,046,027.08 annually for ASR, $11,336,423.95 annually for brackish groundwater desalination, $15,406,055 annually for groundwater importation, and $9,857,558.50 annually for direct reuse. Using the Region K water supply strategies and cost estimates cited above to provide water to offset 5.2 cfs of pumping during DOR conditions would cost approximately: $14,314,816.21 annually for ASR, $3,684,301.09 for brackish groundwater desalination, $5,006,918 annually for groundwater importation, and $3,203,674.60 annually for direct reuse.

Implementation of alternative water supply strategies under any of the four dEIS alternatives would require considerable financial investments that would in turn impact socioeconomic resources. Although the Edwards Aquifer saline zone has the potential to provide substantial water for the area, the construction of a desalination plant would be expensive and the estimated time frame for completion would exceed the immediate need for alternative water supplies. Aquifer storage and recovery could be used to store water for future use; however, wells would be more costly due to the required storage depth and protective well construction (Smith et al. 2012).

These alternative water sources, although viable, would have substantial socioeconomic impacts as water will become more expensive under these alternatives. The expected high cost of developing alternative water supplies would have an impact on the population of the project area as some, if not all, of the construction costs and debt payments would likely be passed along to consumers, in part, through increased water rates. The Texas Municipal League (2017) reports that the average residential fee for 5,000 gallons of water within the Austin metropolitan area more than doubled, from more than $17.56 per month to $38.24, between 2011 to 2016. Much of the cost is attributed to the payment of debt on the development of previously constructed infrastructure. Although the effects of construction costs and subsequent debt payment for the alternative water supplies on water rates within the study area cannot be quantified at this time, it is assumed that costs for water within study area could increase substantially, if similar to the recent rate increases in Austin. However, the effects of increased rates felt by individual users would potentially lessen over time as the population continues to grow and, subsequently, costs associated with construction and debt payment become more widely dispersed. Additionally, the anticipated population growth in the study area would be expected to be supported by these alternative water supplies.

dEIS Alternative Measures Applicable to Socioeconomic Resources

Aquifer management measures included in one or more of the dEIS alternatives (summarized in **Table 2-1**) that would potentially impact socioeconomic resources are listed in **Table 4-3** and are discussed below. Three additional measures involving reduced aquifer withdrawals under Alternatives 1, 3, and 4 are also included. Only those measures that distinguish the alternatives (i.e., do not occur under all four alternatives) are included in the evaluation.

Table 4-3. dEIS Alternative Measures Potentially Impacting Socioeconomic Resources

Conservation Measure Number	Applicable Alternative	Description of Measure	Expected Effects of Measure on Socioeconomic Resources*
1.4	Alternative 2	Develop and maintain programs that inform and educate citizens of all ages about groundwater and springflow-related matters, which affect both water supplies and salamander ecology.	No adverse effects because water use would not be directly affected.
2.2	Alternatives 1, 2, and 3	Ensure permitted wells and well systems are operated as intended by requiring reporting of monthly meter readings, making periodic inspections of wells, and reviewing pumpage compliance at regular intervals that are meaningful with respect to the existing Aquifer conditions.	Minimal to low adverse effects as these measures would increase the efficiency of monitoring aquifer withdrawals.

Conservation Measure Number	Applicable Alternative	Description of Measure	Expected Effects of Measure on Socioeconomic Resources*
3.2	Alternatives 2 and 4	Encourage and assist District permittees to diversify their water supplies by assessing the feasibility of alternative water supplies and fostering arrangements with currently available alternative water suppliers.	Potentially low to high adverse impacts depending on the cost of development of alternative water supplies passed through to consumers.
5.2	Alternatives 2 and 4	Implement a drought management program that step-wise curtails Aquifer use to at least 50% by volume of currently (2014) authorized aggregate monthly use during Extreme Drought, and that designs/uses other programs that provide an incentive for additional curtailments where possible (for example, cap-and-retire of historical production permits, accelerated and/or larger severe drought curtailments in exchange for additional authorized use during non-drought periods.	Potentially moderate to high adverse impacts depending on the demand for water during drought conditions.
7.1	Alternative 2	Improve recharge to the Aquifer by conducting studies as engineering feasibility is established and allowed by law (subject to rules and /or approval by TCEQ or City of Austin if within certain locations within the study area), physically altering (cleaning, enlarging, protecting, diverting surface water to) discrete recharge features that will lead to an increase in recharge and water in storage beyond what otherwise would exist naturally.	Potentially low to moderate beneficial impacts by increasing water recharged to the aquifer.
7.2	Alternatives 2 and 4	Conduct technical investigations and, as engineering feasibility is established, assist water supply providers in implementing engineered enhancements to the regional supply strategies, including desalination, Aquifer storage and recovery, and effluent reclamation and re-use, to increase the options for water-supply substitution and reduce dependence on the Aquifer.	Potentially moderate to high adverse impacts depending on costs of engineered enhancements to regional water supply strategies that would be passed through to water consumers.

Conservation Measure Number	Applicable Alternative	Description of Measure	Expected Effects of Measure on Socioeconomic Resources*
8.2	Alternative 2	Adopt rules that restrict to the greatest extent practicable, and as legally possible, the total amount of groundwater withdrawn monthly from the Aquifer during Extreme Drought conditions in order to minimize take and avoid jeopardy of the Covered Species as a result of the Covered Activities, as established by the best science available. This is established as a limitation on actual withdrawals from the Aquifer to a total of no more than 5.2 cfs on an average annual (curtailed) basis during Extreme Drought, which will produce a minimum springflow of not less than 6.5 cfs during a recurrence of the DOR.	Potentially moderate to high adverse impacts due to mandated water reductions during drought periods.
**	Alternative 1	Voluntary pumping reductions of pumping withdrawals during declared drought to levels that would assure survival of the Covered Species. This would establish a total pumping limit of less than 1 cfs to provide a minimum monthly spring flow of 11 cfs during DOR conditions	Potentially high adverse impacts due to severely curtailed water use during periods of highest water demand.
**	Alternative 3	Adopt mandatory drought reduction rules that would restrict the total amount of groundwater withdrawn monthly during extreme drought to a level that would assure survival of the Covered Species during drought of record conditions. This would establish a total pumping limit of less than 1 cfs to provide a minimum monthly springflow of 11 cfs during DOR conditions	Potentially high adverse impacts due to severely curtailed water use during periods of highest water demand.
**	Alternative 4	Develop and implement water supply strategies that would result in augmenting or substituting withdrawals from the aquifer with water from other sources in order to reduce withdrawals to less than 1 cfs to provide a minimum monthly springflow of 11 cfs during DOR conditions	Initially, same effects as Conservation Measure 8.2 until Alternative Water Supplies are developed, then potentially high costs accrued from development of regional water supply strategies that would be passed through to water consumers; negative effects in higher costs of water would likely be attenuated with continued economic growth sustained by the development of additional water supplies.

Conservation Measure Number	Applicable Alternative	Description of Measure	Expected Effects of Measure on Socioeconomic Resources*

*Categories of Socioeconomic Effects: Low (Minor) – Effects would be small but measurable with little overall impact on socioeconomic resources. Moderate – Effects would be readily apparent and widespread, but would not substantially affect socioeconomic resources. High (Major) – Effects would be readily apparent and substantially change the economy or social services.
**Additional measures that would potentially have major socioeconomic impacts.

The magnitude of the impacts of the measures in **Table 4-3** would vary depending on whether the impacts would directly affect pumpers, water suppliers, or end users. Measures that would most affect available water supplies (**Measures 3.2, , 7.1, 7.2**, and **8.2**), in addition to voluntary pumping reductions under Alternative 1, mandated pumping reductions under Alternative 3, and augmentation/substitution of other water supplies under Alternative 4, if implemented, could have impacts on population trends, minority and low-income populations, and community resources.

4.4.1 Population Effects

As discussed in **subsection 3.4.1.2**, population estimates for the five principal counties in the study area determined total population growth between 2000 and 2010 to be approximately 29.3 percent, or 296,000 people. In addition, population projections detailed in **subsection 3.4.1.3** estimate an increase in the population in the study area of approximately 105 percent, or 1.7 million people, between the years of 2020 and 2070. Based on the projected population growth rate, it is anticipated that the region will experience not only an increased cost of water, but will also face limitations in water use based on drought conditions.

4.4.1.1 Alternative 1: No Action

Under Alternative 1, the District would manage and regulate pumping only during non-drought conditions. Maximum allowable pumping would be limited to 16 cfs. The District would notify permittees of approaching drought and issue notices to stop pumping once drought is declared. Pumping reductions would depend on voluntary compliance from pumpers. If voluntary pumping reductions are not made after notification by the District at the onset of a declared drought and take of the Covered Species begins to occur, individual permittees would be subject to violations of the ESA, unless individual ITPs were obtained.

Voluntary cessation of aquifer pumping would potentially reduce groundwater use in the study area through conservation, drought management, localized regulatory requirements, and reliance on alternative water supplies. However, the reduction of nearly all Aquifer pumping during prolonged drought conditions would eventually imply a limit on the potential population growth if alternative water sources could not be developed and made available. This could result in substantial adverse impacts to pumpers, water users, other entities within the the study area, and the general population due to potential water shortages. Such impacts would last until substitute water supplies could be developed. Although eventual development of supplemental water supplies is not included as a direct action or measure under Alternative 1, such development could result in potentially high indirect costs and associated economic impacts.

Such an outcome could have negative effects on approximately 70,000 people dependent on the Aquifer in addition to 24 different water utilities that are authorized to pump water from the Aquifer (BSEACD 2017). It is assumed that the need to assure the public health and safety of citizens would necessitate the provision of alternative water supplies, thereby avoiding, albeit at increased cost, these potential negative impacts.

In summary, impacts of Alternative 1 on the population within the study area are expected to be moderate to high.

4.4.1.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping under the District HCP

With the issuance of an ITP and aquifer management under the District's HCP, aquifer pumping would be limited during DOR conditions to no more than 5.2 cfs. This alternative would allow management of the Aquifer to address state-mandated DFCs. To address future growth, Alternative 2 would eventually require the development of alternative water supplies at higher costs, resulting in higher costs for new development in the project area in order to ensure adequate water supplies are available. However, because the volume of developed alternative water supplies would be reduced by the groundwater withdrawals allowed under Alternative 2, these additional costs are not expected to greatly impact existing populations or deter overall population growth in comparison to the other alternatives.

Measures 1.4, 2.2, 3.2, 5.2, 7.1, **7.2** and **8.2** listed in **Table 4-3** would mitigate take of Covered Species by improving existing District monitoring programs and implementing a drought management program that reduces groundwater withdrawal in the study area. These measures would serve to protect springflow during drought conditions by providing additional water to the springs equivalent to the amount of water cut back from pumping (see discussion on Aquifer Discharge in **subsection 3.1.1.6**). However, the resultant restricted use of groundwater under Measures 5.2 and 8.2 would have the effect of reducing the period and volume reliability of groundwater supplies to residential, commercial, and industrial users in the study area during critical, exceptional, and emergency drought stages, and would require the development of alternative water supplies to supplement available supplies during the drought stage reductions. This would involve additional site development costs and could decrease the attractiveness for development of residential, commercial, and industrial locations in the study area when compared to competing locations with reliable surface water supplies already in place. Alternative 2 would encourage the diversification of water sources to avoid future water shortages that would limit population growth.

In summary, while the impacts of Alternative 2 on those portions of the population relying on water pumped from the aquifer would be moderate to high in the absence of alternative water supplies during worst drought conditions, the future development of alternative water supplies would greately ameliorate these adverse effects. The current and future availability of surface water transported into the study area via existing and future water transmission lines would result in low adverse impacts to the overall population within the study area.

4.4.1.3 Alternative 3: Water Demand Reduction

Alternative 3 requires the imposition of mandated pumping restrictions in order to provide springflow at Barton Springs equivalent to that occurring during the DOR. Such restrictions under DOR conditions would reduce aquifer pumping to less than 1 cfs. This would require the most stringent pumping restrictions among the four alternatives, essentially curtailing nearly all withdrawals from the Aquifer. Without the availability of alternative water supplies to make up for water that can no longer be pumped from the Aquifer, public and private entities that would relysoley on aquifer groundwater would be at risk of not being able to sustain critical needs or emergency services. Monetary compensation to landowners for highly restricted pumping could be required under court rulings which have upheld groundwater withdrawal as a property right and subject to compensation if restrictions rise to the level of a property taking. In this regard, Alternative 3 could result in substantial adverse impacts to pumpers, water users, other programs within the District, and the general population within the study area due to potential water shortages occurring until substitute water supplies could be developed to offset these impacts. Unless eventual supplemental water supplies (not included as a direct action or measure under Alternative 3) could be developed, population growth in the area could slow and decline. As a result of these possible effects, adverse impacts of Alternative 3 on the population could be high.

4.4.1.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would involve the identification of and support for development of alternative water supplies and conjunctive use as outlined in **Measures 3.2** and **7.2**. Although all of the alternatives would require some effort to implement alternative water supplies, Alternative 4 would require the highest level of development and implementation in comparison to Alternatives 1, 2, and 3. Until these other water supplies become available to completely offset groundwater withdrawals, some level of pumping restrictions would also be required.

Several studies have been conducted within the study area discussing the need for alternative water supplies based on the need for reduction of pumpage during times of drought. There are a number of alternative sources potentially available to the region within the study area; however, each has limitations (Smith et al. 2012). Alternative sources include desalination, reclaimed wastewater, rainwater harvesting, and aquifer storage, among other methods.

As it relates to population within the study area, the development of alternative water supplies is critical to sustain population growth; however, the planning horizon, permitting requirements, and financial investments required to develop many of the alternative water supplies would not necessarily make them available short-term. For example, the required time to plan, develop, and integrate a water project into existing infrastructure, such as a Aquifer Storage and Recovery (ASR) project, can require over a decade with substantial investment requirements (SAWS 2017). The current lack of alternative water supplies in the immediate future is not anticipated to have a great effect on population; but long term solutions which solely rely on alternative water supplies would imply higher incremental costs for new development, particularly if the alternative water supplies identified require higher amounts of energy to produce, store, and deliver. With the commitment to develop and fund alternative sources of water, the high costs of development of these projects could have moderate to high adverse impacts on the population because much of the increasing higher costs of these water projects could eventually be passed through to the water users via increased water utility rates. However, as discussed above, these impacts of increased rates on individual users would potentially lessen over time as the costs associated with construction and debt payment become more widely dispersed among a larger population. Additionally, the anticipated population growth in the study area would be expected to be supported by these alternative water supplies.

4.4.2 Minority and Low-Income Populations

During the last few decades, Federal agencies have been mandated to include environmental justice evaluations in project planning. Executive Order (EO) 12898 “Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations” requires each Federal agency to “make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations.”

According to population projections by the Texas State Data Center presented in **subsection 3.4.1.3**, the Hispanic demographic sector is expected to have the highest rate of population increase in most of the counties within the study area by 2050. In addition, according to 2012 American Community Survey census data, Hispanic and Black/African American populations in Travis and Hays Counties (the majority of the study area) had lower median household incomes and higher percentages of persons living below the poverty level than white populations.

Any increase in the cost of water to all water users could have disproportionate consequences on minority and low-income populations who must allocate a higher proportion of their budget to housing and utility costs. Approximately 11 percent of households in the five affected counties are low-income, and 49 percent of the population is considered minority (U.S. Census Bureau, 2010b).

The anticipated impacts for each of the alternatives are addressed below.

4.4.2.1 Alternative 1: No Action

Alternative 1 includes voluntary measures by permittees to restrict water withdrawals from the Aquifer to less than 1 cfs to maintain minimum springflows at Barton Springs during DOR conditions. Immediate effects from the water reductions, coupled with the cost of the development of any alternative water supplies needed to reduce future pumping demand, would likely result in adverse impacts to those segments of the population currently dependent on the Aquifer(including the minority and low-income populations). If eventual supplemental water supplies (not included as a direct action or measure under Alternative 1) are developed, this would potentially increase water bills as much of the cost of new infrastructure for water projects not funded by existing state or federal water development funds would be passed through to the water consumers. Although the potential increase in water rates associated with development of supplemental water supplies within the study area is not known, some water rates within the nearest major city (Austin) have more than doubled between 2011 and 2016 (Texas Municipal League 2017). If similar rate increases occur throughout the study area as a result of future development of new water supplies, this would potentially result in adverse impacts to minority and low-income customers, as a larger percentage of their income would be allocated to paying the increased water rates.

4.4.2.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping under the District HCP

Alternative 2 includes measures that would restrict Aquifer withdrawals to less than or equal to 5.2 cfs during DOR conditions. Because these withdrawal restrictions are substantially less severe than Alternatives 1, 3, and 4, anticipated economic costs associated with these restrictions to the regional population (including the minority and low-income populations) are expected to be low in comparison to Alternatives 1, 3, and 4.

4.4.2.3 Alternative 3: Water Demand Reduction

Under Alternative 3, the impacts to the regional population (including minority and low-income populations) would be greater than those under Alternative 2, as both the need and cost for alternative water sources would be higher. Costs for development of the alternative water supplies needed to meet water demand would be passed to consumers, resulting in higher water use rates that could have a disproportionate impact on the minority and low-income populations.

4.4.2.4 Alternative 4: Water Supply Augmentation and Substitution

Under Alternative 4, alternative water supplies would be used to supplement the loss of springflow during times of drought. As discussed in **Section 4.4**, measures to develop alternative water supplies would be costly. Financing of land, new infrastructure, debt service, and subsequent operation of alternative water supplies would likely be reflected in higher water use rates that could have a disproportionate impact on the minority and low-income populations. Similar to Alternatives 1 and 3, impacts of Alternative 4 to minority and low-income populations would be high.

4.4.3 Community and Public Resources

The four alternatives evaluated would have varying effects on community and public resources in the study area. Such resources would include governmental facilities and services including police and fire protection, medical services, schools, libraries and recreational facilities.

Direct effects of the alternatives on community and public resources would depend on the severity of pumping limits and reductions, types of resources involved, and location within the region. Within the overall types of community and pubic resources, little or no impact would occur to the functioning of governmental facilities, schools, libraries, medical services, museums, zoos, and botanical gardens. Limitations in the use of Aquifer groundwater that might result in reduced functioning of essential services could adversely affect human health or safety, or result in loss or degradation of public resources and would require the acquisition of supplemental alternative water supplies. Recreational facilities such as swimming pools, golf courses, and parks may be moderately or substantially affected depending on the pumping restrictions and water use limitations during drought periods. Landscapes associated with community and public resource infrastructure that include water fountains, grasses, trees, and shrubs could also be moderately to severely impacted by measures to reduce Aquifer water use.

While constructed recreational facilities may be adversely impacted, natural water-based recreation associated with the Aquifer, primarily swimming in Barton Springs and other water activities on lower Barton Creek, would be positively impacted by all measures to restrict Aquifer withdrawals. Recreation in Zilker Park, especially Barton Springs, affects local trade and service sectors, and contributes heavily to the community's perception of a high quality of life.

All four alternatives considered include restricting pumpage to levels that would eventually require the development of some supplemental water supplies. As mentioned above, the costs for land acquisition, construction, debt service, and operation of these water supply projects would require financing strategies and the long-term commitment of community financial resources in addition to end user cost recovery by private sector suppliers. The dedication of these public revenues for the duration of the required financing term would represent a substantial long-term commitment of community financial resources amounting to a new loss of economic benefits as community income would be diverted from other expenditures to pay for higher water rates needed to meet debt services, not to mention costs associated with operation and maintenance of the new facilities.

4.4.3.1 Alternative 1: No Action

Alternative 1 impacts on community and public resources would be moderate to high during DOR conditions and could even become severe if the water lost from the voluntary elimination of nearly all Aquifer pumping (less than 1 cfs) could not quickly be offset by other water sources. Should this happen, the operative capacity of public facilities including swimming pools, parks, libraries and governmental offices could be substantially reduced. Emergency services would likely need to be prioritized in terms of water allocation in order to ensure operations are maintained. Furthermore, the need for communities to maintain both an adequate water supply, as well as an operational water supply system, could be adversely affected depending on the availability and quality of other water sources.

4.4.3.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District HCP

Alternative 2 would establish withdrawal limits on pumpage that could potentially impose some impacts on community and public resources during DOR conditions. Community facilities would be faced with meeting higher water conservation needs and potentially having less available water to operate and maintain their facilities, particularly in regards to landscape irrigation. As a result, community facilities such as public swimming pools that are filled regularly and sports fields that require irrigation for summertime use and are dependent on groundwater could experience reduced hours of operation. Cities, water supply corporations and water districts in the study area could also impose watering schedules. In lieu of these regulations, demand for alternative water sources would increase. Under Alternative 2, essential community services including police, fire, medical and other emergency services would experience no substantial impacts, as it is assumed that these services would receive top priority in regards to water allocation, and water demand would be met using existing water sources.

Overall, Alternative 2 would have low adverse effects on community and public resources, except during periods of highly restricted pumping.

4.4.3.3 Alternative 3: Water Demand Reduction

Adverse impacts of Alternative 3 measures on community and public resources would be similar to Alternative 1, higher than Alternative 2 and could even be severe if the water lost from the virtual elimination of Aquifer pumping could not be quickly offset by the rapid substitution of other water sources. Under these circumstances, the operative capacity of public facilities including swimming pools, parks, libraries and governmental offices could be substantially reduced. As with Alternative 1, emergency services could be forced to rely on alternative water supplies and the need for communities to maintain both an adequate water supply, as well as an operational water supply system, could be adversely affected depending on the availability and quality of other water sources.

4.4.3.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would require the development of the highest level of alternative water supplies. The additional water supplies would be beneficial for community resources, allowing water usage to be maintained during periods of drought. However, costs associated with planning efforts and development of the water supply projects would result in incremental costs that would be passed onto community resources. Due to the long planning horizon required for development of some of the water supply strategies, Aquifer pumping would need to be restricted until adequate water supply strategies could be implemented to eventually offset Aquifer withdrawals. Pumping restrictions could adversely affect community resources short term, but such impacts would be reduced and eventually eliminated as alternative water sources become available.

4.4.4 Economic Impacts

As discussed in **subsection 3.4.2**, Austin is one of the top tourist destinations in Texas with Leisure and Hospitality being the fourth largest employment sector in the area. Recreational tourism is a popular industry in the city, with natural assets such as Barton Springs, Zilker Park, Deep Eddy, Lakes Travis, Austin and Walter Long, Lady Bird Lake, various hike-and-bike trails, parks and wilderness preserves creating a strong eco-tourism attraction for the city. Water-based recreation associated with the Edwards Aquifer, primarily swimming and canoeing, particularly affects the local trade and service sectors. The Barton Springs Pool, located in Zilker Park, is fed by water naturally discharging from the Barton Springs segment of the Edwards Aquifer. In 2013, an estimated 595,000 people visited Barton Springs Pool.

Potential economic impacts of the four alternatives will depend, to a substantial degree, on the regional economic context within which the alternative water management measures would be implemented.

Several major roadway and residential construction projects are ongoing within the project area. The availability, quality, reliability and cost of municipal and industrial water supplies to this potential growth area could have substantial repercussions for the future economic development of the study area. According to the Real Estate Center at Texas A&M, the Austin-Round Rock MSA saw a total of 21,000 housing units authorized by building permits in 2013 (Real Estate Center at Texas A&M 2014). The number of residential housing building permits is more than double the number issued from 2008 to 2011 (Kerr 2013). As of January 2013, an estimated 48 projects were under construction or within the planning stages within the downtown Austin area (COA 2013b).

The growth pole theory is generally defined as a group or cluster of industries that are centered on and linked with one or more propulsive industries in a close set of market relationships, forming a center of growth and dynamism in an economy. This concept has been widely applied in regional economics and planning both as an explanation for the geographic clustering of particular industries and as a policy model for understanding economic growth in rural regions. Propulsive industries are groups of key industries whose interaction and expansion can provide a stimulus to growth. They are considered to have certain characteristics, principally technological sophistication, with connections to other industries forming the group, and expanding demand for their products (Pearce 1986).

The development of propulsive industries generally affects the rest of the economy both by generating demand for the products of other industries as inputs, and, by stimulating innovation and technical progress. Both the Samsung Electronics and Dell Computer complex components fit into these regional economic development paradigms. A reasonable conclusion, in terms of the potential economic context of the study area, could be that these businesses represent a potentially propulsive industry that could, given the development of roadway and support infrastructure in the Saline Water Zone portion of the study area, rapidly drive the development of a high-tech growth corridor focused around the computer and microelectronics industry. Suburban residential development in the District that is directly or indirectly supported by such industries located either inside or outside of the District would also be stimulated or propelled by the industry.

As mentioned above, each of the four alternatives suggest the supplement of additional water sources. Alternative water supplies would encourage the conjunctive development and use of Edwards Aquifer groundwater with surface water or other alternative sources. This would entail the development of a parallel or dual water supply system infrastructure along with the current Edwards Aquifer groundwater supply system. The additional capital and operating costs associated with the provision of a new surface (or alternative groundwater) supply system would contribute to higher development costs throughout the study area. These higher costs could eliminate the comparative advantage enjoyed by developments using low-cost Edwards Aquifer groundwater relative to developments requiring higher cost surface supplies, or in some circumstances, possibly result in relatively higher infrastructure costs associated with a dual supply system. Higher development infrastructure costs in the study area associated with dual supply systems would necessarily be passed on in the development process, resulting in higher priced or higher density end products on the local real estate market, perhaps impacting sales and related economic values as a result of price competition with nearby developments not required to have a dual supply system in place.

4.4.4.1 Alternative 1: No Action

Reduction of groundwater use in the study area during DOR conditions through voluntary reduction in groundwater withdrawals to less than 1 cfs would have the effect of reducing the period of time and volume reliability of groundwater supplies pumped by about 24 different water utilities that serve over 70,000 end-users (BSEACD 2017). Notwithstanding effects to residential users, reliability of municipal and industrial water supplies is an important factor in the determination of industrial location decisions by major economic entities, especially high technology microelectronic plants, some of whom require a highly reliable water supply of as much as 3 mgd or 5.6 cfs. Many such industries who might want to locate facilities in the study area would likely respond to the lower reliability of Aquifer supplies by developing alternative surface water supplies which would generate additional site development costs. These higher costs could put potential industrial locations in the study area at a competitive disadvantage, at least relative to similar locations with reliable surface water supplies already in place. In summary, impacts of Alternative 1 on the regional economy could be high, because in the absence of alternative water supplies, there would be no water available to users dependent on the Aquifer, and if alternative water supplies were developed, much of the costs would be passed through to the water users.

4.4.4.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District HCP

Alternative 2 allows the achievement of groundwater planning objectives called Desired Future Conditions (DFCs) involving 1) an upper limit on withdrawals of 16 cfs and 2) maintenance of springflow not less than 6.5 cfs during a recurrence of DOR conditions which requires that groundwater withdrawals not exceed 5.2 cfs during DOR conditions (TWDB 2014c; BSEACD 2017).

This management program would provide a relative economic advantage to those users who have already acquired permitted firm-yield withdrawals from the District compared with those water purveyors who would be required to develop higher cost surface water or alternative groundwater supplies. These differential effects would persist through time and provide market advantages to users with historic-use permits and market constraints to those without such permits. These market advantages would endow Edwards Aquifer historic-use permits granted by the District with considerable value should legislation be passed allowing the transfer of water use rights between users.

An effort to increase surface water supplies in the study area could to some extent adversely affect development costs, reducing the relative price advantage provided by low-cost Edwards Aquifer groundwater supplies. This measure would differentially favor property owners and developers who have already secured withdrawal permits, especially historic-use permits, to serve existing and proposed developments relative to those who will have to rely upon surface water supplies for future development needs.

In summary, impacts of Alternative 2 on the regional economy would be lower in comparison with the other alternatives because up to 5.2 cfs of pumping would still be allowed under DOR conditions, representing about one-third of the maximum allowed under Desired Future Conditions (16 cfs), thereby reducing the amount of water that would need to be supplemented by alternative water supplies.

4.4.4.3 Alternative 3: Water Demand Reduction

Alternative 3 would impose the highest restrictions on Aquifer pumpage. These restrictions would encourage the conversion of existing groundwater use to surface or alternative uses through the adoption of District rules or additional legislation. This alternative could require considerable infrastructure development for alternative water supplies with high associated costs. For most water suppliers, these increased costs for conversion to surface water use would be passed on to end users (residents and businesses) and manifest in the form of higher capital costs and increased water rates to pay for the needed infrastructure and the higher cost of surface water treatment and distribution. This effect could initially lead to a reduction in the rate of economic growth in the study area as real estate developments in the study area that depend on groundwater lose competitive price advantages. However, the effects of increased rates felt by individual users would potentially lessen over time as the population continues to grow and, subsequently, costs associated with construction and debt payment become more widely dispersed.

As noted above, measures that would have the effect of reducing the reliability of municipal and industrial groundwater supplies to commercial and industrial users in the study area would require the development of higher cost alternative surface water supplies.

Measures requiring additional pumping restrictions on conditional permittees and, with legislation, on certain Historic Non-exempt Users would have the same effect as the measures described above that reduce available groundwater withdrawals. In general, these impacts would have a negative economic impact in the study area.

Because Alternative 3 would have the highest pumping restrictions, monetary compensation to owners of land over the Aquifer would likely be required under State of Texas court rulings which have upheld groundwater withdrawal as a property right and subject to compensation if restrictions rise to the level of a property taking [*EAA v. Day* (369S.W.3d 814 (Tex.2012); and *EAA v. Bragg* (No. 04-11-00018, 2013 WL 5989430 (Tex.App. – San Anonio, November 13, 2013)].

As the mandated groundwater withdrawal reductions are implemented, direct impacts would be immediate and severe, until eventual supplemental water sources become available. In summary, adverse impacts of Alternative 3 on the regional economy would potentially be high, because in the absence of alternative water supplies, little or no water would be available to pumpers and water users during DOR conditions when it would be most needed.

4.4.4.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would require the development of the highest level of alternative water supplies. As noted above, the additional water supplies would be beneficial for community resources, lessen restrictions on pumpage, and allow water to be maintained during times of drought. However, as previously noted, costs associated with planning efforts and development of alternative water supplies would be passed onto water users. Some measures outlined in Alternative 2 would likely be implemented in the early stages of Alternative 4 until alternative water sources can be located, planned, constructed, and implemented. These impacts have been outlined above and would result in an overall high negative impact on the economy of the study area.

4.4.5 Summary of Impacts to Socioeconomic Resources

The four alternatives evaluated would ensure springflow of Barton Springs during DOR conditions, but at different flow regimes that would result in different levels of potential biological impact. Alternatives 1, 3, and 4 provide the highest levels of springflow during DOR conditions and exhibit the lowest potential biological impacts to endangered species. These alternatives, however, would result in the highest adverse impacts to communities and people as there would be no other available water, except through the development of alternative water supplies with attendant economic costs, as indicated in the beginning of **Section 4.4**. Alternative 2 provides the highest benefits to community functions, but results in lower springflow during DOR conditions and corresponding higher potential biological impact for endangered species. As the need for the development of surface water and alternative supplies increases with additional limits and restrictions on Aquifer use, water users in the study area could be more likely to be impacted by somewhat higher costs of living that would be influenced by higher costs of development of alternative water supplies. Other factors being equal and given study area demographic trends, a substantial proportion of population growth could be of Hispanic ethnicity and potentially of lower income brackets. As with any increase in costs, low-income and minority populations are likely to feel the burden more acutely. Community resources and infrastructure development would be strained if an increased proportion of public expenditures are diverted to the development of alternative water supplies. However, in the long term, shifts to alternative water supplies and the associated cost adjustments for new development are probably inevitable and potentially more reliable, regardless of the District's actions under these alternatives, given regional trends toward urbanization.

Alternative 1 would result in moderate to high negative impacts to socioeconomic resources, while not providing protection to the District under the ESA as no ITP would be issued. However, individual pumpers could apply for separate ITPs.

Alternative 2 would provide the District protection of an ITP for any incidental take occurring to Covered Species while also resulting in the lowest economic impacts among the four alternatives.

Alternative 3 would virtually eliminate Aquifer pumping through mandated reductions, not be cost effective, result in high (negative) economic impacts.

Alternative 4 has the potential to be the most time intensive and costly alternative for populations and community resources within the study area based on the estimated cost of development and operation of alternative water supplies, and would result in high negative economic impacts.

4.5 Land Use

Urban land uses are growing rapidly in the study area in response to a strong demand for suburban housing in the Austin area, and the provision of municipal and industrial water supplies is playing an important role in the character and timing of this growth.

As noted in **subsection 3.4.1**, various governmental and planning entities have produced population projections for the Central Texas region and the study area that suggest continued moderate to high population growth rates. Underlying these population projections is the assumption that water for municipal and industrial uses will be provided to support this growth, either from the Edwards Aquifer or from alternative ground or surface sources.

Although the quantity and spatial distribution of future urban land use development in the study area is expected to be mainly influenced by the same historically important factors that have shaped the growth of the Austin area in the past, substantial effects to urban land use resources in the study area are possible under any of the alternatives depending on the availability of future groundwater and/or alternative water supplies. Urban development in the study area is regulated by ordinances and governmental code at the municipal and county levels of government. Larger municipalities impose zoning and subdivision regulations while counties regulate development primarily through subdivision, road and other public facility code provisions, and on-site wastewater disposal code requirements. Although these ordinances and regulations could be amended in the future, in the study area, they have traditionally been designed and enforced to address growth and development issues related to water quality protection in the Barton Springs segment of the Edwards Aquifer.

In recent years, cities and counties in the District's jurisdictional area have been requiring, as a condition of subdivision plat approval, assurances of an adequate public water supply for future land use and development. Beginning in 2004, the District instituted a policy whereby all future groundwater permits would be conditional, or subject to pumping curtailment or even cessation in the event of an extreme drought, as well as a requirement that an alternative water supply be available to shift from Edwards Aquifer water. This provision has the potential to significantly impact the extent and nature of Edwards Aquifer-dependent development in the District.

Notwithstanding the trends and issues noted in this section, future development and redevelopment in the study area are likely to be predominantly influenced by existing growth management policies and regulatory provisions, resulting in a future urban land use pattern that would be a logical continuation of existing development trends and regulations. Impacts of aquifer water withdrawal restrictions under all four of the alternatives on future land use will likely be attenuated as an increasing proportion of the study area is served by surface water purveyors and the development of other alternative water supplies.

4.5.1 Alternative 1: No Action

Measures under Alternative 1 would force future development in the study area to rely more heavily on alternative water supplies, with higher costs and longer infrastructure development lead times. These measures could, therefore, affect the timing and character of future growth in the study area. Higher public water costs could mandate higher cost (and denser) housing and longer infrastructure development schedules and could delay to some degree future development beyond the market-based development regime currently in place.

In response to higher water costs associated with conversion to other water supply sources, municipal water providers in the study area would pass these costs on to their customers through higher retail prices. New development within the Austin-San Marcos metropolitan corridor could reflect the need for more water efficient landscaping by reducing the total amount of new project acreage devoted to landscaping, by installing more efficient irrigation systems, or by utilizing more drought-tolerant landscape plants. These responses could have the effect of reinforcing or increasing the demand for higher density urban development, especially for infill or redevelopment projects in existing developed portions of the study area. However, in the absence of supplemental water supplies, the reduced availability of groundwater that would occur during prolonged droughts would not encourage future development. Consequently, the current rapid rate of conversion of open, undeveloped land to developed urban or suburban land uses would be expected to decline.

4.5.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping under the District HCP

Impacts to urban development under Alternative 2 are expected to be lower than Alternatives 1, 3, and 4. Measures that would place withdrawal limits on permitted pumpage or otherwise limit groundwater production in the District, would have the effect of forcing more future development in the study area to acquire surface water supplies or groundwater from another aquifer or from sources outside the study area rather than lower the cost of Edwards groundwater procured locally. This could have the effect of driving up the cost of development as higher cost alternative water supplies and treatment and delivery infrastructure would be needed.

Municipal water providers could respond to higher water costs associated with conversion to other water supplies by passing higher water costs on to their customers. This would likely stimulate the introduction or expansion of voluntary and mandatory water conservation programs including changes in landscape design and irrigation use. These programs, if persistently applied, could eventually lead to a transition in the character of the existing urban landscape involving low-maintenance, drought tolerant vegetation.

4.5.3 All of the alternatives would eventually require development of additional water supplies to address the increasing demand from population growth, with resulting possible effects to the rate of land use conversion. Such effects would be expected to be less under Alternative 2, because aquifer pumping would not be as severely restricted as the other alternatives, thus requiring less supplemental water to satisfy future demand. Alternative 3: Water Demand Reduction

With the elimination of nearly all Aquifer pumping under Alternative 3 and the need to convert to alternative water supplies, impacts could occur to pumpers, water suppliers, and end users. This would affect the local economy and potentially slow urban development and reduce the rate of conversion of open space to urban and suburban land uses, which a portion of the population would consider a positive impact. The extent of these affects would be influenced by how fast alternative water supplies could be developed. Conversion from lower cost local groundwater use to higher cost alternative water sources would increase land development costs which is a negative impact. Resulting increased development costs could affect the quantity, density, location, and timing of future development and the character of the urban landscape. Negative impacts to urban land uses noted for Alternative 2 could be greater under Alternative 3 as a result of more emphasis on the reduction of local groundwater use. Such impacts could be substantial initially for current or future planned developments, but may not affect overall urban land use throughout the study area, as an increasing proportion of the study area is served by surface water purveyors and the development of other alternative water supplies.

4.5.4 Alternative 4: Water Supply Augmentation and Substitution

The short-term effects of the measures under Alternative 4 for impacts to land use would be similar to Alternative 3, as alternative water supplies would need to be developed eventually to fully offset pumping reductions. However, after identified alternative water supplies become a reality, the long term effects of the projects would provide positive benefits to the area and support increased urban and suburban land uses with a commensurate decline in open space and undeveloped land.

4.6 CULTURAL RESOURCES

4.6.1 Types and Extent of Impacts

This section summarizes the expected impacts of each of the alternatives on cultural resources in the study area. Cultural resources include pre-historic as well as historic artifacts, features, and archeological sites. Evaluations are limited to the Barton Springs and Barton Creek area, the vicinity of anticipated direct effects. Environmental or cultural resource effects of other projects involving the construction of alternative water supplies, installation of multiple-well DO augmentation mitigation facilities in the immediate vicinity of Barton Springs in Alternative 2, and construction of recharge enhancement features would have separate environmental and cultural resource evaluations required as part of the permitting and regulatory compliance process.

The overwhelming majority of possible direct impacts (whichever the Alternative), would be located along lower Barton Creek from Barton Springs to Lady Bird Lake (Colorado River). Under normal or above normal rainfall conditions, maximum and minimum water level elevations of lower Barton Creek (below Barton Springs Pool) are not anticipated to change appreciably as a result of implementing any of the alternatives. Under low-flow conditions, the frequency and duration of inundation may vary under the alternatives. As such, sites that currently are subject to varied water flows at Barton Creek and Barton Springs (sites immediately adjacent to the waterway channels) will continue to be impacted in much the same way as they are now while those sites on higher creek terraces will most likely continue to be unaffected. Any effects from new pumping regulations or construction-related action will need to be assessed on a case-by-case basis once those locations are determined.

Alternatives Considered and Associated Effects

Natural and human impacts will result in varying degrees from implementation of each alternative. Generally, water levels are expected to be the same for this portion of the Barton Creek Watershed. Impacts to cultural resources will be more affected by their location than by flow changes among the alternatives, but even those effects will be relatively minor. Cultural resource sites potentially impacted by each of the four alternatives are listed in **Table 4-4**. Types of cultural site impacts include mechanical impacts, biochemical impacts to organic compounds, and looting during wet-dry cycles associated with varying flow levels. More-detailed descriptions of cultural resource sites are provided in **Appendix E**.

Table 4-4
Summary of Impacts to Cultural Resource Sites from Water Flow Variations for Each of the Four dEIS Alternatives

Site	NRHP/State Antiquities Landmark (SAL)	Location	Potential Impact of Alternatives 1–4
41TV1364	SAL	Barton Springs	Some potential impact
41TV2	SAL	Barton Springs	Some potential impact
41TV689	NRHP/SAL	Barton Springs	No impact
41TV690	NRHP/SAL	Barton Springs	Some potential impact
41TV197	N/A	Barton Springs	Some potential impact
41TV324	NRHP	Barton Creek	No impact
41TV1762	SAL	Barton Creek	No impact

Documented sites along Barton Creek that will not be impacted by any of the alternatives are listed in **Table 4-5**. Sites described as “Will not be impacted” are located sufficiently above the current water levels that any alteration in surface water flow would not affect any portions of the sites. Sites described as “Some potential impact” are close enough to the current watercourse that any alteration in surface water flow will most likely carry some impact to some portion of the site; however, the extent of this impact is currently unknown. All four alternatives carry minimal erosional potential, with Alternatives 1, 3, and 4 containing the highest potential due to increased springflow in the vicinity of Barton Springs. With all alternatives, there will be periods of time in which seasonally inundated archeological sites may be exposed and susceptible to human impacts (looting and modification). These human impacts are potentially more hazardous to buried archeological sites in the Barton Springs area than fluctuating water levels. Although all four alternatives are expected to have impacts on the identified archeological sites, Alternative 2 will likely carry the most impacts in relation to water level fluctuation while Alternatives 1, 3, and 4 will have incrementally fewer impacts. Given the overall minimal adjustment in water flow and surface water levels with any of the proposed alternatives, any impacts associated with one alternative will likely be seen in the others, to varying degrees.

Table 4-5
Documented Archeological Sites Along Barton Creek
That Will Not Be Impacted by Any of the Alternatives

41TV1379	41TV391	41TV384	41TV580
41TV357	41TV398	41TV377	41TV579
41TV338	41TV993	41TV386	41TV345
41TV588	41TV992	41TV387	
41TV389	41TV385	41TV704	

4.6.1.1 Alternative 1: No Action

Under Alternative 1, primary impacts would result from the frequency and duration of inundation of archeological sites. Greater fluctuation of flow would increase mechanical impacts from wet-dry cycling and erosion. Prehistoric ceramic artifacts, and typically preserved organic materials such as bone, pollen and shell, would be the most adversely impacted during these cycles. The result would be the dissolution of these artifacts and loss of accompanying data. Biochemical impacts could result when water covers the sites, causing changes in soil composition and accompanying loss of information about the sites. The most susceptible organic materials to biochemical change would be wood, bone, pollen, and seeds. Generally, artifacts such as stone tools and other lithics would be least affected. With more frequent wet-dry cycles, effects of inundation would be exacerbated. Human impacts (primarily looting) may occur when previously submerged sites become more accessible. This is considered to be the most important possible impact to archeological sites. A greater probability of impacts exists for sites adjacent to Barton Springs because the variability of flow would be greater than along Barton Creek. Flow fluctuations that lead to such cyclical inundations already occur as a result of storm runoff in the Barton Creek watershed, and they will continue to occur to a similar extent with or without implementation of any of the alternatives evaluated here.

4.6.1.2 Alternative 2: Issuance of an Incidental Take Permit for Permitted Pumping Under the District Habitat Conservation Plan

Under Alternative 2, the types of impacts described for frequency and duration of inundation of sites would be the same as those described for Alternative 1. However, under Alternative 2, a slightly higher frequency of lower springflow is predicted during drought conditions than would occur under Alternative 1, thus resulting in a slightly higher frequency of exposure of inundated sites and potential disturbance from human impact. Water level fluctuation would continue and human impacts would remain a threat. But again, the flow fluctuations that lead to such cyclical inundations already occur as a result of storm runoff in the Barton Creek watershed, and they will continue to occur to a similar extent with or without any of the alternatives evaluated here.

4.6.1.3 Alternative 3: Water Demand Reduction

Under Alternative 3, types of impacts to archeological sites would be similar to Alternatives 1 and 2. However, maximum restrictions on pumping would result in the least decline in water levels below Barton Springs during dry periods, similar to Alternative 1. This would result in the least exposure of inundated sites and the shortest duration of this exposure, reducing the potential for human impact. But as with Alternatives 1 and 2, flow fluctuations that lead to such cyclical inundations already occur as a result of storm runoff in the Barton Creek watershed, and they will continue to occur to a similar extent with or without any of the alternatives evaluated here. Overall water level fluctuation will continue and human impacts will remain a primary threat to sites.

4.6.1.4 Alternative 4: Water Supply Augmentation and Substitution

Under Alternative 4, types of impacts to archeological sites would be similar to Alternatives 1, 2, and 3. Alternative 4 would result eventually in the least amount of pumping, similar to Alternatives 1, and 3, and similarly would lead to the least decline in water levels below Barton Springs during dry periods. As with Alternative 3, this would result in the least exposure of inundated sites and the shortest duration of this exposure, reducing the potential for human impact. But as with Alternatives 1, 2, and 3, flow fluctuations that lead to such cyclical inundations already occur as a result of storm runoff in the Barton Creek watershed, and they will continue to occur to a similar extent with or without any of the alternatives evaluated here. Overall, water level fluctuation will continue and human impacts will remain a primary threat to sites.

4.6.2 Summary of Potential Cultural Resource Impacts

Each of the four alternatives could have direct impacts on those sites that are situated immediately adjacent to Barton Creek and Barton Springs from lower flows occurring during drought conditons. Reduction in water flow could expose additional, previously unknown elements of known sites to looting and inundation/exposure cycles. While consistent inundation or exposure maintains a general stasis of intact organic materials in a site (inundation still producing some negative effects), alternating between the two states causes notable and rapid degradation of the primarily organic materials' viability for further research, leaving generally only non-organic artifacts (burned rocks, flakes, stone tools, etc.) within the site boundaries. Looting can result in the destruction of all once-intact research elements, both organic and inorganic.

Alternatives 1, 3, and 4 would have potentially lower impacts to exposure of potential artifacts than Alternative 2 under drought conditions. Under low flows there would be some small risk of exposure of artifacts to looting or human disturbance. Higher flows supported by Alternatives 1, 3, and 4 during drought conditions would minimize such risk.

Variations in the level of Barton Creek will likely not adversely affect any nearby historic buildings, but this may not be true for all types of cultural resources. It is important to note that the distributional patterning and density of archeological sites around Barton Creek and Barton Springs indicate that there is some possibility that variable flows of Barton Creek under any of the alternatives could have an impact on cultural resources, especially in undisturbed river bank deposits. Site-specific studies would be needed to determine the extent of potential impacts and identify measures to avoid or minimize those impacts. The design of these studies would be coordinated among the District, COA, and SHPO in compliance with Section 106 of the National Historic Preservation Act (1966, as amended) and the Antiquities Code of Texas (ACT). The scope of work should conform to the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation and Chapter 26 of the Texas Historical Commission's Rules of Practice and Procedure for the ACT.

4.7 COMPARISON OF DIRECT IMPACTS BY ALTERNATIVES

Direct impacts of the four alternatives with respect to the affected resources, as presented in **Sections 4.1** through **4.6**, are summarized for comparison in **Table 4-6**. The most substantial impacts to the Barton Springs ecosystem are driven by measures that affect Aquifer pumping and resulting springflow. Alternative 1, No Action, Alternative 3, Water Demand Reduction, and Alternative 4, Water Supply Augmentation and Substitution would provide the greatest level of protection to the Barton Springs ecosystem and the Barton Springs and Austin blind salamanders by sustaining a higher level of water flow through the spring ecosystems during drought, including conditions that would correspond to the drought of record.

Table 4-6. Comparison of Environmental Consequences of the dEIS Alternatives

Affected Environment	Alternative 1 No Action	Alternative 2 Issuance of ITP for Implementation of HCP	Alternative 3 Water Demand Reduction	Alternative 4 Water Supply Augmentation and Substitution
Physical Environment (Section 4.1)				
Geology (4.1.1)	Minimal or no impacts.	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Soils (4.1.2)	Minimal or no impacts.	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Air Quality (4.1.3)	Minimal or no impacts.	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Climate (4.1.4)	Minimal or no impacts.	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Water Resources (Section 4.2)				
Surface Water (4.2.1)	Minimal or no effects on creeks other than lower Barton Creek, where flow would result largely from spring discharge.	Possible reduced streamflow below recharge enhancement features; otherwise, minimal or no effects on creeks other than lower Barton Creek, where flow would result largely from spring discharge, but with less flow than Alternatives 1, 3, and 4 during drought conditions due to higher level of pumping.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Surface Water Quality (4.2.2)	*Lower Barton Creek:* Highly variable impacts depending on contributions of localized runoff from rainfall events and mixing with groundwater discharge. *Other Creeks:* Minimal or no impact.	*Lower Barton Creek:* Same as Alternative 1. *Other Creeks*: Same as Alternative 1	*Lower Barton Creek:* Same as Alternatives 1 and 2. *Other Creeks*: Same as Alternatives 1 and 2.	*Lower Barton Creek:* Same as Alternatives 1, 2, and 3. *Other Creeks*: Same as Alternatives 1, 2, and 3.

Table 4-6, cont'd

Affected Environment	Alternative 1 No Action	Alternative 2 Issuance of ITP for Implementation of HCP	Alternative 3 Water Demand Reduction	Alternative 4 Water Supply Augmentation and Substitution
Groundwater/ Springflow (4.2.3)	Historical lowest average monthly springflow (11 cfs) would occur <1% of the time during DOR conditions.	Historical lowest average monthly springflow (11 cfs) would occur about 4% of the time; predicted lowest springflow (6.5 cfs) would occur <1% of the time during DOR conditions.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Groundwater Quality (4.2.4)	Will ameliorate future groundwater quality degradation through voluntary pumping reductions, but would not eliminate it completely.	Contains more measures to ameliorate future groundwater quality degradation to a greater extent than Alternatives 1, 3, and 4, but would not eliminate it completely.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Wildlife Resources (Section 4.3)				
Aquatic Resources (4.3.1)	*Lower Barton Creek:* Minimal or no impact in average years; possible adverse impacts in drier or driest years. *Other Creeks:* Minimal or no impacts.	*Lower Barton Creek*: Minimal or no impact in average years; slightly higher adverse impact than Alternatives 1, 3, and 4 during drier years. *Other Creeks:* Same as Alternative 1 except streams below recharge enhancement features where some impacts from reduced flows could occur.	*Lower Barton Creek:* Same as Alternative 1. *Other Creeks:* Same as Alternative 1.	*Lower Barton Creek:* Same as Alternatives 1 and 3. *Other Creeks:* Same as Alternatives 1 and 3.
Terrestrial Resources (4.3.2)	Minimal or no direct impacts.	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Regional Threatened/ Endangered Species (4.3.3)	Minimal or no impacts.	Minimal or no impacts.	Minimal or no impacts.	Minimal or no impacts.

Table 4-6, cont'd

Affected Environment	Alternative 1 No Action	Alternative 2 Issuance of ITP for Implementation of HCP	Alternative 3 Water Demand Reduction	Alternative 4 Water Supply Augmentation and Substitution
Barton Springs Salamander (4.3.4)	Potential 25% mortality at 12 cfs < 1% of the time.	Potential 25% mortality at 12 cfs 5% of the time; and ≥50% mortality at lowest predicted flow of 6.5 cfs <1% of the time, but includes conservation measures to minimize and mitigate take that contribute to recovery of the species (see Table 2-1).	Same as Alternative 1.	Same as Alternatives 1 and 3.
Austin Blind Salamander (4.3.4)	Impacts to ABS similar to Barton Springs salamander; impacts under Alternative 1 are expected to be lower than Alternative 2 because of slightly higher aquifer levels and resulting springflow during drought conditions.	Potentially slightly higher impacts than Alternative 1 due to predicted lower springflows during drought conditions, but also includes conservation measures to minimize and mitigate take that contribute to recovery of the species (see Table 2-1).	Same as Alternative 1.	Same as Alternatives 1 and 3.
Socioeconomic Resources (Section 4.4)[1]				
Population (4.4.1)	Moderate to high adverse impacts.	Low adverse impacts.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Minority and Low Income Populations (4.4.2)	High adverse impacts.	Low adverse impacts.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Community and Public Resources (4.4.3)	Moderate to high adverse impacts.	Low adverse impacts.	Same as Alternative 1.	Short-term moderate to high adverse impacts eventually eliminated once alternative water supplies are developed.
Economic Impacts (4.4.4)	Moderate to high adverse impacts.	Low adverse impacts.	High adverse impacts.	Same as Alternative 3.
Land Use (Section 4.5)[2]				

Table 4-6, cont'd

Affected Environment	Alternative 1 No Action	Alternative 2 Issuance of ITP for Implementation of HCP	Alternative 3 Water Demand Reduction	Alternative 4 Water Supply Augmentation and Substitution
Urban/Suburban Land Use	Moderate to high adverse impacts.	Low adverse impacts.	Same as Alternative 1.	Initially, same as Alternatives 1 and 3, but would result in eventual increases in urban/suburban landuse.
Cultural Resources (Section 4.6)[3]				
Barton Springs/Barton Creek	Some potential minor impacts to 4 archeological sites during droughts; minimal or no impacts to 21 other archeological sites.	Slightly higher potential of impact disturbance, possibly resulting in minor to moderate impacts to 4 archeological sites during droughts than Alternatives 1, 3, and 4 due to potentially lower flows; minimal or no impacts to 21 other archeological sites.	Same as Alternative 1.	Same as Alternative 1 and 3.

[1]Socioeconomic Impact Definitions -
Low (Minor) – Effects would be small but measurable with little overall impact on socioeconomics.
Moderate – Effects would be readily apparent and widespread, but not substantially affect socioeconomics.
High (Major) – Effects would be readily apparent and substantially change the economy or social services.

[2] Land Use Impact Definitions –
Low (Minor) – Effects would be small but measureable, and would affect only a small portion of the study area.
Moderate – Effects would be readily apparent and widespread within localized areas.
High (Major) - Effects would be readily apparent and would substantially slow land use conversion within the study area.

[3]Cultural Resources Impact Definitions -
Low (Minor) – Effects would be slight, and would affect a limited area of an archeological site or group of sites, and would not affect the character or integrity of any of the sites.
Moderate - Effects would be measureable and perceptible and could change one or more defining features of an archeological site, but not to the extent of diminishing its overall integrity or character, and could expose other previously unknown elements of known sites.
High - Effects would be substantial, noticeable, and permanent; with changes affecting the character and integrity of one or more of the archeological sites.

At the same time, these alternatives provide the greatest uncertainty in the establishment of future water management policy, because they would either greatly reduce water available to support existing economic activities and could preclude further economic growth, or require greater reliance on higher cost water supplies that would be reflected in higher development costs that could affect many economic sectors.

Under Alternative 1, No Action, there would be no ITP and no implementation of an HCP. The District would manage the Aquifer only during non-drought conditions which would limit pumping to 16 cfs. The District would issue notices to permittees to stop pumping once drought is declared and take of Covered Species is imminent. During DOR conditions, it is assumed that compliance by all permittees could reduce total aquifer pumping to less than 1cfs (resulting in minimum average monthly springflow at Barton Springs of 11 cfs). Unless protected by individual ITPs, pumpers would have no protection from violation of the ESA in the event that reductions were not sufficient to prevent take of Covered Species. Economic impacts under Alternative 1 would be higher than Alternative 2 and similar to Alternatives 3 and 4. Alternative 1 would result in high biological benefits to the Covered Species as cessation of pumping during DOR conditions would ensure that monthly springflow would not drop below 11 cfs.

Under Alternative 2, Issuance of an ITP for Permitted Pumping under the District HCP, a pumping withdrawal limit of no more than 5.2 cfs would be implemented by the District during DOR conditions that would ensure a minimum average monthly springflow at Barton Springs of 6.5 cfs. Additional measures would be implemented to reduce groundwater demand, encourage development of alternative water sources, provide mitigation measures to improve the DO regime of springflows, and adapt management strategies to future changing conditions.

Implementation of these HCP measures and the issuance of an ITP under the ESA would provide protection for District-authorized pumping. Although the combination of pumping and low Aquifer recharge could result in monthly springflow as low as 6.5 cfs, any take resulting from this springflow would be covered under the ITP. Alternative 2 would result in potentially higher biological impacts to the Covered Species than Alternatives 1, 3, and 4, but would have the lowest economic impacts among the alternatives.

Alternative 3, Water Demand Reduction, provides the most restrictive mandated pumping withdrawal limits (<1 cfs) to ensure monthly springflow equivalent to the lowest historical flow that occurred during the DOR (11 cfs). However, this alternative would result in higher negative economic impacts than Alternative 2 and would require the greatest number of regulatory and policy actions from the District Board and other involved governmental agencies including the Texas Legislature.

Alternative 4, Water Supply Augmentation and Substitution, would provide additional water supplies not currently available, which would reduce water demand and subsequent groundwater pumping. Under Alternative 4, augmented or substituted water supplies would be substantial enough to reduce the level of pumping to less than 1 cfs to ensure springflow equivalent to the lowest historical average monthly flow occurring during the DOR (11 cfs), similar to Alternatives 1 and 3. While this alternative would provide high biological benefits similar to Alternatives 1 and 3, the water supplies needed to offset Aquifer pumping would require substantial lead time to develop at very high economic cost. Due to the long development horizon for this alternative, an ITP would still be needed to provide take coverage under the ESA until pumping would be sufficiently reduced enough to ensure minimum springflow during droughts. This would require additional costs for the development and implementation of an HCP until sufficient alternative water supplies could be developed and brought online. The lead time requirements and high development costs associated with this alternative substantially reduce its overall feasibility.

In summary, the impact evaluation of the four dEIS alternatives indicates Alternative 2 to be the most balanced alternative in consideration of biological benefits, economic costs, and the current political and regulatory environment.

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5.0 INDIRECT AND CUMULATIVE EFFECTS

5.1 INDIRECT IMPACTS

The CEQ defines indirect (or secondary) impacts as those ". . . caused by the action and are later in time or farther removed in distance, but are still reasonably foreseeable. Indirect impacts 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). These induced actions are those that would not occur in the absence of a proposed action. Agency guidance documents (CEQ 2005; FHWA 2003) on preparation of cumulative and indirect effects assessments emphasize that these assessments should focus on individual resources such as surface water, land, or wildlife habitat, as well as on the overall effects to the human and natural environment.

Indirect impacts to the environment of the dEIS study area (**Figure 1-2**) include the indirect or induced impacts resulting from the direct impacts of the four alternatives. These indirect impacts would be primarily determined by those measures that impose limits and reductions on the permitted pumping of groundwater in the study area and that, in turn, encourage the development of alternative water supplies. Alternatives 3 and 4 include the most aggressive measures for reducing Aquifer pumping and are therefore expected to generate the most induced and indirect effects in the study area.

The most substantial indirect impacts associated with the four alternatives would occur from: (1) the reduction in Aquifer pumping; (2) the encouragement of the development of alternative water supplies; and (3) the development of water supplies and infrastructure needed to implement water augmentation and substitution. The indirect impacts would result from the shift in use of Aquifer groundwater to the development and use of water from alternative sources. This shift would potentially affect population distribution, urban and suburban growth, and landscape management, with resulting effects to the regional economy.

Indirect impacts resulting from the measures under Alternative 2 would be less substantial than those that would occur under the reduced pumping imposed by Alternatives 1 and 3. Indirect impacts of Alternatives 1, and 3 to social resources would, overall, reduce the amount of Aquifer water available for community and public resources and could restrict the growth of the local economy and the tax base needed to support the maintenance, operation, and expansion of public facilities. Alternative 4 would have the same indirect impacts to urban development as Alternatives 1 and 3 until new water supplies became available, which would lift the restrictions on water use but also increase costs of water use.

5.2 CUMULATIVE IMPACTS

The CEQ defines cumulative impacts as ". . . the impact on the environment which results from the incremental impact of the proposed action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time" (40 CFR § 1508.7).

5.2.1 Resources Included in Cumulative Impact Analysis

CEQ guidance (CEQ 2005) on preparation of cumulative and indirect effects indicates that these assessments should focus on individual resources such as surface water, land, or wildlife habitat, as well as on the overall effects on the human and natural environment. The resources addressed in this cumulative impacts assessment include surface water, groundwater, biological resources, land, and socioeconomic resources. The goal is to determine whether the proposed action's direct and indirect impacts, considered with other past, present and reasonably foreseeable actions, would result in substantial degradation of a resource that would not result from the proposed action when considered independently. The analysis will focus on resources that are currently in poor or declining health or at risk, regardless of the anticipated magnitude of potential impacts. In some cases, the geographic limits for a particular resource may be different from those of the study area, depending on the methodology for assessing each specific resource.

5.2.2 Current Condition/Health of the Resource

This section briefly summarizes the historical context, existing conditions, and trends of the five resource categories considered in this cumulative effects analysis. This summary includes past and present actions as defined by CEQ guidelines. Another element in characterizing current resource conditions is the collection of plans, programs, and policies implemented by other agencies or organizations that are intended to protect the human and natural resources of the region. These plans, programs, and policies are addressed in **subsection 5.2.3**. For more information on existing conditions, see **Section 3.0**, **Affected Environment**.

5.2.2.1 Surface Water

The Barton Springs segment of the Edwards Aquifer lies within the central portion of the Colorado River Basin. Discharge from the springs flows into Barton Creek, then into Lady Bird Lake, an impoundment of the Colorado River. The base flow of the Colorado River is affected by stream management as regulated by the TCEQ and the LCRA. The Colorado River Basin is characterized in the State of Texas Water Quality Inventory published by the TCEQ as having mixed levels of water quality (TCEQ 2015b). The water quality of the Highland Lakes is good, with periodic depressed DO concentrations resulting from seasonal mixing. Elevated nutrient levels and fecal coliform densities found in many of the Colorado River's tributary streams in the Austin area originate mostly from unidentified nonpoint source runoff.

The most notable trend in the provision of surface water supplies and wastewater services in the study area is the increasing availability of these services to new residential, commercial and industrial development from large, centralized providers, including cities, municipal utility districts, river authorities and private water supply corporations. This trend has been driven by the accelerated increases in demand for urban and suburban land uses of rapidly growing cities, particularly in and adjacent to Austin, compared to formerly rural and agricultural areas. Municipal and industrial water supplies, mostly from the Highland Lakes, and wastewater services are currently provided to a large part of the study area by the LCRA, GBRA, municipalities, water supply corporations and special utility districts.

5.2.2.2 Groundwater and Aquifer-fed Springs

The Barton Springs segment of the Edwards Aquifer provides water for municipal, industrial, agricultural, and domestic uses for about 70,000 people (BSEACD 2013). Long-term average annual recharge to the Aquifer is currently estimated at about 67 cfs (Hauwert 2014).

Discharge from the Aquifer is primarily from springflow and pumping from wells. Average long-term annual discharge from Barton Springs is estimated to be about 53 cfs or 38,000 acre-feet per year (BSEACD 2004), while Cold Springs and Deep Eddy Springs together contribute about 5.5 cfs or 3,900 acre-feet per year (Raymond Slade, pers. comm.). High water marks occurred in 1935, 1991, and 1995. Barton Springs pool has been closed to the public a number of times since the 1980s due to unsafe levels of fecal coliform bacteria in its waters arising from surface runoff of impaired quality that overtops the upper dam and enters the pool directly from Barton Creek. Studies also indicate a long-term gradual decline in water quality in the discharges of Barton Springs itself (**subsection 3.2.2.2**).

Most permitted pumpage is for municipal and industrial purposes and occurs in the southeast part of the Aquifer. In 2013, permitted (authorized) pumpage was about 2.8 billion gallons (8,593 acre-feet, or 12 cfs), while actual pumpage was less than 8 cfs (BSEACD 2017).

Non-permitted pumpage, such as domestic and livestock supply, is estimated to be about 200 million gallons per year. See **subsection 3.1.1.6** for more-complete descriptions on the hydrology and management of the Aquifer.

5.2.2.3 Biological Resources

The dEIS study area is rich in biodiversity. It encompasses a range of terrestrial habitat types, many of which are suitable to many common wildlife species in addition to several rare or otherwise sensitive species endemic to the area. Rapid urbanization continues to cause habitat loss for terrestrial wildlife, including several endangered species. The Barton Springs salamander was federally listed as endangered on April 30, 1997, while the Austin blind salamander was federally listed as endangered on September 19, 2013. Regular surveys conducted by the COA indicate the population varies considerably according to specific years and individual spring discharge sites (COA 2014b). Barton Springs salamanders are found in highest abundance and highest density in Eliza Spring, with the second highest abundance in the main (Parthenia) spring (COA 2014b). Habitat restoration in Eliza Spring in 2003 dramatically affected abundance with an average of 191 individuals counted during the years 1995–2011 (COA 2013a).

Since the Austin blind salamander occupies a more subterranean habitat than the Barton Springs salamander, most of the observations of this species have been of individuals that were accidentally flushed out of their underground habitat. Substantially fewer Austin blind salamanders than Barton Springs salamanders have been observed by City of Austin biologists during regular surveys.

5.2.2.4 Land Use

As more fully described in **Section 3.5**, the study area is situated within the Edwards Plateau and the Texas Blackland Prairies ecological regions, representing a major geological, physiographic, and ecological transition zone in Texas characterized by a diverse landscape. The Edwards Plateau ecological region encompasses approximately 24 million acres, including a large portion of the Hill Country in west-central Texas, as well as the Llano Uplift and Stockton Plateau regions. The Texas Blackland Prairies ecological region consists of nearly level to gently rolling topography. It has been estimated that less than 1 percent of the once-extensive Texas Blackland Prairies landscape remains in a near-natural condition (Smeins and Diamond 1986). The key pattern of historic development in recent years has been the rapid urbanization within the study area, involving a transition from rural and agricultural land uses to low to moderate density urban land uses, particularly in the north-central portion of the study area.

5.2.2.5 Socioeconomic Resources

The dEIS study area is directly influenced by the rapidly growing Austin area economy (see **Section 3.4**). The prospect for accelerated high technology industrial development in the study area continues to be substantial, driven by a number of factors. These include the renewed growth of the existing regional high technology complex in the Austin metropolitan area, exemplified by the substantial expansion of Facebook and Pioneer Surgical Technology in 2010, eBay in 2011, Samsung Electronics semiconductor manufacturing plant in 2012, Oracle America, Inc., in 2013; improvements to the regional transportation network within the study area, including SH 130, SH 45, MoPac, and major arterials connecting to the IH 35 corridor; and an expanding water and wastewater infrastructure provided by cities, river authorities, special districts, and water supply corporations. Development of SH 45, SH 130, and other major transportation network improvements and supporting infrastructure could influence growth in the study area, particularly with regard to the development of a growth corridor along these major facilities focused on high technology industries. Current socioeconomic resource conditions are more fully described in **subsections 3.4.1** through **3.4.2**. Projected growth in the study area is discussed in **subsection 3.4.1.3**.

5.2.3 Policies, Plans, and Programs

Recognition of the need to protect water, land, and biological resources in the Austin metropolitan region and in the study area has given rise to a variety of regulations, plans and programs to protect these natural resources. **Table 5-1** describes the primary plans, ordinances, and programs initiated by a variety of agencies, with a summary of general effects on surface and groundwater resources, land, biological, resources, and socioeconomic resources in the region.

5.2.4 Reasonably Foreseeable Actions

Table 5-2 identifies reasonably foreseeable future actions that could contribute to cumulative impacts to resources in the study area. These actions are considered likely to occur (and in some cases are currently underway) in the foreseeable future, regardless of which HCP alternative is selected as the Proposed Action. The future actions considered in the analysis include transportation projects, public and private utilities, and private real estate developments. **Table 5-2** describes each action and provides a general profile of its potential effects on surface and groundwater, land, biological resources, and socioeconomic resources in the study area.

5.2.5 Cumulative Impacts

For each resource identified in **subsection 5.2.1**, cumulative impacts were evaluated qualitatively in light of the following factors: the historical context and current condition and trend of each resource; the reasonably foreseeable actions that may adversely impact these resources; the pertinent regulations, programs, and policies designed to protect each resource from development pressures; and the proposed action. These factors address the influences that are likely to determine the current and future condition of each resource.

Because some of the policies and plans, including the proposed action, are designed to address the adverse trends and impacts from reasonably foreseeable actions to human and natural resources in the study area, this cumulative impacts analysis focuses on the “net” cumulative effects on each resource that remain after full compliance with the regulatory requirements at all levels.

Table 5-3 summarizes the cumulative impacts to identified resources of the past, present and reasonably foreseeable actions when added to the direct and indirect impacts estimated for each of the four alternatives. Further discussion of the cumulative effects of the four alternatives on the various resources follows.

Table 5-1. Public Plans, Policies, and Programs Considered in the Cumulative Effects Analysis

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
Barton Springs/Edwards Aquifer Conservation District (BSEACD) Drought Contingency and Conservation Plans 2011	The District requires User Conservation Plans (UCPs) and User Drought Contingency Plans (UDCPs) for five categories of users, including: agricultural, commercial, industrial, public water suppliers, and general. The UDCP is guided by the Drought Contingency Plan of the District and must comply with the Drought Contingency Rules of the District. Its intent is to maintain an adequate supply of water during the various stages of periodic drought.	Reduced withdrawals from the Aquifer during drought and non-drought conditions would result in higher levels; higher springflows; beneficial impact to Aquifer biological resources; and more reliable groundwater production.
BSEACD Groundwater Management Plan 2013	As required by TWC 36.1071 and 36.1072, a GCD must submit to the TWDB Executive Administrator a district management plan that meets the requirements of 31 TAC 356.5–356.6. The TWDB Executive Administrator must review, comment for purposes of revision, and ultimately approve the management plan submitted by the District. The District must re-adopt their plan with or without revisions at least once every 5 years. This groundwater management plan incorporates relevant regional water management strategies outlined in the current 2011 Regional Water Plans developed by Region K and Region L and included 2012 State Water Plan.	Reduced withdrawals from the Aquifer by existing and future developments during drought and non-drought conditions to comply with managed available groundwater is expected to result in higher Aquifer levels; higher springflows; beneficial impacts to biological resources; and more reliable groundwater production.
Groundwater Management Under H.B. 1763, 79th Legislature	The bill strengthens the joint management planning between GCDs in a groundwater management area (GMA). This new statute requires GCDs to base their groundwater management plans on the "Managed Available Groundwater" as determined by the TWDB to be indicated by the "Desired Future Conditions" in the GMA established through joint regional planning.	Reduced withdrawals from the Aquifer during drought and non-drought conditions would lead to higher index well levels; higher springflows; beneficial impacts to biological resources; and more reliable groundwater production for wells.
USFWS Barton Springs Salamander Recovery Plan Amended to Include the Austin Blind Salamander (USFWS 2016a)	The Recovery Plan includes planning and scientific research activities intended to generate information that will assist with management of the Barton Springs and Austin blind salamanders and assess success of the recovery programs for the two species. Monitoring the implementation of those management actions is intended to ensure that management tools are appropriately and effectively addressing impacts on the species. Implementation of the Recovery Plans is strictly voluntary and dependent on the cooperation and commitment of numerous partners.	Recovery of the species from endangered status; increased knowledge of species requirements; development of management tools to monitor and manage species; and potential socioeconomic impacts from limitations on aquifer use.

Table 5-1, cont'd

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
City of Austin Watershed Protection Ordinances 2013	In October 2013, the Austin City Council passed a new Watershed Protection Ordinance, completing Phase 1 of the new ordinance. Phase 2, Green Stormwater Infrastructure, is currently in the stakeholder process. The new ordinance was crafted to improve creek and floodplain protection; prevent unsustainable public expense on drainage systems; simplify development regulations where possible; and minimize the impact on the ability to develop land.	Beneficial impacts to surface water quality; higher quality water recharging to Aquifer; higher quantity of surface water recharging to Aquifer; higher quality Aquifer water; beneficial impact to biological resources in springs ecosystem; change in character of new development in Contributing and Recharge Zones; and reduced land use development and density in Contributing and Recharge Zones with short-term negative impacts to jobs, earnings, and output, and long-term benefits from Aquifer protection.
Lower Colorado River Authority (LCRA) Highland Lakes Watershed Ordinance 2014	In response to the impact of stormwater pollution, LCRA implemented the Highland Lakes Watershed Ordinance (HLWO) to protect water quality throughout the Highland Lakes region. Development within the Ordinance area is required to protect water quality and creek erosion. This Ordinance applies to the Lake Travis watershed in Travis County and portions of Burnet and Llano Counties in the Colorado River Watershed.	Beneficial impacts to surface water quality from stormwater control facilities and performance standards; higher quality water recharging to Aquifer; higher quality Aquifer water; beneficial impact to biological resources in springs ecosystem; and minor increase in development costs.
City of Austin Water Conservation Program 2014	Program components include rebates for: efficient appliances, water audits, waste reporting, rainwater harvest, soil moisture meters, watering timers, pool covers, and educational programs related to landscaping and irrigation.	Beneficial impacts to surface water quantity through demand reduction; change in character of landscape features in Contributing and Recharge Zones; decreased need for alternative water supplies; lower cost of water supplies.
City of Austin's Barton Springs HCP 2013	Authorizes the incidental take of the federally endangered Barton Springs salamander and Austin blind salamander that would result from the operation and maintenance of Barton Springs Pool and the adjacent springs.	Beneficial impacts to species habitat in Barton Springs Pool from more careful management procedures; increased protection provided by Incidental Take Permit for the City of Austin from an enforcement action under the ESA; beneficial impacts to surface water quality; higher quality water recharging to Aquifer; higher quality Aquifer water.

Table 5-1, cont'd

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
The Regional Water Quality Protection Plan for the Barton Springs Segment of the Edwards Aquifer and Contributing Zone 2005	A collaborative investigation among virtually all the political jurisdictions and various stakeholder groups in the Contributing and Recharge Zones of the Barton Springs segment of the Edwards Aquifer produced a consensus set of recommendations to protect the water in the aquifer. The various actions and initiatives comprising these recommendations are being pursued and extended by the individual political jurisdictions. An intergovernmental work group meets periodically to assess progress on the plan, discuss needs and options, share information and lessons learned, and jointly support each others' initiatives. Sponsors including the Cities of Dripping Springs, Austin, Buda, Kyle, Rollingwood, Sunset Valley, Bee Cave, the counties of Blanco, Hays, and Travis, and the BSEACD, Hays-Trinity Groundwater Conservation District, and Blanco-Pedernales Groundwater Conservation District.	Beneficial impacts to surface and groundwater resources; higher quality Aquifer water; beneficial impact to biological resources in springs ecosystems; change in character and cost of new development in Contributing and Recharge Zones; and increased implementation of stormwater quality Best Management Practices (BMPs) in Contributing and Recharge Zones with short-term negative impacts to cost of new development and related impacts to jobs, earnings, and output, and long-term benefits from Aquifer protection.
Region K Lower Colorado Regional Water Plan 2011	The 2011 plan covers the 2010–2060 timeframe and identifies the difference between available supplies and demand for each water user group as either a surplus or a need. Needs are estimated for each decade, and a listing of potential alternative strategies to meet those needs is provided to TWDB.	Alternative water supplies identified in Plan would reduce Aquifer demand and increase springflow at Barton Springs, providing beneficial impact on biological resources at Barton Springs Pool.
TCEQ's Edwards Aquifer Protection Program	This is an ongoing program that provides tools, guidance and other information regarding the Edwards Aquifer Protection Program and serves to regulate activities, including construction, that have the potential for polluting the Edwards Aquifer. Development within the Recharge, Transition, or Contributing Zones of the Edwards Aquifer must first have an application including construction plans approved by the TCEQ. Personnel from the Edwards Aquifer Protection Program review these plans. If a plan is approved, the site is monitored for compliance. Certain facilities are prohibited in the Recharge or Transition Zones, such as Type 1 municipal solid waste landfills and waste disposal wells.	Beneficial impact to biological resources in springs ecosystem; change in type and cost of new development in Contributing and Recharge Zones; and increased implementation of stormwater quality BMPs in Contributing and Recharge Zones with short-term negative impacts to cost of new development and related impacts to jobs, earnings, and output, and long-term benefits from Aquifer protection.

Table 5-1, cont'd

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
Safe Drinking Water Act 1996	(Described in detail in regulations section of water resources **subsection 3.2.2.2**)	Beneficial impacts to surface water and groundwater quality; higher quality water recharging to Aquifer; higher quality aquifer water; beneficial impact to biological resources in springs ecosystem; change in character and cost of new development in Contributing and Recharge Zones; and increased implementation of stormwater quality BMPs in Contributing and Recharge Zones with short-term negative impacts to cost of new development and related impacts to jobs, earnings, and output, and long-term benefits from Aquifer protection.
Clean Water Act Section 305b and 303d (Texas Water Quality Inventory)	(Described in detail in regulations section of water resources **subsection 3.2.1.4**)	Beneficial impacts to surface water quality; higher quality water recharging to Aquifer; higher quality Aquifer water; beneficial impact to biological resources in springs ecosystem; change in character and cost of new development in Contributing and Recharge Zones; and increased implementation of stormwater quality BMPs in Contributing and Recharge Zones with short-term negative impacts to cost of new development and related impacts to jobs, earnings, and output, and long-term benefits from Aquifer protection.
Balcones Canyonlands Conservation Program	The BCCP is a 30-year regional permit that allows for incidental take of eight endangered species outside of proposed preserve lands, and provides mitigation for new public schools, roads and infrastructure projects of the participating agencies (Travis County, the City of Austin, and the LCRA). A minimum of 30,428 acres of endangered species habitat in western Travis County make up the Balcones Canyonlands Preserve, including preservation of 62 known karst (cave) features and rare plants.	Beneficial impacts to surface water quality; higher quality water recharging to Aquifer; higher quality Aquifer water; beneficial impact to biological resources in springs ecosystem; change in character and cost of new development in Contributing and Recharge Zones; and increased implementation of stormwater quality BMPs in Contributing and Recharge Zones with short-term negative impacts to cost of new development and long-term benefits from Aquifer protection.
Hays County HCP 2011	A regional habitat conservation plan that includes conservation measures to minimize and mitigate incidental take of the Golden-cheeked Warbler and Black-capped Vireo that would occur as a result of activities including, but not limited to, public or private land development, transportation projects, or utility projects.	Conservation measures include the establishment of a preserve system of 10,000–15,000 acres to mitigate for the incidental take of Golden-cheeked Warblers and Black-capped Vireos. The preserve system will protect habitat for other wildlife, and protect water quality of the Barton Springs segment of the Edwards Aquifer.

Table 5-1, cont'd

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
Comal County HCP 2014	A regional habitat conservation plan that includes conservation measures to minimize and mitigate incidental take of the Golden-cheeked Warbler and Black-capped Vireo associated with proposed road construction, maintenance, and improvement projects; utility construction and maintenance; school development and construction; public or private construction and development; and land clearing within Comal County, Texas.	Conservation measures will include the establishment of a preserve system of approximately 6,500 acres to mitigate for the take of Golden-cheeked Warblers and Black-capped Vireos. The preserve system will protect habitat for other wildlife and contribute to the protection of water quality of both surface water and groundwater.
City of Austin Water Quality Protection Land (WQPL) program 1998 to present	The program acquires land in fee title and conservation easement in the Barton Springs contributing and recharge zone to provide for the conservation and maintain the safety of part of the City's water supply. The objective is to produce the optimum level of clean, high-quality water from project lands to recharge the Barton Springs segment of the Edwards Aquifer.	The program manages more than 26,000 acres – about 9,000 acres as fee simple and 17,000 acres as conservation easements – to preserve and protect surface and groundwater quantity and quality. The preserve lands would protect habitat for wildlife and contribute to the protection of water quality of both surface water and groundwater.
Travis County Conservation Development Ordinance 2006	Outlines a concept that includes a number of purposes, including: to encourage the permanent preservation of open space, ranch and agricultural lands, woodlands and wildlife habitat, natural resources including aquifers, water bodies and wetlands, and historical and archeological resources; to promote interconnected green space and corridors throughout the community; protect community water supplies; and minimize stormwater runoff.	The preservation of open space, green space, woodlands, and wetlands would protect habitat for other wildlife and contribute to the protection of water quality of both surface water and groundwater.
Conservation Easements Established by Private Conservation Groups 1990-Present	Establishment of conservation easements on private land. Allows landowners to retain ownership and control, but ensures land under the easement will remain in a natural condition and not be developed in the future.	The preserve lands would protect habitat for wildlife and contribute to the protection of water quality of both surface water and groundwater.
Other plans, programs, and regulations by other entities	The Cities of Buda, Sunset Valley, and Dripping Springs and the Village of Bee Caves have water quality protection ordinances (see **Appendix C**).	Same as above.

Table 5-2. Summaries of Reasonably Foreseeable Actions and Impacts to Resources Considered in the Cumulative Effects Analysis

Reasonably Foreseeable Actions	Description	Type of Impact
Transportation		
SH 45 SW	3-mile, 4-lane toll parkway/freeway with non-tolled frontage roads. Currently in the environmental review process.	Induced land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and if water quality protection measures fail, possible increased pollution; increased recharge of polluted water to Aquifer; and increased threat to biological resources from polluted groundwater.
MoPac Improvement and MoPac South Projects	Improvements to MoPac under the MoPac Improvement Project are underway between Parmer Lane and Lady Bird Lake. Additional improvements from Lady Bird Lake to Slaughter Lane (MoPac South Project) are currently being evaluated in the environmental process.	Induced land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and if water quality protection measures fail, possible increased pollution; possible increased recharge of polluted water to aquifer; and increased threat to biological resources from polluted groundwater.
Public and Private Utilities		
Austin-San Antonio Inter-municipal Commuter Rail (Lone Star Rail)	Planned rail district following the UP rail line west of IH 35 between Austin and San Antonio. Should this project be developed, it would enhance regional capabilities of rail transportation in central Texas.	Induced land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and if water quality protection measures fail, possible increased pollution; possible increased recharge of polluted water to Aquifer; increased threat to biological resources from polluted groundwater.
Planned Water Supply Projects	Various proposals under Region K & L Regional Water Plans to be implemented by: municipalities; river authorities; water supply corporations; and private developers. Several entities have announced plans to provide new surface and groundwater supplies to portions of the study area. These supplies will represent alternatives to the use of Edwards groundwater for existing and new developments.	New infrastructure would facilitate land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and pollution; increased recharge of polluted water to Aquifer; increased threat to biological resources from polluted groundwater. Benefits would be derived by providing alternative water supplies to entities that otherwise would rely on the Edwards Aquifer, allowing conversion to surface water supplies either entirely or through conjunctive use thus reducing demand on the Aquifer and improving springflow.

Table 5-2, cont'd

Reasonably Foreseeable Actions	Description	Type of Impact
River Authorities	The provision of additional water supplies, treatment, transmission, distribution and wastewater facilities and services by the LCRA, and GBRA in the study area.	New infrastructure would facilitate land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and pollution; increased recharge of polluted water to the Aquifer; increased threat to biological resources from polluted groundwater.
Municipal Utility Districts (MUDs)	The provision of additional water and wastewater facilities and services by various municipal utility districts in the study area.	New water and wastewater infrastructure would facilitate land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and pollution; increased recharge of polluted water to the Aquifer; increased threat to biological resources from polluted groundwater.
Water Control & Improvement Districts	The provision of additional water facilities and services by various water control and improvement districts in the study area.	New water supply infrastructure would facilitate land use growth including increased residential, commercial and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and pollution; increased recharge of polluted water to the Aquifer; increased threat to biological resources from polluted groundwater.
Private Real Estate Developments		
Water Supply Corporations	The provision of additional retail water facilities and services by various private supply corporations in the study area.	New water supply infrastructure would facilitate land use growth including increased residential, commercial, and industrial development creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and pollution; increased recharge of polluted water to the Aquifer; increased threat to biological resources from polluted groundwater.
Various small to large scale private real estate development projects	The development of residential, commercial and industrial projects within the study area. Low-density single family and commercial projects are likely to occur in the western portion of the study area. Low and medium density residential, large-scale commercial and industrial projects will likely occur throughout the study area.	New private developments on undeveloped tracts, including increased residential, commercial, and industrial land uses creating jobs, earnings and output; increased impervious cover; increased stormwater runoff and pollution; increased recharge of polluted water to the Aquifer; increased threat to biological resources from polluted groundwater.

Table 5-3. Cumulative Impacts on Resource Categories of the dEIS Alternatives

Current Condition/Trend	Impacts from Past, Present, and Reasonably Foreseeable Actions	Effects of Policies, Plans, and Programs	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Surface Water (In-stream Flows)						
Generally good, but deteriorating trend (quality)	Increased impervious cover, runoff, erosion, and sedimentation in waterways (reduced quality).	Improved quality from stormwater quality protection measures; reduced demand from conservation programs.	Greatest increases to Barton Creek flows are below springs and inflows to Lady Bird Lake; continued declining quality of instream flows.	Increases to Barton Creek flows are below springs and inflows to Lady Bird Lake; continued declining quality of instream flows.	Greatest increases to Barton Creek flows are below springs and inflows to Lady Bird Lake; continued declining quality of instream flows.	Greatest increases to Barton Creek flows are below springs and inflows to Lady Bird Lake; continued declining quality of instream flows.
Surface Water (Municipal and Industrial Supplies)						
Provision of surface water supplies	Increased provision of alternative surface water supplies to the study area; increased private development; increased provision of transportation facilities.	Increased use from utility developments and conversion from groundwater to surface water supplies.	Gradually increased conversion to other water supplies including surface water supplies.	Gradually increased conversion to other water supplies, including surface water.	Higher rate of conversion to other water supplies, including surface water, followed by increased cost to water users.	Greatest rate of conversion to other water supplies, including surface water followed by increased cost to water users.
Groundwater and Aquifer-fed Springs (Quality and Quantity)						
Generally good, but deteriorating trend	Increased availability of water supplies; increased polluted runoff and sediments to Aquifer; increased withdrawals due to growth.	Limited withdrawals, demand reduction measures. Some reduction of pollutants in recharge	Low demand reduction and conversion to other water supplies; highest adverse cumulative impacts; continued declining quality.	Low demand reduction and conversion to other water supplies; highest adverse cumulative impacts; continued declining quality.	High demand reduction and moderate conversion to other water supplies; enforcement of demand reduction measures; increased water availability for springflow; low adverse cumulative impacts; stable quality; increased quantity.	Moderate Demand reduction and highest conversion to other water supplies; enforcement of demand reduction measures; increased water availability for springflow; low adverse cumulative impacts; increased quality, quantity and cost.
Biological Resources						

Table 5-3, cont'd

Current Condition/Trend	Impacts from Past, Present, and Reasonably Foreseeable Actions	Effects of Policies, Plans, and Programs	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Barton Springs and Austin blind salamanders designated endangered	Reduced quality and quantity of groundwater could eventually lead to greater mortality and habitat modification resulting in "take".	Efforts to improve quality and reduce withdrawal of groundwater would benefit species.	High demand reduction; low adverse cumulative impacts.	Low demand reduction; moderate adverse cumulative impacts through implementation of HCP measures.	High demand reduction measures; low adverse cumulative impacts;	Moderate demand reduction; highest conversion to other water supplies; low adverse cumulative impacts.
Land						
Conversion from rural to urban land uses	Increased conversion from undeveloped rural land to infrastructure, residential, commercial, and industrial uses.	Additional open space acquisition and regulations to reduce impervious cover and control stormwater runoff would preserve some existing undeveloped land.	Low to moderate negative impacts on rural and urban land uses.	Low to moderate negative impacts on rural and urban land uses.	Moderate to high negative impacts on rural and urban land uses.	Moderate to high short-term negative impacts to rural and urban land use; with long-term positive benefits to both.
Socioeconomics						
Rapidly growing regional economy; highly used and socially valued recreational resources in Zilker Park and Barton Springs.	Increased jobs, earnings, and output; Increased stress on recreational areas due to demand and use.	Increased regulation of development and reduced availability of developable land would increase land and development costs; recreational areas and open space would benefit.	Conversion to other water supplies would make the study area slightly less affordable; increased springflow would benefit water-based recreation at the springs in Barton Creek and Lady Bird Lake; low adverse economic impacts.	Reduced developable land and conversion to other water supplies would lead to increased land and development costs and make the study area less affordable; increased springflow would benefit water-based recreation at the springs, Barton Creek and Lady Bird Lake; low adverse economic impacts.	Austere pumping limits would stimulate conversion to other water supplies that would lead to increased land and development costs and make the study area less affordable; highest springflow would benefit water-based recreation at the springs, Barton Creek and Lady Bird Lake; high adverse economic impacts.	Maximum conversion to alternate water supplies would make the study area less affordable; increased springflow would benefit water-based recreation at the springs in Barton Creek and Lady Bird Lake; high adverse short-term economic impacts, changing to long-term positive economic benefits; high beneficial quality of life impacts.

5.2.5.1 Surface Water

Past, present and reasonably foreseeable actions in the study area indicate that rapid urbanization will continue to occur with negative impacts to surface water quality as a result of increased impervious cover, polluted stormwater runoff and the discharge of treated wastewater into surface streams. Implementation of the policies and plans outlined by **Measure 1.1** for all of the alternatives (**Table 2-1**) would substantially mitigate these trends, but surface water quality degradation is expected to continue.

Climate change could contribute adverse cumulative impacts to surface water resources under all of the proposed alternatives. Predictions for increases in a warmer and drier climate could result in a higher frequency of reduced streamflows and continued lower volumes of water stored in lakes and reservoirs.

5.2.5.2 Groundwater and Aquifer-fed Springs

As noted above for surface water resources, past, present, and reasonably foreseeable actions in the study area indicate that rapid urbanization will continue to occur with adverse impacts to groundwater quality as a result of increased impervious cover, polluted stormwater runoff, and the discharge of treated wastewater into surface streams. Recharge to the Aquifer of polluted stormwater would have a negative impact on groundwater water quality and the quality of water issuing from the springs. Implementation of the policies and plans outlined by **Measure 1.1** for all of the alternatives (**Table 2-1**) would help to mitigate these trends, but groundwater and spring water quality would continue to decline. In addition, more intense development in the Contributing and Recharge Zones of the Barton Springs Segment of the Edwards Aquifer will increase the potential for direct discharge of domestic wastewater from publicly owned treatment works into these zones.

Measures 1.1, 4.4, 5.1, 5.3, 6.1, 6.2, and 6.3 under each of the alternatives (**Table 2-1**) would aid in sustaining springflow and groundwater availability. **Measures 4.1** and **4.2** under all four alternatives would reduce the adverse cumulative impacts to groundwater quality associated with rapid urbanization of the contributing watersheds.

Climate change could contribute adverse cumulative impacts to groundwater resources under all of the proposed alternatives. Mace and Wade (2008) and Loáiciga et al. (1996) suggest that the Edwards Aquifer is probably Texas's most vulnerable Aquifer and groundwater resource with respect to climate change and variability. If there is a long-term drying of the climate in south-central Texas, area groundwater users can expect to be under more frequent drought restrictions.

Loáiciga et al. (2000) studied the climate change impacts on the Edwards Aquifer. Climate change scenarios were created from scaling factors derived from several general circulation models to assess the likely impacts of Aquifer pumping on the water resources of the Edwards

Aquifer. Historical evidence and the results of this research indicate that without proper consideration to variations in Aquifer recharge and sound pumping strategies, the water resources of the Edwards Aquifer could be adversely impacted under a warmer climate.

5.2.5.3 Biological Resources

As noted above for surface and groundwater resources, past, present, and reasonably foreseeable actions in the dEIS study area indicate that rapid urbanization is expected to continue to occur and will potentially result in adverse impacts to terrestrial habitat of wildlife species not tolerant to human disturbance. Adverse impacts would also occur to surface and groundwater quality as a result of increased impervious cover, polluted stormwater runoff and the discharge of treated wastewater into surface streams. Decreased water quality would have substantial adverse impacts to the biological resources in the spring ecosystem. Implementation of the policies and plans outlined by **Measure 1.1** in **Table 2-1** under each of the alternatives would substantially mitigate these trends, but surface and groundwater quality would continue to decline, continuing the threat to the endangered biological resources in the springs. Alternatives 1, 3, and 4 do not include specific measures to sustain or improve surface or groundwater quality. They do, however, include measures designed to increase springflow by reducing withdrawals from the Aquifer. These measures would have positive effects on groundwater quality and the ecosystems' biological resources by sustaining a higher level of dilution of pollutants and would therefore create indirect effects that would help offset the adverse cumulative impacts of rapid urbanization on the biological resources in the study area.

Measures 1.1, 4.4, 5.1, 5.3, 6.1, 6.2, and 6.3 under each of the alternatives (**Table 2-1**) would aid in sustaining springflow and groundwater availability, thus providing positive benefits for the biological resources inhabiting the spring ecoystems.

The City of Austin's HCP for Barton Springs Pool Operation and Maintenance (COA 1998) and Major Amendment and Extension of the HCP (COA 2013a) would have cumulative impacts on the endangered species population in the Barton Springs complex during low flow conditions under all four alternatives. As cleaning the pool is stressful to these species, the City's HCP acknowledges the resulting potential harm and harassment and contains measures to minimize and mitigate any incidental take associated with those activities. Any activities under the City HCP that take place at Barton Springs during discharges of less than or equal to 30 cfs would potentially have cumulative impacts on the endangered species. The District's HCP includes several measures that are to be specified/authorized in an MOU between the District and City, and the District will seek to include in the MOU specific constraints on operation and maintenance that represent discretionary actions in order to minimize or avoid such cumulative impacts.

Climate change could contribute to adverse cumulative impacts to biological resources, particularly the Covered Species. A warmer and drier climate would increase the risk of lower springflows. Decreased springflow and increased water temperature could adversely affect habitat components, food availability, and salamander behavior, in addition to producing other possible undetermined effects. Warmer water temperature would result in a reduced concentration of the dissolved oxygen critically important to the salamanders. While the salamanders have lived through significant droughts in the past, the effects of a severe and prolonged drought on the species in the future are unknown because of changes to the landscape due to human development. Severe drought, in combination with other factors such as changes in water quality, increased impervious cover, and introduction of non-native species, could make it more difficult for the species to survive. However, the extent of these effects and synergy with other cumulative effects is not currently known.

Each of the four alternatives reviewed in this dEIS include measures for managing the Barton Springs segment of the Edwards Aquifer under drought conditions for the benefit of the Barton Springs and Austin blind salamanders. Drought conditions are common to the region, and the ability to retreat underground may be an evolutionary adaptation by *Eurycea* salamanders to such natural conditions. However, it is important to note that although salamanders may survive a drought by retreating underground, this does not necessarily mean they are resilient to future worsening drought conditions in combination with other environmental stressors. Groundwater pumping, for which the District seeks an ITP, may in the future occur alongside climate change, decreased water infiltration to the Aquifer, potential increases in saline water encroachments into the Aquifer, and increased competition for spaces and resources underground. Collectively, all these factors may negatively affect the habitat of the two salamanders, and may exacerbate drought conditions to the point where they cannot survive. In addition, threats to surface habitat at a given site may not extirpate populations of these salamander species in the short term, but this type of habitat degradation may severely limit population growth and increase a population's overall risk of extirpation from cumulative impacts of other stressors occurring in the surface watershed of a spring. More discussion concerning cumulative impacts on the Barton Springs and Austin blind salamanders can be found in the listing information provided by the Service in the *Federal Register* (78 FR 5128).

5.2.5.4 Land Use

As described in **Section 4.5**, undeveloped land within the study area is undergoing rapid conversion from rural/agricultural uses to urban and suburban uses. Implementation of the policies and plans outlined by **Measure 1.1** in **Table 2-1** under each of the alternatives would address these trends primarily through growth management regulations oriented toward water quality protection, but the conversion of rural land to urban land would continue. **Measures 1.1, 4.4, 5.1, 5.3, 6.1, 6.2, and 6.3** under each of the alternatives (see **Table 2-1**) would have the effect of sustaining springflow and groundwater availability and of increasing the reliability of wells in the unconfined zone during critical periods.

5.2.5.5 Socioeconomics

Past, present, and reasonably foreseeable actions in the dEIS study area indicate that rapid economic development will continue to occur with positive impacts to the regional economy. Implementation of the policies and plans outlined in **Measure 1.1** in **Table 2-1** would guide management of the Aquifer in response to future economic growth by adapting management strategies in response to changing economic conditions and corresponding groundwater demand.

Alternatives 1 and 3 reduce Aquifer pumping withdrawals through voluntary and mandatory means, respectively. Such pumping reductions, without the availability of alternative water supplies, would result in substantial adverse cumulative effects to the regional economy. As there would likely be severe water shortages, a number of water users as well as public and private facilities would be adversely affected. Severe pumping restrictions may constitute partial taking of private property that would require fair compensation to landowners. This could result in both direct as well as additional cumulative costs. Alternative 2 includes additional measures to mitigate any adverse impacts to the two Covered Species. These measures would not result in any appreciable cumulative effects to area communities or economies.

Measures 1.1, 4.4, 5.1, 5.3, 6.1, 6.2, and 6.3 under each of the alternatives (**Table 2-1**) would aid in sustaining springflow and groundwater availability and increase the reliability of wells in the unconfined zone during critical periods.

Alternative 4 includes measures to reduce groundwater use in favor of higher cost alternative water supplies. These measures would tend to increase water use rates which in turn would result in adverse cumulative effects in other sectors of the economy. These effects would lessen the cumulative benefits of regional economic development, earnings, and business sales.

In summary, actions under all four dEIS alternatives would have cumulative impacts on ground-water resources, Aquifer-fed springs, biological resources, land resources, and socioeconomics in the study area. Alternative 2 would contribute the most to the positive cumulative effects of past, present and reasonably foreseeable actions on the regional economy within the dEIS study area. Alternatives 1, 3, and 4 would provide the most protection to springflow during drought conditions, but would have higher adverse cumulative effects to the regional economy than Alternative 2.

5.3 RELATIONSHIP BETWEEN SHORT-TERM USES OF MANS ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

CEQ NEPA Regulations (40 CFR Part 1500 et seq.) require that issues related to environmental sustainability be discussed in an EIS. In general, this dEIS discussion is not considered an environmental effect for which either significance is defined, or mitigation is recommended.

However, the discussion, as it relates to environmental consequences, must be included in the dEIS, and should consider "the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity (42 U.S.C. 4332[C][iv]).

The short-term effects on and uses of the environment in the study area evaluated for the four dEIS alternatives are related to long-term effects and the maintenance and enhancement of long-term productivity. Short-term refers to construction and/or implementation of a conservation or mitigation measure. Long-term refers to an indefinite period beyond the initial construction or initiation of the conservation measure and includes longer term preservation and management actions, as well as on-going operation, maintenance, or management activities.

The specific impacts of the dEIS alternatives vary in type, intensity, and duration according to the types of measures and activities occurring at any given time. Implementation of the preferred Alternative 2: Issuance of an ITP for permitted pumping under the District HCP would require tradeoffs between long-term productivity and short-term uses of the environment. Alternative 2 would result in the attainment of short-term and long-term springflow protection and habitat preservation at the expense of some social, economic, and biological impacts.

Examples of short-term losses:

- Potentially reduced populations of Covered Species in relation to lower springflow during drought conditions;
- Changes in water quality from reduced flows;
- Recreational impacts at Barton Springs;
- Costs associated with enhanced recharge through physical alteration of recharge features; and
- Restrictions in water use such as lawn watering.

Examples of short-term benefits:

- Protection of springflow by staged drought management pumping restrictions;
- Enhanced recharge through physical alteration of recharge features; and
- Public awareness of Aquifer conditions.

Examples of long-term losses:

- Loss of unrestricted use of groundwater withdrawals;
- Decline in water quality from continued urban and suburban development;
- Costs for development and operation of alternative water supplies; and
- Costs for monitoring and enforcement of wells, Aquifer levels, and water quality.

Examples of long-term benefits:

- Protection of a sustainable groundwater supply;
- Protection of springflow during drought conditions including DOR;
- Protection of suitable habitat for Covered Species;
- Increased public awareness for conservation of water and endangered species; and
- Support for development of alternative water supplies.

Among the four alternatives evaluated, Alternative 2 provides the best balance of short-term uses with long-term productivity. Conservation measures associated with an approved HCP would be both long-term and short-term, with the ultimate goal of providing long-term protection for Barton Springs and the Covered Species. A number of mitigation measures and adaptive strategies would be implemented during normal Aquifer conditions as well as periods of drought to protect the Covered Species and would serve both short-term and long-term needs. The imposition of a long-term drought management plan to regulate pumping from the Aquifer will require implementation of long-term future water management strategies, both to supplement available water supplies to satisfy current water demands and to provide additional water supplies to meet the growing water demands of the region.

Implementation of the HCP sets in motion several processes that potentially enhance conservation over the long-term. With the HCP in place, the issuance of an ITP would allow the District and pumpers to continue using the water resources of the Aquifer while conservation measures are implemented. This orderly and systematic approach to implementing the measures is intended to streamline compliance and conservation efforts in the region. In the long term, this balanced approach to water use and conservation would provide funding for mitigation and management, as well as public benefits and other long-term positive effects.

5.4 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

This section fulfills the requirements of NEPA (40 CFR 1502.16) to address irreversible and irretrievable commitments of resources. Irreversible impacts are those that cause, through direct or indirect effects, use or consumption of resources in such a way that they cannot be restored or returned to their original condition despite mitigation. An irretrievable impact or commitment of resources occurs when a resource is removed or consumed. These types of impacts are evaluated to ensure that consumption is justified.

Irreversible and irretrievable commitment of some resources could occur for each of the four alternatives depending on specific circumstances and the measures employed. All of the alternatives would likely result in some loss of biological resources (including the Covered Species) as a result of reduced springflow and resulting decline of populations. However, historical records indicate that this loss would not be permanent due to the capacity of the Covered Species to rebound as springflows recover from DOR conditions, unless the springflow were suppressed sufficiently long enough to permanently damage the capacity for species survival and resulting population increases. The risk of this possibility increases if springflow drops below historically recorded levels. The prevention of irreversible or irretrievable loss of biological resources would require an irreversible and irretrievable commitment of other resources that would vary among the four alternatives.

5.4.1 Alternative 1: No Action

Under Alternative 1 higher springflows associated with voluntary pumping reductions to less than 1 cfs would result in lower biological impact to the Covered Species during the worst drought conditions in comparison to Alternative 2. While the No Action alternative would not include a District ITP and associated HCP, each permitted pumper would be expected to comply with pumping cessation notices issued by the District or would need to seek an individual ITP for the Covered Species in order to continue pumping.

Under the No Action Alternative during DOR conditions, compliance by all permittees could reduce total Aquifer pumping to less than 1 cfs with resulting projected minimum average monthly springflow at Barton Springs of 11 cfs, which would be equivalent to the historic lowest flow during DOR conditions. Efforts by pumpers to voluntarily cease pumping during DOR conditions would involve potentially high commitments of irreversible and irretrievable resources involving time, labor, and finances. Under Alternative 1, reducing groundwater withdrawals would increase the demand for alternative water supplies. Increased supplies of surface water concurrent with stricter regulations for groundwater use would result in higher land and utility costs that would influence the local economy. Commitments of irretrievable resources to promote less reliance on groundwater and higher use of surface water through the development of physical infrastructure to collect and transport surface water supplies would be high under Alternative 1.

5.4.2 Alternative 2: Issuance of an ITP for Permitted Pumping under the District HCP

Alternative 2 would limit Aquifer pumping during DOR conditions to no more than 5.2 cfs, which would allow a predicted minimum average monthly springflow at Barton Springs of 6.5 cfs in comparison to the historical low average monthly springflow of 11 cfs that occurred during the DOR. Adverse effects would be considered irretrievable only if Aquifer levels were never allowed to recover to historic average levels and resulting habitat conditions never recovered because of permanently reduced flows or permanent alterations to the pools and outlets and associated infrastructure at the springs.

Even after the lowest recorded flow at Barton Springs occurred during the drought of record in 1950 to 1956, there appeared to be no irreversible or irretrievable loss of biological resources. The spring ecosystem recovered naturally, even with continued anthropogenic influences associated with continued Aquifer pumping and development within the Aquifer contributing and recharge zones. However, with the higher water withdrawals of the present day, irreversible changes could occur without adequate mitigation measures to protect the species during periods of reduced flows. It is noteworthy that there is a reasonable likelihood that over the course of thousands of years the Barton Springs salamander survived droughts worse than the DOR, but these events would not have been compounded by any anthropogenic influences associated groundwater withdrawals or associated human development within the Aquifer recharge and contributing zones.

Among the four alternatives, Alternative 2 contains the most mitigation measures to minimize and mitigate take of the Covered Species. These additional measures would require a higher commitment of irreversible and irretrievable resources with regard to staff time, funding, and operational support than Alternative 1, but not as high a commitment of staff time, funding, and operational support as Alternatives 3 and 4.

5.4.3 Alternative 3: Water Demand Reduction

Under Alternative 3, Water Demand Reduction would be achieved by imposing regulatory limits that would restrict Aquifer groundwater withdrawals to less than 1 cfs. This would result in a predicted average monthly springflow of 11 cfs, which would be equivalent to the historic lowest flow during DOR conditions. This alternative would require a high level of resources in staff time and funding to promote, support, and prepare the legislation to authorize the pumping restrictions; and, if authorized, financially compensate landowners if the pumping restrictions constitute a private property taking as allowed by a recent Texas Supreme Court ruling. Additional irretrievable resources involving staff time, legal support, and related funding would be needed for the substantial monitoring and enforcement that would also be required.

5.4.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 involves reducing the amount of pumping to the same level as Alternative 3, through the augmentation and substitution of other water supplies. Alternative water supply projects have been identified and discussed in **Section 4.4**.

Alternative 4 would result in potentially low biological impacts to Covered Species similar to Alternatives 1 and 3, but would also result in high commitments of human and financial resources to design, fund, build, and operate the infrastructure required to implement these alternative water supply projects.

Among the four alternatives, Alternative 2 provides the most practical and reasonably attainable measures that, despite resulting in irretrievable commitments of funding and management resources, would best balance economic and biological impacts.

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6.0 COORDINATION AND CONSULTATION

6.1 PUBLIC INVOLVEMENT

The current dEIS was prepared in consultation with the Service subsequent to a previous combined “Preliminary Draft HCP/Environmental Impact Study” that was submitted to the Service in June 2007. The combined document was based on public comment and scoping that was initially obtained from a public scoping meeting held in Austin, Texas on August 23, 2005. A summary of these comments is provided in **Appendix A-4**. Additional public comment and coordination was obtained through the involvement of two HCP steering committees: a Citizens Advisory Committee (CAC) and Biological Advisory Team (BAT). A summary of this early coordination and scoping is described in **subsection 1.6.2**. After the combined draft HCP/Environmental Impact Study was submitted to the Service in June 2007, several events occurred that required reevaluation of and major modifications to the dHCP and dEIS. After completing a review of the combined draft document, the Service requested that the HCP and dEIS be prepared independently as separate documents. The Service also offered suggestions for improvement of the HCP. Additional scientific data also became available concerning the effects of dissolved oxygen on the biology of the Barton Springs salamander in addition to other pertinent data concerning updated predicted springflow frequencies during the period of record, and relationships between springflows and dissolved oxygen concentrations.

In response to new scientific information that became available, and circumstances that had changed since the initial draft HCP and dEIS was submitted, it became necessary to re-scope the project to determine whether any new issues existed. A public scoping meeting was held on April 3, 2014, to update the scope of issues and concerns concerning the proposed action. A record of public comments received is posted online at ***http://www.regulations.gov*** and is also included in **Appendix A-2**.

Based on these events, the District began substantial revision to the HCP and consolidated the functions of the CAC and BAT into the HCP Management Advisory Committee (MAC). The purpose of the MAC is to advise and assist in the coordination of conservation activities affecting Covered Species at Barton Springs, and to monitor the implementation of the District HCP to ensure compliance with conditions of the ITP. Members of the MAC are listed in **Appendix A-1**.

To provide additional opportunity for public involvement, the District Board conducted a public hearing on September 11, 2014, to solicit any public comments on the District’s Draft HCP prior to submission of an ITP application package to the Service. A summary of the public hearing is provided in **Appendix A-3**.

6.2 AGENCY INVOLVEMENT

No other agencies were involved with the development of this dEIS.

Public Review and Distribution

This dEIS will be available for review and comment during a 60-day public review period. The Notice of Availability will be posted on the Austin Ecological Services Office website at ***http://fws.gov/southwest/es/austintexas***. Comments may be provided at www.regulations.gov.

6.3 CONSULTATION WITH OTHERS

The following individuals (listed in alphabetical order) contributed information that was incorporated into this dEIS:

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- Dr. Kent Butler (Deceased), Kent Butler Associates
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- Brian Hunt, Certified Professional Geologist, Barton Springs/Edwards Aquifer Conservation District
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9.0 RESPONSE TO COMMENTS

To be provided.

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10.0 GLOSSARY

This glossary was prepared to provide terms commonly used in describing underground and surface hydrological processes. It also provides additional terminology to assist in understanding information provided in this environmental document. Definitions were derived in part by referencing the Barton Springs/Edwards Aquifer Conservation District (2006), Edwards Aquifer Authority (1998), and Eckhardt (2014).

Acid rain. The acidic rainfall that results when rain combines with sulfur or nitrogen oxide emissions from combustion of fossil fuels.

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

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

Ammonia (NH_3). A colorless, pungent gas composed of nitrogen and hydrogen. It is the simplest stable compound of these elements and serves as a starting material for the production of many commercially important nitrogen compounds.

Aquifer. A water-bearing stratum of permeable rock, sand or gravel.

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

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

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

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

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

Bad water. Characterized by having more than 1,000 milligrams per liter of dissolved solids. It may be low in dissolved oxygen, high in sulfates and have a higher temperature. The bad water line is the eastern boundary of fresh water in the Edwards Aquifer in the Barton Springs segment.

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

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

Best management practices (BMPs). Professionally accepted, state-of-the-art management techniques.

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

Cavern. A large underground opening in rock (usually limestone) that occurs when some of the rock is dissolved by slightly acidic water.

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

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

Coliform bacteria. Non-pathogenic microorganisms used in testing water to indicate the presence of pathogenic bacteria.

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

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

Conduit. A natural or artificial channel through which fluids may be conveyed.

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

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

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

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

Desalination. The process of salt removal from sea or brackish water.

Desired Future Conditions (DFC). Aquifer conditions jointly determined as "desired" by defined groups of groundwater conservation districts (members of a Groundwater Management Area) as required by HB 1763, 79th Legislature.

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

Dispersion. The movement and spreading of contaminants out and down in an aquifer.

Dissolution. The process of dissolving.

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

Dissolved solids. Inorganic material contained in water or wastes. Excessive dissolved solids make water unsuitable for drinking or industrial uses. See Total Dissolved Solids.

District Management Plan. A groundwater district management plan that meets the requirements of 31 TAC § 356.5 as required by Texas Water Code, §36.1071 and §36.1072.

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

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

Drought of Record (DOR). Worst drought occurring according to the historical record. Although the Texas Water Development Board indicates this drought lasted from 1950-1956, other sources (Smith et al. 2013) indicate the drought began in 1947 and lasted through 1956.

Drought stages. Stages of pumpage reductions established by the BSEACD: No Drought, Water Conservation (Voluntary); Alarm; Critical; Exceptional; and Emergency Response.

Drought trigger. A level of the aquifer as determined by depth to water or rate of discharge of Barton Springs that when reached during drought conditions will determine a drought stage and require an associated percentage reduction in the amount of groundwater pumped.

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

Edwards Aquifer. Water bearing zone comprising Edwards and Associated Limestones.

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

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

Environment. Aggregate of external conditions that influence the life of an individual organism or population.

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

Escarpment. The topographic expression of a fault.

Fault zone aquifer. An aquifer developed in association with a zone of faulting, e.g., Balcones fault zone and the resulting Balcones Escarpment with the associated Edwards fault zone aquifer.

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

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

Floodplain. Land next to a river that becomes covered by water when the river overflows its banks.

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

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

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

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

Groundwater. Water that is stored under the earth’s surface.

Groundwater availability model. A mathematical model of aquifer dynamics used to estimate the availability of groundwater under specific assumptions.

Groundwater Conservation District (GCD). A regulatory district established by the Texas Legislature to conserve and manage groundwater.

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

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

Groundwater storage. The storage of water in groundwater reservoirs.

Hydrogeology. A term which denotes the branch of geology relating to subsurface or subterranean waters; that is, to all waters below the land surface.

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

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

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

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

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

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

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

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

Intermittent stream. One that flows periodically. Compare to perennial stream.

Irrigation. Supplying water by artificial means to crops.

Limestone. Rock that consists mainly of calcium carbonate and is chiefly formed by accumulation of organic remains.

Modeled Available Groundwater (MAG). An amount of groundwater determined to be available by the TWDB modeling of specific aquifers based on "desired future conditions" identified by groups of groundwater conservation districts under the requirements of HB 1763, 79^{th} Legislature.

Maximum contaminant level (MCL). The maximum level of a contaminant allowed in water by Federal law. Based on health effects and currently available treatment methods.

Milligrams per liter (mg/l). A measure of chemical concentration; this measure is numerically equivalent to parts per million (ppm) in dilute aqueous solutions.

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

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

Outcrop. Exposed at the surface. The Edwards limestone outcrops in its recharge zone.

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

Perennial stream. One that flows all year round. Compare to intermittent stream.

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

Permeable. Having a texture that permits liquid to move through the pores.

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

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

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

Pollutant. Any substance which restricts or eliminates the use of a natural resource.

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

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

Parts per billion (ppb). Number of parts of a chemical found in one billion parts of a solid, liquid, or gaseous mixture. Numerically equivalent to micrograms per liter (µg/l).

Parts per million (ppm). Number of parts of a chemical found in one million parts of a solid, liquid, or gaseous mixture. Numerically equivalent to milligrams per liter (mg/l).

Recharge. Process involved in absorption and addition of water to the zone of saturation.

Recharge zone. The area in which water infiltrates into the ground and eventually reaches the zone of saturation in one or more aquifers. For the Barton Springs portion of the Edwards Aquifer, an area in southern Travis and northern Hays Counties defined by the BSEACD in which recharge to the Edwards Aquifer occurs.

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

Refugium. A suitable artificial environment into which endangered plants and animals are temporarily removed during a period of extreme ecosystem stress.

Riparian zone. A stream and all the vegetation on its banks.

River or creek basin. The area drained by a river or creek and its tributaries.

Runoff. Surface water entering rivers, freshwater lakes, or reservoirs.

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

Salinity. Amount of dissolved salts in a given volume of water.

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

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

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

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

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

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

Spray irrigation. Application of finely divided water droplets to crops using artificial means.

Specific conductance. Specific conductance is a measure of how well water can conduct an electrical current. Conductivity increases with increasing amount and mobility of ions. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water. Therefore, specific conductance is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of salinity.

Spring. A place where groundwater flows from rock or soil upon the land and becomes surface water.

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

Stream. A general term for a body of flowing water.

Streamflow. The discharge that occurs in a natural channel.

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

Subterranean. Being or lying under the surface of the Earth.

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

Total dissolved solids. The concentration of dissolved minerals in water, expressed in units of milligrams per liter (mg/l).

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

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

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

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

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

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

Appendix A

Public Involvement

Appendix A-1

Membership of the HCP Management Advisory Committee

Appendix A-1

Membership of the District HCP Management Advisory Committee

Table A-1 Membership of the District HCP Management Advisory Committee (MAC)

Member	Organization	Function
Cindy Loeffler	Texas Parks and Wildlife Department (TPWD)	State Regulatory Agency
Kevin Connally	U.S. Fish and Wildlife Service (FWS)	Federal Regulatory Agency
Chris Herrington	City of Austin	City Government
Jon White	Travis County	County Government
Todd Voteller	Guadalupe-Blanco River Authority (GBRA)	Water Supplier
Laurie Dries	City of Austin	Ecological Expert
Jason Biemer	City of Kyle	Groundwater User/Supplier
Jennifer Walker	Sierra Club	Conservation Group
Bryan Brooks	Baylor University	Ecological Expert
David Loftis	Centex Materials	Groundwater User
Scott Nester	Private Landowner	Private Property Interests
Christy Muse	Private Landowner	Private Property Interests
Clif Ladd	At-large	Consultant
Karen Huber	At-large	Consultant

Appendix A-2

Public Comment in Response to Published Notice of Intent by the U.S. Fish and Wildlife Service to Prepare an Environmental Assessment

Appendix A-2

Public Comments in Response to Published Notice of Intent by U.S. Fish and Wildlife Service to Prepare an Environmental Assessment

Notice of Intent to Prepare an Environmental Assessment for the Barton Springs/Edwards Aquifer Conservation District for Proposed Incidental Take Permit Addressing Take of Two Federally Listed Species in Central Texas

Notice by FWS on 03/05/2014

Comment Period Closed on Apr 04, 2014 11:59 PM ET

Docket ID: FWS-R2-ES-2013-0128

Agency: Fish and Wildlife Service (FWS)

Parent Agency: Department of the Interior (DOI)

Summary:

We, the U.S. Fish and Wildlife Service (Service), advise the public that we intend to prepare a draft Environmental Assessment (EA) to evaluate the impacts of, and alternatives to, the proposed issuance of an incidental take permit to the Barton Springs/Edwards Aquifer Conservation District (District). The permit, issued under the Endangered Species Act, as amended (Act), would allow for potential take of two federally listed species associated with the ongoing management and withdrawal of groundwater from the Barton Springs segment of the Edwards Aquifer (Aquifer) in Central Texas.

Comment

I oppose killing two species of salamander for this aquifer. you need to find another plan. there is no reason to allow these two species to be murdered. this comment is for the public record.

Comment

April 4, 2014

RE: “Notice of Intent to Prepare an Environmental Assessment for the Barton Springs/Edwards Aquifer Conservation District for the Proposed Incidental Take Permit Addressing Take of Two Federally Listed Species in Central Texas”

Docket ID: FWD-R2-ES-2013-0128

Dear Mr. Zerrenner:

The notice indicates that the U.S. Fish and Wildlife Service (UWFWS) intends to prepare a draft Environmental Assessment (EA) to evaluate the impacts of, and alternatives to, the proposed issuance of an incidental take permit to the Barton Springs/Edwards Aquifer Conservation District (District). It is the Sierra Club's position that a full Environmental Impact Statement (EIS) is warranted in this case. The potential for significant threat to the survival and viability of the Barton Springs salamander and the Austin blind salamander are real. The threats are numerous, but the one threat that is most directly controlled by the District is pumping from the Barton Springs/Edwards Aquifer. The District's current management plan and rules will allow flow from Barton Springs to decrease to 6.0 cubic feet per second (cfs) during a severe drought. The District's goal or "Desired Future Condition" per their Water Management Plan is to preserve 6.5 cfs of spring flow and it should be noted that the District is working to find solutions towards preserving the full 6.5 cfs. However, this proposed spring flow volume is nearly one half of what has been recorded historically (11.7 cfs) and could result in take or harm of the species in question. For this reason alone, we believe that a full EIS is warranted.

Another key issue in providing take protection associated with very reduced flows during drought periods will be measures to monitor and ensure that the water quality of those flows is high enough to minimize stress to salamanders at all of the spring orifices where salamanders occur. While the District does not directly regulate water quality, lower flows could result in lower water quality.

The notice uses very broad language and states that incidental take "that may result from activities associated with management and pumping of the Barton Springs segment of the Edwards Aquifer in Caldwell, Hays, and Travis Counties, Texas." "Management" is a very broad term and it does not seem appropriate to seek take protection for activities beyond pumping and regulation of pumping from the Barton Springs/Edwards Aquifer. The scope of issues that must be addressed in an EA or EIS would expand dramatically if the intent is to provide broader coverage.

Thanks you for your consideration of these comments. We look forward to working with USFWS and the District on this matter.

Sincerely,

Jennifer Walker
Sierra Club, Lone Star Chapter

Comment

Attention: U.S. Fish and Wildlife Service

Subject: Docket #FWS-R2-ES-2013-0128: Notice of Intent to Prepare an Environmental Assessment for the Barton Springs/Edwards Aquifer Conservation District for Proposed Incidental Take Permit Addressing Take of Two Federally Listed Species in Central Texas

To whom it may concern,

My name is Lexi Erwin, and I am submitting comment as a student studying Programs in the Environment at the University of Michigan. This comment will focus on the proposed environmental assessment to gain the permission to “take” two federally listed species in Central Texas from the Barton Springs/Edwards Aquifer Conservation District. I do not agree with the action that is being proposed and my primary reasons for that are listed below.

First, the term “take” is not defined in the assessment, but federalregister.gov provides the definition. To “take” a specimen from its habitat means to either harm, harass, pursue, hunt, shoot, wound, kill, trap, capture, or collect a specimen. The environmental assessment references the benefits of taking these 2 species from their habitat to better the Conservation District, however: it could be argued that no matter how great the benefits, using these specific measures is ethically wrong.

Second, to “take” equates to harassing the fish, which will mean injuring the animal and disrupting the natural behavior of this fish. The fish will lose its ability to breed, to protect, and to provide shelter for similar species. The fish has the potential of becoming endangered because of the lack of ability adapt to a new habitat or thrive the same way it does now, in a new environment.

Third, the disruption of the individual behavior equates to a lack of diversity in the conservation district. The species-by-species approach, removing and adding one species at a time, will hurt the multispecies habitat in place. This can cause other species to begin to die off because they needed the support and the production of the other species that are being removed from the area.

Thank you for allowing me to comment on the assessment of the Barton Springs/Edwards Aquifer.

Lexi Erwin, a University of Michigan Student

Appendix A-3

Minutes from the Public Hearing on the Barton Springs/Edwards Aquifer Conservation District Draft Habitat Conservation Plan Held on September 11, 2014

Appendix A-3

Minutes from the Public Hearing on the Barton Springs/ Edwards Aquifer Conservation District Draft Habitat Conservation Plan Held on September 11, 2014

The following minutes were extracted from the Barton Springs/Edwards Aquifer Conservation District Board of Directors Meeting Minutes of the Regular Meeting and Public Hearing held on September 11, 2014.

> **The Board will hold a Public Hearing for the proposed draft Habitat Conservation Plan (HCP) that has been developed in support of a prospective application for an Incidental Take Permit (ITP) from the United States Fish and Wildlife Service. The proposed HCP includes measures necessary to avoid, minimize, and mitigate potential adverse effects or "take" of the endangered Barton Springs salamander (*Eurycea sosorum*) and Austin blind salamander (*Eurycea waterlooensis*) associated with District-permitted withdrawals of groundwater from the Barton Springs segment of the Edwards Aquifer.**

Dr. Larsen opened the Public Hearing at 6:15 p.m.

Mr. Dupnik and Brian Hunt provided a presentation providing a brief history of the project, the context for the HCP, an HCP overview, and suggested next steps.

Dr. Laurie Dries, the MAC chair, provided a summary of comments from the MAC on the most recent draft plan that was received.

Ms. Dries first stated that the MAC agrees with the conservation measures proposed in the plan and commended the decision to hire a technical editor noting that improving the readability of the document will facilitate document review and reduce future comments. Mr. Dries further described some remaining concerns and questions related to the need to better explain the take estimate methodology, the "gap" between the permitted pumping and the adopted extreme drought MAG, and the absence of a distinction between lethal and sublethal take in the take estimates. Ms. Dries concluded by thanking the District and expressed appreciation for the District's efforts to address all of the MAC comments submitted to that point.

Mr. Jon Beall of Save Barton Creek Association also commended the District for their efforts to obtain the ITP, and thanked everyone who worked on it.

Mr. Dupnik read a letter that was submitted by Save Our Springs Alliance into the record.

There were no other public comments; therefore, Mr. Smith moved to close the Public Hearing at 7:15 p.m.

Ms. Stone seconded the motion and it passed with a vote of 4 to 0.

Appendix A-4

Summary of Results of Public Scoping Meeting of August 23, 2005 and Letters Received

Appendix A-4

Summary of Results from Public Scoping Meeting of August 23, 2005 and Letters Received

Table A-4. Summary of results from public scoping meeting of August 23, 2005 and letters received

Issue Categories	Number of Comments
Groundwater flow routes need study	1
Need to protect prey species in aquifer; uncertainty as to how flow changes will impact species and food base	2
Biodiversity unknown, evidence of genetic links between Barton Springs and San Marcos salamander species	3
Consider 1950's drought impacts; restrict water usage during times of drought; CAC should help revise District's Drought Trigger Methodology	4
More outreach needed to make process understandable, alternatives should be described early in HCP process; initial CAC meeting and scoping meeting of the Service on August 23, 2005 were designed to inhibit and manage discussion, as well as information flow; facilitation of communication between the members of the CAC needed; facilitate communication between BAT and CAC; input of the CAC and the BAT is already improperly constrained	7
Investor-owned water utility must balance limiting aquifer pumping against obligation to serve demand under state law	1
Role of conjunctive use in HCP	1
New road and water infrastructure in aquifer contributing and recharge zones needed to serve growth is too expensive, better to use money to buy land and preserve	4
County land regulation authority needed; conservation development emphasis needed	2
Sprawl development subsidizes growth; acquisition of open space needed over the recharge zone and within the service area of the District; address growth served by groundwater	3
Economic impact of pumping limits needs study	1
Sustainable population concept should be considered	1
District should use pricing to manage groundwater via market; greater water conservation from District customers needed	2
Expand scope to address synergistic effects of pollution and water quantity/quality in more detail	1
Pesticides and sedimentation are main threats to species; habitat stressors also include reduced springflows, oxygen content, toxic pollutants including petroleum by-products	2

Table A-4, continued

Issue Categories	Number of Comments
To the maximum extent practicable, minimize and mitigate the impacts of taking and assure that the taking will not appreciably reduce the likelihood of the survival and recovery of the species in the wild; over-reliance on adaptive management to make up for inadequate up-front planning does not meet the legal requirements of the ESA	2
EIS should examine in detail the stochastic risk of species extinction; impact of any authorized take should be minimized by establishing minimum springflows that are clearly sufficient to ensure the continued survival and recovery of the species	2
Captive breeding and off-site refugia are not reliable or legally adequate means of ensuring the continued survival of the species in the wild	1
TOTAL	40

CAC = Citizens' Advisory Committee
HCP = Habitat Conservation Plan
BAT = Biological Advisory Team
ESA = Endangered Species Act
EIS = Environmental Impact Study
Source: Service, draft comments from BSEACD HCP EIS scoping, 09/07/05

Appendix B

Summary of Climate Change Impacts in Texas
Focus on Central Texas

ECOLOGIA CONSULTING

Summary of Climate Change Impacts in Texas

Focus on Central Texas

Wendy S. Gordon, Ph.D.

7/2014

This document is a synthesis and summary of the most recent climate assessments covering the U.S. Data for Texas have been extracted from these reports, with a focus on changes in temperature and the hydrologic cycle that have occurred in Central Texas since about 1900 as well projected changes for the next 20 years.

Current State of Climate Assessments

Updated climate assessments covering the United States were published in 2013 and early 2014. The most relevant reports are: 1) *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 4, Climate of the U.S. Great Plains* (NOAA, 2013), 2) *the Third National Climate Assessment (NCA) Report* (Melillo et al., 2014), and 3) the *Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change* (IPCC, 2013). The *Regional Climate Trends and Scenarios for the U.S. National Climate Assessment, Part 4, Climate of the U.S. Great Plains* was one of a series of regional analyses undertaken to support the *Climate Change Impacts in the United States: The Third National Climate Change Assessment*. Concurrent to the U.S. effort was the five-year update of the global assessment of the IPCC. In preparation for AR5, a new generation of global climate models or general circulation models (GCMs) were built and tested. The IPCC's Third Assessment Report and Fourth Assessment Report were largely based on the third phase of the Coupled Model Intercomparison Project (CMIP3) simulations. The fifth phase of the Coupled Model Intercomparison Project (CMIP5) provided the basis for most of the assessment of future climate change by Working Group 1 of AR5. Thirty-nine models were included in CMIP5 at the time of the IPCC assessment. CMIP3 involved 21.

For AR5, the scientific community defined a set of four new scenarios, denoted Representative Concentration Pathways (RCP). They are identified by their approximate total radiative forcing (the amount of energy being added to the Earth's climate system) in year 2100 relative to 1750: 2.6 watts per square meter ($W\ m^{-2}$) of the Earth's surface for RCP2.6, 4.5 $W\ m^{-2}$ for RCP4.5, 6.0 $W\ m^{-2}$ for RCP6.0, and 8.5 $W\ m^{-2}$ for RCP8.5. These four RCPs include one scenario in which greenhouse gas emissions are mitigated leading to a very low forcing level (RCP2.6), two stabilization scenarios (RCP4.5 and RCP6), and one scenario with very high greenhouse gas emissions (RCP8.5). Thus, the RCPs represent a range of 21st century climate policies, as compared with the no-climate policy of the Special Report on Emissions Scenarios (SRES) (e.g., A1B, B1) that were used in the Third Assessment Report and the Fourth Assessment Report. For RCP6.0 and RCP8.5, radiative forcing does not peak by year 2100; for RCP2.6 it peaks and declines; and for RCP4.5 it stabilizes by 2100. CMIP5 relies on these four RCPs. It is worth noting that the emissions trajectory in RCP8.5 is similar to SRES A2 and RCP4.5 is roughly comparable to SRES B1.

The models comprising CMIP5 represent improvements in resolution and other climate modeling capabilities over CMIP3. Interestingly, despite increases in model resolution and complexity, projected patterns and magnitude of future temperature and precipitation changes are not substantially different from CMIP3 to CMIP5. The IPCC concluded that the broad similarity of outcomes between the two modeling projects demonstrated the fundamental soundness of the underlying climate models. For instance, Wuebbles et al. (2013) found that in comparing new CMIP5 results with earlier CMIP3 simulations, CMIP5 simulations generally yielded similar patterns and magnitudes of future temperature and precipitation extremes in the U.S. relative to projections from the earlier CMIP3 simulations.

Neither the *Third National Climate Assessment* nor the supporting Great Plains climate assessment used CMIP5 output; the information was not sufficiently developed to meet those programs' timelines. Hence, IPCC AR5 might be considered the most state-of-the art of the recent assessments. Nonetheless, there are insights to be gathered from each of the assessments and comparisons are provided where analyses allow.

Climate projections through 2035 are the focus of this report. To the extent that projections could be isolated for Central Texas from larger-scale modeling domains, those results are presented. GCMs operate on grid cells that may be as large as 200 miles on a side and many of the graphics reported in IPCC AR5 or the *Third National Climate Assessment*, for example, do not provide the fine detail to locate Austin, TX or the Edwards Aquifer on a map. In some cases, the climate variable of interest shows the same widespread pattern across Texas, negating the need for locational specificity. In other cases, data presented from simulations may show heterogeneity across the state and it becomes challenging to interpolate mottled color patterns. In those instances, a range of values has been reported.

Observed Changes in Temperature

The *Third National Climate Assessment* reports that U.S. average temperature has increased by 1.3° F to 1.9° F since 1895; most of this increase has occurred since 1970 (Melillo et al., 2014). In the contiguous U.S., the last decade was the warmest on record and 2012 was the warmest year on record. Temperatures in the U.S. are expected to rise another 2° F to 4° F over the next few decades. There is a statistically significant upward trend in temperature for the winter (0.14°F/decade) and spring (0.11°F/decade) months in the Southern Great Plains for the period 1895-2011 (NOAA, 2013). Since 1991, temperatures have averaged 1 to 1.5°F higher than the 1901-1960 average over most of the U.S. In Central Texas that increase has been about 1°F (Figure 1).

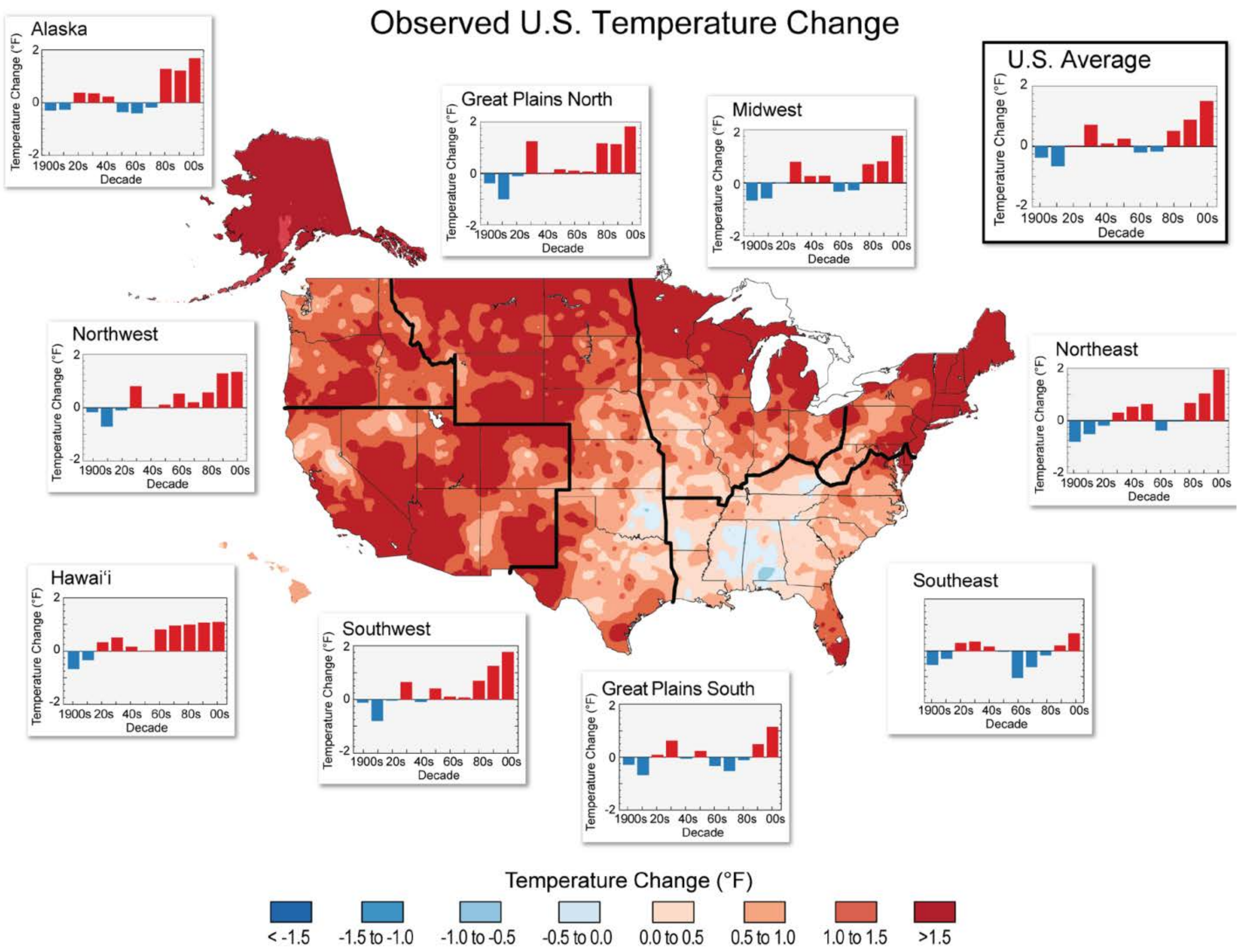


Figure 1. Observed U.S. temperature change from 1991-2012 compared to the 1901-1960 average (1951-1980 for Alaska and Hawai'i) in degrees Fahrenheit. Bars on the graphs show average temperature changes by decade relative to the long-term average for each region. The far right bar in each graph (2000s) includes 2011 and 2012. The period from 2001 to 2012 was warmer than any other decade in every region. From Melillo et al., 2014.

Observed Changes in the Hydrologic Cycle

Average annual precipitation over the continental U.S. increased nearly two inches between 1895 and 2011 (Georgakakos et al., 2014). Central Texas experienced increases in precipitation on the order of 5-15% from 1991-2012 compared to the 1901-1960 average (Figure 2). This increase reflects, in part, the major droughts of the 1930s and 1950s, which made the early half of the record drier. Nonetheless, it is consistent with the trend of increasing precipitation observed across the Great Plains in recent decades (Georgakakos et al.,, 2014) and it is consistent with a previous analysis by the U.S. Climate Change Research Program (USGCRP,

Observed U.S. Precipitation Change

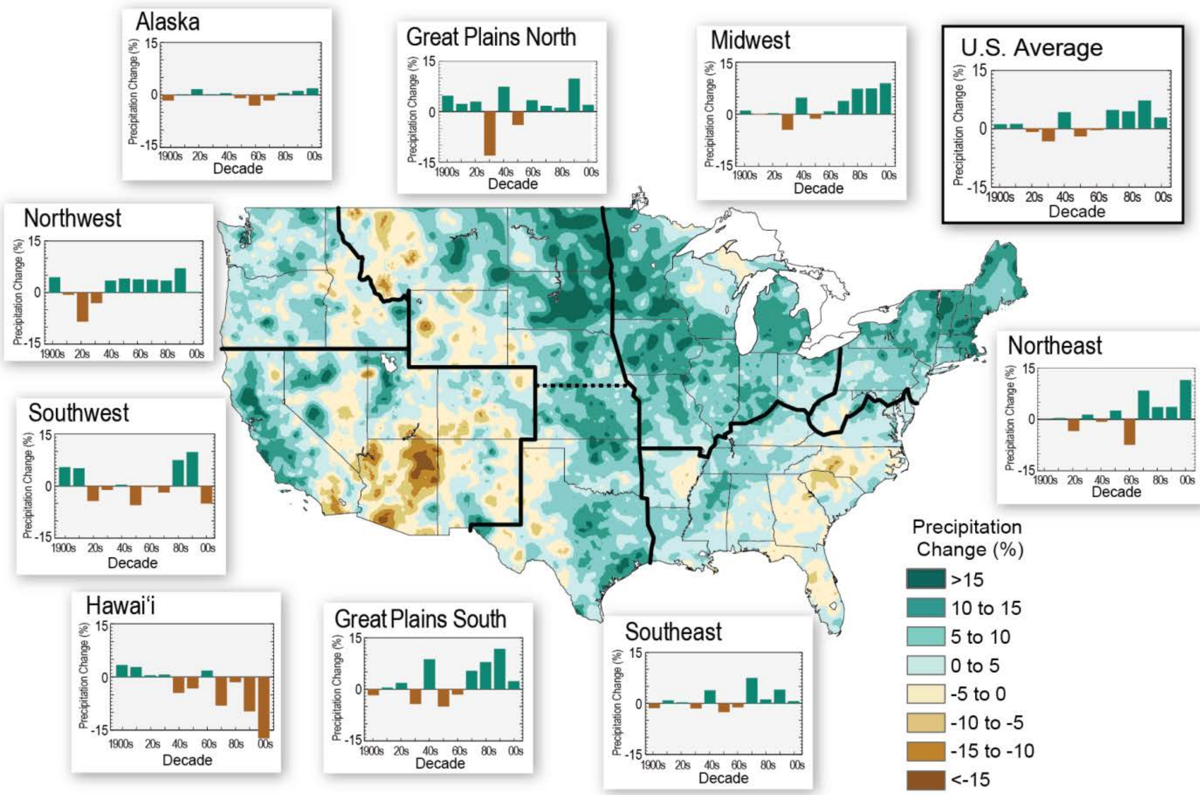


Figure 2. Observed U.S. precipitation change for 1991-2012 compared to the 1901-1960 average (1951-1980 for Alaska and Hawai'i). Bars on the graphs show average precipitation differences by decade relative to the long-term average. The far right bar is for 2001-2012. From Melillo et al., 2014.

2009) using the slightly different reference period of 1958-2008 that showed very similar results, especially over Central Texas (Figure 3).

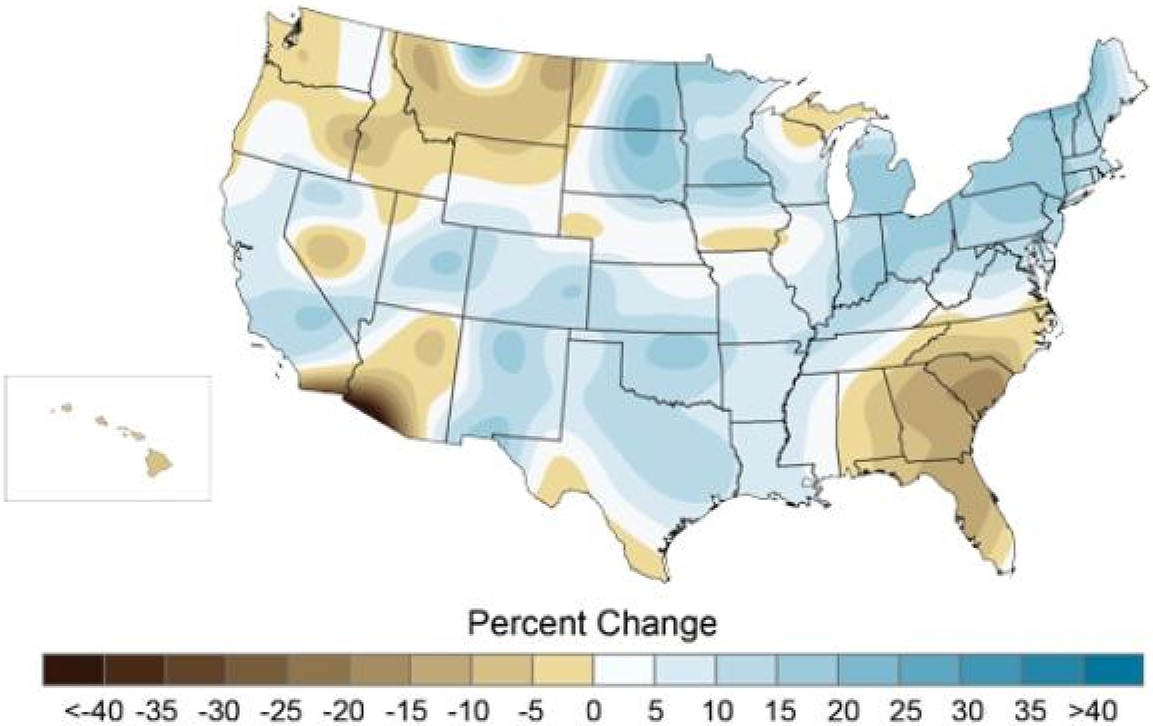


Figure 3. Observed change in average annual precipitation in the U.S. from 1958-2008 (USGCRP, 2009).

McRoberts and Nielsen-Gammon (2011) calculated a linear trend of 10-15% increase (per century) in annual precipitation from a dataset extending from 1895-2009 for the South Central Texas climate division. They also noted a possible upward trend bias of 1-3%.

Across most of the U.S., the heaviest rainfall events – defined as the heaviest 1% of all daily events – have become heavier and more frequent (Melillo et al., 2014; Figure 4). Since 1991, the amount of rain falling in very heavy precipitation events has been above average in every region of the country. Warmer air can contain more water vapor than cooler air. Global analyses show that the amount of water vapor in the atmosphere has, in fact, increased over both land and oceans (Melillo et al., 2014). Observed global trends suggest extreme precipitation increases of about 4% per 1° F of warming (Boucher et al., 2013).

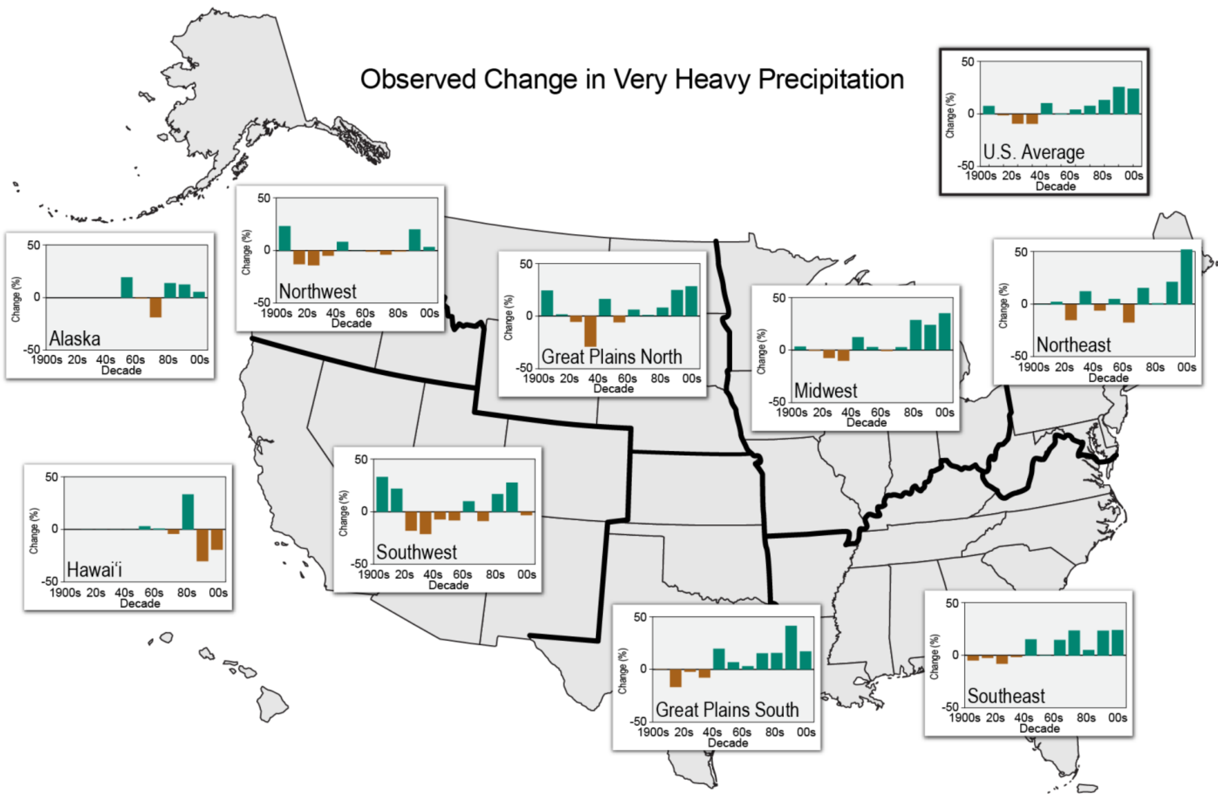


Figure 4. Percent changes in the annual amount of precipitation falling in very heavy events, defined as the heaviest 1% of all daily events from 1901 to 2012 for each region of the U.S. The far right bar is for 2001-2012. Changes are compared to the 1901-1960 average (1951-1980 for Alaska and Hawai'i). From Melillo et al., 2014.

The USGCRP (2009) reported that between 1958 and 2008, the amount of rain that fell in very heavy precipitation events increased by about 15% over Texas. Additional studies have corroborated this finding including the *Third National Climate Assessment*, which reported a 16% increase in precipitation falling in very heavy precipitation events over the Great Plains from 1959 to 2012 (Melillo et al., 2014). Groisman et al. (2012) examined the frequency of moderately heavy, heavy, very heavy, and extreme precipitation across the U.S. In the past several decades, the frequency of very heavy precipitation events (upper 0.3% of daily precipitation or greater than 4.0 inches of daily rain in the central U.S. including Texas) and extreme precipitation events (greater than 6 inches of daily rain in the central U.S.) began to increase over much of the conterminous U.S. east of the Rockies. The contribution of these events to annual totals also increased. Over the central U.S., changes in very heavy precipitation became statistically significant during the past 30-40 years, showing an increase of 10-40%. There was a 40% increase in the frequency of daily rain events above 6 inches in the central U.S. Moreover, 88% of these extreme gain days were not tropical cyclone related nor were tropical cyclones a major factor responsible for temporal changes reported for intense precipitation. Very heavy rainfall is linked to El Nino months rather than La Nina months over the central U.S.; La Nina conditions are associated with a smaller number of very heavy precipitation events over the central U.S. than other El Nino Southern Oscillation phases including neutral. The frequency of El Nino events compared with La Nina events increased in the 30 years from 1979-2009 compared with the prior 30 years. Because La Nina events became less frequent in the past decades, this aspect of global climate change may be contributing to the observed increase of very heavy and even extreme precipitation (Groisman et al., 2012).

Soil moisture, on a regional scale, has historically been difficult to monitor and has often been inferred from models, but it is well-recognized that soil moisture plays a major role in the water cycle including the production of runoff and the recharge of groundwater aquifers. In the last 20 years, soil moisture appears to have declined in parts of the Southeast, Southern Great Plains, and Southwest (Melillo et al., 2014). In the Southern Great Plains, droughts have increased during the last 40 years (Walsh et al., 2014). Increasing temperatures have made droughts more severe and widespread than they would be otherwise (USGCRP, 2009). In Texas, the summer of 2011 was both the warmest on record and the driest on record (records dating back to 1895). From a paleoclimatic perspective using tree rings as a proxy for drought, the 2011 drought in Texas was approximately equal in intensity to the worst droughts of the past 429 years (NOAA, 2013).

Future Climate Projections

Climate modeling has advanced greatly and continues to advance. Nonetheless, there are many uncertainties associated with long-term climate modeling, from emissions trajectories, to cloud parameterizations, to unknown future volcano events, to land use changes, etc. The uncertainties stack up the more decades into the future one is trying to peer. By simulating historical climate and comparing it to observations, the climate modeling community can quantify and correct for biases. Some findings, for example, are that model simulations of precipitation generally reproduce the overall observed trend – and CMIP5 offers a slight improvement over CMIP3 - but observed decade-to-decade variations are greater than what the models produce or they typically simulate too much light precipitation and too little heavy precipitation, particularly in the tropics and middle latitudes (NOAA, 2013). There are small differences generated by the CMIP3 and CMIP5 assembleges of models but those differences are within observational uncertainties in the area that includes Texas. Over Central Texas, the multi-model average tends toward a small, wet bias. Investigations attribute this to being too moist throughout the troposphere (Flato et al., 2013). In general, the scale at which the hydrologic cycle operates is much more variable than the factors influencing surface temperature. Hence, it is not surprising that climate models have greater difficulty generating agreement on hydrologic variables than temperature.

A viewer recently developed by NASA and USGS derives high resolution data sets from the CMIP5 simulations of temperature and precipitation using statistical downscaling methods[1] to produce the NEX-DCP30 data on a very fine 800-m grid that covers the continental United States (CONUS) (http://www.usgs.gov/climate_landuse/clu_rd/nex-dcp30.asp) (Adler and Hostetler, 2013). The full NEX-DCP30 dataset includes 33 climate models and their respective downscaled data for historical (1950-2005) and 21st century simulations under the four RCP emission scenarios developed for AR5. The NEX-DCP30 Viewer includes historical and future (2006-2099) climate for RCP4 and RCP8 from 30 of the models. To create a manageable number of permutations for the viewer, the NEX-DCP30 data are averaged into 25-year climatologies that span the 21st century. Even though these data are available at a much finer resolution than that generated by GCMs, the added value of using regional climate models, from which downscaled projections are derived, mainly appears in the simulation of topography-influenced phenomena, such as that associated with mountain chains or along coasts, and in simulating extremes with relatively small spatial or short temporal character. Hence, for much of Texas, downscaling does not generate projections different from that generated at the scale of a GCM grid.

Projected Temperature Changes

The projected change in average air temperature over Central Texas for 2016-2035 based on RCP4.5 is an increase of 1.8 - 2.7 degrees F over the 1986-2005 period, with slightly greater warming occurring in the summer months than the winter months (Kirtman et al., 2013). CMIP5 warming projections are similar to the earlier CMIP3 projections based on the A2 scenario for the period 2021-2050 included in the *Third National Climate Assessment* (recall that present-day emissions exceed the B1 scenario so B1 is not equivalent to RCP4.5) (Figure 5).

Using the NEX-DCP30 data viewer for Hays and Travis Counties, CMIP5 output averaged over the time period of 2025-2049 projects an increase in annual average maximum temperature of about 3° F (Table 1) compared to the historical period of 1980-2004, regardless of the RCP specified (Adler and Hostetler, 2013). The similarity of outcomes irrespective of RCP is because of lags in the climate system. Near-term (i.e., next few decades) changes in temperature and precipitation reflect greenhouse gases that have already been emitted into the atmosphere. Average annual minimum temperature increases about 2.5° F in RCP4.5 and 3° F in RCP8.5

[1] Downscaling is a method for obtaining high-resolution climate or climate change information from relatively coarse-resolution general circulation models (GCMs). Typically, GCMs have a resolution of 150-300 km by 150-300 km. To assess impacts at smaller scales some method is needed to estimate the smaller-scale information.

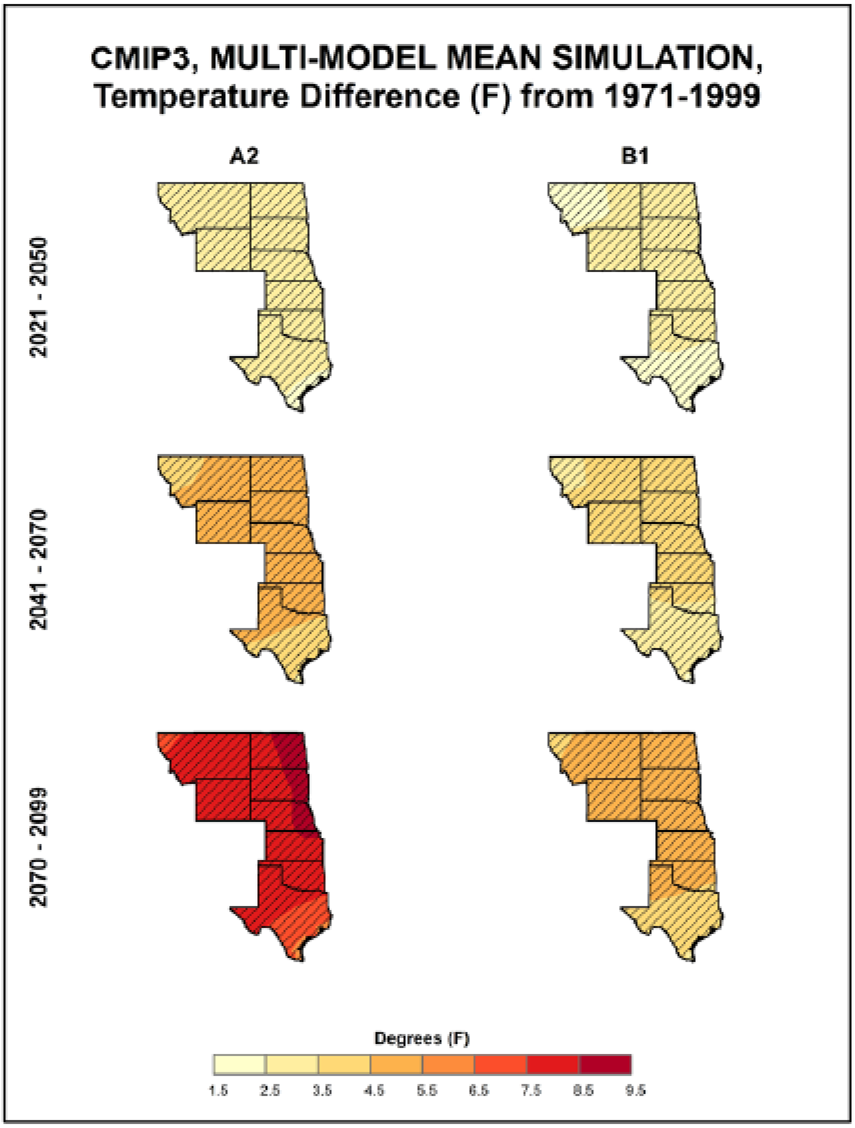


Figure 5. Simulated difference in annual average temperature (°F) for the Great Plains region, for each future time period (2021-2050, 2041-2070, and 2070-2099) with respect to the reference period of 1971-1999. These are multi-model averages for the high (A2) and low (B1) emissions scenarios from the 14 (B1) or 15 (A2) CMIP3 global climate simulations. Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change in temperature, and more than 67% agree on the sign of the change (see text). Temperature increases throughout the 21st century, though more rapidly for the high emissions scenario. From NOAA, 2013.

(Table 1). Hence, the higher RCP produces greater nighttime warming. The patterns are the same for monthly and annual data.

	Percentile	1980-2004	RCP4.5	RCP8.5
Max Temp	25	67.07	69.48	69.65
	50	80.74	83.81	83.78
	75	90.81	94.46	94.47
Min Temp	25	43.64	45.53	46.15
	50	57.40	59.69	60.46
	75	69.09	72.14	72.41

Table 1. Summary of average annual maximum and minimum temperatures (°F) from 30 CMIP5 climate models for Travis County, Texas for the time period of 2025-2049 compared to 1980-2004. Data for Hays County are fractionally different. From Adler and Hostetler, 2013.

Thus, in most land regions the frequency of warm days and warm nights will likely increase in the next decades, while that of cold days and cold nights will decrease. Models project near-term increases in the duration, intensity and spatial extent of heat waves (the occurrence of a previous temperature record being exceeded) and warm spells. These changes may proceed at a different rate than average warming (Kirtman et al., 2013). This increased risk of heat waves results from globally increasing temperatures being superimposed on natural variability. Studies of recent heat waves, including the Texas heat wave of 2011, show an anthropogenic or human contribution to their occurrence (Bindoff et al., 2013).

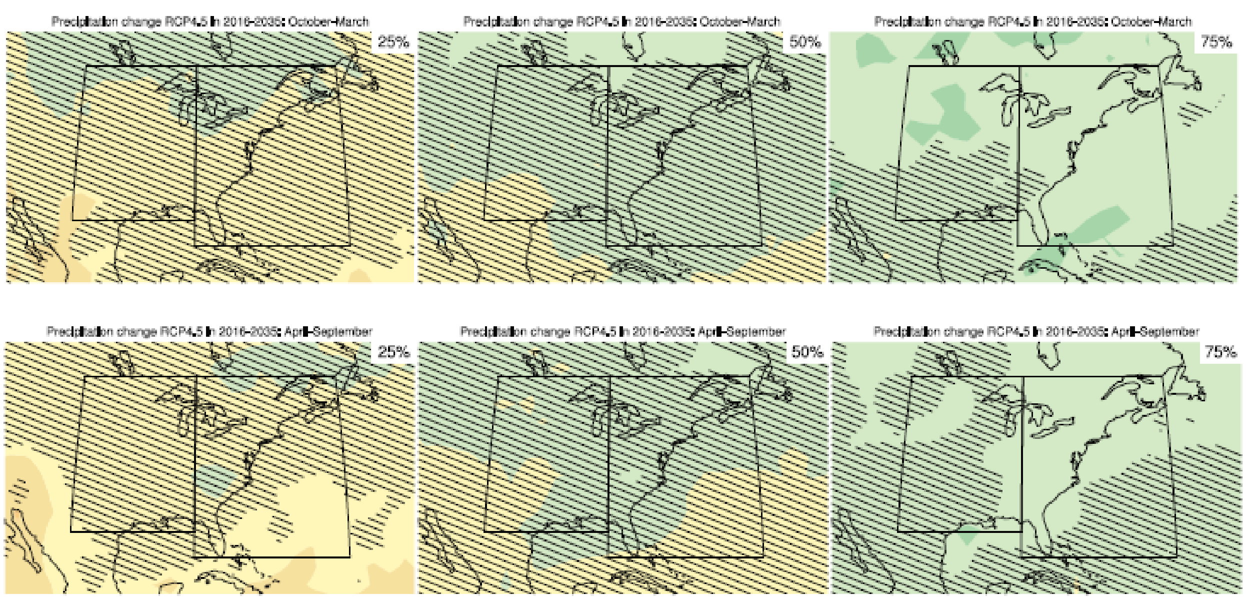
Projected Changes to the Hydrologic Cycle

For every 1° F rise in temperature, the water holding capacity of the atmosphere increases by about 4%. Floods and droughts are likely to become more common and more intense as regional and seasonal precipitation patterns change, and rainfall becomes more concentrated into heavy events (with longer, hotter dry periods in between). At regional scales, however, precipitation changes may be influenced by aerosol emissions from human activity and will continue to be influenced by natural variability embedded in the climate system (Kirtman et al., 2013).

Soil moisture, especially in summer, is expected to decline with higher temperatures and attendant increases in the potential for evapotranspiration (evaporation of water from soil and the release of water to the air from plant leaves) in much of the country, especially across the southern U.S. (Melillo et al., 2014). The IPCC AR5 estimated a 3-4% decline in soil moisture for 2016-2035 (RCP4.5) compared to 1986-2005 over Central Texas based on evapotranspiration exceeding precipitation by a very small amount (Kirtman et al., 2013). The small projected change in evapotranspiration (+/- 5%) is best explained by the already low amounts of soil moisture found in subtropical areas.

Summer droughts are expected to intensify in most regions of the U.S., with longer-term reductions in water availability in response to both rising temperatures and changes in precipitation. As warming changes water cycle processes, the amount of runoff generated by each unit of precipitation is expected to decline, especially across the southern U.S. (Melillo et al., 2014). Kirtman et al. (2013) quantified the reduction at about 10-20%. All of these projected changes fall within the range of annual variability and owing to simplified hydrologic schemes in many of the CMIP5 models, projections of soil moisture and runoff have large uncertainties. Hence, the IPCC found there was “low confidence” in projected changes in soil moisture and runoff (Kirtman et al., 2013).

AR5 projects the average precipitation change over Central Texas for 2016-2035 using RCP4.5 to be in the range of +/- 10% (Kirtman et al., 2013; Figure 6). In fact, at the resolution of the GCMs, Central Texas borders the zone between increasing and decreasing precipitation for much of the year. Kirtman et al. (2013) concluded that large uncertainties in the sign of projected changes were seen especially in regions located on the border between increasing and decreasing precipitation zones. More recent research has highlighted the fact that if models agree that the projected change is small relative to naturally-occurring variability, then agreement on the sign of the change is not expected (Tebaldi et al., 2011). Natural variability contributes 50 to 90% of the total uncertainty in all regions in projections of average precipitation changes for the next decade. Therefore, response uncertainty, as in how myriad physical processes will change and interact, is the dominant source of uncertainty (Kirtman et al., 2013).



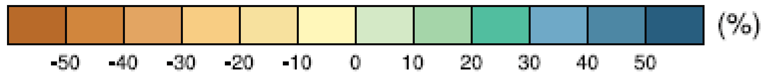


Figure 6. Maps of precipitation changes in 2016–2035 compared to 1986–2005 in the RCP4.5 scenario. For each point, the 25th (left-hand column), 50th (middle) and 75th (right-hand column) percentiles of the distribution of the CMIP5 model simulations are shown; results include both natural variability and inter-model spread. Hatching denotes areas where the 20-year average differences of the percentiles are less than the standard deviation of model-estimated, present-day, natural variability of 20-year average differences (Christensen et al., 2013).

The annual average precipitation values simulated by CMIP5 and downscaled are either the same or negligibly smaller for 2025-2049 compared to the historical period of 1980-2004 for both RCPs; month-to-month changes are also not statistically significant (Alder and Hostetler, 2013). These results are again similar to CMIP3 simulations whereby the A2 scenario yields a projection of a 0-3% decrease in precipitation in 2021-2050 compared to the reference period of 1971-1999 (Figure 7).

A factor contributing to uncertainty in the direction of precipitation change is that Central Texas is part of a zone known as the humid subtropics and sits adjacent to a semi-arid zone to the west and south (the Desert Southwest) that is projected to expand northward and eastward. Just how far and how quickly the semi-arid zone expands plays a role in whether Central Texas will likely see reduced precipitation. At the global scale, IPCC AR5 found that average precipitation will "more likely than not" decrease in the subtropics (Kirtman et al., 2013).

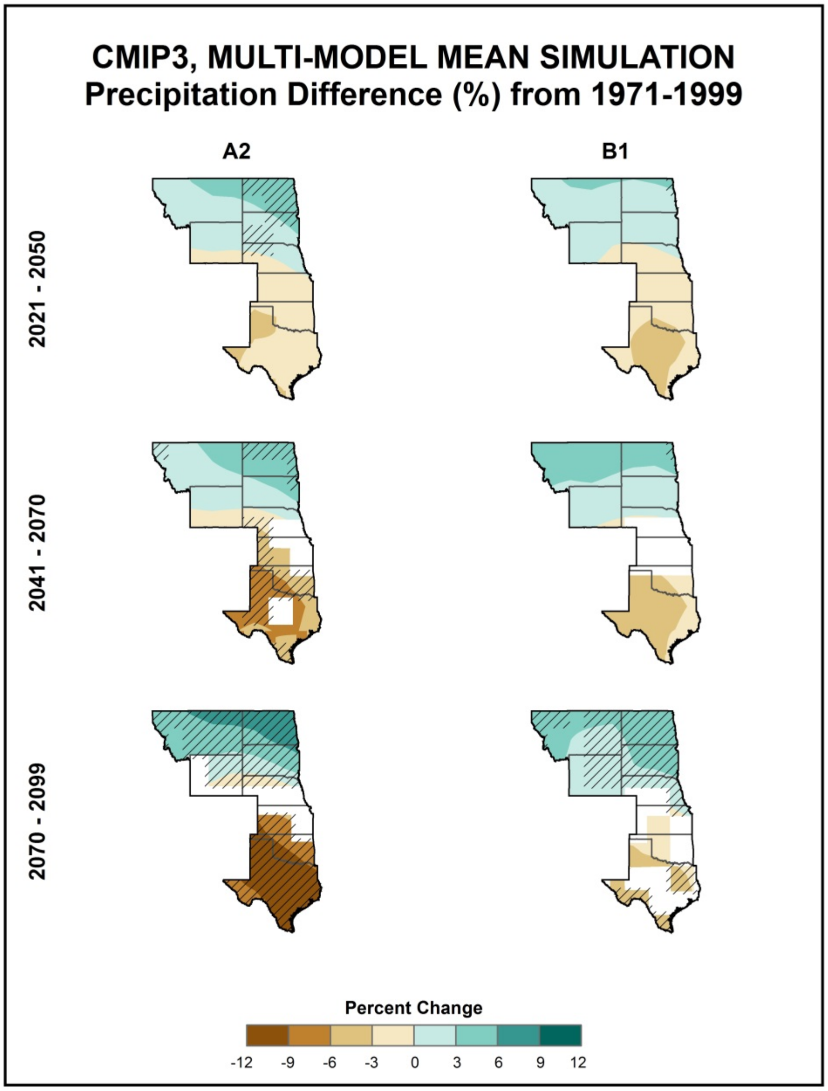


Figure 7. Simulated difference in annual average precipitation (%) for the Great Plains region for each future time period (2021-2050, 2041-2070, and 2070-2099) compared to the reference period of 1971-1999. These are multi-model averages for the high (A2) and low (B1) emissions scenarios. Color only (category 1) indicates that less than 50% of the models show a statistically significant change in precipitation. Color with hatching (category 3) indicates that more than 50% of the models show a statistically significant change in precipitation, and more than 67% agree on the sign of the change. Whited-out areas (category 2) indicate that more than 50% of the models show a statistically significant change in precipitation, but less than 67% agree of the sign of the change. Generally, the models simulate increases in the Northern Great Plains and decreases in the Southern Great Plains. From NOAA, 2013.

There is some evidence from comparing observations to simulations of the recent past that climate models might be underestimating the magnitude of changes in precipitation in many regions and this could imply that projected changes in precipitation are underestimated by current models. However, the magnitude of any underestimation has yet to be quantified, and is subject to considerable uncertainty (Kirtman et al., 2013).

Floods are projected to intensify in most regions of the U.S., even in areas where average annual precipitation is projected to decline (Melillo et al., 2014). A comparison of CMIP5 simulations of extreme precipitation (defined as 2-day duration, 1-in-5-year events) over the past four decades to observations shows that the multi-model median, or most common outcome, captures the increasing trend, though it is smaller than observed. However, the standard deviation between models is extremely large, often greater than the signal, indicating that there are large differences between the models. Some models are highly correlated with observations while others generate negative correlation coefficients. In terms of future projections, there is a trend of increasing extreme precipitation and greater convergence among the models (Wuebbles et al., 2013). Average precipitation is expected to increase less than extreme precipitation because of energy constraints in the atmosphere (Bindoff et al., 2013).

An alternate indicator of long-term trends in extreme precipitation is the fraction of annual total precipitation that falls in the heaviest 1% of daily events. Models show an increase in this indicator throughout the last century and they are broadly consistent with observed changes from 1958 to 2007. By the end of 2100, a 50% increase in the annual fraction of precipitation falling in the heaviest events is projected for the mid-low scenario (RCP4.5), while a 90% increase is projected for the higher scenario (RCP8.5). In general, CMIP5 results suggest that a growing percentage of annual precipitation will fall in the top 1% of events over time, and these results are consistent with conclusions reached in similar analyses of CMIP3 simulations (Wuebbles et al., 2013). The 1-in-20-year heavy downpour (based on 1958-2008 statistics) is projected to occur once every 4 to 15 years depending on location (USGCRP, 2009). By IPCC AR5 calculations, return periods of these 1-in-20-year events are projected to be reduced by about 6 to 11% per °F over most of the mid-latitude land masses (Collins et al, 2013).

As is the case with CMIP3 21st century projections, CMIP5 simulations generally produce decreases in soil moisture and an increase in drought frequency, duration, area, and severity with increasing temperature. The recent increase in frequency of severe to extreme drought in the western U.S. is simulated by CMIP5 (Wuebbles et al., 2013). Confidence in the expectation of future intensification of droughts is high in the Southern Great Plains as increased evapotranspiration will lead to decreases in soil moisture regardless of how average precipitation changes (Melillo et al., 2014).

Water Quantity Impacts of Climate Change

Expected changes in precipitation and land use in aquifer recharge areas, combined with changes in demand for groundwater over time, will affect groundwater availability in ways that are not well monitored or understood. The *Third National Climate Assessment* concluded that across the southern U.S., surface and groundwater supplies are already under pressure and are expected to be reduced further as increasing evaporative losses lead to declining runoff and groundwater recharge, increasing the likelihood of water shortages for many off-stream and in-stream water uses (Georgakakos et al., 2014). The Southeast, Southwest, and Great Plains are highly vulnerable because climate change is projected to reduce water availability, increase demand, and exacerbate shortages. Confidence is therefore judged to be high that groundwater aquifers will be influenced by climate change through impacts on recharge and by increased groundwater use, though exactly how these impacts will be manifest remains unexplored (Georgakakos et al., 2014).

Climate models do not, in general, yet include dynamic representations of the groundwater reservoir and its connections to streams, the soil-vegetation system, and the atmosphere, hampering progress in understanding the potential impacts of climate change on groundwater and groundwater-reliant systems (Georgakakos et al., 2014). Among the most significant implications of climate change for water resources management is the very real possibility that there will be increasing variability at the tails of the hydrograph – that is floods and/or droughts will become more frequent, of greater intensity, and of longer duration.

Water Quality Impacts of Climate Change

Air and water temperatures, precipitation frequency and intensity, and floods and droughts affect water quality. Increased low flows under drought conditions as well as increased overland flow during floods have the potential to worsen water quality (Georgakakos et al., 2014).

More intense rainfall and flooding could result in increased loads of suspended solids, sediment, E. coli and contaminants such as metals associated with soil erosion and fine sediment transport from the land. Increased storm events may flush pollutants (herbicides, pesticides and nutrients) into streams, particularly in urban areas (Whitehead et al., 2009).

Lower river flows imply less volume for dilution and, hence, higher concentrations of pollutants, which could also increase biological oxygen demand and lower dissolved oxygen concentrations (Whitehead et al., 2009). Intensifying droughts can increase the length of time pollutants remain in water bodies. Reduced summer flows often produce elevated levels of phosphorus while ammonium levels fall due to higher nitrification rates (Whitehead et al., 2009). This gives rise to increased nitrate concentrations as ammonia decays to nitrate. Excess nutrients can lead to algal blooms, which further depress DO levels.

River water temperatures are in close equilibrium with air temperature and as air temperatures rise, so will river water temperatures. Increasing water temperatures can reduce dissolved oxygen levels because the solubility of oxygen in water falls as water temperature rises. Water temperature has increased in many rivers, a trend generally expected to persist with climate warming (Georgakakos et al., 2014). Dissolved oxygen is necessary for aquatic life. A minimum level (30-day mean) of 5.5 mg/l of DO is recommended as a water quality criterion by U.S. EPA for warmwater systems to protect aquatic life (USEPA. 1986). As dissolved oxygen levels in water drop, aquatic life is put under stress.

In addition to affecting aquatic species through the DO saturation curve, water temperature also affects many freshwater species due to their cold-blooded nature. They may have a limited range of thermal tolerance and temperature is known to control the growth rates – through the control of chemical reactions - of phytoplankton, macrophytes and epiphytes, making freshwater ecosystems sensitive to rising temperatures (Whitehead et al., 2009). In addition, sensitivity to temperature changes could be magnified by changes in other water quality and quantity factors such as water velocity, DO, and nutrient cycling resulting in the disruption the life cycles and food webs of organisms such as algae, macroinvertebrates, amphibians, fishes and birds (USACEIWR, 2013).

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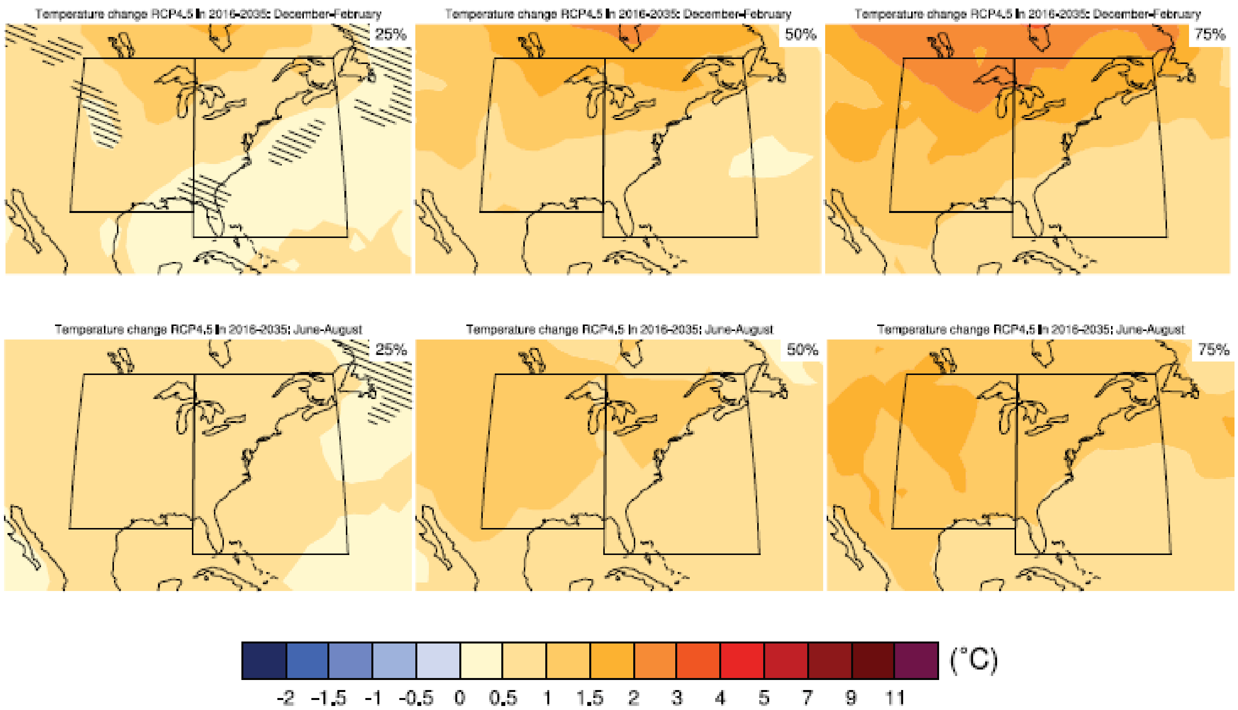
Appendix: Regional Temperature Change Maps from IPCC AR5

Maps of projected temperature changes in 2016–2035 compared to 1986–2005 based on the RCP4.5 scenario. For each point, the 25th (left-hand column), 50th (middle) and 75th (right-hand column) percentiles of the distribution from CMIP5 simulations are shown; results includes both natural variability and inter-model spread. Hatching denotes areas where the 20-year average differences of the percentiles are less than the standard deviation of model-estimated, present-day, natural variability of 20-year average differences.



Appendix C

Water Quality in the Barton Springs Segment of the Edwards Aquifer

Appendix C

Summary of Recent Groundwater Quality Studies

This appendix summarizes results of recent studies of water quality within the Barton Springs Segment of the Edwards Aquifer. The highly fractured limestone formations and resulting fissures, cavities, and transport conduits typical of karst aquifers, in conjunction with thin soils, make the Barton Springs-Edwards Aquifer susceptible to water quality degradation from land surface erosion and runoff. Included within this appendix are descriptions of studies conducted to assess water quality of the Edwards Aquifer. Management and planning efforts to protect groundwater quality are summarized in **Appendix D**.

Historically, the quality of water in the Barton Springs Segment of the Edwards Aquifer has been high. Water quality in the aquifer, and at Barton Springs, has been analyzed by several investigators, including Andrews et al. (1984), Slade et al. (1986), Turner (2000), and Mahler et al. (2006, 2011, 2013). These investigations indicate that the aquifer and its discharging Barton Springs have experienced varying levels of water quality degradation as a result of human development over the aquifer and its contributing zone. The Edwards Aquifer has been ranked most vulnerable to degradation from anthropogenic contamination statewide based on its hydrogeological structure (Texas Groundwater Protection Committee 2003). Water quality of the Barton Springs complex is primarily determined by quality of surface waters in the recharge zone as they recharge the aquifer and mix with groundwater while traveling to downstream springs. The quality of groundwater emanating from Barton Springs is positively related to quality of recharging waters (Mahler et al. 2006). The character of that relationship varies with amount of groundwater discharge and surface conditions (storm vs. base flow). Nutrients and pollutants from urban runoff negatively affect Barton Springs.

Streams, wells and springs have been analyzed regularly for nutrients, physiochemical properties, indicator bacteria, major ions, trace elements, and pesticides to track, among other attributes, the effects of urbanization on water quality during both base-flow and storm-flow conditions. By integrating the findings of dye-tracing studies carried out from 1997 to 2005 with extensive water quality sampling, a picture, albeit still incomplete, has emerged of how contaminants are delivered to the springs following storms, as well as the amount of contaminants and recharge that go into storage. Mahler et al. (2006) concluded that when aquifer conditions are low, recharge entering the aquifer is transported rapidly to the springs with little dilution or loss to storage. In contrast, when aquifer flow conditions are high, recharge is diluted by mixing with previously stored aquifer water, and, in turn, some of the recharge water with its associated contaminants is stored within the aquifer for future discharge.

Years of study have led to the conclusion that water quantity, water chemistry, and water quality of the Barton Springs segment of the Edwards Aquifer are inter-related. During recharge events, the water quality of recharge waters from streams exerts a strong influence on the quality of water discharging at the springs. During non-recharge conditions, Barton Springs discharge is a reflection of the long-term water quality of the aquifer. Stormwater runoff is generally of poorer quality than base flows and these flows may contain elevated concentrations of suspended solids, nutrients, bacteria, and oxygen-demanding material, while having lower concentrations of total dissolved solids concentrations (salinity) and dissolved oxygen (DO) (Mahler and Bourgeais 2013). Storm conditions, however, tend to be transitory and the quality of discharging spring water returns to antecedent levels as rain events subside. While average flows and typical drought flows of recharge streams tend to be of high quality (i.e., have smaller pollutant loads than stormwater), a prolonged drought that reduces springflows will tend to increase salinity and decease DO in the springs (Herrington and Hiers 2010). These changes appear to be driven by the mixing of older, more saline water from the eastern part of the aquifer, also known as the “saline zone,” which have much lower DO (Mahler and Bourgeais 2013). Salinity and DO are the two water quality parameters are believed to be of primary importance to the two salamander species. Investigations of these and other commonly tracked water quality parameters are summarized below.

Nutrients

Nutrients, primarily nitrogen and phosphorus, are essential for plant growth, though they can become pollutants in certain circumstances. Water bodies with high levels of nutrients are able to support abundant algae and aquatic plant growth; excess nutrients can lead to eutrophication (excessive growth of algae), resulting in the reduction of dissolved oxygen in water. Major sources of nutrients include fertilizer runoff, animal manure, and domestic and industrial wastewater effluent.

Although nutrients occur naturally in the environment of the study area, streams of the Edwards Plateau are considered nutrient-poor (oligotrophic) and aquatic ecosystems are adapted to a low-level of nutrient inputs (Mabe 2007).

Investigations of nutrient loadings into the Barton Springs complex have identified only nitrate above a detection threshold under base-flow conditions (Mahler et al. 2006). Samples collected for the 2006 study showed nitrate concentrations in Main, Eliza, and Old Mill Springs to be close to one another. The average nitrate concentration in samples from Upper Spring was 2.05 mg/L versus 1.24, 1.19, and 1.21 mg/L at Main, Eliza, and Old Mill Springs, respectively. For comparison, a reference well in the Barton Springs segment that was assumed to be representative of background groundwater composition had an average nitrate concentration of 1.3 mg/L. At the time of the study, nitrate concentrations in Main, Eliza, and Old Mill Springs appeared to be related to recharge conditions. Maximum values coincided with periods of little recharge, implying that recharge from streams diluted naturally occurring nitrates in the ground water. The fixed baseline value of nitrate concentration for the aquifer was estimated at 1.5 mg/L. The higher value at Upper Spring may have reflected different underlying dynamics or the presence of anthropogenic nitrate sources. The study suggested that during periods of extreme recharge (i.e., extended rainfall), nitrate concentrations might be elevated rather than diluted, indicating complex interactions with anthropogenic sources.

Additional sampling conducted by USGS between November 2008 and March 2010 showed a substantial increase in nitrate loadings to the five streams recharging the Barton Springs complex compared to samples collected between 1990 and 2008. Nitrate concentrations from Onion Creek had increased 6- to 10-fold while those at Barton Springs were also higher (Mahler et al. 2011). Median nitrate concentrations in routine samples from all sites were higher during wet periods than dry periods. Increases in nitrate concentrations have coincided with rapid increases in number of septic systems and land applications of treated wastewater associated with widespread development over the contributing zone. Moreover, nitrate detected bears the signature of human or animal waste. This 2011 investigation indicates that baseline concentrations of nitrate have shifted upward even without any direct discharges of treated wastewater to the watershed.

Potassium has been found to increase in response to storms. Potassium concentrations increased at all four springs following one storm Mahler et al. (2006) sampled. They raised the possibility that its source could be fertilizer washed into aquifer. However, no long-term trends in potassium concentrations have been detected by the City of Austin (Herrington and Hiers 2010).

Orthophosphates are typically below detection levels at Main Spring, but concentrations in storm samples from two of the creeks were 3-5 times greater than those in routine samples during the 2008-2010 study (Mahler et al. 2011). No trends in orthophosphorus or phosphorus have been detected by long-term (non-storm) monitoring by the City of Austin (Herrington and Hiers 2010).

Dissolved Oxygen

Over a 24-hour period, DO levels fluctuate naturally in most water bodies. Oxygen production – or photosynthesis – normally varies because it is light dependent. Oxygen production occurs during daylight hours, increasing in concentration throughout the day. Around sunset, photosynthesis ceases and DO levels begin to drop due to respiration and consumption by aquatic organisms. The lowest DO levels usually occur just before dawn. In addition to photosynthesis, oxygen is added to a water body by natural aeration (wind, rain, and water currents). A surplus of oxygen-demanding substances, such as decaying biological material, will deplete DO levels. Elevated temperatures reduce the solubility of DO and decrease the amount of oxygen in water. Moreover, high temperatures increase metabolism, respiration, and the demand for oxygen by aquatic organisms.

Dissolved oxygen (DO) at all spring orifices decreases as discharge from the Barton Springs complex decreases (Mahler et al. 2011). Conversely, higher discharge generally coincides with higher DO concentrations. DO concentrations vary among the four springs since DO is temperature- and recharge-dependent and each spring demonstrates a unique profile. Cold water can hold more oxygen than warm water and high flow velocities increase physical disturbance of the water surface allowing oxygen to mix with water. Measurements taken from January 2004 through October 2011 by the City of Austin showed average DO to be highest at Upper Barton (7.21 mg/L), followed by Main (6.02 mg/L), Eliza (5.55 mg/L) and Old Mill Springs (5.37 mg/L) (City of Austin 2013). Main Spring exhibited less variability than the other springs (range of 4.5 mg/L to 7.55 mg/L). A dataset of daily average DO spanning October 2006 to June 2012 as recorded by USGS at Main Spring shows a range of 4.0 mg/L to 8.5 mg/L, with a median value of 6 mg/L (Mahler and Bourgeais 2013; **Figure 1** shows data from 2008-2014 and **Table 1** contains an example of DO data for a single date). Between 2003 and 2005, Mahler et al. (2006) recorded dissolved oxygen concentrations ranging from 5.5 to 7.9 mg/L, with a median of 6.6 mg/L in Main Spring; however, they noted instrument reliability and environmental conditions may have diminished the accuracy of the data. Nonetheless, the lowest DO readings coincided with the lowest discharge and high recharge events boosted DO concentrations.

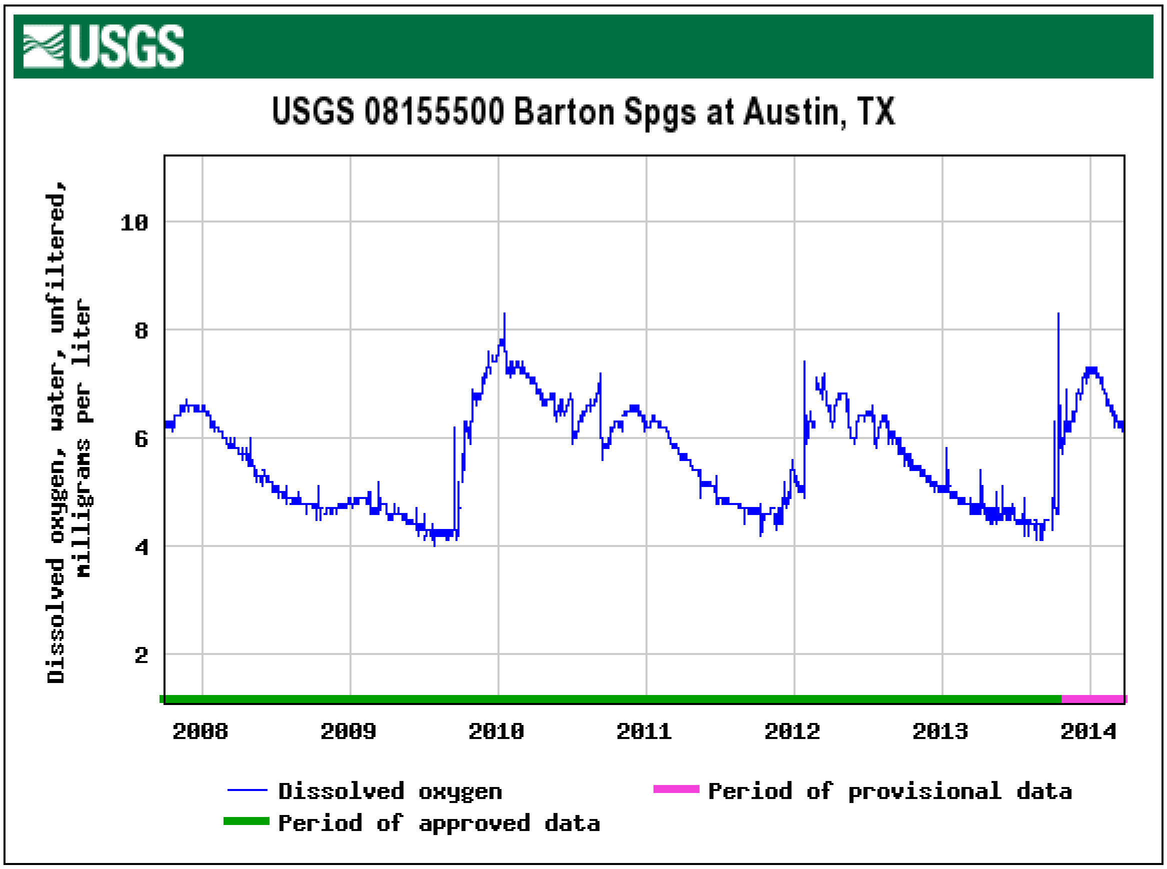


Figure 1. Dissolved oxygen data from 2008 to 2014 from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Daily dissolved oxygen, water, unfiltered, milligrams per liter -- statistics for Mar 25 based on 8 years of record more						
Min (2013)	25th percen-tile	Median	Mean	Most Recent Instantaneous Value Mar 25	75th percen-tile	Max (2010)
4.7	4.9	5.7	5.8	6.2	6.6	7.1

Table 1. Sample dissolved oxygen data from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

DO concentrations are diminished during drought: Lows of 3.61 mg/L and 1.04 mg/L were recorded at Eliza and Old Mill Springs, respectively (not counting Upper Spring, which ceases to flow at times) (City of Austin 2013). USGS data show the low at Main Spring during the drought in 2009 at 4 mg/L (Mahler and Bourgeais 2013). Mahler and Bourgeais (2013) note that daily mean DO was less than the No Observable Adverse Effect Level for the Barton Springs salamander surrogate - the San Marcos salamander - of 4.4 mg/L (Woods et al. 2010) for three days in 2006, 127 days in 2009, of which 88 were consecutive, and six days in 2011. Limited sampling suggests that surface habitats associated with Barton Springs have higher DO concentrations than subterranean habitats (City of Austin 2013) but extensive data do not exist.

While long-term DO measurements have been recorded and in some instances suggest decreasing trends at Main Spring (City of Austin 2013, Herrington and Hiers 2010), these data are also controversial because of changes to instrumentation over time and some questionably low DO values from 1996 that have never been recorded since, even during recent drought conditions (Mahler and Bourgeais 2013). The most reliable and consistent measurements emanate from work by the USGS since 2006, which show a very small positive trend (Mahler and Bourgeais 2013).

A detailed investigation of nutrient loading into the Barton Springs segment of the Edwards Aquifer between 2008 and 2010 found that estimated mean monthly loads of nitrogen in stream recharge were greater than those in Barton Springs, and DO concentrations in Barton Springs discharge were significantly less than those in stream recharge, consistent with nitrification within the aquifer (Mahler et al. 2011). Nitrification involves the oxidation of organic N to NO_3 and the reduction of dissolved oxygen, consuming dissolved oxygen in the process.

During low-flow conditions, temperature is high, DO drops and salinity increases, which could be a reflection of water being contributed by the saline zone (Mahler and Bourgeais 2013). Such water is likely to be older than recharge water and more depleted in oxygen. Low DO has also been documented at Main Spring when discharge is high, although values were not as low as under drought conditions (Mahler and Bourgeais 2013). DO may be reduced under high-flow conditions due to input of oxygen-demanding substances carried by stormwater runoff and/or the release of stored aquifer water that is more depleted in oxygen.

Temperature

The average water temperature of Barton Springs is approximately 21° C with a small range of variation under normal conditions (Mahler et al. 2006, Gillespie 2011; **Figure 2** and **Table 2**). Mahler et al. (2006) reported a significant correlation between air and water temperature of Main Spring. Rapid changes in water temperature coincide with large rainfalls. The City of Austin (2013) reported a minimum to maximum temperature range at Main, Eliza, and Upper Springs for the period January 2004 to October 2011 to be 18.4° - 22.3° C. A wider range (10.8° - 26.2° C) is reported for Old Mill, which is subject to diminished discharge of cool ground water during droughts. Long-term monitoring by the City of Austin has detected a trend of increasing water temperature (Herrington and Hiers 2010).

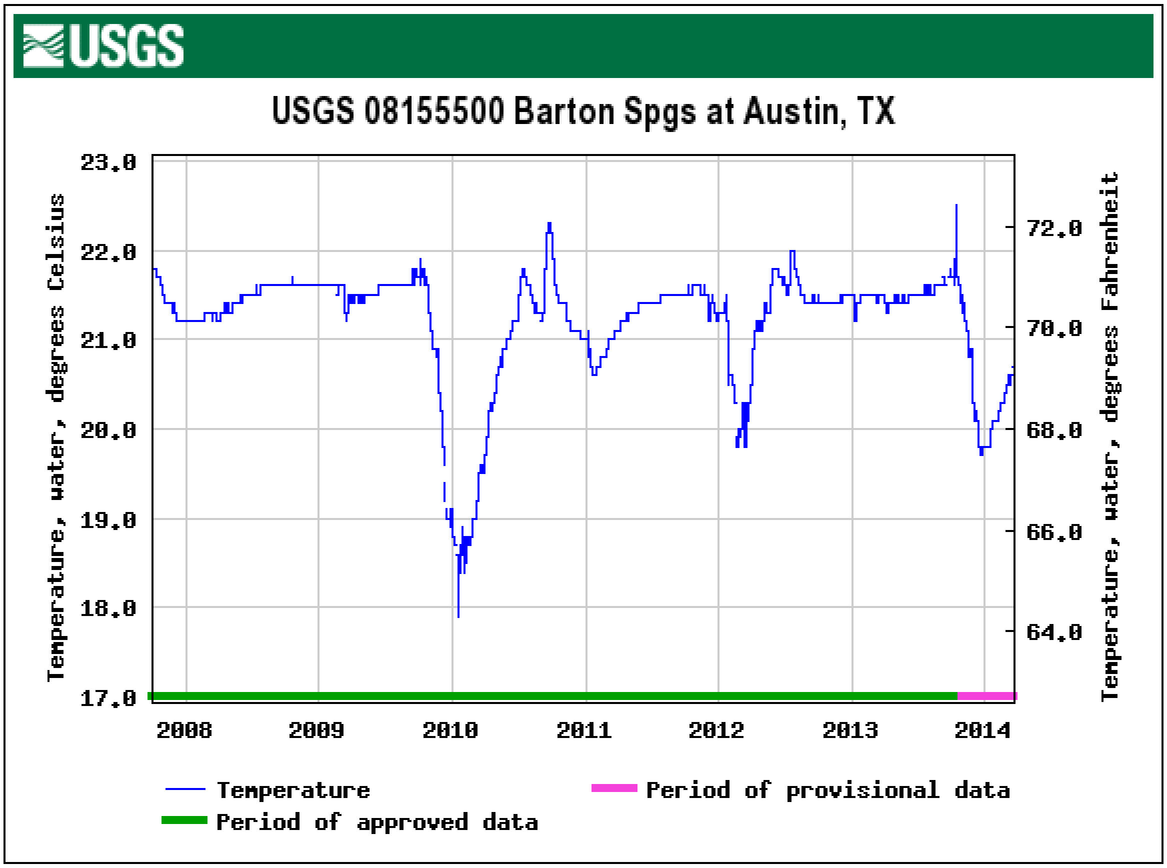


Figure 2. Plot of water temperature from 2008-2014 from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Daily temperature, water, degrees celsius -- statistics for Mar 25 based on 9 years of record more

Min (2010)	25th percen-tile	Most Recent Instantaneous Value Mar 25	Mean	Median	75th percen-tile	Max (2009)
19.6	20.1	20.8	20.8	21.1	21.4	21.5

Table 2. Sample water temperature data from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Salinity

Ions that are released from soil and rock and become dissolved in water increase the conductivity of water. Salinity refers to inorganic salts in water and salinity differs from one watershed to another depending on the underlying rock type. Reduced instream flows and high evaporation rates can increase salt levels. Salinity is measured indirectly as specific conductance, which is the ability of water to carry an electric current and is dependent on the amount of dissolved solids in water. Salinity can also be measured by quantifying the amount of chloride, sulfate, and total dissolved solids (TDS) in water.

Salinity in the Barton Springs complex varies within a fairly narrow range, with the difference in conductance between average and lowest flows over seven years recorded as 75 µS/cm, which corresponds to a variation in total dissolved solids (TDS) of less than 50 mg/L (Herrington and Hiers 2010). Even at the lowest flows, the highest TDS concentrations measured at the springs are about 475 mg/L. For comparison, water is considered fresh if TDS is under 1000 mg/L.

Conductivity varies at the springs, with increasing conductivity as discharge decreases and decreasing conductivity with storm events (**Figure 3**). Main Spring averages ~650 µS/cm (**Figure 4** and **Table 3**), while Old Mill averages ~700 µS/cm (Mahler et al. 2006, City of Austin 2013). At Barton Springs discharge less than about 40 ft^3/s, concentrations of sodium, chloride, and sulfate are inversely proportional to discharge, indicating some influx of saline zone water into the springs (Mahler et al. 2006). Rainwater, relatively low in conductivity compared to ground water, dilutes the salinity of discharging spring water, though conductivity of recharging creeks appears to be increasing, and under extreme high flow conditions, conductivity increases as discharge increases for reasons that are not fully understood (Barbara Mahler, personal communication on March 25, 2014). Long-term (non-storm) monitoring by the City of Austin has detected increases, decreases and no trend among various ions; however, the City does report an overall increase in conductivity (Herrington and Hiers 2010).

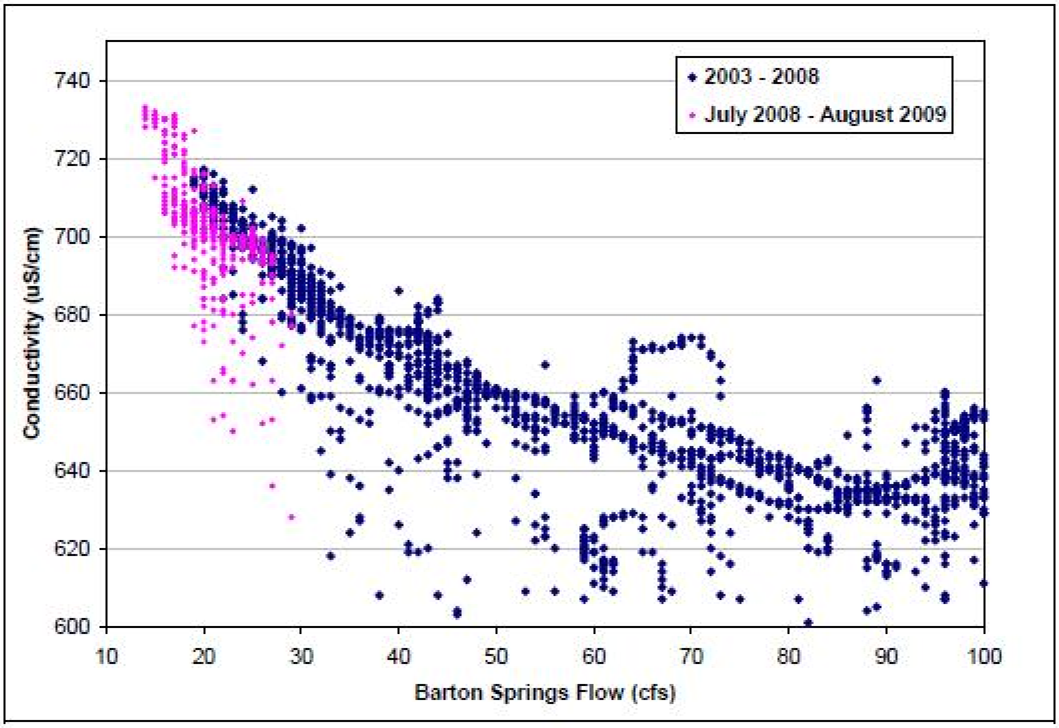


Figure 3. Inverse relationship of spring discharges and water salinity, expressed as specific conductance (Herrington and Hiers, 2010).

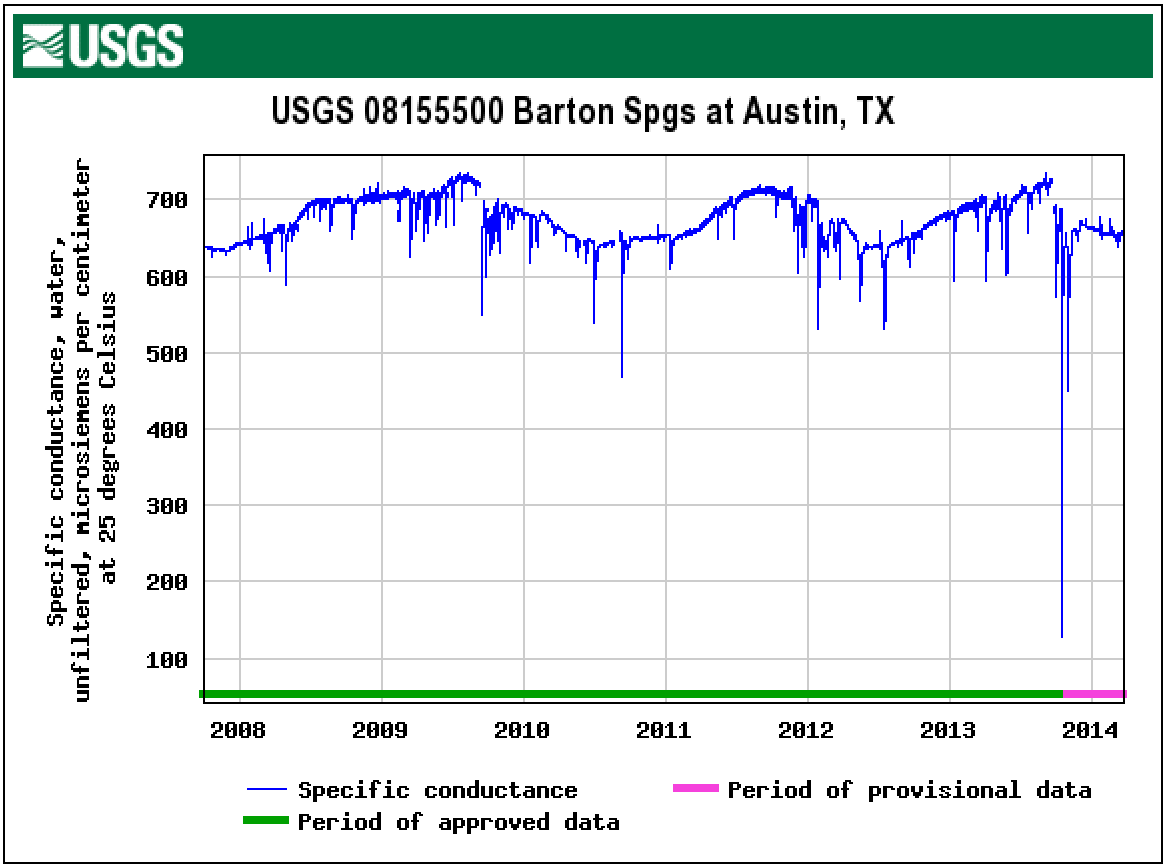


Figure 4. Specific conductance data from 2008 to 2014 from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Daily specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees celsius -- statistics for Mar 25 based on 8 years of record more

Min (2008)	25th percen-tile	Most Recent Instantaneous Value Mar 25	Median	Mean	75th percen-tile	Max (2009)
654	657	659	663	673	696	704

Table 3. Sample specific conductance data from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Suspended Solids and Sedimentation

Suspended solids refer to mineral or organic particles suspended in the water column. Those solids reduce the penetration of sunlight into the water column. They may also carry nutrients or other contaminants. High flows are often associated with heavy sediment loads due to surface runoff and also because the force of the water keeps the solids suspended rather than allowing them to settle. Short-term turbidity increases are common during storm conditions as a watershed becomes urbanized. Turbidity, caused by suspended solids, has been significantly increasing during storm-flow conditions for more than 20 years (Mahler et al. 2006).

Prior to 1990, under base-flow conditions, 82 percent of the turbidity levels during recharge were less than 2 NTUs and all storm-flow turbidities were less than 12 NTUs. In the late 1990s, 74 percent of the base-flow turbidity levels during recharge conditions were between 2 and 12 NTUs, and 34 percent of storm-flow turbidities were between 12 and 50 NTUs (Turner 2000). Recent analysis of long-term (non-storm) monitoring data by the City of Austin did not detect any long-term trends in turbidity or total suspended solids (Herrington and Hiers 2010). Between 2003 and 2005, USGS reported that 95% of all turbidity measurements at Main Spring were less than 5.7 NTU and the median value was 1.7 NTUs (**Figure 5** and **Table 4**). Peaks were associated with rainfall events (**Figure 5**). A maximum value of 74 NTUs at Main Spring was recorded in association with a storm (Mahler et al. 2006).

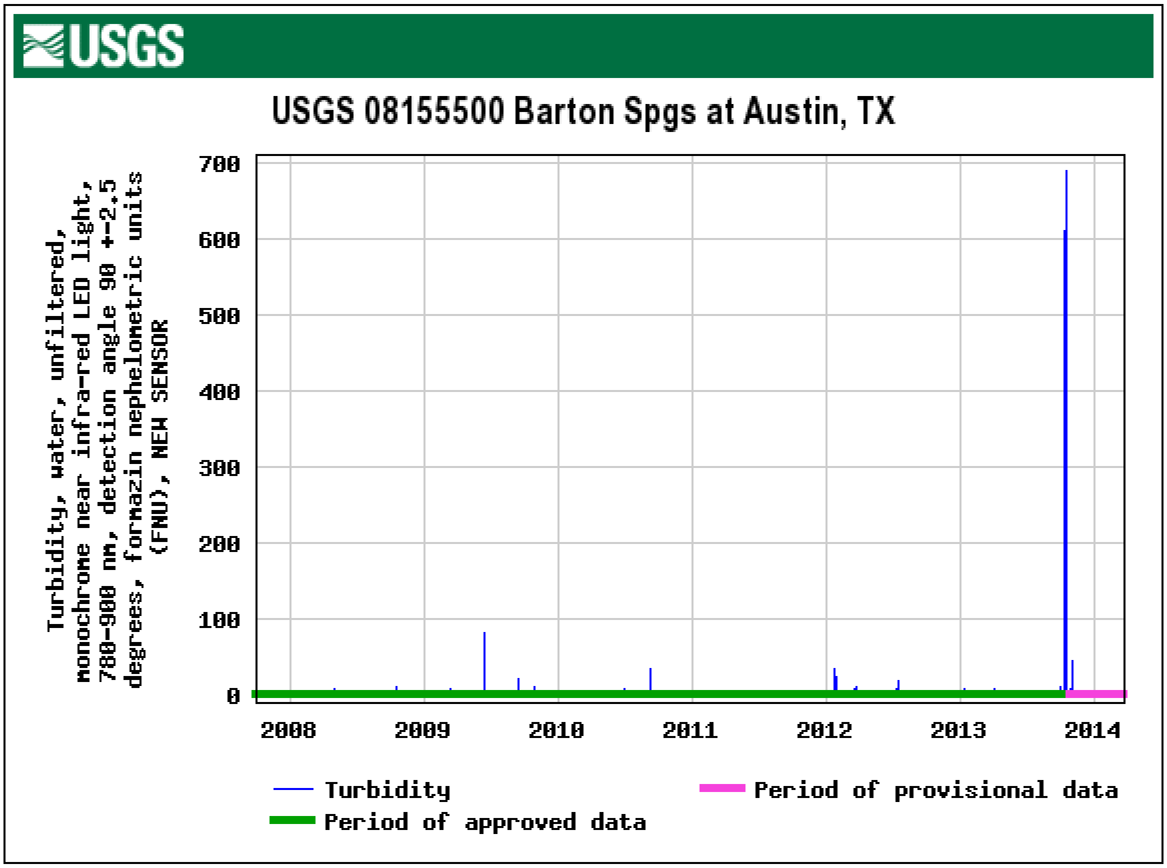


Figure 5. Turbidity data from 2008 to 2014 from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Daily turbidity, water, unfiltered, monochrome near infra-red led light, 780-900 nm, detection angle 90 +-2.5 degrees, formazin nephelometric units (fnu) -- statistics for Mar 25 based on 6 years of record more

Min (2008)	25th percen-tile	Median	Most Recent Instantaneous Value Mar 25	Mean	75th percen-tile	Max (2012)
0.6	0.7	0.8	1.1	1.2	2.0	2.9

Table 4. Sample turbidity data from http://nwis.waterdata.usgs.gov/tx/nwis for station 08155500 Barton Springs at Austin, TX, accessed 3/25/14.

Solids that are carried into the aquifer from surface runoff may eventually be discharged through the springs. Mahler and Lynch (1999) found that sediments begin to discharge from Main Spring whenever a rainfall event of 1.5 inches or greater occurs within the Barton Springs watershed. Further, the amount of sediment discharged from Main Spring in a 24-hour period following a 2-inch rainfall event is approximately one metric ton.

Suspended sediments can inhibit the respiratory function of fishes and neotenic salamanders (Garton 1977; Werner 1983); decrease the ability to locate food or escape from predators (EPA 1986; Schueler 1987); and become a vector for contaminants toxic to aquatic animals (Ford and Williams 1994; Menzer and Nelson 1980; Landrum and Robbins 1990; Medine and McCutcheon 1989).

Trace Metals

Edwards water contains trace concentrations of metals, such as copper, nickel, and arsenic, which leach naturally from rocks and soils. USGS sampled sediment in discharging spring water and creeks in the Barton Creek watershed between 2000 and 2002 (USGS, 2003). Arsenic, chromium, copper, and nickel in discharging spring sediment was measured at higher concentrations than in surface-water sediments. The converse was true for lead and zinc, two metals strongly related to urban land use. Based on their analysis, USGS concluded that most of the metals in discharging aquifer sediments seem to be a natural consequence of the geochemistry of the aquifer rather than pollution. Elevated levels of lead and zinc were associated with the two urbanized sites sampled. There are numerous anthropogenic sources of metals and in the urban environment these sources might include roadway, parking lot, and roof runoff, landfill leachate, wastewater, and fertilizers. Concentrations of all metals are well below U.S. EPA maximum contaminant levels for drinking water nor have any trends been detected (Herrington and Hiers 2010).

Bacteria

Bacteria have long served as an indicator of water quality. *E. coli*, present in human waste, serves as the indicator bacteria for freshwater bodies in Texas. Densities of *E. coli* were measured between 2008 and 2010 in the creeks of the Barton Springs watershed and at Barton Springs itself. During the dry period, densities were low (<100 MPN/100mL) in surface waters and in spring discharge. During the rainy period, densities of *E. coli* in routine samples collected from streams contributing to discharge at the springs varied from less than 10 to 4,800

MPN/100mL (Mahler et al. 2011). Samples taken from Main Spring during the wet period contained 2-450 MPN/100mL. Previous sampling was based on fecal coliform so comparisons are difficult. While there were indications of fecal coliform increasing over time at Barton Springs, the City of Austin reports that concentrations of indicator bacteria are well below the State of Texas standard for contact recreation (Herrington and Hiers 2010).

Pesticides

Pesticides are used on a variety of landscapes in the study area from residential lawns to ranchland to golf courses. Most pesticides applied to these landscapes are water-soluble and can infiltrate into the subsurface via fractures and sinkholes. These pesticides travel through the aquifer and discharge at the springs. Water quality monitoring studies conducted at Barton Springs by the USGS during the years 2003-2005 revealed measurable levels of atrazine, diazinon, prometon, carbaryl, and simazine, though pesticides were detected more frequently in Upper Spring than at the other three springs and, in most cases, at higher concentrations (Mahler et al. 2006). Atrazine, a widely used weed killer, was the focus of litigation between the Center for Biological Diversity, SOS Alliance, and the EPA in August 2005. This prompted a study by the EPA's Office of Pesticide Programs (2006), which concluded that acute and chronic levels of concern for atrazine were not exceeded and that existing levels of atrazine would have no effect on survival, growth, and reproduction on individuals of the Barton Springs salamander via direct effects. No long-term trends in pesticides have been reported by the City of Austin (Herrington and Hiers 2010).

Volatile Organic Compounds

Volatile organic compounds (VOCs) include constituents of gasoline such as toluene, benzene, and methyl tertiary-butyl ether. Other volatile organic compounds include chloroform, a byproduct from the addition of chlorine to water, and tetrachloroethene, a metal degreaser and dry cleaning solvent. VOCs were detected in historical samples from wells and springs in the Barton Springs watershed. Data collected after the mid-1990s continued to show the presence of chloroform, toluene, and tetrachloroethene (Mahler et al. 2006). Between 2003 and 2005, nine of 85 VOCs were detected: Two drinking-water disinfection by-products (chloroform and bromodichloromethane), one gasoline compound (toluene), four solvents, and two other industrial VOCs (Mahler et al. 2006). Chloroform and tetrachloroethene were detected in all routine samples collected from the four springs; other VOCs were detected less frequently or at specific springs. No long-term trends have been reported by the City of Austin (Herrington and Hiers 2010).

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Appendix D

Groundwater Quality Management and Planning Efforts

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D.1 Edwards Aquifer Protection Program

The Edwards Aquifer was designated as a sole source aquifer, and TCEQ promulgated rules regulating development activity in the Edwards Aquifer recharge, transition, and contributing zones (30 TAC Chapter 213). Subchapter A applies to all regulated activities (defined as construction-related or post-construction activity) within the recharge zone, to certain activities within the surrounding transition zone that stretches along the eastern and southern boundary of the recharge zone, and to other activities that may potentially contaminate the aquifer and hydrologically connected surface streams. Persons or entities subject to the rules must submit an Edwards Aquifer protection plan to the TCEQ prior to certain types of construction in the recharge or transition zones of the Edwards Aquifer. The plan must include a geological assessment report identifying pathways for movement of contaminants to the aquifer and a report on BMPs and measures to prevent and abate pollution of the aquifer. After the plan is approved, notice must also be filed in the county deed records that the property is subject to an approved Edwards Aquifer protection plan. Certain facilities are also prohibited from being built in the recharge or transition zones, such as Type 1 municipal solid waste landfills and waste disposal wells; direct discharge of wastewater to streams in the recharge (but not contributing) zone is also prohibited.

30 TAC Chapter 213 Subchapter B applies to regulated activities in the Edwards Aquifer contributing zone. All activities that disturb the ground or alter a site's topographic, geologic, or existing recharge characteristics are subject to regulation, which would require either sediment and erosion controls or a Contributing Zone Plan to protect water quality during and after construction. Exemptions include construction of single-family residences on lots larger than five acres where no more than one single-family residence is located on each lot; agricultural activities; oil and gas exploration, development, and production; clearing of vegetation without soil disturbance; and maintenance of existing structures not involving additional site disturbance.

D.2 U.S. Fish and Wildlife Service Concurrence on Optional Enhanced Measures for the Protection of Water Quality in the Edwards Aquifer

In February, 2005, the USFWS and the TCEQ entered into a joint agreement (TCEQ 2005) with regard to a set of development guidelines for the Edwards Aquifer Protection Program. In a letter to Governor Rick Perry, the USFWS notified the State of Texas that the federal government will recognize that new, optional water quality measures serve to protect certain federally listed endangered species, including the Barton Springs salamander, if voluntarily implemented in developments over the Edwards Aquifer (USFWS 2005a). The letter further stated that non-federal landowners using these practices would have the USFWS support that no "take" under the ESA would occur provided certain conditions are met.

D.3 U.S. Fish and Wildlife Service Recovery Plan for the Barton Springs Salamander (*Eurycea sosorum*)

The Final Rule listing the Barton Springs Salamander as endangered (62 FR 23377-23392) identified the primary threats or reasons for listing as "the degradation of the quality and quantity of water that feeds Barton Springs" as a result of urban expansion over the watershed. The restricted range of this species makes it vulnerable to both acute and chronic groundwater contamination. These threats could result in the "destruction, modification, or curtailment of the species habitat or range" through "chronic degradation, catastrophic hazardous materials spills, increased water withdrawals from the aquifer, and impacts to the surface habitat." The USFWS has completed a Recovery Plan for the Barton Springs salamander (USFWS 2016) that addresses water quality and quantity concerns for the species.

The Final Rule listing the salamander identifies a comprehensive regional plan as a means to protect the Barton Springs salamander from the above-mentioned threats. Although such a plan had not been developed at the time the Recovery Plan was completed, certain state and local entities, including the City of Austin (COA), have taken actions to protect the salamander and its habitat, such as adopting water quality protection ordinances and acquiring thousands of acres of open space in the Barton Springs watershed.

The goal of the Recovery Plan is to ensure the long-term viability of the Barton Springs salamander in the wild, allowing initially for reclassification to threatened status and, ultimately, recovery of the species to a point where it is a secure, self-sustaining component of its ecosystem, so that the protections of the ESA of 1973, as amended, are no longer necessary.

According to the Recovery Plan, the Barton Springs salamander should be considered for reclassification when:

(1) the Barton Springs watershed is sufficiently protected to maintain adequate water quality (including sediment quality) and ensure the long-term survival of the Barton Springs salamander in its natural environment;

(2) a plan is implemented to avoid, respond to, and remediate hazardous material spills within the Barton Springs watershed such that the risk of harm to the Barton Springs salamander is insignificant;

(3) an aquifer management plan is implemented to ensure adequate water quantity in the Barton Springs watershed and natural springflow at the four spring outlets that comprise Barton Springs;

(4) a healthy, self-sustaining natural population of Barton Springs salamanders is maintained;

(5) surface management measures to remove local threats to the Barton Springs ecosystem have been implemented; and

(6) genetically representative captive breeding populations have been established, and a contingency plan is in place to ensure the survival of the species should a catastrophic event destroy the wild population.

The Recovery Plan identified five recovery strategies for the species:

(1) Protect water quality (including sediment quality) within the Barton Springs watershed;

(2) Sustain adequate water quantity at Barton Springs;

(3) Manage surface habitat at Barton Springs;

(4) Maintain a captive population of Barton Springs salamanders for research and restoration purposes; and

(5) Develop and implement an education and outreach plan.

With a concerted effort to meet all of the recovery criteria, including full cooperation of all partners needed to achieve recovery, the Recovery Plan envisions that reclassifying the status of the species from endangered to threatened could be met within ten years, and delisting could be accomplished within ten years following reclassification.

The Recovery Plan identifies the District as the relevant entity to establish pumping limits that should be an integral part of an aquifer management plan. The Recovery Plan concludes that groundwater pumping from the Barton Springs segment of the Edwards Aquifer should be limited, particularly during drought, when pumping should be reduced by aquifer management such that springflow at Barton Springs does not drop below that level which would support the long term survival of the Barton Springs salamander in its natural environment. According to this plan, aquifer management should ensure that natural springflows are continuous at Main Springs, Eliza Springs, and Sunken Gardens Springs even in the most severe drought, and that flows should not fall below the historic low flow of 10 cfs, as measured by the USGS for all four sites combined. However, the Recovery Plan does not address the statutory, legal, and institutional constraints on reducing pumping for such purposes.

The Recovery Plan also recommends that the District develop a Proposed Habitat Conservation Plan that would identify the effects of groundwater pumping on the Barton Springs and Austin blind salamanders and would include measures to avoid, minimize, and mitigate for those impacts resulting from permitted groundwater pumping. The Recovery Plan noted that the District staff would collaborate with experts and various agencies to develop an HCP that addresses the needs of the salamanders, groundwater demands and sustainability, and includes appropriate planning and aquifer management strategies needed to protect the Barton Springs and Austin blind salamanders from degradation of water quantity.

D.4 Local Groundwater Quality Programs

Local municipalities, especially the COA, have also imposed aquifer protection requirements. The COA Land Development Code (LDC) has imposed watershed ordinances to require development standards for erosion and sedimentation control, impervious cover limits, stream or creek setback requirements and water quality control within its boundaries and extraterritorial jurisdiction (Land development restrictions instituted by the COA are codified in the Austin City Code, Title 25, "Land Development").

The COA is a home-rule city that derives its land use control and development authority from the Texas Constitution. That authority is articulated in the City Charter that stipulates that development must conform to a comprehensive plan (COA 2014a).

Comprehensive plans integrate social, economic and environmental planning into a framework to which zoning and subdivision ordinances must conform. The COA's current comprehensive plan, Imagine Austin, adopted by the City Council in 2012, articulated many of the city's watershed protection goals. The COA protects water quality through the Land Development Code (LDC) that governs zoning, subdivision and the site plan process. The city's watershed protection ordinances are codified, particularly in those sections of the LDC that address subdivision and site plan (COA 2014a).

Although the COA does not use zoning expressly for water quality purposes, the reduced density or impervious cover percentage requirements for various zoning districts may in fact provide water quality benefits. Subdivision regulations have become one of the most important regulatory tools that cities possess and have historically governed the division of land into two or more separate parcels for future sale or use. Projects that require subdivision or site plan approvals must comply with the COA's watershed ordinances. These ordinances have evolved over time to: 1) reflect current understanding of water quality and stormwater hydrology and 2) cover all 45 watersheds within the city's planning area, either wholly or in part.

The COA has adopted several watershed ordinances since 1980. These include: Lake Austin, Lake Austin Peninsula, Barton Creek, Williamson Creek, Lower Watersheds, Comprehensive, Interim, Composite, and Save Our Springs Ordinance. Several of those ordinances have been amended on more than one occasion. The following descriptions are intended only to highlight the major watershed ordinances and may include discussions of: impervious cover, density, transfer of impervious cover or development rights, stormwater treatment and detention requirements, construction site management and stream setbacks or buffer zones.

The Lake Austin Watershed Ordinance (LAWO) was adopted permanently in January 1980 and represents the COA's first major attempt to address water quality degradation in the face of increasing urbanization. Key features of the ordinance included: slope based impervious cover limits of up to 30 percent that were eventually raised to a maximum of 80 percent with transfers, a provision for water quality and quantity structural controls when minimum ordinance standards were not met and a requirement for an erosion/sedimentation control plan prior to subdivision application approval. It should be noted that all of the city's watershed ordinances include provisions for an erosion/sedimentation control plan. The LAWO did not require stream setbacks or buffer zones. The ordinance did, however, prohibit building sites within the 100-year floodplain of any creek or tributary in the watershed.

The Barton Creek Watershed Ordinance (BCWO) was passed in 1980 and represented a significant departure from the LAWO. Key features of the ordinance included: impervious cover limits capped at 35 percent for commercial and multi-family development, and the use of density limits that varied with the location of the development. The BCWO did not require water control structures, nor did it provide a mechanism whereby an applicant could increase impervious cover using alternate methods. This ordinance relied entirely on non-structural water quality controls and introduced stream set-back requirements that created five water quality zones with enumerated development restrictions for each one. The ordinance also provided incentives (increased density) for the transfer of development rights that included the conveyance of land in the critical water quality zone, for water quality protection, to the city as parkland.

The Williamson Creek Watershed Ordinance (WCWO) applied to that part of Williamson Creek crossing the recharge zone and was passed in December 1980. The WCWO included a requirement for stormwater treatment, a departure from previous ordinances. Key features of the ordinance included: impervious cover limits for single- and two-family homes of 40 percent and limits of up to 65 percent for commercial and multi-family developments, the use of stream setbacks based on the present concept of major, intermediate and minor waterways and the inclusion of a critical water quality zone that was to remain free of all but certain types of development.

The Lower Watersheds Ordinance (LWO) was adopted in 1981 and extended water quality protection into the Slaughter, Bear, Little Bear, and Onion Creek watersheds. The LWO resembles the WCWO in many ways, except that it reduces impervious cover allowances for commercial development to 40 percent and 55 percent with transfers, and for residential development, reduces it to 30 percent and 40 percent with transfers. The LWO introduced a water quality buffer zone, and set impervious cover limits of up to 18 percent and 15 percent, respectively, for single-family and commercial development in this zone.

The Comprehensive Watersheds Ordinance (CWO) was adopted in 1986, superceded previous watershed ordinances, and extended water quality protection throughout the COA's planning area to all but the urban watersheds. While similar in some respects to its predecessors, the CWO contained a number of significant innovations. For the first time, watersheds that do not provide a portion of our drinking water received significant water quality protection. The CWO was also the first ordinance to use net site area (NSA) impervious cover calculations instead of calculations based on gross site area (GSA). GSA includes the entire site, while NSA requirements include only a site's buildable areas and can reduce overall impervious cover. The ordinance included other firsts too, such as the designation of critical environmental features and provisions for their protection. The CWO also began to organize watersheds into groups based on their relationship to 1) the city's water supply, in particular Lake Austin, 2) the Barton Springs Edwards Aquifer recharge zone and to some extent the Northern Edwards Aquifer, and 3) the degree of urbanization within a watershed, i.e. urban, suburban, or rural.

The SOS Ordinance was adopted in 1992 and differed from its predecessors because it became law by citizen initiative. Two ordinances worth noting preceded the SOS Ordinance: the Interim and Composite Ordinance. These ordinances addressed development in the Barton Springs Zone, which includes Barton Creek and the other creeks draining to, or crossing, the Edwards Aquifer recharge zone. Highlights of these ordinances included: the first requirements for non-degradation (based on stormwater discharge concentrations) and provisions that excluded variances, unless a demonstrable improvement in water quality was shown. Variances, which made departures from an ordinance permissible, were a general feature of watershed ordinances up until this time.

The SOS Ordinance, applied throughout the Barton Springs Zone, required: non-degradation (based on total average annual loading), reduced impervious cover to 15-percent NSA for all development in the recharge zone, 20-percent NSA for development in the Barton Creek portion of the contributing zone, and 25-percent NSA for development in the remaining portions of the contributing zone in Williamson, Slaughter, Bear, Little Bear, and Onion Creeks.

The SOS Ordinance has withstood a number of legal challenges. Efforts to protect water quality in Austin and throughout Texas are still beset by a State law that provides "grandfathering" of some developments from current regulations. The most recent enactment of this state law was as House Bill 1704 by the 76th legislature. H.B. 1704 is the culmination of previous legislation that essentially freezes regulations on the date the first permit application is filed until the project is complete.

While no major watershed ordinances have been passed since the SOS ordinance, other efforts that may result in new ordinances or ordinance amendments include the city's Smart Growth initiative, an effort to reshape urban and suburban growth so that it will enhance our communities, strengthen the economy, and protect the environment. Akin to earlier comprehensive planning efforts, Smart Growth concepts were originally described by the Citizen's Planning Committee beginning in late 1994. An important Smart Growth principle is the city's division into Drinking Water Protection and Desired Development Zones. This division is a reflection of the sensitivity of watersheds that are located over, or adjacent to, the Barton Springs Edwards Aquifer recharge zone or that supply water to Lake Austin. Smart Growth initiatives seek to direct growth away from these areas into less environmentally sensitive areas, while at the same time seeking LDC amendments and policy changes that will protect or enhance watershed water quality throughout Austin.

The *Environmental Criteria Manual* (COA 2014b) is the fifth volume in Series One of the City of Austin's Development Criteria Manuals. The rules contained in the manual apply to tracts of land within the corporate limits of the COA and its extraterritorial jurisdictional areas as defined in the Austin City Code. The rules are designed, intended and are to be administered in a manner to not contravene the provisions of the Austin City Code and to promote uniformity, clarity and stability in the application of development regulations.

The rules have been promulgated to administer and implement the technical criteria necessary to accomplish the environmental protection and management goals of the Austin City Code. The guidelines and design criteria presented in this manual address the issues of water quality management, landscaping, preservation of trees and natural areas, the underground storage of hazardous materials and construction activity in city parks.

The City of Austin Watershed Protection Department maintains and Environmental Integrity Index (EII) that characterizes chemical, biological, and physical integrity of Austin's creeks and streams (COA 2014c).

The LCRA has established the Highland Lakes Watershed Ordinance that applies to all land modification activity within the Lake Travis watershed in Travis County, the Colorado River watershed in Burnet County and a portion of Llano County (LCRA 2014). The ordinance applies to the construction of buildings, roads, paved storage areas and parking lots. A permit may be required prior to commencing these activities. This includes any land-disturbing and construction activities, such as: clearing of vegetative cover, excavating, dredging and filling, grading, contouring, mining and the deposit of refuse, waste or fill. The LCRA also monitors permit applications submitted through other regulatory agencies.

The Travis County Commissioners Court adopted Standards for Construction of Streets and Drainage in Subdivisions that contains provisions for the protection of water quality (§82.209) Travis County (2014)

D.5 Regional Water Quality Protection Plan

Rapid growth and development in northern Hays County and southwest Travis County created concerns about an increasing potential for pollution of groundwater and surface waters. These concerns included not only the impacts to drinking water supplies but to the threatened or endangered species that reside in the area. This led to the development of the Regional Water Quality Protection Plan for the Barton Springs Segment of the Edwards Aquifer and its Contributing Zone. (Naismith Engineering 2005).

In December, 2002, officials of Hays County and the City of Austin convened a Regional Summit to begin discussions on the impacts development was having on the region and particularly to water quality in the Barton Creek Watershed. From this initial effort a Regional Group was established to address the water quality issues facing the area of the Barton Springs segment of the Edwards Aquifer and its contributing zone and the desire to preserve water quality in this area. The Regional Group was comprised of an Executive Committee and Core Committee whose members were made up of representatives from the cities of Dripping Springs, Austin, Buda, Kyle, Rollingwood, Sunset Valley, the Village of Bee Cave; Hays and Travis counties; and the Barton Springs/Edwards Aquifer Conservation District and the Hays Trinity Groundwater Conservation District.

It was determined by the group that there was a need to develop a regional approach to water quality protection within the Barton Creek watershed in order to protect the quality of drinking water and the endangered species in the aquifer and springs ecosystem, particularly the Barton Springs salamander. The group believed that the completion of a regional water quality protection plan would provide the basis for political subdivisions, to the extent allowed by law, to implement local water quality protection plans and ordinances and provide best management practices that could be adopted by local stakeholders for water quality protection.

The planning process used to develop the regional plan was a very public, stakeholder-driven process involving public input in every aspect of the development of the plan. Building consensus as the plan was developed was seen as critical to producing a plan that could be adopted and implemented by local governments and stakeholders. Elements of the planning process included:

- Stakeholder involvement in all phases of development of the Water Quality Protection Plan;

- Identification of the best management practices for the protection of water quality in the area;

- Identification of entities that can implement water quality protection measures within the planning area;

- Development of model ordinances to implement and enforce water quality protection plans for the area; and,

- Development of a consensus-based Water Quality Protection Plan including best management practices, water quality protection strategies and regional planning tools to protect both surface and groundwater quality.

The planning effort was funded by grants from the Lower Colorado River Authority and the TWDB and through in-kind services from many other entities. The planning area is the Barton Springs segment of the Edwards Aquifer and its contributing zone. The area covers northern Hays County, southwest Travis County and a small section of Blanco County. The area includes the cities of Dripping Springs, Austin, West Lake Hills, Buda, Hays City, Kyle, Mountain City, Rollingwood, Sunset Valley, the Villages of Bee Cave and Bear Creek and the areas of the Barton Springs/Edwards Aquifer and Hays Trinity Conservation Districts. This study area comprises a portion of the EIS study area.

At a meeting of the Executive and Core Committees on June 13, 2005, the following resolution was adopted:

> "The Core Committee of the Regional Water Quality Planning Project for the Barton Springs Segment of the Edwards Aquifer and its Contributing Zone endorses the final draft of the Regional Water Quality Protection Plan, including the amendments dated June 3, 2005, as a framework for adoption of water quality standards by the local governments represented on the Core Committee, recognizing that each has a unique role to play in achieving the regional solution and that it will take more time and a continuing strenuous effort by government and the public to reach the level of water quality protection described in the Plan."

The 2005 document is considered the final version of the plan.

D.6 Barton Springs/Edwards Aquifer Conservation District

The Barton Springs/Edwards Aquifer Conservation District (District) strongly supports a collaborative, cooperative approach to ensuring the availability of aquifer water in sufficient quantity and quality to meet all uses. These uses include high-quality drinking water supply (including the sole source for several tens of thousands of citizens), critical ecological habitat of many plant and animal species (including some that are threatened or endangered), and an iconic recreational and aesthetic resource. The District believes that it is vital to the protection and enhancement of the uses of the Barton Springs Segment that a regional, multi-agency approach be used for planning, studying and evaluating effects, impacts, and mitigation strategies, and also for coordinating among regulatory programs.

As noted above, a consensus plan, the “Regional Water Quality Protection Plan for the Barton Springs Segment of the Edwards Aquifer and its Contributing Zone” (Naismith Engineering 2005) has been developed to provide the basis for the implementation of needed measures. The

District participated in developing the regional plan and supports not only its consensus-building approach but also its conclusions and recommendations, as a balanced, scientifically sound, and politically acceptable plan to protect uses of the aquifer. The District considers all sponsors and stakeholder groups involved in creating the plan as cooperating entities that will now use the plan as a guide for action.

The District is concerned about all impacts on the Edwards Aquifer water system, whether related to quantity or quality. It fully understands the interest possible impacts evoke in various stakeholder groups and the not unreasonable concerns of interested parties that possible effects might prove to be actual effects, and that postulated impacts (i.e., consequences) of those effects might prove to be not just potential but real, adverse, or even irreversible or irretrievable.

Measures to address future quality protection that the District believes are feasible and within its authority to implement are included in its proposed HCP and identified in **Table 2-1** of the EIS.

Specific programs that are underway at the District and are intended to improve groundwater management in the long term include: (1) the Drought Management Plan; (2) the well permits program; (3) conservation and education programs; (4) groundwater availability model formulation; and (5) Implementation of the HCP. The District will continue to provide leadership with initiatives to address the use, conservation, protection, and enhancement of ground water resources.

D.7 Other Municipalities

The Cities of Buda, Sunset Valley, Dripping Springs and the Village of Bee Caves have water quality protection ordinances. The City of Sunset Valley has very strong aquifer-related regulations, and most importantly, the City of Dripping Springs has subdivision and site development watershed ordinances that cover more than 100 square miles of the EIS study area.

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Appendix E

Cultural Resources in the Vicinity of Lower Barton Creek and Barton Springs

Appendix E
Cultural Resources in the Vicinity of Lower Barton Creek and Barton Springs

E.1 Archeological Surveys

Following Barton Creek from the confluence of the Short Spring Branch and Barton Creek to the Colorado River, several archeological surveys have been conducted in the vicinity of Barton Springs and Barton Creek. Five such surveys took place in the immediate Barton Springs/Zilker Park area: 3 surveys (1988, 1989 and 1992) took place on behalf of the City of Austin for a proposed water line for South Austin that followed the left bank of the Springs/Creek through Site 41TV1364. The initial survey resulted in the discovery of the major site while the following two phases attempted to find viable alternatives to the proposed route, eventually concluding (in 1992) that deep tunneling through the site area was best. In 1996, the City of Austin sponsored a shovel test survey of the right Barton Springs/Creek bank for proposed improvements to the Zilker Loop Trail. Through the course of investigations, archeologists visited Sites 41TV2, 689 and 690. Site 41TV2 was found to contain artifacts and was recommended for testing before any improvements in the area were to proceed. The remaining survey is located southeast of Site 41TV2, but no documentation of the survey could be located.

Moving away from the main Barton Springs area, archeologists conducted a series of eight surveys between Zilker Park and the Short Spring Branch confluence. Two of these surveys were visits and assessments of a number of the sites discussed below. In 1974 the EPA conducted a survey of several sites along the Barton Creek banks, visiting Sites 41TV384-386, 388-389, 391, and 324. No records were available regarding this survey. In 1979, TPWD conducted a similar survey and assessment of several of the same sites. Among those visited were Sites 41TV384-386, 991, 386, 389, 391, 324 and 398. Also, this survey covered a large area west of Site 41TV324. The survey was a brief assessment of each of the visited sites and recommendations for each. Site descriptions below are largely excerpts from these site discussions. Another EPA survey was conducted in 1981 for a proposed waterline along Lost Creek Boulevard at the northeastern terminus of the discussion area. This survey visited Site 41TV345 and found it to be largely destroyed by road construction and vandalism. The State Department of Highways and Public Transportation (SDHPT, currently TxDOT) conducted two surveys that overlap Barton Creek, both in the vicinity of the intersection of MoPac Expressway (Loop 1) and Loop 360 (Capital of Texas Highway). In December of 1976, SDHPT surveyors assessed Loop 360 from MoPac south to Lamar Boulevard. No records are available for this survey; however no sites lie within the survey corridor so it is likely that all visited terrain was clear of significant archeological materials. In April of 1983, SDHPT surveyed a proposed 1.5 mile extension of

MoPac from Loop 360 to US 290. Through the course of this survey archeologists revisited Sites 41TV386 and 338. These sites were found to be intact enough to warrant further testing. Finally, Espey Huston and Associates surveyed a proposed 138-kV electrical transmission line that would extend from the Barton Substation, cross Barton Creek, and run to the Oak Hill Substation. The survey located (among others) Sites 41TV579-580 and found both to be minor lithic scatters of nominal import.

E.2 NRHP/SAL Properties in Close Proximity to Barton Springs and Barton Creek

E.2.1 Barton Springs Area National Register of Historic Places/State Archaeological Landmark Properties

Nearest the confluence of Barton Creek and the Colorado River, the Barton Springs area, is a series of four recorded historic and prehistoric archeological sites. All of these sites are listed as either NRHP or State Archeological Landmark (SAL) Properties. The right bank of Barton Springs in this area is part of a Barton Springs National Register of Historic Places Archeological and Historical District while Zilker Park, which encompasses both sides of the waterway, is its own National Register Historic District.

Vara Daniel Site (SAL) – 41TV1364 – The Vara Daniel Site is located on the northern promontory of Barton Creek and Colorado River. Site recorders describe it as an "immense, intact, stratified, multi-component, primary subsistence location with at least two distinct cultural horizons." The massive site covers at least a 1,650-feet-diameter area that extends from the Creek bank almost to the Colorado River. There are no defined site boundaries as all 11 subsurface trenches dug to investigate the site (in anticipation of a proposed subsurface waterline) were positive for archeological materials. Within the mapped site boundaries archeologists noted a wide array of prehistoric artifacts including shell, burned rock, groundstone, bifaces and unifaces, Paleoindian and Archaic period dart points, and extensive lithic debitage. Deposits ranged in depth from 24 inches to 12 feet in depth. One Paleoindian period hearth feature was recorded intact at a depth of 9 feet below the surface. The site was recommended for avoidance or testing, if the proposed waterline could not be diverted. It is part of the Zilker Park Historic District.

Barton Springs Site (SAL) – 41TV2 – The Barton Springs Site, located opposite 41TV1364 between Barton Springs Pool and Campbell's Hole, is a burned rock midden and lithic scatter site first investigated in 1928 and revisited in 1979. It is the main component of the Barton Springs National Register Archeological and Historical District. The site is composed of a series of smaller lithic concentrations of cores, flakes, burned rock hearths, and rock shelters that extends along Barton Creek's right bank over a distance of approximately 1,650 feet. No diagnostics were observed during site investigation. As of its 1979 revisit, the site was found to be at least 70 percent intact.

Gail Rabb House Site (NRHP/SAL) – 41TV689 – The Gail Rabb House Site is located on a terrace overlooking a small southern tributary of Barton Creek. It is included in the Barton Springs National Register Archeological and Historical District. The house site is attributed to the Gail Rabb family who moved to the area in 1860 and owned the land until 1958. The site itself is composed of three distinct features including a limestone cistern (now filled with sediment and a tree), two rubble piles (one pile composed of limestone and one of dirt), and a cluster of domestic vegetation (irises and crepe myrtle). No evidence of the actual house structure remains (vandals burned it down in 1962), however archival documents indicate that it was a Greek Revival style home with two stories and an array of outbuildings (also no longer extant). At the time of its recording in 1983, the site area was used as a baseball field.

41TV690 (NRHP/SAL) – This small historic mill site is located approximately 220 yards west of the Gail Rabb House Site and extends across both the left and right bank of Barton Creek near the Barton Springs Pool dam. Among the historic elements observed in association with the site are a limestone ashlar masonry foundation with coursed rubble fill built into the terrace on the south (right) bank and a possible foundation and rubble pile on the left. The right bank feature is probably a mill; the left bank feature may have been a bridge or crossing above the mill. The ashlar blocks are slanted after the third course (a support course for the mill machinery). No individual historic artifacts were found in the site area. Mr. Gail Rabb, who owned much of the land in the area, likely built the mill; however, some records also name Henry Stern (who bought some of the land from Mr. Rabb) as the mill's builder.

Sunshine Camp Site – 41TV197 – Very little information is available for Site 41TV197, the Sunshine Camp Site. According to available data, the site is located somewhere "just north of Barton Springs Pool," however, THC library files (less clear on its exact location) have placed it in a 0.25-square-mile area throughout the main portions of Zilker Park, fully encompassing 41TV1689 and 1690, and almost entirely covering 41TV2 and 1364. Scant site records simply state that the site was "surface collected by boys at camp" in 1956, and that the camp boys retained the artifacts (whatever artifacts they may be). With such scant data, it is unclear if this site truly qualifies for NRHP or SAL designation, however, since it lies within the Zilker Park historic district and encompasses several National Register properties and SALs it is included in this portion of the discussion.

E.2.2 Barton Creek Area NRHP/SAL Properties

From the western edge of Zilker Park and Barton Springs to the confluence of Barton Creek and the Short Spring Branch there are three listed archeological sites. One of these sites, 41TV324, is a historic ranch site, while another, 41TV1379, is an extensive prehistoric burned rock midden site. The third site, 41TV1762, is a combination rockshelter and occupation site spanning both banks of a Barton Creek tributary. Below is a brief description of each of these sites.

Andrew M. Cox Ranch/Barton Creek Corrals (NRHP) – 41TV324 – The Andrew Cox Ranch (also known as the Barton Creek Corrals Site) is found on both the left and right banks of Barton Creek, extending southwest from Loop 360 to the immediate western bank of the creek. The National Register property covers an area of approximately 70 acres. The mid to late 19th century historic ranch site is primarily composed of a series of dry-laid stone wall enclosures and corrals with no occupational buildings extant. Several wagon-wheel rutted limestone roads are evident along the left bank side of the property. It is unclear what the current condition of the site is, however, according to the 1975 National Register listing, several of the walls/corrals had toppled over the years. In addition to the historic ranching component, the Cox Ranch site also has a minor prehistoric lithic scatter component. There is only cursory discussion of this portion of the site in any of the reports.

The Hidden Hollow Site (SAL) - 41TV1762 – This lithic scatter and rockshelter site is found on a promontory overlooking Barton Creek and an unnamed east-west Barton Creek tributary. The site lies on both the north and south banks of the tributary with the northern component containing two open rockshelters and the southern side composed of an open lithic scatter with two associated hearth features. One Perdiz arrow point was observed within the site boundaries along with a core, though all other artifacts were minor lithic debitage. Numerous looters' holes were present throughout the site area. The Hidden Hollow Site covers an area of about 0.6 acre. The site was recommended for formal SAL listing and its accompanying legal protection. It received this designation in 1995.

The Pot Luck Site (SAL) – 41TV1379 – This extensive burned rock midden site covers an area of approximately 1.8 acres and is situated on a high terrace overlooking the right bank of Barton Creek, approximately 231 feet to the east. Surveyed in November 1991, the extensive single midden (or tight complex of smaller middens) contained deposits that were estimated to extend up to one meter in depth. The site bore evidence of years of repeated looting (site recorders actually scared off two looters as they approached the site) with numerous deep potholes and spoil piles throughout the area. While there was little remaining of the site, archeologists estimated that at least some deposits were still intact. Site recorders recommended formal SAL designation for the site to afford it greater legal protection. The site received that designation in 1992.

E.2.3 Archeological Sites in Close Proximity to Barton Creek

E.2.3.1 Sites Potentially Eligible for NRHP/SAL Listing

Six archeological sites, found within 500 feet of the main Barton Creek Waterway, are described as potentially eligible for inclusion in the NRHP or as a SAL. All sites whose records either contained strong indications of eligibility or formal recommendations for testing (or any other more detailed analysis) are considered potentially eligible NRHP/SAL sites. Of the six sites described below, two are likely associated with the NRHP Cox Ranch Site (41TV324), and the remainders are prehistoric occupation sites and rockshelters.

41TV357 – This site sits on two southern terraces overlooking Barton Creek and is composed of a series of small rock shelters five to ten meters above the cliff base. Within the shelters, recorders noted several rock hearths with soot staining the ceilings. The majority of artifacts encountered within the site are primary flaking debitage. Site data do not include any formal recommendations; however if the shelters remain intact, they could be potentially eligible for NRHP/SAL listing

41TV338 – This site covers approximately 0.75 acre and is situated on a terrace overlooking the creek. The light lithic scatter was defined as having deposits reaching depths of up to 20 inches. It was recommended for testing, if any future impacts were anticipated.

41TV588 – This surficial lithic scatter occupies an area of approximately 24,240 square feet (20,200 square meters) and lies at the foot of a ridge overlooking Barton Creek to the southwest. Artifacts include cores, bifaces, unifaces and lithic debitage. The site was recommended for testing to determine how intact the cultural materials were within the site boundary.

41TV389 – This historic archeological site covers approximately 0.5 acre and contains several stone features including large worked stones, a stone wall, columns, and a possible road remnant. At the time of its initial recording, researchers postulated that the site could be related to the NRHP Cox Ranch Site (41TV324), which lay to the immediate north. The site was recommended for formal testing for defined association with the Cox Ranch Site.

41TV391 – This historic and prehistoric site covers approximately 6.2 acres and is partially overlapped by the Cox Ranch. The historic elements of the site are most likely also associated with the Cox Ranch but were not described within the survey report. The prehistoric elements are classified as a minor upland lithic scatter. The site was recommended for survey and mapping, citing its direct relation to Site 41TV324.

41TV398 - This prehistoric lithic scatter site is located on the right bank of Barton Creek at the confluence of the creek and two of its small, unnamed tributaries. One San Marcos point was recovered during site investigations; however, all other artifacts were limited to lithic debitage. Situated on a sandy promontory, site recorders maintain that 41TV398 could contain enough stratification to potentially produce local chronologies, contributing to understanding of local prehistory. The site was recommended for avoidance.

E.2.3.2 Archeological Sites

Twelve minor prehistoric and historic archeological sites were documented within 500 feet of the main Barton Creek waterway between the western edge of Zilker Park and the confluence of

Barton Creek and the South Spring Branch. Of these, the overwhelming majority (n=11) are defined as minor, surficial lithic scatters and procurement areas with nominal deposition and very little definable patterning. The remainder is a once-significant burned rock midden site (now destroyed by development). Mostly situated within the Barton Creek Greenbelt and thus subject to frequent foot traffic, a number of the sites contain evidence of repeated looting. Below is a brief discussion of each of these sites, moving upstream along Barton Creek from Zilker Park to the South Spring Branch confluence.

41TV993 – Located on a wooded terrace approximately 0.5 mile southwest of the Hollow Creek confluence, this 2.4-acre site is described as an open, surficial lithic scatter. No diagnostics were observed on the surface or in either of the two site shovel tests excavated, but one uniface was documented. A moderate dirt roadway that cuts through the site area has disturbed much of the main site components. 41TV993 was not recommended for further work, and planned office development in the area has likely destroyed any remnants of the site.

41TV992 – This 1.5-acre surficial lithic scatter site is located along the left bank of Barton Creek, approximately 0.5 mile southwest of the Hollow Creek confluence. Situated in a wooded area clearing, the site did not contain any diagnostic tools; however, one worked flake was observed on the surface. At the time of recording, the site was defined as disturbed and eroded and did not display any visible patterning. The site was not recommended for any further work.

41TV385 – This site occupies an area of approximately 94 acres in an eastern oxbow of Barton Creek east of Loop 360. It is composed of three smaller light lithic scatters with flakes, tested cobbles, a core, and biface. Shallow soils are found throughout the site area and the site recorders recommended no further work.

41TV384 – This small lithic quarry and primary manufacturing site covers approximately 0.1 acre. Artifacts encountered include tested cobbles, cores, and dense lithic debitage. The site area has no soil deposition, and surveyors recommended no further work for the site.

41TV991 – This site is a Paleoindian period prehistoric open campsite with evidence of multiple components. The surficial lithic scatter occupies an area of approximately 11 acres. Among the items collected during a surface survey are: one Angostura dart point, one Midland dart point, and one stemmed dart point base. The site does not appear to be intact and is likely wash from the higher landform. It has no deposition and has been recommended for no further work.

41TV977 – This light surficial lithic scatter covers about 2.5 acres. Artifacts found within the site boundaries include one small biface fragment and lithic debitage extending to a depth of approximately five centimeters below the ground surface. No further work was recommended for this site.

41TV386 – This site occupied an area of approximately 37 acres in 1979 and just 12 acres seven years later. The site sits on a terrace overlooking a southward oxbow of Barton Creek immediately west of Loop 360. The site is described as a surficial lithic scatter with extremely shallow deposits of lithic debitage, early Middle Archaic dart points (Nolan, Pedernales), and other bifaces and biface fragments. In 1979, recorders recommended that, if affected by any future work, the site should be surface-collected and possibly tested. In 1984, the site was defined as approximately one percent intact and not recommended for any further investigations.

41TV387 – This site occupies an area of 1.2 acres and is defined as a lithic scatter site with heavy scatters of expended cores, bifaces, and flakes. It lies on a terrace overlooking the creek to the east. The site was recommended for surface collection and possible testing (if affected by future impacts) to determine the depth and extent of site deposits.

41TV704 – This 198-square-foot site sits atop a high bluff overlooking Barton Creek and one of its small tributaries. The “L”-shaped prehistoric lithic scatter site contains a variety of cores, biface fragments, and plentiful lithic debitage. The site is, however, entirely surficial and was not recommended for any further work following its initial recordation.

41TV580 – This 4-acre surficial lithic scatter is found surrounding an electrical substation on a bluff overlooking Barton Creek to the west. The site did not contain any features nor were any formal tools recorded, however, the presence of numerous primary flakes and cores indicates that the site is likely the remnant of lithic procurement activities. The site was not recommended for any other work.

41TV579 – This site occupies an area of approximately 2.8 acres and is characterized as a surficial lithic procurement and scatter site. No formal tools were found within the site boundaries, and archeologists recording the site did not recommend that any further work was warranted.

41TV345 – This site was studied in two phases over the span of four years. In 1975, the site was characterized as a relatively extensive burned rock midden site situated on a high terrace overlooking the creek to the east, immediately south of the confluence of Barton Creek and Short Spring Branch. Among the materials observed on the 0.5-acre site were the midden itself, numerous hearth features, and “flint,” all within the main site boundaries. At that time it had been heavily looted with potholes throughout. The site was recommended for intensive testing. By the time of a 1979 follow-up survey, the site was described as being “in the process of being totally destroyed.” Development in the area had severely impacted the site, and looting had continued. A planned expanded roadway was scheduled to completely destroy the remnants of the site. It is likely that this site is no longer extant.

Appendix F
Lists of Potentially Occurring Vertebrate Species Within the dEIS Study Area

Table F-1
County Occurrence of Amphibians and Reptiles (See Table 3-3 for Federal and State Listed species potentially occurring in the study area)

Common Name	Scientific Name	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop
Salamanders & Newts:								
small-mouthed salamander	*Ambystoma texanum*	X	X			X	X	X
tiger salamander	*Ambystoma tigrinum*							X
Jollyville Plateau salamander	*Eurycea tonkawae*	X						
Barton Springs salamander	*Eurycea sosorum*	X						
San Marcos salamander	*Eurycea nana*		X			X		
Cascade Caverns salamander	*Eurycea latitans*				X	X		
Texas salamander	*Eurycea neotenes*		X	X				
Austin blind salamander	*Eurycea waterlooensis*	X						
Texas blind salamander	*Eurycea rathbuni*		X	X				
Fern bank salamander	*Eurycea pterophila*		X	X				
Comal blind salamander	*Eurycea tridentifera*					X		
Blanco blind salamander	*Eurycea robusta*		X					
western slimy salamander	*Plethodon albagula*	X	X	X	X	X	X	
Frogs & Toads								
cricket frog	*Acris crepitans*	X	X	X	X			
Blanchard's cricket frog	*Acris blanchardi*	X	X	X	X	X	X	X
green toad	*Bufo debilis*	X	X			X		
red-spotted toad	*Bufo punctatus*	X	X	X	X	X		
Texas toad	*Bufo speciosus*	X	X		X	X	X	X
Gulf Coast toad	*Bufo valliceps*	X	X	X	X	X	X	X
Houston toad	*Bufo houstonensis*							X
Woodhouse's toad	*Bufo woodhousii*	X	X		X	X	X	X
barking frog	*Eleutherodactylus augusti*	X	X		X			
eastern narrow-mouthed toad	*Gastrophryne carolinensis*	X				X		X
western narrow-mouthed toad	*Gastrophryne olivacea*	X	X		X	X	X	X
green tree frog	*Hyla cinerea*	X	X			X	X	X
gray tree frog	*Hyla versicolor*	X	X	X	X	X	X	X
Cope's gray tree frog	*Hyla chrysoscelis*	X	X	X	X	X	X	X
Clark's tree frog	*Pseudacris clarkii*	X	X	X	X	X	X	X
Strecker's chorus frog	*Pseudacris streckeri*	X	X	X		X	X	X
upland chorus frog	*Pseudacris feriarum*	X	X					X
western chorus frog	*Pseudacris triseriata*	X	X	X				
crawfish frog	*Rana areolata*							
Rio Grande leopard frog	*Rana berlandieri*	X	X	X	X	X	X	X

Table F-1, cont'd

Common Name	Scientific Name	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop
American bullfrog	*Rana catesbeiana*	X	X		X	X	X	X
southern leopard frog	*Rana sphenocephala*	X	X		X		X	X
Couch's spadefoot toad	*Scaphiopus couchii*	X	X		X	X	X	X
Hurter's spadefoot toad	*Scaphiopus hurterii*	X					X	X
cliff chirping frog	*Syrrhophus marnocki*	X	X	X	X	X	X	X
Alligator								
American alligator	*Alligator mississippiensis*	X	X					X
Turtles								
spiny softshell turtle	*Apalone spinifera*	X	X	X	X	X	X	X
eastern snapping turtle	*Chelydra serpentina*	X	X		X			X
Cagle's map turtle	*Graptemys caglei*		X	X	X	X		
Texas map turtle	*Graptemys versa*	X	X	X				X
yellow mud turtle	*Kinosternon flavescens*	X	X		X	X	X	X
eastern mud turtle	*Kinosternon subrubrum*	X	X			X		X
Florida red-bellied cooter	*Pseudemys nelsoni*		X	X				
Texas river cooter	*Pseudemys texana*	X	X	X	X	X		X
eastern musk turtle (stinkpot)	*Sternotherus odoratus*	X	X	X	X	X		
eastern box turtle	*Terrapene carolina*	X	X					X
ornate box turtle	*Terrapene ornata*	X	X	X	X	X	X	X
Texas tortoise	*Gopherus berlandieri*					X		
pond slider	*Trachemys scripta*	X	X	X	X	X	X	X
Lizards and Skinks								
Mediterranean gecko	*Hemidactylus turcicus*	X	X	X	X	X	X	
green anole	*Anolis carolinensis*	X	X	X	X	X	X	X
common spotted whiptail	*Cnemidophorus gularis*	X	X	X	X	X	X	X
six-lined racerunner	*Cnemidophorus sexlineatus*	X	X			X	X	X
greater earless lizard	*Cophosaurus texanus*	X	X	X	X	X		
eastern collared lizard	*Crotaphytus collaris*	X	X	X	X	X		X
Great Plains skink	*Eumeces obsoletus*	X		X				
prairie skink	*Eumeces septentrionalis*							X
four-lined skink	*Eumeces tetragrammus*	X	X	X	X	X		
Texas alligator lizard	*Gerrhonotus infernalis*	X	X	X	X	X		
spot-tailed earless lizard	*Holbrookia lacerata*	X	X	X	X	X		X
common lesser earless lizard	*Holbrookia maculata*		X	X				
keeled earless lizard	*Holbrookia propinqua*		X	X				
slender glass lizard	*Ophisaurus attenuatus*	X	X		X			X
Texas horned lizard	*Phrynosoma cornutum*	X	X	X	X	X	X	X

Table F-1, cont'd

Common Name	Scientific Name	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop
Texas spiny lizard	*Sceloporus olivaceus*	X	X	X	X	X	X	X
crevice spiny lizard	*Sceloporus poinsettii*			X	X	X		
prairie lizard	*Sceloporus consobrinus*	X	X	X	X	X	X	X
eastern fence lizard	*Sceloporus undulatus*		X	X	X			
rose-bellied lizard	*Sceloporus variabilis*		X			X	X	
little brown (ground) skink	*Scincella lateralis*	X	X	X	X	X	X	X
ornate tree lizard	*Urosaurus ornatus*	X	X	X	X	X		X
Snakes								
copperhead	*Agkistrodon contortrix*	X	X	X	X	X	X	X
cottonmouth	*Agkistrodon piscivorus*	X	X	X	X	X	X	X
glossy snake	*Arizona elegans*	X	X			X	X	X
North American racer	*Coluber constrictor*	X	X		X	X	X	X
western diamond-backed rattlesnake	*Crotalus atrox*	X	X	X	X	X	X	X
timber rattlesnake	*Crotalus horridus*						X	X
black-tailed rattlesnake	*Crotalus molossus*	X	X		X	X		
ring-necked snake	*Diadophis punctatus*	X	X	X	X			
Great Plains rat snake	*Elaphe emoryi*	X	X	X	X	X	X	X
Baird's rat snake	*Elaphe bairdi*							
corn snake	*Elaphe guttata*		X	X	X			
Texas rat snake	*Elaphe obsoleta*	X	X	X	X	X	X	X
plains hog-nosed snake	*Heterodon nasicus*			X				
eastern hog-nosed snake	*Heterodon platirhinos*	X	X	X	X	X		X
Chihuahuan nightsnake	*Hypsiglena jani*		X		X	X		
prairie kingsnake	*Lampropeltis calligaster*	X	X			X		X
common kingsnake	*Lampropeltis getula*	X	X				X	X
milk snake	*Lampropeltis triangulum*	X			X	X		
western thread (blind) snake	*Leptotyphlops dulcis*	X	X	X	X	X	X	X
coachwhip	*Masticophis flagellum*	X	X	X	X	X	X	X
striped whipsnake	*Masticophis taeniatus*	X	X	X	X	X		
Texas coral snake	*Micrurus fulvius*	X	X	X	X	X	X	X
southern water snake	*Nerodia fasciata*	X					X	X
plain-bellied water snake	*Nerodia erythrogaster*	X	X	X	X	X	X	X
diamond-backed water snake	*Nerodia rhombifer*	X	X	X	X	X	X	X
rough green snake	*Opheodrys aestivus*	X	X	X	X	X	X	X
gophersnake (bullsnake)	*Pituophis catenifer*	X	X	X	X	X	X	X
long-nosed snake	*Rhinocheilus lecontei*	X	X			X	X	X
eastern patch-nosed snake	*Salvadora grahamiae*	X	X	X	X	X	X	X

Table F-1, cont'd

Common Name	Scientific Name	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop
western ground snake	*Sonora semiannulata*	X	X	X	X	X	X	X
Dekay's brown snake	*Storeria dekayi*	X	X		X	X		X
flat-headed snake	*Tantilla gracilis*	X	X	X	X	X	X	X
plains black-headed snake	*Tantilla nigriceps*	X	X	X	X	X		
black-necked garter snake	*Thamnophis cyrtopsis*	X	X	X	X	X		
checkered garter snake	*Thamnophis marcianus*	X	X	X	X	X	X	X
western ribbon snake	*Thamnophis proximus*	X	X	X	X	X	X	X
common gartersnake	*Thamnophis sirtalis*	X	X	X				
lined snake	*Tropidoclonion lineatum*	X	X			X	X	
rough earth snake	*Virginia striatula*	X	X	X	X	X	X	X
smooth earth snake	*Virginia valeriae*	X			X	X		

Source: Dixon 2013.

Table F-2
Birds Abundant to Fairly Common within the Study Area

black-bellied whistling-duck	*Dendrocygna autumnalis*	Acadian flycatcher	*Empidonax virescens*
wood duck	*Aix sponsa*	eastern phoebe	*Sayornis phoebe*
gadwall	*Anas strepera*	ash-throated flycatcher	*Myiarchus cinerascens*
blue-winged teal	*Anas discors*	great crested flycatcher	*Myiarchus crinitus*
northern shoveler	*Anas clypeata*	willow flycatcher	*Empidonax traillii*
green-winged teal	*Anas carolinensis*	least flycatcher	*Empidonax minimus*
bufflehead	*Bucephala albeola*	western kingbird	*Tyrannus verticalis*
ruddy duck	*Oxyura jamaicensis*	eastern kingbird	*Tyrannus tyrannus*
American wigeon	*Anas americana*	scissor-tailed flycatcher	*Tyrannus forficatus*
northern pintail	*Anas acuta*	loggerhead shrike	*Lanius ludovicianus*
redhead	*Aythya americana*	white-eyed vireo	*Vireo griseus*
ring-necked duck	*Aythya collaris*	blue-headed vireo	*Vireo solitarius*
lesser scaup	*Aythya affinis*	red-eyed vireo	*Vireo olivaceus*
wild turkey	*Meleagris gallopavo*	blue jay	*Cyanocitta cristata*
northern bobwhite	*Colinus virginianus*	western scrub-jay	*Aphelocoma californica*
eared grebe	*Podiceps nigricollis*	American crow	*Corvus brachyrhynchos*
pied-billed grebe	*Podilymbus podiceps*	purple martin	*Progne subis*
double-crested cormorant	*Phalacrocorax auritus*	cliff swallow	*Petrochelidon pyrrhonota*
neotropic cormorant	*Phalacrocorax brasilianus*	cave swallow	*Petrochelidon fulva*
great blue heron	*Ardea herodias*	barn swallow	*Hirundo rustica*
snowy egret	*Egretta thula*	treesSwallow	*Tachycineta bicolor*
great egret	*Ardea alba*	bank swallow	*Hirundo rustica*
little blue heron	*Egretta caerulea*	Carolina chickadee	*Poecile carolinensis*
cattle egret	*Bubulcus ibis*	black-crested titmouse	*Baeolophus atricristatus*
green heron	*Butorides virescens*	verdin	*Auriparus flaviceps*
black-crowned night-heron	*Nycticorax nycticorax*	Carolina wren	*Thryothorus ludovicianus*
white ibis	*Eudocimus albus*	Bewick's wren	*Thryomanes bewickii*
white-faced ibis	*Plegadis chihi*	house wren	*Troglodytes aedon*
Bback vulture	*Coragyps atratus*	marsh wren	*Cistothorus palustris*
turkey vulture	*Cathartes aura*	ruby-crowned kinglet	*Regulus calendula*
osprey	*Pandion haliaetus*	blue-gray gnatcatcher	*Polioptila caerulea*
northern harrier	*Circus cyaneus*	eastern bluebird	*Sialia sialis*
sharp-shinned hawk	*Accipiter striatus*	hermit thrush	*Catharus guttatus*
Cooper's hawk	*Accipiter cooperii*	Swainson's thrush	*Catharus ustulatus*
red-shouldered hawk	*Buteo lineatus*	American robin	*Turdus migratorius*
Swainson's hawk	*Buteo swainsoni*	northern mockingbird	*Mimus polyglottos*
red-tailed hawk	*Buteo jamaicensis*	long-billed thrasher	*Toxostoma longirostre*
crested caracara	*Caracara cheriway*	curve-billed thrasher	*Toxostoma curvirostre*

Table F-2, cont'd

American kestrel	*Falco sparverius*	European starling	*Sturnus vulgaris*
common moorhen	*Gallinula chloropus*	American pipit	*Anthus rubescens*
American coot	*Fulica americana*	cedar waxwing	*Bombycilla cedrorum*
killdeer	*Charadrius vociferus*	orange-crowned warbler	*Vermivora celata*
black-necked stilt	*Himantopus mexicanus*	Nashville warbler	*Vermivora ruficapilla*
greater yellowlegs	*Tringa melanoleuca*	yellow warbler	*Dendroica aestiva*
lesser yellowlegs	*Tringa flavipes*	yellow-rumped warbler	*Dendroica coronata*
American golden plover	*Pluvialis dominica*	black-throated green warbler	*Dendroica virens*
American avocet	*Recurvirostra americana*	black-and-white warbler	*Mniotilta varia*
spotted sandpiper	*Actitis macularia*	common yellowthroat	*Geothlypis trichas*
least sandpiper	*Calidris minutilla*	Wilson's warbler	*Wilsonia pusilla*
upland sandpiper	*Bartramia longicauda*	yellow-breasted chat	*Icteria virens*
semi-palmated sandpiper	*Calidris pusilla*	summer tanager	*Piranga rubra*
western sandpiper	*Calidris mauri*	spotted towhee	*Pipilo maculatus*
Baird's sandpiper	*Calidris bairdii*	chipping sparrow	*Spizella passerina*
pectoral sandpiper	*Calidris melanotos*	clay-colored sparrow	*Spizella pallida*
stilt sandpiper	*Calidris himantopus*	field sparrow	*Spizella pusilla*
long-billed dowitcher	*Limnodromus scolopaceus*	vesper sparrow	*Pooecetes gramineus*
common snipe	*Gallinago gallinago*	lark sparrow	*Chondestes grammacus*
Wilson's phalarope	*Phalaropus tricolor*	savannah sparrow	*Passerculus sandwichensis*
Franklin's gull	*Leucophaeus pipixcan*	grasshopper sSparrow	*Ammodramus savannarum*
ring-billed gull	*Larus delawarensis*	song sparrow	*Melospiza melodia*
Forster's tern	*Sterna forsteri*	Lincoln's sparrow	*Melospiza lincolnii*
rock pigeon	*Columba livia*	White-throated sparrow	*Zonotrichia albicollis*
white-winged dove	*Zenaida asiatica*	white-crowned sparrow	*Zonotrichia leucophrys*
mourning dove	*Zenaida macroura*	swamp sparrow	*Melospiza georgiana*
Inca dove	*Scardafella inca*	Harris's sparrow	*Zonotrichia querula*
common ground-dove	*Columbina passerina*	northern sardinal	*Cardinalis cardinalis*
yellow-billed cuckoo	*Coccyzus americanus*	pyrrhuloxia	*Cardinalis sinuatus*
greater roadrunner	*Geococcyx californianus*	indigo bunting	*Passerina cyanea*
eastern screech-owl	*Megascops asio*	painted bunting	*Passerina ciris*
great horned owl	*Bubo virginianus*	dickcissel	*Spiza americana*
barred owl	*Strix varia*	yellow-headed blackbird	*Xanthocephalus xanthocephalus*
cmmon nighthawk	*Chordeiles minor*	red-winged Blackbird	*Agelaius phoeniceus*
chuck-will's-widow	*Caprimulgus carolinensis*	eastern Meadowlark	*Sturnella magna*
chimney swift	*Chaetura pelagica*	western meadowlark	*Sturnella neglecta*
ruby-throated ummingbird	*Archilochus colubris*	great-tailed grackle	*Quiscalus mexicanus*
black-chinned hummingbird	*Archilochus alexandri*	common grackle	*Quiscalus quiscula*

Table F-2, cont'd

belted kingfisher	*Megaceryle alcyon*	Brown-headed cowbird	*Molothrus ater*
golden-fronted woodpecker	*Melanerpes aurifrons*	orchard oriole	*Icterus spurius*
red-bellied woodpecker	*Melanerpes carolinus*	Bullock's oriole	*Icterus bullockii*
ladder-backed woodpecker	*Picoides scalaris*	house finch	*Carpodacus mexicanus*
downy woodpecker	*Picoides pubescens*	American goldfinch	*Carduelis tristis*
northern flicker	*Colaptes auratus*	house sparrow	*Passer domesticus*
eastern wood-pewee	*Contopus virens*		

Source: Travis Audubon Society 2012; Hornsby Bend Bird Observatory 2012.

Table F-3
County Occurrence of Mammals

Common Name	Scientific Name	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop
Virginia opossum	*Didelphis virginiana*	X	X	X	X	X	X	X
nine-banded armadillo	*Dasypus novemcinctus*	X	X	X	X	X		X
southern short-tailed shrew	*Blarina carolinensis*							X
Elliot's short-tailed shrew	*Blarina hylophaga*							X
least shrew	*Cryptotis parva*	X						
eastern mole	*Scalopus aquaticus*	X						X
Mexican free-tailed bat	*Tadarida brasiliensis mexicana*	X	X	X	X	X	X	X
hoary bat	*Lasiurus cinereus*	X		X		X		
northern yellow bat	*Lasiurus intermedius*	X						
eastern red bat	*Lasiurus borealis*	X	X	X	X	X	X	X
Seminole bat	*Lasiurus seminolus*	X	X				X	X
eastern pipistrelle	*Pipistrellus subflavus*	X	X		X	X		X
cave myotis bat	*Myotis velifer*	X	X	X	X	X	X	X
evening bat	*Nycticeius humeralis*	X		X				
raccoon	*Procyon lotor*	X	X			X	X	X
American mink	*Mustela vison*	X	X					
American badger	*Taxidea taxus*	X						
northern river otter	*Lontra canadensis*	X						
hog-nosed skunk	*Conepatus leuconotus mearnsi*	X	X					
striped skunk	*Mephitis mephitis*	X	X		X	X	X	X
western spotted skunk	*Spilogale gracilis*				X			
eastern spotted skunk	*Spilogale putorius*	X	X		X		X	X
red fox	*Vulpes vulpes*	X				X		X
gray fox	*Urocyon cinereoargenteus*	X	X			X	X	X
mountain lion	*Puma concolor*	X	X	X	X			

coyote	*Canis latrans*	X	X	X	X	X	X	X
ringtail	*Bassariscus astutus*	X	X	X	X	X	X	X
bobcat	*Lynx rufus*	X	X	X	X	X	X	X
eastern gray squirrel	*Sciurus carolinensis*		X					
eastern fox squirrel	*Sciurus niger*	X	X	X	X	X	X	X
rock squirrel	*Spermophilus variegatus*	X	X	X	X	X		
southern flying squirrel	*Glaucomys volans*							X
mexican ground squirrel	*Spermophilus mexicanus*	X	X			X		
Attwater's pocket gopher	*Geomys attwateri*	X			X		X	X

Table F-3, cont'd

Common Name	Scientific Name	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop
Llano pocket gopher	*Geomys texensis*			X				
Merriam's pocket mouse	*Perognathus merriami*	X						
hispid pocket mouse	*Chaetodipus hispidus*	X			X		X	
hispid cotton rat	*Sigmodon hispidus*	X	X	X	X	X	X	X
white-footed mouse	*Peromyscus leucopus*	X	X	X	X	X	X	X
deer mouse	*Peromyscus maniculatus*	X	X		X	X	X	
Texas mouse	*Peromyscus attwateri*	X	X		X	X		
white-ankled mouse	*Peromyscus pectoralis*	X	X	X	X	X		
northern pygmy mouse	*Baiomys taylori*	X	X		X	X	X	X
house mouse	*Mus musculus*	X	X	X	X	X	X	X
plains harvest mouse	*Reithrodontomys montanus*	X						
fulvous harvest mouse	*Reithrodontomys fulvescens*	X	X		X	X	X	
American beaver	*Castor canadensis*	X	X	X				
nutria	*Myocastor coypus*	X	X			X	X	
eastern woodrat	*Neotoma floridana*	X					X	
southern Plains woodrat	*Neotoma micropus*		X					
roof rat	*Rattus rattus*	X	X	X	X	X	X	X
Norway rat	*Rattus norvegicus*	X	X	X	X	X	X	X
northern pygmy mouse	*Baiomys taylori*	X	X			X		
swamp rabbit	*Sylvilagus aquaticus*	X	X	X	X	X	X	
eastern cottontail	*Sylvilagus floridanus*	X	X		X		X	X
black-tailed Jackrabbit	*Lepus californicus*	X	X	X	X	X	X	X
white-tailed deer	*Odocoileus virginianus*	X	X	X	X	X	X	X
axis deer	*Cervus axis*	X	X	X	X	X	X	X
fallow deer	*Cervus dama*	X	X	X	X	X	X	X
blackbuck	*Antilope cervicapra*	X	X	X	X	X	X	X
domestic hog (feral)	*Sus scrofa*	X	X	X	X	X	X	X

Source: Schmidly 2004.