ENVIRONMENTAL IMPACT STATEMENT
FOR THE
BARTON SPRINGS/EDWARDS AQUIFER CONSERVATION DISTRICT HABITAT CONSERVATION PLAN

Prepared for:

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HABITAT CONSERVATION PLAN

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Cover Sheet

Environmental Impact Statement (EIS) for Authorization of Incidental Take and Implementation of the Barton Springs/Edwards Aquifer Conservation District (District or BSEACD) Habitat Conservation Plan (HCP) for take of the Covered Species: Barton Springs salamander (*Eurycea sosorum*, BSS) and Austin blind salamander (*Eurycea waterlooensis*, ABS).

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The U.S. Fish and Wildlife Service (Service) received an application from the BSEACD for a permit to take two federally listed, endangered species incidental to otherwise lawful activities pursuant to section 10(a)(1)(B) of the Endangered Species Act of 1973, as amended. This EIS 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.

The Incidental Take Permit (ITP) would provide exceptions to the prohibitions of take for the Covered Species 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 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 EIS 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: no action, water demand reduction, and 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 Environmental Impact Statement (EIS) describes the potential impacts of the issuance of a proposed Incidental Take Permit (Permit, ITP) to the Barton Springs/Edwards Aquifer Conservation District (BSEACD or 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*, BSS) and Austin blind salamander (*Eurycea waterlooensis*, ABS) (Covered Species). The District submitted the HCP to the U.S. Fish and Wildlife Service (Service) as part of an application for an incidental take permit (ITP or 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 (Covered Activities) for a period of 20 years (permit term). The Covered Activities include pumping withdrawals from the Barton Springs segment of the Edwards Aquifer (Aquifer) that are authorized under permits from the District in portions of Travis and Hays counties, 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 BSS and ABS 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 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 EIS Alternatives Evaluated

Four alternatives were selected for analysis in this EIS. Each of the four alternatives are briefly described below and summarized in **Table ES-1**. See **Section 2.4** for full descriptions of the alternatives.

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. While the District would pursue its legislatively mandated Aquifer management responsibilities, without an HCP there is no cap during non-drought conditions. The

District would notify permittees of approaching drought and issue notices requesting permittees significantly curtail or stop pumping once drought is declared. Under the No Action Alternative, each permittee would be expected to comply voluntarily with pumping cessation, but the District would not be able to enforce those restrictions. However, if all permittees complied, pumping would be less than 1 cfs (assumes nearly complete cessation of pumping) with resulting projected lowest average monthly springflow at Barton Springs of 11 cfs, which was reached during the 1950's DOR that the Covered Species are known to have survived. 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.

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

Alternative 2 would involve approval of the District's HCP addressing authorized pumping of the Aquifer and the issuance of an ITP by the Service. Alternative 2 minimization measures would meet state-mandated Desired Future Conditions (DFCs) by establishing a cap of 16 cfs on all pumping, and limit Aquifer pumping during DOR-like conditions to no more than 5.2 cfs, thereby maintaining a minimum average monthly springflow at Barton Springs of 6.5 cfs. The District's HCP incorporates actions to minimize and mitigate unavoidable incidental take and includes demand reduction measures, recharge enhancment, supporting a salamander refugium, programs encouraging the development and use of new water supplies, cooperative efforts with other entities, and mechanisms to adapt management strategies and respond to emergencies. Although the combination of pumping and low Aquifer recharge could result in monthly springflows as low as 6.5 cfs, the expected frequency of occurrence is less than 1 percent. Among the four alternatives evaluated in this EIS, Alternative 2 provides the most technically feasible and economically achievable 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, including during drought conditions. The District would require (and enforce) 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 during the DOR. These regulatory curtailments, backed with effective enforcement to ensure compliance, would protect springflow for the Covered Species. However, this alternative would employ the most severe regulatory measures to achieve the level of pumping reductions needed and may require one or more sources of replacement water for some indeterminate fraction of the amount curtailed to meet the needs of the public.

Recent rulings by the Texas Supreme Court upheld the rights of groundwater conservation districts (like the District) 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 limit on how much curtailment is “reasonable” and “fair” before property rights are infringed, which would require compensation for the loss of the amount of water prohibited from pumping. This alternative would result in low biological impacts but with potentially high economic impacts, due to the potential need to compensate a significant number of permittees. Additionally, it 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.

ES 3.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would involve the development of other alternative water supplies that would augment and replace the amount of water pumped from the Aquifer to achieve the goal of substantially reducing Aquifer pumping to a level below 1 cfs to provide for a minimum average monthly springflow of 11 cfs during DOR 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 shorter-term ITP and associated HCP would be pursued. 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 DOR conditions. The District currently does not have the regulatory authority to develop alternative water supplies. Therefore, use of augmented or substituted water supplies would have to be implemented voluntarily by other entities, or the Texas Legislature would have to give the District the authority (and likely funding) to develop these alternative sources. There are also current limitations on the amount of alternative water supplies that could economically be made available to groundwater users within the region.

In summary, the most substantial impacts to the Barton Springs ecosystem are driven by measures that affect Aquifer pumping. The largest and most assured positive impacts to the Covered Species are associated with Alternative 3, Water Demand Reduction, and Alternative 4, Water Supply Augmentation and Substitution. While these alternatives could be considered Environmentally Preferred Alternatives, because they provide the greatest level of protection to the Barton Springs ecosystem by sustaining a higher level of water flow through the spring ecosystems during drought, the likelihood of them being successfully or completely implemented is slim. Additionally, 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 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.

ES 4.0 Scoping

The scoping process is described in **Section 1.6** and comments received are included in **Appendix A2 through A5. Public Involvement**.

Table ES-1. Comparison of EIS 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 BSS and ABS	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	BSEACD permittees that choose to continue pumping the Aquifer during drought would need to apply for individual ITPs.	BSEACD	None, if pumping is completely curtailed.	BSEACD
Terms of ITP	N/A	20 years	N/A	5 years
Maximum Allowable Pumping (cfs) During Non-drought Conditions Including ASR Requirements	No cap	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.
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
Effects of Mitigation or Conservation Measures	Minimum Benefit	Maximum Benefit	None	Limited to Interim HCP until alternative water supplies supersede groundwater pumping.
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.
Cumulative Costs	< $6,000,000	≥ $18,000,000	< $6,000,000	Costs would range between $64,000,000,000 and $286,000,000, 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 2018); 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 Lower Colorado 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.

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Acronyms and Abbreviations

AACOG	Alamo Area Council of Governments
ABS	ABS
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)
BSS	BSS
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
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 Statement
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
USEPA	United States Environmental Agency
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

1.0 PURPOSE AND NEED FOR THE ACTION

1.1 INTRODUCTION

This Environmental Impact Statement (EIS) has been prepared in accordance with the requirements of the National Environmental Policy Act (42 United States Code [U.S.C.] 4321–4327; NEPA) 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) by the Barton Springs/Edwards Aquifer Conservation District (District or BSEACD) throughout its jurisdictional area (see Figure 3-1 in the HCP). The District seeks an ITP for incidental "take" of two federally protected species, the Barton Springs salamander (*Eurycea sosorum*, BSS), and the Austin blind salamander (*Eurycea waterlooensis*, ABS), collectively the Covered Species.

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 Aquifer that may result in incidental take of the BSS and ABS.

1.2 COVERED SPECIES

The BSS and ABS are the two species that will be covered under the ITP. The BSS was listed as endangered on April 30, 1997 (62 FR 23377), and the ABS was listed as endangered with designated critical habitat on August 20, 2013 (78 FR 51277). These are hereafter referred to as Covered Species.

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 EIS 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 Species in the course of conducting otherwise lawful activities as provided for by the ESA. Covered Activities include regulated water withdrawals from the Aquifer permitted by the District. 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 EIS is to evaluate the effects of HCP implementation and its alternatives on the environment pursuant to requirements of NEPA. The EIS evaluates environmental consequences of the Preferred Alternative, two other Action Alternatives, and a No Action Alternative for an EIS Study Area that conforms with the HCP planning area (see Figure 3-1 in the HCP).

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 Covered Species. The 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 pumping 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 Preferred Alternative, the District could face significant difficulty in balancing its state-mandated management functions and goals of regulating the water resources of the 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 (GCDs) to regulate groundwater withdrawals.

Although the Rule of Capture remains in effect, GCDs 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 GCDs 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 GCD 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 (BSP), 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 3-1 in the HCP)**.** 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 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 (Study Area). The EIS Study Area includes all areas shown in color on Figure 3-1 in the HCP.

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):

- 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 Public Involvement

1.6.1.1 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). Issues identified during scoping were incorporated into a combined draft HCP and EIS dated August 2007. Subsequent to preparation of this document, the ABS became listed as an endangered species and new information became available for the BSS. The Service, therefore, initiated a process to update the scope of issues and concerns regarding 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).

1.6.1.2 Scoping Meetings

The first scoping meeting was held in Austin, Texas, on August 23, 2005. A second 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**.

1.6.1.3 Advisory Groups

The District utilized several advisory groups to assist in the preparation of the 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 Management Advisory Committee (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 the MAC. The MAC is composed of experts, stakeholds, and private citizens and 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 the Covered Species, 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 throughout the permit term.

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. For example, the Service recently issued an amendment to an existing ITP for the BSS and ABS covering the City of Austin's (COA) management, operation, and maintenance of the BSP, and approved an associated HCP (COA 2013a). Therefore, close coordination will be required between the District and the 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 BSP and lower Barton Creek. Additionally, coordination with the Texas Parks and Wildlife Department (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 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 EIS 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 effects 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 EIS considers the physical, biological, and socioeconomic effects of the Proposed Action and the alternatives in the Study Area.

This EIS addresses four alternatives:

1. No Action;
2. Issuance of an Incidental Take Permit for Permitted Pumping under the District HCP (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 EIS.

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).

2.0 ALTERNATIVES ANALYSIS

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

2.1 ALTERNATIVES CONSIDERED

A number of alternatives were considered for this EIS evaluation. Several evaluated alternatives were dismissed from further consideration because they 1) overlapped or were redundant with existing alternatives identified and evaluated in this EIS, 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 Protection 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 for a number of local governmental entities in cooperation with a citizen committee (Naismith Engineering 2005). These governmental entities included the: cities of Dripping Springs, Austin, Buda, Kyle, Rollingwood, Sunset Valley, Village of Bee Cave; counties of Blanco, Hays, and Travis; and BSEACD, 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 were either beyond the legal authority of the District or were redundant with alternative measures that are evaluated in this EIS.

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 BSP as part of the conditions for obtaining a section 10(a)(1)(B) ITP for the BSS (COA 1998) and obtained a recent amendment to the current ITP, which added the ABS (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 EIS because many of the factors creating the incidental take (from the City’s operation of BSP) 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 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 EIS) 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 EIS 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 COVERED SPECIES

There are two Covered Species that will be addressed under each of the four alternatives. The BSS and the ABS have been proposed for incidental take coverage under section 10(a)(1)(B) of the ESA. The BSS was federally listed as endangered on April 30, 1997 (62 FR 23377), and the ABS was listed as endangered with designated critical habitat on August 20, 2013 (78 FR 51277). A description of the species can be found in the *Barton Springs Salamander Recovery Plan amended to include the Austin Blind Salamander* (USFWS 2005, amended 2016).

2.3 DESCRIPTION OF ALTERNATIVES EVALUATED

2.3.1 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 without an HCP there is no cap during non-drought conditions. The District would notify permittees of approaching drought and issue notices requesting permittees significantly curtail or stop pumping once drought is declared. Under the No Action Alternative, each permittee would be expected to vouluntarily comply with pumping cessation, but the District would not be able to enforce those restrictions. However, if all permittees complied, pumping would be less than 1 cfs (assumes nearly complete cessation of pumping) with resulting projected lowest average monthly springflow at Barton Springs of 11 cfs, which was reached during the 1950's DOR that the Covered Species are known to have survived. Protection of listed species would depend on voluntary compliance by the District's permittees. If Aquifer pumping reductions were not realized during any drought conditions that resulted in take of the two species there would be no 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.

The lack of a District HCP could result in many pumping entities applying for separate ITPs, each with its own permit area, pumping paramaters, and mitigation. Nothing in this alternative requires or presupposes that permitted pumpers seeking ITPs would coordinate their activities. Therefore, there would be an increased burden on the Service to manage multiple permits, closely monitor reduced springflows and effects of reduced springflows on the species, and to enforce provisions of multiple ITPs should take be exceeded. While this could be considered an Environmentally Preferred Alternative, due to the potential for springflows to remain at or above DOR conditions, there is no assurance that a significant enough number of pumpers would either cease pumping or get their own ITP to reduce take of the Covered Species. Additionally, this alternative would result in the most severe pumping reductions and, consequently, would provide the greatest uncertainty in the establishment of future water management policy. This alternative would either greatly reduce water available to support existing economic activities and could preclude further economic growth, or it would require greater reliance on higher cost water supplies that would be reflected in higher development costs that could affect many economic sectors (see **Section 4.4.4 Economic Impacts**).

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

Alternative 2 would involve approval of the District's HCP addressing authorized pumping of the Aquifer and the issuance of an ITP by the Service. Alternative 2 minimization measures would meet state-mandated DFCs by establishing a cap of 16 cfs on all pumping, and limit Aquifer pumping during DOR-like conditions to no more than 5.2 cfs, thereby maintaining a minimum average monthly springflow at Barton Springs of 6.5 cfs. The District's HCP incorporates actions to minimize and mitigate unavoidable incidental take and includes demand reduction measures, recharge enhancment, supporting a salamander refugium, programs encouraging the development and use of new water supplies, cooperative efforts with other entities, and mechanisms to adapt management strategies and respond to emergencies. Although the combination of pumping and low Aquifer recharge could result in monthly springflows as low as 6.5 cfs, the expected frequency of occurrence is less than 1 percent. Among the four alternatives evaluated in this EIS, Alternative 2 provides the most technically feasible and economically achievable measures available for Aquifer management and conservation of the Covered Species (**Table ES-1**) and is, therefore, the Preferred Alternative.

2.3.3 Alternative 3: Water Demand Reduction

Under Alternative 3, the District's permitting program would control Aquifer pumping, including during drought conditions. The District would require (and enforce) 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 during the DOR. These regulatory curtailments, backed with effective enforcement to ensure compliance, would protect springflow for the Covered Species. However, this alternative would employ the most severe regulatory measures to achieve the level of pumping reductions needed and may require one or more sources of replacement water for some indeterminate fraction of the amount curtailed to meet the needs of the public.

Recent rulings by the Texas Supreme Court upheld the rights of GCDs (like the District) 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 limit on how much curtailment is "reasonable" and "fair" before property rights are infringed, which would require compensation for the loss of the amount of water prohibited from pumping. This alternative would result in low biological impacts but with potentially high economic impacts, due to the potential need to compensate a significant number of permittees. Additionally, it 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. 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.

2.3.4 Alternative 4: Water Supply Augmentation and Substitution

Alternative 4 would involve the development of other alternative water supplies that would augment and replace the amount of water pumped from the Aquifer to achieve the goal of substantially reducing Aquifer pumping to a level below 1 cfs to provide for a minimum average monthly springflow of 11 cfs during DOR conditions, similar to Alternatives 1 and 3. 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 shorter-term ITP and associated HCP would be pursued. 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 DOR conditions. The District currently does not have the regulatory authority to develop alternative water supplies. Therefore, use of augmented or substituted water supplies would have to be implemented voluntarily by other entities, or the Texas Legislature would have to give the District the authority (and likely funding) to develop these alternative sources. There are also current limitations on the amount of alternative water supplies that could economically be made available to groundwater users within the region.

Table 2-1. Comparison of EIS Alternative Measures

Alternative Measures	**Alternative**			
	No Action	**HCP**	**Water Demand Reduction**	**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
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 by new 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

Table 2-1, cont'd

Alternative Measures	Alternative			
	No Action	HCP	Water Demand Reduction	Water Augmentation/ Substitution
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]
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		

Table 2-1, cont'd

Alternative Measures	Alternative			
	No Action	HCP	Water Demand Reduction	Water Augmentation/ Substitution
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 COA 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
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 DOR.		X		

Table 2-1, cont'd

Alternative Measures	**Alternative**			
	No Action	**HCP**	**Water Demand Reduction**	**Water Augmentation/ Substitution**
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)				
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 through the 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		

Table 2-1, cont'd

Alternative Measures	Alternative			
	No Action	HCP	Water Demand Reduction	Water Augmentation/ Substitution
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		
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.

Table 2-1, cont’d

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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 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 environment. 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 tens of 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, Kirschberg evaporites (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 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).

Kainer Formation – 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.

Person Formation – This 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 – This 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 – This 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 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. 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 geographical distribution of major geological features throughout the Study Area is illustrated on **Figure 3-2**.

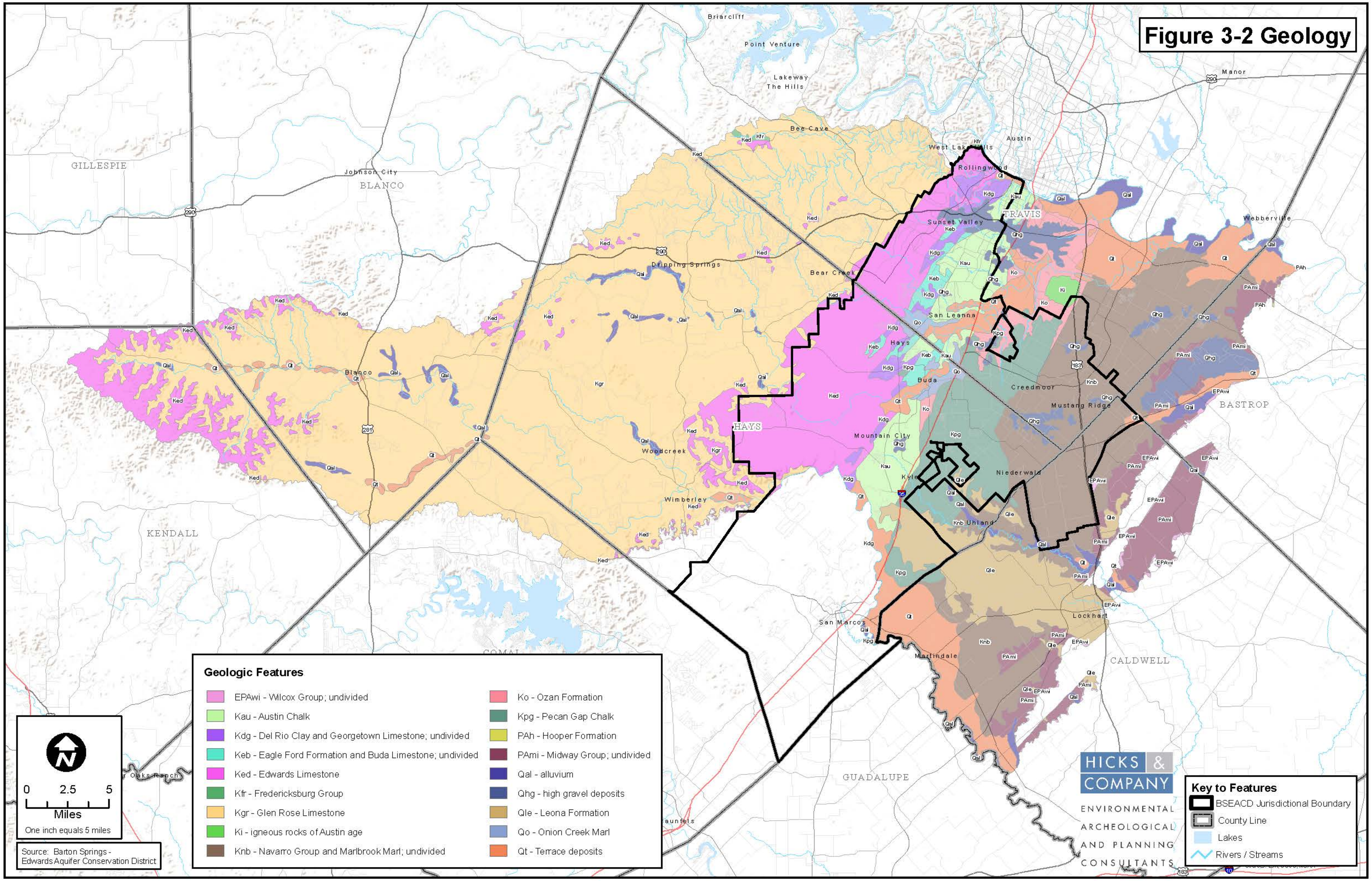

Figure 3-2 Geology

Source: Barton Springs - Edwards Aquifer Conservation District

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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 west of Uvalde County through the San Antonio area northeast to Bell County (see **Figure 3-3**). 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 3-3**).

Barton Springs Segment of the Edwards Aquifer

The Barton Springs Segment of the Edwards Aquifer (**Figure 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 2018). In 2011, a drought year, the Barton Springs segment supported 6,206 acre-ft/yr (2.02 billion gallons) of actual pumping (BSEACD 2013); in 2015, which was a wet year, the segment supported 4,608 acre-ft/yr (1.50 billion gallons) of actual pumping (BSEACD 2018). Groundwater use was characterized as 82 percent public-supply, 10 percent industrial, and 8 percent irrigation (domestic, commercial, and non-agricultural irrigation).

The geologic formations of interest in the 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, 3-4 and 3-5.** 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

Figure 3-3. Edwards Aquifer

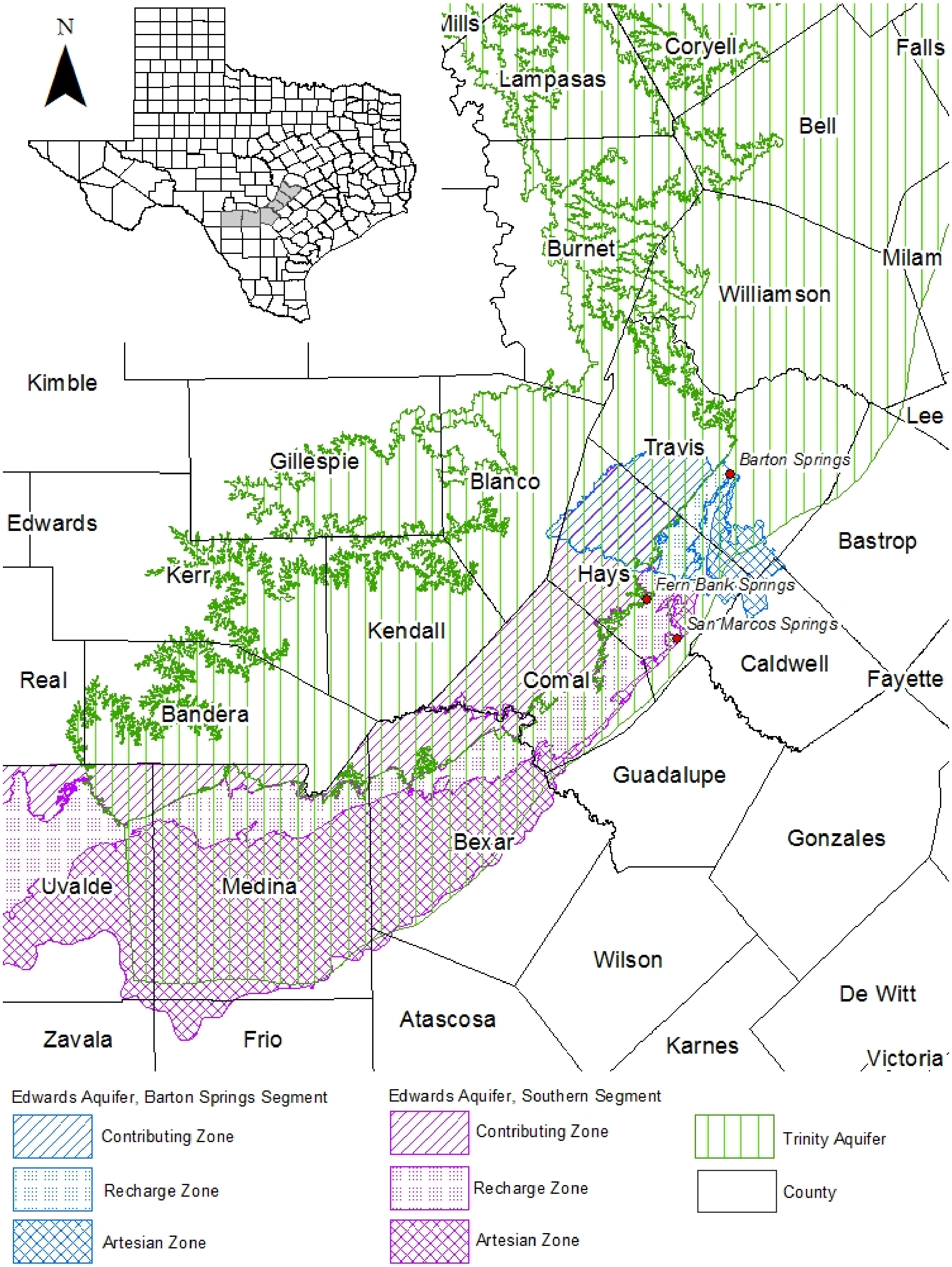
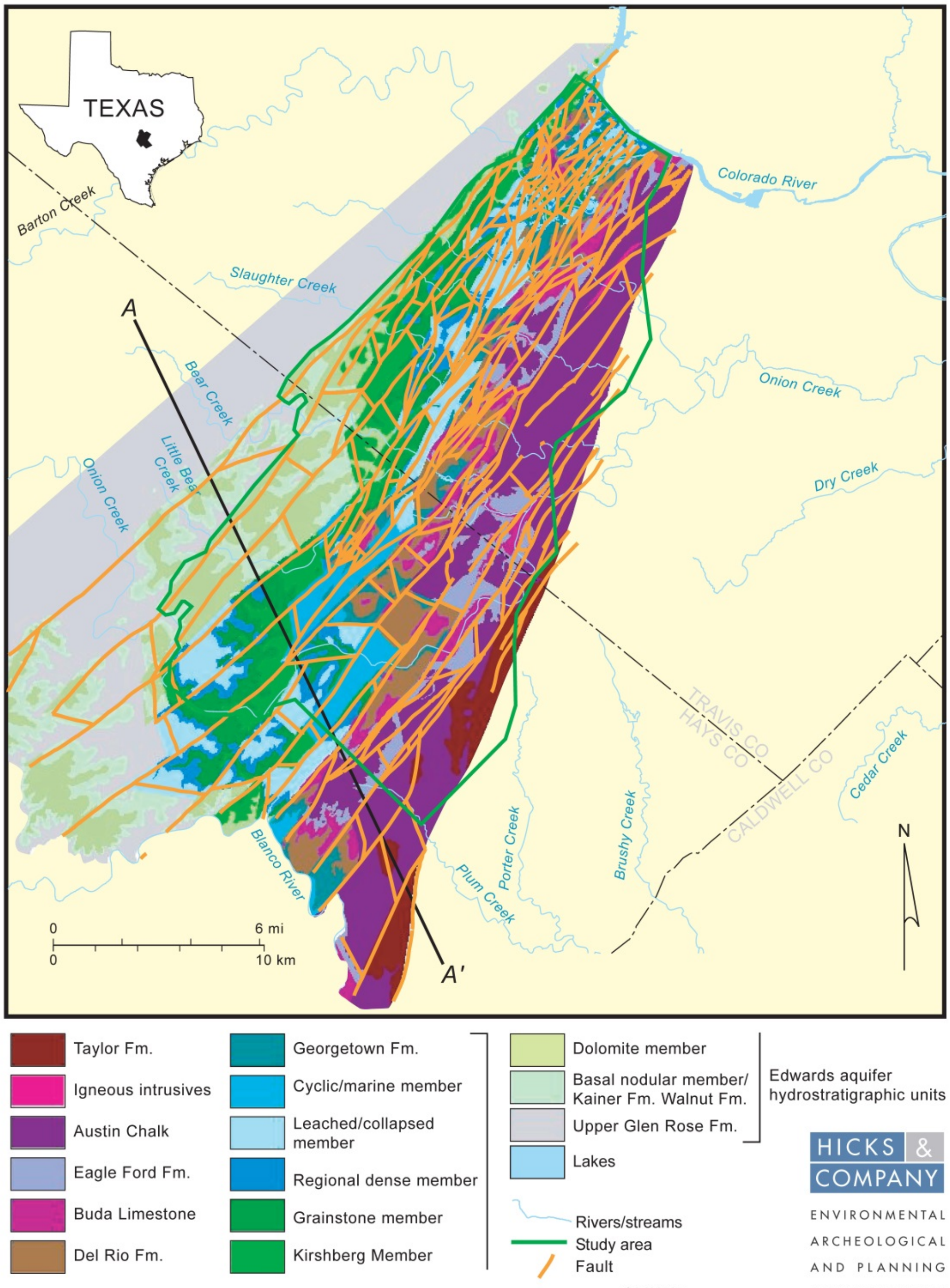


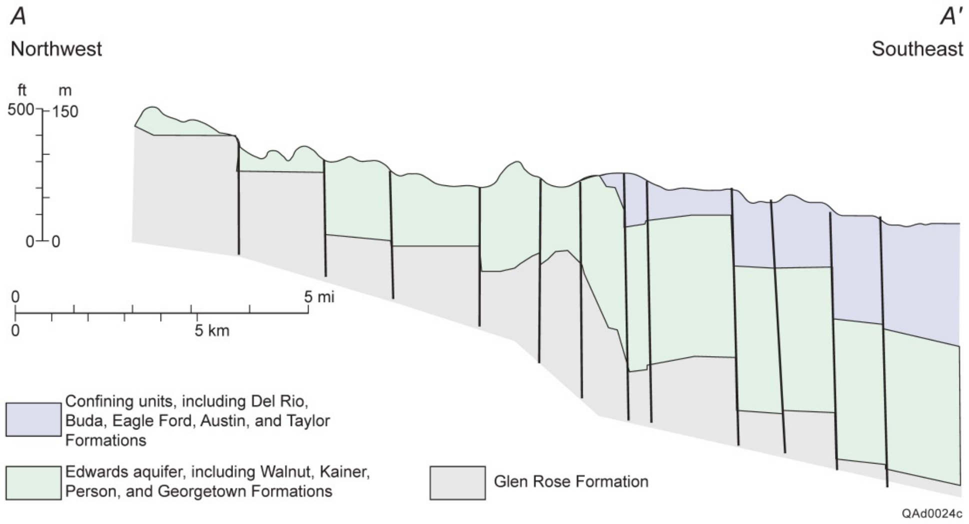
Figure 3-4. Surface Geology in the Barton Springs Segment, Edwards Aquifer



Source: Scanlon et al. (2001)

Figure 3-4 Surface Geology in the Barton Springs Segment, Edwards Aquifer

Figure 3-5. Geologic Cross-section of the Barton Springs Segment, Edwards Aquifer. Location of the Cross-section is shown in Figure 3-4.



Source: Scanlon et al. (2001)

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Figure 3-5 Geologic Cross-section of the Barton Springs Segment, Edwards Aquifer. Location of the Cross-section is shown in Figure 3-4 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 (**Figure 3-3**). 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.

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 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 2018) (see Figure 3-1 in the HCP). 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 2018) 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 percent) comes from soil infiltration or direct flow into discrete recharge features, such as caves, sinkholes, fractures, and solution cavities within stream channels (Slade 2014, BSEACD and COA 2001). 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) (see Figure 3-2 in the HCP). 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 Figure 3-2**) is located between two relatively impermeable formations, the Glen Rose formation below, and the Del Rio clay above (**See Figure 3-5**). 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).

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) 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 (see Figure 3-2 in the HCP). 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 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 Aquifer is extremely dynamic, with rapid fluctuations in springflow, water levels, and storage, reflecting changes in recharge (climatic conditions) and pumpage (demand). 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.

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). 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.

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.

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 2018). 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, but those wells produce about 95 percent of the total groundwater pumped from the Aquifer. 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 ARR and SA 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 ARR 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 (USEPA) 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

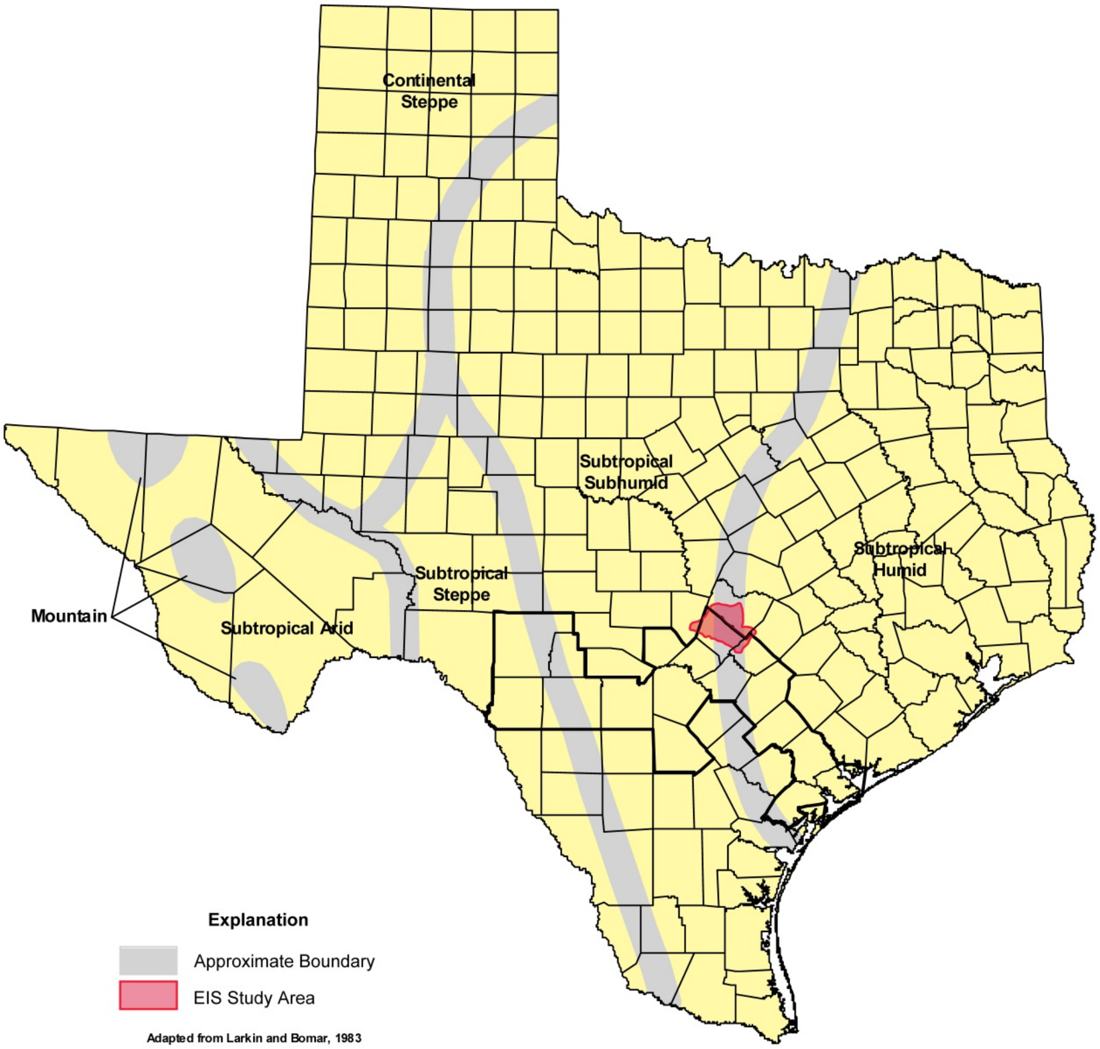
The prevailing climate of the Study Area is within a transitional zone between a subtropical sub-humid region to the west and a subtropical humid region to the east (Larkin and Bomar 1983) (**Figure 3-6**). The subtropical sub-humid climate type is characterized, in general, by long, hot summers and 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).

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 (Gordon 2014). 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.

Figure 3-6. Climate Regions of Texas



Adapted from Larkin and Bomar, 1983

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Figure 3-6
Climatic Regions of Texas

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 last Texas drought is thought to have begun in fall 2010 and persisted through the summer of 2015. While there has been more rainfall since 2015, almost 75 percent of Texas is still experiencing abnormally dry to exceptional drought conditions (Fenimore 2018).

The last 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 define “drought of record” as the period of time when natural hydrological conditions provided the least amount of water supply (31 Texas (Administrative Code [TAC] §357.10). 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). Additional discussion on climate projections follows in the next **subsection 3.1.4.3**.

3.1.4.3 Climate Change

In a August 1, 2016, memorandum, the CEQ provided final 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. Compounding effects of climate change to impacts of the proposed alternatives on the affected environment of the EIS 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 EIS 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).

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 EIS. 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 NCA 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). Between 1991 and 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 (Gordon 2014). 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 (Gordon 2014). 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 (Gordon 2014).

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, Gordon 2014). 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, Gordon 2014). 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.

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).

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). However, if Central Texas stays within the humid subtropices the increasing precipation may reduce this effect. 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

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 climate change scenarios 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 **subsection 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 HCP (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 BSS and ABS. 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 **subsection 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 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 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 3-4**). 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 Aquifer is described in **subsection 3.1.1.6**.

3.2.1.2 Aquifer-fed Springs

The 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 (see Figures 3-4 and 5-2 in the HCP).

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 (circa 1917). 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). See Section 3.2.2.1.2 of the HCP for a description of historical flows.

The Barton Springs complex comprises four springs, including the main spring in BSP (Parthenia Spring), Eliza Spring, Old Mill Spring (also called Sunken Garden or Zenobia Spring), and Upper Barton Spring (see Figure 3-4 in HCP). Two dams built in the 1920s maintain the current confines of BSP (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.

Previously, the surface outflow stream from Eliza Spring was contained within a buried pipe, which has until now carried water from Eliza in the subsurface directly into the BSP bypass culvert. However, the COA is restoring the spring run at Eliza to more natural conditions (the Eliza Spring Daylighting Project).

During non-drought, Barton Springs provides good to excellent water quality conditions for its biological assemblage. However, during drought these conditions can degrade and have negative affects upon the Covered Species. See Section 3.2.2.2.1 of the HCP for descriptions of the water quality, chemistry, and temperature paramaters of the BSP during drought and non-drought stages.

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 (TSWQS).

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 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	

Segment Name	Segment Number	Evaluated Water Uses	Impairment Category[1]
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	1808-01through 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
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. Source: (TCEQ 2015b).
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.

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 have 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 Aquifer and provides greater variability in yield and water chemistry (BSEACD 2018). 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 (mg/L) (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 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 (Hicks & Company 2014a). 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 BSP 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 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.

Nutrients

Nutrients, primarily nitrogen, phosphorus, 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 orthophosphorous or phosphorous compounds have been detected by long-term (non-storm) monitoring by the COA (Herrington and Hiers 2010).

Dissolved Oxygen

Dissolved oxygen 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. Dissolved oxygen 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 equivocal 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).

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).

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 milileters [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 BSS 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 the 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 (Hicks & Company 2014b).

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 BSP (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 BSP 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 BSP, but is not currently common (DeeAnn Chamberlain, COA, pers. comm.). Seven families of aquatic beetles have been collected in BSP.

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 BSP 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 B**, **Table B-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 B**, **Table B-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 B, Table B-3**. Threatened and Endangered Species and Other Species of Greatest Conservation Need.

3.3.6.1 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 ESA, 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

TPWD oversees rare 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 (2016) 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**.

3.3.6.2 Covered Species

The two endangered species to be covered by the ITP are the BSS and ABS. 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 U. S. The BSS 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 BSS. The ABS 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 5-2 in the HCP). Details about the species' biology and life history can be found in the HCP and *Barton Springs Salamander Recovery Plan* amended to include the Austin Blind Salamander (USFWS 2005, amended 2016).

3.3.6.3 Other Species of Greatest Conservation Need

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 3-3. 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.

Table 3-3, cont’d

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
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.
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.
ABS *Eurycea waterlooensis* FE	X							Mostly restricted to subterranean cavities of the Edwards Aquifer; dependent upon water flow/quality from the Aquifer; only known from the outlets of Barton springs (Sunken Gardens (old Mill) Spring, Eliza Spring, and Parthenia (Main) Spring which forms BSP).
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.

Table 3-3, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
BSS *Eurycea sosorum* FE, SE	X	X						Dependent upon water flow/quality from the 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.
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.

Table 3-3, cont'd

	Travis	Hays	Blanco	Kendall	Comal	Caldwell	Bastrop	Habitat Description
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.
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).

Table 3-4. Species of Greatest Conservation Need Potentially Occurring in Counties Represented in the Study Are

	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.

Table 3-4, cont'd

	Travis	**Hays**	**Blanco**	**Kendall**	**Comal**	**Caldwell**	**Bastrop**	**Habitat Description**
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.
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.

Table 3-4, cont'd

	Travis	Hays	Blanc o	Kendall	Comal	Caldwell	Bastrop	Habitat Description
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.
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.

Table 3-4, cont’d

	Travis	**Hays**	**Blanco**	**Kendall**	**Comal**	**Caldwell**	**Bastrop**	**Habitat Description**
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.
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.

Table 3-4, cont’d

	Travis	**Hays**	**Blanco**	**Kendall**	**Comal**	**Caldwell**	**Bastrop**	**Habitat Description**
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								
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 *Halipluus 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.

Table 3-4, cont’d

	Travis	**Hays**	**Blanco**	**Kendall**	**Comal**	**Caldwell**	**Bastrop**	**Habitat Description**
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.
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.

Table 3-4, cont'd

	Travis	**Hays**	**Blanc o**	**Kendall**	**Comal**	**Caldwell**	**Bastrop**	**Habitat Description**
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.
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 EIS focus on five of the seven counties represented in the EIS Study Area that comprise the Austin-Round Rock (ARR) Metropolitan Statistical Area (MSA) as defined by the U.S. Office of Management and Budget: 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.

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, Caldwell County has a minority (non-White) population of over 50 percent, while nearly half of the total population in Travis County (49.5 percent) is minority (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									
Texas Counties	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	38,066	16,841	2,456	90	344	8	54	351	17,922	21,225	55.8
Bastrop	74,171	42,446	5,535	315	449	54	115	1,067	24,190	31,725	42.8
Blanco	10,497	8,336	62	47	49	4	5	85	1,909	2,161	20.6
Hays	157,107	92,062	4,970	502	1,699	104	226	2,143	55,401	65,045	41.4
Travis	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 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)	Tax Receipts 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 BSP, located in Zilker Park, is fed by water naturally discharging from the 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, BSP 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

	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 EIS 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	% 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 from the 2006 and 2011 dataset was analyzed for the Study Area (MRLC 2014). 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. Land cover within the Study Area based on the 2011 dataset is geographically portrayed on **Figure 3-7** 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 3-6**, 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.

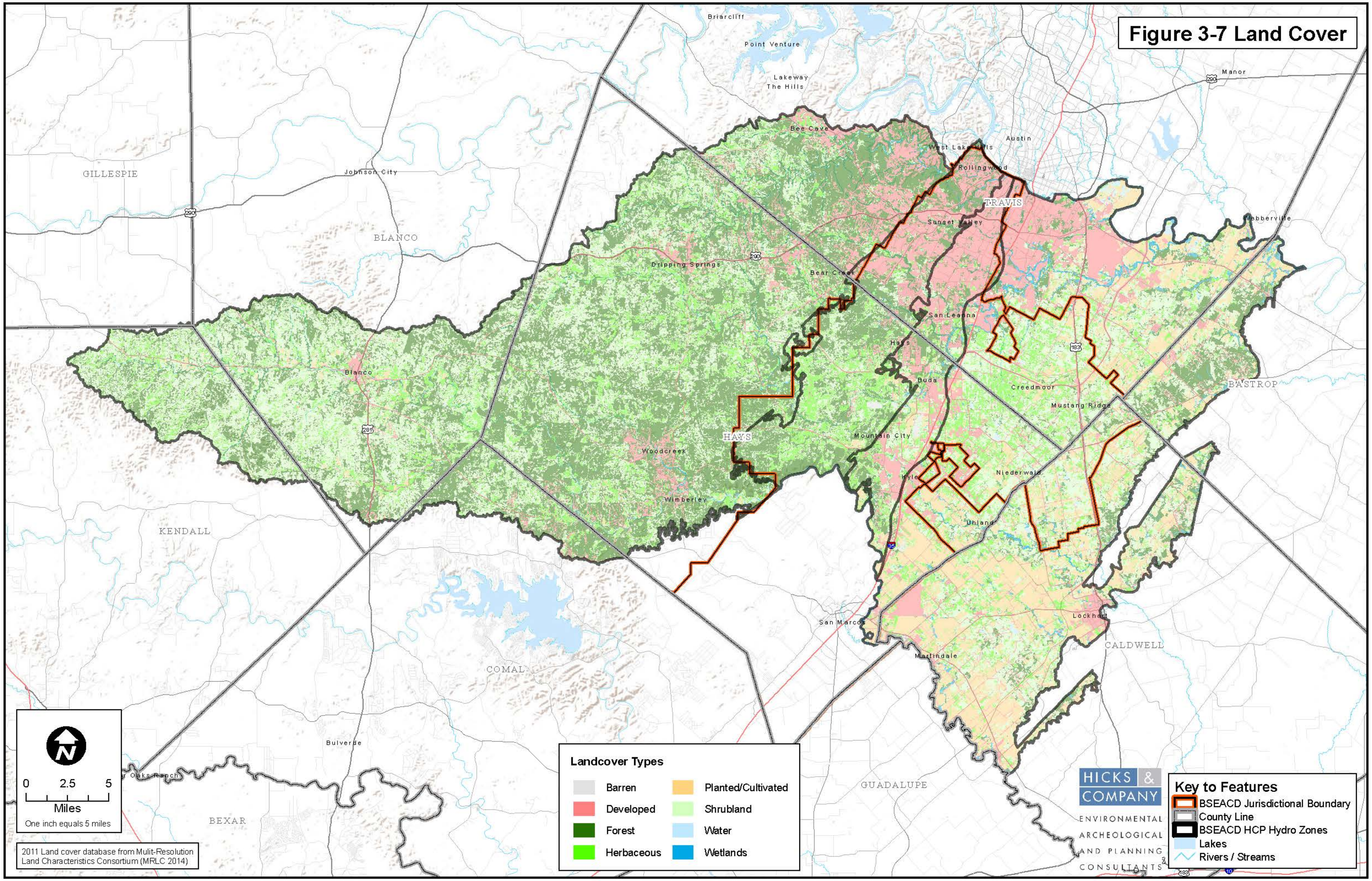

Figure 3-7 Land Cover

2011 Land cover database from Mulit-Resolution Land Characteristics Consortium (MRLC 2014)

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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.

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.

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

	Acres in Farms						**Average Size of Farm (acres)**		
	2002		**2007**		**2012**		**2002**	**2007**	**2012**
	Acres	**% of County**	**Acres**	**% of County**	**Acres**	**% of County**			
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, COA 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 Springsand 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: Collins 1996, Takac et al. 1992, and 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 continues 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 (8800–2550 BP), 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.

Hicks & Company (2014c) provides 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.

4.0 ENVIRONMENTAL CONSEQUENCES

The following sections provide a description of the current environmental condition of the resources being potentially impacted by the Proposed Action followed by an analysis of the impacts that the Proposed Alternatives could have on these resources. Each resource is analyzed for several types of impacts: direct, indirect, beneficial, and adverse. These terms have been defined in the CEQ's NEPA regulation 40 CFR 1508, as shown below:

- **Direct effect:** An impact that occurs as a result of the proposed action or alternatives in the same place and at the same time as the action.
- **Indirect effect:** An impact that is caused by the proposed action or alternative and is later in time or farther removed in distance than the action, but is still reasonably foreseeable. Indirect impacts may include growth inducing impacts and other impacts related to induced changes in the pattern of land use, population density or growth rate, and related impacts on air and water and other natural systems, including ecosystems.
- **Beneficial impacts:** A positive change in the condition or appearance of the resource or change that moves the resource toward a desired condition.
- **Adverse effect:** A change that moves the resource away from a desired condition or detracts from its appearance or condition.

Per 40 CFR 1508.27, the significance of an impact must be considered in terms of both its context as well as the intensity of the impact. These terms are defined as:

- **Context:** the significance of an action must be analyzed in several contexts such as society as a whole (human, national), the affected regions, the affected interests, and the locality. Significance varies with the setting of the proposed action. For instance, in the case of a sitespecific action, significance will usually depend upon the impacts in the locale rather than in the world as a whole. Both short-term and long-term impacts are relevant.
- **Intensity:** refers to the severity of the impact.

In this EIS the context of an impact is described in the narrative for each resource and is based on the above requirements. The intensity of an impact is ranked as negligible, minor, moderate or major.

4.1 PHYSICAL ENVIRONMENT

This section describes direct impacts of each of the four EIS 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 minor 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 EIS alternatives would be negligible.

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 EIS 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, affects from all of the EIS alternatives are expected to be negligible with regard to the rate of erosion or affects to 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 and groundwater resources occurring within the Study Area are described in this section for each of the four EIS alternatives.

4.2.1 Surface Water

Because none of the alternatives would 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 largely result from spring discharge. Therefore, this section only addresses lower Barton Creek, which is below the dam of BSP and extends to the confluence of the Colorado River (Lady Bird Lake).

4.2.1.1 Alternative 1: No Action

If pumping was reduced by pumpers during drought conditions, spring flows, and thus surface water flows in lower Barton Creek, would be expected to maintain at least a minimum flow, during such drought conditions resulting in minor effects. However, if voluntary cessation was not done, lower flows could result in moderate effects on available surface water.

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 could result in lower flows than under Alternative 1, assuming full cessation occurred. However, District minimization and mitigation commitments are expected to reduce this possibility. For example, use of the recharge enhancement structure built at Antioch Cave (**Measure 3 in Table 2-1**) would divert water from Onion Creek into Antioch Cave, which would increase Aquifer levels and thus flows at Barton Springs. However, this could result in reduced flows immediately downstream in Onion Creek, depending on the efficiency of the recharge enhancement features. During periods of moderate-to-high runoff, effects of recharge enhancement on downstream flows would be minor due to the higher volume of flows. However, during drier conditions, recharge enhancement features could further reduce downstream flows that could have a moderate adverse affect on 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, assuming all pumpers voluntarily reduced pumping, and would be higher than Alternative 2. If, however, under Alternative 1 pumping was not ceased, Alternative 3 would have higher flows than Alternative 1.

4.2.1.4 Alternative 4: Water Supply Augmentation and Substitution

Effects of Alternative 4 on 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 BSP 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. 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.

4.2.2.1 Alternative 1: No Action

Lower Barton Creek

In years of average to above-average rainfall Alternative 1's effects 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 upper 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 minor 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 minor variation in temperature and DO between BSP 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 and also below-average rainfall, effects of 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, with some minor variation in temperature and DO between BSP 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 similar to Alternative 1.

4.2.2.3 Alternative 3: Water Demand Reduction

Lower Barton Creek

In years of average to above-average and also below-average rainfall, effects of Alternative 3 on surface water quality in lower Barton Creek would be similar to effects under Alternatives 1 and 2 as springflow would not be substantially different in comparison to Alternative 1, with some minor variation in temperature and DO between BSP and the confluence with Lady Bird Lake (Colorado River).

Other Creeks

Effects of measures under Alternative 3 on water quality in other creeks within the Study Area are expected to be similar to Alternatives 1 and 2.

4.2.2.4 Alternative 4: Water Supply Augmentation and Substitution

Lower Barton Creek

In years of average to above-average and also below-average rainfall, effects of Alternative 4 on surface water quality in lower Barton Creek would be similar to effects under Alternatives 1, 2, and 3, until alternative water strategies are developed to substitute for the Aquifer withdrawals. Once the alternative water strategies start to substitute for those withdrawals, Alternative 4 should have higher water quality, due to an expectation of higher average flows.

Other Creeks

Effects of measures under Alternative 3 on water quality in other creeks within the Study Area are expected to be 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. As part of flow analysis for the HCP, a "synthetic" hydrograph of springflow at Barton Springs was created (see Figure 3-5 in the HCP). It represents springflow that would have existed naturally, without any pumping from the Aquifer, for the period of historical record (1917–2013, POR). This synthetic hydrograph was constructed using measured (for later parts of the period) and inferred (for certain earlier parts of the period) monthly springflow (plus pumpage) data. This EIS analyzes the frequency of occurrence (percent of time) that springflow would fall below specified levels under the four alternatives and summarizes them in **Table 4-1**.

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 minor effects would be expected with springflow predicted to be at or below 30 cfs. Springflow levels at or below 20 cfs would occur about 10 percent of the time and would have moderate effects. 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.

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 and have moderate effects. 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 total springflow during conditions similar to the DOR is not projected under Alternative 2 due to mandated limitations imposed by the District on aquifer withdrawals of not more than 5.2 cfs during extreme drought. However, according to the COA (2017) all springs except the main spring would likely be moderately affected. Upper Barton Spring and Old Mill Spring would stop flowing more frequently under Alternative 2, with a higher risk of reduced or no flow to Eliza Spring. Although Eliza Spring flows at a combined spring dischargeof 14 cfs, it may not continue to flow at 6.5 cfs (COA 2017). The lowest discharge measured for Eliza Spring was 1.4 cfs on May 9, 2013, which represented 6.4 percent of the combined spring discharge of 22 cfs measured by the USGS.

4.2.3.3 Alternative 3: Water Demand Reduction

Alternative 3 employs the strictest pumping restrictions eliminating all permittee pumping through mandated reductions, unlike Alternative 1, which relies on voluntary reductions. 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 result in similar flows as 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.

Table 4-1. Barton Springs Discharge Thresholds and Predicted Levels of Impact Under Alternatives 1–4

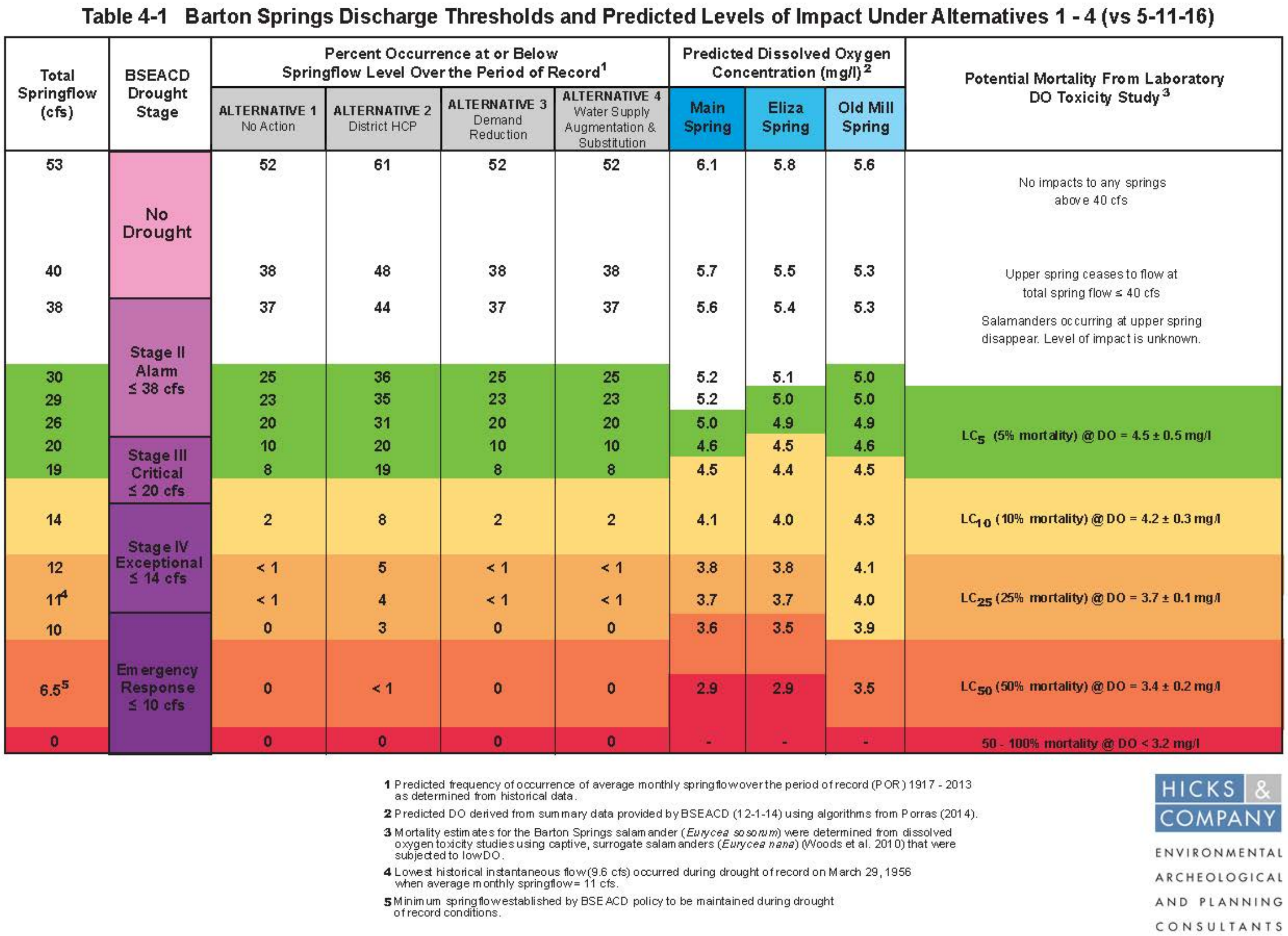

Table 4-1 Barton Springs Discharge Thresholds and Predicted Levels of Impact Under Alternatives 1 - 4 (vs 5-11-16)

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		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		25	36	25	25	5.2	5.1	5.0	
29		23	35	23	23	5.2	5.0	5.0	LC_5 (5% mortality) @ DO = 4.5 ± 0.5 mg/l
26		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		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		< 1	5	< 1	< 1	3.8	3.8	4.1	LC_{25} (25% mortality) @ DO = 3.7 ± 0.1 mg/l
11[4]		< 1	4	< 1	< 1	3.7	3.7	4.0	
10	Emergency Response ≤ 10 cfs	0	3	0	0	3.6	3.5	3.9	
6.5[5]		0	< 1	0	0	2.9	2.9	3.5	LC_{50} (50% mortality) @ DO = 3.4 ± 0.2 mg/l
0		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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4.2.4 Groundwater Quality

Impacts of the four EIS alternatives on important groundwater quality parameters are discussed in this section. While the quality of water discharged from the 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 EIS alternatives, by reducing aquifer withdrawals (albeit 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 EIS alternatives would potentially beneficially 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 minor deleterious impacts of various types, including water quality.

Alternative 2 contains the most beneficial 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 EIS alternatives have the potential to beneficially 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 EIS alternatives on regionally occurring fauna and flora within the Study Area. 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 minor gradual, as well as episodic, changes to the aquatic communities, including the abundance and distribution of species.

Lower Barton Creek

In years of average to above-average rainfall, effects of Alternative 1 on fish and aquatic invertebrate communities in the stream channel and to the adjacent 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 BSP. 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 have minor adverse affects on the spatial coverage of aquatic habitat. The existing streamside riparian community would not likely change; however, the extent and duration of droughts could result in a reduced water table along the banks of the streambed which could induce minor stress to established trees and shrubs within the riparian corridor (Stromberg et al. 2010).

Other Creeks

Alternative 1 would have negligible 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 Alternative 2 on fish and aquatic invertebrate communities and to the associated riparian corridor would be similar to Alternative 1. In years of below-average rainfall or during drought conditions, potential minor adverse effects under Alternative 2 would be slightly greater, because 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 moderately 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 3**, **Table 2-1**) could moderately 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 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 negligible, 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 would be 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 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 would be 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, ensuring flows equivalent to those existing during the DOR, similar to Alternatives 1 and 3.

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 would be similar to Alternatives 1 and 3.

4.3.2 Terrestrial Resources

Reductions in pumping and subsequent changes in springflow under each of the four EIS alternatives would have negligible 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 minor affects of 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, negligible 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 through 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, minor 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 have minor indirect influences on habitat conditions (hotter and drier) for these karst species. However, the extent to which Aquifer levels influence 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 minor 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 between the dam at BSP 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 BSP during the COA'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 BSS and ABS.

4.3.4.1 Alternative 1: No Action

Alternative 1 would be expected to negligibly affect the BSS and ABS 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 4-1**) 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 moderately 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 2005, amended 2016). 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 Aquifer decreases. However, under Alternative 1 during POR conditions, discharge at Barton Springs would never fall below 10 cfs (**Table 4-1**).

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 BSS, goes dry when the combined discharge from the Barton Springs complex falls below approximately 40 cfs. At that point, BSS 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, BSS 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, BSS experienced steep reductions in abundance and curtailment of reproduction and recruitment; the ABS largely disappeared from surface habitat (COA 2013a). Increases in water temperature have also been associated with detrimental effects on other Edwards Aquifer perennibranchiate (an organism that retains or gills through life) *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 COA. 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 percent 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 2018). Woods et al. (2010) also calculated the LC_5 (concentration at which 5 percent mortality occurs) for the San Marcos salamander at a DO concentration of 4.5 ±0.5 mg/L (see **Table 4-1**). 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 2018) (see **Table 4-1**). Under Alternative 1, assuming total voluntary compliance, 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 4-1**), assuming total voluntary compliance. 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, which would never be reached (see **Table 4-1**), assuming total voluntary compliance. However, if voluntary compliance was not completely achieved, this alternative would result in higher chances of exceeding each of these percentages depending on what percent of permittees did not comply.

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

Similar to Alternative 1, DO levels will fall to 5.0 mg/L at Old Mill Spring (within the upper range of LC_5) when springflow is 30 cfs. However, 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 about 20 percent of the time at Eliza Spring. The upper limit of the LC_{25}, 3.8 mg/L, is predicted to occur at Main Spring and Eliza Spring 5 percent of the time. The upper limit of the LC_{50}, 3.6 mg/L, is predicted to occur at Main Spring about 3 percent of the time (**see Table 4-1**). Under a repeat of the DOR conditions, 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, and the springs would never cease flowing, but with some impacts to the Covered Species likely occurring. Upper Barton Spring and Old Mill Spring would cease flowing more often under Alternative 2, with a higher risk of reduced or no flow at Eliza Spring where most of the Barton Springs salamanders occur. Springflow ceases at Upper Barton Spring when total springflow falls below 40cfs (**Table 4-1**); Old Mill Spring ceases flow at an approximate total springflow of 20 cfs (COA 2017), with little or no flow at Eliza Spring at a total flow of 6.5 cfs (COA 2017). The extent of the potentially moderate to major adverse impacts to the salamanders at these springs is difficult to assess as they reappear at the springs when flows resume. The proportion of springflow at Eliza Spring relative to combined springflow may decrease during drought of record conditions, and even if some springflow at Eliza Spring is maintained at a combined springflow of 6.5 cfs, the flow could be too low to sustain salamander populations regardless of oxygen supplementation (COA 2017). The COA has indicated that the population abundance of salamanders observed at the various spring discharge locations has yet to return to the levels observed prior to the droughts of 2009 and 2011 (COA 2017).

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 DFCs. In addition, there are several indirect measures that would be implemented under Alternative 2 that would involve other parties. Examples include: research, 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 (see Section 6.2.2 of the HCP for details). 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, beneficial 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 percent of the time) during conditions similar to the POR. Additionally, the commitment for pumping restrictions, during drought conditions under Alternative 2 that can be regulated and enforced, would be accompanied by other Aquifer protection measures that would minimize impacts to the Covered Species (**Table 2-1)**.

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 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. 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 BSS 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 4-1**). 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, but only after substitute water supplies were acquired.

4.4 SOCIOECONOMIC RESOURCES

Environmental consequences to the community resources (described in **Section 3.4)** in the Study Area are presented in this section for each of the four EIS alternatives, including direct impacts related to population trends, minority populations, low-income populations, and community resources.

Several documents were used to evaluate the socioeconomic impacts of each of the alternatives. These studies are summarized below.

District Habitat Conservation Plan (2018)

The District HCP (Alternative 2) presents several regulatory and managerial conservation measures to be implemented by the District in support of an application for an ITP for the BSS and ABS. Included 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 4-2**.

Alternative Water Supplies for the Barton Springs Segment of the Edwards Aquifer and for the Region (Smith et al. 2012)

This report outlines sources of water which could be used as alternatives to historically permitted withdrawals from the 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 (ASR)
- 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 (see **Table 2-1, Measures 3.1, 3.2, and 3.3**).

2011 Region K Water Plan (LCRWPG 2010)

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. This plan contains 4 water management strategies that appear to be most feasible under Alternative 4: ASR, Edwards-BFZ Aquifer brackish groundwater desalination, groundwater importation, and a water reclamation initiative: Direct Reuse.

EIS (2018) Alternative Measures Applicable to Socioeconomic Resources

Aquifer management measures included in one or more of the EIS alternatives (summarized in **Table 2-1**) that would potentially impact socioeconomic resources are listed in **Table 4-2** 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 4-2. EIS Alternative Measures Potentially Impacting Socioeconomic Resources

Conservation Measure (see Table 2-1 for full description)	Applicable Alternative	Expected Effects of Measure on Socioeconomic Resources*
1.4 Programs to inform and educate citizens.	Alternative 2	No adverse effects because water use would not be directly affected.
2.2 Ensure permitted wells are properly operated and maintained.	Alternatives 1, 2, and 3	Negligible to minor adverse effects as these measures would increase the efficiency of monitoring aquifer withdrawals.
3.2 Encourage water diversification.	Alternatives 2 and 4	Potentially minor to major adverse impacts depending on the cost of development of alternative water supplies passed through to consumers.
5.2 Implement curtailment of water use during extreme drought.	Alternatives 2 and 4	Potentially moderate to major adverse impacts depending on the demand for water during drought conditions.
7.1Improve recharge through physically altering features.	Alternative 2	Potentially minor to moderate beneficial impacts by increasing water recharged to the aquifer.
7.2 Pursue desalinization, ASR, effluent reclamation, etc. for alternate water supplies.	Alternatives 2 and 4	Potentially moderate to major adverse impacts depending on costs of engineered enhancements to regional water supply strategies that would be passed through to water consumers.
8.2 Restrict pumping to minimize take and avoid jeopardy.	Alternative 2	Potentially moderate to major adverse impacts due to mandated water reductions during drought periods.
** Voluntary pumping reductions during drought.	Alternative 1	Potentially major adverse impacts due to severely curtailed water use during periods of highest water demand.

Conservation Measure (see Table 2-1 for full description)	Applicable Alternative	Expected Effects of Measure on Socioeconomic Resources*
** Mandatory pumping reductions during extreme drought.	Alternative 3	Potentially major adverse impacts due to severely curtailed water use during periods of highest water demand.
** Water supply strategies to augment or substitute withdrawals during DOR.	Alternative 4	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.

The magnitude of the impacts of the measures in **Table 4-2** 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. 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 major adverse impacts to pumpers, water users, other entities within 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 major 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 2018). 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. Therefore, impacts of Alternative 1 on the population within the Study Area are expected to be moderate to major.

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 expected to have only a minor impact on 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 4-2** 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 major in the absence of alternative water supplies during worst drought conditions, the future development of alternative water supplies would greatly 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 minor 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 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 rely solely 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 major 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 an 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 anticipated to have only a minor 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 major 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, the 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.

Implementation of alternative water supply strategies under any of the four EIS alternatives would require considerable financial investments that would in turn negatively 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 major 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 $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.

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.” Therefore, the anticipated impacts for each of the alternatives are addressed below.

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 5 affected counties are low-income, and 49 percent of the population is considered minority (U.S. Census Bureau 2010b).

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 moderate 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 high adverse impacts to minority and low-income customers.

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 minor 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, such as 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. 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 majorly 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 majorly 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 major during DOR conditions, if all permittees ceased pumping, and could even become severe if the water lost could not be 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 negligible 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 minor 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 moderately 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; Travis, Austin, Walter Long, and Lady Bird lakes; and 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 BSP, located in Zilker Park, is fed by water naturally discharging from the Aquifer. In 2013, an estimated 595,000 people visited BSP.

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 (2014), the ARR MSA saw a total of 21,000 housing units authorized by building permits in 2013. 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 2018). 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 major, 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 (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 2018). This management program would provide a relative economic advantage to those users who are exempt from withdrawal restrictions 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 exempt permits and market constraints to those without such exemptions. 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 have a minor affect on 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 exempt 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 DFCs (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 major, 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 overall major negative impacts 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. 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 major 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 from 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, and result in major (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 major 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 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 have a moderate to major effect by forcing 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 minor to moderate 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 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, moderate to major 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 major 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 BSP) 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 4-3**. Types of cultural site impacts include mechanical impacts, biochemical impacts to organic compounds, and looting during wet-dry cycles associated with varying flow levels. Hicks & Company (2014c) provide more-detailed descriptions of cultural resource sites.

Table 4-3. Summary of Impacts to Cultural Resource Sites from Water Flow Variations for Each of the Four EIS 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 listed in **Table 4-4**. 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 minor 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 minor to moderate 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 4-4. 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 minor to moderate 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 could be the dissolution of these artifacts and loss of accompanying data.

Minor to moderate 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 conditions. 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 less minor to moderate impacts from exposure of potential artifacts than Alternative 2 under drought conditions. Under low flows there would be some minor 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 a minor to moderate 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 4-5**. 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 BSS and ABS by sustaining a higher level of water flow through the spring ecosystems during drought, including conditions that would correspond to the DOR.

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.

Table 4-5. Comparison of Environmental Consequences of the EIS Alternatives

Affected Environment	No Action	Issuance of ITP for Implementation of HCP	Water Demand Reduction	Water Supply Augmentation and Substitution
Physical Environment (Section 4.1)				
Geology (4.1.1)	Negligible or none	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Soils (4.1.2)	Negligible or none	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Air Quality (4.1.3)	Negligible or none	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Climate (4.1.4)	Negligible or none	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)	Negligible 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, Negligible 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:* Negligible or no	*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.
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:* Negligible or no impact in average years; possible adverse impacts in drier or driest years. *Other Creeks:* Minimal or no impacts.	*Lower Barton Creek*: Negligible 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.

Table 4-5, cont'd

Affected Environment	No Action	Issuance of ITP for Implementation of HCP	Water Demand Reduction	Water Supply Augmentation and Substitution
Terrestrial Resources (4.3.2)	Negligible or none	Same as Alternative 1.	Same as Alternatives 1 and 2.	Same as Alternatives 1, 2, and 3.
Regional Threatened/ Endangered Species (4.3.3)	Negligible or none	Negligible or none	Negligible or none	Negligible or none
BSS (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.
ABS (4.3.4)	Impacts to ABS similar to BSS; 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 major adverse impacts.	Minor adverse impacts.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Minority and Low Income Populations (4.4.2)	Major adverse impacts.	Minor adverse impacts.	Same as Alternative 1.	Same as Alternatives 1 and 3.
Community and Public Resources (4.4.3)	Moderate to major adverse impacts.	Minor 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 major adverse impacts.	Minor adverse impacts.	High adverse impacts.	Same as Alternative 3.
Land Use (Section 4.5)[2]				
Urban/Suburban Land Use	Moderate to major adverse impacts.	Minor 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.

Table 4-5, cont'd

Affected Environment	No Action	Issuance of ITP for Implementation of HCP	Water Demand Reduction	Water Supply Augmentation and Substitution
[1]Socioeconomic Impact Definitions -	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. Major – Effects would be readily apparent and substantially change the economy or social services.			
[2] Land Use Impact Definitions –	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. Major - Effects would be readily apparent and would substantially slow land use conversion within the Study Area.			
[3]Cultural Resources Impact Definitions -	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. Major - Effects would be substantial, noticeable, and permanent; with changes affecting the character and integrity of one or more of the archeological sites.			

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Under Alternative 1, No Action, there would be no ITP and no implementation of an HCP. 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 major 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, 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 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 as part of the ITP would provide ESA protection for District-authorized pumping, since the combination of pumping and low Aquifer recharge could result in take of the Covered Species. 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 EIS alternatives indicates Alternative 2 to be the most balanced alternative in consideration of biological benefits, economic costs, and the current political and regulatory environment.

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 in the EIS Study Area 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 (2005) guidance 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 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.

5.2.2.1 Surface Water

The Aquifer lies within the central portion of the Colorado River Basin. Discharge from the springs flows into Barton Creek, then into Lady Bird Lake. 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 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 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 2018). Non-permitted (exempt) pumpage, such as domestic and livestock supply, is estimated to be about 200 million gallons per year.

5.2.2.3 Biological Resources

The 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 BSS was federally listed as endangered on April 30, 1997, while the ABS 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). BSSs 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 ABS occupies a more subterranean habitat than the BSS, most of the observations of this species have been of individuals that were accidentally flushed out of their underground habitat. Substantially fewer ABSs than BSSs have been observed by COA biologists during regular surveys.

5.2.2.4 Land Use

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 Study Area is directly influenced by the rapidly growing Austin area economy, and 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.

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 5-2 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 water 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 2016 Regional Water Plans developed by Region K and Region L and included 2017 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 BSS Recovery Plan Amended to Include the ABS (USFWS 2005, amended 2016)	The Recovery Plan includes planning and scientific research activities intended to generate information that will assist with management of the BSS and ABS 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.
COA 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.

Table 5-3, cont'd

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
COA 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.
COA's Barton Springs HCP 2013	Authorizes the incidental take of the federally endangered BSS and ABS that would result from the operation and maintenance of BSP and the adjacent springs.	Beneficial impacts to species habitat in BSP from more careful management procedures; increased protection provided by Incidental Take Permit for the COA from an enforcement action under the ESA; beneficial impacts to surface water quality; higher quality water recharging to Aquifer; higher quality Aquifer water.
The Regional Water Quality Protection Plan for the 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 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 2016	The 2016 plan covers the 2017–2067 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 BSP.
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 spring 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 5-3, 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 COA, 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 Aquifer.
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.

Table 5-3, cont'd

Public Plans, Policies, and Programs	Description	Potential Effects on Resources
COA 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 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 (Hicks & Company 2014a).	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 under construction	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 complete between Parmer Lane and Lady Bird Lake. Additional improvements from Lady Bird Lake to Slaughter Lane (MoPac South Project) are currently under construction.	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.

Table 5-3, cont'd

Reasonably Foreseeable Actions	Description	Type of Impact
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.
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 EIS 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)						

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
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						
BSS and ABS 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						

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
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 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 EIS 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 COA's 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 EIS include measures for managing the Aquifer under drought conditions for the benefit of the BSS and ABS. 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 BSS and ABS 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 EIS 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 EIS alternatives would have cumulative impacts on groundwater 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 EIS 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 EIS 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 EIS, 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 EIS 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 EIS 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 DOR 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 BSS 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 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.

6.0 COORDINATION AND CONSULTATION

6.1 PUBLIC INVOLVEMENT

A public scoping meeting was held in Austin, Texas, on August 23, 2005. A “Preliminary Draft HCP/Environmental Impact Study” was submitted to the Service in June 2007, based on public comment and scoping. 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 CAC and BAT (described in **subsection 1.6.2**.). After the June 2007 submission, several events occurred that required reevaluation of and major modifications to the documents, including the Service requesting the HCP and EIS be prepared independently as separate documents and also offering suggestions for improvement of the HCP. Additional scientific data also became available concerning the effects of DO on the biology of the BSS, other pertinent data concerning updated predicted springflow frequencies during the POR, and relationships between springflows and DO concentrations.

In response to new scientific information that became available, and circumstances that had changed since the initial combined draft 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 regarding the proposed action. A record of public comments received is posted online at ***http://www.regulations.gov*** and is also included in **Appendix A2**. 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 this public hearing is provided in **Appendix A3**.

Based on these events, the District substantially revised the HCP and consolidated the functions of the CAC and BAT into the MAC **(Appendix A1)**. 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 the ITP.

A public meeting was held on August 22, 2017, during the 60-day public comment period for the dHCP and dEIS. Comments received during the public comment period and responses to these comments are addressed in **Section A5. Public Review of dHCP and dEIS and Response to Comments.**

6.2 AGENCY INVOLVEMENT

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

6.3 CONSULTATION WITH OTHERS

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

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- Dr. Kent Butler (Deceased), Kent Butler Associates

- Dr. Wendy Gordon, Ecologia Consulting
- Brian Hunt, Certified Professional Geologist, BSEACD
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9.0 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 GCDs (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 GCDs under the requirements of HB 1763, 79th 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 A1

Membership of the HCP Management Advisory Committee

Appendix A2

Public Comment in Response to Published Notice of Intent by the U.S. Fish and Wildlife Service to Prepare an Environmental Assessment

Appendix A3

Minutes from the Public Hearing on the Barton Springs/Edwards Aquifer Conservation District Draft Habitat Conservation Plan Held on September 11, 2014

Appendix A4

Summary of Results of Public Scoping Meeting of August 23, 2005 and Letters Received

Appendix A5

Public Review of DHCP and DEIS and Response To Comments