EDWARDS AQUIFER
HABITAT CONSERVATION PLAN
2018 Annual Report

Submitted to
THE U.S. FISH & WILDIFE SERVICE

MARCH 26, 2019

On behalf of
THE EDWARDS AQUIFER HABITAT CONSERVATION PLAN PERMITTEES

HABITAT CONSERVATION PLAN
EDWARDS AQUIFER

Prepared by

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ENVIRONMENTAL CONSULTING • PLANNING • PROJECT MANAGEMENT

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Edwards Aquifer

Habitat Conservation Plan

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EXECUTIVE SUMMARY

Edwards Aquifer Habitat Conservation Plan

The Edwards Aquifer Habitat Conservation Plan (EAHCP)[1] is the primary document that establishes the cooperative effort to protect the water of the Southern Segment of the Edwards Aquifer ("Edwards" or "Aquifer") both for people in the region and the threatened and endangered species[2] that inhabit the Aquifer, and aquatic spring environments whose water largely emanates from the Aquifer. This effort began when regional stakeholders and the U.S. Fish & Wildlife Service (Service or USFWS) initiated the Edwards Aquifer Recovery Implementation Program (EARIP) in 2006. The Texas Legislature mandated participation in the process by the Edwards Aquifer Authority (EAA), Texas Commission on Environmental Quality, Texas Department of Agriculture, Texas Parks & Wildlife Department (TPWD), and Texas Water Development Board (TWDB). The EARIP planning group led to the creation of the process known as the EAHCP Program, which has now been fully transitioned from the EARIP. The EAHCP was completed in November 2012 and led to the approval of an Incidental Take Permit (ITP) under the federal Endangered Species Act of 1973 (ESA) issued in February 2013 by the USFWS to be effective in March 2013. The ITP has been amended once, and a copy of the amended ITP is included in **Appendix A1** of this Annual Report. This Annual Report has been prepared for submittal to the USFWS, as required by the ITP. Because of EAHCP implementation efforts, there have been various amendments and clarifications made to the EAHCP, or its supporting documents, since the issuance of the ITP. **Appendix A2** is a table summarizing the amendments and clarifications from November 2012 through December 2018.

The Permittees under the ITP are the EAA, the City of New Braunfels (CONB), the City of San Marcos (COSM), Texas State University (Texas State), and the City of San Antonio acting by and through its San Antonio Water System (SAWS) Board of Trustees.

Covered Species Protected by the EAHCP

The EAHCP addresses the conservation needs of seven endangered species, one threatened species, and three species that have been petitioned for listing, as shown below in **Table ES-1**. Under the EAHCP, the Covered Species are protected by the ITP issued by the USFWS. The ITP authorizes "take" of the Covered Species listed in **Table ES-1**, as that term is defined in the ESA.[3]

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[1] All acronyms and abbreviations in this Annual Report are defined in the **LIST OF ACRONYMS AND ABBREVIATIONS** located on pages xxiv - xxvi.

[2] All aquatic animal and plant species referenced in this Annual Report are listed in the **LIST OF ALL SPECIES OF MANAGEMENT INTEREST REFERENCED** located on pages xxvii - xxviii.

[3] "Take," as defined by the ESA, means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." "Harm" is also defined in the implementing regulations as "an act which actually kills or injures wildlife; such an act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly interfering with essential behavioral patterns including breeding, feeding and sheltering" (50 CFR 17.3). Plants (e.g., Texas wild-rice) are treated differently under the ESA and are not subject to the take rules.

Table ES-1. Covered Species Under the EAHCP ITP

Common Name	Scientific Name	Federal Status	Associated Springs in the EAHCP
Fountain Darter	*Etheostoma fonticola*	Endangered	Comal & San Marcos
San Marcos Gambusia	*Gambusia georgei*	Endangered	San Marcos
Comal Springs Dryopid Beetle	*Stygoparnus comalensis*	Endangered	Comal
Comal Springs Riffle Beetle	*Heterelmis comalensis*	Endangered	Comal & San Marcos
Peck's Cave Amphipod	*Stygobromus pecki*	Endangered	Comal
Texas Wild-Rice	*Zizania texana*	Endangered	San Marcos
Texas Blind Salamander	*Eurycea (+Typhlomolge) rathbuni*	Endangered	San Marcos
San Marcos Salamander	*Eurycea nana*	Threatened	San Marcos
Texas Cave Diving Beetle*	*Haideoporus texanus*	Petitioned	Comal & San Marcos
Comal Springs Salamander	*Eurycea sp.*	Petitioned	Comal
Texas Troglobitic Water Slater	*Lirceolus smithii*	Petitioned	San Marcos

* Also known as the "Edwards Aquifer Diving Beetle."

The Texas Cave Diving Beetle, Comal Springs Salamander, and Texas Troglobitic Water Slater are "petitioned" species and are not yet subject to the "take" prohibition in the ESA.

Geographic Area Covered by the EAHCP

As shown in **Figure ES-1**, the ITP provides incidental take coverage for authorized activities in all or parts of Uvalde, Medina, Atascosa, Bexar, Comal, Guadalupe, Hays and Caldwell counties, Texas that are within the EAA's jurisdictional boundary. This region is the Plan Area in which pumping from the Edwards Aquifer is regulated by the EAA and affects the springs and spring ecosystems inhabited by the Covered Species. The Plan Area also includes the recreational areas associated with the Comal Springs and the San Marcos Springs that are managed under the EAHCP by the CONB, and the COSM and Texas State, respectively. As shown in **Figure ES-1,** the Contributing Zone is part of the Edwards Aquifer *system* but is not technically a part of the Edwards Aquifer itself.

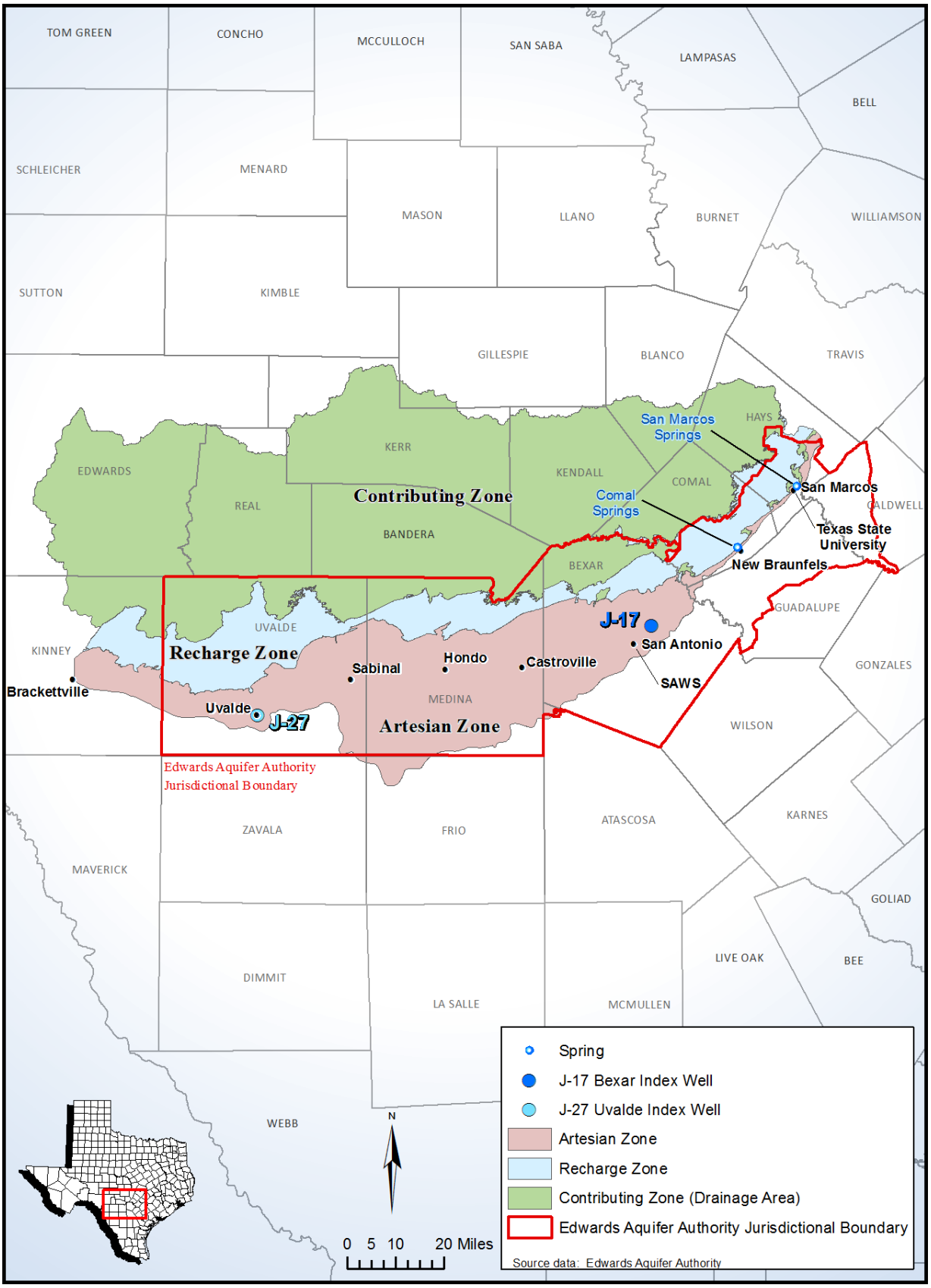

Figure ES-1. Incidental Take Coverage Area for ITP No. TE-63663A-1 (EAA Jurisdictional Boundary).

Effects on Covered Species in 2018

Chapter 5.0 – 2018 ANNUAL TAKE ESTIMATES and **Appendix N** of the Annual Report provide an overview of net disturbance percentages and a summary of incidental take for 2018 (**Table ES-2**). As shown in **Table ES-2**, only the fountain darter in the Comal system had a net disturbance when considering the project footprint for EAHCP Conservation Measure activities overlaid on occupied habitat. The net disturbance was approximately 2 percent of the total occupied habitat for the fountain darter in the Comal system. In the San Marcos system, only the fountain darter and San Marcos salamander had net disturbances calculated at approximately 5 percent and less than 1 percent, respectively, of their total occupied habitat. In summary, the net disturbance in 2018 was under the 10 percent disturbance rule as outlined in ITP Condition M.1.a and 2.a.

Table ES-2 also shows the calculated incidental take on the Comal system with respect to the EAHCP Covered Species. The calculated value of incidental take for the fountain darter in the Comal system was slightly higher in 2018 than observed during 2017. The primary cause for the increase in fountain darter take was due to lower discharge conditions in 2018, which resulted in larger spring to fall aquatic vegetation (habitat) reductions primarily in the Upper Spring Run section. In 2018, all invertebrate restoration activities occurred in the riparian zone resulting in no calculated incidental take for the listed Comal invertebrates. For the San Marcos system, incidental take for the fountain darter also went up slightly in 2018 compared to 2017. The slight increase in the San Marcos system was due to a larger footprint for EAHCP mitigation of primarily native aquatic vegetation restoration in 2018 relative to 2017. The Texas wild-rice exclusion zone implemented for 21 days in the summer below Spring Lake Dam resulted in the minor amount of incidental take calculated for the San Marcos salamander.

2018 Edwards Aquifer Conditions, Management, and Notable Conditions

After above average rainfall conditions in 2015 and 2016, and below average conditions in 2017, the Edwards Aquifer region experienced below average rainfall conditions during the spring and summer of 2018. By late July, some parts of the Edwards Aquifer region were categorized by the National Drought Mitigation Center as in extreme to severe drought. Comal springflow reached a low of 161 cubic feet per second (cfs) on August 30, 2018 and San Marcos springflow reached a low of 117 cfs on August 29, 2018. Due to prolonged low-flow conditions below 120 cfs in the San Marcos River, Condition M of the ITP was enacted on August 28, 2018, thus suspending aquatic vegetation restoration activities. After San Marcos' springflow stabilized above 120 cfs, the Condition M restoration restrictions were officially lifted on September 20, 2018. Rainfall during the fall of 2018 helped replenish the aquifer and improved springflow within the Comal and San Marcos systems.

Table ES-2. Summary of Impacted Habitat and Net Disturbance and Incidental Take for EAHCP Covered Species Compared Against ITP Maximum Permit Amounts

Covered Species Per System	EAHCP Mitigation/Restoration		EAHCP Measures/ Drought	Combined Impacted Habitat 2018TOTAL (m^2)	Incidental Take		2018 Incidental Take Total	ITP Maximum Permit Amount	ITP Permit Maximum Minus (Combined First Six Years)
	Impacted Habitat (m^2)	Net Disturbance % Of Total Occupied Habitat	Impacted Habitat (m^2)		EAHCP Mitigation/ Restoration	EAHCP Measures/ Drought			
COMAL SYSTEM									
Fountain Darter	1,599	1.5%	3,356	**4,955**	2,399	5,034	**7,432**	797,000	736,334
Comal Springs Riffle Beetle	0	0%	0	**0**	0	0	**0**	11,179	8,887
Comal Springs Dryopid Beetle	0	0%	0	**0**	0	0	**0**	1,543	1,527
Peck's Cave Amphipod	0	0%	0	**0**	0	0	**0**	18,224	18,057
SAN MARCOS SYSTEM									
Fountain Darter	4,763	5%	3,188	**7,951**	7,145	4,783	**11,927**	549,129	474,024
San Marcos Salamander	15	< 1%	0	**15**	45	0	**45**	263,857	261,183
Texas Blind Salamander	0	0%	0	**0**	0	0	**0**	10	10
Comal Springs Riffle Beetle	0	0%	0	**0**	0	0	**0**	N/A	N/A
Comal Springs Dryopid Beetle	0	0%	0	**0**	0	0	**0**	N/A	N/A

EAHCP 2018 Budget and Expenditures

The EAHCP Expense Report located in **Appendix H** of this Annual Report shows Table 7.1 of the EAHCP funding amounts for 2018 totaling $17,912,597, as compared to the EAA Board-approved/amended 2018 Program Funding Applications totaling $22,571,454. The 2018 actual expenses were $21,354,428. Unspent funds in the Program Administration, ASR Operations and Maintenance, LID/BMP Management, Applied Environment Research, and Refugia budgets account for most of the difference between total approved budget and actual expenses.

The report also breaks down the adopted budget, Program Funding Applications budget, and actual expenses. By the end of 2018, the reserve balance for the EAHCP was $31,354,603, which includes unspent funds accumulated since the inception of the EAHCP.

The EAHCP Expense Report also shows the actual revenue for 2018 of $16,733,938 compared to the budgeted revenue of $16,516,190, which is a variance of $217,748. Approximately 92 percent of the actual revenue comes from Aquifer Management Fees (AMFs).

EAHCP Activities Completed in 2018

As stated above, the five Permittees under the ITP are the EAA, CONB, COSM, Texas State, and SAWS. Under the Implementing Agreement (IA), the TPWD is an additional cooperating agency. These are the agencies working to implement the EAHCP. The Permittees are each tasked with certain responsibilities for implementation of the EAHCP, as directed by the ITP. During Phase I of implementing the EAHCP, the Permittees are undertaking 38 Conservation Measures for springflow protection, habitat protection, and other measures identified in the EAHCP.

The ITP requires an annual report be submitted to the USFWS to show progress towards permit implementation. **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, of this 2018 Annual Report describes actions by the Permittees and the TPWD, including subsections discussing their *EAHCP Obligations*, *2018 Compliance Actions*, and *Proposed Activities for 2019*.

In Year 2018, EAHCP completed an ambitious year, from securing a sound understanding of EAHCP data and modeling, to ensuring increased establishment of native aquatic habitat in both the Comal and San Marcos ecosystems. Overall, the EAHCP work falls into items that are more programmatic, while other functions deal mainly with field work associated with habitat and species protection. Both components of the program are building on work and research accomplished over the last five years, along with regional stakeholder guidance and recommendations from the National Academy of Sciences (NAS).

In addition, the EAHCP began discussions regarding the Strategic Adaptive Management Process (SAMP) outlined in the Funding and Management Agreement (FMA) as the transition from Phase I (Years 2013 – 2020) to Phase II (Years 2020 – 2028) of the EAHCP and ITP.

Highlights of major EAHCP accomplishments for 2018 are summarized below.

Springflow Protection Measures –

With regard to the four EAHCP springflow protection elements (the Voluntary Irrigation Suspension Program Option [VISPO], the Regional Water Conservation Program [RWCP], the Critical Period Management Program [CPMP] – Stage V, and the SAWS Aquifer Storage and Recovery [ASR] program), the EAHCP continues to make headway to complete all four of these elements prior to Year 2023, which is the tenth year of the ITP and five years in advance of the Year 2028.

a. *VISPO* – In 2018, EAHCP staff[4] did not initiate efforts to enroll new participants in the VISPO as the goal of 40,000 acre-feet (ac-ft) was achieved in 2014 and no more water was needed at this time.

b. *RWCP* – In 2018, SAWS continued its Leak Detection and Repair Program, including a portion of the program funded by the EAA through an agreement between the EAHCP and SAWS, which completes the RWCP goals of conserving 20,000 ac-ft of water. This five-year agreement with SAWS guarantees approximately 10,000 ac-ft of Edwards Aquifer water will be left unpumped through the term of the ITP.

c. *CPMP – Stage V* – This element was approved by the EAA Board of Directors in early 2012 and has been implemented as necessary. Due to decreased Aquifer levels and springflows, Stage I of the CPMP in the San Antonio Pool was triggered on May 20, 2018, July 14, 2018, and September 13, 2018, for a total of 36 days. Stage II in the San Antonio Pool was triggered on June 20, 2018 and July 27, 2018, for 82 days.

d. *SAWS ASR Program* –This Conservation Measure (EAHCP §5.5) supports the SAWS operation of the ASR for the EAHCP to ensure that the Comal Springs continue to flow during a repeat of the drought of record (DOR), and consists of three basic components: (1) the injection (recharge), storage, and recovery of EAHCP Groundwater at the SAWS ASR; (2) the acquisition by lease and lease options of EAHCP Groundwater by the EAA; and (3) forbearance of Edwards pumping by SAWS under its EAA-issued groundwater withdrawal permit during certain drought conditions stated in the EAHCP and the SAWS-EAA Interlocal Contract (ILC). From the effective date of the ITP in 2013 through 2018, SAWS has injected 99,375 ac-ft of EAHCP Groundwater. Additionally, because the drought triggers under the EAHCP and the SAWS-EAA ILC were not satisfied at any time during 2018, SAWS did not recover any EAHCP Groundwater in storage from the SAWS ASR.

   Once the program goal for the storage component of the SAWS ASR Program is achieved, there is intended to be as much as 126,000 ac-ft stored and available to ease the effects of a DOR. From the effective date of the ITP in 2013 through 2018, the EAA has acquired 39,984 ac-ft in leases. In 2018, the EAHCP completed a Nonroutine Adaptive Management Process (AMP) Proposal initiated by the EAA to resolve some of the program's structural issues regarding the "tiering" of leases/lease options and creating market products that will be better received.

[4] As used in this Annual Report, "EAHCP staff" is used to refer to EAA employees who are assigned to the Threatened and Endangered Species Team.

Habitat Restoration: Comal and San Marcos Spring Systems –

a. *Comal Springs Systems –*
Vegetative Restoration in the Old Channel, Landa Lake, and Upper Spring Run – Aquatic vegetation restoration activities in 2018 included removal of non-native aquatic vegetation and planting of target native aquatic plants as well as monitoring, mapping, and maintenance of restored areas. A summary of 2018 restoration results follows.

   i. *Old Channel* – In 2018, a total of 497 m^2 was planted in seven restoration plots in the Old Channel Long-Term Biological Goal (LTBG) and Restoration reaches. A total of 5,460 plants were installed in 2018 within the Old Channel Restoration Reach and the LTBG Reach combined.
   ii. *Landa Lake* – In 2018, 302 m^2 of area was planted in five restoration plots in Landa Lake. A total of 4,053 plants were planted into the Landa Lake LTBG Reach in 2018.
   iii. *Upper Spring Run* – Although submerged aquatic vegetation (SAV) plantings were a goal for the Upper Spring Run in 2018, construction activities surrounding the New Braunfels Utilities environmental education facility at the headwaters altered this plan. As such, more resources were devoted to completing the removal of all *Hygrophila* and installing restoration plantings in the Old Channel LTBG Reach and Landa Lake than originally anticipated. This adjustment highlighted the importance of flexibility in the restoration plan and goals to best use resources in an economically responsible fashion.

   Control of Harmful Non-Native Animal Species – CONB efforts in 2018 involved five removal sessions, each for three days, between February and September. In 2018, approximately 1,844 pounds (lbs.) of invasive species biomass was removed from Landa Lake, that consisted of armored catfish, tilapia, and nutria. Between 2013 and 2018, CONB staff reported that a total of 16,100 lbs. (or approximately 8 tons) of invasive biomass has been removed from the Comal River system.

b. *San Marcos Springs Systems –*
Texas wild-rice Enhancement and Restoration – Restoration activities in 2018 involved removal of non-native plant species, propagation of new Texas wild-rice plants, and continued monitoring of new stands. Since 2013, Texas wild-rice has expanded an estimated 5,914 m^2, or 240 percent, through planting and natural expansion. Since 2017, Texas wild-rice coverage has decreased by an estimated 2,049 m^2. Texas wild-rice stands have been lost in areas that have high rates of recreation.

   Riparian Restoration – The COSM focused riparian vegetation treatment (e.g., removal and planting) efforts at the following work sites throughout 2018: Purgatory Creek in Bicentennial Park; Crook Park and Wildlife Annex; Rio Vista Park; and Sessom Natural Area.

   Control of Harmful Non-Native and Predator Species – COSM hosted two spearfishing tournaments in 2018 to remove non-native invasive species. From 2015 – 2018, COSM staff reported that 1,613 lbs. of invasive species biomass have been removed through spearfishing tournaments.

c. *Refugia* – In 2017, the EAA contracted with the USFWS to operate off-site refugia operations at the San Marcos Aquatic Resource Center (SMARC) and the Uvalde National Fish Hatchery (UNFH). The primary activities occurring in 2018 were related to species collection, species research, and facility construction. Covered Species were collected throughout the year by both USFWS facilities, in accordance with their 2018 Work Plan, and held at these two facilities.

   In 2018, four research projects in support of a successful refugia were completed:

   1) Life-history study of Comal Springs dryopid beetles (*Stygoparnus comalensis*);

   2) Life-history study of Peck's Cave Amphipod (*Stygobromus pecki*);

   3) Continuation of Comal Springs riffle beetle (CSRB) (*Heterelmis comalensis*) life history and captive propagation techniques; and

   4) Testing a non-invasive trigger to induce reproduction in both pair-wise and group mating of San Marcos salamander.

   The 2018 Refugia Annual Report (*Implementation of the Refugia Program under the Edwards Aquifer Habitat Conservation Plan Annual Report 2018*) can be found in **Appendix K3a** and contains details of all the activities described above, monthly progress reports, and reports and work plans related to the Peck's cave amphipod, CSRB, and San Marcos salamander.

d. *Hydrological Model: MODFLOW Model* – During 2018, the updated and recalibrated MODFLOW model was used to repeat the "bottom-up" analysis cited in the EAHCP to demonstrate the effectiveness of the springflow protection Conservation Measures. Two separate sets of bottom-up analyses were conducted in support of the SAMP. Other groundwater modeling activities conducted during 2018 included an uncertainty analysis conducted by the U.S. Geological Survey (USGS) under a joint funding agreement with the EAA. A goal of this analysis was to identify whether there are alternative ways to calibrate the MODFLOW model that could give equally good calibration results, and the extent to which such alternative models may differ from the version used to demonstrate the effectiveness of the EAHCP springflow protection measures. These efforts are ongoing and results will be available in 2019.

e. *Applied Research* – The Applied Research Program in 2018 primarily focused on two studies. The Sessom Creek Sediment Export Study was developed to establish a sediment loading curve for Sessom Creek, comprised of a fitted relationship between flow and entrained constituent concentration, and to assess what factors are contributing to the sediment exports in the San Marcos River and sediment deposition on Texas wild-rice as a recurring issue (**Appendix K1**). The Sessom Creek Sediment Export Study will continue in 2019 and results will be available in 2020. The second study was focused on addressing identified several shortcomings noted in the *National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 1 (*NAS *Report 1)* and the *National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 2 (*NAS *Report 2)* of the current methodologies to assess densities and population estimates of the CSRB. The CSRB Work Group was formed and conducted a literature review focused on

specific areas in need of more research (**Appendix K2**). The CSRB literature review will be available in 2019 and will help inform the CSRB Work Group's decisions.

f. *Strategic Adaptive Management Process* – The Year 2018 marked the first year of SAMP activities as the program transitions from Phase I (2013 – 2020) into Phase II (2020 – 2028). SAMP activities in 2018 revolved around four sources: lessons learned from implementation of Phase I Conservation Measures, MODFLOW DOR simulations, recommendations from the NAS *Report 3* and the Phase II Work Plan Work Group (Phase II Work Group). The Permittees continued to implement monitoring, research and modeling activities to provide information that help inform SAMP decisions.

EAHCP Program Activities –

The EAHCP completed another active year. As discussed above, EAHCP staff managed and facilitated one Nonroutine AMP resulting in amendment to the EAHCP, and one clarification of an EAHCP element. EAHCP program staff also facilitated more than 20 public meetings. These meetings included regular meetings of the IC, Adaptive Management Science Committee (SC), and the Adaptive Management Stakeholder Committee (SH), topical based Work Groups to inform program decisions, and a meeting of the National Academy of Sciences/Science Review Panel (SRP/NAS).

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LIST OF ACRONYMS AND ABBREVIATIONS

ac-ft	acre-foot/acre-feet
AMF	Aquifer Management Fee(s)
AMP(s)	Adaptive Management Process(es)
ASR	Aquifer Storage and Recovery
BioMP	Biological Monitoring Program
BIO-WEST	BIO-WEST, Inc.
BMP(s)	best management practice(s)
BTEX	benzene, toluene, ethylbenzene and xylene
CC	Conservation Crew
cfs	cubic feet per second
cm	Centimeter(s)
COI(s)	Certificate(s) of Inclusion
CONB	City of New Braunfels
COSM	City of San Marcos
CPMP	Critical Period Management Program
CPS Energy	City Public Service Energy
CSRB	Comal Springs riffle beetle
°C	degrees Celsius
DAC	Dive Authorization Course
DEET	Diethyl-meta-toluamide
DEHP	Bis(2-ethylhexyl) phthalate
D4S	Diving for Science
DO	dissolved oxygen
DOC	Dissolved Organic Carbon
DOR	Drought of record
EAA	Edwards Aquifer Authority
EAHCP	Edwards Aquifer Habitat Conservation Plan
EARIP	Edwards Aquifer Recovery Implementation Program
EcoModel	Ecological Model
ESA	federal Endangered Species Act of 1973
FAB	Freeman Aquatic Building
FMA	Funding and Management Agreement
ft	foot/feet
ft^3	cubic foot/feet
GBRA	Guadalupe-Blanco River Authority
GWQP(s)	General Water Quality Parameter(s)
HAZMAT	Hazardous Material
HCP	Habitat Conservation Plan
HHCB	galaxolide
HHW	Household Hazardous Waste
IA	Implementing Agreement
IC	Implementing Committee
IH	Interstate Highway
ILC	Interlocal Contract

List of Acronyms and Abbreviations (Continued)

IPMP	Integrated Pest Management Plan
ITP	Incidental Take Permit
lb(s).	pound(s)
LTBG(s)	Long-Term Biological Goal(s)
m	meter(s)
m^2	square meters
m^3	cubic meters
MCL	maximum contaminant level
MCWE	Meadows Center for Water and the Environment
mg/kg	milligram(s) per kilogram
mg/L	milligram(s) per liter
msl	mean sea level
MTBE	methyl tert-butyl ether
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
µS/cm	micro-Siemens per centimeter
NAS	National Academy of Sciences
NAS *Report 1*	*National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 1*
NAS *Report 2*	*National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 2*
NAS *Report 3*	*National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 3*
NBU	New Braunfels Utilities
No.	Number
NOA	Notice of Availability
NRA	Nueces River Authority
NTU	nephelometric turbidity units
NVSS	nonvolatile suspended solids
oz.	ounce
PAH	non-polycyclic or polycyclic aromatic hydrocarbon
PCB(s)	Polychlorinated Biphenyl(s)
PEC	probable effect concentration
Phase II Work Group	Comprehensive Phase II Work Plan Work Group
POCIS	polar organic chemical integrative samples
PPCP(s)	Pharmaceutical and personal care product(s)
RCMC	Regional Conservation Monitoring Committee
RR	Restoration Reach
RTI	Real Time Instrumentation
RWCP	Regional Water Conservation Program
SAMP	Strategic Adaptive Management Process
SARA	San Antonio River Authority
SAV	submerged aquatic vegetation
SAV Report	Submerged Aquatic Vegetation Analysis and Recommendations Report

List of Acronyms and Abbreviations (Continued)

SAWS	San Antonio Water System
SC	Adaptive Management Science Committee
SCUBA	Self Contained Underwater Breathing Apparatus
SCTWAC	South Central Texas Water Advisory Committee
SER	Scientific Evaluation Report
Service	U.S. Fish & Wildlife Service
SH	Adaptive Management Stakeholder Committee
SMARC	San Marcos Aquatic Research Center
SMRF	San Marcos River Foundation
sp./spp.	species (singular)/species (plural)
SRP	Science Review Panel
SRP/NAS	Science Review Panel/National Academy of Sciences
SSA	State Scientific Area
SU	standard units
SVOC(s)	Semi-volatile Organic Compound(s)
TAC	Texas Administrative Code
TCEP	tris(2-carboxyethyl)phosphine
TCEQ	Texas Commission on Environmental Quality
TCPP	Tris (chloroisopropyl) phosphate
TDA	Texas Department of Agriculture
TDCPP	Tris(1,3-dichloroisopropyl) phosphate
TEC	threshold effect concentrations
Texas State	Texas State University
THC	Texas Historical Commission
TKN	Total Kjeldahl Nitrogen
TOC	Total Organic Carbon
TP	total phosphorus
TPH	total petroleum hydrocarbons
TPWD	Texas Parks & Wildlife Department
TSBC	Texas-specific background concentration
TSS	total suspended solids
TTU	Texas Tech University
TWDB	Texas Water Development Board
TxDOT	Texas Department of Transportation
UNFH	Uvalde National Fish Hatchery
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
VISPO	Voluntary Irrigation Suspension Program Option
VOC(s)	Volitale Organic Compound(s)
VSS	volatile suspended solids
WQP	Expanded Water Quality Monitoring Program
WQPP	Water Quality Protection Plan
WRIP	Water Resources Integration Program
yd^3	cubic yards

LIST OF ALL SPECIES OF MANAGEMENT INTEREST REFERENCED[5]

Common Name	Scientific Name
Covered Species Under Incidental Take Permit No. TE-63663A-1 and the Edwards Aquifer Habitat Conservation Plan	
Comal Springs dryopid beetle	*Stygoparnus comalensis*
Comal Springs riffle beetle	*Heterelmis comalensis*
Comal Springs salamander	*Eurycea* sp.
Fountain darter	*Etheostoma fonticola*
Peck's cave amphipod	*Stygobromus pecki*
San Marcos gambusia	*Gambusia georgei*
San Marcos salamander	*Eurycea nana*
Texas blind salamander	*Eurycea (=Typhlomolge) rathbuni*
Texas cave diving beetle (or Edwards Aquifer diving beetle)	*Haideoporus texanus*
Texas troglobitic water slater	*Lirceolus smithii*
Texas wild-rice	*Zizania texana*
Species included in the Submerged Aquatic Vegetation Objectives	
Delta arrowhead	*Sagittaria platyphylla*
Creeping primrose-willow	*Ludwigia repens*
Fanwort (or Cabomba)	*Cabomba caroliniana*
Mosses, liverworts, and allies	Bryophytes
Illinois pondweed	*Potamogeton illinoensis*
Umbrella pennyroyal (or manyflower marshpennywort)	*Hydrocotyle umbellata*
Texas wild-rice	*Zizania texana*
Native Aquatic Plant Species Used in Restoration	
Grassleaf mudplantain	*Heteranthera dubia*
Native Species	
Big claw river shrimp	
Non-native Animal and Plant Species Removed or Monitored	
Armored catfishes (or suckermouth catfishes)	Loricariidae
Chinaberry	*Melia azedarach*
Chinese privet	*Ligustrum sinense*
Chinese tallow	*Triadica sebifera*
Indian swampweed	*Hygrophila polysperma*
Giant ramshorn	*Marisa cornuarietis*
Giant reed	*Arundo donax*
Gill parasite (no common name)	*Centrocestus formosanus*
Hydrilla (or water thyme)	*Hydrilla verticillata*
Japanese honeysuckle	*Lonicera japonica*
Japanese privet (or Japanese ligustrum)	*Ligustrum japonicum*
Nutria	*Myocastor coypus*
Red-rim melania	*Melanoides tuberculatus*
Tapegrass (or eelgrass)	*Vallisneria spiralis*
Elephant ear (or coco yam, or taro)	*Colocasia esculenta*

[5] Sources for common and scientific names are Integrated Taxonomic Information System; https://www.itis.gov and PLANTS National Database; https://plants.usda.gov/java/.

List of All Species of Management Interest Referenced (Continued)

Common Name	Scientific Name
Tilapia (or blue tilapia)	*Oreochromis* spp.
Watercress	*Nasturtium officinale*
Water hyacinth	*Eichhornia crassipes*
Water lettuce	*Pistia stratiotes*
Water sprite	*Ceratopteris thalictroides*
White mulberry	*Morus alba*
Zebra mussel	*Dreissena polymorpha*

GLOSSARY OF TERMS INCLUDED IN THE 2018 EAHCP ANNUAL REPORT

Term or Phrase	Term or Phrase Definition
Conservation Measure	Specified projects to be implemented by the Permittees in order to minimize and mitigate to the maximum extent practicable and will not appreciably reduce the likelihood of the survival and recovery of the Covered Species due to the performance of the Covered Activities by the Permittees during the term of the ITP.
Covered Activity	Those activities identified in the ITP and the EAHCP and performed by the Permittees within the boundaries of the EAA, including recreation and pumping from the Edwards Aquifer within the EAA's boundaries, for which incidental take coverage has been provided during the term of the ITP.
Critical period	A period characterized by certain defined lower aquifer levels, which are primarily managed by the triggering of increasing withdrawal restrictions from the Aquifer.
Critical period sampling	High flow and low flow specific sampling to evaluate disturbance and recovery, as well as declining or improving conditions linked to flow. High flow (after a flood event) sampling must be approved by EAA staff working with the contractor. Low flow sampling is linked to a series of flow triggers.
Curtail or Curtailment	The act of reducing or restricting something. In the case of a Forbearance Agreement, the right to withdrawal under an EAA Groundwater Withdrawal Permit would be reduced or restricted.
Defined period of extreme drought Drought/drought conditions Extreme drought conditions	In the EAHCP, the "springflow protection" Conservation Measures are based off of the specific drought triggers that are tailored for each measure, except for the RWCP, which has no drought triggers. These measures are designed to prevent springflows at Comal Springs and San Marcos Springs from being reduced below certain levels stated in the EAHCP during a repeat of the "Drought of Record," which refers to the six-year drought that occurred from 1951 through 1956, and specifically to a drought characterized by an average recharge for any seven-year period of less than 168,700 ac-ft as derived from the period 1950 through 1956. Reference to drought or extreme drought is in perspective of similar experiences.
Destructive scour Scour	The removal of sediment such as sand or rocks, and vegetation due to swiftly moving water from flood or severe storm event.
EAA Act	The Act of May 30, 1993, 73rd Leg., R.S., ch. 626, 1993 Tex. Gen. Laws 2350, as amended.

GLOSSARY OF TERMS INCLUDED IN THE 2018 EAHCP ANNUAL REPORT (continued)

Term or Phrase	Term or Phrase Definition
EAA Groundwater Withdrawal Permit	An Initial Regular Permit or Regular Permit issued by the EAA.
Forbearance	The complete curtailment of all or part of a right to make withdrawals under a specific EAA Groundwater Withdrawal Permit.
Forbearance agreement	A contractual agreement whereby a permit holder agrees to the complete curtailment of all or part of the permittee's or permit holder's right to make withdrawals under a specific EAA Groundwater Withdrawal Permit when certain conditions, commonly referred to as "triggers" are met in exchange for compensation.
High flow	Referencing a flood event or severe storm event that could have negatively impacted the Covered Species and their habitat. System monitoring association with high flow must be approved by EAA staff and is not quantitatively defined in the EAHCP.
Initial Regular Permit	An EAA Groundwater Withdrawal Permit originally issued by the EAA under Subsection 1.16(d) of the EAA Act.
Instars	An insect developmental stage between larvae to adult. Each instar is a separate molt.
Lease Option	As used in the SAWS ASR Program, a type of contractual agreement whereby the EAA has the option to lease the right to make withdrawals from the Edwards Aquifer under an an EAA Groundwater Withdrawal Permit when certain conditions are met. In the context of the SAWS ASR program of the EAHCP, the EAA was originally charged with entering into such contracts with the option to lease an EAA Groundwater Withdrawal Permit becoming called upon the existence of a specific ten-year rolling recharge average. The difference between a Lease, Lease Option, and a Forbearance Agreement is that a Lease is a contractual arrangement to presently grant the exclusive possession of the right to make withdrawals from the Edwards Aquifer under an an EAA Groundwater Withdrawal Permit, a Lease Option is a contractual agreement providing a right to call for the lease right under certain conditions, and a Forbearance Agreement is a contractual agreement to curtail withdrawal of an EAA Groundwater Withdrawal Permit to make withdrawals from the Edwards Aquifer under an an EAA Groundwater Withdrawal Permit in the future under certain conditions in exchange for compensation.
Long Term Biological Goal (LTBG) Reach	River segments in both the Comal and San Marcos rivers that are specifically specified in the EAHCP and hold

GLOSSARY OF TERMS INCLUDED IN THE 2018 EAHCP ANNUAL REPORT (continued)

Term or Phrase	Term or Phrase Definition
	quantitative goals associated with specific plants regarded as fountain darter habitat.
Low flow(s) Low flow conditions Extreme low flow	A period of springflow that decreases below the long-term average and the minimum averages identified in Tables 4-2 and 4-13 of the EAHCP significantly. Low-flow may also be specified in the Comal system as 130 cfs or lower, and in the San Marcos system as 120 cfs or lower based on Condition M in the ITP.
Negative impacts	Generic term associated with impacts to the Covered Species and their habitat through reduced springflow, flood, contaminated runoff, excess recreation in protected areas, and other potentially threatening activities to the Comal and San Marcos Springs ecosystems.
Phase I – EAHCP Implementation	Phase I of the EAHCP is the time period between the years 2013 – 2020 of the ITP, during which the Permittees implemented the Habitat Restoration, Springflow Protection, Research, Modeling, and Monitoring, and Refugia Conservation Measures required by the EAHCP and the ITP to determine their effectiveness in achieving the EAHCP Biological Goals and Objectives.
Phase II – EAHCP Implementation	Phase II of the EAHCP is the period of the ITP during the years 2020 – 2028 when continued implementation of existing, or modifications to existing, Conservation Measures, or implementation of new Conservation Measures may be necessary to achieve the Biological Goals and Objectives in the EAHCP as a result of the Strategic Adaptive Management Process.
Regular Permit	An EAA Groundwater Withdrawal Permit issued by the EAA after August 12, 2008, resulting from the sale or amendment of an Initial Regular Permit or the consolidation of two or more such permits.
Restoration Reach	River segments in both the Comal and San Marcos rivers created out of the 2016 AMP to satisfy the EAHCP Key Management Objective of proportionally expanding SAV restoration beyond the LTBG reaches.
Strategic Adaptive Management Process	The Strategic Adaptive Management Process (SAMP) is employed during the transition from Phase I (2013-2020) to Phase II (2020-2028) of the EAHCP and the ITP. Specifically, the decisions made through SAMP pertain to the selection of Conservation Measures for Phase II of EAHCP implementation. SAMP is essentially the formal use of the Adaptive Management Process identified in Sections 7.13 and potentially 7.14 of the FMA, as the EAHCP transitions from Phase I to Phase II, to answer the following questions (FMA §7.13.7):

GLOSSARY OF TERMS INCLUDED IN THE 2018 EAHCP ANNUAL REPORT (continued)

Term or Phrase	Term or Phrase Definition
	• Are any of the current Biological Objectives not necessary to meet the Biological Goals? • Are any of the current the Biological Objectives not adequate to meet the Biological Goals? • Are any of the current Phase I Conservation Measures not necessary to meeting the Biological Objectives? • Are the Phase I Conservation Measures meeting the Biological Objectives? • Are any of the current Phase I Conservation Measures not achieving the Biological Objectives? • Has the Science Review Panel failed to make a determination, or is inconclusive about, whether the current Phase I Conservation Measures are achieving the Biological Objectives?
Texas wild-rice Reach	River segments in the San Marcos River specified in the EAHCP that provide quantitative goals associated with Texas wild-rice restoration.
Tiller	A stem produced by grass plants, and refers to all shoots that grow after the initial parent shoot grows from a seed.
Trigger	To cause an event or situation to happen or exist. In the case of the VISPO, CPMP, and SAWS ASR springflow protection programs, including the Forbearance Agreements associated therewith, a trigger would be a condition that causes or requires the curtailment of all or part of the right to make withdrawals under a specific EAA Groundwater Withdrawal Permit.
Withdrawal	An act that results in taking groundwater from the Edwards Aquifer by or through manmade facilities, including pumping.

1.0 BACKGROUND AND 2018 EDWARDS AQUIFER CONDITIONS, MANAGEMENT, AND NOTABLE CHALLENGES, EAHCP OVERSIGHT, AND COORDINATION

The Edwards Aquifer Habitat Conservation Plan (EAHCP)[6] was approved by the U.S. Fish & Wildlife Service (Service or USFWS) as a regional plan to protect the federally-listed species[7] associated with the Edwards Aquifer while helping to ensure stability of the Edwards Aquifer as a water supply for the region (RECON Environmental, Inc. [RECON] et al. 2012). After approval of the EAHCP, the Service issued an Incidental Take Permit (ITP) under the federal Endangered Species Act of 1973 (ESA), with an effective date of March 18, 2013.

The permit is ITP Number (No.) TE-63663A-1 (as amended January 21, 2015), and was issued to five cooperating Permittees: the Edwards Aquifer Authority (EAA); the City of New Braunfels (CONB); the City of San Marcos (COSM); Texas State University (Texas State); and the City of San Antonio acting by and through its San Antonio Water System (SAWS) Board of Trustees. The permit authorizes certain "Covered Activities" (EAHCP Chapter 2.0), even under circumstances where the activities may incidentally cause "take" of a Covered Species. The EAHCP identifies four categories of activities that may result in incidental take: "(1) the regulation and use of the Edwards Aquifer; (2) recreational activities in the Comal and San Marcos Springs and river ecosystems; (3) other activities in, and related to, the Comal and San Marcos Springs and river ecosystems; and (4) activities involved in and related to the implementation of the minimization and mitigation measures in these ecosystems" (EAHCP §2.1). The Adaptive Management Process (AMP) may also result in incidental take (EAHCP §2.8).

As mentioned previously, the ITP has been amended once since it was issued by the USFWS. A copy of the amended ITP is contained in **Appendix A1** of this report. Because of EAHCP implementation efforts, there have been various amendments or clarifications made to the EAHCP, or its supporting documents, since the issuance of the ITP. **Appendix A2** is a table summarizing the amendments or clarifications from November 2012 through December 2018.

The ITP provides incidental take coverage for authorized activities in Uvalde, Medina, Atascosa, Bexar, Comal, Guadalupe, Hays, and Caldwell counties, Texas, within the EAA's jurisdictional boundary, which is the area in which pumping from the Edwards Aquifer is regulated by the EAA (**Figure 1.0-1**). As shown in **Figure 1.0-1,** the Contributing Zone is part of the Edwards Aquifer system but is not technically a part of the Edwards Aquifer itself.

The species covered under the EAHCP are listed in **Table 1.0-1**.

[6] All acronyms and abbreviations in this Annual Report are defined in the **LIST OF ACRONYMS AND ABBREVIATIONS** located on pages xxiv - xxvi.

[7] All aquatic animal and plant species referenced in this Annual Report are listed in the **LIST OF ALL SPECIES OF MANAGEMENT INTEREST REFERENCED** located on pages xxvii - xxviii.

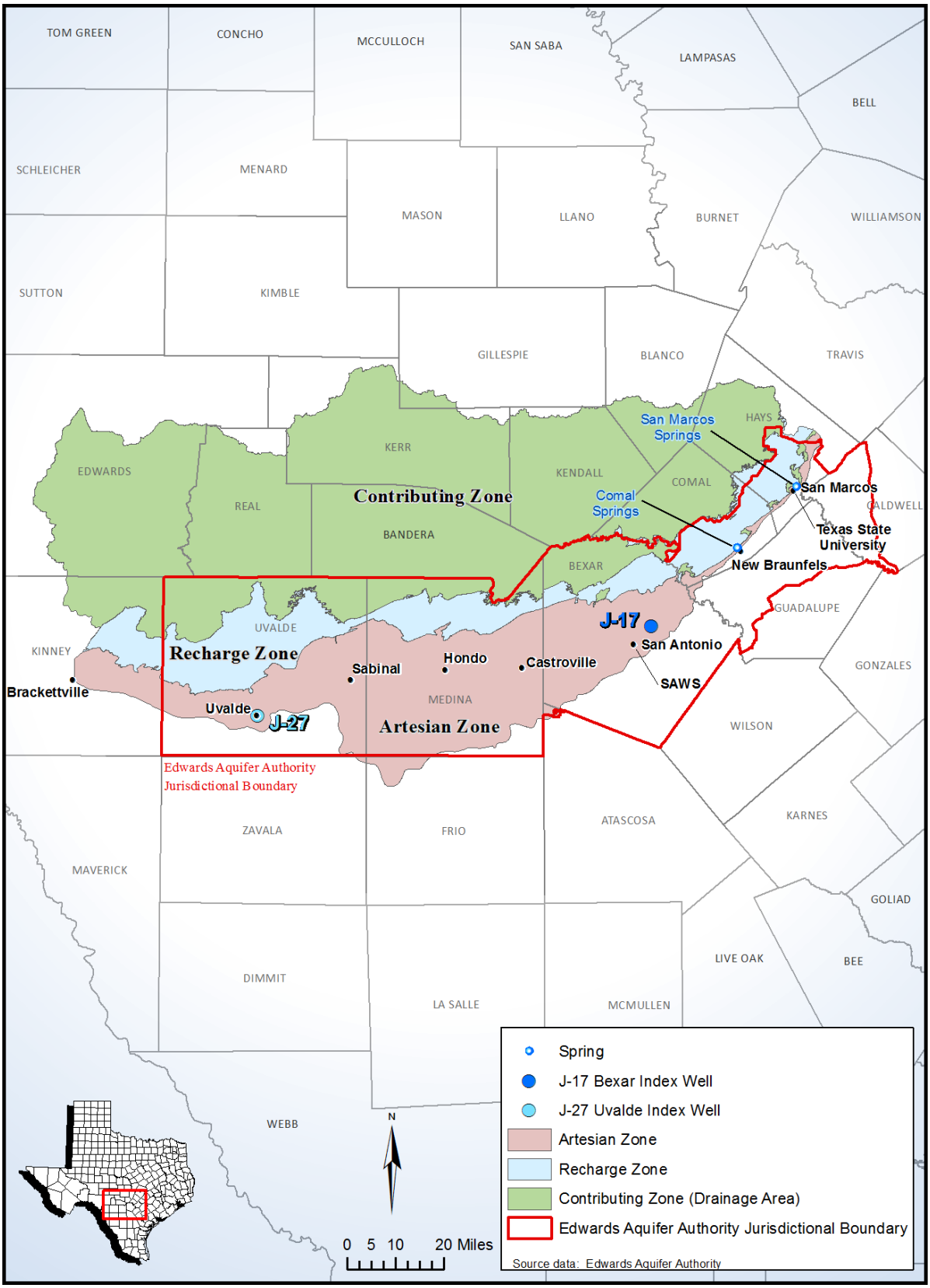

Figure 1.0-1. Incidental Take Coverage Area for ITP No. TE-63663A-1 (EAA Jurisdictional Boundary).

Table 1.0-1. Covered Species Under the EAHCP ITP

Common Name	Scientific Name	Federal Status	Associated Springs in the EAHCP
Fountain darter	*Etheostoma fonticola*	Endangered	Comal & San Marcos
San Marcos gambusia	*Gambusia georgei*	Endangered	San Marcos
Comal Springs dryopid beetle	*Stygoparnus comalensis*	Endangered	Comal
Comal Springs riffle beetle	*Heterelmis comalensis*	Endangered	Comal & San Marcos
Peck's cave amphipod	*Stygobromus pecki*	Endangered	Comal & San Marcos
Texas wild-rice	*Zizania texana*	Endangered	San Marcos
Texas blind salamander	*Eurycea (=Typhlomolge) rathbuni*	Endangered	San Marcos
San Marcos salamander	*Eurycea nana*	Threatened	San Marcos
Texas cave diving Beetle*	*Haideoporus texanus*	Petitioned	Comal & San Marcos
Comal Springs salamander	*Eurycea sp.*	Petitioned	Comal & San Marcos
Texas troglobitic water slater	*Lirceolus smithii*	Petitioned	San Marcos

* Also known as the "Edwards Aquifer Diving Beetle."

1.1 Incidental Take Permit Requirements

The ITP lists many requirements and conditions, among which are the elements to be included in the Annual Reports. The ITP requires an Annual Report be submitted to the USFWS Austin Ecological Services Office and to the USFWS Albuquerque Region 2 Office by March 31 of each year, for the preceding calendar year. As specified by Condition U of the ITP (see **Appendix A1**), "The report will document the Permittees' activities and permit compliance for the previous year, thus documenting progress toward the goals and objectives of the Edwards Aquifer Recovery Implementation Program (EARIP) Habitat Conservation Plan (HCP) and demonstrating compliance with the terms and conditions of this incidental take permit."

The Annual Report must include:

a. EAA permitted withdrawals;
b. Reference well levels;
c. Springflows at Comal and San Marcos springs;
d. Aquifer recharge;
e. Aquifer discharge from wells and springflow;
f. Critical period management reductions;
g. Water quality data;
h. Location of sampling sites;
i. Methods for data collection and variables measured;
j. Frequency, timing, and duration of sampling for these variables;
k. Description of the data analysis and who conducted the analysis.

The Annual Report must also document the following EAHCP Management activities:

a. Adaptive management undertaken during the year;
b. Expenditures by the EAA on implementation activities;
c. Proposed activities for the next year;
d. Report on the status of implementation of minimization and mitigation measures and their effectiveness;
e. Interim updates and final copies of any research, thesis or dissertation, or published studies accomplished in association with the EARIP or EAHCP;
f. Description of species-specific research and management actions undertaken with specific reference to the biological goals and objectives identified for each species;
g. Any changes to the Biological Goals and Key Management and Flow-related Objectives of the EAHCP and the reasons for such changes;
h. Any changes to the objectives for the monitoring program;
i. Effects on the Covered Species or Permit Area;
j. Evaluation of progress towards achieving the Biological Goals and Objectives;
k. Any recommendations regarding actions to be taken.

Table 1.1-1 identifies each condition of the ITP as it is stated in the ITP and provides a reference for the EAHCP Permittees' efforts in 2018 as documented in this Annual Report to comply with these conditions.

Table 1.1-1. ITP Conditions and EAHCP 2018 Annual Report References Documenting Permittee Compliance Efforts

ITP Condition	ITP Condition Subsection	ITP Condition Title	Annual Report Chapter, Section, Subsection, or Appendix Reference
D.		Acceptance of the permit serves as evidence that the Permittees agree to abide by all conditions stated. Terms and conditions or the permit are inclusive. Any activity not specifically permitted is prohibited. Please read through these conditions carefully as violations of permit terms and conditions could result in your permit being suspended or revoked. Violations of your permit terms and conditions that contribute to a violation of the Endangered Species Act (ESA) could also subject Permittees to criminal or civil penalties.	**1.0**
E.		The authorization granted by this Permit will be subject to full and complete compliance with and implementation of the EARIP HCP and all specific conditions contained herein. The Permit terms and conditions shall supersede and take precedence over any inconsistent provisions in the HCP or other program documents.	**1.0**
F.		This permit does not include incidental take coverage for any federal facility which withdraws groundwater from the Edwards Aquifer.	**1.0**
G.		COVERED SPECIES: This permit only authorizes incidental take of animal species, or impacts to plant species of the following 11 species: 1) Fountain Darter, 2) San Marcos Gambusia, 3) Comal Springs Dryopid Beetle, 4) Comal Springs Riffle Beetle, 5) Peck's Cave Amphipod, 6) Texas Wild Rice, 7) Texas Blind Salamander, 8) San Marcos Salamander, 9) Texas cave diving beetle, 10) Comal Springs Salamander, 11) Texas Troglobitic Water Slater	**1.0** (**Table 1.0-1.1-1**)
H.		INCIDENTAL TAKE AUTHORIZATION: The following amount of incidental take is authorized by this permit over the 15 year permit term.	**5.0** (**Table 5.0-4.2-1**)
	1.	No more than 797,000 fountain darters in Comal Springs, Landa Lake and the Comal River, and no more than 549,129 fountain darters in the San Marcos Springs, Spring Lake, and San Marcos River.	**5.0** (**Table 5.0-4.2-1**)
	2.	No more than 11,179 Comal Springs riffle beetles.	**5.0** (**Table 5.0-4.2-1**)
	3.	No more than 1,543 Comal Springs dryopid beetles.	**5.0** (**Table 5.0-4.2-1**)
	4.	No more than 18,224 Peck's cave amphipod.	**5.0** (**Table 5.0-4.2-1**)
	5.	No more than 10 Texas Blind salamanders.	**5.0** (**Table 5.0-4.2-1**)
	6.	No more than 263,857 San Marcos salamanders.	**5.0** (**Table 5.0-4.2-1**)

Table 1.1-1. ITP Conditions and EAHCP 2018 Annual Report References Documenting Permittee Compliance Efforts

ITP Condition	ITP Condition Subsection	ITP Condition Title	Annual Report Chapter, Section, Subsection, or Appendix Reference
	7.	Incidental take of the Texas cave diving beetle will be provided for individuals of the species killed, harmed, or harassed by springflows with monthly averages above 50.5 cfs (1.43 cms) during HCP Phase I; and by springflows with monthly averages above 51.2 cfs (1.45 cms) during Phase II at San Marcos Springs, if and when this species is listed as threatened or endangered and as long as the HCP is fully implemented. Take limits will be exceeded if these minimum flow rates are not met.	Not applicable as species not listed during report period.
	8.	Incidental take of the Texas troglobitic water slater will be provided for individuals of the species killed, harmed, or harassed by springflows with monthly averages above 50.5 cfs (1.43 cms) during HCP Phase I; and by springflows with monthly averages above 51.2 cfs (1.45 cms) during Phase II at San Marcos Springs, if and when this species is listed as threatened or endangered and as long as the HCP is fully implemented. Take limits will be exceeded if these minimum flow rates are not met.	Not applicable as species not listed during report period.
	9.	Incidental take of the Comal Springs salamander will be provided for individuals of the species killed, harmed, or harassed by springflows with monthly averages above 27 cfs (0.76 cms) during HCP Phase I and by continuous springflows to 45 cfs (1.27 cms) during Phase II at Comal Springs if and when this species is listed as threatened or endangered, as long as the HCP is fully implemented. Take limits will be exceeded if these minimum flow rates are not met.	Not applicable as species not listed during report period.
I.		The endangered San Marcos gambusia has not been collected since 1982 and may no longer exist in the wild, but the Service will provide incidental take coverage for individuals of this species resulting from the covered activities if the species is located or becomes established within the Permit Area, as long as the HCP is fully implemented.	Not applicable as species neither located nor established during report period.
J.		COVERED AREA: This permit only authorizes incidental take of covered species within all of Bexar, Medina, and Uvalde counties, and parts of Atascosa, Comal, Caldwell, Hays, and Guadalupe counties (Permit Area).	**1.0** (**Figure 1.0-1**)

Table 1.1-1. ITP Conditions and EAHCP 2018 Annual Report References Documenting Permittee Compliance Efforts

ITP Condition	ITP Condition Subsection	ITP Condition Title	Annual Report Chapter, Section, Subsection, or Appendix Reference
K.		The EAA will support and coordinate with the U.S. Fish and Wildlife Service (Service) on the work relating to the San Marcos Aquatic Resource Center's operation and maintenance of a series of off-site refugia at the Service's San Marcos, Uvalde, and Inks Dam facilities (Section 6.4 of the HCP). The support of the refugia will augment the existing financial and physical resources of these facilities, and provide supplementary resources for appropriate research activities, as necessary, to house and protect adequate populations of Covered Species and expanded knowledge of their biology, life histories, and effective reintroduction techniques. The use of this support will be limited to the Covered Species in the EARIP HCP.	**3.1.2**
L.		COVERED ACTIVITIES FOR WHICH THE INCIDENTAL TAKE IS AUTHORIZED - BY PERMITTEE	**1.0**
	1.	Edwards Aquifer Authority	**3.1**
	2.	City of New Braunfels	**3.2**
	3.	City of San Marcos	**3.3**
	4.	Texas State University	**3.4**
	5.	San Antonio Water System	**3.5**
M.		The Permittees are jointly responsible for the following measures that specifically contribute to recovery and for which incidental take is authorized:	**3.0**
	1.	Comal Springs, Landa Lake, and the Comal River:	**3.2**
	2.	San Marcos Springs, Spring Lake, and the San Marcos River:	**3.3** and **3.4**
N.		Upon locating a dead, injured, or sick individual of the covered species, or any other endangered or threatened species, the Permittee is required to contact the Service's Law Enforcement Office in Austin, Texas, (512) 490-0948 for care and disposition instructions. Extreme care should be taken in handling sick or injured individuals to ensure effective and proper treatment. Care should also be taken in handling dead specimens to preserve biological materials in the best possible state for analysis of cause of death. In conjunction with the care of sick or injured endangered/threatened species, or preservation of biological materials from a dead specimen, the Permittee and any contractor/subcontractor has the responsibility to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed.	No events meeting this description were reported for 2018.

Table 1.1-1. ITP Conditions and EAHCP 2018 Annual Report References Documenting Permittee Compliance Efforts

ITP Condition	ITP Condition Subsection	ITP Condition Title	Annual Report Chapter, Section, Subsection, or Appendix Reference
O.		Conditions of the permit shall be binding on, and for the benefit of, the Permittees and any successors and/or assignees. If the permit requires an amendment because of change of ownership, the Service will process it in accordance with regulations (50 CFR 13.23). Any new Permittee must meet issuance criteria per regulations at 50 CFR 13.25. The covered activities proposed or in progress under the original permit may not be interrupted, provided the conditions of the permit are being followed.	No changes in ownership, or interruptions in Covered Activities, to report.
P.		If, during the tenure of the permit, the project design and/or the extent of the habitat impacts is altered, such that there may be an increase in the anticipated take of covered species, the Permittees are required to contact the Service's Austin Ecological Services Office and obtain an amendment to this permit before commencing any construction or other activities that might result in take beyond that authorized by this permit. If authorized take is exceeded, all activities that are shown to cause take must immediately cease and any take above that authorized shall be reported to the Austin Ecological Services Field Office (505) 490-0057) within 48 hours.	No increases in anticipated take, or exceedance of authorized take, to report.
Q.		If actions associated with implementation of the EARIP HCP are shown to result in incidental take of listed species not covered by this permit, those activities that are shown to cause take must immediately cease and any take that has occurred shall be reported to the Austin Ecological Services Field Office (505) 490-0057) within 48 hours.	No events meeting this description were reported for 2018.
R.		CHANGED CIRCUMSTANCES	**4.0,** and **Appendices A3** through **A6**
T.		MONITORING REQUIREMENTS	**1.0**
	1.	The Permittees will monitor compliance with the HCP and provide an annual report as described below.	**1.1**
	2.	The Permittees will develop a monitoring program to determine whether progress is being made toward meeting the long-term biological goals and objectives.	**3.1.7**
	3.	The Permittees will develop and oversee a monitoring program to identify and assess potential impacts, including incidental take, from Covered Activities and provide a better understanding and knowledge of the species' life cycles and desirable water quality- and springflow-related habitat requirements of the Covered Species (Section 6.3 of the HCP).	**3.1.6**
U.		Annual Reporting:	See discussion below

Table 1.1-1. ITP Conditions and EAHCP 2018 Annual Report References Documenting Permittee Compliance Efforts

ITP Condition	ITP Condition Subsection	ITP Condition Title	Annual Report Chapter, Section, Subsection, or Appendix Reference
	1.	The EARIP Applicants will provide an annual report, due on March 31 of each year	**1.1**
	2.	The report will document the Permittees' activities and permit compliance for the previous year, thus documenting progress toward the goals and objectives of the EARIP HCP and demonstrating compliance with the terms and conditions of this incidental take permit. The annual report will include:	**1.1**
	a.	EAA Permitted withdrawals	**Appendix E**
	b.	Reference well levels	**Appendix D**
	c.	Springflows at Comal and San Marcos Springs	**Appendix D**
	d.	Aquifer recharge	**Appendix D**
	e.	Aquifer discharge from wells and springflow	**Appendix D**
	f.	Critical period management reductions	**3.1.5**
	g.	Water quality data	**Appendix C**
	h.	Location of sampling sites	**Appendix C**
	i.	Methods for data collection and variables measured	**Appendix C**
	j.	Frequency, timing, and duration of sampling for the variables	**Appendix C**
	k.	Description of the data analysis and who conducted the analysis	**Appendix C**
	3.	The report will document HCP Management activities, including:	See discussion below
	a.	Adaptive management activities undertaken during the year	**3.1.11.2** and **4.0**
	b.	Expenditures by the EAA on implementation activities	**1.3**
	c.	Proposed activities for the next year	**Appendices J5** through **J8**
	d.	Report on the status of implementation of minimization and mitigation measures and their effectiveness	**1.0**
	e.	Interim updates and final copies of any research, thesis or dissertation, or published studies accomplished in association with the EARIP or HCP	**3.1.7** and **7.0**
	f.	Description of species-specific research and management actions undertaken with specific reference to the biological goals and objectives identified for each species	**2.0**, **3.1.1**, **3.1.11.2**, **3.1.12**, **3.2.2**, **3.3.8,** **3.5.2**, **4.0**, and **Appendices A3** through **A6**

Table 1.1-1. ITP Conditions and EAHCP 2018 Annual Report References Documenting Permittee Compliance Efforts

ITP Condition	ITP Condition Subsection	ITP Condition Title	Annual Report Chapter, Section, Subsection, or Appendix Reference
	g.	Any changes to the Biological Goals and Key Management and Flow-related Objectives of the HCP and the reasons for such changes	No changes during report period.
	h.	Any changes to the objectives for the monitoring program	No changes during report period.
	i.	Effects on the Covered Species or Permit Area	No changes during report period.
	j.	Evaluation of progress toward achieving the Biological Goals and Objectives.	**1.4.1.2, 1.4.4, 2.0**, **3.1.1**, **3.1.11.2**, **3.1.12**, **3.2.2**, **3.3.8**, **3.5.2**, **4.0**, and **Appendices A3** through **A6**
	k.	Any recommendations regarding actions to be taken	**6.0**
	4.	Information provided in the annual report will be used to determine what, if any, adaptive management strategies should be implemented to most effectively implement the conservation program outlined in the EARIP HCP and to ensure that management changes in response to new, appropriate data are implemented in a timely fashion.	**6.0**

This document serves as the Annual Report for the calendar year 2018. The comments received on earlier drafts of the 2018 Annual Report are included in **Appendix B**.

1.2 2018 Edwards Aquifer Conditions, Management and Notable Conditions – Springflows

Well discharge and recharge data are included in the 2017 Hydrological Reports (**Appendices D1** through **D4**). **Appendix E** contains a listing of all EAA groundwater withdrawal permits.

After above average rainfall conditions in 2015 and 2016, and below average conditions in 2017, the Edwards Aquifer region experienced below average rainfall conditions during the spring and summer of 2018. By late July, some parts of the Edwards Aquifer region were categorized by the National Drought Mitigation Center as in extreme to severe drought (**Figure 1.2-1**). Comal springflow reached a low of 161 cfs on August 30, 2018 (U.S. Geological Survey [USGS] gage #08168710) and San Marcos springflow reached a low of 117 cubic feet per second (cfs) on August 29, 2018 (USGS gage #08170000). Due to prolonged low-flow conditions below 120 cfs in the San Marcos River, Condition M of the ITP was enacted on August 28, 2018, thus suspending aquatic vegetation restoration activities. After San Marcos' springflow stabilized above 120 cfs, the Condition M restoration restrictions were officially lifted on September 20, 2018. Rainfall during the fall of 2018 helped replenish the aquifer and improved springflow within the Comal and San Marcos systems.

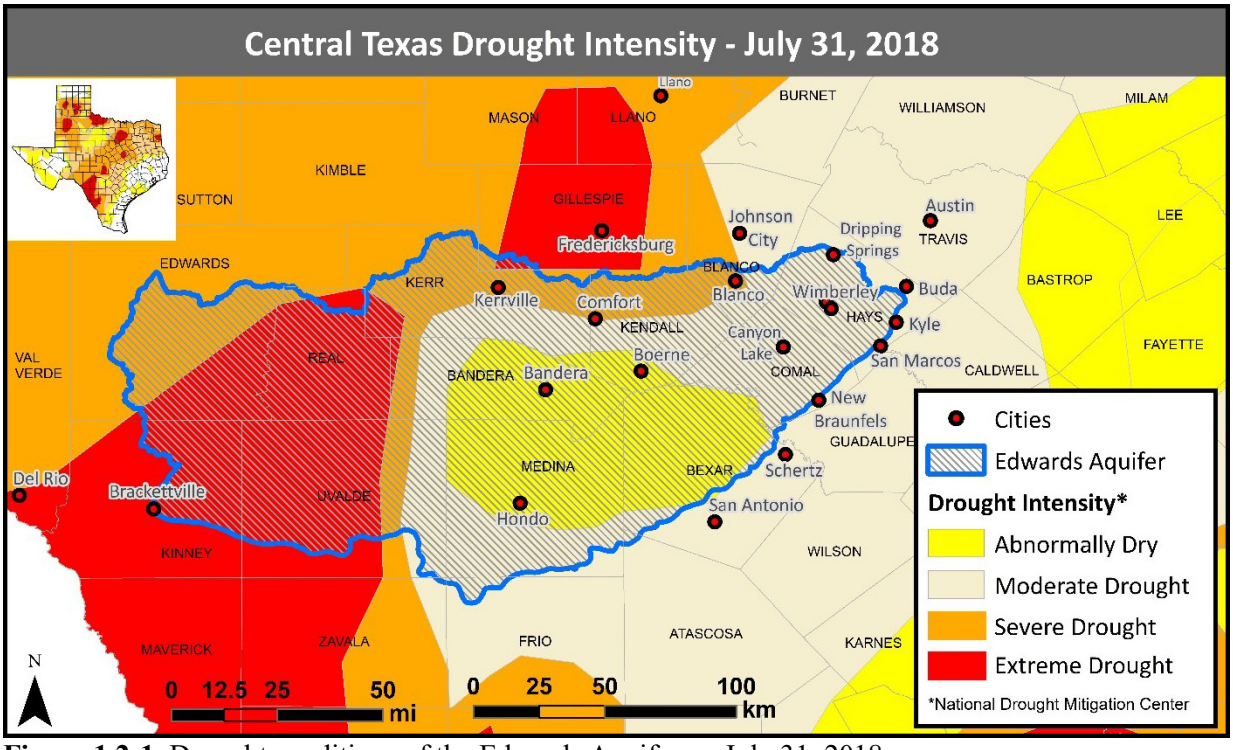

Figure 1.2-1. Drought conditions of the Edwards Aquifer on July 31, 2018.

1.3 2018 Financial Report

As specified in Section 4.6 of the Funding and Management Agreement (FMA), each year the EAA Board of Directors approves each Permittee's Program Funding Application's budget. The Program Funding

Applications are the mechanism by which the Permittees request funding to implement the Conservation Measures or other EAHCP Program-related activities. The EAA Board of Directors approved the 2018 Program Funding Applications budgets for each of the Permittees at their meeting on November 14, 2017.

Throughout the course of 2018, the EAA Board of Directors approved one amendment to the EAHCP budget to meet the needs of the program. Specifically, the item amended and adjusted was the Refugia Conservation and Adaptive Management Measure. Other transfers between various accounts for reclassification of expenditure needs had a net impact of $0 on the budget and did not require EAA Board of Directors approval. The amendments and transfers are identified in the EAHCP Expense Report located in **Appendix H** of this Annual Report.

The EAHCP Expense Report shows Table 7.1 of the EAHCP funding amounts for 2018 totaling $17,912,597. These amounts can be compared to the EAA Board-approved/amended 2018 Program Funding Applications totaling $22,571,454. **Figure 1.3-1** reflects the 2018 EAA Board-approved/amended 2018 Program Funding Applications, by budget and EAHCP activity.

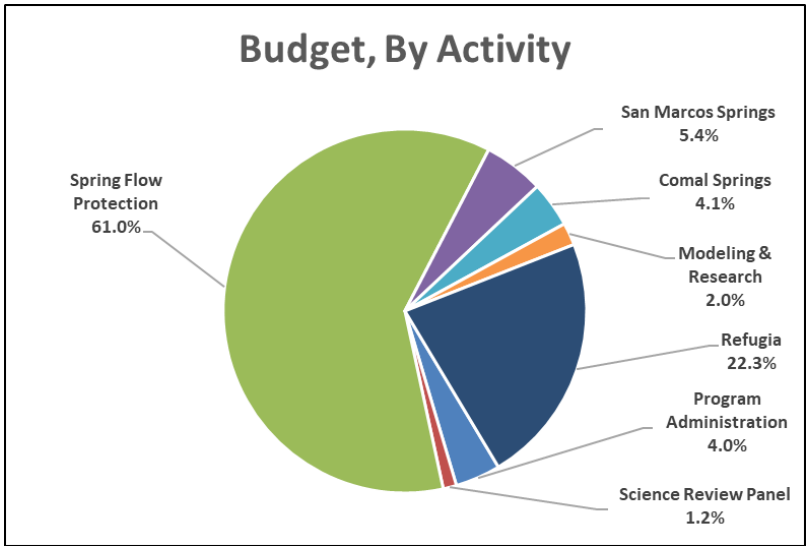

Figure 1.3-1. 2018 EAA Board-approved/amended 2018 Program Fund Applications, by budget and EAHCP activity.

The 2018 actual expenses were $21,354,428. Unspent funds in the Program Administration, ASR Operations and Maintenance, LID/BMP Management, Applied Environment Research, and Refugia budgets account for most of the difference between total approved budget and actual expenses. **Figure 1.3-2** shows the 2018 actual expenses by each EAHCP activity.

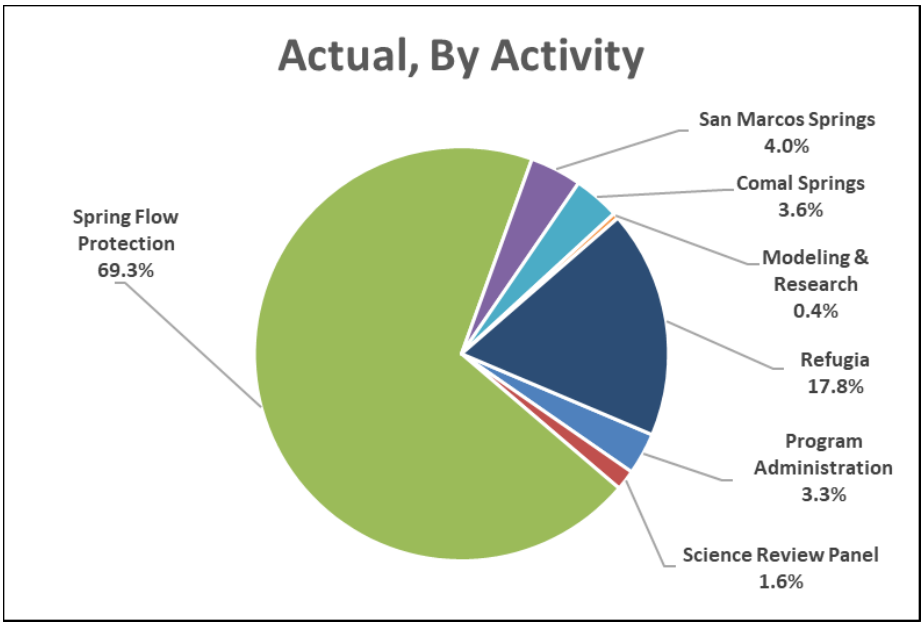

Figure 1.3-2. 2018 actual expenses by EAHCP activity.

The report also breaks down the adopted budget, Program Funding Applications budget, and actual expenses. By the end of 2018, the reserve balance for the EAHCP was $31,354,603, which includes unspent funds accumulated since the inception of the EAHCP (**Figure 1.3-3**).

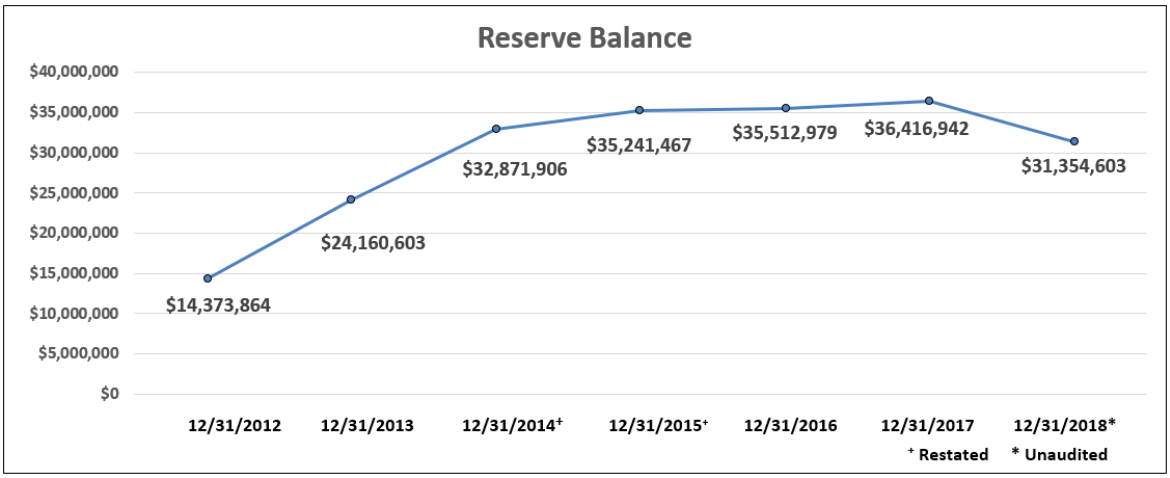

Figure 1.3-3. Reserve balances for EAHCP since program inception.

The EAHCP Expense Report also shows the actual revenue for 2018 of $16,733,938 compared to the budgeted revenue of $16,516,190, which is a variance of $217,748. Approximately 92 percent of the actual revenue comes from Aquifer Management Fees (AMFs).

1.4 2018 EAHCP Committee Activities

Article Seven of the FMA establishes the roles of four committees for the EAHCP: the Implementing Committee (IC); the Adaptive Management Stakeholder Committee (SH); the Adaptive Management

Science Committee (SC); and the Science Review Panel/National Academy of Sciences (SRP/NAS) (EAA et al. 2012). The activities of these four committees and their Work Groups in 2018 are described in the following subsections.

Also, Section 5.1.3 of the EAHCP establishes the role and responsibilities of the Regional Conservation Monitoring Committee (RCMC) (RECON et al. 2012). The activities of this committee are not covered in this Annual Report as the RCMC authorized the EAHCP Program Manager to submit a "Statement of Program Finalization" to the IC as the obligations of the Regional Water Conservation Program (RWCP) and the RCMC under the EAHCP were fulfilled in 2016.

1.4.1 Activities of the Implementing Committee

The IC supervises implementation of the EAHCP and ensures compliance with documents such as the ITP, EAHCP and FMA. There are five voting members of the IC who represent the five Permittees, and one representative of the Guadalupe-Blanco River Authority (GBRA) who serves as a non-voting member. **Table 1.4-1** lists the members of the IC for 2018. The IC met four times in 2018. The IC also met jointly with the SH once, and with the SH and SC two times, during 2018. The agendas and minutes for those meetings are provided in **Appendix I1**.

Table 1.4-1. Members of the Implementing Committee for 2018

Member	Entity	Alternate
Darren Thompson*	SAWS	Donovan Burton
Mark Enders**	CONB	Greg Malatek
Roland Ruiz***	EAA	Brock Curry
Robert Mace, Ph.D.	Meadows Center for Water and the Environment (MCWE) – Texas State	Kimberley Meitzen
Tom Taggart	COSM	Melani Howard
Nathan Pence	GBRA	Jonathan Stinson

* Committee Chair
** Committee Vice Chair
*** Committee Secretary

Highlights of the IC meetings in 2018 are listed below.

- <u>February 8, 2018:</u>
  - Approval of the Aquifer Storage and Recovery (ASR) Nonroutine AMP Proposal[8];
  - Approval to direct the Program Manager to submit the necessary ASR Nonroutine AMP Proposal documentation to the USFWS on behalf of the IC;
  - Approval to amend the 2018 Refugia, Biomonitoring, and Applied Research Work Plans;

[8] EAHCP staff originally developed a list of defined terms beginning with the EAHCP 2016 Annual Report, for words or phrases that have specific meaning within the context of discussion related to the EAHCP. The original list of defined terms was developed in response to comments received by the EAHCP staff from a Permittee and was developed to add clarity and consistency as to the standard meaning and use of these words or phrases. EAHCP staff further expanded the **GLOSSARY OF TERMS FOR THE 2018 ANNUAL REPORT**, located on pages xxix - xxxi of this Annual Report, to include terms used in the ASR Nonroutine AMP Proposal approved by the IC on February 8, 2018.

- Approval to amend the 2018 EAA Funding Application based on the amended Refugia Work Plan.

- March 22, 2018:
  - Discussion of the status of the Voluntary Irrigation Suspension Program Option (VISPO) and potential need for a Memorandum of Clarification to USFWS regarding price structure;
  - Approval of the *EAHCP 2017 Annual Report* for submittal to the USFWS;
  - Presentation of the 2017 Biological Monitoring and Water Quality Monitoring reports, schedule for contract renewals, and long-term plans.
- May 9, 2018:
  - Joint meeting of the IC, SH and SC to tour the Comal Springs Systems.
- May 17, 2018:
  - Presentation of the 2017 Recharge Estimate and 10-year Rolling Recharge Average;
  - Presentation of the EAA 2019 Work Plans;
  - Presentation of the COSM and Texas State 2019 Work Plans;
  - Presentation of the CONB 2019 Work Plans;
  - Presentation of the timeline and process to facilitate the Strategic Adaptive Management Process (SAMP);
  - Approval of the VISPO Memorandum of Clarification and authorization to the Program Manager to submit the memorandum to the USFWS.
- June 21, 2018:
  - Approval of the EAHCP 2019 Work Plan as presented on May 17, 2018, and approval to submit them to the EAA Board of Directors.
- October 18, 2018:
  - SAWS staff presentation on ASR operations;
  - Concurrence to appoint Jack Sharp to the SC;
  - Presentation of the *2018 Budget Work Group Report*;
  - Approval to amend the 2019 COSM and Texas State Work Plans;
  - Approval to amend the 2019 EAA Work Plans;
  - Approval of the 2019 EAHCP Funding Application for submittal to the EAA Board of Directors.
- December 20, 2018:
  - Joint meeting of the IC, SH and SC.

1.4.1.1 EAHCP Budget Work Group

The Budget Work Group's charge from the IC is to "collaborate with and inform the EAA Budget Process, as it relates to the EAHCP, EAHCP reserve and EAHCP AMF, and address fiscal issues as they arise and are referred by the IC." Also, as approved by the IC, the Budget Work Group will be in existence for the duration of the ITP.

The members of the Budget Work Group for 2018 were Tom Taggart (IC Member) – Budget Work Group Chair, Brock Curry (EAA Designee), Steve Raabe (SH Member), Myron Hess (SH Member), Mary Bailey (SAWS Designee), and Adam Yablonski (Member-at-Large). The Work Group met on October 4, 2018, to

review and discuss the EAA 2019 budget process to monitor the management of EAHCP revenue and expenses. The Work Group's report titled *Report of the 2018 Budget Work Group* (October 11, 2018) was submitted to the IC. Copies of the Budget Work Group's charge, meeting agenda and minutes, and final report can be found in **Appendix I2.**

1.4.1.2 Comprehensive Phase II Work Plan Work Group

The EAHCP contains a two-phased implementation strategy. Phase I involved implementing a package of Conservation Measures quickly upon issuance of the ITP. These measures (described in Chapter 5 of the EAHCP) provide protection for the species covered by the ITP and their associated ecosystems. During an AMP (described in Chapter 6 of the EAHCP), the IC is to use the information from monitoring data collected during Phase I, along with evaluating technical and engineering alternatives and improved groundwater, biological and ecological models, to make appropriate modifications, if any are needed, to the Phase I program. The EAHCP contemplated implementing specified additional measures, if necessary, to achieve the biological goals, during the second phase of the implementation strategy. In Phase II, to begin no later than Year 8 of the ITP, the specified additional measures (EAHCP §5.5.2) needed to achieve the springflows to meet the biological goals of the EAHCP may be implemented, if required.

As stated in Section 4.3 of the FMA, the IC is to develop and approve a Comprehensive Phase II Work Plan. EAHCP staff is planning to seek input from the IC, SH, SC and the public in early 2019, and to submit the Work Plan for IC approval consideration in the spring of 2019.

In advance of the public comment process, the EAHCP Program Manager created the Comprehensive Phase II Work Plan Work Group (Phase II Work Group) in late 2018. The members of the Phase II Work Group were Cindy Loeffler (Texas Parks & Wildlife Department [TPWD]), Mark Enders (CONB), Patrick Shriver (SAWS), Julia Carrillo (EAA), Nathan Pence (GBRA), and Melani Howard (COSM). Ms. Loeffler and Mr. Enders serve as Phase II Work Group co-chairs. The Phase II Work Group is charged with, while operating on a consensusbasis, reviewing and providing comments to the EAHCP Program Manager on the draft Comprehensive Phase II Work Plan prepared by EAHCP staff. To prepare the initial draft of the Work Plan, EAHCP staff carefully considered the recommendations contained in the *National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 1* (NAS *Report 1*), the *National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 2* (NAS *Report 2*), the recently-published *National Academy of Sciences – Review of the Edwards Aquifer Habitat Conservation Plan: Report 3* (NAS *Report 3*), the EAHCP SAMP Management Whitepaper, EAA drought of record (DOR) MODFLOW simulations, the FMA, and six years of EAHCP program management experience, as they relate to all EAHCP programs.

The Work Group met on November 29, 2018 and December 5, 2018, to consider and develop their recommendations. A final the Phase II Work Group Report will be presented at the IC meeting on January24, 2019. Copies of the Phase II Work Groups' charge, meeting agendas, and final report can be found in **Appendix I3**.

For additional discussion related to the NAS *Report 3*, please refer to subsection 1.4.4, Activities of the Science Review Panel/National Academy of Sciences, below.

1.4.2 Activities of the Adaptive Management Stakeholder Committee

Table 1.4-2 lists the 27 SH representatives, their affiliations, the interests they represented, and their alternates for 2018.

Table 1.4-2. Members of the Adaptive Management Stakeholder Committee in 2018

Member	Affiliation	Representing	Alternate
Myron Hess*	National Wildlife Federation	Environmental Interest from the Texas Living Waters Project	Annie Kellough
Doris Cooksey**	City Public Service Energy (CPS Energy)	CPS Energy	Louisa Eclarinal
Patrick Shriver***	SAWS	SAWS	Brandon Payne
Carl Adkins	Texas BASS Federation Nation	Recreational interest in the Guadalupe River Basin	Tim Cook
Chuck Ahrens	EAA	EAA	Javier Hernandez
Bruce Alexander	East Medina County Special Utility District	Holder of an initial regular permit issued by the EAA for a retail public utility located west of Bexar County	Tim Kelly, Mayor – City of Castroville
Buck Benson	Alamo Cement/Pulman Law	Holder of an initial regular permit issued by the EAA for industrial purposes	Shanna Castro/Paul Hunt
Roger Biggers	New Braunfels Utilities	Retail public utility in whose service area the Comal Springs or San Marcos Springs is located	Trino Pedraza
Jim Bower	City of Garden Ridge	Holder of an EAA initial regular permit issued to a small municipality (population under 50,000) located east of San Antonio	David R. Heier
James Dodson	City of Victoria	Holder of a municipal surface water right in the Guadalupe River Basin	No alternate named
Rader Gilleland	Gilleland Farms	Holder of an initial regular permit issued by the EAA for irrigation	Adam Yablonski
Renee Green	Bexar County	Bexar County	Kerim Jacaman
Cindy Hooper	Texas Commission on Environmental Quality (TCEQ)	TCEQ	Cary Betz
Melani Howard	COSM	COSM	Laurie Moyer
Dan Hunter	Texas Department of Agriculture (TDA)	TDA	David Villarreal
Cindy Loeffler	TPWD	TPWD	Colette Barron
Glenn Lord	DOW Chemical	Holder of an industrial surface water right in the Guadalupe River Basin	Dwaine Schoppe
Mark Enders	CONB	CONB	Greg Malatek
Kimberly Meitzen	Texas State	Texas State	Andy Sansom
Gary Middleton	South Central Texas Water Advisory Committee (SCTWAC)	SCTWAC	No alternate named

Table 1.4-2. Members of the Adaptive Management Stakeholder Committee in 2018

Member	Affiliation	Representing	Alternate
Con Mims	Nueces River Authority (NRA)	NRA	Sky Lewey
Kirk Patterson	Regional Clean Air and Water	Edwards Aquifer Region municipal ratepayers/general public	Carol Patterson
Nathan Pence	GBRA	GBRA	Mike Urrutia
Ray Joy Pfannstiel	Guadalupe County Farm Bureau	Agricultural producer from the Edwards Aquifer Region	Gary Schlather
Steve Raabe	San Antonio River Authority (SARA)	SARA	Allison Elder
Humberto Ramos	Guadalupe Basin Coalition	Guadalupe River Basin municipal ratepayers/general public	Mike Dussere
Dianne Wassenich	San Marcos River Foundation (SMRF)	Conservation organization	Annalisa Peace

* Committee Chair
** Committee Vice Chair
*** Committee Secretary

The SH met two times in 2018. The SH also met jointly with the IC once, and with the IC and SC two times, during 2018. The agendas and minutes for the SH meetings and joint meetings are included in **Appendix I4**.

Highlights of the SH meetings are noted below.

- February 8, 2018:
  - Presentation of the *2017 Net Disturbance and Incidental Take Assessment*;
  - Approval to recommend the ASR Nonroutine AMP Proposal; as amended;
  - Approval of an expedited process to prepare and submit the ASR Nonroutine AMP SH Report to the IC;
  - Presentation of the timeline and process to facilitate the SAMP;
  - Presentation on model inputs and assumptions for SAMP hydromodeling.
- May 9, 2018:
  - Joint meeting of the IC, SH and SC to tour the Comal Springs Systems.
- June 21, 2018:
  - USFWS presentation on the five-year status review of listed species and the status of the San Marcos Gambusia;
  - Presentation of the 2017 EAA Withdrawal Summary;
  - Discuss SC membership resignation and consider membership appointment.
- October 18, 2018:
  - Approve joint nomination to fill the SC membership vacancy;
  - Presentation and discussion of the NAS *Report 3*;
  - Presentation and discussion of MODFLOW modeling results and assumptions.
- December 20, 2018:
  - Joint meeting of the IC, SH and SC.

1.4.3 Activities of the Adaptive Management Science Committee

The SC consists of eleven experts who have technical expertise in one or more of the following areas: (a) the Edwards Aquifer or its management; (b) the Comal Springs and River; (c) the San Marcos Springs and River; or (d) the Covered Species. The SC serves as an independent scientific panel to advise, consult, and provide recommendations to the SH and IC (**Table 1.4-3**).

The SC met five times in 2018. The SC also met jointly with the IC and SH twice during 2018. The agendas and minutes for the SC meetings and joint meetings are included in **Appendix I5**.

Table 1.4-3. Members of the Adaptive Management Science Committee in 2018

Member	Affiliation	Expertise	Nominating Entity
Floyd Weckerly, Ph.D.*	Texas State	Population Ecology Experimental Design	SH
Chad Norris, M.S.**	TPWD	Aquatic Biology Aquatic Invertebrate Specialist	SH
Tom Arsuffi, Ph.D.*	Texas Tech University (TTU)	Aquatic Biology Stream Ecology	IC
Janis Bush, Ph.D.	University of Texas at San Antonio	Plant Ecology Experimental Design	SH
Jacquelyn Duke, Ph.D.	Baylor University	Stream Ecology Riparian Ecohydrology	IC
Charlie Kreitler, Ph.D.	LBG-Guyton Associates (Retired)	Hydrogeology Groundwater Science	IC
Conrad Lamon, Ph.D.	Statistical Ecology Associates LLC	Ecological Modeling	IC
Glenn Longley, Ph.D.	Edwards Aquifer Research and Data Center (Retired)	Biologist Edwards Aquifer Specialist	SH
Robert Mace, Ph.D.***	Texas Water Development Board (TWDB)	Hydrology Hydrogeology	Joint IC and SH
Doyle Mosier, M.S.	TPWD (Retired)	Instream Flows Aquatic Habitats	IC
Jackie Poole, M.A.	TPWD (Retired)	Botany/Taxonomy Texas wild-rice Specialist	SH

* Committee Chair
** Committee Vice Chair
*** Jack Sharp, Ph. D., was appointed on October 18, 2018, to fill the SC vacancy created by the departure of Dr. Robert Mace from the SC to serve on the IC.

Highlights of the 2018 SC meetings are listed below.

- January 31, 2018:
  - Approval to recommend the ASR Nonroutine AMP Proposal as amended;
  - Approval of an expedited process to prepare and to submit the ASR Nonroutine AMP Scientific Evaluation Report (SER) to the SH;
  - Presentation of the 2017 Biological Monitoring Reports;

- Approval of 2018 Work Plan Amendments for the Refugia, Biomonitoring, and the Applied Research programs;
- Presentation and discussion of formation and goals of the Research Work Group to discuss the Comal Springs riffle beetle (CRSB) Biomonitoring Program.

- March 8, 2018:
  - Presentation of the 2017 Applied Research results: *Distributional Patterns of Aquatic Macrophytes in the San Marcos and Comal Rivers from 2000 to 2015*;
  - Presentation of the 2017 Applied Research results: *Analysis of Comal Springs and San Marcos Springs Long-Term Monitoring Dataset*;
  - Presentation on possible creation of a SC Work Group ("Comal Spring riffle beetle Work Group") to review CSRB monitoring activities.
- May 9, 2018:
  - Joint meeting of the IC, SH and SC to tour the Comal Springs Systems.
- May 9, 2018:
  - Presentation on proposed methodology for the Sessom Creek Sediment Export study;
  - Approval of recommendation regarding the COSM and Texas State 2019 Work Plans;
  - Approval of recommendation regarding the CONB 2019 Work Plan;
  - Approval of recommendation regarding the EAA 2019 Work Plan;
  - Approval of creation, charge, and membership of the SC Work Group ("Comal Spring riffle beetle Work Group").
- August 9, 2018:
  - Presentation of timeline and process to facilitate the SAMP;
  - Presentation on model inputs and assumptions for SAMP hydrologic modeling;
  - Presentation of the City of New Braunfels' *Landa Lake Dissolved Oxygen Management Plan*;
  - Presentation on Spring 2018 system-wide, aquatic vegetation mapping results.
- November 7, 2018:
  - Presentation on floating vegetation mats within the Comal River system;
  - Presentation and discussion of NAS *Report 3*;
  - Presentation on MODFLOW drought of record simulations;
  - Presentation of the timeline and process to facilitate the SAMP Phase 2 Work Plan;
  - Election of a new SC Chair and Vice Chair for 2019.
- December 20, 2018:
  - Joint meeting of the IC, SH, and SC.

1.4.3.1 Research Work Group

The Research Work Group is charged with, while operating on a consensus-basis, suggesting specific Applied Research projects to be conducted during 2018 and 2019 as part of the Applied Research Program, and suggesting refinements to the methodology proposed for Refugia research projects. The Work Group meets on an as-needed basis and is expected to be in existence for the duration of the ITP. The Work Group

members are derived from the SC membership. The Work Group members are Chad Norris (TPWD), Tom Arsuffi (TTU), Floyd Weckerly (Texas State), and Conrad Lamon (Statistical Ecology Associates LLC).

The Research Work Group met on January 31, 2018 and discussed the following:

- Proposed methodology for the ongoing Refugia macroinvertebrate life history projects:
  - Peck's cave amphipod;
  - Comal Springs dryopid beetle;
  - Comal Springs riffle beetle;
- Proposed methodology for the Refugia research project: *Propagation of the San Marcos salamander*;
- Proposed methodology for evaluating the Refugia Program's invertebrate collection techniques.

The Research Work Group met on December 6, 2018 and discussed the following:

- Proposed methodology for the Refugia research project: *Factors affecting pupation in the endangered Comal Springs riffle beetle*;
- Proposed methodology for the Refugia research project: *Identifying conditions affecting pupation rates in the endangered Comal Springs riffle beetle*;
- Proposed methodology for the Refugia research project: *Captive population nutrition and longevity of the Comal Springs riffle beetle;*
- Proposed methodology for the Refugia research project: *An investigation into San Marcos salamander reproductive dysfunction;*
- Proposed methodology for the Refugia research project: *Long-term marking success of salamander species*.

Copies of the Research Work Group's charge and meeting agendas can be found in **Appendix I6**.

1.4.3.2 Comal Springs Riffle Beetle Work Group

The CSRB Work Group was formed to provide input on a specific set of questions related to management of the CSRB as implemented under the EAHCP. The Work Group is comprised of members from the SC as well as external experts to examine questions related to three primary areas – Cotton lure sampling methodology; Refugia collections and Applied Research collections – and EAHCP LTBG biological monitoring.

The Work Group met on May 24, 2018. Copies of the Work Group's charge and meeting agenda can be found in **Appendix I7**.

1.4.4 Activities of the Science Review Panel/National Academy of Sciences

In December 2013, the EAA entered into a contract with the National Academy of Sciences (NAS) to create an independent Science Review Panel (SRP) as defined in Section 7.10 of the FMA. The purpose of the SRP/NAS is to provide scientific advice in support of the EAHCP on several scientific initiatives: 1) ecological modeling; 2) hydrologic modeling; 3) biological and water quality monitoring; 4) applied research; and 5) resolve major scientific issues in the EAHCP and AMP, including the determination of the

issues specifically identified in Section 7.13.7 of the FMA. The twelve SRP/NAS members are selected by the NAS.[9]

Table 1.4-4 lists the eleven SRP/NAS members for 2018. In 2018, the SRP/NAS met once from January 3 – January 5, 2018, at the EAA's offices in San Antonio, Texas. The agenda for that meeting is provided in **Appendix I8**.

Table 1.4-4. Science Review Panel/National Academy of Sciences Members for 2018

Member	Affiliation	Area of Expertise
Danny Reible, Ph.D.*	TTU	Chemical Engineering
Jonathan Arthur, Ph.D.	Florida Geological Survey	Hydrogeology and Hydrochemistry
M. Eric Benbow, Ph.D.	Michigan State University	Entomology of Aquatic Ecosystems
Stuart E.G. Findlay, Ph.D.**	Carey Institute of Ecosystems Studies	Freshwater Ecosystems
K. David Hambright, Ph.D.	University of Oklahoma	Biology and Water Quality
Lora Harris, Ph.D.	University of Maryland	Aquatic Ecosystems, with expertise in Ecological Modeling
Steve A Johnson, Ph.D.**	University of Florida	Wildlife Ecology and Conservation
James A. Rice**	North Carolina State University	Aquatic Ecology
Kenneth A. Rose, Ph.D.	Louisiana State University	Population Modeling
J. Court Stevenson, Ph.D.**	University of Maryland (Retired)	Botany
Laura Toran, Ph.D.	Temple University	Groundwater Monitoring and Modeling

* Committee Chair
** New SRP/NAS member for Phase 3 and NAS *Report 3*

Table 1.4-5 lists former members of the SRP/NAS that served during Phases 1 and 2 of the SRP/NAS' work to support the EAHCP.

Table 1.4-5. Former Science Review Panel/National Academy of Sciences Members

Member	Affiliation	Area of Expertise
Robin K. Craig, Ph.D., J.D.	University of Utah	Water Law
Timothy K. Kratz, Ph.D.	University of Wisconsin—Madison	Aquatic Ecology
Andrew J. Long, Ph.D.	USGS	Hydrology
Laura Murray, Ph.D.	University of Maryland	Wetlands Ecology
Jayanthan Obeysekera, Ph.D.	South Florida Water Management District	Hydrologic Modeling
Greg D. Woodside, P.G., C.HG.	Orange County Water District	Watershed Management and Planning

The SRP/NAS is proceeding with a multi-year, formal review process in three distinct phases. The final deliverable for each phase consists of a published report. Phase 1 was completed in February 2015 with the publication of NAS *Report 1* (NAS 2015). This review focused on the EAHCP's hydrologic and ecological models, water quality and biological monitoring, and applied research programs.

The second phase of the SRP/NAS process was completed on December 30, 2016 with the publication of NAS *Report 2* (NAS 2016). For this second report, the SRP/NAS focused its evaluation and

[9] The NAS/National Research Council Committee is serving as the EAHCP SRP.

recommendations concerning NAS *Report 1* implementation, the EAHCP's monitoring programs, scenarios for ecological and hydrological modeling, and Conservation Measure implementation. NAS *Report 2* determined that satisfactory progress was achieved in several different EAHCP programs and also identified areas for continued improvement.

The third phase of the SRP/NAS process was initiated in the fall of 2017, with the NAS' issuance of the *Study Announcement – Review of the Edwards Aquifer Habitat Conservation Program – Phase 3* (see **Appendix O1**). NAS *Report 3* (NAS 2018) was issued in the fall of 2018 and focuses on the relationships among proposed EAHCP Conservation Measures (including flow protection and habitat restoration), Biological Objectives (such as water quality criteria, habitat condition, and specified spring flow rates), and Biological Goals (such as maintaining populations of the Covered Species). A copy of NAS *Report 3* is included in **Appendix O2**. On September 18, 2018, the NAS issued a Certificate of Compliance with the completion of NAS *Report 3* (**Appendix O3**). With the delivery of the final NAS *Report 3*, the activities of the SRP/NAS under Sections 7.9 and 7.13 of the FMA have been completed.

1.4.5 Committee and Work Group Support

During 2018, EAHCP staff successfully facilitated four IC meetings, five SC meetings, two SH meetings, one joint SH and IC meeting, one joint committee meeting (IC, SH, and SC), one SRP/NAS meeting, and organized the meetings of four Work Groups.

Public accountability and the transparency of the EAHCP process are important guiding principles for EAHCP program management and continued to be so in 2018. Thus, staff responsibilities for meeting facilitation included ensuring that committee meetings were conducted in accordance with the FMA, using the Operational Procedures of the Implementing Committee of the Edwards Aquifer Habitat Conservation Plan (Nov. 2013), the Parliamentary Rules of Condcut of the Implementing Committee of the Edwards Aquifer Habitat Conservation Plan (Nov. 2013), the Program Operational Rules for EAHCP Program Adaptive Management Stakeholder Committee Members and Participants (May 2014), and the Operational Procedures of the Science Committee of the Edwards Aquifer Habitat Conservation Plan (Apr. 2014), as may be appropriate, as a guide to best practices for providing notice, holding open sessions, and providing records of meetings. Agendas and notices for all meetings were posted a minimum of one week in advance of the meeting date, meetings were held publicly with opportunities for public comment, and minutes were posted publicly.

Facilitating meetings by EAHCP staff also included coordinating meeting logistics, such as reserving venues for meetings, preparing and providing meeting materials, and providing refreshments. For meeting venues, EAHCP Permittees and other regional Partners played an important role by providing courtesy meeting facilities and assisting with other accommodations as needed. Through the cooperation of the EAHCP Permittees and Partners in 2018, SC meetings were held at the San Marcos Activity Center and CONB's Landa Haus, IC meetings were held at the EAA and the San Marcos Activity Center, SH meetings were held at the San Marcos Activity Center and the EAA, Work Group meetings were held at the San Marcos Activity Center, the EAA, and the San Marcos Aquatic Research Center (SMARC), and the SRP/NAS meeting was held at EAA.

In addition to their work involving standing EAHCP committees in 2018, staff facilitated and executed the development of the Phase II Work Group. Between Phase II, Budget, Research and Comal Springs riffle beetle Work Groups, staff organized and facilitated six additional public meetings.

2.0 BIOLOGICAL GOALS AND OBJECTIVES FOR COVERED SPECIES

The Biological Goals and Objectives of the EAHCP were initially described in Section 4.1 of the EAHCP and are summarized below in **Table 2.0-1** through **Table 2.0-5**[10]. The identification of biological goals and objectives is one of five components in the "5-Point Policy" outlined in the HCP Handbook Addendum (USFWS and NMFS 2000) and identified in the current HCP Plan Handbook (USFWS and NMFS 2016). LTBGs are the rationale behind the minimization and mitigation strategies and, conversely, minimization and mitigation measures are the means for achieving the LTBGs and objectives.

Section 4.1 of the EAHCP includes details for all Covered Species in sections covering the LTBGs, key management objectives, flow-related objectives, historical and present-day perspective, and methods and discussion. The LTBGs, key management objectives, and flow-related objectives are subject to change under limited circumstances set out in the FMA, and they are summarized in **Table 2.0-1** through **Table 2.0-5**. The EAHCP Biological Goals and Objectives summarized in **Table 2.0-1** through **Table 2.0-5** reflect the clarifications of, and/or amendments made to, the EAHCP through 2018.

[10] The Biological Goals and Objectives have been modified from those in Section 4.0 of the EAHCP by several clarifications and amendments regarding fountain darter habitat and populations in the Comal and San Marcos rivers, as submitted by the EAHCP to the USFWS in correspondence dated September 20, 2016, which were subsequently approved by the USFWS in correspondence dated October 24, 2016 (included in the EAHCP 2016 Annual Report, Appendix A).

Table 2.0-1. Comal Springs Long-Term Biological Goals

FOUNTAIN DARTER

- **Long-Term Biological Goals:** Areal coverage of aquatic vegetation (habitat) within four representative reaches of the Comal system (Upper Spring run [upstream most portion of the system to Spring Island], Landa Lake [Spring Island to the outflow to Old and New channels], Old Channel, and New Channel) and fountain darter density (population measurement) per aquatic vegetation type (See Figure 4-1 of the EAHCP).

- **Habitat-Based and Population Measurement Goals (including proposed aquatic vegetation restoration efforts):**

Fountain Darter Habitat (Aquatic Vegetation) Goal in Meters Squared (m^2)						
Study Reach	**Bryophytes**	***Potamogeton***	***Ludwigia***	***Cabomba***	***Sagittaria***	***Vallisneria***
Upper Spring Run	1,750	0	25	25	850	0
Landa Lake	3,950	25	900	500	2,250	12,500
Old Channel	550	0	425	180	450	0
New Channel	150	0	100	2,500	0	0
TOTALS	**6,400**	**25**	**1,450**	**3,205**	**3,550**	**12,500**

Fountain Darter Median Density Goal (number/m^2)					
Bryophytes	***Potamogeton***	***Ludwigia***	***Cabomba***	***Sagittaria***	***Vallisneria***
20	3.3	7	7	1	1

- **Population Measurement Goal:** Maintain the median densities of fountain darters observed per aquatic vegetation type per system at a level greater than or equal to that observed from 2002 - 2012 in the EAA Variable Flow Study monitoring.

COMAL SPRINGS RIFFLE BEETLE

- **Habitat-Based Goal:** Maintain silt-free habitat conditions via continued springflow, riparian zone protection, and recreation control throughout each of three sample reaches: Spring Run 3; Western shoreline; and Spring Island area (See Figure 4-2 of the EAHCP).

- **Population Measurement Goal:** Maintain greater than or equal to the median densities observed from 2006 - 2012 in the EAA Variable Flow Study monitoring.

- **Long-Term Biological Goals:**

Three Sample Reaches	**Spring Run 3**	**Western Shoreline**	**Spring Island Area**
Habitat	Silt-free gravel and cobble substrate ≥ 90% of each study area		
Density (# of Species/Lure)	≥ 20	≥ 15	≥ 15

COMAL SPRINGS DRYOPID BEETLE AND PECK'S CAVE AMPHIPOD

- **Long-Term Biological Goal:** Water quality not to exceed 10% deviation (daily average) from historically recorded water quality conditions (long-term average) within the Edwards Aquifer as measured issuing from the spring openings at Comal Springs, including all water quality constituents currently measured in the EAA Variable Flow Study.

Table 2.0-2. Comal Springs Key Management Objectives (Listed in No Particular Order)

FOUNTAIN DARTER

- Implement active native vegetation restoration and protection in Landa Lake and Old Channel and extend restoration activities beyond study reaches in equal proportion to effort expended per study area in relation to total area of Landa Lake and Old Channel.
  - By establishing known "restoration reaches" with current study reaches, aquatic vegetation includes majority of key fountain darter habitat in areas upstream and downstream of Landa Lake study reach and entire stretch of the Old Channel study reach from Landa Lake Dam to existing Old Channel study reach.
  - **Fountain Darter Habitat (Aquatic Vegetation) in Meters Squared and Median Density (Number/M² Per Habitat Type) to Define "Restoration Reaches" in Comal River:**

Fountain Darter Habitat (Aquatic Vegetation) Goal in Meters Squared (m^2)							
Study Reach	**Bryophytes**	***Potamogeton***	***Ludwigia***	***Cabomba***	***Sagittaria***	***Vallisneria***	**TOTALS**
Landa Lake UP[A]	5,500	0	25	250	250	0	6,025
Landa Lake DOWN[B]	500	0	50	125	100	22,500	23,275
Old Channel UP[C]	1,250	100	850	200	750	750	3,900
TOTALS	**7,250**	**100**	**925**	**575**	**1,100**	**23,250**	**33,200**

Fountain Darter Median Density Goal (number/m^2)							
	Bryophytes	***Potamogeton***	***Ludwigia***	***Cabomba***	***Sagittaria***	***Vallisneria***	
	20	3.3	7	7	1	1	**TOTALS**
# darters * veg total	145,000	330	6,475	4,025	1,100	23,250	180,180

[A] Landa Lake Long-Term Biological Goal reach to downstream boundary of Spring Island.
[B] Landa Lake Long-Term Biological Goal reach to weir across from City of New Braunfels Park Office.
[C] Old Channel from Long-Term Biological Goal reach upstream to Landa Lake Dam.

- Surface water quality within Comal River not to exceed a 10% deviation (daily average) from historically recorded water quality conditions (long-term average) measured at 15 EAA Variable Flow Study water quality monitoring locations (See Figure 4-1 of the EAHCP for monitoring locations), including water quality constituents measured in the EAA Variable Flow Study except water temperature and dissolved oxygen.
  - Monitor and evaluate water temperatures on instantaneous basis within four representative study reaches so they are maintained at < 25° C throughout the Comal system.
  - Monitor and evaluate dissolved oxygen concentrations on instantaneous basis within four representative study reaches so they are maintained at > 4.0 mg/L throughout fountain darter habitat.

COMAL SPRINGS RIFFLE BEETLE

- Edwards Aquifer water quality not to exceed 10% deviation (daily average) from historically recorded water quality conditions (long-term average) as measured issuing from spring openings at Comal Springs, including water quality constituents measured in the EAA Variable Flow Study.
- Implement active riparian habitat restoration adjacent to spring openings (Spring Run 3 and Western Shoreline) to limit sedimentation experienced following rainfall events.

COMAL SPRINGS DRYOPID BEETLE AND PECK'S CAVE AMPHIPOD

- No discussion in the EAHCP for Key Management Objectives for these two species.

Table 2.0-3. San Marcos Springs Long-Term Biological Goals

TEXAS WILD-RICE

- **Long-Term Biological Goal:**

River Segment	Areal Coverage (m^2)	Reach Percentage of Total Areal Coverage
Spring Lake	1,000 – 1,500	N/A
Spring Lake Dam to Rio Vista Dam	5,810 – 9,245	83 – 66
Rio Vista Dam to IH-35	910 – 1,650	13 – 12
Downstream of IH-35	280 – 3,055	4 – 22
TOTALS	**8,000 – 15,450**	**100**

FOUNTAIN DARTER

- **Long-Term Biological Goals:** Areal coverage of habitat within three representative river reaches of the San Marcos system (See Figure 4-3 of the EAHCP) and fountain darter density (population measurement) per aquatic vegetation type.
- **Habitat-Based and Population Measurement Goals:**

Fountain Darter Habitat (Aquatic Vegetation) in Meters Squared (m^2)						
Study Reach	***Ludwigia***	***Cabomba***	***Potamogeton***	***Sagittaria***	***Hydrocotyle***	***Zizania***
Spring Lake Dam	100	50	200	200	50	700
City Park	150	90	1,450	300	10	1,750
IH-35	50	50	250	150	50	600
TOTALS	**300**	**190**	**1,900**	**650**	**110**	**3,050**

Fountain Darter Median Density Goal (number/m^2)					
Ludwigia	***Cabomba***	***Potamogeton***	***Sagittaria***	***Hydrocotyle***	***Zizania***
7	7	5	1	4	5

- **Population Measurement Goal:** Maintain greater than or equal to the median densities observed per aquatic vegetation type per system from 2002 - 2012 in the EAA Variable Flow Study monitoring.

SAN MARCOS SALAMANDER

- **Habitat-Based Goal:** Maintain silt-free habitat conditions via continued springflow, riparian zone protection, and recreation control throughout each of the following three sample reaches: Hotel area; Riverbed area; and eastern spillway below Spring Lake Dam (See Figures 4-3 and 4-4 of the EAHCP).
- **Population Measurement Goal:** Maintain greater than or equal to the median densities observed during monitoring from 2002 – 2012.
- **Long-Term Biological Goals:**

Three Representative Reaches	Hotel Area (Spring Lake)	Riverbed Area (Spring Lake)	Eastern Spillway Below Spring Lake Dam
Habitat	Silt-free gravel and cobble substrate ≥ 90% of each study area		
Density (# of Species/m^2)	≥ 15	≥ 10	≥ 5

TEXAS BLIND SALAMANDER

- **Long-Term Biological Goals:** Water quality not to exceed 10% deviation (daily average) from historically recorded water quality conditions (long-term average) within the Edwards Aquifer as measured issuing from the spring openings in Spring Lake, including water quality constituents currently measured in the EAA Variable Flow Study.

Table 2.0-4. San Marcos Springs Key Management Objectives (Listed in No Particular Order)

TEXAS WILD-RICE

- Minimum Texas wild-rice Coverage Per River Segment During Drought of Record-Like Conditions:

River Segment	Areal Coverage (m^2)	Reach Percentage of Total Areal Coverage
Spring Lake	500	N/A
Spring Lake Dam to Rio Vista Dam	2,490	83
Rio Vista Dam to IH-35	390	13
Downstream of IH-35	120	4
TOTALS	**3,550**	**100**

- Active restoration and Texas wild-rice expansion efforts and long-term monitoring focused on high-quality habitat areas.
- Recreation awareness throughout river system at all flows, with designated controls implemented in the following high quality habitat areas (combined river segments) when total San Marcos discharge is below 100 cfs:

Combined River Segment	TPWD Individual Segments
Spring Lake Dam to Rio Vista Dam	B, C
Rio Vista Dam to IH-35	F
Downstream of IH-35	K

FOUNTAIN DARTER

- Implement active native vegetation restoration and protection in all three representative reaches, and restoration activities to extend efforts beyond study reaches in equal proportion to effort expended per study area in relation to total river segment.
  - By establishing known "restoration reaches" with current study reaches, aquatic vegetation includes majority of key fountain darter habitat in areas upstream and downstream of the City Park study reach and entire stretch of the river from downstream of the IH-35 study reach to the IH-35 bridge.
  - **Fountain Darter Habitat (Aquatic Vegetation) in Meters Squared and Median Density (Number/M^2 Per Habitat Type) to Define "Restoration Reaches" in San Marcos River:**

Fountain Darter Habitat (Aquatic Vegetation) Goal in Meters Squared (m^2)							
Study Reach	***Ludwigia***	***Cabomba***	***Potamogeton***	***Sagittaria***	***Hydrocotyle***	***Zizania***	**TOTALS**
Sewell Park	25	25	150	25	10	1,100	1,335
Below Sewell to City Park[A]	50	50	500	700	20	2,300	3,620
Hopkins Street – Snake Island	50	50	475	750	10	950	2,285
Cypress Island – Rio Vista	50	50	150	50	0	350	650
IH-35 Expanded[B]	50	100	250	450	50	450	1,350
TOTALS	**225**	**275**	**1,525**	**1,975**	**90**	**5,150**	**9,240**

Fountain Darter Median Density Goal (number/m^2)							
	Ludwigia	***Cabomba***	***Potamogeton***	***Sagittaria***	***Hydrocotyle***	***Zizania***	
	7	7	5	1	4	5	**TOTALS**
# darters * veg total	1,575	1,925	7,625	1,975	360	25,750	39,210

[A] Sewell Park to upstream Boundary of City Park Long-Term Biological Goal reach.
[B] Immediately downstream of established IH-35 Long-Term Biological Goal reach to IH-35.

- Surface water quality within San Marcos River not to exceed a 10% deviation (daily average) from historically recorded water quality conditions (long-term average) measured at EAA Variable Flow Study water quality monitoring stations (See Figure 4-3 of the EAHCP), including water quality constituents currently measured in the EAA Variable Flow Study, excluding temperature and dissolved oxygen.
  - Monitor and evaluate water temperatures on instantaneous basis within three representative study reaches so they are maintained at < 25 °C throughout the San Marcos system.
  - Monitor and evaluate dissolved oxygen concentrations on an instantaneous basis within three representative study reaches so concentrations are maintained at > 4.0 mg/L throughout fountain darter habitat.

SAN MARCOS SALAMANDER

- Continue aquatic gardening for Riverbed Area similar to what has occurred from 2002 - 2012 in Spring Lake.
- Implement recreation control in Eastern Spillway below Spring Lake Dam, particularly at total San Marcos discharge of < 100 cfs.

TEXAS BLIND SALAMANDER

- No discussion in the EAHCP for Key Management Objectives for this species.

Table 2.0-5. Flow Related Objectives for All Covered Species – Comal and San Marcos Springs

Flow Objectives	Comal Springs	San Marcos Springs
Long-term average flow	Daily average of 225 cubic feet per second (cfs) total Comal discharge.	Daily average of 140 cfs total San Marcos discharge.
Minimum flow	Daily average of 30 cfs total Comal discharge not to exceed a period of six months followed by average daily flows of 80 cfs for three months.	Daily average of 45 cfs total San Marcos discharge not to exceed a period of six months followed by average daily flows of 80 cfs for three months.

3.0 PLAN IMPLEMENTATION IN 2018

Communication and cooperation among and between all stakeholders in the Edwards Aquifer Region were critical in developing the EARIP HCP and continue as guiding principles for operation of the EAHCP by the Permittees, TPWD, stakeholders, and the USFWS. Also, equally meaningful is the on-going collaboration that takes place between the participants and USFWS to help address developments that are identified through the process of implementing the EAHCP. Continual and focused communications with the USFWS, as occurred before, during, and after the memorandum of clarification regarding VISPO and the Nonroutine AMP in 2018 are invaluable to the program, and the commitment to open and regular communications by the USFWS and the Permittees remains unchanged.

Section 10(a)(2)(A) of the ESA requires that any application for an ITP be accompanied by an HCP. HCPs must describe the measures the applicant will undertake to monitor, minimize, and mitigate the impacts of the taking of listed species (USFWS and NMFS 1996, 2016). This chapter of the Annual Report discusses the progress achieved in 2018 towards meeting the measures outlined in the EAHCP, and the efforts to comply with the ITP requirements. This chapter describes actions by each of the Permittees and the TPWD, including subsections discussing their *EAHCP Obligations*, *2018 Compliance Actions*, and *Proposed Activities for 2019*.

The following sections describe the activities implemented in 2018 pursuant to the ITP and its conditions, as described in **Appendix A1** of this report. All measures were implemented according to the reviewed and approved 2018 Work Plans. The 2018 Work Plans approved by the IC on June 15, 2017, and as amended in 2017 and 2018, are included in this Annual Report in **Appendix J1** through **Appendix J4**. The 2019 Work Plans approved by the IC on June 21, 2018, are included in this Annual Report as **Appendix J5** through **Appendix J8**.

3.1 Edwards Aquifer Authority

The EAA is a political subdivision established by the 73rd Texas Legislature in May 1993, with the passage of the EAA Act to preserve and protect the Edwards Aquifer. As established by the Legislature, the EAA is governed by a 15-member voting elected board of directors serving staggered four-year terms with as near as possible one-half of the board being elected every two years representing stakeholder interests within an eight-county area, including all or parts of Uvalde, Medina, Atascosa, Bexar, Comal, Guadalupe, Hays, and Caldwell counties, plus two appointed nonvoting members – one from Medina or Uvalde counties serving alternating four-year terms, and one from the South Central Texas Water Advisory Committee (SCTWAC). The SCTWAC also provides regular input to the EAA and, as directed by statute, provides a status report biennially in even-numbered years on the effectiveness of the EAA.

Geologists, hydrogeologists, environmental scientists, biologists, environmental technicians, educators, and administrative staff collaborate daily to fulfill the EAA's statutory mission of managing and protecting the Edwards Aquifer to the benefit of approximately two million South Texans who rely on the Aquifer as their primary source of water.

The EAA is responsible for the following measures under the EAHCP:

- Applied Research (EAHCP §6.3.4)
- Refugia (EAHCP §5.1.1, §6.4.2, §6.4.3, and §6.4.4)
- Voluntary Irrigation Suspension Program Option (EAHCP §5.1.2)
- Regional Water Conservation Program (EAHCP §5.1.3)
- Critical Period Management Program – Stage V (EAHCP §5.1.4)
- Expanded Water Quality Monitoring (EAHCP §5.7.2)
- Biological Monitoring (EAHCP §6.3.1, §6.4.3, and §6.4.4)
- Groundwater Modeling (EAHCP §6.3.2)
- Ecological Modeling (EAHCP §6.3.3)
- Impervious Cover and Water Quality Protection (EAHCP §5.7.6)

3.1.1 Applied Research (EAHCP §6.3.4)

EAHCP Obligations:

The Applied Research Program is intended to enhance understanding of the ecology of the Comal and San Marcos aquatic ecosystems, support the development of the EAHCP Ecological Model (EcoModel), provide scientifically-rigorous information to program management concerning the EAHCP's success in meeting its stated Biological Goals and Objectives, and provide improved data and information to support refugia operations.

2018 Compliance Actions:

The initial stage of the Applied Research Program conducted studies prescribed in the EAHCP to fill critical gaps in data regarding the species and their habitat. As the new data were acquired, additional applied research questions were developed by the SC to better inform management of the systems support and compliance with the EAHCP's requirements. The studies conducted in 2018 are listed below.

Applied Research Program Activities for 2018

1) *Sessom Creek Sediment Export Study*
   Rationale and role of this study in the EAHCP process: Ongoing research in the San Marcos River system noted that sediment deposition on Texas wild-rice is a recurring issue (RECON et al. 2012, Earl and Wood 2002). Sandbar and sediment removal from the San Marcos River were not proven to be a long-lasting or cost-effective method to manage sediment accumulation and are currently considered unsuccessful. Therefore, sediment removal Conservation Measures are now directed towards enhancing sediment prevention, placing the emphasis on keeping sediments out of the system. The Sessom Creek Sediment Export Study was developed to establish a sediment loading curve for Sessom Creek, comprised of a fitted relationship between flow and entrained constituent concentration and to assess what factors are contributing to the sediment exports.

   Since March 2018, stormwater sampling has been completed for 12 storm events, resulting in 312 water samples. Water quality parameters analyzed include: sediment (total suspended solids [TSS],

nonvolatile suspended solids [NVSS], volatile suspended solids [VSS]) and nutrients (total and soluble nitrogen and phosphorous). In the 12 storm events, a wide range of conditions were captured, and preliminary modeling efforts have started to develop a predictive model for estimating sediment loads and nutrients in Sessom Creek. The study will continue into next year with the final report anticipated to be completed by December 2019.

The annual summary progress report for the Sessom Creek Sediment Export Study can be found in **Appendix K1**.

2) *Literature review on the Comal Springs riffle beetle*
Rationale and role of this study in the EAHCP process: NAS *Report 1* and NAS *Report 2* identified several shortcomings of the current methodologies to assess densities and population estimates of the CSRB. To aid in addressing the issues, a CSRB Work Group was formed and one of their primary objectives was to conduct a literature review. Specific questions of the literature review were focused at three areas in need of more research:

a) What sampling methodologies for the CSRB are feasible options for sampling in the Comal system that would provide better estimates of abundance at a locale than the cotton lure? What has been previously tried?

b) Are there other examples of environmental monitoring programs adversely effecting macroinvertebrate populations? What do recolonization studies tell us about the potential negative impacts of repeated sampling?

c) How do other HCPs around the country communicate macroinvertebrate biological goals and objectives with USFWS?

The literature review for *The Comal Spring Riffle Beetle and Suggestive Methodologies* can be found in **Appendix K2**.

Proposed Activities for 2019:

The Applied Research Program is a dynamic program in which existing research and data gaps are evaluated by EAA staff, the SC, and additional subject matter experts. Studies continue to be conducted as deemed necessary and appropriate. The SC remains an integral component of the development of research methodologies, as well as helping to resolve unforeseen conditions or challenges that may arise during applied research activities. In 2019, the SC will be participating in two separate Work Groups designed to target various research issues for the EAHCP. The first will be to reconvene the previous Research Work Group to begin discussing topics of future and current refugia research. The second one will be a Work Group designed to discuss research pertaining specifically to the CSRB.

The Sessom Creek Sediment Export Study started in 2018 will continue through 2019.

3.1.2 Refugia (EAHCP §5.1.1, §6.4.2, §6.4.3, and §6.4.4)

EAHCP Obligations:

Pursuant to Sections 5.1.1, 6.4.2, 6.4.3, and 6.4.4 of the EAHCP, the EAA supports and coordinates with the USFWS on the work relating to the SMARC operation and maintenance of two off-site refugia. ITP Condition K requires that "the support of the refugia will augment the existing financial and physical resources of these facilities, and provide supplementary resources for appropriate research activities, as necessary, to house and protect adequate populations of Covered Species and expand knowledge of their biology, life histories, and effective reintroduction techniques."

2018 Compliance Actions:

Refugia Operations

Refugia operations were established to provide protection for the Covered Species included in the ITP in accordance with the EAHCP, and to allow research on those species. Establishing off-site refugia for the Covered Species is necessary to provide back-up populations that can be used to re-establish endemic populations in case of extirpation from the wild. In 2017, the EAA contracted with the USFWS to operate off-site refugia operations at the SMARC and the Uvalde National Fish Hatchery (UNFH) and those contracts continued into 2018.

The primary activities occurring in 2018 were related to species collection, species research, and facility construction.

The Covered Species were planned for collection throughout the year by both USFWS facilities, in accordance with their 2018 Work Plan (**Appendix J2**). The species census for December 2018 is shown in **Table 3.1-1**.

Table 3.1-1 shows the number of organisms incorporated in the refugia and total census at the end of December 2018 of Edwards Aquifer organisms taken to facilities for refugia by species and facility housed. Further details of these numbers can be found in supporting documents.

Table 3.1-1. Number of Organisms Incorporated in Refugia, and Total Census as of December 2018, of Edwards Aquifer Organisms Taken to Facilities (by Species and Facility)

Species	Incorporated into Refugia SMARC	Incorporated into Refugia UNFH	SMARC Dec 31 Census	UNFH Dec 31 Census	SMARC Survival Rate	UNFH Survival Rate
Fountain darter-San Marcos *Etheostoma fonticola*	326	294	503	435	56%	81%
Fountain darter-Comal *Etheostoma fonticola*	0	0	237	48	62%	73%
Comal Springs riffle beetle *Heterelmis comalensis*	443	16	162	14	26%	21%
Comal Springs dryopid beetle *Stygoparnus comalensis*	3	0	2	0	13%	0%
Peck's Cave amphipod *Stygobromus pecki*	308	58	272	25	58%	24%
Edwards Aquifer diving beetle *Haideoporus texanus*	0	-	0	-	-	-
Texas troglobitic water slater *Lirceolus smithii*	38	0	2	0	**	-
Texas blind salamander *Eurycea rathbuni*	55	-	95	-	93%	-
San Marcos salamander *Eurycea nana*	122	99	275	232	71%	83%
Comal Springs salamander *Eurycea* sp.	40	15	72	18	83% ([1]92%)	95%
Texas wild rice plants *Zizania texana*	52	15	220	80	82%	98%

[1]Survival rate of Comal springs salamanders without escape events

** unable to distinguish wild stock from captive bred (Fx) generations; therefore, survival rate could not be calculated

During the entirety of 2018, refugia populations were held in existing facilities at the SMARC and UNFH. To accommodate for the increased housing of Covered Species needed for the refugia program (salvage stock), construction began at the SMARC facility in late 2017 and was completed in September 2018. Construction on the UNFH facility started in 2018 and is anticipated for completion in early 2019.

The *Implementation of the Refugia Program under the Edwards Aquifer Habitat Conservation Plan Annual Report 2018* can be found in **Appendix K3a.** The report contains the details of all the activities described above, the monthly progress reports, and the species propagation plans for the Covered Species.

Given the limited knowledge surrounding many of the Covered Species, a successful research program is paramount to building a successful refugia. In 2018, four research projects were completed and are described below:

1) Life-history study of Comal Springs dryopid beetles (*Stygoparnus comalensis*);
2) Life-history study of Peck's cave amphipod (*Stygobromus pecki*);
3) Continuation of CSRB (*Heterelmis comalensis*) life history and captive propagation techniques;
4) Testing a non-invasive trigger to induce reproduction in both pair-wise and group mating of San Marcos salamander.

Life history study of Comal Springs dryopid beetles (*Stygoparnus comalensis*)

Research initiated in 2017 was continued into 2018 with the focus on producing eggs and larvae of the Comal Springs dryopid beetle and understanding adult response to flow. The key objectives included: identifying sexual dimorphic characters, determining if eggs are deposited above or below water, estimating fecundity and incubation duration, identifying larval habitat, documenting larval growth rates (if possible), and identifying adult response to flow (current). Through their investigations, unique characteristics were identified to help distinguish males and females. Among 10 mating beetle pairs, egg clutch fecundity ranged from 1 to 40 eggs with about 8.25 eggs per viable female with egg incubation duration estimated to be up to 70 days. Comal Spring dryopid beetle larvae appear to utilize more terrestrial type habitat, possibly using air pockets within substrate cervices. Documenting larval growth rates has been started but further investigation continues. When given the choice, Comal Spring dryopid beetle adults tended to move against the flow even when food was in the opposite direction. The project report can be found in **Appendix K3b**.

Life history study of Peck's cave amphipod (*Stygobromus pecki*)

The focus of this study was to better understand life history traits of the Peck's cave amphipod with the main objectives being to: estimate how many molts occurred to reach sexual maturity, investigate factors effecting sex ratios, estimate fecundity and egg incubation rates, detect differences between immature sympatric congeners, and estimate growth rates. The study has been able to rear some individuals from egg, which will account for estimating growth from the first instar. Other individuals collected in the drift sampling will be used to record growth for succeeding instars. Peck's cave amphipods appear to have greater survivability in captivity compared to other congeners, but fecundity rates seem to be comparable across *Stygobromus* congeners. The project report can be found in **Appendix K3c**.

Continuation of Comal Springs riffle beetle (*Heterelmis comalensis*) life history and captive propagation techniques

The final report for the CSRB was completed in early 2018. The study was able to identify a general life-cycle for the CSRB. The study found that eggs hatch about three weeks after they are laid. The larvae then undergo six molts for a total of seven instars with the development through the first six instars taking approximately four months while the seventh instar lasts at least another four months and is unknown how long the upper duration. After a period in the seventh instar, larvae molt into pupae. After about a month, pupae molt into adults and it is thought that the life span as an adult is approximately a year. Larvae were found to prefer treatment substrates containing cloth and also had the greatest survival rates on treatments involving cloth. The full report can be found in **Appendix K3b**.

Testing a Non-Invasive Trigger to induce Reproduction in Both Pair-Wise and Group Mating of San Marcos Salamander

To date, a reliable method to successfully breed San Marcos salamanders in captivity is lacking. The main goal of this study was to test if reproduction could be reliably triggered in the San Marcos salamander by the separation/reunion technique. Other areas of focus for this study were to compare breeding success in pair-wise versus group breeding tanks and to better quantify egg production and survival rates of the San Marcos salamander in captivity. The study had mixed results with courtship observed between both the pair-wise and group breeding tanks, but only one egg clutch was deposited throughout the study. Observations from this study were able to determine that reproductive investigations should proceed with group breeding tanks rather than pair-wise. Video of courtship behaviors are being analyzed to document time to courtship and number of courtship bouts observed for the San Marcos salamander. The project report can be found in **Appendix K3d**.

Proposed Activities for 2019:

The USFWS will continue to operate off-site refugia facilities in 2019, in accordance with its contractual agreement with the EAA and the 2019 work plan found in **Appendix J6**. Main activities include completion of construction projects at SMARC and UNFH, species collections in accordance with their work plan, and research activities. The proposed 2019 refugia research projects include:

1) Environmental influences of pupation rates of CSRB (outside contractor);
2) CSRB nutrition supplementation;
3) Long-term marking success of salamander species;
4) Further investigation into San Marcos salamander reproductive dysfunction.

3.1.3 Voluntary Irrigation Suspension Program Option (EAHCP §5.1.2)

EAHCP Obligations:

The VISPO is a voluntary springflow protection program designed to compensate irrigation permit holders for not pumping from the Edwards Aquifer during certain drought conditions. Prior to 2019, participants could enroll in a five-year or 10-year program option. Enrollment commits the permit holder to suspend pumping of enrolled water for one calendar year if, on the previous October 1 trigger date, the Aquifer level at the J-17 Index Well was at or below 635 feet mean sea level (ft msl). At all other times, a participant's use of enrolled water is not restricted under the VISPO forbearance agreements, although restrictions under the EAA's CPMP continue to apply. Participants are paid an annual standby fee for their enrollment in the program and are provided an additional forbearance payment in years where water use suspension is mandated by the terms of their VISPO forbearance agreements.

Pursuant to Section 5.1.2 of the EAHCP, the EAA is responsible for administering the VISPO. The goal for this program is 40,000 acre-feet (ac-ft) of enrolled EAA-issued irrigation permits. This program accepts both "Base Irrigation Groundwater" and "Unrestricted Irrigation Groundwater" withdrawal rights. Unrestricted Irrigation Groundwater is not restricted as to its place or purpose of use, while Base Irrigation Groundwater is restricted as to place and purpose of use for irrigation use.

2018 Compliance Actions:

On October 1, 2017, the Aquifer level at the J-17 Index Well was recorded at 665.5 ft msl and therefore did not trigger VISPO forbearance by permit holders in 2018. All VISPO participants were paid only the standby amount in 2018, with combined total VISPO payments amounting to $2,228,299 as presented by county in **Table 3.1-2**. Throughout the year, several ownership changes of permits occurred requiring amendments to existing VISPO forbearance agreements including one amendment of a five-year term to a 10-year term; however, the total combined enrollment of 40,921 ac-ft., as shown in **Table 3.1-2**, remains the same as 2016. No new enrollments effective in 2018 occurred due to the VISPO program enrollment goal being met in 2014.

Table 3.1-2. VISPO Total Enrollment (in ac-ft), and Payments (in dollars), by County

Enrollment Option	Atascosa	Bexar	Comal	Hays	Medina	Uvalde	TOTALS
5-Year Base	354	764	0	67	2,818	14,532	18,535
5-Year Unrestricted	0	120	0	57	664	5,925	6,766
Subtotal	354	884	0	124	3,482	20,457	25,301
10-Year Base	0	1,451	0	0	6,152	4,183	11,786
10-Year Unrestricted	0	122	0	0	1,801	1,911	3,834
Subtotal	0	1,573	0	0	7,953	6,094	15,620
TOTAL	**354**	**2,457**	**0**	**124**	**11,435**	**26,551**	**40,921**
PAYMENTS	**$18,528**	**$136,736**	**$0**	**$6,537**	**$640,715**	**$1,425,783**	**$2,228,299**

Proposed Activities for 2019:

On October 1, 2018, the Aquifer level recorded at the J-17 Index Well was 676.9 ft msl and as a result, forbearance is not required by permit holders in 2019. Since 2019 is not a trigger year, standby payments will be made by March 2019 to all participants. All VISPO participants were notified by mail of the October 1, 2018, Aquifer level reading and that no forbearance from withdrawals will be required in 2019.

Beginning January 1, 2019, VISPO agreements totaling 9,489.024 ac-ft of groundwater withdrawal rights that are currently enrolled in the VISPO will expire as well as an additional 15,812.121 ac-ft beginning in year 2020. As of May 2018, EAA staff has been soliciting permit holders to either re-enroll or replace expiring VISPO agreements. As of the January 2019 EAA Board of Directors meeting, VISPO agreements totaling 39,645.943 ac-ft have been fully executed and will remain in effect throughout 2019.

3.1.4 Regional Water Conservation Program (EAHCP §5.1.3)

EAHCP Obligations:

The RWCP was included in the EAHCP to provide an opportunity for permit holders not currently engaged in conservation programs to have a mechanism for implementing water conservation to offset their current levels of pumping. This program includes municipal and industrial use permit holders, as well as exempt well owners.

The RWCP included the following elements:

1) Lost water and leak detection;
2) High-efficiency plumbing fixtures and toilet distribution;
3) Commercial/industrial retrofit rebate;
4) Water reclamation.

Pursuant to Section 5.1.3 of the EAHCP, the goal of the RWCP is to conserve 20,000 ac-ft of permitted or exempt Edwards Aquifer water. Of this amount, 10,000 ac-ft will be held by the EAA in the Groundwater Trust where it will remain un-pumped for the term of the ITP to reduce stress on the Aquifer, and thereby reduce stress on Comal Springs and San Marcos Springs. The other 10,000 ac-ft of conserved groundwater will remain available for withdrawal by the participating entity.

2018 Compliance Actions:

In 2016, SAWS began implementing their five-year Leak Detection and Repair Program, as outlined in their agreement with EAA under the RWCP. This Leak Detection and Repair Program satisfies the total RWCP goal for water committed into the Groundwater Trust for the remainder of the ITP. The estimated savings are shown in **Table 3.1-3** with a total savings of 19,612 ac-ft of conserved water. One-half of the conserved water (9,806 ac-ft) will be placed in the Groundwater Trust through the RWCP to remain un-pumped through 2028.

Table 3.1-3. Estimated Savings (in ac-ft) of Conserved Water

Water	2016	2017	2018	2019	2020	TOTALS
Estimated Savings (ac-ft)	4,745.00	4,745.00	4,745.00	4,745.00	632.00	**19,612.00**
Groundwater Trust (ac-ft)	2,372.50	2,372.50	2,372.50	2,372.50	316.00	**9,806.00**

SAWS reported a total of 8,747 ac-ft of water saved through increased leak repair capabilities for 2016 and 2017. For 2018, SAWS reported a total of 4,494 ac-ft of water saved. This information can be found in more detail in **Appendix K4**.

Proposed Activities for 2019:

In 2019, the EAA will continue administering the RWCP primarily through the SAWS Leak Detection and Repair Program. SAWS will report their provisional numbers to EAA in April and October of 2019. Final data will be included in an official report, which will be provided to the EAA in February of 2020.

3.1.5 Critical Period Management Program – Stage V (EAHCP §5.1.4)

EAHCP Obligations:

Stage V of the EAA Critical Period Management Program (CPMP) mandates a 44 percent reduction in the authorized groundwater withdrawal amount of EAA-issued groundwater withdrawal permits and is applicable to permit holders in both the San Antonio and Uvalde pools. For the San Antonio Pool, Stage V is triggered when the 10-day average Aquifer level at the J-17 Index Well drops below 625 ft msl, or if the springflows at Comal Springs decline below 45 cfs based on a 10-day rolling average, or below 40 cfs based on a three-day rolling average. In the Uvalde Pool, Stage V is triggered when the Uvalde County J-27 Index Well Aquifer level drops below 840 ft msl.

2018 Compliance Actions:

Due to decreased Aquifer levels and springflows, Stages I and II of the CPMP in the San Antonio Pool were triggered in 2018. Stage I was triggered on May 20, 2018, July 14, 2018 and September 13, 2018 for a total of 36 days. Stage II in the San Antonio Pool was triggered on June 10, 2018 and July 27, 2018 for 82 days in 2018. Declarations of both stages resulted in a total reduction of 8.7 percent to all permits in 2018 in the San Antonio Pool. No stages were triggered in the Uvalde Pool during 2018, and therefore, there were no reductions triggered for permits in the Uvalde Pool. **Table 3.1-4** and **Table 3.1-5** below show the requirements for all CPMP stages for both the San Antonio and Uvalde pools, respectively.

Table 3.1-4. CPMP Triggers, Stages, and Reductions for the San Antonio Pool of the Edwards Aquifer

Wells/Springs	Critical Period Stage I*	Critical Period Stage II*	Critical Period Stage III*	Critical Period Stage IV*	Critical Period Stage V**
J-17 Index Well Level (msl)	<660	<650	<640	<630	<625
San Marcos Springs Flow rate (cfs)	<96	<80	N/A	N/A	N/A
Comal Springs Flow rate (cfs)	<225	<200	<150	<100	<45** or <40**
Withdrawal Reduction	20%	30%	35%	40%	44%

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

** In order to enter into Critical Period Stage V, the applicable springflow trigger is either less than 45 cfs based on a 10-day rolling average, or less than 40 cfs, based on a three-day rolling average. Expiration of Critical Period Stage V is based on a 10-day rolling average of 45 cfs or greater.

Table 3.1-5. CPMP Triggers, Stages, and Reductions for the Uvalde Pool of the Edwards Aquifer

Wells/Springs	Critical Period Stage I*	Critical Period Stage II*	Critical Period Stage III*	Critical Period Stage IV*	Critical Period Stage V**
J-27 Index Well Level (msl)	N/A	<850	<845	<842	<840
San Marcos Springs Flow rate (cfs)	N/A	N/A	N/A	N/A	N/A
Comal Springs Flow rate (cfs)	N/A	N/A	N/A	N/A	N/A
Withdrawal Reductions	N/A	5%	20%	35%	44%

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

** In order to enter into Critical Period Stage V, the applicable springflow trigger is either less than 45 cfs based on a 10-day rolling average, or less than 40 cfs, based on a three-day rolling average. Expiration of Critical Period Stage V is based on a 10-day rolling average of 45 cfs or greater.

Proposed Activities for 2019:

In 2019, the EAA will continue to enforce CPMP restrictions, consistent with the EAA's rules and as discussed in the EAHCP.

3.1.6 Expanded Water Quality Monitoring (EAHCP §5.7.2)

EAHCP Obligations:

The EAA will continue its historical groundwater and surface water quality monitoring programs. In addition to historical monitoring, the EAA will expand its water quality monitoring efforts to include stormwater and additional groundwater and surface water sampling as necessary around Landa Lake, the Comal River, Spring Lake, and the San Marcos River.

2018 Compliance Actions:

The EAA continued the Expanded Water Quality Monitoring Program (WQP) (EAHCP §5.7.2), collecting additional samples and sample types to detect early signs of water quality impairments to the Comal and San Marcos river and spring systems. An overview of the associated data collected and sampling events for 2018 and a matrix of analytical parameters by sample type are provided in **Table 3.1-6** and **Table 3.1-7**.

Table 3.1-6. Summary of Data Types and Water Quality Sampling Events for 2018

San Marcos River	Sample Dates
Stormwater	5/4/18
Sediment	6/26/18
Passive Diffusion Samplers	2/18/18, 4/18/18, 6/18/18, 8/18/18, 10/18/18, 12/18/18
Polar Organic Chemical Integrative Sampler (only at HSM 470*)	2/18/18, 4/18/18, 6/18/18, 8/18/18, 10/18/18, 12/18/18
Comal River	**Sample Dates**
Stormwater	3/28/18
Sediment	6/27/18
Passive Diffusion Samplers	2/18/18, 4/18/18, 6/18/18, 8/18/18, 10/18/18, 12/18/18
Polar Organic Chemical Integrative Sampler (only at HCS 460)	2/18/18, 4/18/18, 6/18/18, 8/18/18, 10/18/18, 12/18/18

* For an explanation of the sampling location codes referenced in this table (e.g. HSM 470), please refer to the following:

- HSM = San Marcos; and HCS = Comal
- The number following the abbreviation is either 1, 2 or 3 to indicate whether location is:
  - 1 = surface water sampling
  - 2 = stormwater sampling
  - 3 = sediment sampling
  - 4 = passive diffusion sampling
- The last two digits correspond to a specific sample location

Table 3.1-7. Analytical Parameters by Sample Type

Analytical Parameter	Sediment Samples	Stormwater Samples	Passive Diffusion Sampling	Polar Organic Chemical Integrative Sampler
Total petroleum hydrocarbons (TPH), benzene, toluene, ethylbenzene and xylene (BTEX), 1,3,5 and 1,2,4-trimethylbenzene, methyl tert-butyl ether (MTBE), phenanthrene, naphthalene1-methyl naphthalene, octane, cis and trans-1,2-dichloroethene, 1,1-dichloroethane, chloroform, 1,1,1-trichloroethane, 1,2-dichloroethane, carbon tetrachloride, trichloroethene, tetrachloroethene, chlorobenzene, 1,4-dichlorobenzene, 1,1,2-trichloroethane, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane, 1,3-dichlorobenzene, and 1,2-dichlorobenzene.	No	No	Yes	No
Volatile Organic Compounds (VOCs)	Yes	Yes	No	No
Semi-volatile Organic Compounds (SVOCs)	Yes	Yes	No	No
Organochlorine Pesticides	Yes	Yes	No	No
Polychlorinated Biphenyls (PCBs)	Yes	Yes	No	No
Herbicides	Yes	Yes	No	No
Metals (Al, Sb, As, Ba, Be, Cd, Cr (total), Cu, Fe, Pb, Mn, Hg, Ni, Se, Ag, Tl, and Zn)	Yes	Yes	No	No
General Water Quality Parameters (GWQP); Total Alkalinity (as $CaCO_3$), Bicarbonate Alkalinity (as $CaCO_3$), Carbonate Alkalinity (as $CaCO_3$); Cl, Br, NO_3, SO4, Fl, pH, TDS, TSS, Ca, Mg, Na, K, Si, Sr, CO_3,)	No TDS or TSS	Yes	No	No
Phosphorus (total)	Yes	Yes	No	No
Total Organic Carbon (TOC)	Yes	Yes	No	No
Dissolved Organic Carbon (DOC)	Yes	Yes	No	No
Total Kjeldahl Nitrogen (TKN)	No	Yes	No	No
Bacteria (*E. coli*)	No	Yes	No	No
Field Parameters (DO, pH, Conductivity, Turbidity, Temperature)	No	Yes	No	No
TPH, BTEX, 1,3,5 and 1,2,4-trimethylbenzene, MTBE, phenanthrene, naphthalene1-methyl naphthalene, octane, cis and trans-1,2,-dichloroethene, 1,1-dichloroethane, chloroform, 1,1,1-trichloroethane, 1,2-	No	No	Yes	No

Table 3.1-7. Analytical Parameters by Sample Type

Analytical Parameter	Sediment Samples	Stormwater Samples	Passive Diffusion Sampling	Polar Organic Chemical Integrative Sampler
dichloroethane, carbon tetrachloride, trichloroethene, tetrachloroethene, chlorobenzene, 1,4-dichlorobenzene, 1,1,2-trichloroethane, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane, 1,3-dichlorobenzene, and 1,2-dichlorobenzene.				
17-a-estradiol, 17-a-ethynylestradiol, 17-b-estradiol, diethylstilbestrol, epitestosterone, estriol, estrone, progesterone, testosterone, bisphenol A, diclofenac, gemfibrozil, ibuprofen, ioperamide, naproxen, salicylic acid, triclosan, acetaminophen, amoxicillin, atenolol, atorvastatin, azithromycin, caffeine, carbamazepine, ciprofloxacin, cotinine, Diethyl-meta-toluamide (DEET), diazepam, fluoxetine, galaxolide (HHCB), meprobamate, methadone, oxybenzone, phenytoin (dilantin), praziquantel, primidone, quinoline, sucralose, sulfamethoxazole, tris(2-carboxyethyl)phosphine (TCEP), Tris (chloroisopropyl) phosphate (TCPP), Tris(1,3-dichloroisopropyl) phosphate (TDCPP), trimethoprim	No	No	No	Yes
Caffeine	No	Yes	No	No

Sampling activities were minimally affected by weather conditions in the area. Significant rainfall occurred during the first half of 2018. On March 28, 2018, the New Braunfels area received approximately 1.28 inches of rain, and the EAA was able to safely obtain stormwater samples from the Comal River. On May 4, 2018, the San Marcos area received approximately 1.02 inches of rain, and the EAA was able to safely obtain stormwater samples from the San Marcos River. Rainfall was sparse from May 2018 through the middle of August 2018. Significant rainfall occurred during the last quarter of 2018 due to El Niño conditions that impacted both the New Braunfels and San Marcos areas. The New Braunfels area received approximately 17.5 inches of rain, and the San Marcos area received approximately 13.4 inches of rain during September 2018.

Summary of 2018 Results

EAA collected passive diffusion samples, polar organic chemical integrative samples (POCIS), stormwater and sediment samples from the Comal and San Marcos spring systems. The sampling events met the

requirements of the EAHCP and provided background data for these two systems. The limited number of detections above comparative standards is indicative of generally high-water quality. However, the total non-polycyclic and polycyclic aromatic hydrocarbons (PAH) and selenium results that exceeded comparative standards were of concern.

Concentrations of bis(2-Ethylhexyl) phthalate (DEHP); methylene chloride; 2, 4-D; arsenic; iron; lead; mercury; manganese; nickel; strontium; and zinc, were above a maximum contaminant level (MCL) for water, or probable effect concentration (PEC) or Texas-specific background concentration (TSBC) for sediment metals, are listed in **Table 3.1-8.**

Table 3.1-8. Concentrations Above Maximum Contaminant Level (MCL), Probable Effect Concentration (PEC), or Texas-Specific Background Concentration (TSBC)

Sample Location	Month	Sampling Method	Detection	Concentration	MCL, PEC, or TSBC
HCS210[1] Lead 1	March 2018	Stormwater	DEHP[2]	8.33 J[3] µg/L[4]	6 µg/L
HCS270[5] Lead	March 2018	Stormwater	DEHP	8.03 J µg/L	6 µg/L
HCS310[6]	June 2018	Sediment	Nickel	12.9 mg/kg[7]	10 mg/kg
HCS310	June 2018	Sediment	Strontium	107 mg/kg	100 mg/kg
HCS310	June 2018	Sediment	Zinc	63.2 B[8] mg/kg	30 mg/kg
HCS320[9]	June 2018	Sediment	Strontium	126 mg/kg	100 mg/kg
HCS320	June 2018	Sediment	Zinc	10.1 B mg/kg	30 mg/kg
HCS330[10]	June 2018	Sediment	Strontium	180 mg/kg	100 mg/kg
HCS330	June 2018	Sediment	Zinc	10.5 B mg/kg	30 mg/kg
FDHCS330	June 2018	Sediment	Iron	15,100 mg/kg	15,000 mg/kg
FDHCS330	June 2018	Sediment	Lead	16.1 mg/kg	15 mg/kg
FDHCS330	June 2018	Sediment	Nickel	16.1 mg/kg	10 mg/kg
FDHCS330	June 2018	Sediment	Strontium	141 mg/kg	100 mg/kg
FDHCS330	June 2018	Sediment	Zinc	54.3 B mg/kg	30 mg/kg
HCS340[11]	June 2018	Sediment	Strontium	140 B mg/kg	100 mg/kg
HCS360[12]	June 2018	Sediment	Strontium	280 mg/kg	100 mg/kg
HCS360	June 2018	Sediment	Zinc	84.9 B mg/kg	30 mg/kg
HSM210 Lead 1[13]	May 2018	Stormwater	2, 4-D	0.0372 J p[14] B µg/L	0.07 µg/L
HSM230 Lead 2[15]	May 2018	Stormwater	2, 4-D	0.306 J B µg/L	0.07 µg/L
FDHSM230 Trail	May 2018	Stormwater	DEHP	17.9 J µg/L	6 µg/L
HSM231 Trail[16]	May 2018	Stormwater	Methylene Chloride	5.61 J B µg/L	5 µg/L
HSM231 Trail[17]	May 2018	Stormwater	2, 4-D	0.0855 J p B µg/L	0.07 µg/L
HSM250 Trail[18]	May 2018	Stormwater	DEHP	14.0 J µg/L	6 µg/L
HSM250 Peak	May 2018	Stormwater	2, 4-D	0.236 J B µg/L	0.07 µg/L
FDHSM260 Trail[19]	May 2018	Stormwater	2, 4-D	0.0813 J p µg/L	0.07 µg/L
HSM270 Peak[20]	May 2018	Stormwater	2, 4-D	0.171 J p B µg/L	0.07 µg/L
HSM270 Trail	May 2018	Stormwater	2, 4-D	0.0827 J p µg/L	0.07 µg/L
HSM310[21]	June 2018	Sediment	Mercury	0.0459 mg/kg	0.04 mg/kg
HSM310	June 2018	Sediment	Strontium	104 mg/kg	100 mg/kg
HSM310	June 2018	Sediment	Zinc	38.4 B mg/kg	30 mg/kg
HSM310	June 2018	Sediment	Selenium	1.78 J mg/kg	0.3 mg/kg
HSM320[22]	June 2018	Sediment	TOTAL PAH[23]	39.71 mg/kg	22.8 mg/kg
HSM320	June 2018	Sediment	Strontium	127 mg/kg	100 mg/kg
HSM320	June 2018	Sediment	Zinc	38.2 B mg/kg	30 mg/kg
HSM320	June 2018	Sediment	Selenium	0.681 J mg/kg	0.3 mg/kg
HSM330	June 2018	Sediment	Strontium	177 mg/kg	100 mg/kg
FDHSM330[24]	June 2018	Sediment	Arsenic	5.96 mg/kg	5.9 mg/kg
FDHSM330	June 2018	Sediment	Strontium	120 B mg/kg	100 mg/kg

Table 3.1-8. Concentrations Above Maximum Contaminant Level (MCL), Probable Effect Concentration (PEC), or Texas-Specific Background Concentration (TSBC)

Sample Location	Month	Sampling Method	Detection	Concentration	MCL, PEC, or TSBC
HSM340[25]	June 2018	Sediment	Arsenic	9.79 mg/kg	5.9 mg/kg
HSM340	June 2018	Sediment	Lead	26.1 mg/kg	15 mg/kg
HSM340	June 2018	Sediment	Strontium	147 mg/kg	100 mg/kg
HSM340	June 2018	Sediment	Zinc	33.8 B mg/kg	30 mg/kg
HSM340	June 2018	Sediment	Selenium	0.316 mg/kg	0.3 mg/kg
HSM350[26]	June 2018	Sediment	Mercury	0.167 mg/kg	0.04 mg/kg
HSM350	June 2018	Sediment	Strontium	132 F1[27] B mg/kg	100 mg/kg
HSM350	June 2018	Sediment	Selenium	0.395 mg/kg	0.3 mg/kg
HSM360[28]	June 2018	Sediment	Lead	127 mg/kg	15 mg/kg
HSM360	June 2018	Sediment	Strontium	153 mg/kg	100 mg/kg
HSM360	June 2018	Sediment	Selenium	0.31 mg/kg	0.3 mg/kg
HSM370[29]	June 2018	Sediment	Lead	19.7 mg/kg	15 mg/kg
HSM370	June 2018	Sediment	Manganese	330 B mg/kg	300 mg/kg
HSM370	June 2018	Sediment	Strontium	159 mg/kg	100 mg/kg
HSM370	June 2018	Sediment	Zinc	37.8 B mg/kg	30 mg/kg
HSM370	June 2018	Sediment	Selenium	0.333 mg/kg	0.3 mg/kg

[1] Site located on Klingermann Street, west of the bridge, and on the southern bank of the Comal River.
[2] Bis(2-Ethylhexyl) phthalate
[3] Detection is greater than the method detection limit, but less than the reporting limit
[4] Micrograms per liter
[5] Site located south of Union Avenue and West Lincoln Street near the eastern bank of the Comal River adjacent to the Last Tubers Exit, west of the confluence of Guadalupe and Comal rivers.
[6] Site located on Klingermann Street, west of the bridge, and on the southern bank of the Comal River.
[7] Milligrams per kilogram
[8] Compound was found in the blank and sample.
[9] Site located near upper Landa Lake and north of the island.
[10] Site located near lower Landa Lake, west of the pedestrian bridge, and on the southern bank of the Comal River.
[11] Site located on Elizabeth Street Bridge, east of the bridge, and on the northern bank of the Comal River.
[12] Site located north of Comal River Tube Chute near the western bank of the Comal River.
[13] Sink Creek segment running past the site formally known area as Texas State University Golf.
[14] The percent relative percent difference between the primary and confirmation column or detector is greater than 40%. The lower value was reported.
[15] Sessoms Creek segment running past the Texas State Freeman Aquatic Building parking lot.
[16] Site located on east of North CM Allen Parkway and western bank of San Marcos River.
[17] Sessoms Creek segment running past the Texas State Freeman Aquatic Building parking lot.
[18] Purgatory Creek segment running past Children's Park.
[19] Site located on west of North Interstate 35 Frontage Road and western bank of San Marcos River.
[20] Site located on west of Cape Street and eastern bank of San Marcos River.
[21]Sink Creek segment running past the site formally known area as Texas State University Golf.
[22] Site located at the southwest corner of Spring Lake, near the bank adjacent to the Saltgrass Steakhouse parking lot on 221 Sessoms Drive.
[23] Polycyclic aromatic hydrocarbons
[24] Sessoms Creek segment running past the Texas State Freeman Aquatic Building parking lot.
[25] Site located north of the E. Hopkins St. Bridge, south of the footbridge, close to the western bank of the San Marcos River.
[26] Site located at Rio Vista Park, east of the pedestrian bridge, and eastern bank of San Marcos River.
[27] Matrix spike and/or matrix spike duplicate recovery is outside acceptance limits.
[28] Site located on west of North Interstate 35 Frontage Road and western bank of San Marcos River.
[29] Site located on west of Cape Street and eastern bank of San Marcos River.

Stormwater Samples

Stormwater samples from the Comal and San Marcos spring systems included one storm event per system. The EAA collected either three or five samples from each sample location during a storm event. One to

three samples were collected on the rising limb of the storm hydrograph, one sample collected at the peak, and one sample collected at the tail end. DEHP was detected four times, twice in both the Comal and Sam Marcos rivers. In general, DEHP is quite problematic in that it is common in plastics and other materials. Therefore, the EAA considered DEHP as a likely laboratory or sample equipment artifact. Nonetheless, DEHP detections were "J" flagged indicating that the detection was above the method detection limit, but below the reporting limit. Merphos was detected in all samples analyzed for the San Marcos River and were "B" flagged indicating that the compound was found in the blank and sample. Therefore, the EAA considered merphos as a likely laboratory artifact. Nonetheless, merphos detections were "J" flagged indicating that the detection was above the method limit, but below the reporting limit.

Passive Diffusion Samples

Passive diffusion samples detected tetrachloroethene in all samples analyzed, except for samples from HSM 410. TPH were detected in approximately 75 percent of the samples analyzed. A few other constituents such as 1,2,4,-timethylbenzene, 1,3,5-trimethylbenzene, benzene, toluene, ethylbenzene, and xylene (BTEX), chloroform, o-xylene, p/m-xylene, and undecane were also detected in some samples. The Texas Commission on Environmental Quality (TCEQ) has established acute and chronic surface water benchmarks for freshwater aquatic life and for human consumption of water and fish (30 Texas Administrative Code (TAC) §307.6). None of the concentrations of detected constituents exceeded TCEQ surface water benchmarks for aquatic life or standards for human consumption.

Polar Organic Chemical Integrative Samplers

POCIS were deployed at HCS 460 five times and HSM 470 six times throughout 2018. Of the 43 pharmaceuticals and personal care products (PPCPs) compounds analyzed, 10 were detected. No suitable regulatory standards are available to compare to POCIS results. However, the data are used as a qualitative tool for evaluating the presence of trace concentrations of PPCPs.

Sediment Samples

PAHs are a group of semi-volatile organic compounds common in urban runoff (Mahler et al. 2005) that can have adverse effects on aquatic life including plants, invertebrates, and fish. The effects of exposure vary but can include organ damage, reproductive harm, or immune system weakening (Mahler et al. 2005). Coal-tar parking lot sealants have been identified as a significant source of PAHs in urban waterways and were banned from use in areas surrounding the Recharge Zone of the Edwards Aquifer within Comal and Hays counties by the EAA in 2012. In each sample year thus far, levels of total PAH in sediment samples have exceeded threshold effect concentrations (TEC) and PECs at HSM320.

The final 2018 Expanded Water Quality Monitoring Report, including water quality analysis reports, is included in **Appendix C1**.

Fish Tissue Sampling

The fish tissue sampling was added to the Biological Monitoring Program (BioMP) in 2017 to assess water quality conditions impact on aquatic fauna. Concentrations of PPCPs are measured within the tissue of fish

collected at select locations within the San Marcos and Comal river systems. No suitable regulatory standards are available for comparison to tissue, plasma, and surface water PPCP results. However, the data are used as a qualitative tool for evaluating the presence of trace concentrations of PPCPs. Fish tissue sampling will occur every odd year, therefore, no fish tissue sampling occurred in 2018.

Real Time Instrumentation

The objective for implementing the use of Real Time Instrumentation (RTI) was to measure changes in basic water quality parameters in near real time. The RTIs record data at 15-minute intervals, or nearly continuous basis, depending on the parameters. As such, the instrumentation provides a mechanism for recording water quality changes related to season, time of day, weather, and various other influences. The instrumentation measures the following parameters:

1) DO in milligram(s) per liter (mg/L);
2) pH standard units (SU);
3) Conductivity in micro-Siemens per centimeter (µS/cm);
4) Turbidity in nephelometric turbidity units (NTU);
5) Temperature in degrees Celsius (°C).

The resulting data are included in **Appendix C2** of this Annual Report.

Proposed Activities for 2019:

In 2019, the EAA will continue the WQP consistent with the requirements outlined in the EAHCP. An overview of the WQP 2019 Scope of Work is provided in **Table 3.1-9**.

Table 3.1-9. Overview of 2019 Expanded Water Quality Monitoring Program Scope of Work

Sampling Method	Frequency
Sediment	• Biennially in even years for both systems • Analyze full suite of compounds, as done in years 2013 – 2016; 2018
Real-time monitoring	Add one monitoring station in Comal system

Stormwater	• Reduced to one sampling event per year
	• Test only for Integrated Pest Management Plan (IPMP) chemicals at Comal Springs in odd years, as done in 2017
	  • Only at sites HCS 210* and 260
	• Test full suite of analytes in even years from both systems as done in years 2013 – 2016; 2018
	• Add two samples to the rising limb of the hydrograph for a total of five samples per location
	  • Priority given to locations at tributary outflows

Passive Diffusion Samplers	Currently conducted in both systems

Polar Organic Chemical Integrative Sampler	• Pharmaceutical and personal care product membrane
	  • Only at sites HCS 460 and HSM 470
	  • Left in place for 30-day periods, six times during the year

Tissue sampling	One sample in odd years from both systems, as done in 2017

* For an explanation of the sampling location codes referenced in this table (e.g. HSM 470), please refer to the following:

- HSM = San Marcos; and HCS = Comal
- The number following the abbreviation is either 1, 2 or 3 to indicate whether location is:
  - 1 = surface water sampling
  - 2 = stormwater sampling
  - 3 = sediment sampling
  - 4 = passive diffusion sampling

The last two digits correspond to a specific sample location

3.1.7 Biological Monitoring (EAHCP §6.3.1, §6.4.3, and §6.4.4)

EAHCP Obligations:

The BioMP represents the continuation of the EAA's Variable Flow Study, initiated in 2000, amended to include CPMP and other EAHCP-specific monitoring to monitor changes to habitat availability and population abundance of the Covered Species that may result from the Covered Activities included in the EAHCP and natural events.

The purpose of the BioMP is "to monitor changes to habitat availability and population abundance of the Covered Species that may result from Covered Activities" (EAHCP §6.3.1). Another benefit of the BioMP is to collect data that can be used in the applied research studies (EAHCP §6.3.4) and provide data and information for the EcoModel development (EAHCP §6.3.3). The BioMP includes: (1) comprehensive sampling, (2) any triggered CPMP sampling, (3) any high flow triggered monitoring, (4) any EAHCP-specific sampling required by Section 6.4 of the EAHCP.

The BioMP also includes routine and flow-triggered sampling as required by the EAHCP to monitor natural changes occurring in the system as determined to be appropriate through the AMP as outlined in Sections 6.4.3 and 6.4.4 of the EAHCP.

2018 Compliance Actions:

It is important to recognize that many different sampling components are included in the EAHCP BioMP, and that several sampling location strategies are employed. The sampling locations selected are designed to cover a representative extent of Covered Species habitats in both systems and are a subset that is used for ecological interpretation of the systems, while maximizing resources where practical, and when applicable. As such, the current design employed the following six basic sampling location strategies for the Comal and/or San Marcos systems, with associated sampling components:

1) System-wide sampling
    a) Texas wild-rice full-system mapping—annually (San Marcos only)
    b) Full system aquatic vegetation mapping—once every five years (will not be performed until 2023)
2) Select longitudinal locations
    a) Temperature monitoring—thermistors
    b) Water quality sampling—during CPMP sampling
    c) Fixed-station photography
    d) Discharge measurements (Comal system only)
3) Reach Sampling (four reaches)
    a) Aquatic vegetation mapping
    b) Fountain darter drop netting
    c) Fountain darter presence/absence dip netting
    d) Macroinvertebrate community sampling (San Marcos)
4) Springs Sampling
    a) Endangered Comal invertebrate sampling
    b) Comal Springs salamander sampling
    c) San Marcos salamander sampling
5) River Section/Segment Sampling
    a) Fountain darter timed dip net surveys
    b) Macroinvertebrate community sampling (Comal system)
    c) Fish community sampling
6) Critical Period Sampling
    a) Both systems

The 2018 Biological Monitoring Reports for both the Comal and San Marcos systems are included in **Appendix F** and **Appendix G**, respectively.

Proposed Activities for 2019:

In 2019, the BioMP will continue as completed in previous years with the vegetation mapping only occurring among the representative reaches and not a full system aquatic vegetation mapping as performed in 2018.

3.1.8 Groundwater Modeling (EAHCP §6.3.2)

EAHCP Obligations:

By December 31, 2014, the EAA will take appropriate steps to reduce the level of uncertainty in the MODFLOW model by filling in data gaps to the extent practicable and by reducing the number of structural limitations in the model, and create a new finite-element model to reduce uncertainty in the model results for use during the AMP and to provide assurance/confirmation that modeling results for the Edwards Aquifer and springflows are more reliable and defensible. The EAHCP obligations to reduce uncertainty in the MODFLOW model and develop a new finite-element model by December 31, 2014 have been met.

2018 Compliance Actions:

During 2018, the updated and recalibrated MODFLOW model was used to repeat the "bottom-up" analysis cited in the EAHCP to demonstrate the effectiveness of the four springflow protection Conservation Measures. Two separate sets of bottom-up analyses were conducted in support of the SAMP. The first set of analyses evaluated the effects on springflow of a revised SAWS ASR program with tiers 2 and 3 of the original ASR program combined into a single tier of ASR forbearance requirements, which would be triggered by a 10-year rolling average recharge equal to or less than 500,000 ac-ft/annum. The second set of bottom-up analyses evaluated the "as-implemented" Conservation Measures with the model using a revised distribution of VISPO and ASR forbearance locations according to counties where the actual points of withdrawal associated with a forbearance agreementare located; this analysis also included up to 6,000 ac-ft of federal exempt pumping and an assumption of 126,000 ac-ft of EAHCP ASR storage is available for SAWS forbearance during a repeat DOR. This second set of analyses also included evaluation of the SAWS DOR forbearance schedule and showed that some relatively minor adjustment to this schedule could be made relative to the presumptive schedule to improve the modeled likelihood of achieving the minimum springflow Biological Objectives at Comal Springs.

Other groundwater modeling activities conducted during 2018 included an uncertainty analysis conducted by the USGS under a joint funding agreement with EAA. A goal of this analysis was to identify whether there are alternative ways to calibrate the MODFLOW model that could give equally good calibration results, and the extent to which such alternative models may differ from the version used to demonstrate the effectiveness of the EAHCP springflow protection measures.

Proposed Activities for 2019:

A focus of 2019 groundwater modeling activity will be to complete the MODFLOW uncertainty analysis currently being conducted by the USGS under a joint funding agreement with EAA.

3.1.9 Ecological Modeling (EAHCP §6.3.3)

EAHCP Obligations:

The EAA will oversee and retain a contractor to develop a predictive ecological model to evaluate potential adverse ecological effects from Covered Activities and to the extent that such effects are determined to occur, to quantify their magnitude. The model results will help the Permittees develop alternative approaches or possible mitigation strategies, if necessary.

2018 Compliance Actions:

In 2016, the project team completed a time-advancing, spatially-explicit, individual-based model representing fountain darter population dynamics using EAHCP biological monitoring data collected since 2000 as the foundation. While some of the physical processes are based upon deterministic processes, others, notably dispersal, rely upon statistical models based upon the observational data base for the two rivers. Upon completion and assessment, the submerged aquatic vegetation (SAV) component was successfully linked to the fountain darter component to comprise the "coupled" model.

The developed, calibrated and operational fountain darter model completed the technical portion of this contract effort at the end of 2016. The draft and final documentation, as well as on-site training activities were performed in early 2017, completing the contract. The final report can be found in **Appendix K5.**

Proposed Activities for 2019:

The EcoModel requirements in the EAHCP were satisfied in 2017. EAHCP staff will maintain the EcoModel and use as needed in 2019 and beyond, but no additional development is necessary.

3.1.10 Impervious Cover and Water Quality Protection (EAHCP §6.3.3)

EAHCP Obligations:

The EAA will put together materials regarding the value of a ban on the use of coal tar sealants and work with local governments to explore and encourage their consideration of such a ban.

2018 Compliance Actions:

The effort to place a ban upon coal tar sealants throughout the Aquifer's Recharge Zone was officially completed in 2015 by the EAA Board of Directors. For a complete discussion of the EAA's efforts to implement this Conservation Measure, please refer to the Edwards Aquifer Habitat Conservation Plan 2015 Annual Report, Chapter 3.0 – PLAN IMPLEMENTATION IN 2015, subsection 3.1.11 – Impervious Cover and Water Quality Protection.

Proposed Activities for 2019:

The EAA continues to be available to serve as a resource for any local government that concludes future regulatory action is necessary. Additionally, the EAA will continue to enforce its coal tar rules in Section 713.703 of the EAA Rules.

3.1.11 Program Management

EAHCP Obligations:

Pursuant to Section 2.2 of the FMA, the EAA is responsible for the general management and oversight of the EAHCP, including the duties and responsibilities of the other ITP Permittees, in accordance with the ITP, Implementing Agreement (IA), EAHCP, FMA, and other program documents. Section 5.6.5 of the FMA allows for use of EAHCP monies to fund EAA administrative costs and employee salaries, so long as all incurred costs, including salaries, are with certain exceptions, not used for the costs of non-EAA Permittees' employees or administrative costs relative to the EAHCP.

Part of the EAA's responsibility includes facilitating the employment of the Program Manager, who is responsible for managing the EAHCP program, and ensuring compliance with all relevant program documents. Although referred to in the FMA as the "Program Manager," the title for this position under the EAA organizational structure is also referred to "Senior Director – Threatened and Endangered Species."

2018 Compliance Actions:

In 2018, the EAHCP staff team included the Program Manager (or Senior Director), Director, Chief Science Officer (an EAA-funded position), Senior HCP Program Coordinator, Senior Contract Coordinator, Senior Project Coordinator (an EAA-funded position), two HCP Program Coordinators, and Administrative Assistant II positions. The EAHCP staff experienced some changes as some staff left the EAA to pursue other opportunities. New EAHCP staff members filled the following positions: Program Manager, HCP Manager (formerly Director), Environmental Scientist (formerly Senior Project Coordinator), and Contract Administrator (formerly Senior Contract Coordinator).

Selected Program Management activities completed in 2018 are listed below:

1) EAHCP staff facilitated the budgeting process and financial duties as assigned by the FMA. Staff tracked the budget throughout 2018, providing updates to the IC and as needed to the EAA Board of Directors and the Finance Committee. EAHCP staff implemented the Interlocal Funding Contracts for timely reimbursements of CONB, COSM, and Texas State invoices and included procuring, managing, and tracking more than twelve contracts.
2) EAHCP staff coordinated the 2019 budget preparation process, including the timely approval of: 1) 2019 Work Plans from all Permittees; 2) 2019 Program Funding Applications from the EAA, CONB, COSM, and Texas State; and 3) additionally, EAHCP staff assisted other EAA staff with processing the 2019 Funding Applications and all other necessary budget items with the EAA Board of Directors.

3) During 2018, EAHCP staff successfully facilitated four IC meetings, five SC meetings, two SH meetings, one joint Committee meeting (IC, SH, and SC), one joint SH and IC meeting, and a two-day meeting for the SRP/NAS. Additionally, EAHCP staff facilitated and executed the development of one Work Group and organized the meetings of four Work Groups, including:
   a) Research Work Group: The Program Manager and the IC jointly determined to create an SC Work Group (Research Work Group) comprised of members from the SC to evaluate Applied Research projects conducted during 2018 and planned for 2019 as part of the Refugia Applied Research Program, and to suggest refinements to the methodology proposed for refugia research projects. The Work Group met twice (on January 31, 2018 and December 6, 2018) and discussed proposed refugia research projects.
   b) Budget Work Group: The IC created the Budget Work Group to collaborate with and inform the EAA budget process and to address fiscal issues as they arise and are referred by the Implementing Committee. This Work Group will exist for the duration of the ITP. The Budget Work Group met on October 4, 2018 to discuss The Budget Work Group met on October 4, 2018 to review and discuss the EAA 2019 budget process and monitor management of EAHCP revenue and expenses. The Budget Work Group's report, *Report of the 2018 Budget Work Group*, was submitted to the IC at its meeting on October 18, 2018. This report is included in **Appendix I2**.
   c) Phase II Work Group: At the IC meeting on October 18, 2018, the IC, under the direction of the Program Manager, created the Comprehensive Phase II Work Plan Work Group, also referred to as the Phase II Work Group, to review the NAS *Report 3* recommendations and Conservation Measures for Phase II. They met on November 29, 2018 and December 5, 2018. Their recommendations and the Phase II Work Group report will be presented at the IC meeting January 21, 2019.
   d) CSRB Work Group: The CSRB Work Group met on May 24, 2018 to discuss CSRB sampling, biological monitoring, and refugia collection methodologies.

4) In 2018, EAHCP staff continued to photograph the progress of the restoration activities in the San Marcos and Comal springs systems.

5) To facilitate communication and coordination among the Permittees in 2018, EAHCP staff and the IC members from the COSM and Texas State continued regular quarterly meetings to discuss topics relevant to the San Marcos Springs. The EAHCP Program Manager and Director continued to hold similar dialogues with the CONB on an as-needed basis. Also, the EAHCP staff had regular communications with the CONB, COSM, and Texas State staff to discuss any issues or problems with current projects. Also continued this year, the EAHCP Program Manager and the Chair of the IC, and the Chief Science Officer and the Chair and Vice Chair of the SC, held routine meetings in preparation for upcoming committee meetings.

6) For continued program transparency, the EAA maintained its contract with a local public relations firm to design and publish a bi-monthly newsletter for the EAHCP, the *EAHCP Steward*. In 2018, the EAA published six regular *EAHCP Steward* newsletters. The newsletter articles covered a variety of subjects that included stories on the following topics: "Back Up Plan – Uvalde Fish

Hatchery Site of Redundant EAA Refugia," "Funding Wishes Granted – EAHCP grant program receives $725,000 in new funding," "Give and Take – ITP gives EAHCP partners certainty in water planning," "New Program Measures in Store for ASR Leasing, VISPO," "Making Major Headway at Headwaters in New Braunfels," and "Welcoming Scott Storment."

The *EAHCP Steward* newsletter was distributed to about 400 committee members, partners, elected officials, and interested citizens. An issue of the 2018 *EAHCP Steward* newsletter is included in **Appendix K6**. Plans are to continue with six bi-monthly newsletters for 2019.

7) Additionally, the EAA also continued to publish monthly newsletters for the SAWS ASR leasing program. The *ASR Forum* is a newsletter as part of the EAHCP Program for Edwards Aquifer permit holders.

8) For additional outreach efforts in 2018, EAHCP staff gave multiple presentations to describe in detail the current implementation of EAHCP Conservation Measures, as well as to educate students, teachers, and representatives from local, regional, state, and federal environmental entities on the fundamental background of the EAHCP.

3.1.11.1 Permit Oversight

EAHCP staff is committed to maintain all regulatory permits necessary for the implementation of projects in the San Marcos and Comal systems to ensure compliance with the ITP. This does not include permits required for contractors to perform their specific tasks identified in the scope of work of a contract. The purpose of the permit oversight effort is to ensure current compliance with all federal and state regulatory permits needed for current and future projects. A permit tracking matrix was maintained to assist EAHCP staff and Permittees in identifying additional permits needed.

Staff received technical assistance from two consulting firms in developing permit applications for various state and federal agencies that included the TPWD, TCEQ, Texas Historical Commission (THC) and the U.S. Army Corps of Engineers (USACE). In 2018, EAHCP staff assisted the CONB, COSM, and Texas State in completing and submitting all permit applications and coordination letters appropriate for full compliance.

3.1.11.2 Amendments, Informational Memoranda, and Clarifications

Pursuant to Section 9.2 of the EAHCP, from time to time, it may be necessary to clarify or make amendments to the EAHCP, IA (EAA et al. 2013), FMA, or ITP to deal with issues that arise during implementation. In 2018, the Program Manager submitted one amendment and one clarification request following the approval of AMP Proposals from the IC, SH, and SC. The Program Manager did not submit any such requests to the IA, FMA, or ITP. A summary discussion of the amendment and clarification are as follows:

1) <u>Amendment to the SAWS ASR for Springflow Protection leasing structure</u>
The EAHCP includes a springflow protection program that utilizes the SAWS ASR Facility for storage and recovery of leased Edwards Aquifer water. A proposal to replace the three-tiered lease/lease option system with a simplified two-tiered leasing agreement/forbearance structure and

to revise the 10-Year Rolling Average of Estimated Recharge threshold equal to or less than 500,000 ac-ft/annum as the trigger for the duty to begin forbearance under the new ASR springflow protection forbearance agreements was presented to the IC, SH, and SC.

Appendix A3 includes this amendment request letter, and **Appendix A4** includes the response letter from the USFWS.

2) Clarification of the VISPO compensation schedule

The details of the five- and 10-year VISPO programs were developed by the EARIP VISPO Work Group to ensure prompt enrollment in 2013. Payment structures stated in the EAHCP were not intended to lock-in price points of VISPO groundwater for the term of the ITP, but rather to encourage initial participation in the program. As the first set of five-year VISPO forbearance agreements approached expiration, this clarification was sought to obtain USFWS' confirmation that the original compensation terms were intended only for rollout, and that the EAA may adjust pricing in future years to respond to market conditions as may be warranted to ensure sustained full enrollment in the VISPO program for the duration of the ITP period.

Appendix A5 includes this clarification request letter, and **Appendix A6** includes the response letter from the USFWS.

3.1.12 Challenges Observed and Identified Solutions

Edwards Aquifer Authority

For the EAA, 2018 was a year to reflect upon past successes and consider ways to fulfill its obligations for the SAWS ASR leasing program in a more efficient and cost-effective manner. This could be done by considering the realities of the groundwater market and related considerations, such as improved weather conditions. With some possible tweaking of the existing tiered lease program, experience suggests that the SAWS ASR could be filled sooner than anticipated in the modeled repeat of the DOR and the required water to offset SAWS forbearance could be secured in a simpler, more cost-efficient manner. Moreover, it is possible that doing this could result in an even more effective approach to managing groundwater through DOR conditions, adding greater certainty to the assurance of maintaining continuous minimum springflows.

Securing Full Participation in the ASR Program

Through the AMP, the revised SAWS ASR two-tiered leasing/forbearance agreement structure is more cost-efficient, and easier to explain and promote in the marketplace. The transition to a simplified two-tiered structure is easier to market and execute faster than the previous regime. Such changes are intended to enhance the program's appeal to the regional water market, thus facilitating the ultimate success of the ASR leasing/forbearance agreement program as a Conservation Measure.

EAHCP Program Management

For 2018, the EAHCP Program Management staff observed the following challenges: evaluating necessary changes to the SAWS ASR leasing structure and the VISPO compensation schedule and initiating an AMP

through the EAHCP committees; reviewing and processing recommendations provided by NAS *Report 3*; and developing a comprehensive Work Plan approach.

Adaptive Management Process: ASR and VISPO

To enhance enrollment and efficacy of the springflow protection measures, the SAWS ASR and VISPO programs were the focus of adaptive management changes in 2018. A Nonroutine AMP proposal summarizing the SAWS ASR changes was reviewed and approved by the EAHCP committees. Moreover, a clarification of the VISPO pricing parameters stated in the EAHCP was submitted to USFWS to obtain pricing flexibility for future market demands. Both changes sought to resolve issues identified over the years and will enhance the stability and sustainability of the springflow protection measures.

Implementing SRP/NAS Recommendations

As was done in 2016 and 2017 for the first and second reports from the NAS, EAHCP staff received NAS *Report 3* outlining a series of recommendations that could help in the EAHCP's implementations success and to state its determinations relative to the specific issues raised in Section 7.13.7 of the FMA. The third report focused on the relationship between the Conservation Measures, Biological Objectives, and the Biological Goals. A summary of the *Report 3* recommendations was presented by the NAS Chair, Danny Reible, at the joint IC, SH, and SC meeting on December 20, 2018. NAS *Report 3* recommendations were also compiled by EAHCP staff and discussed at the Phase II Work Group meeting whose members also comprised the NAS Report 2 Work Group. An implementation matrix of the NAS *Report 3* recommendations will be included within the Phase II Work Group Report, which will be presented to the IC in spring 2019.

EAHCP Annual Work Plan Process

Due, in part, to the complexity of implementation of many of the EAHCP's Conservation Measures, the Partners responsible for producing the annual Work Plans and Funding Applications often describe their projected work in generic terms. This result is expected because of how early in the year such planning documents are submitted for approval. Unfortunately, vague planning documents provide EAHCP staff with little comprehensive information regarding priorities, methodologies, and process for any given year's implementation strategy. Not all Conservation Measures require significant detail due to their maintenance approach, but some measures consist of complex methodological aspects and require a systematic approach to successful implementation. In addition, EAHCP staff must substantiate work completed through an internal accounting process, which requires performance to be adequately communicated in the entities' work plans, or else would require formal amendments through the EAHCP committees.

The staff worked in partnership with the EAA, CONB, COSM, and Texas State to include additional details associated with work expected to be performed in 2019. It is expected that such detail may require revisions in the future, yet such a process improves overall transparency and provides staff the adequate details to substantiate reimbursements to the Permittees.

3.2 City of New Braunfels

The CONB is responsible for implementation of the following measures under the EAHCP:

- Flow-Split Management in the Old and New Channels (EAHCP §5.2.1)
- Native Aquatic Vegetation Restoration and Maintenance (EAHCP §5.2.2)
- Management of Public Recreational Use of Comal Springs and River Ecosystems (EAHCP §5.2.3)
- Decaying Vegetation Removal and Dissolved Oxygen Management (EAHCP §5.2.4)
- Control of Harmful Non-Native Animal Species (EAHCP §5.2.5)
- Monitoring and Reduction of Gill Parasites (EAHCP §5.2.6 and §6.3.6)
- Prohibition of Hazardous Materials Transport Across the Comal River and its Tributaries (EAHCP §5.2.7)
- Native Riparian Habitat Restoration (Riffle Beetle) (EAHCP §5.2.8)
- Reduction of Non-Native Species Introduction and Live Bait Prohibition (EAHCP §5.2.9)
- Litter Collection and Floating Vegetation Management (EAHCP §5.2.10)
- Management of Golf Course Diversions and Operations (EAHCP §5.2.11)
- Native Riparian Habitat Restoration (Old Channel Improvements) (EAHCP §5.7.1)
- Management of Household Hazardous Wastes (EAHCP §5.7.5)
- Impervious Cover and Water Quality Protection (EAHCP §5.7.6)

3.2.1 Flow-Split Management in the Old and New Channels of the Comal River (EAHCP §5.2.1)

EAHCP Obligations:

The CONB will control flow entering the Old and New Channels of the Comal River from Landa Lake using the culverts and flow-control structures located between Landa Lake and the Old Channel of the Comal River. The purpose of this activity is to maintain optimal habitat conditions for the Covered Species under varying total flow conditions in the system per the Flow-Split Management Plan and Flow-Split Goals described in the EAHCP and revised in 2016 as part of the EAHCP AMP that was approved by USFWS in October 2016. The revised Table 5-3 is re-stated in this Annual Report as **Table 3.2-1.** below.

2018 Compliance Actions:

CONB staff routinely monitored streamflow conditions in the Comal River system based on local USGS streamflow gaging stations. CONB staff adjusted the flow-control gates between Landa Lake and the Old Channel of the Comal River as-needed throughout 2018 to meet streamflow targets specified in **Table 3.2-1.**

Table 3.2-1. Flow-Split Management for Old and New Channels

Total Comal	Old Channel (cfs)			New Channel (cfs)		
Springflow (cfs)	Fall, Winter		Spring, Summer	Fall, Winter		Spring, Summer
350+	65		60	280+		290+
300	65		60	235		240
250	60		55	190		195
200	60		55	140		145
150		55			95	
100		50			50	
80		45			35	
70		40			30	
60		35-40			25	
50		35-40			15	
40		30			10	
30		20			10	

Proposed Activities for 2019:

The CONB will continue to monitor flow rates in the Old and New Channels of the Comal River and will operate the flow-control gates to meet the flow objectives specified in **Table 3.2-1**.

3.2.2 Native Aquatic Vegetation Restoration and Maintenance (EAHCP §5.2.2)

EAHCP Obligations:

The CONB will implement an Aquatic Vegetation Restoration Program within key, sustainable reaches of the Comal River system including Landa Lake, the Upper Spring Run area, and portions of the Old and New Channels. Restoration activities include the removal of non-native aquatic plant species, planting of target native aquatic plant species, and maintenance of restored areas. The overall goal of the Aquatic Vegetation Restoration Program is to improve habitat conditions for the fountain darter by increasing the amount of usable habitat and by improving the quality of existing habitat in the Comal River system.

2018 Compliance Actions:

Aquatic vegetation restoration activities occurred within Landa Lake, the Old Channel of the Comal River and in the Upper New Channel of the Comal River in 2018. **Figure 3.2-1** indicates the location of the Landa Lake, Upper Spring Run, Old Channel and Upper New Channel LTBG Reaches all outlined in red, as well as the individual restoration reaches outlined in yellow.

Aquatic vegetation restoration activities in 2018 included 1) removal of non-native aquatic vegetation (i.e. *Hygrophila*), 2) planting of native aquatic plants, and 3) monitoring, mapping, and gardening of restored areas.

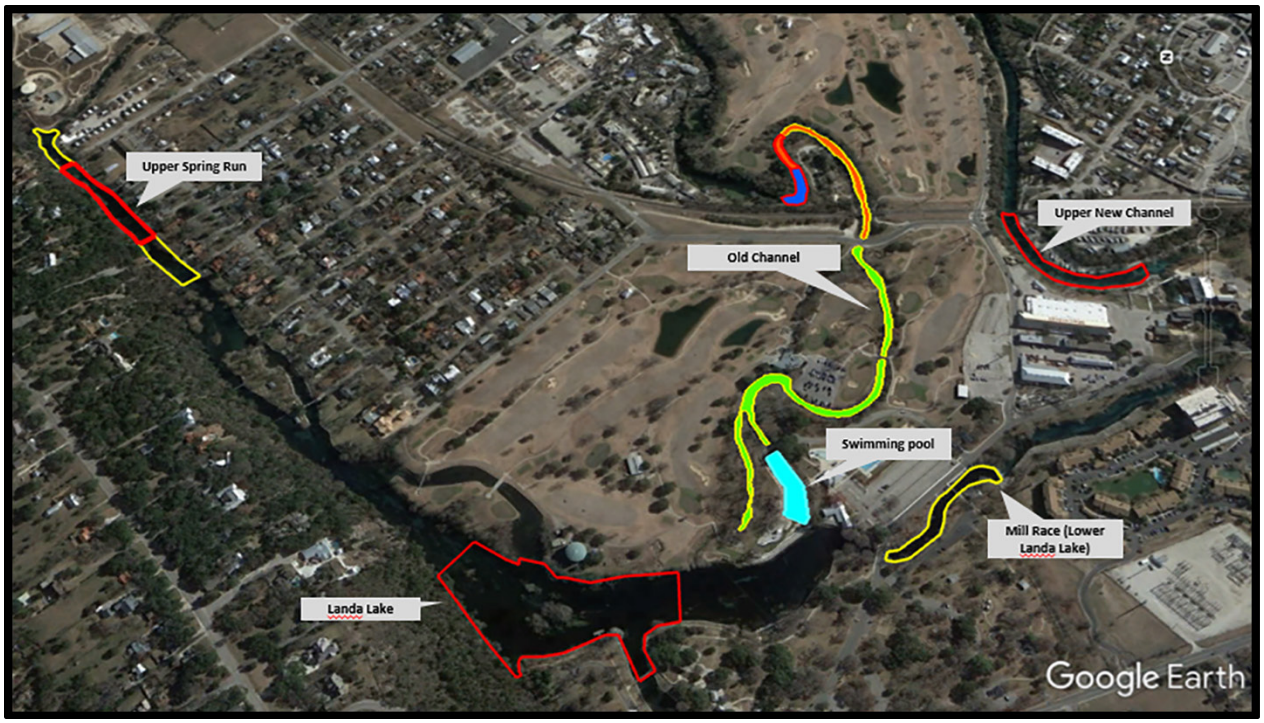

Figure 3.2-1. LTBG reaches and restoration reaches within the Comal River system.

The following sub-sections include summaries of 2018 work activities and results for each individual restoration reach.

Old Channel Aquatic Vegetation Restoration Results & Discussion

In 2018, 479 square meters (m^2) of area was planted in seven restoration plots within the Old Channel LTBG and Restoration reaches (**Figure 3.2-2**). A total of 5,460 plants were installed in 2018 within the Old Channel Restoration Reach and LTBG Reach combined (**Table 3.2-2**). A total of 3,253 plants were planted within new restoration plots with the remainder planted as supplemental plantings in previously established plots.

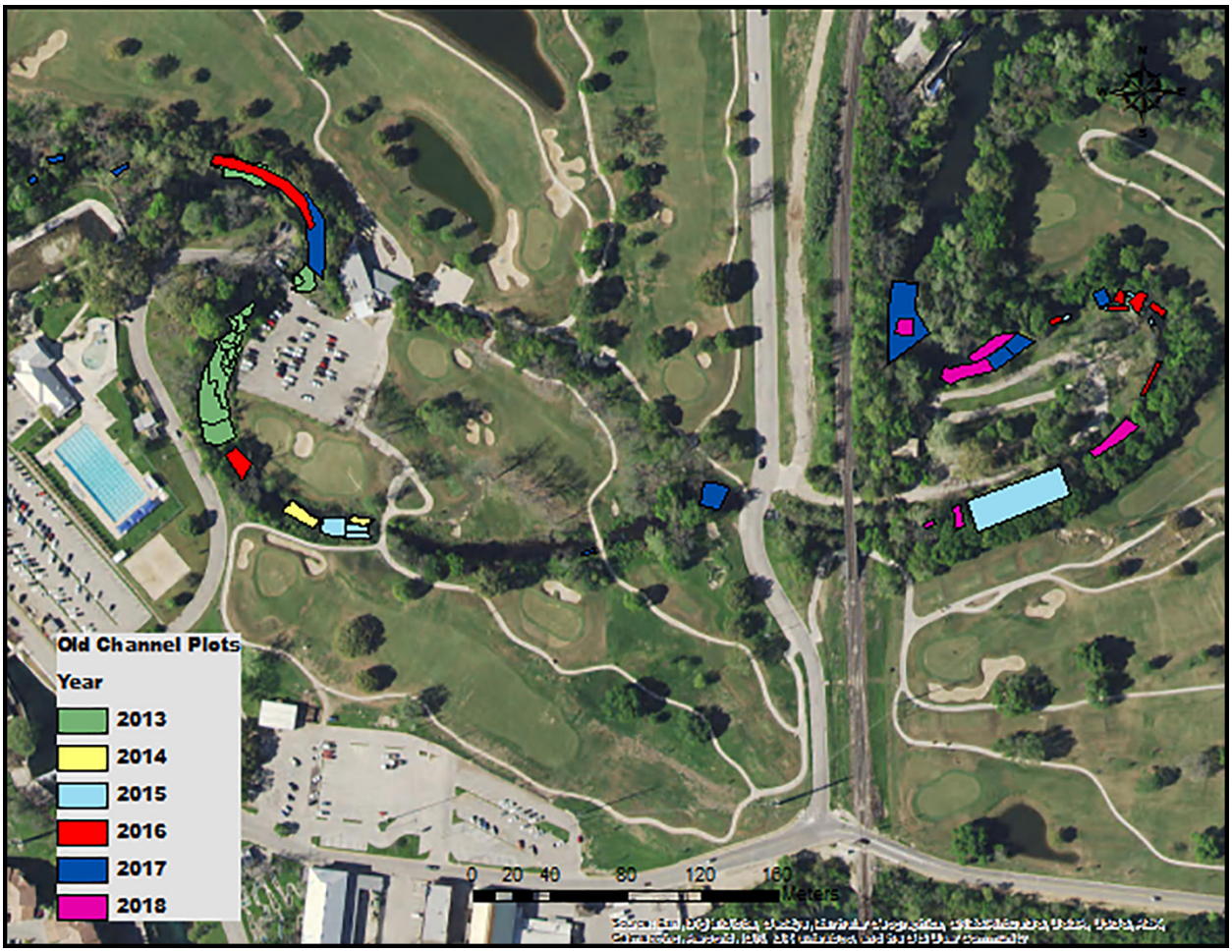

Figure 3.2-2. Aquatic vegetation restoration plots in the Old Channel Restoration and LTBG reaches.

Table 3.2-2. Number of Native Plants Planted Within the Old Channel LTBG and Restoration Reaches, by Plot, in 2018

2018 Old Channel Restoration Plantings				
Date Planted	**Plot**	***Ludwigia***	***Sagittaria***	***Cabomba***
Old Channel LTBG Reach				
5/08/2018	2018A	**288**		
5/10/2018	2017J		200	
6/04/2018	2017G			**150**
6/05/2018	2017G			**35**
6/08/2018	2017J		600	
7/10/2018	2018B			**360**
7/11/2018	2018B			**700**
7/12/2018	2018B			**144**
7/13/2018	2018C	**144**		
7/17/2018	2018D		335	
7/25/2018	2017J		300	
7/26/2018	2017J		225	
7/27/2018	2017J		312	
TOTALS		**432**	**1,972**	**1,389**

Table 3.2-2. Number of Native Plants Planted Within the Old Channel LTBG and Restoration Reaches, by Plot, in 2018

2018 Old Channel Restoration Plantings				
Date Planted	**Plot**	***Ludwigia***	***Sagittaria***	***Cabomba***
Old Channel Restoration Reach				
5/02/2018	FF	**75**		
5/03/2018	N	**50**		
6/06/2018	2017A	**260**		
6/08/2018	2018A		600	
7/20/2018	2018B	**250**		
8/08/2018	2018C	**96**		
8/09/2018	2018B	**336**		
TOTALS		**1,067**	**600**	-

Table 3.2-3 shows aerial seasonal cover, in m^2, of the target SAV species for the Old Channel LTBG and Restoration reaches. As indicated in the coverage data provided in **Table 3.2-3**, the coverage of individual aquatic plant species tends to fluctuate considerably between mapping events and throughout the year. Changes in coverage are the result of expansion from restoration plantings as well as natural decrease/ expansion.

Table 3.2-3. Seasonal Cover (m^2) per Vegetation Type in Old Channel, October 2017 – October 2018

Species	October 2017	February 2018	April 2018	October 2018
Old Channel LTBG Reach				
Ludwigia	106	81	116	239
Sagittaria	45	3	0	6
Cabomba	72	4	44	112
Hygrophila	589	636	663	0
Bryophyte	107	384	220	688
Old Channel Restoration Reach				
Ludwigia	772	843	709	856
Sagittaria	401	638	548	481
Cabomba	118	11	3	21
Potamogeton	474	423	463	570
Vallisneria	938	898	932	888
Hygrophila	0	2	0	2
Bryophyte	561	915	725	692

Following large-scale removal of *Hygrophila* in the downstream portion of the Old Channel LTBG Reach in 2018, four new restoration plots were established with three target vegetation types planted. *Ludwigia* was planted in two plots, *Cabomba* in one plot, and *Sagittaria* in one plot (**Figure 3.2-3**). For the Old Channel LTBG Reach, the increase in vegetative cover achieved as of October 2018 for each target plant species, as well as the 2018 annual restoration goal for that species, is summarized in **Table 3.2-4**.

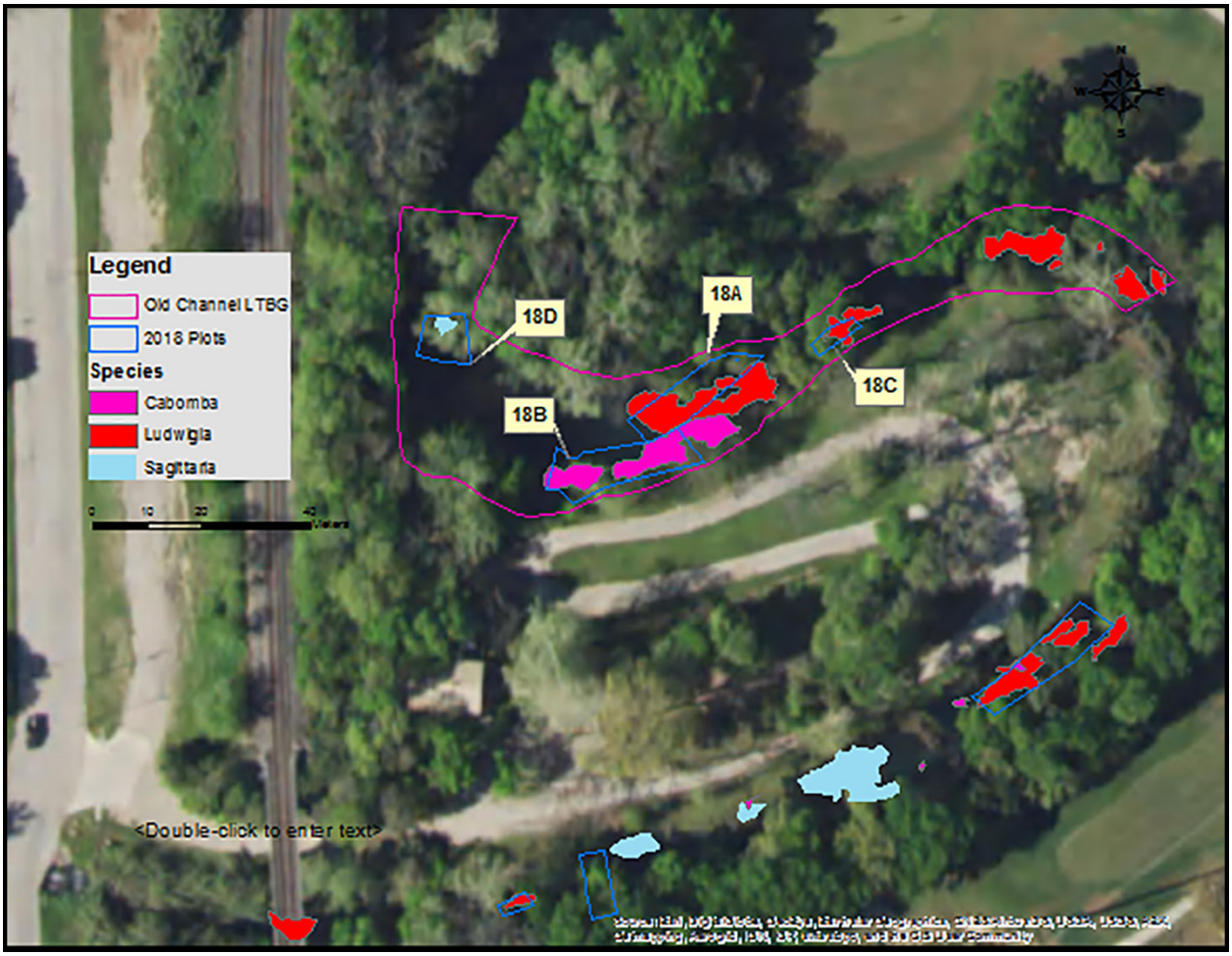

Figure 3.2-3. Location of new restoration plots in the Old Channel LTBG Reach in 2018.

Table 3.2-4. 2018 Annual Restoration Goals and Increases in Target Aquatic Species Vegetation, Old Channel LTBG Reach Results

Plot	Plot Area (m^2)	*Ludwigia* (m^2)	*Cabomba* (m^2)	*Sagittaria* (m^2)
2018A	131	59.4		
2018B	185		76.8	
2018C	24	9.6		
2018D	70			8.0
2018 – TOTALS	**-**	**69.0**	**76.8**	**8.0**
2018 – GOALS	**-**	**75**	**30**	**75**

Cabomba was the only species to exceed the specific 2018 annual restoration goal. A total of 155 m^2 of *Ludwigia* was planted, which is double the 75 m^2 target goal, with 69 m^2 established as of the fall (October) mapping event. *Sagittaria* fell short of the annual target with 70 m^2 planted and approximately 8 m^2 of newly established coverage. *Sagittaria* has been surprisingly slow to establish in the Old Channel LTBG Reach, while it has exhibited vigorous establishment in other river locations. The current hypothesis for its slow establishment is the thick amounts of bryophyte that occasionally settle in this reach for periods of time. The bryophyte turf has been observed to smother newly planted rooted vegetation.

In the Old Channel LTBG Reach, *Ludwigia* and *Cabomba* establishment was given priority over *Sagittaria*. All *Sagittaria* plantings have been limited to one general location in this reach. This allows *Sagittaria* to be separated well away from other species so that if and when robust establishment of *Sagittaria* occurs it will not outcompete *Ludwigia* or *Cabomba*, as has been exhibited in portions of the Old Channel Restoration Reach.

With the complete removal of *Hygrophila* in the Old Channel LTBG Reach and the continued reduction in canopy shading from non-native riparian plants through riparian restoration efforts, growing conditions have and should continue to improve. More suitable habitat has been made available for plantings of *Ludwigia* and *Cabomba*. Based on 2017 and 2018 efforts, these species appear to be establishing.

Three new restoration plots were planted in the Old Channel Restoration Reach just downstream of the Elizabeth Street bridge in 2018 (**Figure 3.2-4**). For the Old Channel Restoration Reach, the increase in aquatic vegetative cover achieved as of October 2018 for each target plant species, as well as the 2018 annual restoration goal for that species, is summarized in **Table 3.2-5.**

Figure 3.2-4. Location of new restoration plots in the Old Channel Restoration Reach, 2018.

Table 3.2-5. 2018 Restoration Goals and Increases in Target Aquatic Vegetation, Old Channel Restoration Reach Results

Plot	Plot Area (m^2)	*Ludwigia* (m^2)	*Cabomba** (m^2)	*Sagittaria* (m^2)	*Potamogeton* (m^2)
2018A	63				
2018B	180	59.2			
2018C	15	5.6			
2018 – TOTALS	**-**	**64.8**	**0***	**0**	**0****
2018 – GOALS	**-**	**75**	**25**	**25**	**10**

* *Cabomba* was not planted to maximize resources.
** *Potamogeton* has exceeded its EAHCP total goal.

Two plots (2018B and 2018C) were planted with *Ludwigia* and one plot (2018A) with *Sagittaria*. Although planted in early summer at over twice the annual goal amount, *Sagittaria* was not observed in plot 2018A during the fall mapping event. In contrast, *Ludwigia* planted later in the year was readily observable and seemed to be establishing well.

Although *Cabomba* was listed as an annual goal to be planted in the restoration reach in 2018, *Cabomba* was limited in supply in easily accessible locations (the usual collection spots including the New Channel and spring fed swimming pool). As such, the project team determined the cost to collect *Cabomba* in deeper areas outweighed the benefit and the project team focused on the most efficient use of available resources. Any *Cabomba* collected in 2018 was planted in Landa Lake LTBG Reach or the Old Channel LTBG Reach since these reaches were higher in priority.

Potamogeton was also not planted in the Old Channel Restoration Reach in 2018. This species has aggressively expanded, more than doubling its cover over the course of 2017 from 267 m^2 to 474 m^2, and in 2018 expanded over 100 m^2 from April to October. At present, it has far exceeded the total EAHCP goal of 100 m^2 of cover in the Old Channel Restoration Reach. This species will not be planted as part of future restoration activities, as long as its coverage remains at or above the EAHCP total coverage goal.

Landa Lake Aquatic Vegetation Restoration Results

In 2018, 302 m^2 of area was planted in five restoration plots in Landa Lake (**Figure 3.2-5**). A total of 4,053 plants were planted into the Landa Lake LTBG Reach in 2018 (**Table 3.2-6**). Approximately 20 percent of the plants planted in Landa Lake were put in as supplemental plantings to recover the decrease of coverage in previously restored plots. Plantings in Landa Lake in 2018 included *Ludwigia*, *Cabomba*, *Sagittaria* and *Potamogeton*.

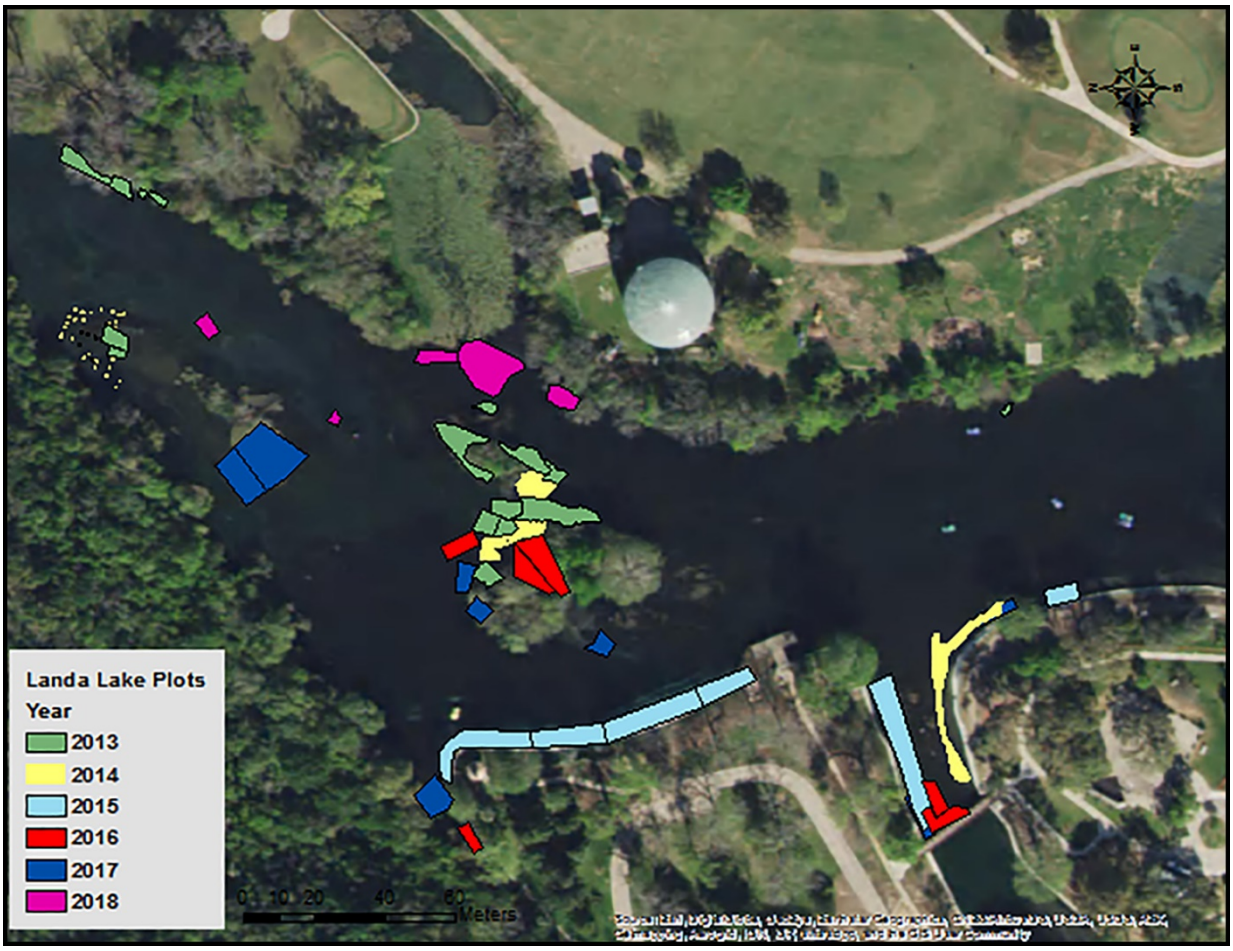

Figure 3.2-5. Map of restoration plots in the Landa Lake LTBG Reach.

Table 3.2-6. Number of Native Plants Planted Within Each Landa Lake Restoration Plot in 2018

2018 Landa Lake Restoration Plantings					
Date Planted	**Plot**	***Ludwigia***	***Sagittaria***	***Cabomba***	***Potamogeton***
3/08/2018	2013A	120*			
3/29/2018	2013A	50*			
4/10/2018	2013A	50			
4/10/2018	2013F	50			
4/10/2018	2013P	50			
4/11/2018	*		110		
4/23/2018	*		200		
5/10/2018	2017A	40			
5/30/2018	2017A	25			
5/30/2018	2015U1	25			
6/06/2018	*		100		
6/21/2018	2018A			720	
6/27/2018	2018A			600	
6/26/2018	2013A	40			
6/29/2018	2013A	75			
7/02/2018	2018A			375	
7/03/2018	2018A			875	

Table 3.2-6. Number of Native Plants Planted Within Each Landa Lake Restoration Plot in 2018

2018 Landa Lake Restoration Plantings					
Date Planted	**Plot**	***Ludwigia***	***Sagittaria***	***Cabomba***	***Potamogeton***
7/05/2018	2018B	75			
7/05/2018	2018C	75			
7/06/2018	2018C	48			
7/06/2018	2018C	160			
7/06/2018	2018D	96			
7/31/2018	2018E				94
TOTALS		**979**	**410**	**2,570**	**94**

*Planted as supplemental plantings in existing plots.

Table 3.2-7 provides seasonal cover of target aquatic plant species in the Landa Lake Restoration Reach between October 2017 and October 2018. *Ludwigia* experienced the highest amount of cover during the baseline mapping event and subsequently decreased thereafter. Complete loss of *Ludwigia* in Spring Run #1 just upstream of the confluence with Landa Lake caused a large overall loss of *Ludwigia* coverage in Landa Lake by Fall 2018. The loss of *Ludwigia* at this location tends to occur each year. However, this year was especially dramatic with a complete loss of cover. *Vallisneria* also decreased from spring to fall as a result of natural loss in some areas. Approximately 100 m^2 of *Vallisneria* were removed by the project team to create more planting areas for other native species. *Vallisneria* was removed and regularly trimmed in certain areas to prevent the buildup of floating vegetation mats.

As in the past, *Cabomba* responded well to 2018 plantings. *Cabomba* coverage doubled from January to October as a direct result of 2018 planting and natural expansion in Spring Run #1. This resulted in a total gain in *Cabomba* coverage in this area. However, previously planted plots of *Cabomba* decreased in size over the course of 2018. Both *Sagittaria* and *Nuphar* were removed to create planting area specifically for *Cabomba* since the previously planted *Cabomba* plots from 2013 to 2016 have not provided any significant long-term results. Plot 2017C had been observed to be an ideal spot for *Cabomba* with dramatic expansion after planting in 2017. However, a loss of 80 m^2 in this specific plot occurred between spring and fall 2018. Bryophyte cover experienced a slight increase between January and October and bryophytes still remain as a significant portion of the plant community in the upper reaches of Landa Lake.

Table 3.2-7. Seasonal Cover (m^2) per Target Vegetation in Landa Lake, October 2017 – October 2018

Species	October 2017	January 2018	April 2018	October 2018
Landa Lake LTBG Reach				
Ludwigia	498	628	572	364
*Sagittaria**	3,227	3,036	2,879	2,712
*Cabomba**	206	149	164	308
Potamogeton	21	26	15	29
*Vallisneria**	15,160	12,761	12,798	11,795
Hygrophila	0	0	0	0
Bryophyte	2,939	2,607	2,273	2,061

*Coverages are a total of naturally occurring and planted *Sagittaria*, *Cabomba,* and *Vallisneria* in Landa Lake.

A total of five restoration plots were planted in Landa Lake in 2018 (**Figure 3.2-6**). Three restoration plots were planted with *Ludwigia*, one with *Cabomba* and one with *Potamogeton*. For the Landa Lake LTBG Reach, the increase in vegetative cover achieved for each target plant species as of October 2018, as well as the 2018 annual goal for that species, is summarized in **Table 3.2-8**. Specific 2018 annual goals for

Ludwigia and *Cabomba* coverage were achieved with *Cabomba* coverage far exceeding the annual goal. *Potamogeton* planted in 2018 did not expand well and although present, was not abundant enough to map for the fall. A large plot of *Cabomba* (2018A) was planted after suitable space was created by removing *Vallisneria*. *Cabomba* did exceedingly well at this planting location, which significantly boosted *Cabomba* coverage in the Landa Lake LTBG Reach.

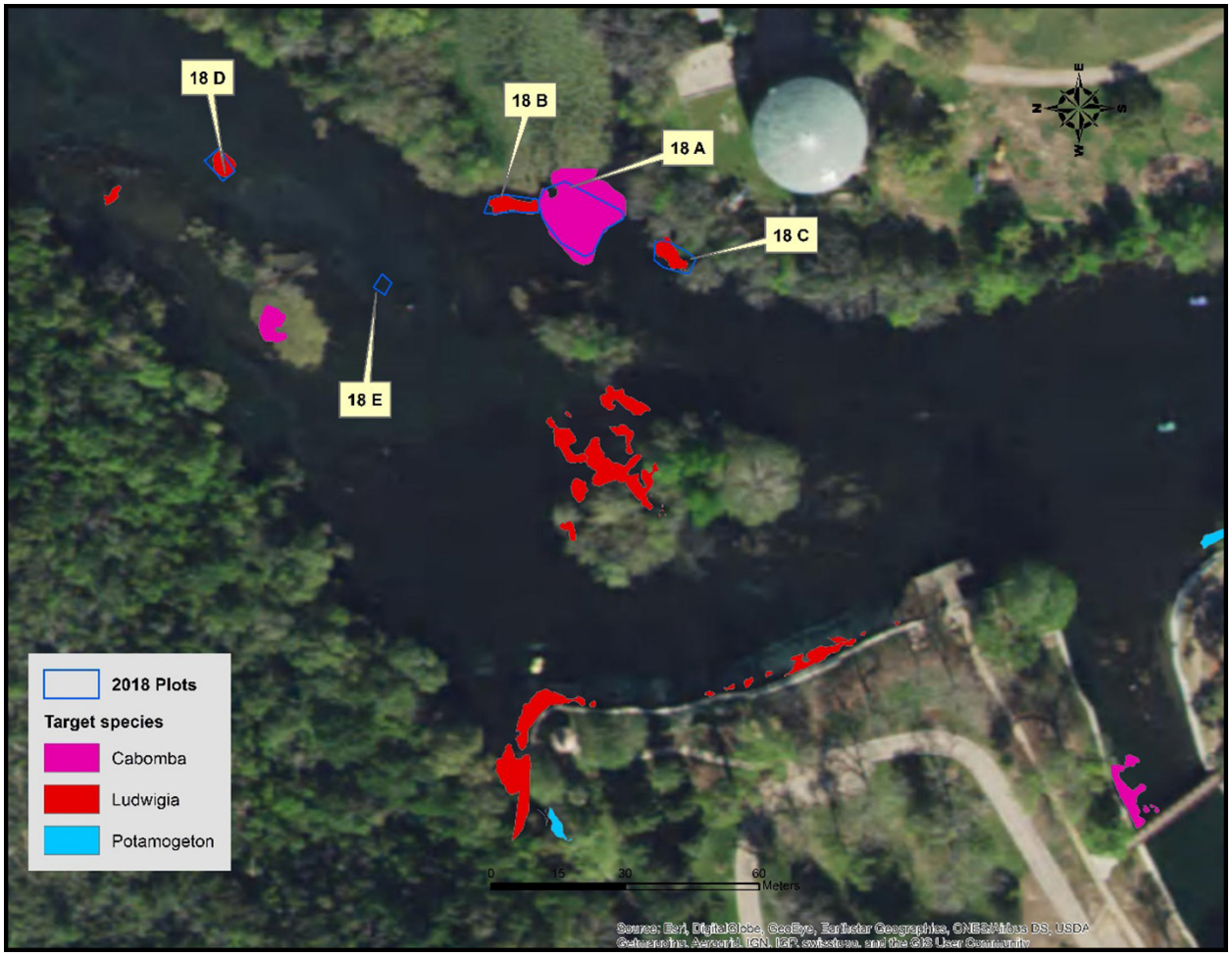

Figure 3.2-6. Location of new restoration plots in the Landa Lake LTBG Reach, 2018.

Table 3.2-8. 2018 Annual Restoration Goals and Increases in Target Aquatic Vegetation Coverage, Landa Lake LTBG Reach Results

Plot	Plot Area (m^2)	*Ludwigia* (m^2)	*Cabomba* (m^2)	*Potamogeton* (m^2)
2018A	189		167.4	
2018B	51	29.7		
2018C	60	28.5		
2018D	23	19.8		
2018E	10			0
2018 – TOTALS	**-**	**78.0**	**167.4**	**0**
2018 – GOALS	**-**	**75**	**50**	**5**

Upper New Channel Aquatic Vegetation Restoration Results & Discussion

In 2018 only one restoration plot was planted within the Upper New Channel LTBG Reach (**Figure 3.2-7**). The date and number of plants planted in this restoration plot are shown in **Table 3.2-9**. A patch of *Hygrophila* adjacent to a larger *Cabomba* patch was removed and replaced with *Cabomba*.

Figure 3.2-7. Map of restoration plot in the Upper New Channel LTBG Reach.

Table 3.2-9. Number of Native Plants Planted Within Each Upper New Channel Restoration Plot in 2018

2018 Upper New Channel Restoration Plantings					
Date Planted	**Plot**	***Ludwigia***	***Sagittaria***	***Cabomba***	***Potamogeton***
8/06/2018	2018A			100	

Table 3.2-10 provides seasonal cover of target aquatic plant species in the Upper New Channel LTBG Reach between January 2018 and October 2018.

Table 3.2-10. Seasonal Cover (m^2) per Target Vegetation in the Upper New Channel LTBG Reach, January 2018 – October 2018

Species	January 2018	April 2018	October 2018
Ludwigia	71	102	106
Cabomba	3	6	29
Hygrophila	603	759	785
Bryophyte	0	277	434

Only *Cabomba* was planted in the Upper New Channel LTBG Reach in 2018. *Ludwigia* was not able to be planted as scheduled because more effort was devoted to plantings in the Landa Lake LTBG and Old Channel LTBG reaches. *Cabomba* was planted in one restoration plot (**Figure 3.2-8**) within the Upper New Channel LTBG Reach where *Hygrophila* had been removed to make a suitable growing location. Despite 100 plants of *Cabomba* being planted in the plot very little *Cabomba* coverage was gained between the time of planting and the fall mapping (**Table 3.2-11**). During fall mapping *Hygrophila* was found to be dominant in the restoration plot.

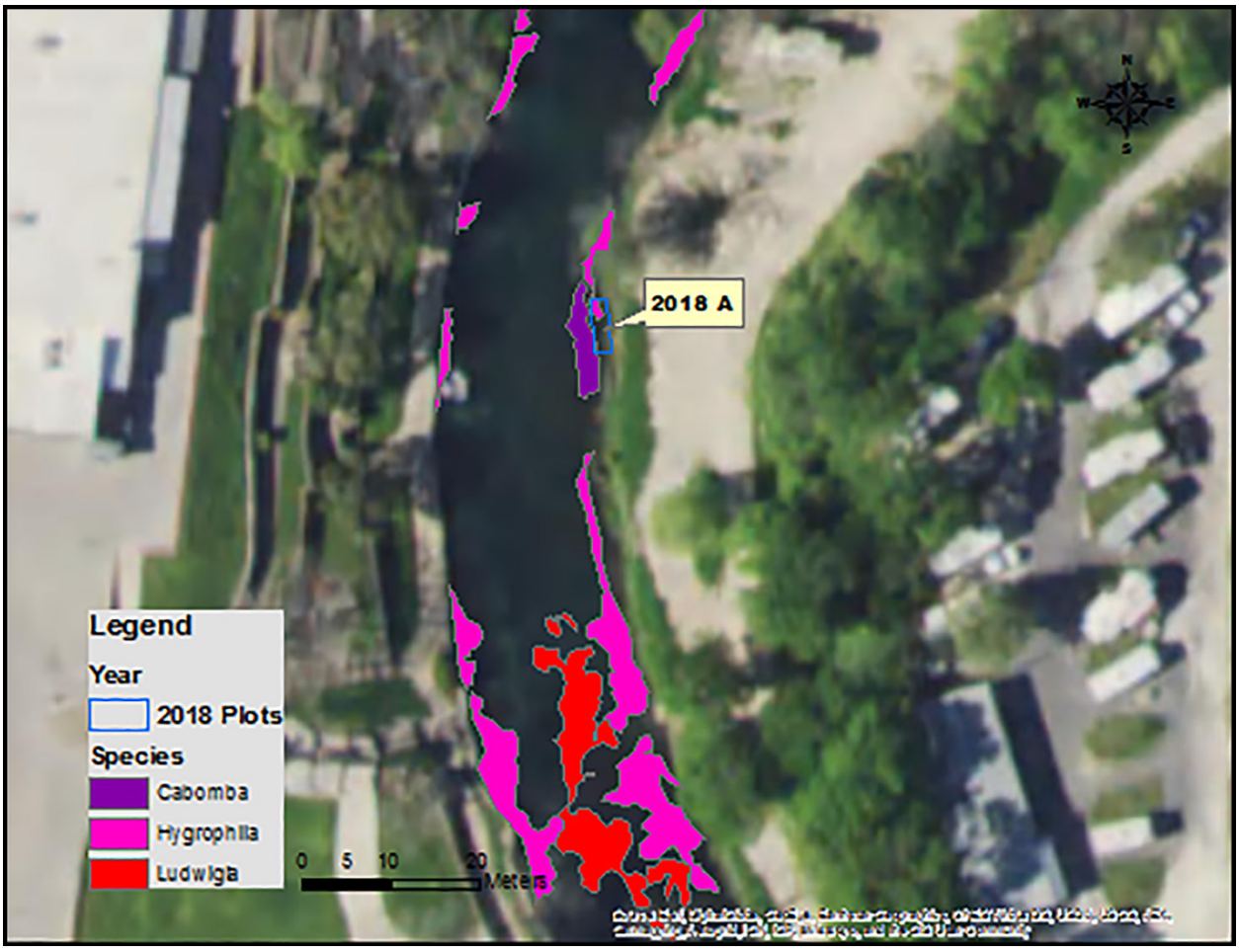

Figure 3.2-8. Location of new restoration plot in the Upper New Channel LTBG Reach, 2018.

Table 3.2-11. 2018 Annual Restoration Goals and Increases in Target Aquatic Vegetation Coverage, Upper New Channel LTBG Reach Results

Plot	Plot Area (m^2)	*Ludwigia* (m^2)	*Cabomba* (m^2)
2018A	19	-	3
2018 – TOTALS	**-**	**-**	**3**
2018 – GOALS	**-**	**15**	**20**

Upper Spring Run Aquatic Vegetation Restoration Results & Discussion

Although SAV plantings were a goal for the Upper Spring Run in 2018, construction activities surrounding the New Braunfels Utilities (NBU) environmental education facility at the headwaters altered this plan. As such, more resources were devoted to completing the removal of all *Hygrophila* and installing restoration plantings in the Old Channel LTBG Reach and Landa Lake than originally anticipated. This adjustment highlights the importance of flexibility in the restoration plan and goals to best use resources in an economically responsible fashion.

Seasonal coverages in 2018 for the Upper Spring Run (**Table 3.2-12**) showed an increase in *Ludwigia* cover from baseline mapping to spring, but then a drastic decrease from spring to fall with all but a few small stands of *Ludwigia* completely disappearing by the end of the monitoring period.

Table 3.2-12. Seasonal Cover (m^2) per Target Vegetation Type in Upper Spring Run LTBG and Restoration Reaches, October 2017 – October 2018

Species	October 2017	January 2018	April 2018	October 2018
Upper Spring Run LTBG Reach				
Ludwigia	21	21	33	3
Sagittaria	961	1011	967	863
Cabomba	7	0	0	0
Hygrophila	0	0	0	0
Bryophyte	1,070	1,679	1,460	913
Upper Spring Run Restoration Reach				
Ludwigia	13	45	57	0
Sagittaria	533	306	430	432
Cabomba	214	171	189	286
Hygrophila	0	0	0	0
Bryophyte	977	1,763	2,224	1,018

Cabomba has historically not done well and has yet to establish in the Upper Spring Run LTBG Reach despite initial planting efforts. However, *Cabomba* continues to do very well in the upper locations of the Upper Spring Run Restoration Reach at the Blieders Creek confluence. At this location, native *Cabomba* has expanded and maintained itself over the long-term. Restored *Ludwigia* on the other hand has decreased with complete loss of *Ludwigia* in all restoration plots planted in the Upper Spring Run Restoration Reach. This observed sensitivity of *Ludwigia* was a key factor in the project team focusing efforts in other reaches in 2018.

The Upper Spring Run stretch is dominated by rocky substrate with some pockets of silt and clay. The inconsistent sediments tend to promote inconsistent and patchy native plant growth especially for *Ludwigia* and *Cabomba*. Similar to Landa Lake, summer senescence also seems to impact *Ludwigia* cover in the

Upper Spring Run as the plants shed top growth greatly reducing their biomass. Finally, the Upper Spring Run becomes excessively dense with bryophyte growth or algae depending on conditions making it difficult for restored plants to compete.

Non-Native Aquatic Vegetation Removal Results (Miscellaneous Reaches)

From 2013 to 2017, significant effort was put into removing and eliminating *Hygrophila* from Blieders Creek, Upper Spring Run, Landa Lake and the upstream-most 1,000 meters (m) of the Old Channel. Baseline mapping in January 2018 showed *Hygrophila* was mostly isolated to the lower half of Old Channel LTBG Reach with a few small patches of *Hygrophila* within the Old Channel Restoration Reach. Blieders Creek, Upper Spring Run, Landa Lake and the spring fed swimming pool have remained clear of *Hygrophila* patches since multiple removal events in 2015 and consistent gardening since 2016. Only two small patches of *Hygrophila* appeared in Blieders Creek in 2018 and one small patch was located in Spring Run #4. No fragments or patches have been found in the spring fed swimming pool since 2016.

Between 2016 and 2018 *Hygrophila* was common in the spillway of Landa Lake as water was flowing through this area due to high lake levels and regular efforts were undertaken to control and remove it to prevent downstream establishment. Mapping in 2018 showed fewer *Hygrophila* patches in the spill way compared to previous years**.** The spillway area ceased flowing by April 2018 and became very dry by July. Regular observations this summer showed *Hygrophila* quickly desiccated along the spillway. There is a strong possibility that this recent desiccation will kill off *Hygrophila* entirely, but regular observations will continue in the possibility that *Hygrophila* emerges when the area becomes re-wetted.

The presence of *Hygrophila* in the Old Channel Restoration Reach from Landa Lake Dam to the LTBG Reach has diminished considerably with only a few small patches observed during baseline mapping. These were subsequently removed. Over the course of 2018 a few spots of *Hygrophila* continued to re-occur but these are controlled by a monthly snorkeling schedule with occasional hookah diving in the deeper sections. As in past years, several patches that were too well rooted for hand removal were covered with 45 mm thick rubber liner held in place by rocks or sandbags. This technique worked well to eliminate patches.

Hygrophila in the Old Channel LTBG Reach covered approximately 600 m^2 at the start of the year. This was the last location of *Hygrophila* slated for removal via current restoration activities. Removal was completed by June with subsequent gardening occurring over the course of the year to control regrowth.

Since 2013 restoration activities have done a significant job in reducing or eliminating *Hygrophila* throughout the desired locations. Although *Hygrophila* will likely always be present in the Comal River, it has been shown that occasional gardening and maintenance is all that will be necessary to keep *Hygrophila* from re-establishing and maintain native plant dominance. **Table 3.2-13** summarizes *Hygrophila* removal activities for 2018.

Table 3.2-13. Amount of *Hygrophila* Removed from Comal River System, per Section, in 2018

Location/Section	Area of *Hygrophila* Removed (m^2)	Period of Work
Landa Lake (outside of the Landa Lake LTBG reach)	<1	Gardened as needed
Old Channel Restoration Reach	<5	Gardened as needed
Old Channel LTBG Reach	~600	May, June
Spring fed Pool	0	Gardened as needed
Upper Spring Run LTBG Reach	0	Gardened as needed
Upper Spring Run Restoration Reach	<1	Gardened as needed
Landa Lake Spillway	<1	Monitored continuously
APPROX. TOTAL REMOVED IN 2018	**~605**	

A full report regarding aquatic plant restoration activities in the Comal River system is included as **Appendix L1** of this report.

Compliance for this measure is based on total coverage of fountain darter habitat in m^2 specified in Table 4-1 of the EAHCP. Status for 2018 is shown in **Table 3.2-14**.

Table 3.2-14. Comal LTBG Fountain Darter Habitat (Aquatic Vegetation) Status in m^2

Reach	Reach Type	Bryophytes	*Potamogeton*	*Ludwigia*	*Cabomba*	*Sagittaria*	*Vallisneria*
Upper Spring Run	LTBG	0	0	3	0	863	0
Upper Spring Run	RR	1,018	0	0	286	432	0
Landa Lake	LTBG	2,061	29	364	308	2,712	11,795
Old Channel	RR	692	570	856	21	481	888
Old Channel	LTBG	688	0	239	112	6	0
New Channel (Upper)	LTBG	434	0	106	29	0	0

LTBG = Long-Term Biological Goal Reach
RR = Restoration Reach

Proposed Activities for 2019:

In 2019, the CONB will continue efforts to increase the coverage and density of target aquatic vegetation preferred by fountain darters for habitat. Aquatic vegetation restoration efforts in 2019 will be focused in the Old Channel, Landa Lake, New Channel and Upper Spring Run LTBG reaches as well as in the Upper and Lower Landa Lake restoration reaches. Restoration in these areas will be conducted in order to work towards achieving established annual coverage goals for 2019. With large-scale removal of *Hygrophila* now completed, restoration efforts will be focused on planting and increasing the coverage of target aquatic vegetation.

3.2.3 Management of Public Recreational Use of Comal Springs and River Ecosystems (EAHCP §5.2.3)

EAHCP Obligations:

The CONB will continue to enforce recreation restrictions on the Comal River that were in place at the time of EAHCP development throughout the duration of the ITP. This restriction specifically applies to

regulations limiting recreation on Landa Lake, the spring runs in Landa Park, and the Old Channel of the Comal River. The CONB will additionally extend its take protection to commercial outfitting businesses willing to meet the conditions of such protection through a Certificate of Inclusion (COI) Program to be developed by the CONB, COSM, EAHCP program staff, and stakeholders.

2018 Compliance Actions:

The CONB continued to enforce City Ordinance Section 142-5, which restricts access to Landa Lake, the Spring Runs (except for the wading pool on Spring Run #2), and portions of the Comal River, including the Old Channel and the "Mill Race" of the New Channel. The CONB Parks and Recreation Department continued to utilize trained park rangers to routinely patrol Landa Park and adjacent areas to prevent access to these areas of sensitive habitat. Signage in Landa Park informing park visitors of the access restrictions remain in place.

Proposed Activities for 2019:

CONB will continue to uphold and enforce existing restrictions limiting recreational access to Landa Lake, spring runs, and portions of the Old and New Channels of the Comal River. The CONB will work with EAHCP program staff and stakeholders to develop a plan to inform river recreation outfitters on the benefits of the EAHCP COI program. The CONB will recruit outfitters who operate on the Comal River and wish to conduct their operations in accordance with the COI program.

3.2.4 Decaying Vegetation Removal and Dissolved Oxygen Management (EAHCP §5.2.4)

EAHCP Obligations:

The CONB will continue to implement a dissolved oxygen (DO) management program in Landa Lake as required by the EAHCP. The program will be focused on monitoring DO concentrations and related water quality parameters in Landa Lake and mitigating for depressed DO levels (<4 mg/L), regardless of the initiating circumstances.

2018 Compliance Actions:

In 2018, the CONB collected additional DO data in Landa Lake. The objective of the data collection was to compile and analyze new DO data and to refine the *Landa Lake Dissolved Oxygen Management Plan 2017,* as needed*,* based upon 2018 data.

Additional DO data was collected between July and September 2018 at seven locations considered to be prime habitat for fountain darters (**Figure 3.2-9**). The DO data was collected using MiniDot DO sondes installed immediately above the streambed substrate or within the lower half of the water column. The intent of locating sensors just off the bottom was to characterize DO conditions in the portion of the water column utilized directly by the fountain darter. Data from the sondes was downloaded weekly and the sondes were cleaned three times per week to prevent bio-fouling of the DO sensor.

Figure 3.2-9. Locations of Mini-DOT dissolved oxygen probes installed in 2018.

Compilation and analysis of new data collection revealed that DO concentrations suitable for fountain darters was maintained in key fountain darter areas throughout the 2018 monitoring period. DO concentrations as measured in 2018 typically exhibited diel fluctuations ranging between 4 to 8 mg/L. High quality fountain darter habitat areas (macrophytes and bryophytes with some flow) continue to support DO concentrations above 4 mg/L. Although periodic observances of DO below 4.0 mg/L were observed in the data collected in 2018, these values were typically reported in lesser quality fountain darter habitat area (limited macrophytes, open substrate and higher levels of algae) and only for short durations of time mostly associated with early morning hours. It is important to note that fountain darters have been routinely collected over the years and were again collected in 2018 in the areas where the sondes were deployed through the EAHCP biological monitoring program drop net, dip net and fish community sampling.

The data recorded by the MiniDot sondes at various locations was compared with and is consistent with DO data collected by both the EAA near-continuous water quality sonde monitoring in Landa Lake and through the EAHCP biological monitoring program during drop net sampling.

Based on the additional DO sampling and subsequent analysis performed in 2018, no revisions to the existing *City of New Braunfels Dissolved Oxygen Management Plan* were necessary. As such, the City of New Braunfels will continue to implement the existing *Landa Lake Dissolved Oxygen Management Plan.*

A full report including 2018 DO monitoring data is included as **Appendix L2** of this report.

Proposed Activities for 2019:

The CONB will monitor DO concentrations in prime habitat areas of Landa Lake and the Upper Spring Run, should total Comal springflow decrease below 100 cfs. The CONB will manage floating vegetation mats and remove decaying vegetation, as needed, if low-DO levels are realized and it is determined that DO concentrations are being negatively influenced by decaying vegetation.

3.2.5 Control of Harmful Non-Native Animal Species (EAHCP §5.2.5)

EAHCP Obligations:

The CONB will implement a non-native species control program that targets armored catfish (*Loricariidae*), tilapia (*Oreochromis* sp.), nutria (*Myocastor coypus*), and giant ramshorn snail (*Marisa cornuarietis*). The CONB will conduct annual monitoring and maintenance activities to ensure continued control of invasive species populations within the Comal River system.

2018 Compliance Actions:

In 2018, the CONB continued to implement a non-native species removal program focused on the targeted species. Efforts in 2018 included five non-native species removal sessions, each three days in length, between February and September 2018. Gill nets, fyke nets, and hand-spears were utilized to capture fish species. Baited box traps were utilized to trap nutria. Over the course of 2018, approximately 1,844 pounds (lbs.) of invasive species biomass were removed from Landa Lake. This volume includes 19 armored catfish, 640 tilapias and 11 nutria. **Table 3.2-15** presents the results of 2018 invasive species removal efforts. The total number removed, biomass, and average biomass per individual are reported for each species.

Table 3.2-15. Summary of 2018 Non-Native Animal Species Removal (February – September 2018)

Species	Number Removed	Biomass (lbs.)	Average Biomass (lbs./individual)
Armored Catfish	19	46.46	2.44
Tilapia	640	1,726.54	2.70
Nutria	11	70.73	6.43
TOTALS	**670**	**1,843.73**	**N/A**

A full report including additional information regarding characteristics of the removed species (i.e., length, weight, and sex ratios) is included as **Appendix L3** of this report. Between 2013 and 2018, approximately 16,100 lbs. (approx. 8 tons) of non-native species biomass has been removed from the Comal River system.

Proposed Activities for 2019:

The CONB will continue the existing program to remove target non-native species, including tilapia, nutria, and armored catfish from the Comal River system utilizing removal methods proven successful in previous years.

3.2.6 Monitoring and Reduction of Gill Parasites (EAHCP §5.2.6 and §6.3.6)

EAHCP Obligations:

The CONB will retain a contractor to establish a monitoring and reduction program associated with the gill parasite, *Centrocestus formosanus* and its intermediate host snail, *Melanoides tuberculatus*. Work activities in 2018 include the continuation of gill parasite cercaria water column density monitoring and host snail distribution and density monitoring.

2018 Compliance Actions:

In 2018, the CONB continued a program to monitor the spatial distribution, abundance, and density of the gill parasite host snail (*M. tuberculatus*) and concentrations of the free-swimming cercaria of the gill parasite.

Host snail distribution and density monitoring was conducted in the study reaches established in previous years. The intent of the snail distribution and density monitoring is to assess changes in spatial distributions, density and size/class structure of the host snail within the Comal River study area. Host snail monitoring has occurred annually since 2013 within the same four sampling reaches. The study reaches include Landa Lake, New Channel Reach, Old Channel Reach, and the Upper Spring Run, and are depicted in **Figure 3.2-10**.

Figure 3.2-10. Gill parasite study reaches within the Comal River system.

Overall capture results from the snail distribution surveys conducted annually between 2013 and 2018 are presented in **Table 3.2-16**. Overall, 300 sites were sampled and at least 1,889 *M. tuberculatus* were collected during the annual comprehensive snail distributional survey in 2018. Sites with greater than 50 snails were not exactly quantified but were simply labeled ">50." *M. tuberculatus* was present at 38 percent of sites sampled, similar to the percent occupied in previous years. In 2018, results revealed that the Upper Spring Run had the highest abundance (n = 650) with Landa Lake ranking second in abundance (n = 604). Once again, similar to prior annual surveys, the Old Channel had the lowest abundance of snails (n = 119). Sixty-nine *M. cornuarietis* were captured (the highest recorded during this six-year sampling window), and *Tarebia granifera* were present at 94 percent of all surveyed sites.

Table 3.2-16. Capture Results for *Melanoides tuberculatus* (MT) and *Marisa cornuarietis* (MC) from All Sites Sampled During 2013 – 2018 System-Wide Surveys for Comal River Study Area

Year	Number of Sites	Estimated Number of MT	% of sites with MT	% of sites w/ >50 MT	Number of MC
2013	245	>1,480	36	3	37
2014	222	>1,628	36	6	16
2015	197	>1,198	42	4	6
2016	330	>1,953	29	9	4
2017	299	>2,882	38	11	46
2018	300	>1,889	38	6	69

Average site-specific densities of *M. tuberculatus* in areas of high abundance have ranged from 1/m^2 to 1,283/m^2 in previous years. In 2018, site-specific densities ranged from 24/m^2 to 1,128/m^2. When evaluated by reach, the highest observed densities in 2018 were found in Landa Lake, followed by the Upper Spring Run, and the New Channel Reach (**Table 3.2-17**). The Old Channel Reach has consistently exhibited lower snail densities and smaller snails in comparison to other reaches.

Table 3.2-17. Mean Annual Snail Density Estimates and Mean Snail Lengths Averaged Over Samples Within Each Reach

	Sampling Reach							
	Upper Spring Run		Landa Lake		New Channel Reach		Old Channel Reach	
Year	Density (per m^2)	Length (mm)	Density (per m^2)	Length (mm)	Density (per m^2)	Length (mm)	Density (per m^2)	Length (mm)
2013	371.7 (±115.6)	26	399.3 (±70.9)	27	607.1 (±221.2)	25	---	---
2014	426.9 (±114)	23	350 (±103.3)	23	343.7 (±37.8)	29	146.2 (±32.6)	16
2015	480.2 (±127.7)	24	185.3 (±55.8)	26	147.1 (±55.9)	27	62 (±6)	15
2016	256 (±102.1)	25	155.7 (±49.5)	21	37.3 (±24)	34	35.6 (±20.9)	13
2017	384(±112.5)	26	431.7 (±287.4)	19	253 (±74.4)	21	76.9 (±52.3)	12
2018	437(±122.9)	29	658.7 (±194.7)	20	406 (±59.8)	22	41.3 (±15.4)	11
Overall	392.6	25.5	363.5	22.7	299	26.3	72.4	13.4

Reach-specific patterns in size structure are apparent. Over the course of the study, *M. tuberculatus* have ranged from 3–68 mm [mean: 25.5 mm (±0.12)] in the Upper Spring Run, 3–64 mm [mean: 22.7 mm (±0.10)] in Landa Lake, and 2-63 mm [mean: 26.3 mm (±0.12)] in New Channel Reach. In contrast, the maximum size is considerably smaller in Old Channel Reach, with *M. tuberculatus* ranging from 5–38 mm

[mean: 13.4 mm (±0.15)]. Multimodal distributions suggest the presence of multiple age classes within the population.

Drifting gill parasite (*C. formosanus*) cercariae monitoring was also conducted in 2018 as in previous years using established monitoring methods. Drifting cercariae monitoring was conducted at three established monitoring sites with the Comal River system (**Figure 3.2-11**). These include a site at the outflow area of Landa Lake, the RV Park along the New Channel, and the Old Channel Reach. The results of the drifting cercariae monitoring conducted annual between 2014 and 2018 are shown in **Table 3.2-18** and **Figure 3.2-12**.

In 54 individual 5-L samples, 306 total *C. formosanus* cercariae were detected in 2018, resulting in an overall annual system wide mean of 1.1 (SE ±0.1) cercariae per liter. Density of cercariae has steadily decreased in all reaches since water column monitoring was initiated in 2014.

Cercariae density results from the Old Channel Reach were the lowest recorded in 2018 (decreasing from the previous recorded low in 2017) with means continuing to decrease season to season. This is likely a result of low numbers of snails capable of being infected (> 17 mm) within this reach. In the Old Channel Reach, 95 percent of snails captured in 2018 were less than 17 mm, suggesting that few cercariae are produced in this reach. Cercariae found in this reach may be the result of downstream drift from Landa Lake. Spring discharge and streamflow was variable throughout the study period. Mean monthly discharge was lowest in 2014 and early 2015, higher in 2016 and 2017, and steadily declined through spring and summer 2018. When examining the relationship between total system discharge and cercariae density at each sampling event, interesting patterns are evident. At both Landa Lake and RV Park along the New Channel, as total system discharge declines, cercariae concentrations increase. This is not surprising, as lower total system discharge results in less flow in these areas. Given less water volume and a consistent number of cercariae being produced, concentrations would be expected to increase. However, due to flow patterns in the system, this trend doesn't hold at the Old Channel Reach. Since flow in the Old Channel Reach is controlled by gated culverts at the Landa Lake Dam, it is relatively constant regardless of total system discharge. When analyzed by season, no distinct pattern in seasonal cercarial concentrations are evident among reaches

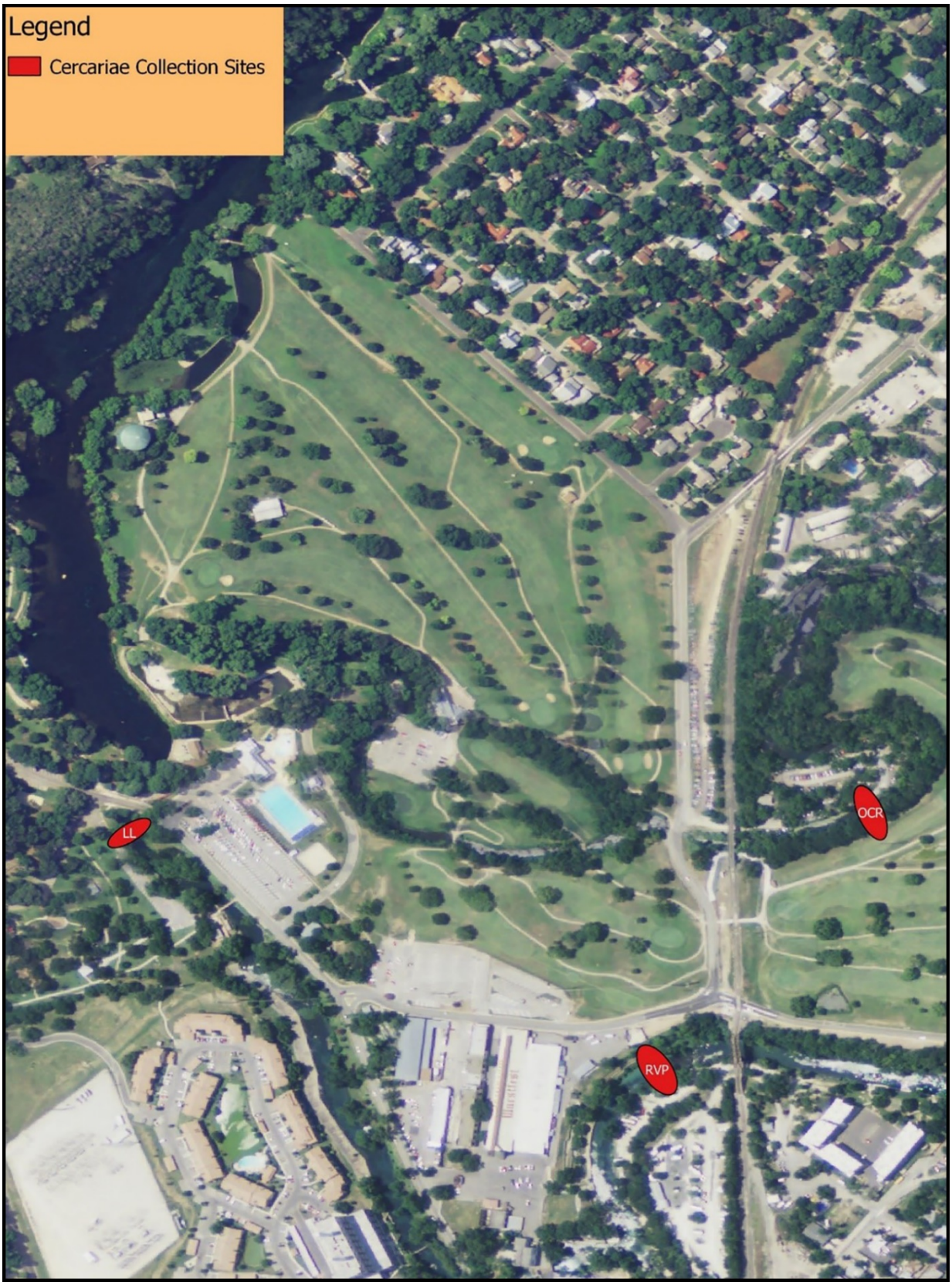

Figure 3.2-11. Drifting cercariae monitoring locations at Landa Lake (LL), RV Park along New Channel (RVP), and the Old Channel Reach (OCR).

Table 3.2-18. Mean Seasonal and Annual Cercaria Concentrations (Cercariae/Liter), 2014 – 2018

Transect	Year	Season			
		Winter	Spring	Summer	OVERALL
Landa Lake Outflow	2014	4.4 (±0.4)	6.1 (±0.5)	13.3 (±0.6)	**7.9 (±1.0)**
	2015	2.6 (±0.3)	2.6 (±0.3)	3.4 (±0.3)	**2.9 (±0.2)**
	2016	0.8 (±0.9)	2.3 (±0.8)	1.9 (±0.8)	**1.6 (±2.2)**
	2017	1.3 (±0.1)	1.4 (±0.3)	1.0 (±0.2)	**1.2 (±0.1)**
	2018	0.8 (±0.1)	1.5 (±0.2)	1.6 (±0.4)	**1.3 (±0.2)**
Old Channel at Elizabeth Ave	2014	0.4 (±0.1)	1.0 (±0.2)	2.0 (±0.3)	**1.1 (±0.2)**
	2015	1.4 (±0.2)	1.9 (±0.2)	2.4 (±0.2)	**1.9 (±0.1)**
	2016	2.0 (±1.1)	1.2 (±0.9)	1.8 (±1.2)	**1.7 (±1.1)**
	2017	0.7 (±0.1)	0.6 (±0.2)	0.5 (±0.1)	**0.6 (±0.1)**
	2018	0.6 (±0.1)	0.3 (±0.1)	0.2 (±0.1)	**0.4 (±0.1)**
New Channel at Landa RV Park	2014	3.8 (±0.3)	7.8 (±0.9)	4.8 (±0.4)	**5.5 (±0.2)**
	2015	4.5 (±0.7)	3.1 (±0.3)	3.6 (±0.3)	**3.7 (±0.2)**
	2016	2.1 (±1.1)	2.5 (±0.8)	2.3 (±0.8)	**2.3 (±0.6)**
	2017	2.0 (±0.6)	2.3 (±0.2)	1.5 (±0.2)	**1.9 (±0.2)**
	2018	1.6 (±0.2)	1.5 (±0.3)	2.1 (±0.2)	**1.7 (±0.2)**
Overall	2014	2.9 (±0.5)	4.9 (±0.8)	6.7 (±1.2)	**4.8 (±0.5)**
	2015	2.9 (±0.3)	2.5 (±0.2)	3.2 (±0.2)	**2.9 (±0.1)**
	2016	1.6 (±0.2)	2.0 (±0.2)	1.9 (±0.1)	**1.8 (±0.1)**
	2017	1.3 (±0.2)	1.4 (±0.2)	1.0 (±0.1)	**1.2 (±0.1)**
	2018	1.0 (±0.1)	1.1 (±0.2)	1.3 (±0.2)	**1.1 (±0.1)**

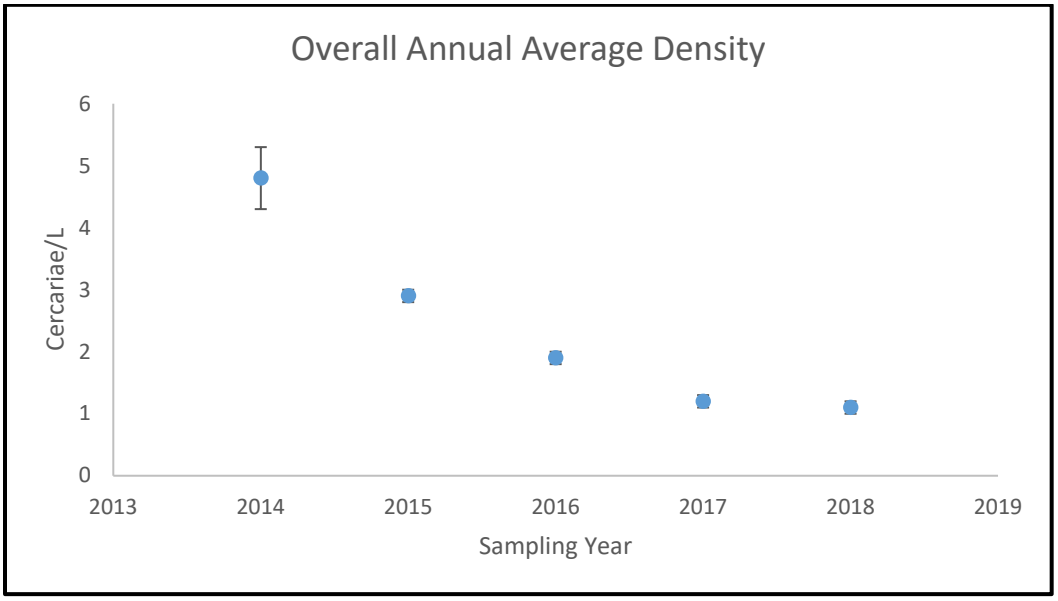

Figure 3.2-12. Overall annual average cercariae density (2014 – 2018).

In summary, monitoring data collected in 2018 was useful in refining the understanding of *Centrocestus formosanus* conditions over time within the Comal system. Due to the complex life cycle of this particular parasite, which involves multiple hosts and life stages, monitoring data continues to focus on the first intermediate host, *Melanoides tuberculatus*, and the free-swimming cercariae. Collecting data on multiple hosts/life stages continues to provide a more complete picture of parasite dynamics within the system.

Host snail distribution sampling results from 2013 through 2018 show that the percentage of sites occupied by *M. tuberculatus* has remained relatively stable and ranged from 29 to 42 percent. *M. tuberculatus* remains abundant in Landa Lake and the New Channel above the old power plant but is still relatively scarce in the Old Channel and lower portions of the New Channel. Overall mean density of snails is relatively similar between Upper Spring Run, Landa Lake, and New Channel, but considerably lower in the Old Channel. Differences in size-class structure were apparent between reaches, with snails in the Old Channel being considerably smaller than those observed in other reaches. The low abundance and small size of snails in the Old Channel suggests that this host snail has not densely colonized this area. This continues to be an extremely positive result considering the importance of the Old Channel relative to the long-term preservation of quality habitat for the fountain darter.

Another positive note is that the annual density estimates of drifting parasite cercariae in the water column have declined since the inception of monitoring, with no distinct seasonal patterns evident. However, relationships between cercariae density and discharge are evident with increased cercariae concentrations under low flow conditions in two of the three cercariae sampling reaches. Although the lowest discharge conditions observed over the monitoring period were in 2014, discharge alone does not seem to adequately explain the continued decrease in cercariae densities. Total system discharge in Summer 2018 were almost as low as those observed in 2014, yet cercariae densities continued to decrease. Therefore, additional factors other than discharge are likely influencing long-term trends in cercariae density.

Data from this study suggest that snail distribution and density have remained rather constant throughout the study, suggesting that decreases in cercariae density are not necessarily tied to changes in snail populations. However, long-term data on snail infection rates is presently not available. Additionally, no data is available on the number/intensity of infected fishes, or on definitive host infection rates. It may be that limitations associated with fish or bird hosts are influencing the parasites' density in the system.

In conclusion, the present densities of host snails and drifting parasite cercariae do not pose a threat to fountain darters in the Comal system. A full report regarding gill parasite monitoring activities in the Comal River system is included as **Appendix L4** of this report.

Proposed Activities for 2019:

Free-swimming cercaria water column concentration monitoring will occur in 2019, if total Comal springflow decreases below 100 cfs. Past results and conclusions suggest that existing conditions do not present any know concern specific to fountain darter in the Comal system, particularly during average and above average streamflow conditions. CONB will pursue discussions with EAHCP program staff and standing EAHCP committees to evaluate the need for continued gill parasite monitoring.

3.2.7 Prohibition of Hazardous Materials Transport Across the Comal River and Tributaries (EAHCP §5.2.7)

EAHCP Obligations:

The CONB was tasked with prohibiting the transport of hazardous material (HAZMAT) on routes crossing the Comal River and its tributaries. This effort was to include legislation, CONB ordinances, and additional signage.

2018 Compliance Actions:

Section 126-185 of CONB City Code designates Interstate Highway (IH)-35 and Loop 337 as through truck routes and hazardous cargo routes through the city limits, effectively prohibiting the transport of hazardous cargo over the Comal River and a majority of its key tributaries (**Figure 3.2-13**). Signs notifying drivers of the designated routes are located along IH-35 and State Highway 46. In 2016, CONB installed HAZMAT cargo prohibition signs at key locations. These locations include Rock Street near Loop 337, Gruene Road near Loop 337, River Road near Loop 337, Oakwood Blvd near Loop 337, and California Avenue near Loop 337 (**Figure 3.2-13)**. The hazardous materials transport prohibitions remained in effect in 2018 and notification signs remain in place and in good condition.

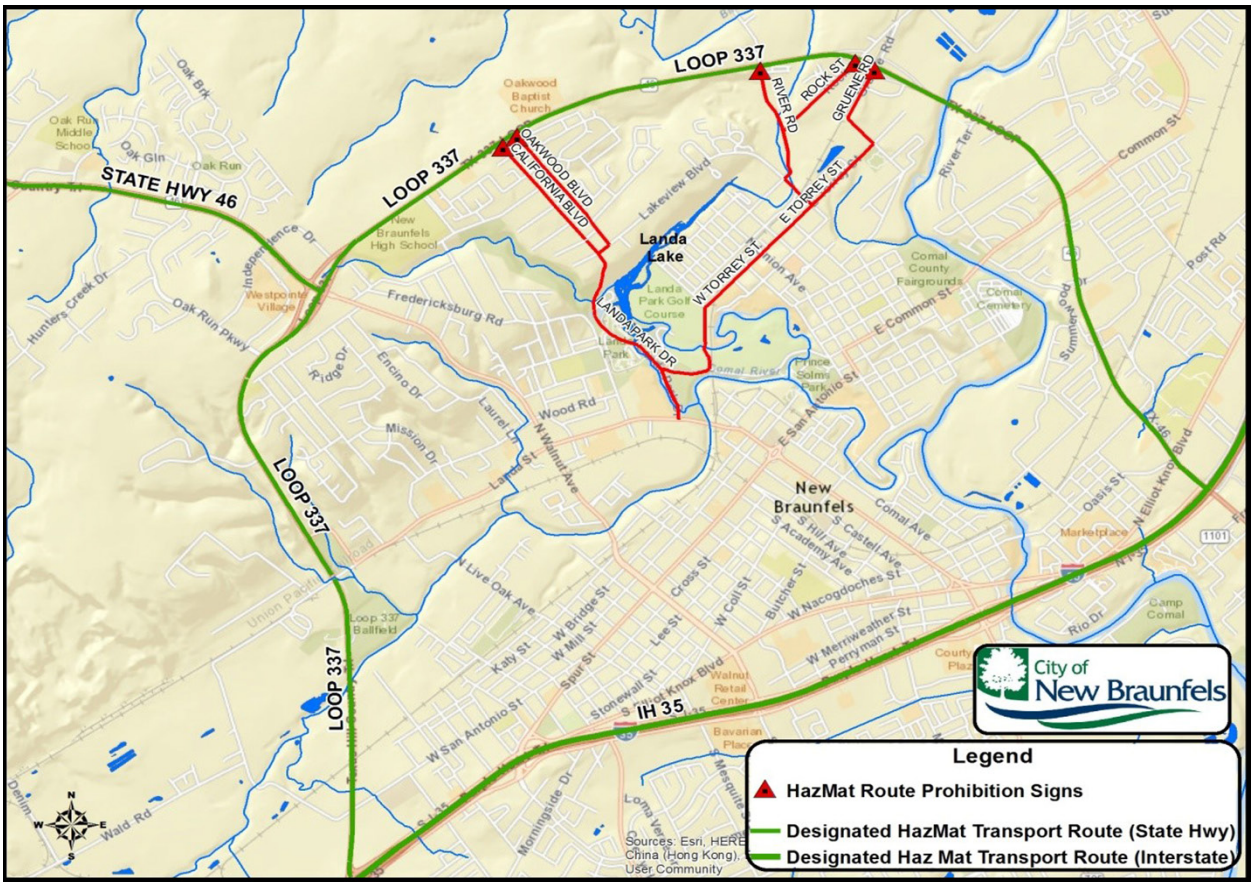

Figure 3.2-13. Map of designated HAZMAT transport routes and locations of HAZMAT route prohibition signs.

Proposed Activities for 2019:

The CONB will maintain HAZMAT signage installed in 2016 and monitor for the presence of trucks carrying hazardous cargo on routes crossing the Comal River and its tributaries.

3.2.8 Native Riparian Habitat Restoration (Riffle Beetle) (EAHCP §5.2.8)

EAHCP Obligations:

In order to improve CSRB habitat, the CONB will implement a restoration program to improve the riparian zone along Spring Run #3 and the western shoreline of Landa Lake, and to minimize sedimentation impacts. The program will involve removal of non-native vegetation and revegetation with native vegetation.

2018 Compliance Actions:

In 2018, the CONB continued to take action to increase the density of riparian vegetation along the banks of Spring Run #3 by converting approximately 430 ft of the southeastern bank from bare ground and turf grass into a riparian buffer zone containing native vegetation commonly found in riparian areas in central Texas. The project area extends from the southwest end of Spring Run #3 and continues along the spring run to near the confluence of Spring Run #3 and Landa Lake (**Figure 3.2-14**). The riparian buffer zone extends up to approximately 20 ft away perpendicularly from the spring run.

Figure 3.2-14. Location of 2018 riparian restoration activities.

The first step was to develop a riparian restoration plan that takes into consideration the heavy pedestrian and visitor traffic that occurs in this area. The riparian restoration plan also considered existing stormwater flowpaths in this area. The riparian restoration plan also accounted for the alignment of a pervious walking trail along Spring Run #3 that has been proposed as part of the Landa Park Master Plan and is intended to be installed in late 2018/early 2019. With consideration given for the high visibility of the project location, the CONB Parks and Recreation Department required that the outcome of this project have a more polished, landscaped appearance than the riparian area along northwest bank of Spring Run #3 where restoration occurred in previous years.

Native plants were selected based on root structure, light requirements, growth habits, and deer-resistance. Native plant species that were included in this restoration projects are listed in **Table 3.2-19**. The plant species were chosen based on the results of previous restoration efforts. Over 570 plant specimens were planted along Spring Run #3 to develop the riparian buffer area. Temporary protective fencing was installed around planting areas to protect the young vegetation from deer and foot traffic. Temporary irrigation was installed, and used as needed, to help the plants establish. Pre- and post-project photos are provided in **Figure 3.2-15** and **Figure 3.2-16**.

Table 3.2-19. Species and Quantities of Native Plants Planted Within the Project Area in 2018

Common Name	Scientific Name	Quantity Planted
Blue mistflower	*Chromolaena odorata*	19
Bushy Bluestem	*Andropogon glomeratus*	28
Buttonbush	*Cephalanthus occidentalis*	6
Cardinal Flower	*Lobelia cardinalis*	72
Common Spike Rush	*Eleocharis montevidensis*	154
Dwarf Palmetto	*Sabal minor*	5
Emory Sedge	*Carex emoryi*	61
Inland Sea Oats	*Chasmanthium latifolium*	155
Little Bluestem	*Schizachyrium scoparium*	10
Turk's Cap	*Malvaviscus arboreus var. drummondii*	12
Whitetop sedge	*Rhynchospora latifolia*	50
TOTAL PLANTED		**572**

Figure 3.2-15. Photos depicting the Spring Run #3 area prior to the installation of the riparian buffer zone.

Figure 3.2-16. Photos depicting the Spring Run #3 following the installation of the riparian buffer zone.

CONB staff continued to visually monitor the riparian zone along the northwest bank of Spring Run #3 and along the western shoreline of Landa Lake where non-native plants have previously been removed. No major additional removal efforts were required in 2018 in these areas. Previously installed sediment capture devices were monitored for structural integrity and effectiveness throughout 2018 and maintained, as needed, to promote the capture of sediment.

Proposed Activities for 2019:

The CONB will continue to monitor the riparian vegetation and buffer area that was established in 2018 along the southeast side of Spring Run #3. Additional plantings of native riparian plan species will occur within the riparian buffer area, as needed, to increase the density of vegetative coverage in this area. The CONB staff will continue to monitor for and remove any re-emergent non-native vegetation in the riparian zone along the northwest side of Spring Run #3 and the western shoreline of Landa Lake. The CONB will monitor restored areas on along both banks of Spring Run #3 and along the western shoreline of Landa Lake to assess plant establishment and look for signs of erosion.

3.2.9 Reduction of Non-Native Species Introduction and Live Bait Prohibition (EAHCP §5.2.9)

EAHCP Obligations:

The CONB will take action to prohibit the introduction of domestic and non-native aquatic organisms, targeting specifically bait species and aquarium trade species into the Comal River system. In addition, the CONB will continue to educate and promote awareness on the adverse impacts of aquarium dumping and use of non-native bait species to the Comal River ecosystem.

2018 Compliance Actions:

The CONB distributed educational materials designed to inform the public of invasive species issues and the negative impacts of aquarium dumping. Information of the negative impacts of introducing non-native aquarium and bait species into the Comal River system was included in English and Spanish in the summer 2018 edition of the CONB's newsletter, "Making the Most of our Resources" (**Figure 3.2-17**). Approximately 10,000 newsletters were included as inserts in the *New Braunfels Herald-Zeitung*, the primary local newspaper for the New Braunfels area.

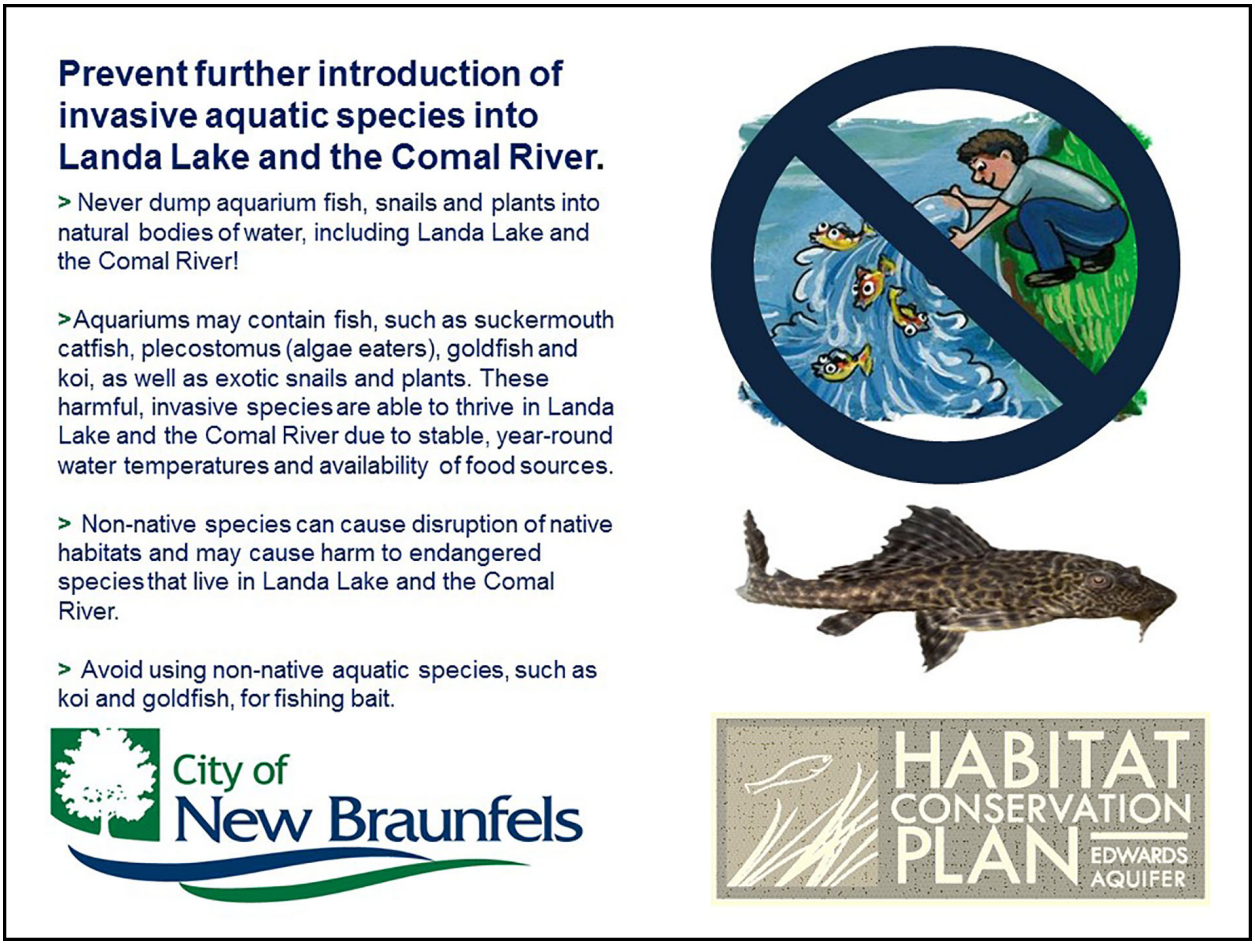

Figure 3.2-17. Educational piece on the negative impacts of invasive species introduction included in the "Making the Most of our Resources" newsletter distributed in the *New Braunfels Herald-Zeitung* newspaper.

Proposed Activities for 2019:

The CONB will continue to educate residents and visitors on the negative impacts of aquarium dumping and usage of specific live bait species. CONB staff will work with TPWD to draft an ordinance prohibiting aquarium dumping and usage of certain live bait species. City staff will present the proposed ordinance to the New Braunfels City Council for consideration.

3.2.10 Litter Collection and Floating Vegetation Management (EAHCP §5.2.10)

EAHCP Obligations:

The CONB will perform activities to manage floating vegetation and litter removal to enhance habitat for the Covered Species. Management activities will include dislodging of vegetation mats that form on top of the water surface, particularly during low flows, to allow continued movement downstream, and removal of litter from the littoral zone and stream bottom. The CONB will manage floating vegetation mats in Landa Lake by removing floating materials entrained on the flow control structures, fishing piers, Three Island

area, Landa Park Drive Bridge and other areas where mats collect. Litter removal in Landa Lake and the Comal River will continue under the existing CONB program.

2018 Compliance Actions:

The CONB continued to implement a program to remove litter and dislodge floating vegetation mats from Landa Lake and portions of the Comal River system where Covered Species habitat is present. Management of floating vegetation mats in key areas of Landa Lake and portions of the Comal River (**Figure 3.2-18**) occurred in 2018 and helped to minimize shading of restored aquatic vegetation areas, entrainment of material in the 48-inch culvert screen and control gate to the Old Channel and oxygen consumption in Landa Lake associated with decaying vegetation.

Litter collection efforts in 2018 consisted of litter removal from the surface of Landa Lake and along the banks of the Old Channel. In 2018, approximately 97 lbs. of litter, or 48 7-gallon bags, was collected.

Proposed Activities for 2019:

The CONB will continue efforts to remove litter and dislodge floating vegetation mats from applicable portions of the Comal River system to prevent negative impacts to flow control structures, aquatic restoration reaches, and Covered Species habitat. In the event of low-flow conditions or receipt of depressed DO levels in Landa Lake, the removal of, and/or increased efforts to dislodge, floating vegetation mats may be initiated to prevent oxygen consumption by decaying vegetative material as per Decaying Vegetation Removal and Dissolved Oxygen Management (EAHCP §5.2.4) and the *Landa Lake Dissolved Oxygen Management Plan 2017*.

Figure 3.2-18. Locations of primary floating vegetation mat management areas.

3.2.11 Management of Golf Course Diversions and Operations (EAHCP §5.2.11)

EAHCP Obligations:

The CONB will develop and implement a Golf Course Management Plan that will include an IPMP designed to target techniques to protect water quality and minimize potential negative effects to the Covered Species.

2018 Compliance Actions:

The CONB continued to update the existing IPMP, as needed, and maintain a vegetative buffer between the golf course and Landa Lake and the Old Channel of the Comal River in order to provide increased water quality protection. This *2016 Landa Lake Golf Course Integrated Pest Management Plan* is in **Appendix L5** of this Annual Report.

Proposed Activities for 2019:

The CONB will continue to update the IPMP and maintain a vegetative buffer between the golf course and Landa Lake and the Old Channel of the Comal River. The IPMP will be revised, as needed, to address any operational changes associated with the management of the golf course grounds.

3.2.12 Native Riparian Habitat Restoration (Old Channel Improvements) (EAHCP §5.7.1)

EAHCP Obligations:

The CONB will initiate a riparian restoration program to enhance the riparian zone along the Old Channel, the golf course, and in the vicinity of Clemens Dam.

2018 Compliance Actions:

The primary riparian restoration activities that took place in 2018 were to remove/ control non-native riparian vegetation along the Old Channel of the Comal River and to establish native vegetation in areas where non-native vegetation was previously treated/ removed.

Non-native species that were targeted in 2018 include elephant ear (*Colocasia* sp.), privet (*Ligustrum* sp.), Chinese tallow (*Triadica sebifera*), giant cane (*Arundo donax*), and chinaberry (*Melia azedarach*). There were two segments of the Old Channel that received varying levels of non-native vegetation treatment and riparian zone restoration in 2018. These segments are described below and shown in **Figure 3.2-19**:

1) **Old Channel Restoration Area A – Old Channel between Golf Course Bridge Crossing and Elizabeth Street:** Non-native vegetation control work in this area in 2018 was focused primarily on re-treatment of re-emergent elephant ear, privet, and chinaberry. Some small stands of johnsongrass (*Sorghum halepense*), Brazilian vervain (*Verbena brasiliensis*), catclaw vine (*Dolichandra unguis-cati*), and Japanese honeysuckle (*Lonicera japonica*) were also treated or

removed by hand. The coverage and density of native vegetation was increased in this section via supplemental planting of several species listed in **Table 3.2-19**.

2) **Old Channel Restoration Area B – Old Channel from Elizabeth Street through the Old Channel LTBG Reach:** Major non-native vegetation removal activities occurred in this reach in 2018. Non-native control work in this area was focused primarily on treatment and removal of elephant ear, privet, Chinese tallow, chinaberry, and giant cane. Much of the fallen vegetative material was used to create linear berms on contour in sloped areas to prevent erosion and to capture soil for future native vegetation planting efforts.

Figure 3.2-19. 2018 Old Channel riparian restoration areas.

Non-native vegetation in Area A was initially treated in 2017 using chemical and/or removed using mechanical methods. In 2018, areas where re-emergent growth of non-native species was observed were treated again with herbicide to ensure the successful elimination of the species. Re-emergent elephant ears were treated with foliar applications of Aquaneat, a Glyphosate-based aquatic herbicide. Additional treatment of this species in area A began in February 2018. Continued follow-up treatment was conducted throughout the year to control the re-emergent elephant ears. Woody non-native vegetation, including privet, Chinese tallow, and chinaberry were treated by scarring the base of the tree to the cambium layer and applying Relegate, a Triclopyr-based herbicide.

In Area B, the target non-native species were treated and in the same manner as in Area A. Additionally, large stands of giant cane were treated and cut in Area B near the Elizabeth Street bridge. Approximately 794 privet trees, 401 Chinese tallow trees, 150 chinaberry trees, and 1,247 giant cane stalks were treated and removed from both areas in 2018. The removed woody vegetation was utilized to construct erosion control berms to promote sediment capture (**Figure 3.2-20**). The felled trees were cut into smaller pieces and used to create berms to catch sediment carried by sheet flow down the slope.

Planting of native riparian vegetation occurred in Area A in 2018 with intent to increase the density and vegetative diversity of the riparian zone along the Old Channel. Planting of native vegetation included planting of potted native plants primarily in the spring and fall of 2018. Planting occurred on both sides of the Old Channel in Area A throughout the year. Volunteer assistance helped to reduce project costs and to educate residents on the importance of riparian zones and the EAHCP in general. A list containing the types and quantities of the species planted within Area A in 2018 is presented in **Table 3.2-20**. Fencing was installed in areas adjacent to the golf course parking lot and in select areas along the Old Channel to delineate the riparian zone, create a no-mow zone, discourage pedestrian traffic and to prevent vehicles from parking and negatively impacting riparian vegetation (**Figure 3.2-21)**.

Figure 3.2-20. Herbicide treatment and felling of privet (*Ligustrum* sp.).

Table 3.2-20. Species and Quantities of Native Plants Planted Within Area A in 2018

Common Name	Scientific Name	Quantity Planted (all 1-5 gallon transplants)
Alamo Vine	*Merremia dissecta*	1
American Beautyberry	*Callicarpa americana*	13
American Sycamore	*Platanus occidentalis*	8
Bald Cypress	*Taxodium distichum*	4
Bur Oak	*Quercus macrocarpa*	2
Bush Honeysuckle	*Lonicera albiflora*	5
Bushy Bluestem	*Andropogon glomeratus*	4
Chili Pequin	*Capsicum annuum*	15
Coralberry	*Symphoricarpos orbiculatus*	14
Eve's Necklace	*Styphnolobium affine*	5
False Indigobush	*Amorpha fruticosa*	8
Fragrant Mimosa	*Mimosa borealis*	3
Fragrant Mistflower	*Chromolaena odorata*	18
Frogfruit	*Phyla nodiflora*	10
Inland Sea Oats	*Chasmanthium latifolium*	59
Kidneywood	*Eysenhardtia texana*	3
Lanceleaf Coreopsis	*Coreopsis lanceolata*	2
Lindheimer Muhly	*Muhlenbergia lindheimeri*	6
Pigeonberry	*Rivina humilis*	24
Possumhaw	*Ilex decidua*	3
Prairie Flameleaf Sumac	*Rhus lanceolata*	13
Red Buckeye	*Aesculus pavia*	3
Roughleaf Dogwood	*Cornus drummondii*	2
Texas Lantana	*Lantana urticoides*	18
Texas Mountain Laurel	*Sophora secundiflora*	22
Texas Persimmon	*Diospyros texana*	6
Tropical Sage	*Salvia coccinea*	5
Turk's Cap	*Malvaviscus arboreus*	90
Yellow Bells	*Tecoma stans*	9
Total Number of Plants Planted		**375**

Figure 3.2-21. Riparian zone fencing and exclosures along Old Channel (top photo); Boy Scout Troop 413 participated in a riparian habitat planting and litter collection project in early November 2018 (bottom photo).

Proposed Activities for 2019:

The CONB will continue efforts to increase the coverage and density of native vegetation by planting transplants and seeding within the riparian zone along the golf course side of the Old Channel between Elizabeth Avenue and the downstream-most end Old Channel LTBG Reach where non-native, invasive plants were removed in 2017 and 2018 (Area B). The CONB will continue to maintain previously restored areas to prevent re-establishment of non-native vegetation and promote native vegetation growth. Sediment control structures along the streambanks will continue to be installed and maintained.

The CONB will also begin efforts to treat and remove non-native riparian vegetation from the banks of Landa Lake and from islands located within Landa Lake. The CONB will also establish riparian protection zones within Landa Park and increase the area and density of native riparian vegetation within those areas.

3.2.13 Management of Household Hazardous Wastes (EAHCP §5.7.5)

EAHCP Obligations:

The CONB will continue to implement a Household Hazardous Waste (HHW) program. The CONB will continue to enhance its HHW program to generate additional participation by the general public.

2018 Compliance Actions:

The CONB held three HHW collection events in 2018. The HHW collection events were held in February, May and October. Overall, 963 cars/participants were recorded with a total of 88,595 lbs. of hazardous waste collected (**Figure 3.2-22**). The CONB produced educational materials to increase awareness of the HHW program and the EAHCP (e.g., including web links to the CONB's EAHCP and HHW website). As compared to 2017 data, there was an increase in the number of participants and the total amount of HHW collected in 2018. The CONB also partnered with NBU to host Operation Med-Safe, which provides an opportunity for residents to discard expired and unused prescription and over-the-counter medications. Operation Med-Safe was held on October 27, 2018.

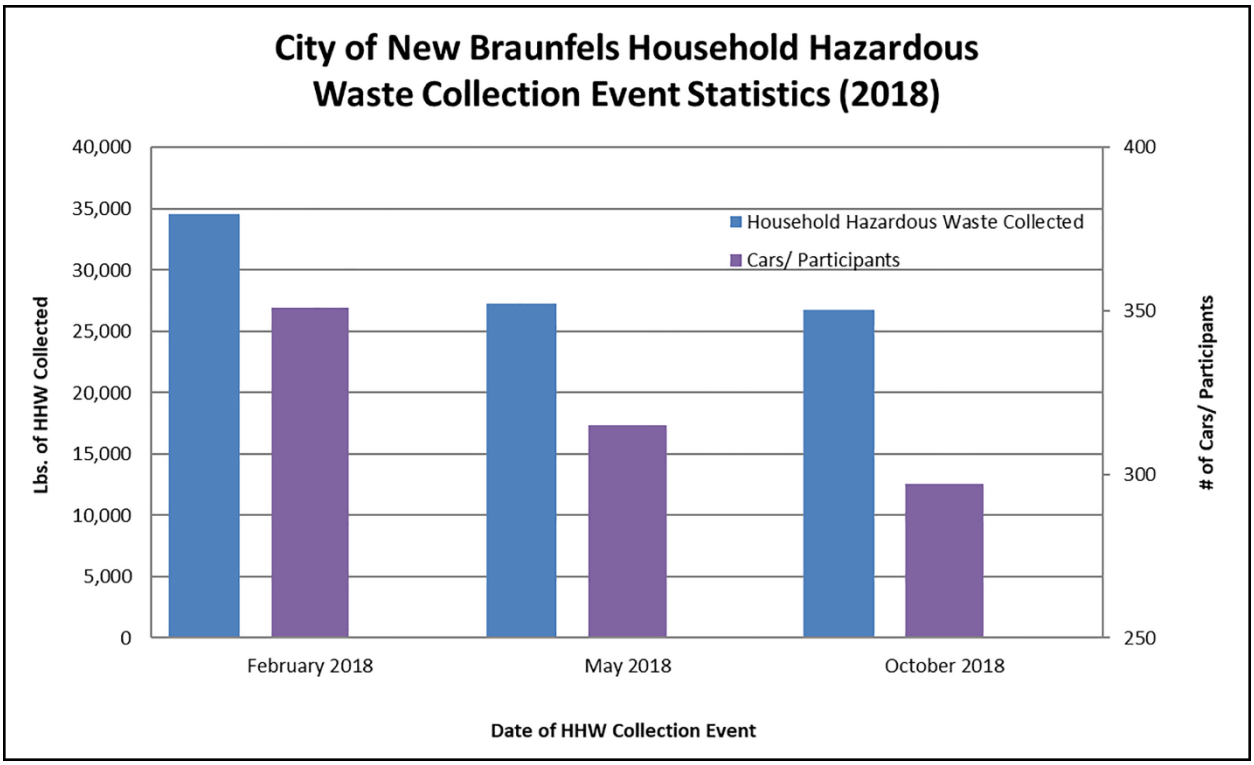

Figure 3.2-22. 2018 Household Hazardous Waste collection event statistics.

Proposed Activities for 2019:

The CONB will continue the HHW program in 2018, which will include three HHW collection events. The CONB will continue to partner with NBU on the Operation MedSafe drug recovery and collection program.

3.2.14 Impervious Cover and Water Quality Protection (EAHCP §5.7.6)

EAHCP Obligations:

The CONB will expand criteria related to desired impervious cover, provide incentives to reduce existing impervious cover on public and private property in New Braunfels, and implement best management practices (BMPs) associated with stormwater runoff in the area of Landa Lake and the spring runs.

2018 Compliance Actions:

The CONB developed a Water Quality Protection Plan (WQPP) in 2017 that identifies stormwater controls and water quality management measures that can be implemented within the Comal River watershed to help reduce pollutant loading and protect water quality. The WQPP identifies seven water quality retrofit projects that can be constructed in the upper portion of Comal River watershed to filter pollutants from and/or promote infiltration of stormwater runoff. The proposed water quality retrofits include rain gardens, permeable parking surfaces and underground stormwater treatment systems. The locations of the proposed water quality retrofits are shown in **Figure 3.2-23**.

In 2018, CONB utilized the WQPP to evaluate and select water quality protection measures to be further develop. The CONB elected to move forward with design and construction of a bio-retention basin (aka rain garden) to be located at North Houston Avenue (Site #3 in **Figure 3.2-23**). CONB completed engineering design and survey work for the North Houston Avenue bio-retention basin project and selected a construction contractor in 2018. Construction of the bio-retention basin will begin in early 2019.

Figure 3.2-23. Locations of proposed water quality retrofit projects.

The CONB performed engineering design for a bio-retention basin at Site #3 located at the end of North Houston Ave adjacent to the Upper Spring Run in 2018 (**Figure 3.2-23**).

Proposed Activities for 2019:

The CONB will complete construction of the bio-retention basin at North Houston Avenue in early 2019. Upon completion, the CONB will monitor and maintain the bio-retention basin to ensure optimal performance.

The CONB will continue to take strides to implement select water quality protection measures identified in the WQPP in 2019. Specifically, the CONB will design and install an underground stormwater treatment vault along Fredericksburg Road (Site #6 in **Figure 3.2-23**) to treat stormwater runoff prior to entering Comal Spring Run #1 and the Comal River system.

Budget permitting, the CONB will also perform engineering design for a measure to treat stormwater runoff from a City-owned parking lot located immediately adjacent to the Mill Race portion of the New Channel

of the Comal River. The proposed measure is to replace the existing impermeable asphalt surface with a permeable parking surface that will allow reduce runoff volume and provide for the filtration of stormwater runoff.

3.2.15 Challenges Observed and Identified Solutions

Overall, the EAHCP habitat protection measures conducted within the Comal River system in 2018 were successful. With respect to aquatic vegetation restoration, it was once again difficult achieving the annual aquatic vegetation coverage goals, despite significant planting efforts. This was due to a variety of reasons that include: 1) competition of the target native plant species given the aggressive nature of *Vallisneria* and *Sagittaria* that tends to outcompete *Ludwigia*, *Cabomba*, and *Potamogeton*; and 2) limited amount of suitable planting space. In order to address both of these challenges, it will be necessary to continue removal of *Vallisneria* and *Sagittaria* in certain locations to make available space for *Cabomba*, *Ludwigia*, and *Potamogeton* and reduce competition. In turn, *Vallisneria* and *Sagittaria* can be planted in locations less suitable for *Cabomba*, *Ludwigia*, and *Potamogeton.* In addition, efforts will continue to be taken to segregate the more aggressive *Sagittaria* from less aggressive *Ludwigia* and *Cabomba* upstream to isolate and limit competition between these species.

Challenges with aquatic vegetation restoration also included the smothering of rooted aquatic vegetation by bryophyte establishment and the limited availability of *Cabomba* in the Comal River system to be utilized as a source of cuttings for restoration efforts. While no immediate solutions have been identified, the CONB will continue to seek avenues to address these issues.

3.3 City of San Marcos

The COSM is responsible for the following measures under the EAHCP:

- Texas wild-rice Enhancement and Restoration (EAHCP §5.3.1 and §6.3.5)
- Management of Recreation in Key Areas (EAHCP §5.3.2)
- Management of Aquatic Vegetation and Litter Below Sewell Park (EAHCP §5.3.3)
- Prohibition of Hazardous Materials Transport Across the San Marcos River and Its Tributaries (EAHCP §5.3.4)
- Reduction of Non-Native Species Introduction (EAHCP §5.3.5)
- Sediment Removal Below Sewell Park (EAHCP §5.3.6)
- Designation of Permanent Access Points and Bank Stabilization (EAHCP §5.3.7)
- Control of Non-Native Plant Species (EAHCP §5.3.8)
- Control of Harmful Non-Native and Predator Species (EAHCP §5.3.9)
- Native Riparian Habitat Restoration (EAHCP §5.7.1)
- Septic System Registration and Permitting Program (EAHCP §5.7.3)
- Minimizing Impacts of Contaminated Runoff (EAHCP §5.7.4)
- Management of Household Hazardous Wastes (EAHCP §5.7.5)
- Impervious Cover and Water Quality Protection (EAHCP §5.7.6)

Implementation of these measures has been accomplished in partnership with Texas State, as specified in the EAHCP. Any measures specified above that were modified in response to drought conditions or any other changes are noted under each EAHCP measure. The COSM implements the EAHCP in partnership with Texas State to maintain consistency in implementation of EAHCP measures that jointly affect the Covered Species and their habitats in the San Marcos River.

3.3.1 Texas wild-rice Enhancement and Restoration (EAHCP §5.3.1 and §6.3.5)

EAHCP Obligations:

The COSM, in partnership with Texas State, will identify areas of optimal habitat for *Zizania texana* (Texas wild-rice) and target those areas for restoration. Restoration will include the removal of non-native submerged aquatic vegetation species, propagation and planting of Texas wild-rice and continual monitoring of new and existing stands. The COSM uses Table 34 of the *Submerged Aquatic Vegetation Analysis and Recommendation Report* (SAV Report) (BIO-WEST and Watershed Systems Services 2016) as the guide for restoration efforts.

2018 Compliance Actions:

Texas wild-rice coverage was increased through maintenance of existing stands and new plantings. Existing stands throughout the river were maintained by gardening non-native regrowth within stands and clearing of adjacent suitable habitat to allow for expansion. Within active work sites (reaches with Texas wild-rice expansion goals listed for 2018 in Table 34) new stands were established by clearing non-natives from areas of suitable habitat followed by replanting with both seed germinated and tiller propagated Texas wild-rice.

Prior to clearing, non-native vegetation was fanned to displace fountain darters or any other aquatic fauna. Removal was then performed manually with vegetation being captured in nets to minimize non-native propagation by fragmentation. After removal, collected material was sorted, any native biota caught within was returned to the river, and all remaining vegetation was disposed of at either the COSM or Spring Lake composting facility.

Denuded areas were replanted with Texas wild-rice grown at USFWS SMARC (seed-germinated) or the Texas State raceways at the Freeman Aquatic Building (FAB) (tiller). To allow for natural expansion and access for future gardening of non-native regrowth, areas were replanted at 20 to 50 percent vegetation coverage.

Geographic area and number of Texas wild-rice individuals planted were tracked through polygons created in ArcMap and overlaid on georeferenced aerial imagery of the river. Using this data, estimates of area planted within active reaches were generated throughout the year to evaluate work progress in relation to 2018 coverage goals as defined by Table 34. **Table 3.3-1** lists the Texas wild-rice planting data that were tracked throughout the year and were used to assess restoration progress during 2018.

Table 3.3-1. Texas wild-rice Individuals Planted, Estimated Area Treated, and Amount of Effort per River Reach in 2018

Reach	Number Planted (Individuals)	Estimated Area Planted (m^2)	Effort (Days)
Spring Lake	3,522	120	7
City Park	120	4	1
Cypress Island	2,304	72	3
IH-35	1,850	86	3
TOTAL RIVER	**7,796**	**282**	**14**

To assess area (m^2) of Texas wild-rice, aerial coverage maps were created in ArcMap with vegetation survey data or by generating vegetation polygons based on georeferenced aerial imagery, which were then field-verified. **Figure 3.3-1** through **Figure 3.3-7** illustrate the area (m^2) of Texas wild-rice observed in fall 2018 for active reaches.

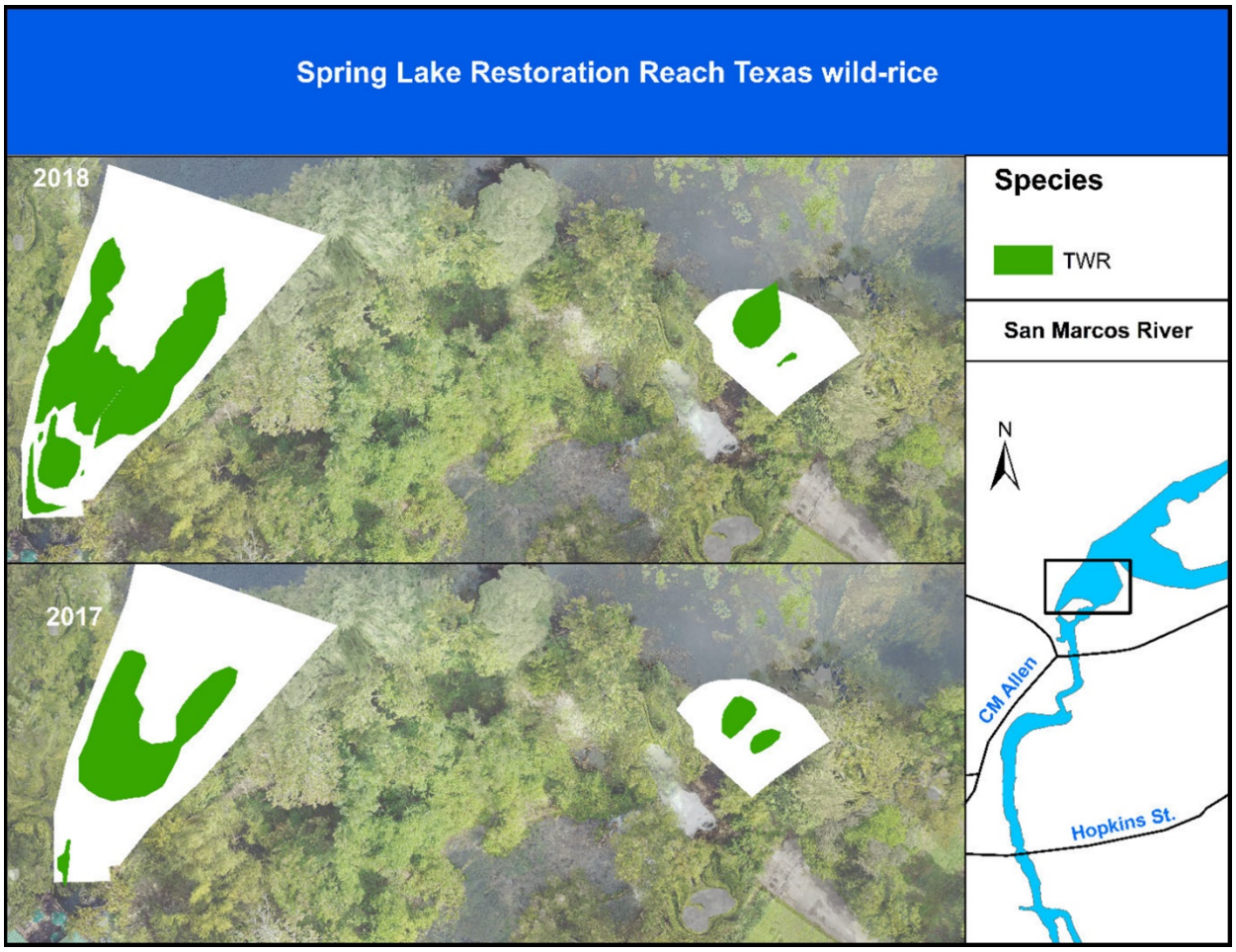

Figure 3.3-1. Texas wild-rice aerial coverage in Spring Lake Restoration Reach in fall 2017 and fall 2018.

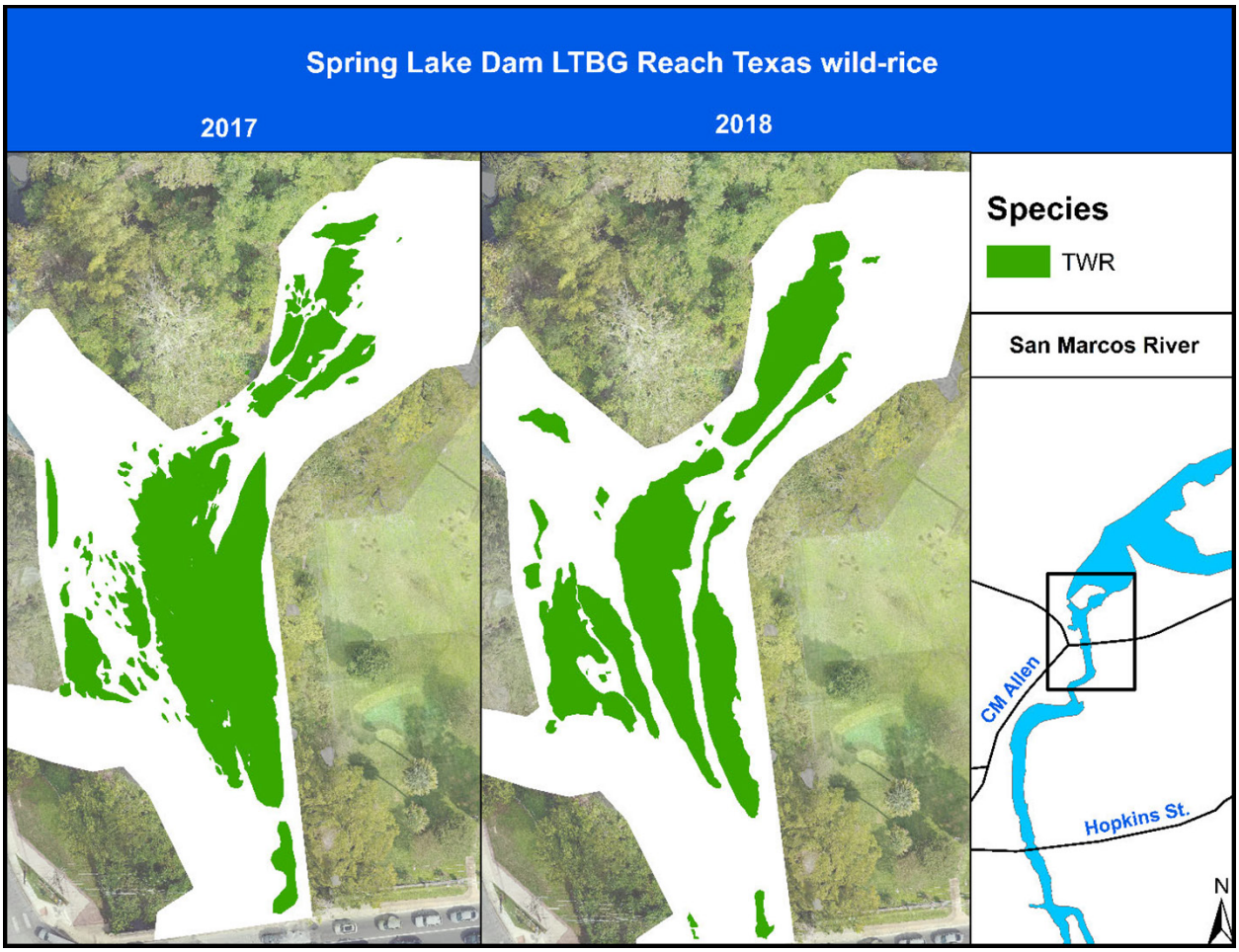

Figure 3.3-2. Texas wild-rice aerial coverage in Spring Lake Dam LTBG Reach in fall 2017 and fall 2018.

Figure 3.3-3. Texas wild-rice aerial coverage in City Park LTBG Reach in fall 2017 and fall 2018.

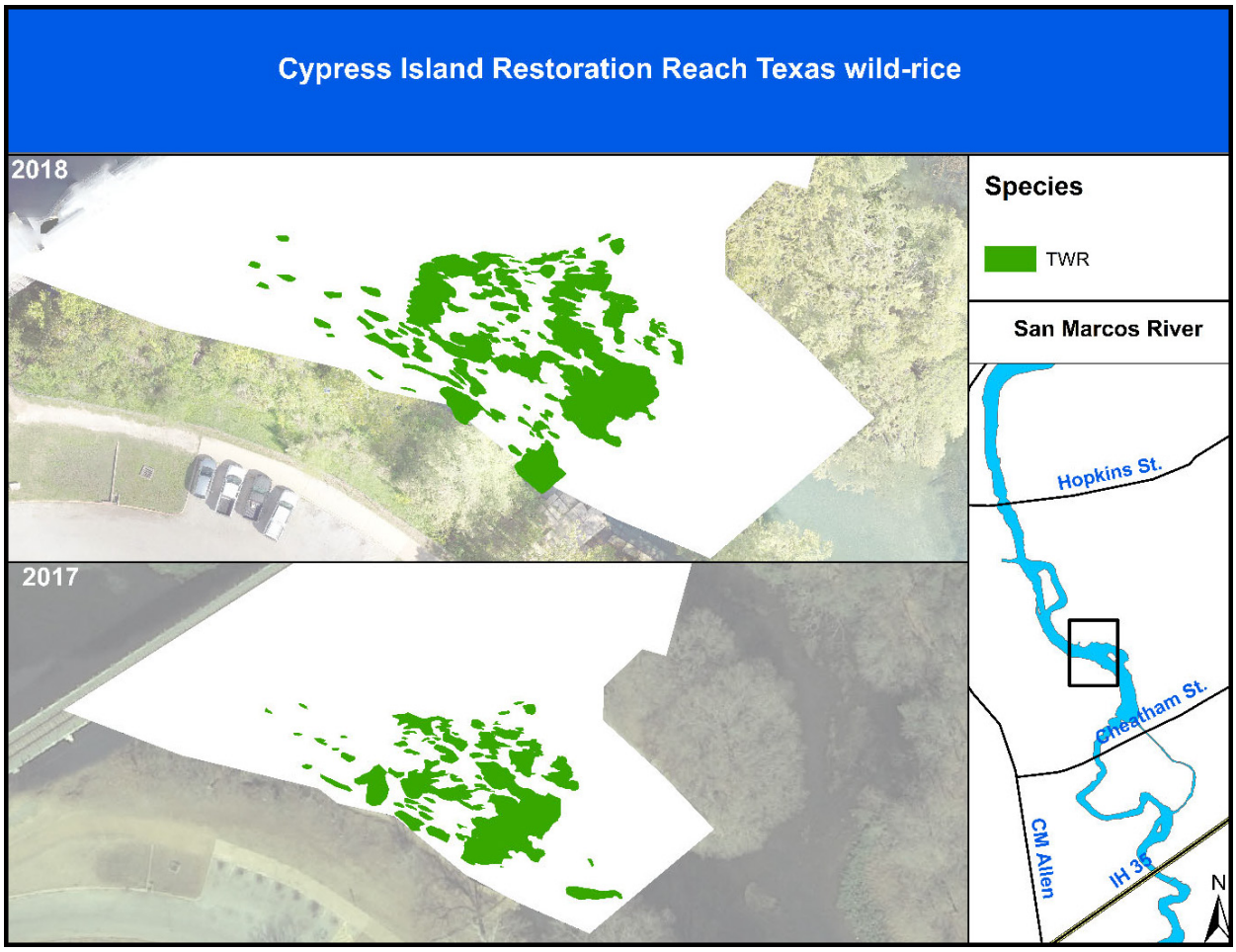

Figure 3.3-4. Texas wild-rice aerial coverage in Cypress Island Restoration Reach in fall 2017 and fall 2018.

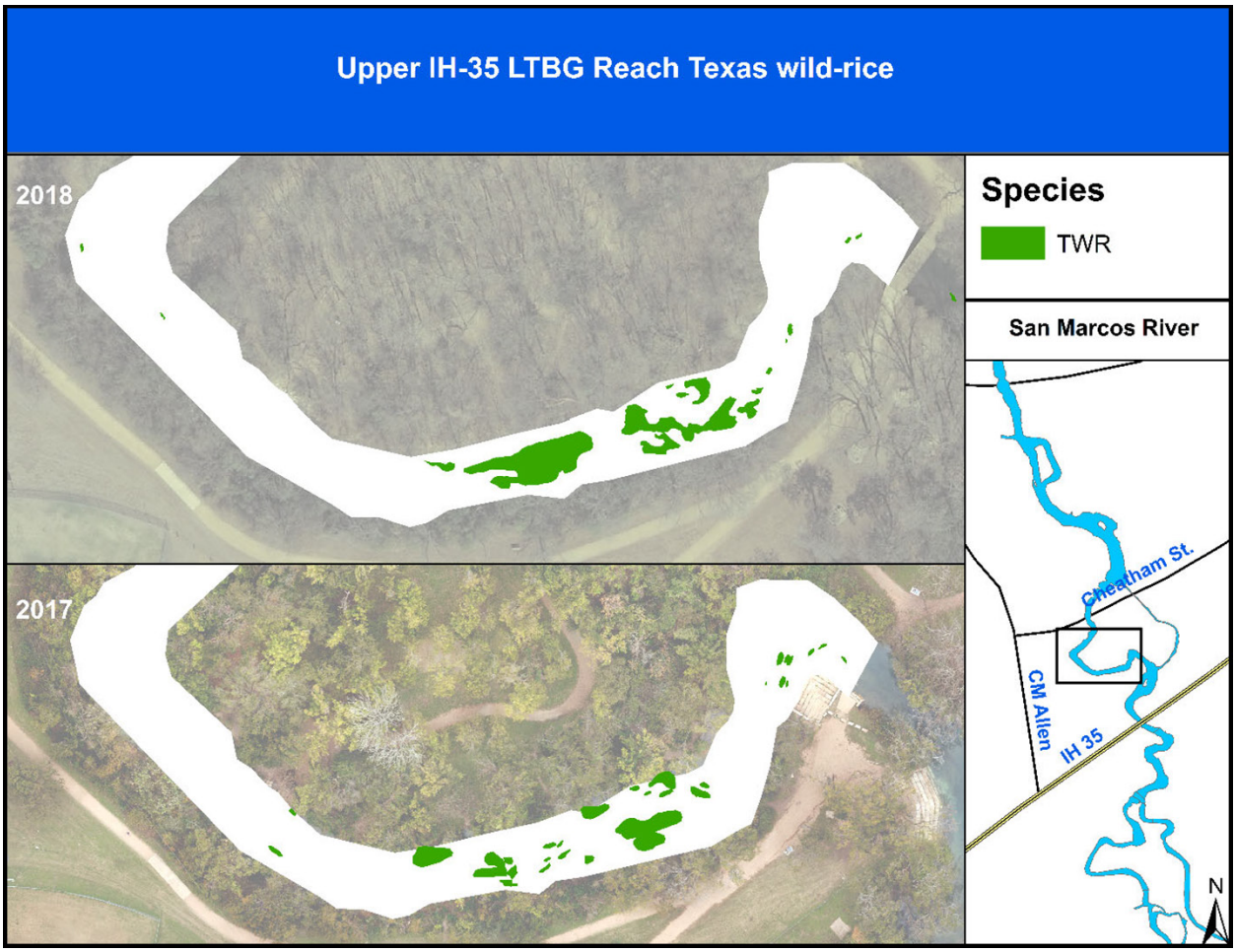

Figure 3.3-5. Texas wild-rice aerial coverage in IH-35 LTBG Reach in fall 2017 and fall 2018.

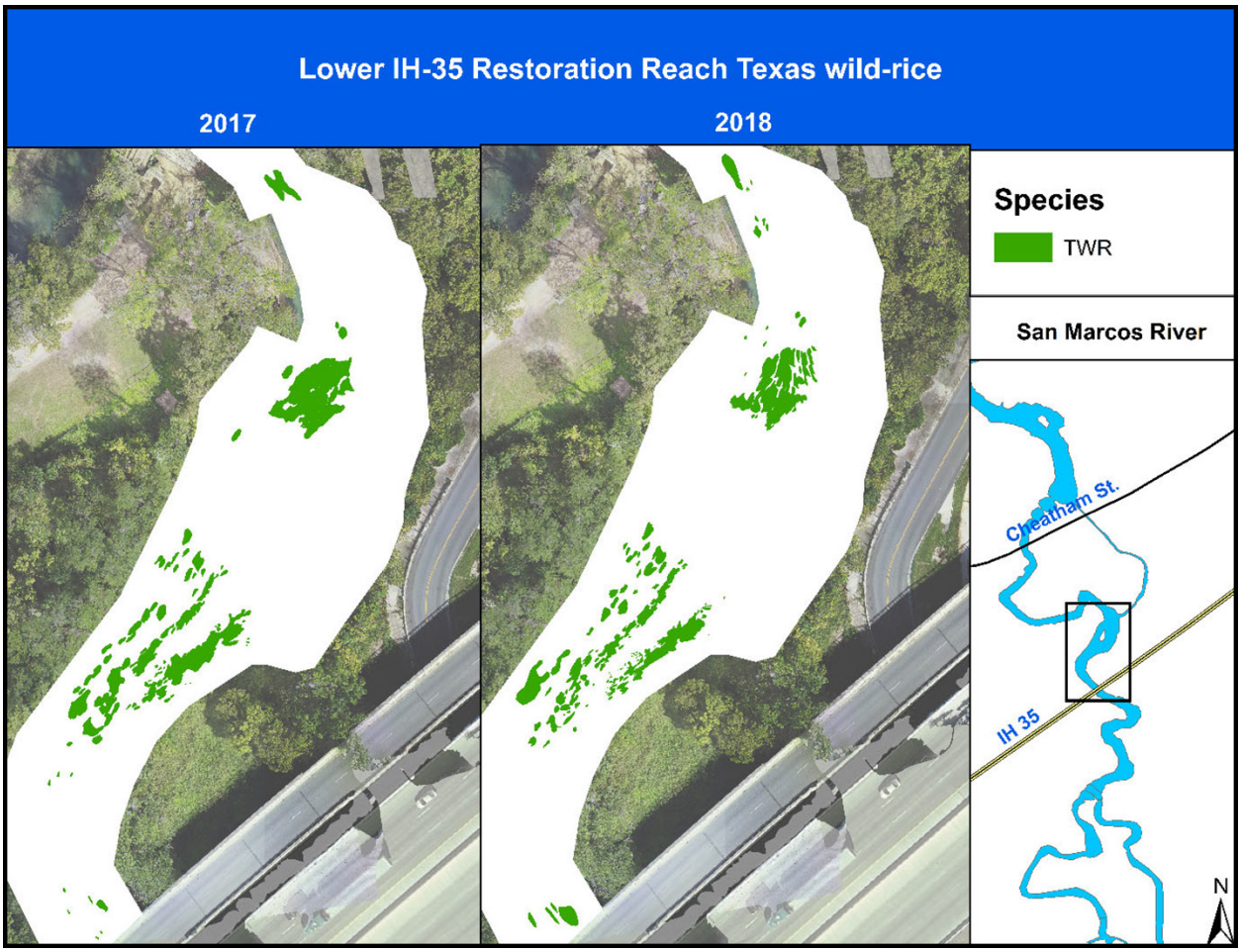

Figure 3.3-6. Texas wild-rice aerial coverage in IH-35 expanded reach in fall 2017 and fall 2018.

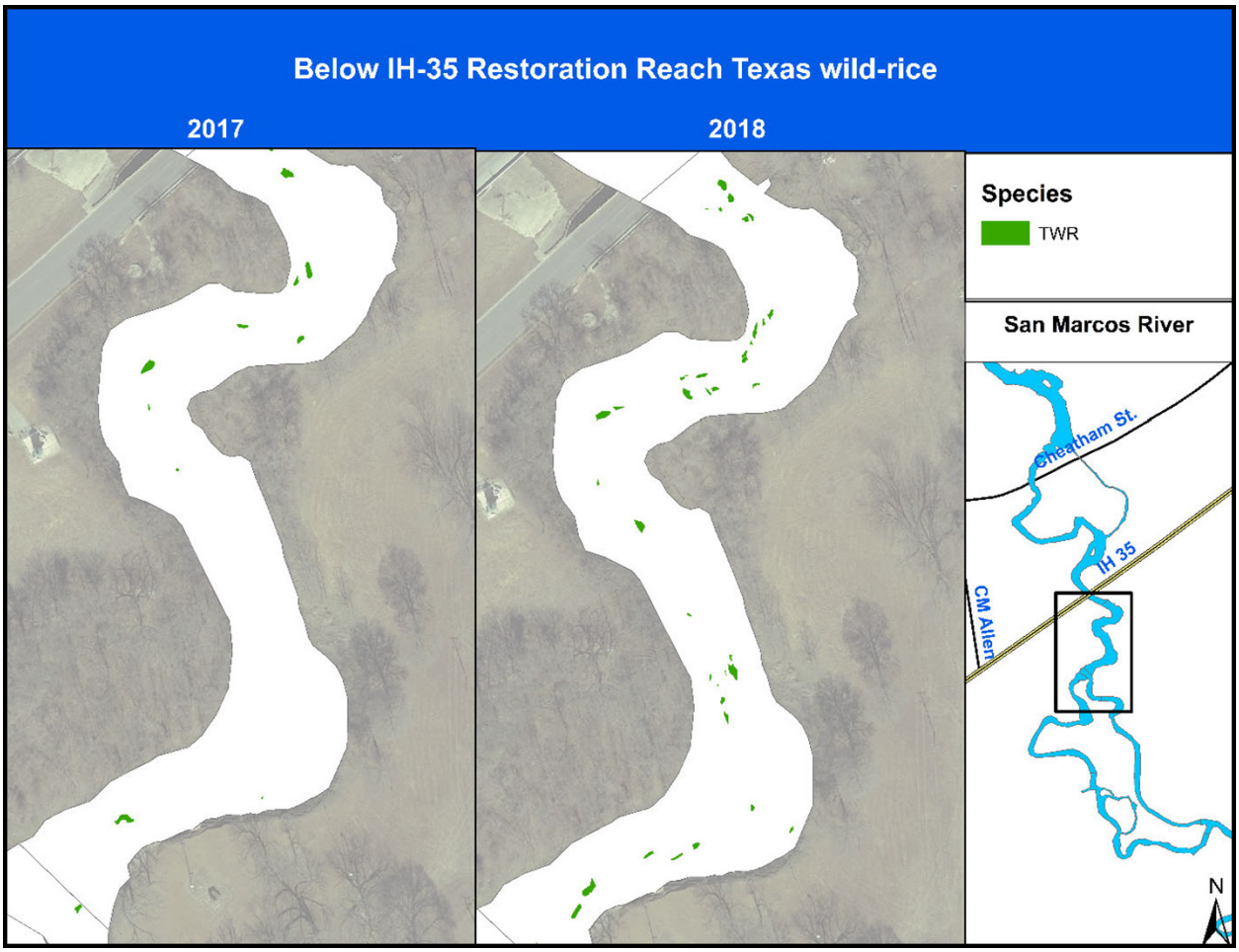

Figure 3.3-7. Texas wild-rice aerial coverage Below IH-35 Restoration Reach in fall 2017 and fall 2018.

Table 3.3-2 quantifies the expansion of Texas wild-rice from 2013 to 2018 throughout the San Marcos River. Since 2013, Texas wild-rice has expanded an estimated 5,914 m^2, or 240 percent, through planting and natural expansion. Since 2017, Texas wild-rice coverage has decreased by an estimated 2,049 m^2. Texas wild-rice stands have been lost in areas that have high rates of recreation. During the summer recreation season, low flows and decreased water levels exposed more areas for wading and increased foot traffic, which may have disturbed and uprooted stands of Texas wild-rice. These stands of Texas wild-rice may recover and grow back over the winter and spring months with increased springflow and reduced disturbance from aquatic recreation.

Cumulative Texas wild-rice coverage goals as defined by Table 34 for 2018 were met or exceeded in all reaches except for Spring Lake, which was approximately five square meters short. Spring Lake work plans for 2019 will be adjusted to rectify the difference.

Work plans for 2018 in the Below IH-35 Restoration Reach were not executed due to the uncertainty of construction or demolition of Cape's Dam, although Texas wild-rice coverage goals are expected to be met in this reach using tillers propagated from upstream stands and natural expansion.

Table 3.3-2. Aerial Coverages of Texas wild-rice by Reach in San Marcos River for 2013 through 2018, and Changes Detected Between Years

Reach	Reach Type	Area coverage (m^2)							
								Change (m^2)	
		2013	2014	2015	2016	2017	2018	2017-18	2013-18
Spring Lake	RR	0	0	0	47	184	246	62	246
Spring Lake Dam	RR	199	360	573	887	1,389	1,088	-301	890
Sewell Park	RR	666	839	1,202	1,186	1,811*	1,191	-620	525
Below Sewell – City Park	R	1,212	1,963	2,253	2,429	2,810*	2,726	-83	1,515
City Park	LTBG	384	603	1,348	1,562	2,247	1,361	-886	977
Hopkins St – Snake Island	RR	0	0	693	0	1,169	815	-353	813
Cypress Island – Rio Vista Dam	RR	0	0	123	238	247	249	2	249
IH-35 (Upper and Lower)	LTBG	0	0	82	276	512	621	109	621
Below IH-35	RR	-	-	-	-	56	76	20	76
TOTAL RIVER		**2,461**	**3,765**	**6,274**	**6,625**	**10,425**	**8,375**	**-2,050**	**5,914**

Numbers in red indicate negative numbers.

Proposed Activities for 2019:

The overall goal for Texas wild-rice has been met in all reaches except for the Spring Lake, Cypress Island, IH-35 combined and below IH-35 reaches. These reaches will be planted according to the annual goals listed in Table 34 for 2019. Cumulative Texas wild-rice coverage goals through 2019 in the Spring Lake Dam, City Park, IH-35 expanded, and Below IH-35 have already been achieved so efforts in those reaches will focus on monitoring and maintenance of existing stands.

3.3.2 Management of Recreation in Key Areas (EAHCP §5.3.2)

EAHCP Obligations:

The COSM will continue to implement recreation mitigation measures approved by the San Marcos City Council on February 1, 2011 (Resolution 2011-21). These include, but are not limited to, implementation of buffer zones around designated recreation areas, a robust river education program, addressing the accumulation of silt in the river through watershed controls, reducing recreational impacts that harm the river (such as litter), and the issuance of COIs to river outfitters to extend the protections of the ITP to those entities.

2018 Compliance Actions:

Several strategies were used by the COSM to manage recreation in key areas:

1) Access control: In 2018, access points were monitored twice for potential undermining to assure public safety and guide maintenance actions.

2) Signage: In 2018, the EAHCP partnered with Keep San Marcos Beautiful to develop a Leave No Trace program consisting of an outreach booth stationed at City Park and Rio Vista Park during peak recreation times. This booth educated river users about how their actions affect the riverine habitat, primarily focusing on litter. The "San Marcos River: Life at 72 Degrees" video was installed at Lions Club tube rental for river users to view while in line as well as posted on social media. Conservation Crew (CC) and interns presented a watershed model and an interactive river habitat card deck game at the Texas State Aquatic Camp (**Figure 3.3-8**). Maps were posted at the Discovery Center showing trails, access points, and other amenities and the city website was updated with this information. The Discovery Center also provides interpretive signage covering aquifer, river habitats, and listed species.

Figure 3.3-8. Educational presentation for Texas State Aquatic Camp participants.

3) Conservation Crew: This work team was developed to educate the public about the EAHCP and to monitor and protect Texas wild-rice stands in high recreation areas. In 2018, the CC was composed of 15 university students and alumni. These individuals were paid by both EAHCP and COSM funding and included volunteer interns. The team began work on May 16, 2018, working Wednesday through Sunday continuing through the Labor Day weekend. Four to six crew members worked in pairs from 11:00 a.m. through 7:00 p.m., kayaking and walking the banks to maximize river user contact.
   a) The CC accomplished many tasks for education, protection of endangered species and their habitats (primarily Texas wild-rice, monitoring, project maintenance, and litter removal).
   b) The CC spoke with river users about the importance of EAHCP projects and listed species habitat protection. The CC participated in eight public events to discuss the EAHCP and educate the public with brochures, signage, interactive river habitat card deck game, and a

watershed model. Hiring university students as CC is an added benefit. These students leave the CC program with a deep understanding of endangered species and the unique nature of the San Marcos River. This benefit extends to the COSM's intern program as well.

c) The CC separated floating vegetation mats (consisting of mostly *Hydrilla verticillata* and *Hygrophila polysperma*) from Texas wild-rice stands to ensure their health. They also installed education signage in Clear Springs and Sewell Park Texas wild-rice enclosures that inform river users about Texas wild-rice stands and the importance of its protection. For other signage, replaced broken sign brackets, damaged signs and t-posts as needed.

d) The CC assisted with other projects, including the Texas wild-rice survey with USFWS, invasive plant removal, and tiller collection. These opportunities provide a "conversation-starter" opportunity between the CC and the public. Areas with an abundance of people such as Rio Vista, City Park and Clear Springs Natural Area are frequently monitored to reduce negative impacts to the river and to ensure park and university rules are observed. Riparian fences and signs are inspected for damage or graffiti, and any problem areas along the river are reported and addressed.

4) Litter removal: During the recreation season, 4,382 cubic feet (ft^3) of litter and mixed recyclables were removed from the river substrate, litter boats, and parks along the river by the CC. The three litter boats are emptied four times a day, helping to prevent litter from entering the river.

5) In support of the Texas wild-rice Protection Zones, the CC installed enclosure buoys with messages about protected species during the time when Condition M of the ITP was enacted in 2018.

6) Rio Vista Falls buffer zone: Rio Vista Falls has a 100-ft buffer zone on the west side of the river that excludes picnic tables, pop-up tents, shelters, and portable grills.

7) Stencil on rented tubes: Applied stencils rubbed off over time, so this action was eliminated. The video loop and signage while tube renters are queuing at City Park replaced this action.

8) Reduction of turbidity: The reduction of turbidity through watershed management strategies is addressed through the COSM WQPP and Texas State Watershed Protection Plan.

9) Recreation management: The CC monitors both COSM and Texas State property and the program is nominally supported by COSM Park Rangers and University Police. Additionally, the Habitat Conservation Plan Manager is funded equally by Texas State and COSM to ensure a unified approach.

Proposed Activities for 2019:

In 2019, the COSM will continue implementation of recreational management goals as outlined above and continue to educate the public engaged in water-based recreation on sustainable river use that protects listed species and their habitats. To help achieve this goal, a litter-based survey will be developed and implemented to start catching trends and educate. The seasonal workers will also conduct continuous litter removal and EAHCP project maintenance while walking/kayaking. The COSM will add a static CC presence at Clear Springs to enforce the Texas wild-rice exclusion zones and minimize the impacts occurring to San Marcos salamanders in the eastern spillway. The COSM will introduce the COI program

as directed by the EAHCP Program Manager to qualified third parties conducting recreational activities in and along the San Marcos River.

3.3.3 Management of Aquatic Vegetation and Litter Below Sewell Park (EAHCP §5.3.3)

EAHCP Obligations:

The COSM will dislodge floating vegetation mats and remove from the system. The COSM will also remove inorganic litter regularly.

2018 Compliance Actions – Floating Mat Removal

From January through October 2018, 132.4 cubic meters (m^3) of floating vegetation mats were pulled from the river. These mats are collected via canoe, taken to removal point where they are sorted to remove entrained fauna (**Figure 3.3-9** through **Figure 3.3-11**). The invasive plant species found in the mats are primarily *Hydrilla* and *Hygrophila*, with smaller amounts of *Eichhornia* and *Pistia.* The predominant native species is *Ceratophyllum,* which comprises 50 – 60 percent of the collected mats in Sewell and Clear Spring reaches. Other natives include *Sagittaria, Zizania*, and *Cabomba*. The COSM's contractor focuses on the heavy mats shading out Texas wild-rice and other native plant stands.

Figure 3.3-9. Vegetation mat composed primarily of *Ceratophyllum* floating down from Clear Springs reach.

Figure 3.3-10. Before and after vegetation mat removal at Bicentennial Park.

Figure 3.3-11. Removed mats loaded up for disposal at composting site outside the San Marcos River watershed.

2018 Compliance Actions – Litter Removal

The COSM's contractor removed inorganic litter from Clear Springs to Stokes Park with the COSM funding the work performed from City Park to IH-35. The contractor removed litter by snorkeling and towing a paddle board. A paddle board was used rather than a canoe or kayak due to the bottom of the boat being flat and more difficult to flip over, it also provided easier to access. Lobster bags were filled with litter then

dumped into totes mounted to the paddle board. The contractor adjusted dives to the conditions, sometimes drifting downstream and other times working upstream. Working upstream was best when there was a lot of litter to be removed because visibility was never lost. When there was a deeper hole with large litter accumulation, the contractor placed a hookah air supply system on the paddle board that allowing workers to stay underwater (**Figure 3.3-12** and **Figure 3.3-13**).

Figure 3.3-12. Litter collection setup.

Figure 3.3-13. Litter collection in progress.

The monthly totals of litter removed exhibits the importance of focusing on areas downstream of IH-35 (**Figure 3.3-14**). Due to the low amounts of litter collected in Spring Lake during the first year of implementation (2013), this location will be accomplished by Texas State as needed under the Spring Lake Management Plan. Minimal litter was collected above City Park, however, including this reach is important for monitoring purposes.

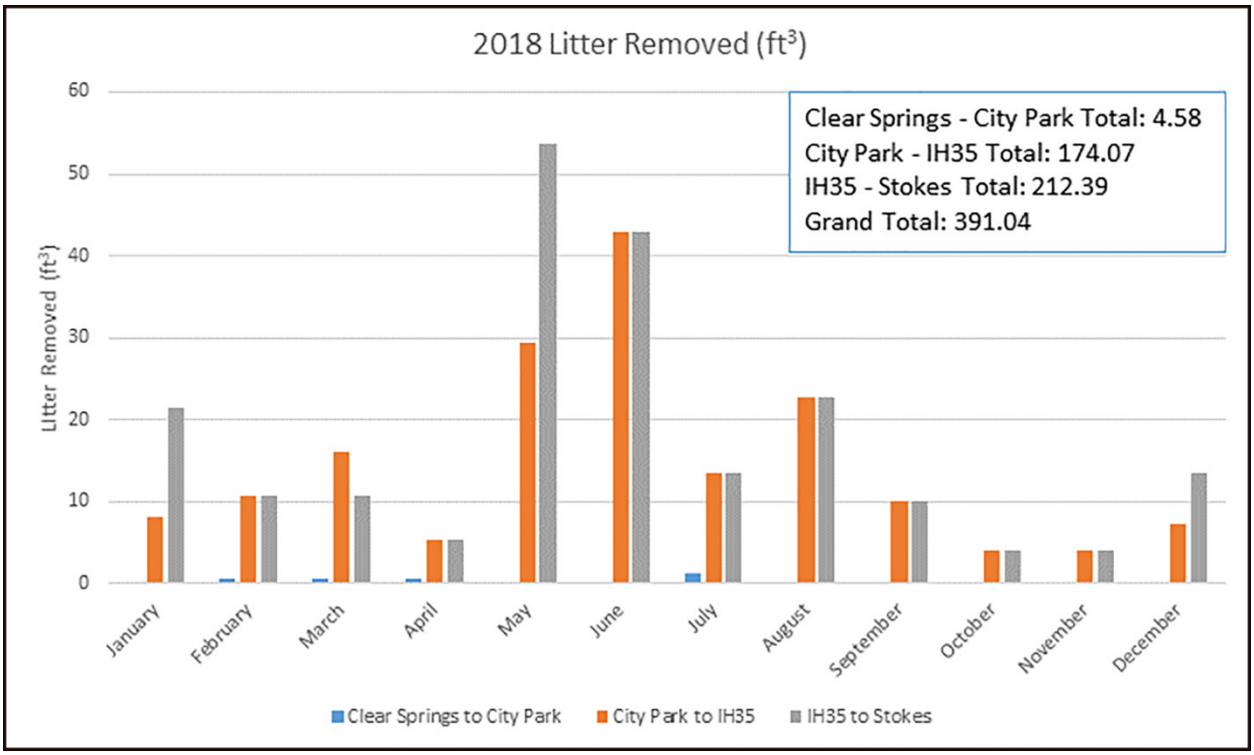

Figure 3.3-14. Cubic feet of litter removed from Clear Springs to Stokes Park.

Proposed Activities for 2019:

In 2019, the COSM will continue to implement litter removal consistent with protocols established in the EAHCP and in the 2019 COSM Work Plan.

3.3.4 Prohibition of Hazardous Materials Transport Across the San Marcos River and its Tributaries (EAHCP §5.3.4)

EAHCP Obligations:

The COSM will coordinate with Texas Department of Transportation (TxDOT) to designate routes for the transportation of hazardous materials that will minimize the potential for impacts to the San Marcos River and its tributaries.

2018 Compliance Actions:

The COSM submitted a revised HAZMAT route based on TxDOT review. TxDOT stated that the route on the east side of the San Marcos River did not follow only state roads and, therefore, could not be approved. However, the west side route, using Wonder World Drive, does meet TxDOT requirements, so COSM will be pursuing the approval of that route.

Proposed Activities for 2019:

The Wonder World Drive route will be submitted for approval to TxDOT as a HAZMAT route.

3.3.5 Reduction of Non-Native Species Introduction (EAHCP §5.3.5)

EAHCP Obligations:

The COSM will partner with Texas State and other groups to establish an education campaign targeted at reducing the introduction of non-native species into the river system. The COSM will also provide opportunities for people to dispose of unwanted aquatic animals and plants to deter aquarium dumps into the river system.

2018 Compliance Actions:

1) Flyer(s):
   a) Posted in Texas State dorms near the end of the spring semester (April);
2) State the harms of releasing non-native fish into our river:
   a) Included in EAHCP signage, presentations, and public events;
3) Advertise through:
   a) Local pet stores (not allowed by Walmart and PetsMart)
   b) Local festivals and parades (Veterans & Mermaid)
   c) Semiannual volunteer polespear tournament public outreach
   d) On social media websites – working with Parks and Communications Departments, San Marcos River Foundation (SMRF) and local Facebook sites
   e) Video posted on city channel for repeat views;
4) Donation:
   a) Discovery Center – in 2018, received 59 unwanted fish; carp, beta, suckermouth, mollies, pictus catfish, tetras, neons and cichlids (**Figure 3.3-15**). Almost 50 percent of the individuals have been adopted.

Figure 3.3-15. Fish drop-off pond at the Discovery Center.

Proposed Activities for 2019:

The COSM, in partnership with Texas State and contractors, will continue to implement efforts described above.

3.3.6 Sediment Removal Below Sewell Park (EAHCP §5.3.6)

EAHCP Obligations:

The COSM will remove sediment from areas along the river between City Park and IH-35. Sediment removal efforts will specifically target potential Texas wild-rice habitat.

2018 Compliance Actions:

The removal of sediment in support of native aquatic planting activities has proven to be both unnecessary and overly expensive. For example, to remove 158 m^3 the cost was $555,000 (2013 – 2015). Additionally, the COSM's contractor has successfully accomplished multiple plantings in silted areas without needing to first remove silt. Therefore, the funds allocated for sediment removal will be used primarily to deter influx of sediment from the Sessom Creek watershed (see related discussion under **Section 3.3.13** of this Annual Report). Since 2017, no funds have been expended for sediment removal. Using the AMP, fund reallocation was approved by the IC and the USFWS. Funds will be available for the plantings, if deemed necessary.

Proposed Activities for 2019:

Sediment will be removed only as needed to support aquatic planting activities.

3.3.7 Designation of Permanent Access Points and Bank Stabilization (EAHCP §5.3.7)

EAHCP Obligations:

The COSM will stabilize banks in City Park, at the Hopkins Street underpass, Bicentennial Park, Rio Vista Park, Ramon Lucio Park, and at the Cheatham Street underpass. Bank stabilization will be conducted using stone terraces and native vegetation along the riparian zone. The COSM will incorporate permanent access points to facilitate river entrance by recreationists that is more protective to the species and their habitats. The COSM will maintain all access points in perpetuity. All bank stabilization/access points were heavily eroded areas that experienced intense use by the public through river access. This strategy of providing access points and enhancing riparian zones provides a balance between recreation and maintaining a healthy riparian buffer and river bank.

2018 Compliance Actions:

The eight existing access point locations (**Figure 3.3-16**) were monitored twice in 2018 that revealed low level undermining on four of the eight access points (**Table 3.3-3** and **Figure 3.3-17)**.

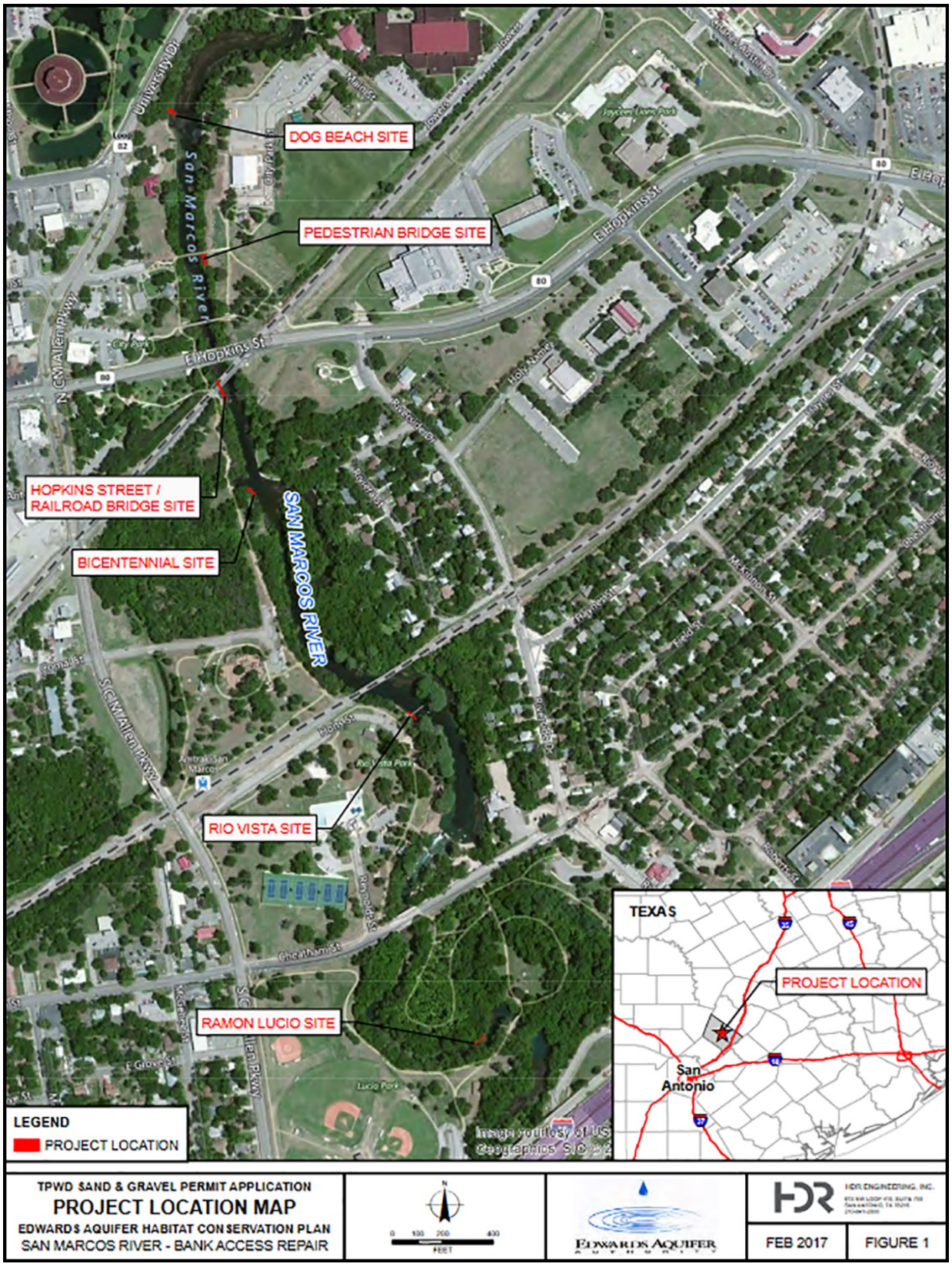

Figure 3.3-16. Locations of stabilized access points along the San Marcos River.

Table 3.3-3. Undermining Measured (in Inches) at Four Access Point Locations – May and October, 2018

Sites	Dog Beach 1	Dog Beach 2	Hopkins 1	Hopkins 2	Bicentennial 1	Bicentennial 2	Rio Vista 1	Rio Vista 2
Depth 1	5	3.5	8	0.5	2	7.5	3	6
Length 1	6	3	2	0.5	1	6	2	3
Depth 2	4	7.5		8		2.5		10
Length 2	8	17		2.5		1		7
Depth 3	6	7.5		5		6		
Length 3	7	5		0.5		4		
Depth 4	8	12		5		3		
Length 4	8	8		3		2		
Depth 5	3	12						
Length 5	4	9						
Depth 6	7	12						
Length 6	6	9						
Depth 7	6	8						
Length 7	3	5						
Depth 8	3	9						
Length 8	4	6						

Figure 3.3-17. Measurements taken at each point under bottommost rock, showing undermining.

Proposed Activities for 2019:

All access points will be monitored semiannually through measurements of undermining and gaps between rocks.

3.3.8 Control of Non-native Plant Species (EAHCP §3.3.8)

EAHCP Obligations:

The COSM will partner with Texas State to develop and implement a non-native plant removal program reaching from Spring Lake downstream to the city boundary. Aquatic, littoral, and riparian non-native plant species will be removed and replaced with native species. The riparian zone will be re-planted to cover a minimum of 15 m in width where possible. The COSM will install fencing to protect the new plantings while they mature. Appropriate permits will be obtained for the removal of non-native plants.

2018 Compliance Actions:

Non-Native Aquatic Plant Removal

In reaches with 2018 native species expansion goals listed in Table 34 of the SAV Report, non-native aquatic vegetation removal was performed manually in areas containing suitable habitat for native SAV species. *Hydrilla verticillata* and *Hygrophila polysperma* were the primary focus for non-native removal efforts as these species are most commonly found occupying suitable SAV habitat. However, this year increased efforts were placed on removing or clearing floating vegetation that accumulated on native SAV stands. *Nasturtium officinale* (watercress), *Eichhornia crassipes* (water hyacinth) and floating vegetation mats block sunlight to aquatic plant stands and can eventually lead to die off. Therefore, removing or clearing vegetation covering native SAV was necessary to maintain health and continued expansion of stands.

Prior to clearing, non-native vegetation was fanned to help displace fountain darters or any other aquatic fauna. Removal was then performed manually with vegetation being captured in nets to minimize non-native propagation by fragmentation.

After removal, collected material was sorted, any native biota caught within was returned to the river, and vegetation was disposed of at either the COSM or Spring Lake composting facility. **Table 3.3-4** itemizes the species found and returned to the river during sorting of captured non-native vegetation. Denuded areas were replanted with native SAV species grown at USFWS SMARC or the Texas State raceways at the FAB. At the end of each month the number of individuals for each native SAV being maintained at the Texas State raceways were recorded to track inventory and asses stock in relation to work plans (**Table 3.3-5**).

Native SAV species were selected for replanting based on habitat preference and corresponding suitability of denuded area. To allow for natural expansion and access for future gardening of non-native regrowth, denuded areas were replanted at 20 to 50 percent vegetation coverage.

Geographic area of removal, planting, and number of individuals of each species planted were tracked through polygons created in ArcMap overlaid on georeferenced aerial imagery of the river. Using this data, estimates of area planted were generated throughout the year to evaluate work progress in relation to 2018 coverage goals as defined by Table 34.

To assess the area (m^2) of native and non-native SAV in active work sites, aerial coverage maps were generated in ArcMap using field-verified georeferenced aerial imagery.

Table 3.3-4. Animal Species Collected and Returned to San Marcos River During Non-Native Vegetation Removal in 2018

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	TOTALS
Cambaridae (crayfish)	35	30	10	75	50	156	82	43	5	**486**
Lepomis sp. (sunfishes)	2	5	3	7	3	20	6	4	5	**55**
Etheostoma fonticola (fountain darter)					1	3				**4**
Eurycea nana (salamander)	1	9								**10**
Ameiurus sp. (bullhead catfish)										**0**
Ambloplites rupestris (rockbass)				1						**1**
Trachemys scripta elegans (red-eared slider)				1	1	4	2			**8**
Pseudemys texana (river cooter)				1	2	3				**6**
Gambusia					1	7				**8**

Table 3.3-5. Number of Individual Plants Per Species Maintained Each Month, Raceways at Freeman Aquatic Building in 2018

Month	Species (individuals)					
	Zizania	*Ludwigia*	*Potamogeton*	*Sagittaria*	*Cabomba*	*Hydrocotyle*
January	1,326	3,790	2,630	0	1,080	0
February	1,743	1,854	1,161	9	900	0
March	1,246	2,630	2,550	5	1,090	0
April	1,309	2,007	3,942	75	2,080	465
May	1,169	6,444	5,745	141	2,080	465
June	2,037	5,670	5,100	399	1,590	0
July	2,350	7,080	4,200	50	1,800	0
August	360	2,820	455	0	0	0
September	375	4,560	1,890	0	2,184	0
October	1,200	4,121	7,245	0	3,458	0

2018 LTBG and Restoration Reaches (Non-Native Submerged Aquatic Vegetation Removal and Native Submerged Aquatic Vegetation Planting Sites)

In 2018, aquatic vegetation treatment work plans were developed based on the proposed EAHCP vegetation coverage goals as defined by Table 34 of the SAV Report. Vegetation treatment efforts included non-native removal and native planting within the Spring Lake Restoration Reach, Spring Lake Dam LTBG Reach, City Park LTBG Reach, Cypress Island Restoration Reach, IH-35 LTBG Reach, and expanded IH-35 Restoration Reach (**Figure 3.3-18**). Non-native aquatic vegetation maintenance was performed in other reaches when necessary.

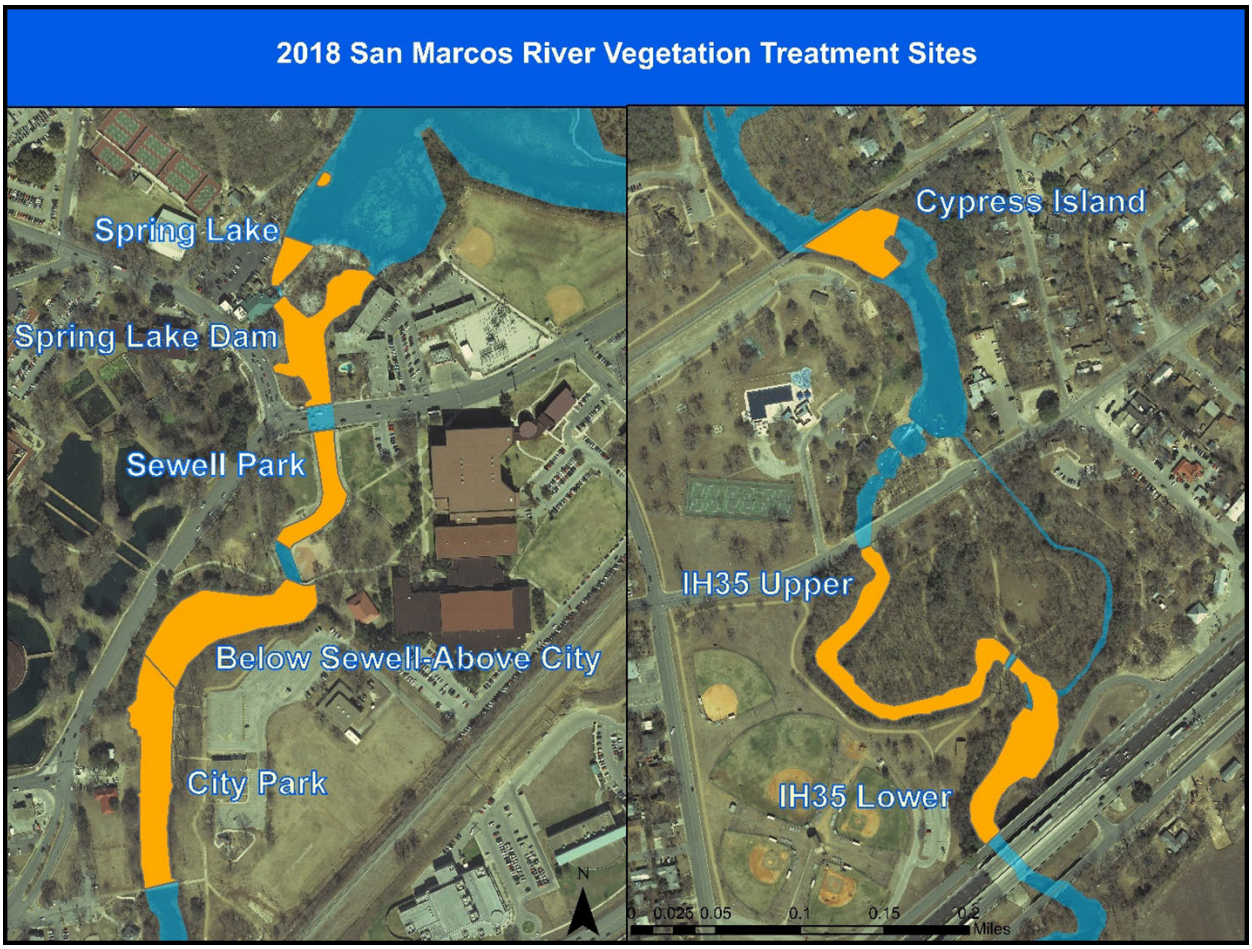

Figure 3.3-18. LTBG and Restoration reaches where vegetation treatment was performed in 2018.

Spring Lake Restoration Reach

In the Spring Lake Restoration Reach, vegetation treatment efforts occurred on 15 days in 2018 during which approximately 105 m^2 of *Hygrophila polysperma* was removed, 102 m^2 of floating vegetation mats were cleared from native SAV stands and 3,522 Texas wild-rice individuals covering an estimated area of 121 m^2 were planted (**Figure 3.3-19**). Texas wild-rice is the only plant permitted by EAHCP for Spring Lake, so Texas wild-rice was planted in areas where non-natives have been removed. Work efforts in Spring Lake occurred adjacent to previously established Texas wild-rice stands from previous years as successful establishment within this reach has been limited to directly above the dam on the eastern and western spillways. Aerial coverage of Texas wild-rice within Spring Lake increased by over 60 m^2 since fall 2017, an approximate 34 percent gain, but was 4 m^2 under the 2018 coverage goal defined by Table 34. **Figure 3.3-20** illustrates the estimated 184 m^2 Texas wild-rice aerial coverage observed in fall of 2017 compared to the 246 m^2 observed in fall 2018 after restoration efforts and natural expansion.

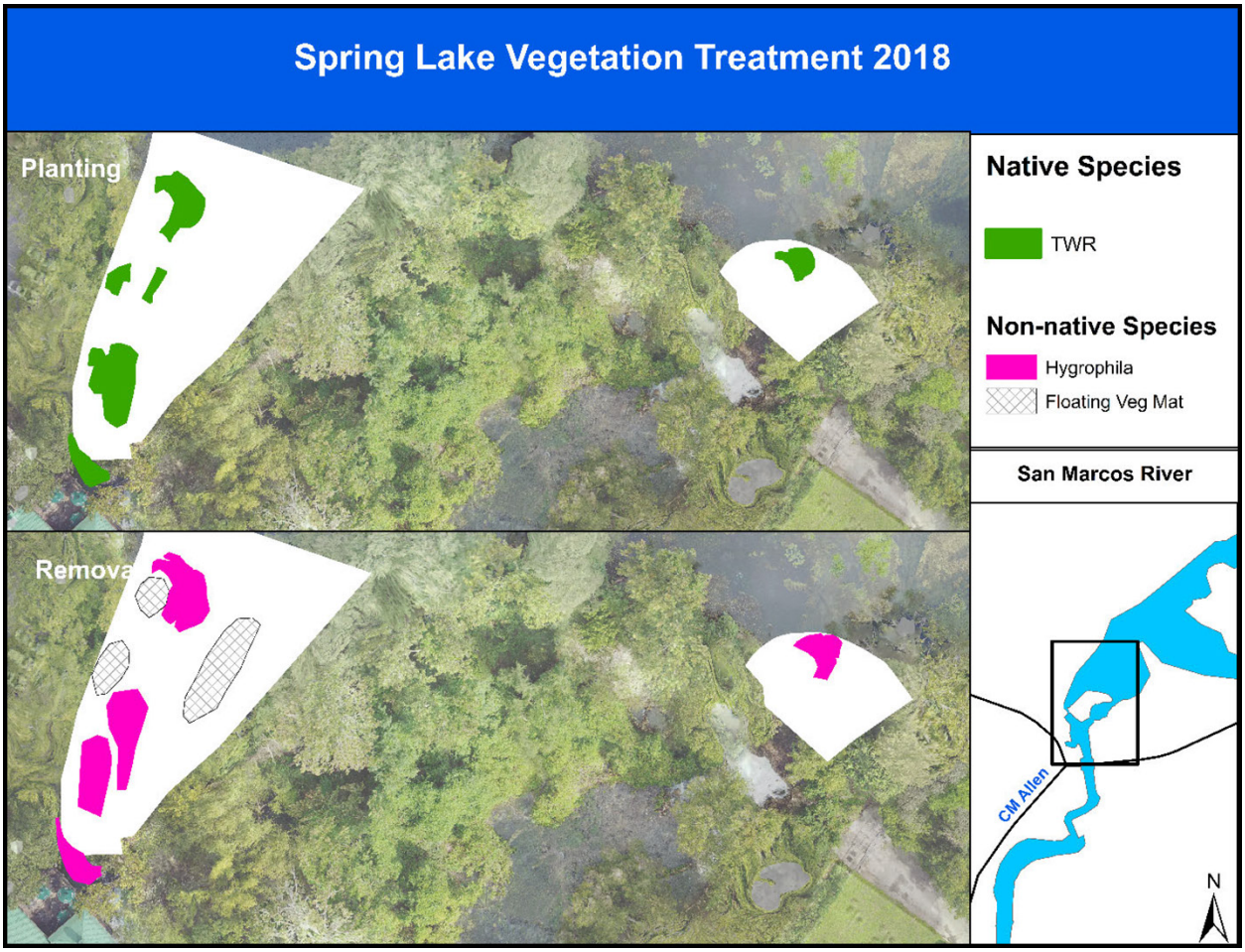

Figure 3.3-19. Locations of vegetation removal and planting in Spring Lake Restoration Reach (2018).

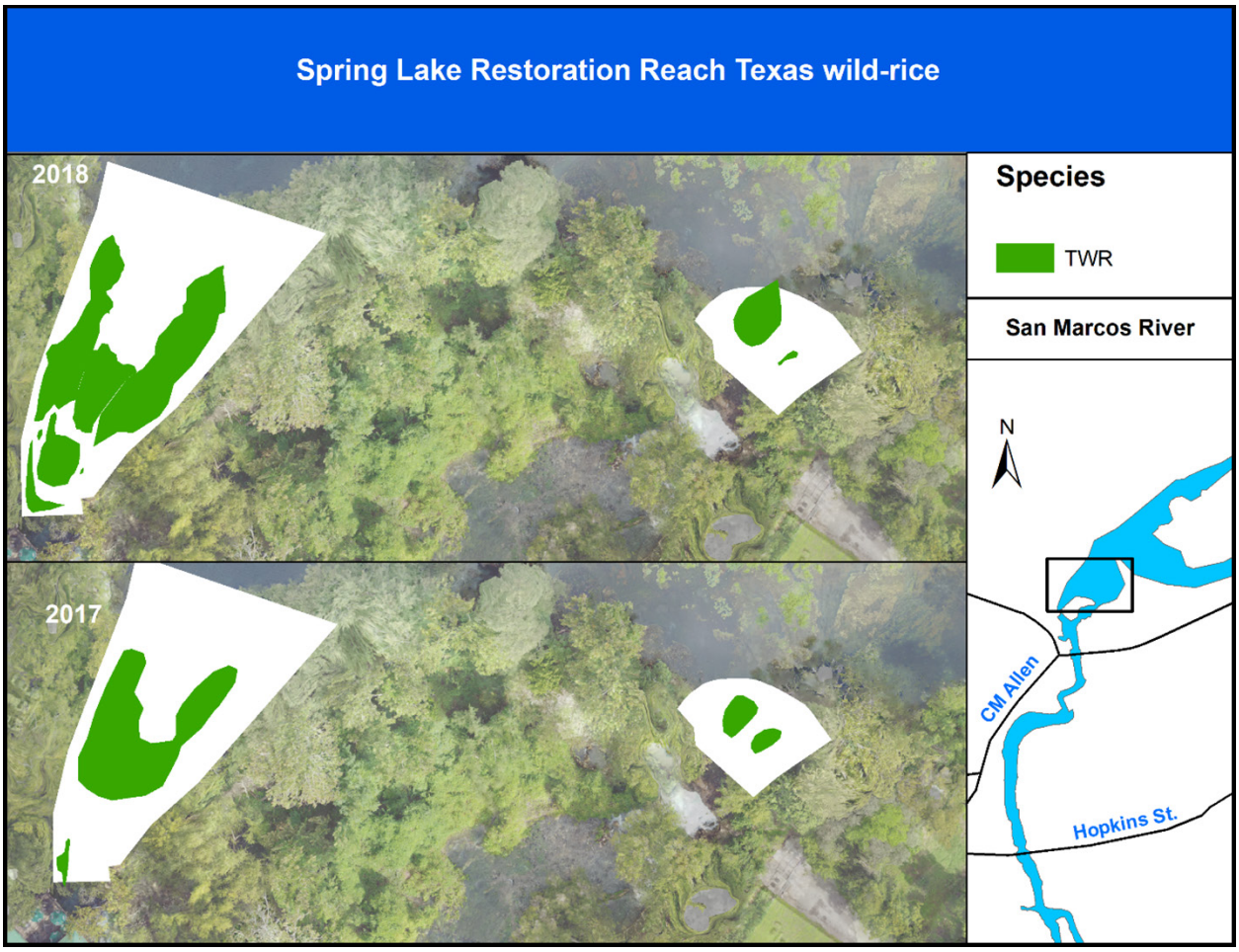

Figure 3.3-20. Aerial coverage of Texas wild-rice in Spring Lake Restoration Reach mapped during fall 2017 and fall 2018.

Spring Lake Dam LTBG Reach

In Spring Lake Dam, vegetation treatment efforts occurred on 22 days during which approximately 14 m^2 of *Hydrilla verticillata*, 79 m^2 *Hygrophila polysperma*, and 31 m^2 of water hyacinth were removed, 1,824 m^2 vegetation mats were cleared from native SAV stands, and 3,118 individuals of various native SAV species covering an estimated 103 m^2 were planted (**Figure 3.3-21**). **Table 3.3-6** details area (m^2) of SAV species observed within Spring Lake Dam LTBG Reach mapped in the fall of 2017 and 2018 and any changes observed between that time. The total area of SAV observed within the reach decreased by 394 m^2 since 2017 with Texas wild-rice and *Potamogeton* accounting for 99 percent of the area lost. **Figure 3.3-22** illustrates areal coverages observed during fall 2017 compared to fall 2018. Despite planting efforts and observed expansion, cumulative Table 34 area goals for 2018 were not reached for *Ludwigia repens, Cabomba caroliniana* or *Sagittaria platyphylla*.

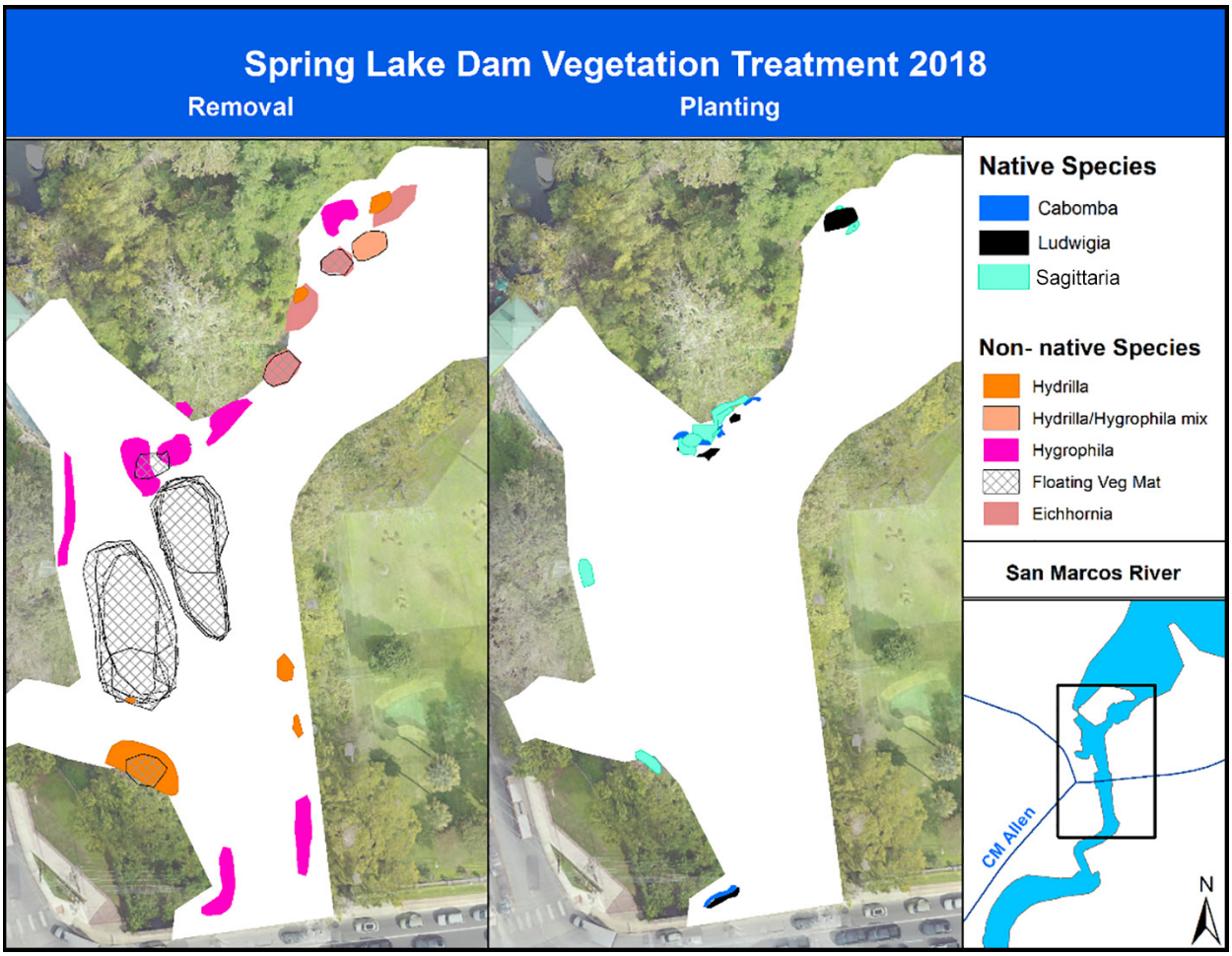

Figure 3.3-21. Locations of aquatic vegetation removal and planting in Spring Lake Dam LTBG Reach (2018).

Table 3.3-6. Area (m^2) of Submerged Aquatic Vegetation Species Observed Within Spring Lake Dam LTBG Reach in 2017 and 2018, and Changes Detected

Species	Area (m^2)		Compared to 2018 Table 34 Goal	Change 2017-18	% of total observed SAV 2018
	2017	2018			
Cabomba	0.9	1.5	-13	0.6	0.1
Ceratophyllum	0.0	6.8	-	6.8	0.5
Heteranthera	0.3	0.1	-	-0.1	0.0
Hydrilla	4.9	0.0	-	-4.9	0.0
Hygrophila	28.2	39.6	-	11.4	2.9
Hydrocotyle	72.5	51.1	+46	-21.5	3.7
Ludwigia	17.3	22.4	-8	5.1	1.6
Potamogeton	238.3	148.0	+73	-90.4	10.7
Sagittaria	25.6	22.3	-43	-3.3	1.6
Vallisneria	0.7	3.3	-	2.6	0.2
Zizania	1,389.3	1,088.7	+1,023	-300.6	78.7
Total Observed SAV	**1,778.0**	**1,383.9**	**-**	**-394.1**	**-**

Numbers in red indicate negative numbers.

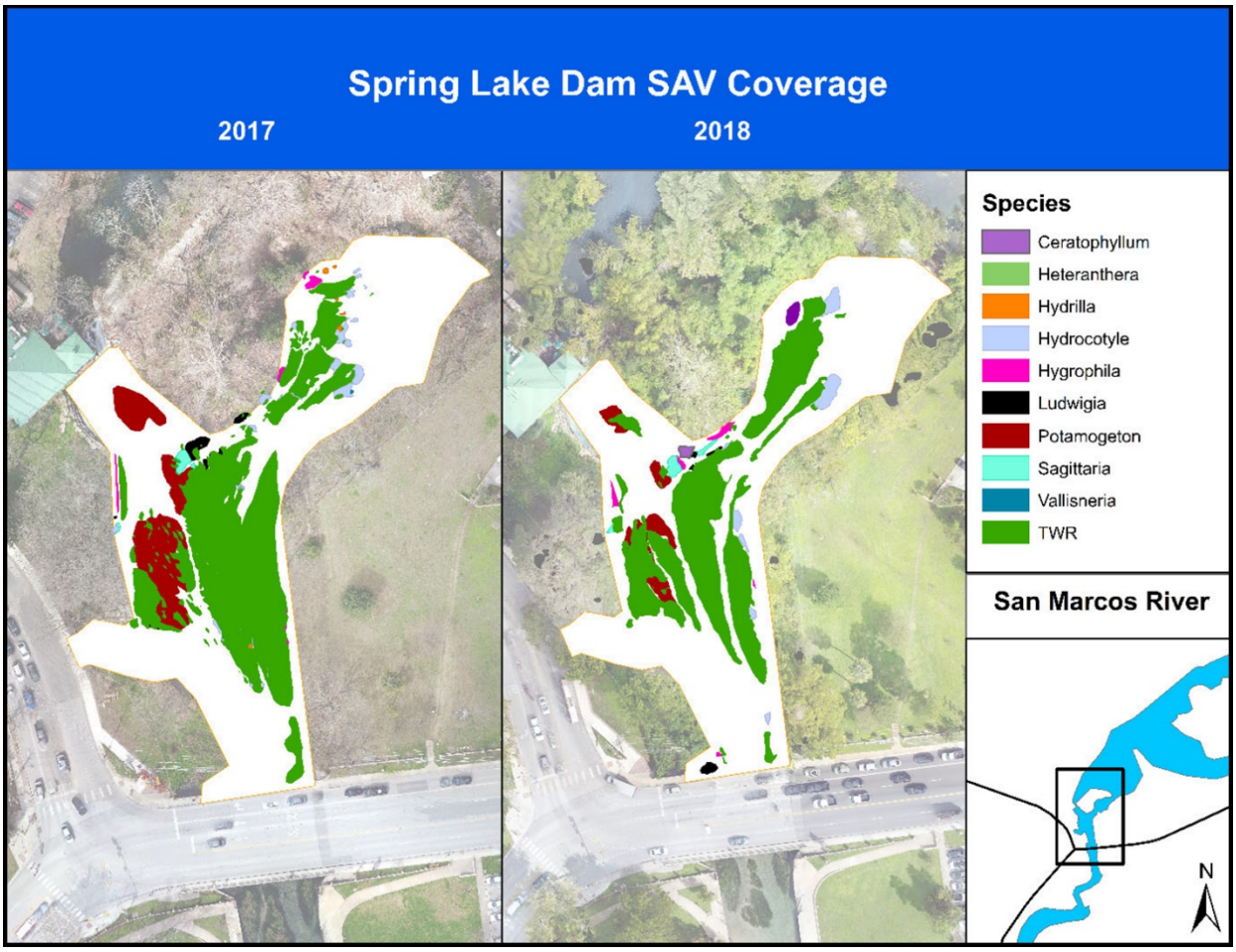

Figure 3.3-22. Submerged aquatic vegetation coverage within the Spring Lake Dam LTBG Reach from fall 2017 to fall 2018.

Sewell Park and Below Sewell-City Park Restoration Reaches

Aquatic vegetation maintenance was performed in the Sewell Park and Below Sewell-City Park Restoration reaches during 2018. The reaches were not active work sites as defined by Table 34 but did require gardening to remove non-native vegetation regrowth within existing stands of native SAV. Non-native removal was performed in Sewell Park for a total of 12 days during which approximately 183 m^2 of *Hydrilla verticillata*, 32 m^2 of *Hygrophila polysperma*, 73 m^2 of watercress were removed and 1957 m^2 of vegetation mats were cleared from native SAV stands (**Figure 3.3-23)**. Non-native removal was performed in the Below Sewell-City Park Restoration Reach for a total of nine days during which approximately 85 m^2 of water hyacinth, 191 m^2 of watercress and 232 m^2 of *Hydrilla* was removed **(Fig. 3.3.27)**. Since no native species expansion was listed in Table 34 for the Sewell Park or Below Sewell to City Park reaches this year, aerial coverage of SAV species were monitored but not mapped. Aerial imagery of aquatic vegetation in Sewell Park captured in the fall of 2017 and fall 2018 showed no significant loss in native SAV coverage (**Figure 3.3-24**). Some seasonal loss due to recreation can be observed but historically it recovers over the winter. Aerial imagery of the Below Sewell-City Park reach shows no significant change in SAV coverages (**Figure 3.3-25**).

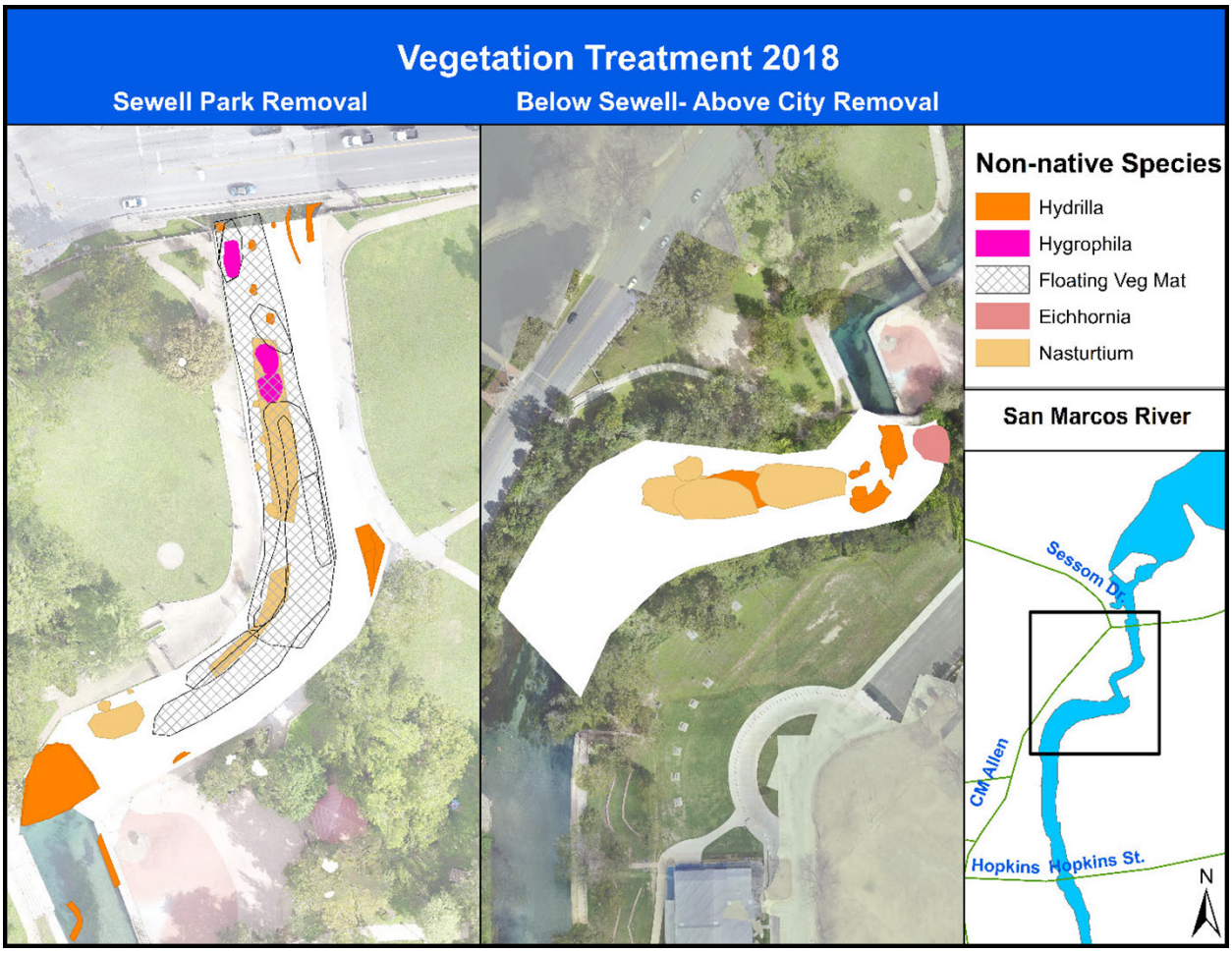

Figure 3.3-23. Locations of non-native vegetation removal in Sewell Park and Below Sewell – City Park Restoration reaches (2018).

Figure 3.3-24. Imagery of submerged aquatic vegetation coverage in Sewell Park Restoration Reach captured during fall 2017 and fall 2018.

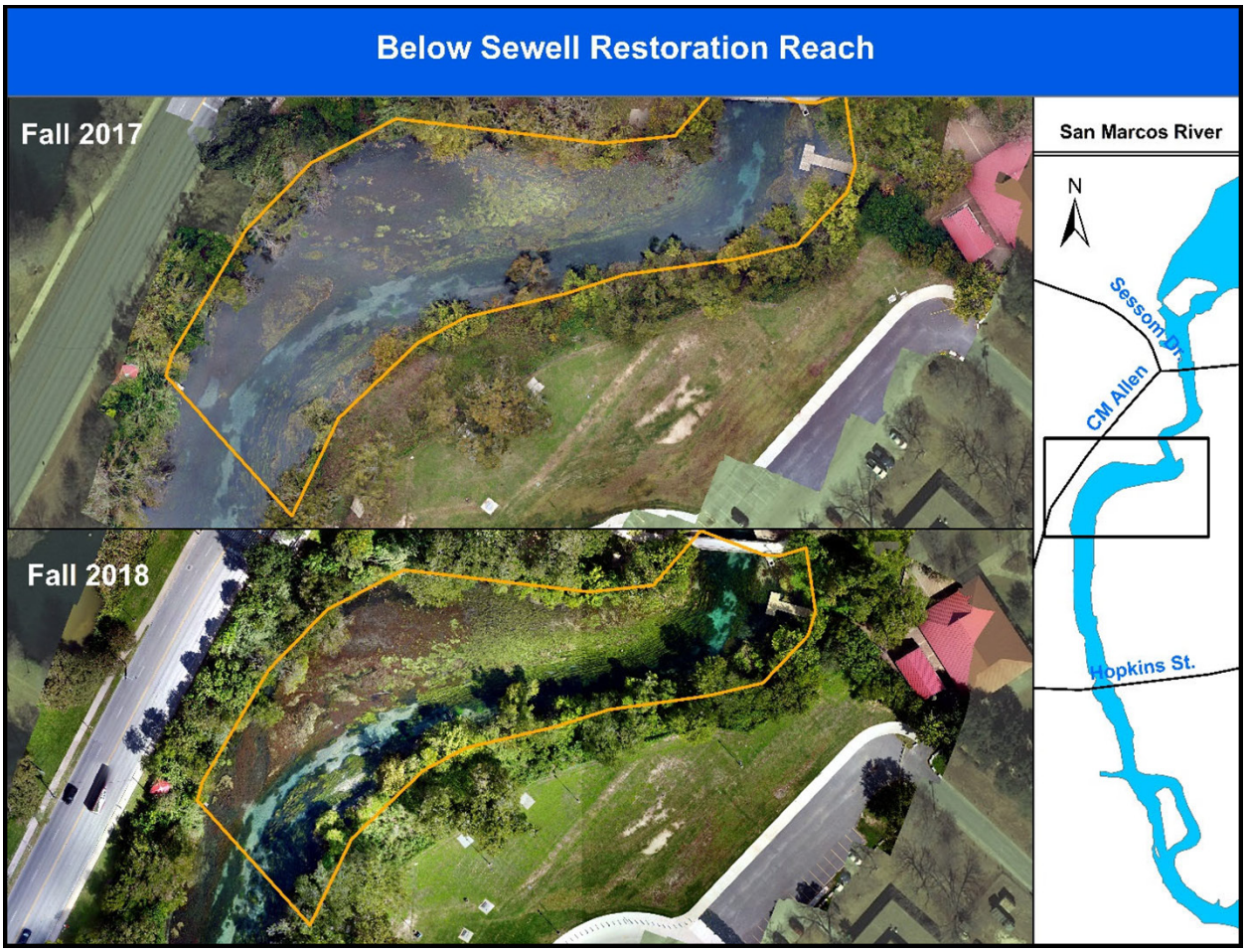

Figure 3.3-25. Imagery of submerged aquatic vegetation coverage in Below Sewell Park – Above City Park Restoration Reach captured during fall 2017 and fall 2018.

City Park LTBG Reach

Vegetation treatment efforts occurred on 47 days in City Park, during which approximately 546 m^2 of *Hydrilla* and 454 m^2 of *Hygrophila* were removed and an estimated 400 m^2 was planted with over 20,000 individuals of various native species as depicted in **Figure 3.3-26. Table 3.3-7** details area (m^2) of SAV species observed within the City Park LTBG reach during fall 2018 mapping. Table 34 goals were met for all species except *Ludwigia* and *Potamogeton*. Despite an overall loss of *Potamogeton* for the year and not meeting the Table 34 goal, successful establishment and expansion of plantings adjacent to existing stands was observed prior to summer loss of vegetation. **Figure 3.3-27** illustrates the 1,127 m^2 decrease in total observed area of SAV observed from fall 2017 to fall 2018 in the City Park LTBG reach.

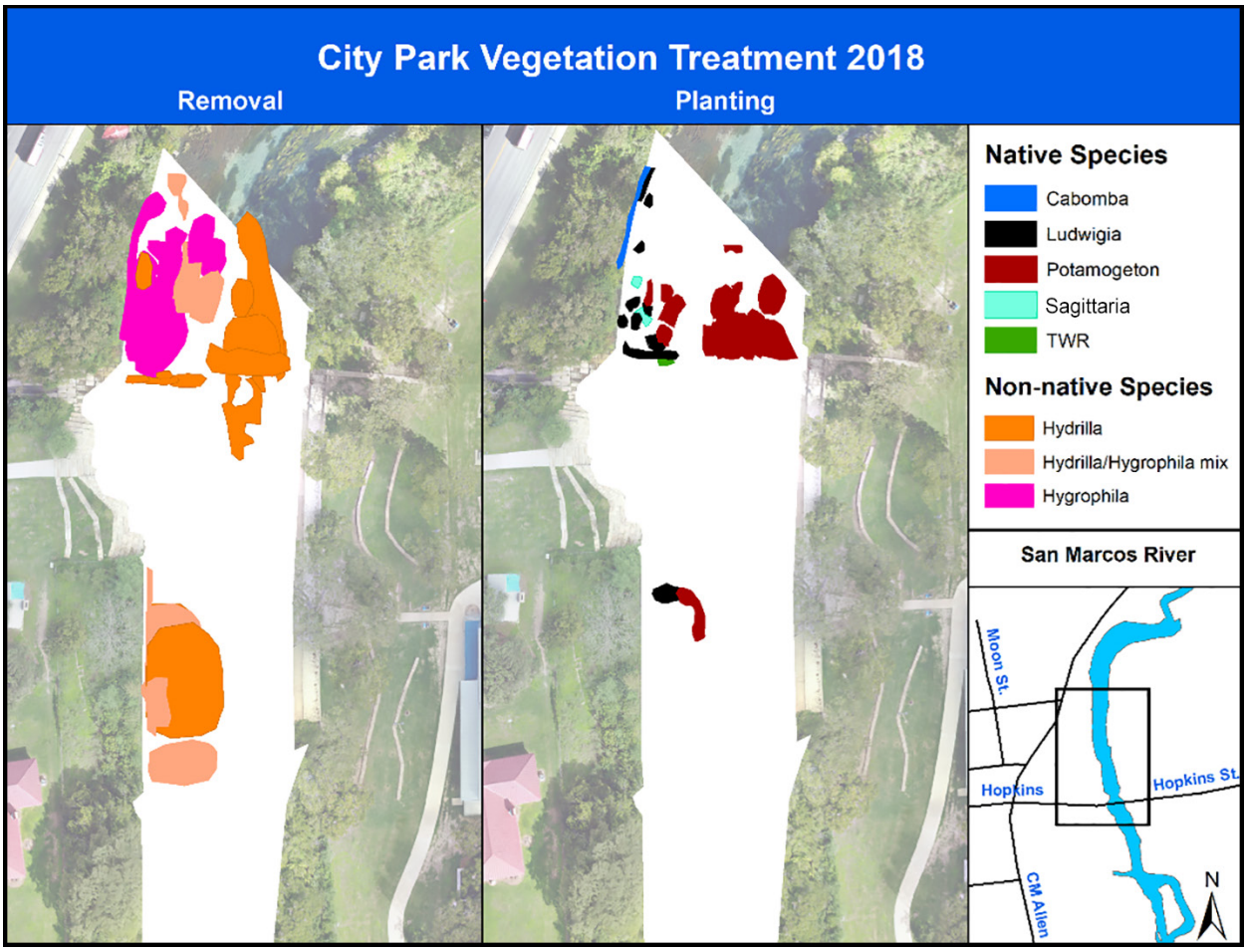

Figure 3.3-26. Locations of removal and planting within City Park LTBG Reach (2018).

Table 3.3-7. Area (m^2) of Submerged Aquatic Vegetation Species Observed Within City Park LTBG Reach in 2017 and 2018, and Changes Detected

Species	Area (m^2) 2017	Area (m^2) 2018	Compared to 2018 Table 34 Goal	Change 2017-18	% of total observed SAV 2018
Cabomba	21.5	50.1	0	28.6	2.1
Ceratophyllum	0.0	174.2	-	174.2	7.3
Heteranthera	0.4	3.1	-	2.8	0.1
Hydrilla	461.1	101.7	-	-359.4	4.3
Hygrophila	538.9	288.2	-	-250.8	12.1
Hydrocotyle	5.5	0.0	-	-5.5	0.0
Ludwigia	46.8	65.3	-5	18.5	2.7
M. heterophyllum	0.0	16.2	-	16.2	0.7
Nasturtium	1.8	6.1	-	4.2	0.3
Potamogeton	212.8	203.3	-147	-9.5	8.6
Sagittaria	142.1	106.8	+62	-35.3	4.5
Zizania	2,070.9	1,360.0	+1,170	-710.9	57.3
Total Observed SAV	**3,501.9**	**2,375.0**	**-**	**-1,126.9**	**-**

Numbers in red indicate negative numbers.

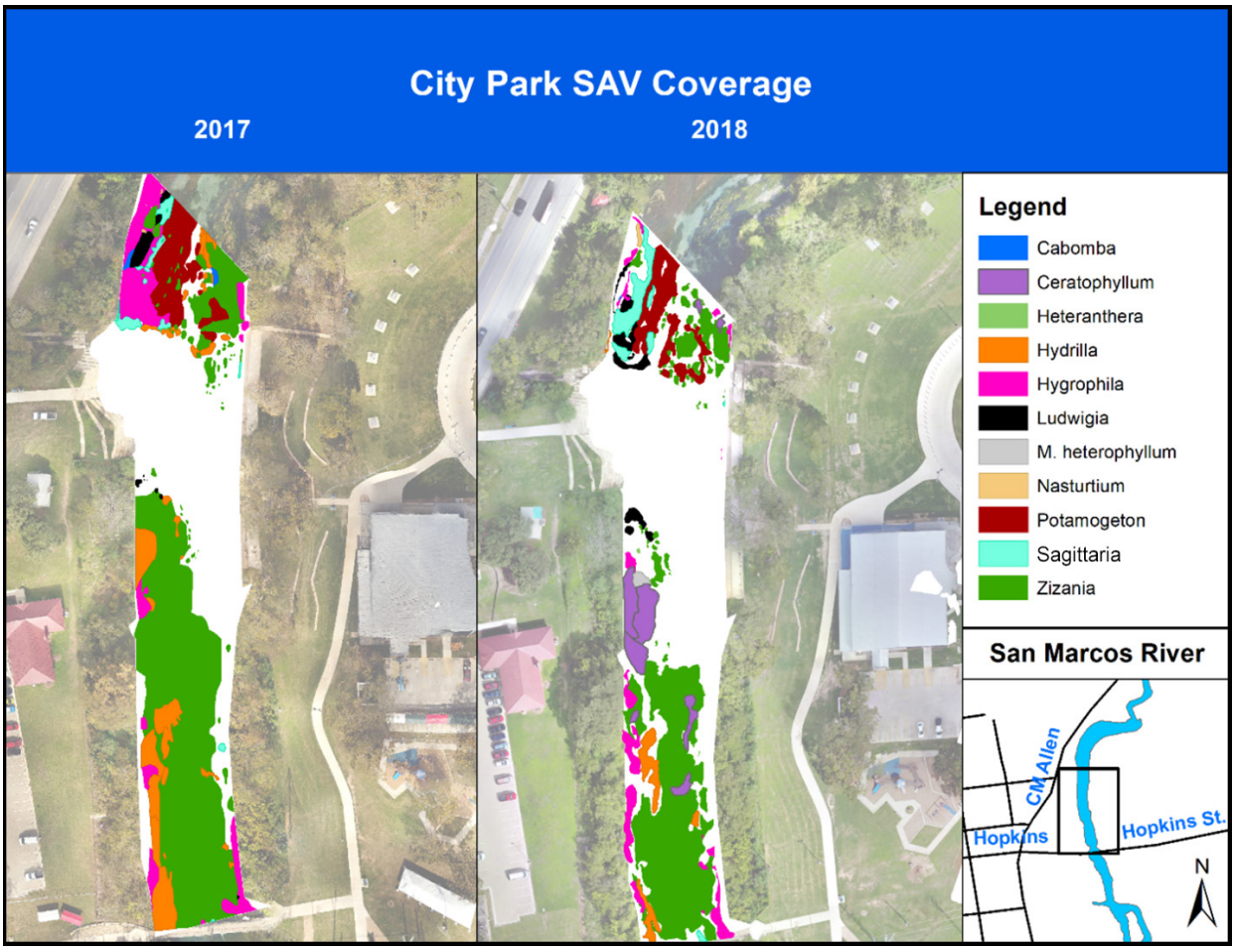

Figure 3.3-27. Submerged aquatic vegetation coverage within the City Park LTBG Reach in fall 2017 and fall 2018.

Cypress Island Restoration Reach

Vegetation treatment efforts in the Cypress Island Restoration Reach occurred on 18 days, during which approximately 230 m^2 of *Hydrilla verticillata* was removed and an estimated 225 m^2 was planted with 9,645 individuals of various native SAV species as depicted in **Figure 3.3-28**. **Table 3.3-8** details area (m^2) of SAV species observed within the Cypress Island restoration reach mapped in the fall of 2018 and changes detected since fall 2017. *Cabomba caroliniana* coverage increased by 195 m^2, a 4,000 percent increase from the 5 m^2 observed during fall 2017, through planting and natural expansion. Most of the new coverage was concentrated in a large, dense stand that naturally established on the eastern side of Cypress Island. For the second year in a row attempts to establish stands of *Potamogeton illinoesis* were unsuccessful despite multiple plantings in what appeared to be suitable habitat. *Hygrophila polysperma* coverage expanded by more than two and a half times what was observed in 2017 with an increase of 101 m^2. **Figure 3.3-29** illustrates the changes in SAV observed between fall 2017 and fall 2018. While Table 34 goals were not met for *Ludwigia, Potamogeton* and *Sagittaria* expansion did occur for each species. The percentage of total observed SAV that was native species increased 8 percent since 2017.

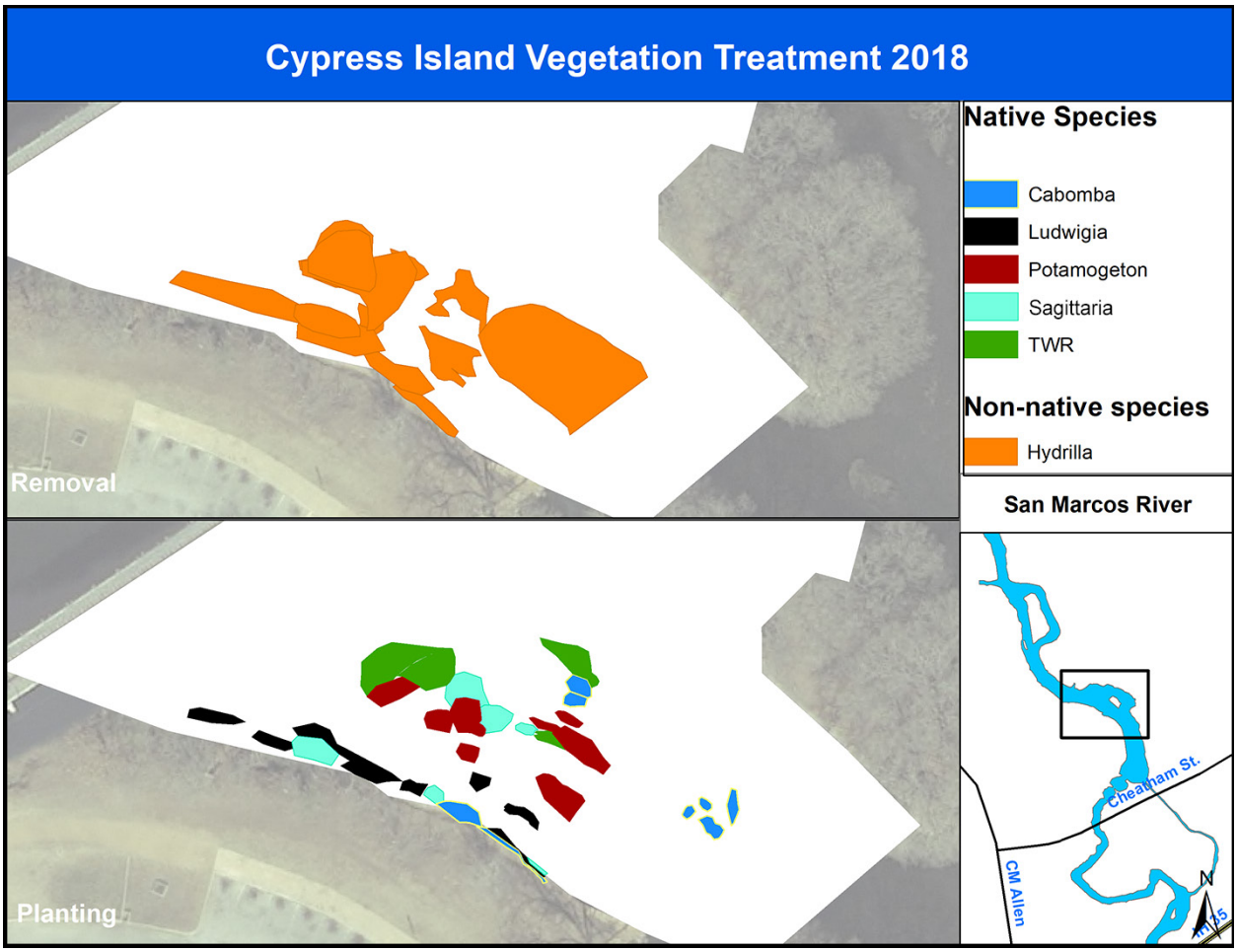

Figure 3.3-28. Locations of vegetation removal and planting in Cypress Island Restoration Reach (2018).

Table 3.3-8. Area (m^2) of Submerged Aquatic Vegetation Species Within Cypress Island Restoration Reach in 2017 and 2018, and Changes Detected

Species	Area (m^2) 2017	Area (m^2) 2018	Compared to 2018 Table 34 Goal	Change 2017-18	% of total observed SAV 2018
Cabomba	4.8	200.5	+181	195.7	9.1
Heteranthera	100.5	100.9	-	0.4	4.6
Hydrilla	1,562.8	1,482.3	-	-80.6	67.0
Hygrophila	38.3	139.4	-	101.1	6.3
Ludwigia	14.9	18.2	-12	3.4	0.8
Potamogeton	1.6	6.1	-29	4.6	0.3
Sagittaria	3.8	14.0	-11	10.2	0.6
Vallisneria	3.1	0.0	-	-3.1	0.0
Zizania	247.7	252.5	+103`	4.8	11.4
Total Observed SAV	**1,977.5**	**2,213.9**	**-**	**236.4**	**-**

Numbers in red indicate negative numbers.

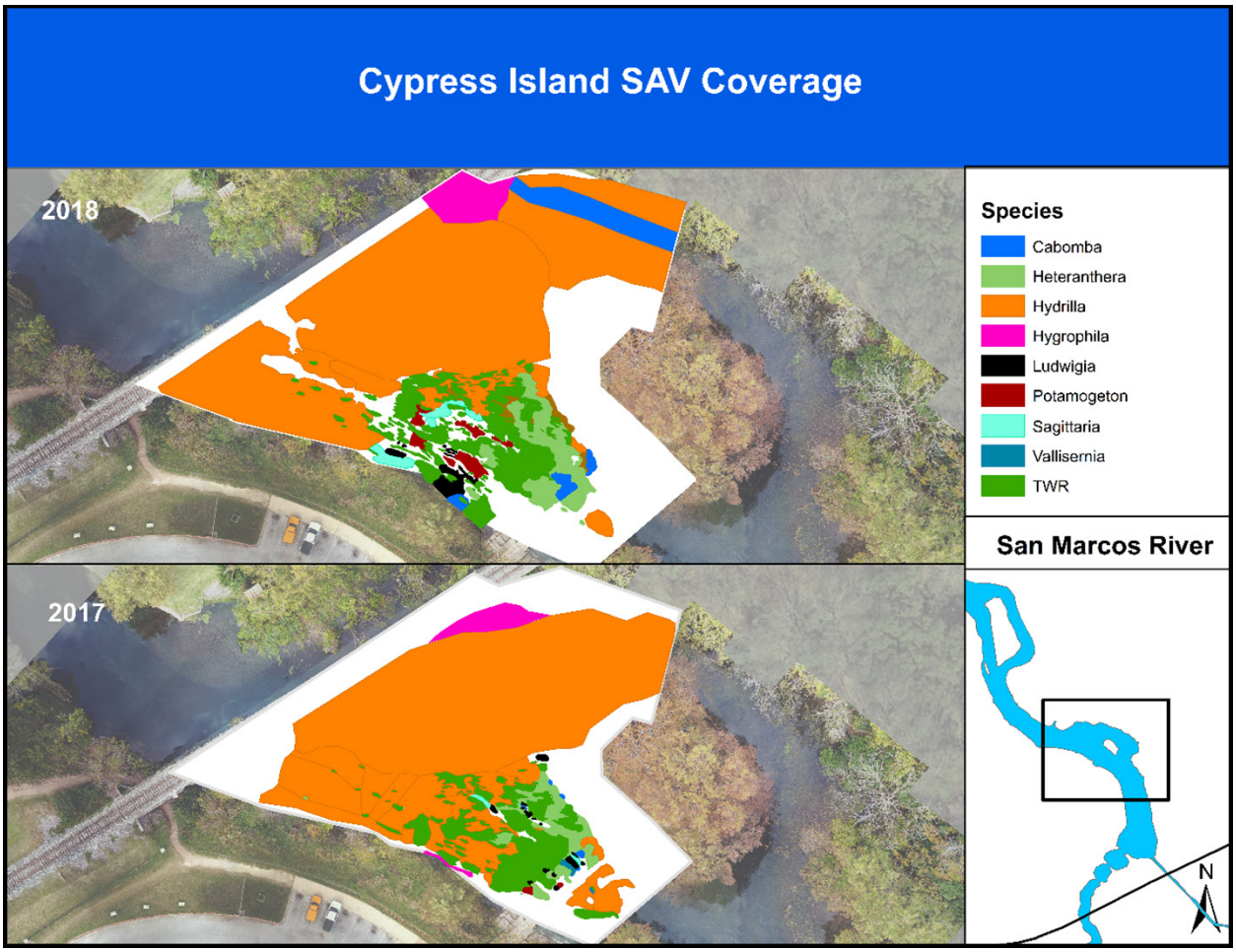

Figure 3.3-29. Submerged aquatic vegetation coverage within the City Park LTBG Reach in fall 2017 and fall 2018.

IH-35 LTBG Reach

Vegetation treatment efforts in the IH-35 LTBG Reach occurred on 14 days during which approximately 40 m^2 of *Hydrilla* and 17 m^2 of *Hygrophila* were removed and an estimated 300 m^2 was planted with 10, 853 individuals of various native SAV species (**Figure 3.3-30)**. **Table 3.3-9** details areas (m^2) of SAV species observed within the IH-35 LTBG Reach mapped in the fall of 2018. Since 2017, the total amount of vegetation within the reach increased by 120 m^2. Of the total vegetation observed 92 percent was native species, a 10 percent increase from 2017. Texas wild-rice, *Hydrocotyle*, *Ludwigia* and *Sagittaria* all expanded since 2017. Despite multiple planting throughout the reach, no *Potamogeton* successfully established. Table 34 goals for *Ludwigia, Sagittaria, Hydrocotyle* and *Potamogeton* were not met. **Figure 3.3-31** illustrates the changes in SAV observed between fall 2017 and fall 2018.

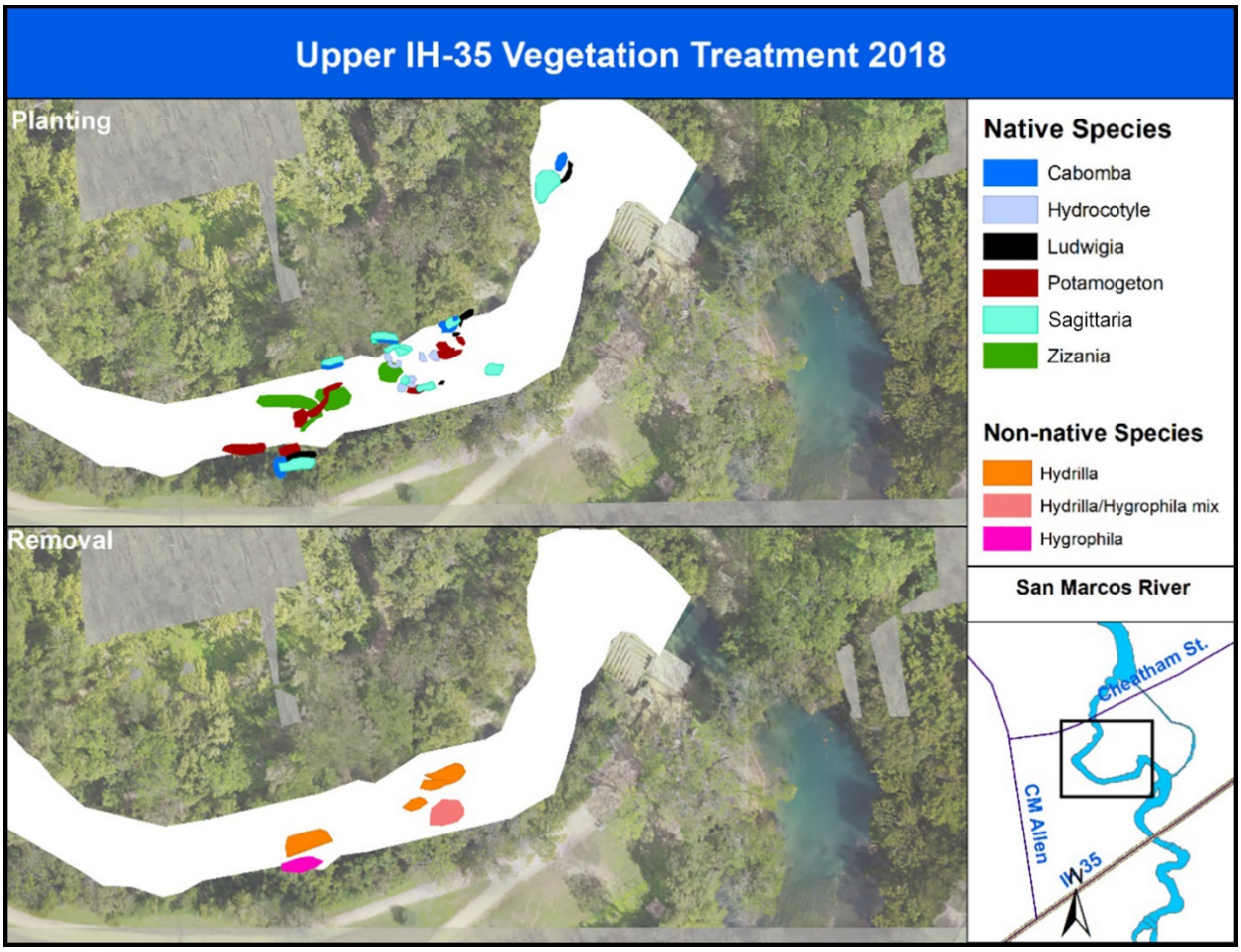

Figure 3.3-30. Locations of removal and planting in IH-35 Upper LTBG Reach (2018).

Table 3.3-9. Area (m^2) of Submerged Aquatic Vegetation Species Observed Within IH-35 Upper LTBG Reach in 2017 and 2018, and Changes Detected

Species	Area (m^2)		Compared to 2018 Table 34 Goal	Change 2017-18	% of total observed SAV 2018
	2017	2018			
Cabomba	33.3	32.0	+17	-1.3	8.2
Ceratophyllum	0.0	12.6	-	12.6	3.2
Heteranthera	5.4	3.2	-	-2.2	0.8
Hydrilla	30.5	0.1	-	-30.4	0.0
Hydrocotyle	0.0	3.8	-6	3.8	1.0
Hygrophila	17.0	30.8	-	13.8	7.9
Ludwigia	7.0	10.1	-5	3.1	2.6
Potamogeton	15.1	0.0	-45	-15.1	0.0
Sagittaria	4.9	17.1	-33	12.2	4.4
Zizania	156.2	280.0	+55	123.8	71.8
Total Observed SAV	**269.5**	**389.8**	**-**	**120.3**	**-**

Numbers in red indicate negative numbers.

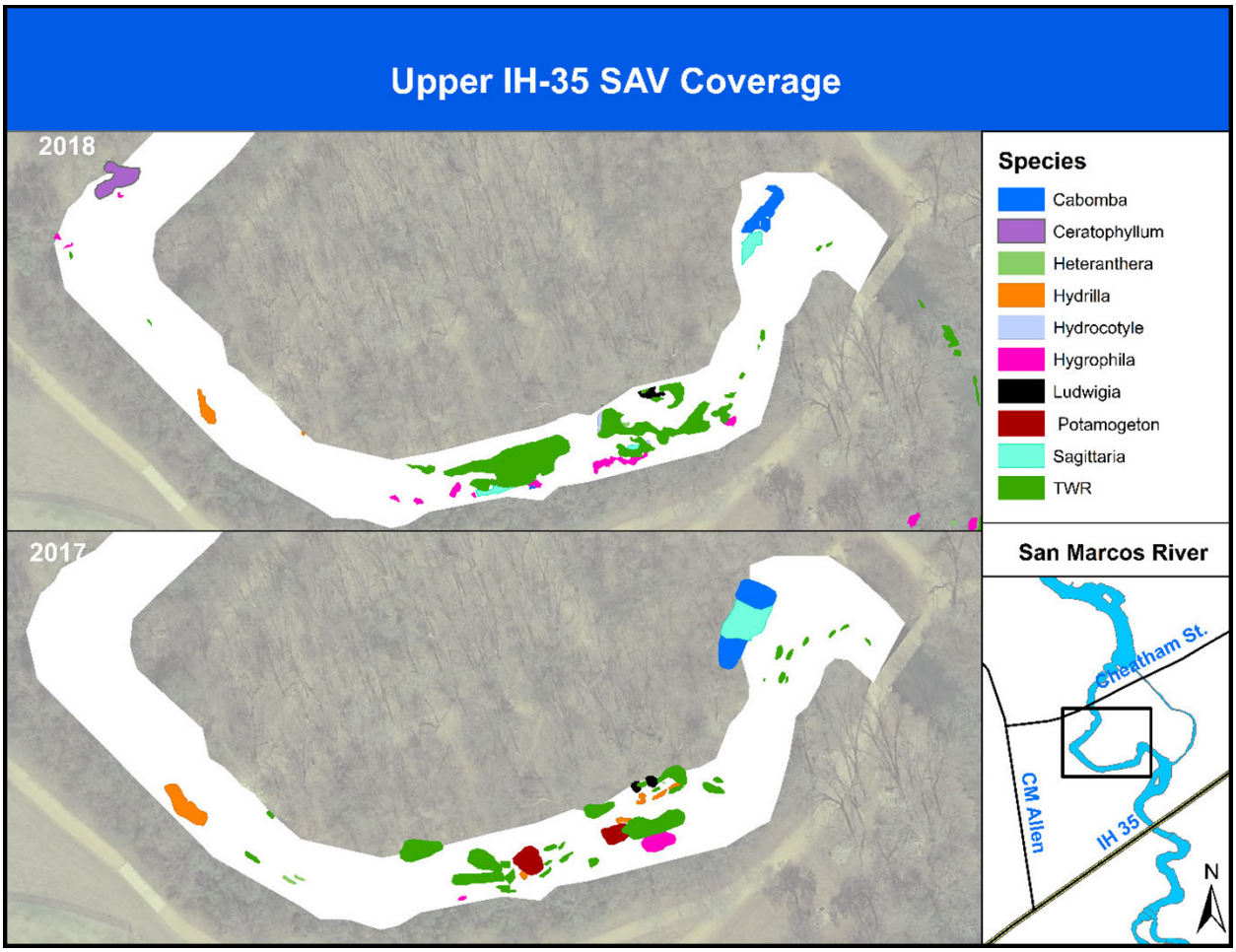

Figure 3.3-31. Submerged aquatic vegetation coverage within the IH-35 Upper LTBG Reach in fall 2017 and fall 2018.

IH-35 Expanded Restoration Reach

Vegetation treatment efforts in the IH-35 Expanded Restoration Reach occurred on 21 days, during which approximately 59 m^2 *Hydrilla* and 286 m^2 *Hygrophila* were removed and an estimated 58 m^2 was planted with 4,043 individuals of various native SAV species. **Figure 3.3-32** and **Table 3.3-10** detail area (m^2) of SAV species observed within the IH-35 Expanded Restoration Reach mapped in the fall of 2018. Of the total observed vegetation 52 percent was native SAV species, a decrease of 31 percent compared to what was observed in 2017. Since 2017, *Cabomba* increased by 65 percent, *Sagittaria platyphylla* decreased by 40 percent, and *Ludwigia repens* decreased by almost 25 percent. *Hygrophilla polysperma* coverage increased by more than two and a half times what it was in 2017 with an increase of 610 m^2. **Figure 3.3-33** illustrates the changes in SAV coverage observed between fall 2017 and fall 2018. The decrease in *Ludwigia* and *Sagittaria* was observed during the summer months that may be attributed to the low flows during that time. Aerial imagery captured throughout 2018 illustrates the decrease in coverage (**Figure 3.3-34**). Simultaneously, during this disturbance *Hygrophila* present at Lower IH-35 was observed to be expanding and increasing in density within existing stands. Of the total observed vegetation, the percentage of non-natives increased from 16 percent in 2017, to 48 percent in 2018. Table 34 area goals for *Cabomba*

and *Potamogeton* were not met. Despite multiple planting throughout the reach, no *Potamogeton* successfully established. *Ludwigia, Sagittaria* and Texas wild-rice were all 100 m^2 or more over cumulative Table 34 goals for 2018

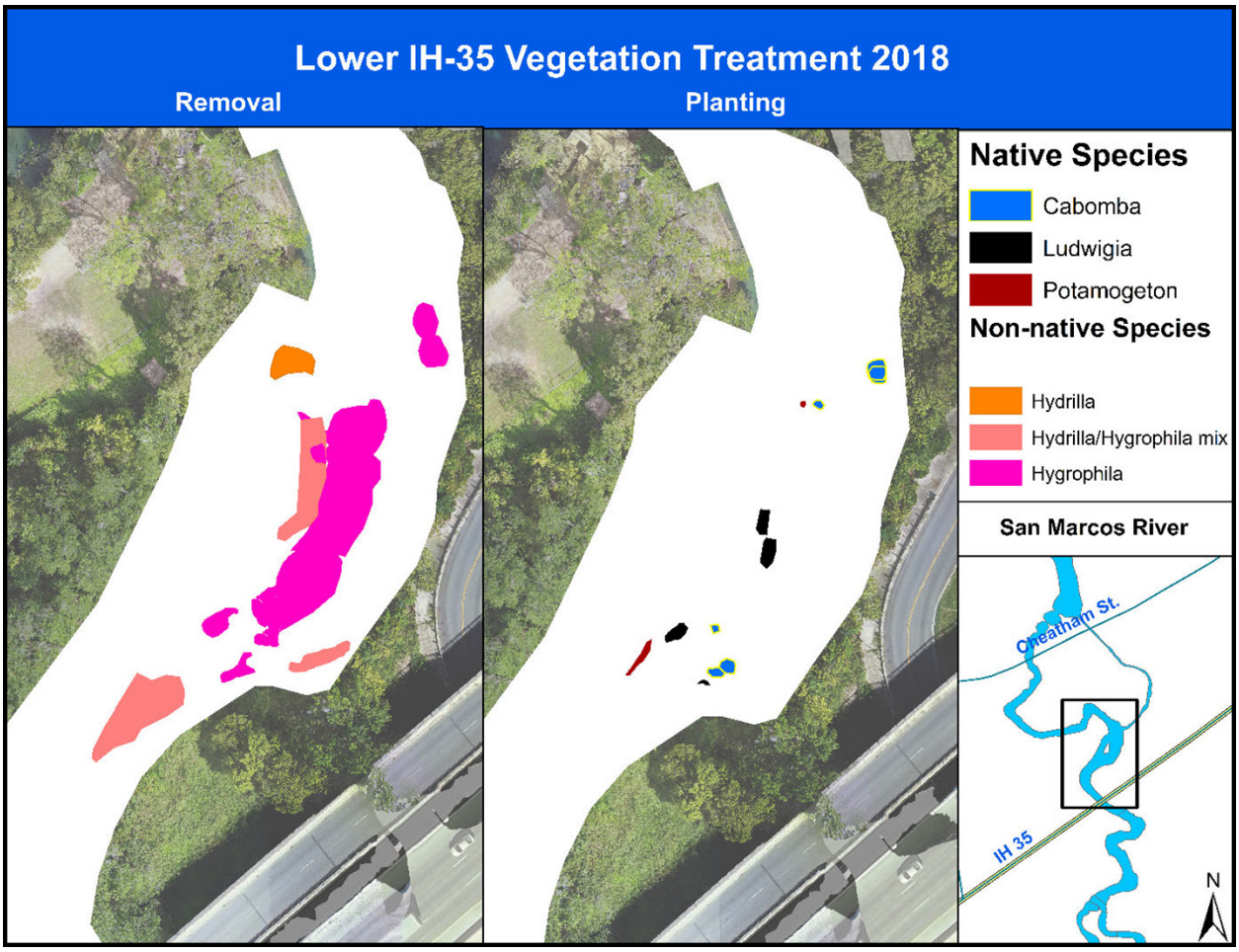

Figure 3.3-32. Locations of removal and planting in IH-35 Expanded Restoration Reach (2018).

Table 3.3-10. Area (m^2) of Submerged Aquatic Vegetation Species Observed Within IH-35 Restoration Reach in 2017 and 2018, and Changes Detected

Species	Area (m^2)		Compared to 2018 Table 34 Goal	Change 2017-18	% of total observed SAV 2018
	2017	2018			
Cabomba	38.4	41.1	+0.9	2.7	2.6
Ceratophyllum	0.0	12.6	-	12.6	0.8
Heteranthera	12.7	4.2	-	-8.5	0.3
Hydrilla	18.5	1.5	-	-17.0	0.1
Hygrophila	237.5	765.8	-	528.3	47.7
Hydrocotyle	6.8	0.0	-	-6.8	0.0
Ludwigia	256.9	136.1	-116	-120.8	8.5
Nuphar	22.4	29.7	-	7.3	1.8
Potamogeton	-	-	+5.5	0.0	0.0
Sagittaria	632.4	274.7	-225	-357.7	17.1
Zizania	344.6	340.7	-248	-3.9	21.2
Total Observed SAV	**1,570.1 977.0**	**1,606.3**	**-**	**36.2**	**-**

Numbers in red indicate negative numbers.

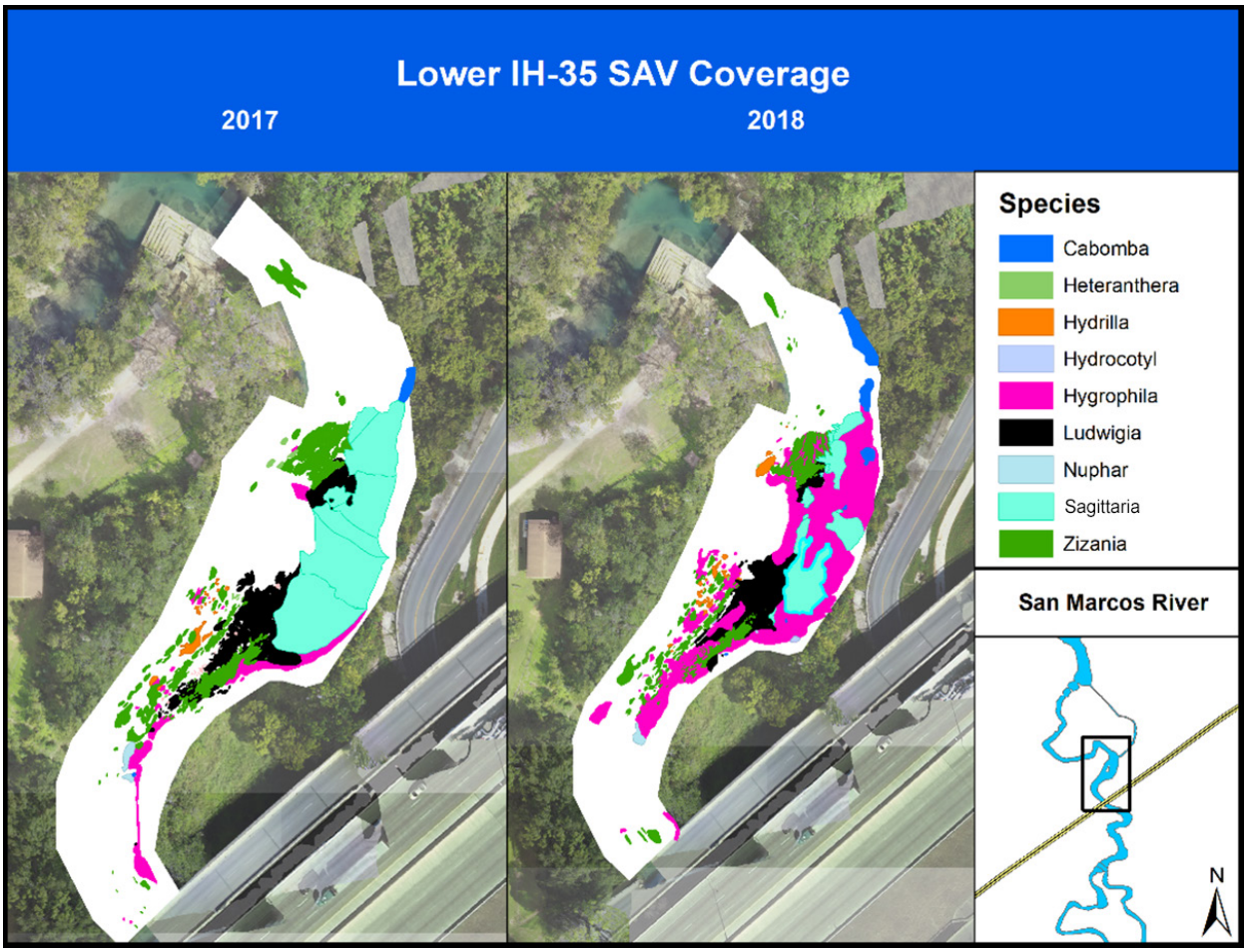

Figure 3.3-33. Submerged aquatic vegetation coverage within the Lower IH-35 Restoration Reach in fall 2017 and fall 2018.

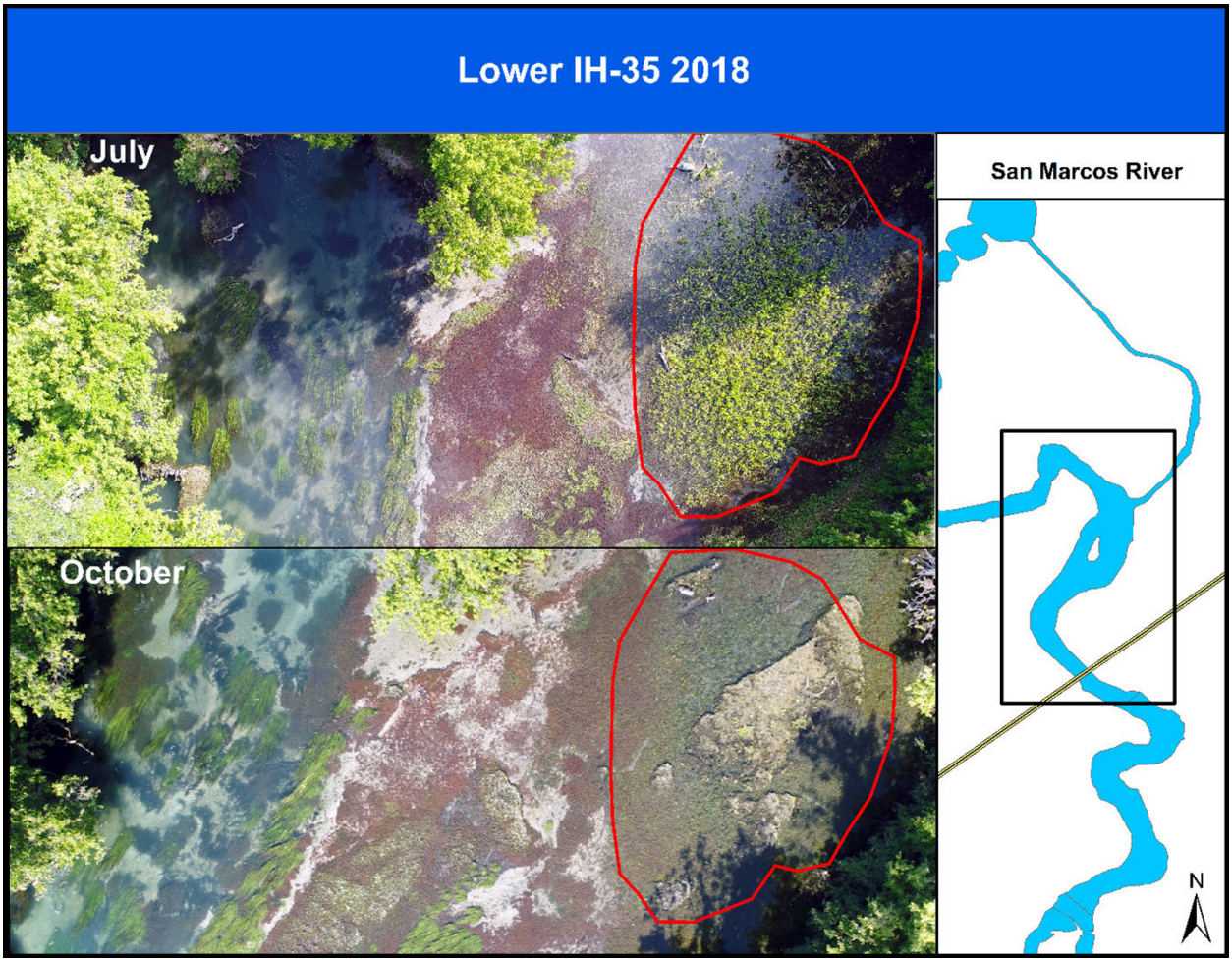

Figure 3.3-34. Imagery of Lower IH-35 captured in July and October 2018 in which loss of *Sagittaria* and *Ludwigia* can be visually observed.

Summary of 2018 Aquatic Vegetation LTBG and Restoration Reaches

Of the total observed vegetation within active reaches, the overall percentage of native SAV species increased from 2017 in City Park, Cypress Island and Upper IH-35. Within all active LTBG and Restoration reaches, Texas wild-rice is the dominant native species. **Table 3.3-11** details the three most dominant species in each active reach according to percent of total SAV area observed in 2018. The IH-35 Restoration Reach saw an increase in non-native vegetation, predominantly *Hygrophila*, since 2017. The percentage of non-natives in Spring Lake Dam increased by 1 percent due to expansion of *Hygrophila* and *Vallisneria*. A decrease in *Hydrilla* was observed in all active reaches since 2017 and efforts to eradicate *Hydrilla* from the Spring Lake Dam LTBG Reach appear to be successful as none was observed during the fall 2018 mapping. **Table 3.3-12** details what percentage of total SAV was native and non-native by reach in 2018. The amount of total SAV area observed in Cypress Island, Upper IH-35 and Lower IH-35 increased since 2017 but decreased in Spring Lake Dam and City Park. The loss in SAV is thought to be primarily caused by recreation activities, specifically trampling of vegetation during wading exacerbated by the low flows that increased the area of riverbed accessible by wading. Despite losses in vegetation, the percent composition of the SAV community within the Spring Lake Dam reach remained largely unchanged – no

species had a change in percent of total observed SAV greater than 3 percent since 2017. In City Park the largest change in the plant community was a 9 percent decrease in *Hydrilla*. Vegetation lost during 2018 is predicted to regrow over the winter and spring seasons. Zones of high recreation have historically experienced a seasonal cycle of summer loss and winter/spring regrowth. (Spring Lake SAV percentages couldn't be calculated, only Texas wild-rice is mapped within the lake).

Table 3.3-11. Submerged Aquatic Vegetation Percent Dominant per Reach Based on Fall 2018 Mapping

Reach	Species and Percentage of Total Observed SAV						
	Zizania	*Hydrilla*	*Hygrophila*	*Potamogeton*	*Cabomba*	*Hydrocotyle*	*Sagittaria*
Spring Lake Dam	79			11		3	
City Park	57		12	9			
Cypress Island	11	67			9		
Upper IH-35	71		8		8		
Lower IH-35	21		47				17

Table 3.3-12. Percent of Native Submerged Aquatic Vegetation Compared to Non-Native Submerged Aquatic Vegetation Coverage per Reach

Reach	Percent Native	Percent Non-Native
Spring Lake Dam	96.9	3.1
City Park	83.6	16.4
Cypress Island	26.8	73.2
Upper IH-35	92.0	8.0
Lower IH-35	52.2	47.8

Failure to meet Table 34 goals is thought to be a combination of two factors: SAV loss from recreation activities and lack of suitable habitat for all native species within every reach that resulted in die off for a portion of planting efforts. Establishment of *Potamogeton* downstream of City Park continues to be unsuccessful. In Cypress Island and Upper IH-35, *Potamogeton* was planted in areas that appeared to be suitable habitat (i.e., fast flowing water and coarser substrates), but died a few weeks after planting.

Compliance for this measure is based on total coverage of fountain darter habitat in m^2 specified in Table 4-21 of the EAHCP. Status for 2018 is shown in **Table 3.3-13**.

Table 3.3-13. Amount of Available Fountain Darter Habitat Based on Amount of Submerged Aquatic Vegetation Coverage per Reach

San Marcos LTBG Fountain Darter Habitat (Aquatic Vegetation) Status in m^2						
LTBG Reach	*Ludwigia*	*Cabomba*	*Potamogeton*	*Sagittaria*	*Hydrocotyle*	*Zizania*
Spring Lake Dam	22.44	1.52	147.99	22.29	51.08	1,088.72
City Park	65.28	50.1	203.34	106.84	0	1,360
IH-35	146.25	73.05	0	291.76	0	627.88
TOTALS	**233.97**	**124.67**	**351.33**	**420.89**	**51.08**	**3,076.60**

Proposed Activities for 2019:

In 2019, aquatic vegetation treatment work plans will be developed based on the proposed EAHCP vegetation coverage goals as defined by Table 34 of the SAV Report. All previously planted stands of native SAV will be maintained.

A focus for the Spring Lake Restoration Reach will be finding the areas of suitable habitat required to meet Table 34 goals for Texas wild-rice. Successful establishment of Texas wild-rice in Spring Lake has been limited to directly upstream of the eastern and western spillways but construction planned for Spring Lake Dam in 2019 might impede planting within these areas.

To minimize downstream propagation by fragmentation, efforts to eradicate *Hydrilla* by removing it in an upstream to downstream sequence will continue in the Headwaters, Sewell and Below Sewell-City, and City Park reaches of the river.

Non-Native Littoral Plant Removal

In 2018, removal efforts consisted of treating invasive, exotic plants from Bert Brown Road to Stokes Road (**Figure 3.3-35** and **Figure 3.3-36**). A large portion of the work was continued removal of upstream sources of elephant ears and other invasive, exotic plants. The elephant ear population upstream of Bert Brown Road was brought to a state of minimal maintenance. Efforts made great progress on Sink Creek along the golf course area. Water Hyacinth and elephant ears in the River and Wetland Boardwalk area were greatly reduced. Small populations of both persist in a few areas therein. Umbrella Sedge was treated wherever found along the river.

Almost all of the littoral areas from Spring Lake to Capes Dam are now under control in regard to littoral invasive, exotic plants. The exceptions are large stands of elephant ears on private property just downstream of IH-35. The littoral invasive, exotic plants between this private property and Cape's Dam are under control.

Hot spot efforts were begun to eradicate the invasive woody plant population in Crook Park on the high bank side of the Old Mill Channel of the river. A large buffer strip 30 ft deep and 330 ft long was completely cleared of Paper mulberry, Wax Leaf Ligustrum, Chinese Tallow and Chinaberry. This removed shade cover from many native plants that were in need of more sunlight to thrive. These invasive woody plants were also removed from select littoral areas along the river where they sprouted up. Two tributary areas were treated for these woody plants as well to keep possible seed source from entering the river.

The COSM's contractor used Aquaneat (glyphosate-based herbicide) for elephant ears and other non-native plants encountered in the littoral zone (10 ounces (oz.) per gallon maximum). This herbicide was mixed with Aqua King Plus Surfactant (1 oz. per gallon) and Turf Mark Blue, Blue Dye. On the upland tree, shrub stumps and root buttresses, the contractor used Relegate **(**Triclopyr-based herbicide) at 10 oz. per gallon. The Relegate was mixed with glyphosate (10 oz. per gallon maximum), Drexel Surf Ac 820 Surfactant (1 oz. per gallon) and Turf Mark Blue, a blue dye. Chemicals were applied with a 1.5-gallon pump-up sprayer set on a steady stream for a more precise target hit, to minimize leaching and non-target plant damage. Root

flares of woody plants were scarred up with a heavy blade to expose more of the cambium layer and treated with an herbicide mix.

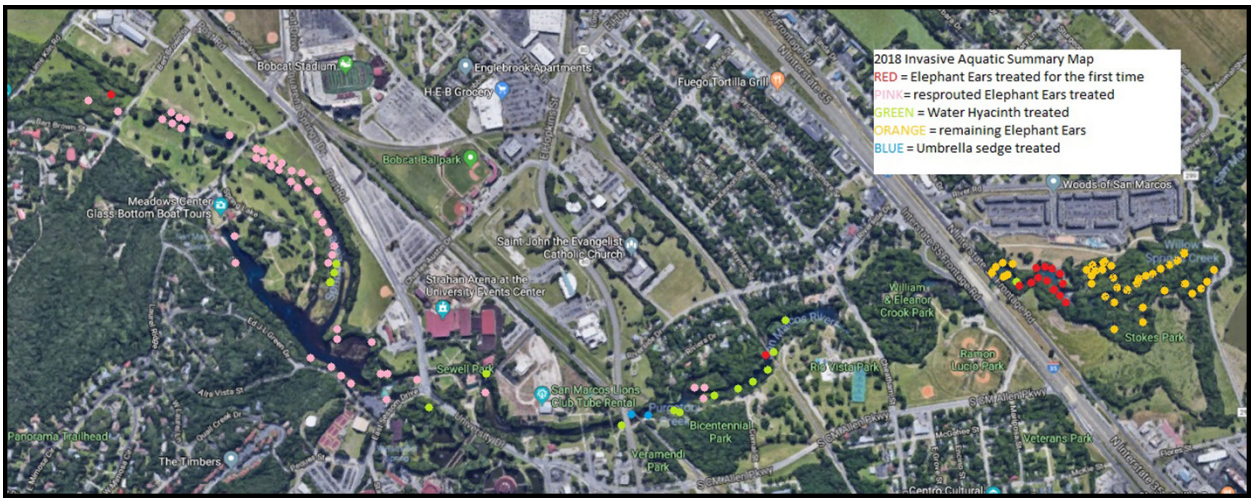

Figure 3.3-35. Status of *C. esculenta* removal (November 2018).

Figure 3.3-36. Status of small caliper littoral invasive plant removal (November 2018).

Proposed Activities for 2019:

The COSM's invasive, exotic removal efforts will extend to Stokes Park for 2019. Any remaining stands of elephant ears along Sink Creek will be treated. When the rest of the elephant ears are treated and under control in these areas, efforts will be focused on removal of invasive, exotic, smaller woody plants. Maintenance in all treated areas will continue with a focus on areas of Spring Lake and in areas of the river that were restored and replanted.

3.3.9 Control of Harmful Non-Native and Predator Species (EAHCP §5.3.9)

EAHCP Obligations:

The COSM, in partnership with Texas State, will implement a non-native species control program that targets the suckermouth armored catfish (Loricariidae), tilapia (*Oreochromis* spp.), red-rimmed melania (*Melanoides tuberculata*), and the giant ramshorn snail *(Marisa cornuarietis)*. The COSM will conduct annual monitoring and maintenance activities to ensure continued control of the invasive population within the San Marcos system.

2018 Compliance Actions:

Tilapia

The tilapia in Spring Lake seek thermal refuge and follow the warmest water throughout the year.

From March to June, the tilapia spawn near the boardwalks and the shallow waters of the slough arm. During this time the COSM's contractor focused all efforts on tilapia removal by bowfishing, spearfishing with a speargun, and using gill nets. The combined effort of all three methods has been the most successful: setting the gill net then bowfishing and spearfishing around it while scaring the tilapia into the net.

After spawning season and throughout summer, from July to September, the tilapia in Spring Lake were too far up the slough arm to have enough visibility to remove, so efforts were focused on the river. Tilapia in the river were targeted by the contractor each week of the summer. The tilapia in the river were most active on clear hot days in the early to late afternoon. The contractor's biannual polespear tournaments were also successful in removing tilapia in the river.

During the months of October to February, the contractor spearfished tilapia with a speargun and had the most success during the coldest mornings and afternoons. At this time, the tilapia were coming to the tip of the slough arm into spring fed water seeking thermal refuge.

Suckermouth catfish (*Hypostomus plecostomus*)

All but one of the catfish captured from Spring Lake to this date have been identified as the sailfin catfish species, with twelve spines along the dorsal fin. Only one small suckermouth catfish was removed from Spring Lake this year, and it was the first suckermouth catfish ever removed within Spring Lake. Only one sailfin catfish was removed in Spring Lake this year as well. The suckermouth catfish species with seven spines along the dorsal fin and the sailfin catfish are both found in the San Marcos River. Only one sailfin catfish was removed from the river this year. In the river, both catfish species were removed using pole spears while in Spring Lake. Catfish were speared at both night and day, but during the recreation season the contractor dives were only conducted in early morning or at night due to the constant turbidity of the water during the day.

Red-Rimmed Melania and Giant Ramshorn Snail Removal

The COSM's contractor worked areas of large concentrations by hand-collection primarily in the Clear Springs Natural Area. Snails were also included in the biannual spearfishing tournament, with an award given for most weight in snails removed.

The contractor set up an educational booth to increase public awareness of non-native invasive fish and promote the polespear tournaments at the annual Mermaid Festival. The contractor created giant suckermouth catfish and mermaid sculptures out of trash removed from the San Marcos River; this sculpture was in the Mermaid Parade and is on display at the contractor's local residence off Riverside Drive to promote environmental stewardship and upcoming tournaments. With permission from the San Marcos Park Rangers, the contractor schedules three week-long pole spear tournaments twice each year to give the community the opportunity to legally polespear and take part in the EAHCP.

Tournaments

The COSM contractor hosted spring and winter spearfishing tournaments that increase the capture of tilapia and catfish, as well as exotic snails.

The total number of invasive species and biomass removed to date through these tournaments are shown in **Table 3.3-14**.

Table 3.3-14. Total Number of Species and Biomass Removed Through All Spearfishing Tournaments to Date (2015 – 2018)

Species	Total Number	Total Biomass (lbs.)
Plecostomus	2,729	1,417
Tilapia	105	196
TOTALS	**2,834**	**1,613**

Monitoring Program

In order to provide details associated with invasive fishes' general abundance in the San Marcos River biomass data was collected in order to more adequately determine the health of the species. **Table 3.3-15** shows the total biomass collected as a relation to the numbers to measure the impact of this Conservation Measure on controlling targeted species.

Table 3.3-15. 2018 Non-Native Species Removal Totals

Species	Total Biomass (lbs.)	Total Number	Average Biomass/Individual (lbs.)
Tilapia	824.08	226	3.65
Catfish (Suckermouth & Sailfin)	727.73	1,256	0.58
Nutria	0	0	0
Red-rimmed snail	5.61	N/A	N/A
Giant ramshorn snail	0	0	0

Proposed Activities for 2019:

In 2019, the COSM will continue regular removal of the tilapia, suckermouth catfish, and snails. Monthly monitoring will continue. Biannual tournaments will continue to increase the removal quantities.

3.3.10 Native Riparian Habitat Restoration (EAHCP §5.7.1)

EAHCP Obligations:

The COSM will restore riparian habitats with native species on City and University property from Clear Springs to Stokes Island. The COSM will establish a program for private landowners to implement riparian restoration on their properties with the opportunity for reimbursement of plant acquisition costs if program criteria are met.

2018 Compliance Actions:

The COSM's contractor, staff and volunteers performed riparian area non-native invasive plant removal throughout 2018. Targeted species include: Chinese tallow, chinaberry, ligustrum, Chinese privet, paper mulberry, tree of heaven, giant reed, Japanese honeysuckle, catclaw vine, heavenly bamboo, red-tipped photinia, golden bamboo, Chinese pistache, johnsongrass, bastard cabbage, and lilac chaste tree.

Ligustrum, Chinese tallow, Japanese honeysuckle and johnsongrass were removed from along Purgatory Creek in Bicentennial Park. Crook Park and Wildlife Annex were cleared of tree of heaven, ligustrum, paper mulberry and chinaberry. Rio Vista's planted islands had seedling invasive species that were removed. Invasive plant removal was performed with chainsaws and hand tools. All cut stumps were chemically treated by licensed staff. Erosion control measures placed all the straight branches and trunks on contour and used mulch produced on-site to fill between the contour logs. **Figure 3.3-37** shows areas of riparian invasive species removal. Areas outlined in yellow indicate areas where more than one treatment was needed. The areas outlined in red indicate areas where only one treatment was needed. The areas along the light blue lines show where bank roots were treated.

Native plantings and seeding occurred in March 2018 and November 2018 to take advantage of spring and fall rains and temperatures. Sites planted included Wildlife Annex, Rio Vista, and Crook parks as well as the Sessom Natural Area. To reduce costs and involve the community, all planting and seeding efforts were performed by volunteers (**Figure 3.3-38** through **Figure 3.3-39**). The COSM continues to plant drought tolerant species, littoral species, and broadcast native seed stock to repopulate riparian buffer zones.

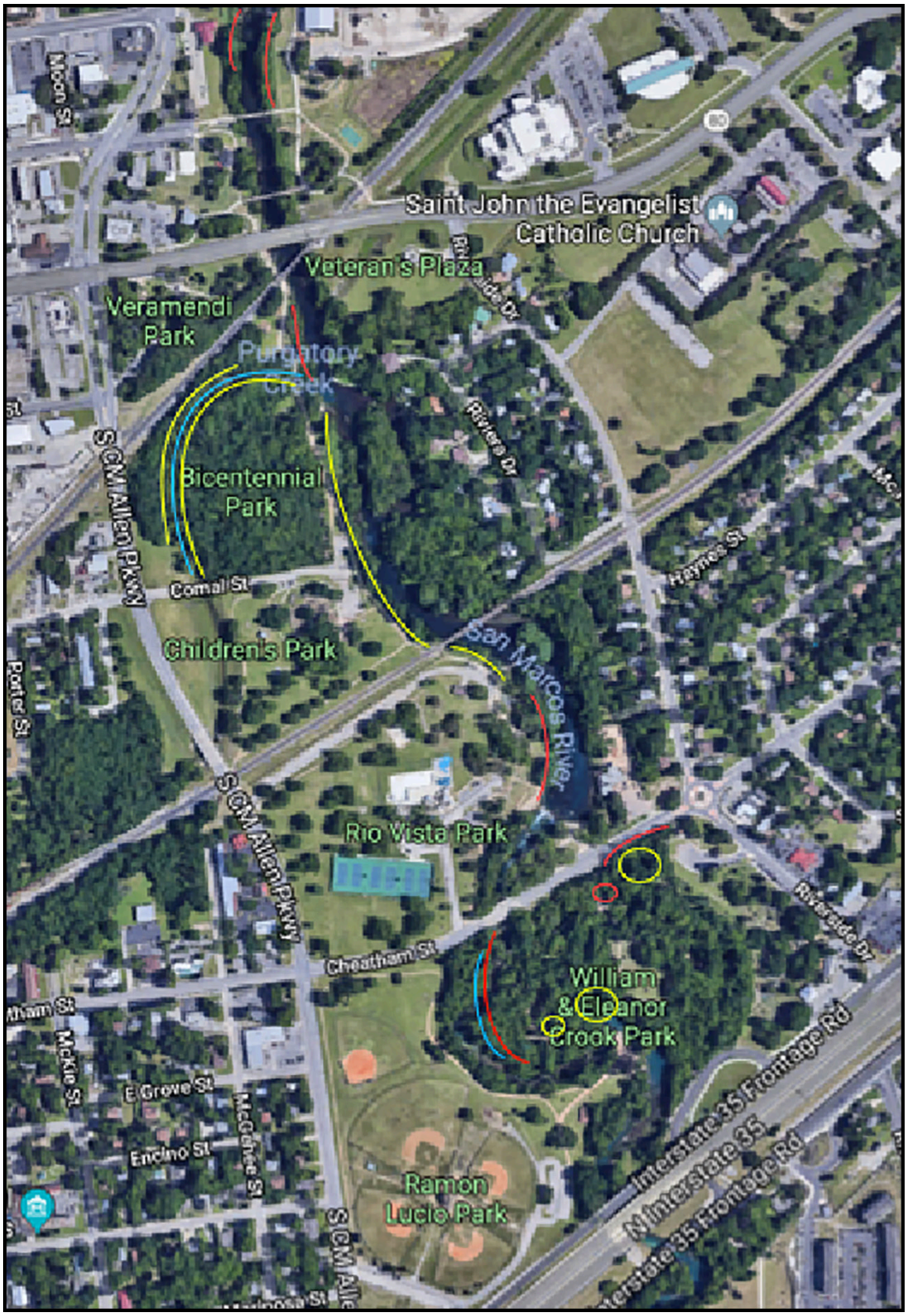

Figure 3.3-37. Areas of riparian invasive species removal.

Figure 3.3-38. Mountain laurel coming up from seeding practices during volunteer work days.

Figure 3.3-39. Volunteer restoration work at Sessom Natural Area.

Proposed Activities for 2019:

Maintenance of riparian areas from Clear Springs to Stokes Park will continue. The COSM will continue to focus on restoration of public areas with volunteer groups.

3.3.11 Septic System Registration and Permitting Program (EAHCP §5.7.3)

EAHCP Obligations:

The COSM will establish a registration, evaluation, and permitting program for aerobic and anaerobic septic systems.

2018 Compliance Actions:

As of January 1, 2018, the San Marcos Environmental Health Department had registration records for 611 septic systems within the COSM's jurisdiction. Four new septic systems were added into service in 2018 yielding a total as of December 31, 2018 of 615 septic systems in the COSM. All systems have been permitted and evaluated to prevent subsurface pollutant loadings into the Edwards Aquifer or San Marcos River.

Proposed Activities for 2019:

The COSM will continue to implement their septic system registration and permitting program. This program includes the required connection to municipal sewer lines according to COSM Ordinance, Section 86.152.

3.3.12 Minimizing Impacts of Contaminated Runoff (EAHCP §5.7.4)

EAHCP Obligations:

The COSM will excavate and stabilize two areas for the construction of two water quality BMPs in the vicinity of the San Marcos River. Once funded, construction of these BMPs will be closely monitored for potential impacts to the river system. Upon completion, the COSM will regularly monitor these ponds to remove and properly dispose of accumulated sediments off-site.

2018 Compliance Actions:

In 2017, the AMP was implemented to change the location of the two water quality BMPs. The new locations are the City Park and Downtown/Hutchison. In 2018, design of the Downtown Pond was completed, and construction will begin in Spring 2019. The City Park pond is complete (**Figure 3.3-40**).

Figure 3.3-40. Final construction stage of City Park pond.

Proposed Activities for 2019:

The COSM will construct the Downtown pond.

3.3.13 Management of Household Hazardous Wastes (EAHCP §5.7.5)

EAHCP Obligations:

The COSM will continue to expand its existing HHW program. This program will include opportunities for collection locations available to the general public.

2018 Compliance Actions:

As a member of the EAHCP, the COSM operates an HHW collection program. This program is available free of charge for all Hays County residents. Visitors are able to drop off household chemicals and paint that are hazardous for the environment. This facility also operates a reuse program for items that are in good condition. Labor for the facility is contracted to Green Guy Recycling. The HHW facility is open to the public every Tuesday and Friday from 12:00 p.m. to 3:30 p.m. It is located at 630 E. Hopkins, San Marcos, TX 78666.

The majority of participants come from the cities of San Marcos, Kyle, Wimberley, and areas outside of the city limits. These areas are home to environmentally sensitive watersheds and the Edwards Aquifer Contributing and Recharge Zones. Offering a safe alternative to improper or illegal dumping of hazardous household chemicals is paramount to improving water quality and regional sustainability.

Drop-Off Center Participation

The primary function of the HHW program is the drop-off center. Residents drive into the unloading area, where they are met by an HHW worker. The participants remain in their vehicle as the worker unloads the containers onto a cart. Each participant fills out a survey and provides their address. From these surveys, monthly participation rates are tracked for each community. The average number of participants for 2018 was 181 per month, compared to 2017 at 180 per month.

The HHW facility was open to all residents of Hays County. The majority of the residents come from the COSM and areas outside of municipal jurisdictions. The San Marcos region is an environmentally sensitive area for the San Marcos River. Preventing illegal dumping and pollution in this region makes great strides towards improving water quality.

Reuse Program Participation

The reuse program supports the drop-off center by attracting residents and diverting reusable items from the disposal stream. When chemicals are unloaded, the worker segregates new and slightly used containers that are ready for use. Many visitors with items eligible for reuse are in the moving process. Rather than moving all of their cleaning supplies, they have the option to deliver them to the HHW. These items are taken to the reuse building and are sorted on shelves. This building is open to the public during regular

operating hours. Reuse participants fill out a form documenting the materials they pick up. This form explains that unused items are to be returned to HHW and not to be thrown into the regular waste stream. Participation for the reuse program has grown over time. The program also serves to educate the public about safe disposal and alternatives to harmful chemicals.

The monthly average participation is 67 participants. This program received many compliments from visitors. Participants save money by collecting reuse items at no cost and the HHW program saves money by reducing disposal expenses.

The annual outreach goal for HHW is 1,400 total participants. In 2018, this goal was exceeded by 112 percent with an annual total of 2,974 participants. The popularity of the reuse program and increased exposure through public outreach contributed to the program's success.

The average participants from drop-offs and reuse for 2018 was 248 participants per month. The drop-off center surveys indicate that the COSM website and word-of-mouth contributed to the steady program participation.

The Chemicals

The household hazardous materials accepted by the HHW facility include a wide-range of common chemicals and waste products. After the household waste is unloaded from the vehicle, the material is sorted and weighed. Each item is sorted based on chemical type. HHW facility workers collaborate with the chemical disposal company to evaluate the waste stream and finding storage and shipping options that reduce the expense. For example, oil based and latex paint, liquid flammables, used motor oil, cooking oil, and anti-freeze are bulked into 55-gallon drums. The remaining chemicals are sorted into either 55-gallon drums or lined gaylord boxes. Each container is stored in a chemical building or under cover until they are shipped to recycling facilities and a chemical landfill.

HHW disposed of approximately 181,129 lbs. of HHW in 2018, an average of 15,094 lbs. per month. Without this program, much of this waste would have been improperly disposed of in the municipal waste stream or illegally dumped.

The amount of household hazardous waste diverted from the waste stream and distributed by the reuse program totaled 9,730 lbs. Not only does this save on costs, it also decreases the demand for new products. The program helps with both material reuse and waste reduction.

Proposed Activities for 2019:

Moving forward, the COSM's goal for 2019 is to increase participation rates and continue to enhance awareness of the impact of HHW on the environment, particularly Covered Species habitat. An additional off-site event in Driftwood will be held in fall 2019.

3.3.14 Impervious Cover and Water Quality Protection (EAHCP §5.7.6)

EAHCP Obligations:

The COSM will establish a program to protect water quality and reduce the impact of impervious cover. Target programs will be identified consistent with the recommendations of the Low Impact Development/Water Quality Work Group Report developed during the EARIP and included as Appendix Q to the EAHCP.

The San Marcos WQPP is a locally-developed approach for compliance with the ESA in San Marcos, Texas. The intent of the WQPP is to provide a holistic, integrated approach for the COSM and Texas State in regard to water quality concerns associated with impervious cover and urban development. In addition to protecting habitat for endangered species, the WQPP will help the entities serve the needs of their growing populations and promote responsible economic development, good public infrastructure, and preserve open space.

2018 Compliance Actions:

The biofiltration pond construction was completed in City Park. This project included the demolition of an existing asphalt parking lot that sent untreated runoff directly to the San Marcos River, construction of a new parking lot further away from the river and graded to runoff into a biofiltration system **(Figure 3.3-40**). The pond includes an inlet that will allow treatment of about 12 acres of off-site runoff from the Strahan parking lot owned by Texas State. It is estimated that the pond system will remove about 8,200 lbs. of TSS and 18 lbs. of total phosphorus (TP) on an annual basis.

Design and specifications for the Downtown Biofiltration Pond rehabilitation project on C.M. Allen Parkway were completed. This project will remediate an existing water quality pond that is not performing. Once installation is complete, it will treat runoff from 32 acres at 80 percent impervious cover. The pond project has been bid and construction will begin in 2019. This pond is estimated to remove about 24 lbs. of TP on an annual basis.

Following through on the Sessom Creek Watershed Restoration Plan envisioned in 2016, the Middle Reach Restoration project is intended to mitigate stream erosion that is generating high sediment loads which impact critical habitat (**Figure 3.3-41**). Using the AMP, the project combines the funding of EAHCP Sediment Removal (Sections §5.3.6 and 5.4.4) with that of Impervious Cover and Water Quality Protection (EAHCP §5.7.6) into one Conservation Measure. In 2018, the 60 percent design phase was completed for all of the Sessom Creek water quality improvements. The project uses a natural channel design approach, with plans to bring the creek back into equilibrium as it responds to urban development in the watershed. Specific recommendations include the use of grade controls, bank stabilization, and water quality features within a reach length of 2,300 linear ft. This project is moving forward in tandem with a COSM effort to remove exposed wastewater lines from the creek and protect municipal infrastructure in the channel. Together, they will support the goal of reducing instream erosion by 50 percent.

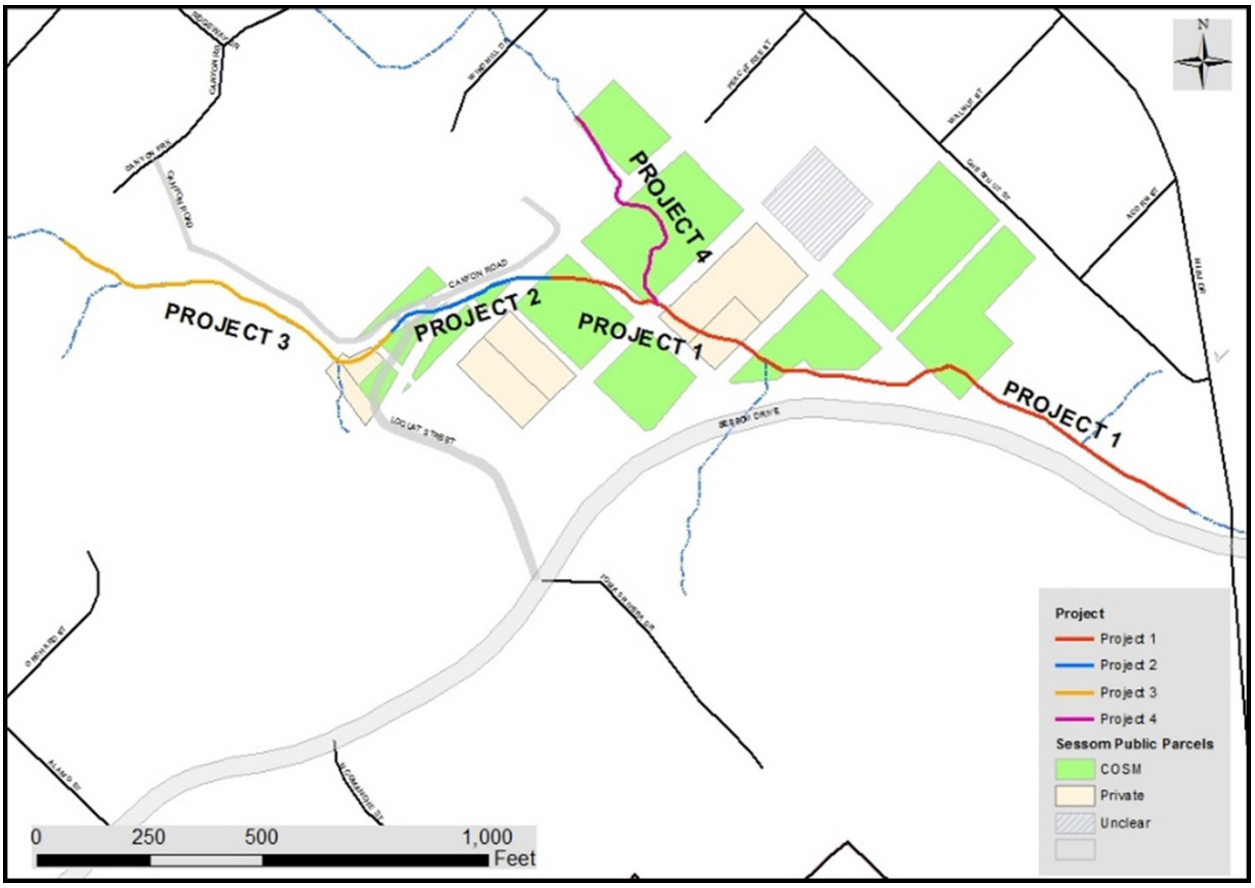

Figure 3.3-41. Project areas 1 & 2 proposed for Phase One implementation; Project areas 3 & 4 proposed for Phase Two implementation pending funding.

Proposed Activities for 2019:

The COSM will complete construction of the Downtown pond and manage the system post-construction to ensure vegetative establishment and long-term success. The COSM will implement the next phase of the Sessom Creek – Middle Reach Restoration project by completing 90% and final designs and contract documents and soliciting bids for project construction. Meetings with Texas State are ongoing to discuss their involvement in protecting water quality in Sessom Creek.

3.3.15 Challenges Observed and Identified Solutions

Administrative

Challenge: Conservation Measure organization is cumbersome for reporting and invoicing.
Solution: Combine Texas wild-rice Enhancement & Removal of non-natives and add planting of natives as the third element to create one combined measure.

Removal of non-native species

Challenge: Finding the best time to dive the river in terms ofclarity. Clarity is becoming less common during recreation season.
Solution: Managing increasing amount of recreation.

Removal of non-native plants and planting natives

Challenge: Finding more suitable Texas wild-rice habitat in Spring Lake.
Solution: Keep working on solving this challenge but be prepared to modify the goal.

Challenge: Not being able to remove non-natives and plant natives outside of designated work zones in Table 34 of the SAV Report.
Solution: Modify Table 34 requirements.

Challenge: Constant vegetation mats in the Headwaters and Sewell parks.
Solution: Establish a method of collecting cuttings from Spring Lake harvester.

Challenge: Difficulty establishing pondweed downstream of Hopkins.
Solution: Modify Table 34 requirements.

Management of Key Recreation

Challenge: Keeping CC motivated as the long hot summer wears on.
Solution: Vary the CC duties so all do both project-oriented and people-oriented tasks.

3.4 Texas State University

Texas State is responsible for the following measures under the EAHCP:

- Texas wild-rice Enhancement and Restoration (§5.4.1 and §6.3.5)
- Management of Recreation in Key Areas (§5.4.2)
- Management of Vegetation (§5.4.3)
- Sediment Removal in Spring Lake and Sewell Park (§5.4.4)
- Diversion of Surface Water (§5.4.5)
- Restoration of Native Riparian Vegetation (§5.7.1)
- Sessom Creek Sand Bar Removal (§5.4.6)
- Diving Classes in Spring Lake (§5.4.7)
- Research Programs in Spring Lake (§5.4.8)
- Management of Golf Course and Grounds (§5.4.9)
- Boating in Spring Lake and Sewell Park (§5.4.10)
- Reduction of Non-Native Species Introduction (§5.4.11)
- Control of Non-Native Plant Species (§5.4.12)
- Control of Harmful Non-Native and Predator Species (§5.4.13)

Implementation of these measures has been accomplished in partnership with the COSM, as specified in the EAHCP. Modifications due to weather conditions are discussed in the subsections below. Texas State extended its EAHCP obligations in partnership with the COSM to maintain consistency in implementation of EAHCP measures that jointly affect the Covered Species and their habitats in the San Marcos River.

3.4.1 Texas wild-rice Enhancement and Restoration (EAHCP §5.4.1 and §6.3.5)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.1** – Texas wild-rice Enhancement and Restoration.

3.4.2 Management of Recreation in Key Areas (EAHCP §5.4.2)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.2** – Management of Recreation in Key Areas.

3.4.3 Management of Vegetation (EAHCP §5.4.3)

EAHCP Obligations:

Texas State will utilize hand-cutting and a harvester boat to manage aquatic vegetation in Spring Lake. Related activities include:

1) Weekly, floating vegetation mats will be dislodged in five springs; each spring will be addressed every two to three weeks;
2) Floating vegetation mats will be dislodged more frequently in the summer;
3) Floating vegetation mats will be dislodged from Texas wild-rice stands weekly;
4) Algae will be removed regularly in the summer;
5) Accumulated sediments around spring orifices will be removed within a 1.5-m buffer radius;
6) From 1.5 to 3.0 m from spring orifices, vegetation will be sheared to a height of 30 centimeters (cm) and from 3.0 to 6.0 m from the orifice, vegetation will be sheared to a height of 1-m;
7) Fifteen to 20 boatloads of plant material will be removed by the harvester boat monthly; including weekly removal from designated zones one, two, and three (EAHCP Figure 5.2);
8) Removed vegetation will be inspected for aquatic species that will be returned to the river system immediately;
9) Vegetation mats will be removed from zones four and five (EAHCP Figure 5.2) on an as-needed basis;
10) Texas State employees or others working with and around Texas wild-rice will be trained by TPWD to recognize and protect the plant while doing work in the San Marcos system;

11) All vegetation removal activities on Texas State property will be managed by a full-time staff person responsible for operating the harvester boat, manually removing floating vegetation mats, and ensuring all staff and volunteers involved in vegetation removal are familiar with the aquatic ecosystem and able to recognize Covered Species.

2018 Compliance Actions:

Management of Submerged and Floating Aquatic Vegetation in Spring Lake

Spring Orifice Maintenance: Texas State personnel at the Meadows Center for Water and the Environment (MCWE) in conjunction with qualified Dive Authorization Course (DAC) volunteers removed accumulated sediment where necessary from target springs in Spring Lake by finning the substrate away. In addition, aquatic vegetation was removed from an approximately 1.5-m radius of each target spring with a machete. The aquatic vegetation within the next 1.5-m radius area around each target spring was cut to a height of 30 cm and the cut material allowed to flow downstream with the current. Aquatic vegetation within the next 3-m radius of target springs was sheared to height of 1 m and cut vegetation allowed to drift downstream. **Table 3.4-1** provides a summary of work conducted for this EAHCP Conservation Measure.

Table 3.4-1. Aquatic Vegetation Maintenance Activities Within Spring Lake in 2018

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTALS
Aquatic Maintenance (approximate dives)	0	10	8	12	10	15	15	10	6	10	8	8	**112**
Aquatic Maintenance Dive Hours (average 1.25 hours/dive)	0	12.5	10	15	12.5	18.75	18.75	13	7.5	12.5	20	0	**140**
AquaCorps Diving Volunteers	78	114	168	132	81	115	139	131	125	113	56	90	**1,381**
Diving for Science (D4S) Dive Hours (average 1.25 hours/dive)	97.5	142.5	210	165	101.25	144	174	164	141	119	119	112.5	**1,726**

Harvester Boat: Maintenance of submerged and floating aquatic vegetation followed the protocols outlined in the EAHCP (Section 5.4.3.1) and the approved Spring Lake Management Plan. The harvesting schedule targets three cuts per week, typically Monday, Wednesday, and Friday mornings. Scheduled harvesting of each zone rotates in order to allow each zone adequate recovery time and ensure that a specific zone is not over cut. This results in each zone being cut two or three times a month. The estimated aquatic vegetation harvest is approximately 10 to 12 cubic yards (yd^3)/per cutting. The total estimated harvest is approximately 1,112.5 yd^3 for the year.

Management of Aquatic Vegetation below Spring Lake Dam to City Park

Texas State collaborated with the COSM to control aquatic vegetation mats entrained on Texas wild-rice stands below Spring Lake Dam to the end of Sewell Park. Aquatic vegetation removal by pushing and removing floating mats, as specified in the EAHCP.

Proposed Activities for 2019:

Texas State will continue to implement floating vegetation mat and litter removal consistent with protocols established in the EAHCP and in the 2019 Work Plan.

3.4.4 Sediment Removal in Spring Lake and Sewell Park (EAHCP §5.4.4)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.6** – Sediment Removal Below Sewell Park.

3.4.5 Diversion of Surface Water (EAHCP §5.4.5)

EAHCP Obligations:

Texas State will reduce the amount of surface water diverted from the San Marcos River in accordance with the following conditions:

- Reduce diversion by two cfs when the USGS gage at University Bridge reads 80 cfs (reduction made below Spring Lake Dam).
- Reduce diversion by an additional two cfs (total four cfs) when the USGS gage at University Bridge reads 60 cfs (reduction made in Spring Lake).
- Reduce diversion by all but one cfs when the USGS gage at University Bridge reads 49 cfs (reduction made in the Sewell Park reach).
- Cease all surface water diversions when the USGS gage at University Bridge reads 45 cfs.

2018 Compliance Actions:

Texas State did not reduce permitted pumping in 2018 to meet EAHCP requirements, since total San Marcos River flows did not reach trigger points (i.e., < 80 cfs). Texas State uses Certificate 18-3866-401 to fill campus ponds. Certificate 18-3866-400 is a pump at Sewell Park that is used to supply the Armory Field (City Park) and the Sewell Park/Jowers complex. Texas State has not used it in a couple of decades because, when it's needed most, the allocation is cut in half. Plus, the water was not filtered adequately so it created clogging issues, so it is unlikely to ever be used.

The total volume of surface water diversions from Spring Lake (Certificate 18-3865) was 15 ac-ft/year for 2018; well below the permitted 100 ac-ft/year. Maximum instantaneous diversion rates are not available.

Proposed Activities for 2019:

Texas State will reduce or cease the diversion of surface water as required by flow conditions and described in the *EAHCP Obligations* above.

3.4.6 Restoration of Native Riparian Vegetation (EAHCP §5.7.1)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.10** – Native Riparian Habitat Restoration.

3.4.7 Sessom Creek Sand Bar Removal (EAHCP §5.4.6)

EAHCP Obligations:

Texas State and the COSM will conduct a study of sediment removal options to determine the best procedure to remove this sand and gravel bar that minimizes impacts to listed species. Texas State will submit the study for review though the AMP and implement the actions coming out of that process.

2018 Compliance Actions:

Monitoring in 2015 showed that the majority of rain events deposited fine sediment at the confluence of Sessom Creek and San Marcos River. The October flood scoured out the sediment bar and redeposited new material including rock from the bank opposite the Spring Lake western spillway as well as dislodging the limestone blocks stabilizing the banks of Sessom Creek. In 2016, the majority of rain events including the heavy rainfall in October resulted in sediment laden runoff from Sessom Creek which further increased the deposition at the sediment bar. Therefore, it was decided and approved through the AMP that the EAHCP would take preventative rather than reactive action by addressing erosion in Sessom Creek, which is the primary source of sediment for the Sessom Creek sand bar.

Proposed Activities for 2019:

A natural creek stabilization design will be constructed for Sessom Creek from LBJ Drive to just above Loquat Street.

3.4.8 Diving Classes in Spring Lake (EAHCP §5.4.7)

EAHCP Obligations:

Every diver participating in the Texas State DAC Program will need to show an understanding of the Covered Species found in Spring Lake and their habitats, as well as the laws and regulations relevant to those species. Divers must exhibit good buoyancy control, have the ability to avoid contact with listed species and critical habitat, and maintain a distance from the lake bottom.

No more than 16 trained divers may be present in Spring Lake at any time. Texas State will conduct training for check-out dives and Self Contained Underwater Breathing Apparatus (SCUBA) classes no more than three times per day, and classes will include a maximum of sixteen students per class.

2018 Compliance Actions:

MCWE updated the Spring Lake Management Plan to reflect all the requirements under the EAHCP and ITP. This includes the following EAHCP measures:

1) Spring Lake Dive Authorization Program (§5.4.7.1)
2) Texas State Continuing Education (§5.4.2)
3) Texas State SCUBA Classes (§5.4.7.3)

The revised plan implements the EAHCP requirements with the following restrictions:

1) Spring Lake Dive Authorization Program – No more than 16 volunteer divers/day and ≤ 8 at one time
2) Texas State Continuing Education – 16 divers/class; ≤ 3 classes/day; restricted to the Dive Training Area
3) Texas State SCUBA Classes – 16 students/class; ≤ 3 classes/day; restricted to the Dive Training Area

The revised Spring Lake Management Plan was submitted and approved by the President's Cabinet in 2012. As part of this effort, MCWE implemented a Diving Program Control Board that reviews all diving activities within Spring Lake to ensure they comply with the Spring Lake Management Plan and the EAHCP. These efforts also include the development of the Spring Lake Dive Accident Management Plan and revised D4S program, which has implemented a more rigorous training program that includes expanded training and orientation on the endangered species. Diving activities in Spring Lake are summarized in **Table 3.4-2**.

Table 3.4-2. Diving Activities in Spring Lake in 2018

Activity FY 2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Reporting Period Totals
Aquatic Maintenance (approximate dives)	0	10	8	12	10	15	15	10	6	10	8	8	112
Texas State Student Dives	0	4	6	0	0	14	10	15	4	67	15	10	145
Public Divers	244	302	419	300	377	264	209	152	91	145			2,503
Volunteer Divers	78	114	168	132	81	115	139	131	125	113	95	90	1,381
Research Dives	4	2	0	0	12	0	0	2	2	4	3	0	29
External Dives (EAA, USFWS, etc.)	0	2	0	2	2	0	12	1	0	10	5	0	34
New Volunteers	0	14	13	0	0	31	27	20	24	19	11	25	184
Wounded Warriors (groups not individuals)	0	0	0	0	2	0	1	0	0	0	9	9	21
TOTALS	**326**	**448**	**614**	**446**	**484**	**439**	**413**	**331**	**252**	**368**	**146**	**142**	**4,409**

Proposed Activities for 2019:

Texas State will continue to implement their diving class program consistent with the protocols identified in the EAHCP.

3.4.9 Research Programs in Spring Lake (EAHCP §5.4.8)

EAHCP Obligations:

No research will be conducted in Spring Lake without prior review and approval by the MCWE to assess impacts to the Covered Species. Where take cannot be avoided, Texas State will provide education to researchers regarding the species and their habitats. Independent researchers may need to obtain individual permits from the USFWS.

2018 Compliance Actions:

The Chief Science Officer at the MCWE chairs the Spring Lake Environmental Committee, which oversees all access to Spring Lake. To this end, MCWE developed an online access request form (http://www.meadowscenter.txstate.edu/ReserveSpecialEvents/SpringLakeAccess.html). Each request is reviewed by the eight-member committee, and if a vertebrate animal is the target of research the Institutional Animal Care and Use Committee is also consulted for approval. In the event that the proposed research involves diving, the application and methods are reviewed by the Spring Lake Diving Control Board and if necessary, scientific diving training is required prior to access. **Table 3.4-3** summarizes the research/access activities in Spring Lake.

Table 3.4-3. Research and/or Access Activities on Spring Lake in 2018

Researcher	Department /Agency	Duration	Description
Nick Menchaca	Atlas Environmental	Still Active	Invasive animal removal
Francis Rose	Texas State Biology	Still Active	Trapping/monitoring turtle community
Edmund Oborny	BIO-WEST, Inc.	Still Active	Edwards Aquifer Research and Data Research Center salamander and fountain darter survey
Eric Ruckstuhl; Aaron Hoot	EBR Enterprises	Still Active	Invasive vegetation removal
Andrew Johnston	Halff Engineering	Still Active	Assess Burleson's Dam
Valentin Cantu; Lindsey Campbell	USFWS	Still Active	Collecting wild San Marcos salamanders and fountain darters
Randy Gibson	USFWS	Still Active	Set/check diversion trap; blind salamander collections
Mary Wicksten	Texas A&M Biology	Still Active	Gastrotrich collecting
Catlin Gabor	Texas State Biology	Still Active	Character of sex pheromone in sailfin mollies
Jerry Cochran	Texas Water Safari	6/9/2018	Texas Water Safari Canoe Race

Table 3.4-3. Research and/or Access Activities on Spring Lake in 2018

Researcher	Department /Agency	Duration	Description
Allison Davis	University of Texas - Integrative Biology	6/21/2018	Collecting Amazon and Sailfin mollies; comparing a/sexual reproduction
Laura Dunn	Two Birds Film	5/25/2018	Documentary film shoot; 6 children swimming
Chad Furl	EAA		Zebra Mussel Monitoring
John Gomez-Simmons	Texas State Sports Clubs - Triathlon	4/22/2018	Triathlon; 1,000-yard swim
Nicholas Herrmann, Sean Farrell	Texas State Anthropology	5/13/2018	Geophysical survey techniques; Terrestrial Archaeology
David Huffman	Texas State Biology	Still Active	Dip-netting and angling native species for scientific research
Brian Hunt	Barton Springs Edwards Aquifer Conservation District	12/22/2018	Dye trace study
Erica Hunter	San Marcos Convention and Visitors Bureau	9/21/2018	UAV flight over Spring Lake
Karen Hall	A Personal Touch Photography	3/2/2018	
Kent Griffin	Texas State Health & Human Performance	6/30/2018	Aquarena Springs Outdoor Education Program
Leah Murray	USFWS/Monarch Joint Venture	11/10/2018	Monarch Butterfly site monitoring
David Lemke	Texas State Biology	7/6/2018	Class instruction and examining plants
Chris Moore	Expedition Texas/31 West Productions	9/2/2018	Filming an episode of Expedition Texas
Melissa Nicewarner Daly	Back on my Feet - Austin	11/3/2018	Bigfoot Trail Race
Payton Palmer-Newton	Texas State Outdoor Recreation	4/21/2018	Trail Cleanup
Barbara Piersol	San Marcos River Walkers	3/17/2018	5k Walk in Golf Course
Jeremiah Pizana	Rotary Club of Greater San Marcos	9/30/2018	Triathlon, 500m swim
Chandler Prude	Texas State Marketing	10/20/2018	Lights for President Trauth holiday video
Benjamin Rauls	Texas State Marketing	7/20/2018	UAV flight for promotional prints
Maria Rocha	Indigenous Cultures Institute	11/18/2018	Sacred Springs Powwow
Rebekah Rylander	Texas State Biology	10/12/2018	Class observing flowering plants and pollinators
Sara Salisbury	Texas State Biology	9/25/2018	Cattail harvesting
Nick Seidel	Scallywompus Events	7/22/2018	Triathlon
Ned Strenth	Angelo State University		Grass shrimp, Palaemon texanus collection
Benjamin Von Cramon	EAA	1/16/2018	Filming of blind salamanders and scene footage
Miranda Wait	Not on My Campus/College Republicans	11/5/2018	5k - South Lawn and Nature Area Trails
Miranda Wait	MCWE/Mermaid Society SMTX	9/15/2018	Mermaid Ball
Miranda Wait			Hoerning wedding
Aaron Wallendorf	MCWE	2/28/2018	Dock removal, floating dock installation

Proposed Activities for 2019:

Texas State will implement their research program consistent with the protocols identified in the EAHCP.

3.4.10 Management of Golf Course and Grounds (EAHCP §5.4.9)

EAHCP Obligations:

Texas State will develop and implement a Grounds Management Plan, including an IPMP. These plans will consider the appropriate application of environmentally-sensitive chemicals to reduce negative impacts to neighboring ecosystems. Any significant changes in the management protocol will be addressed through the AMP.

2018 Compliance Actions:

The Texas State golf course has closed and Texas State plans to convert the area to accommodate other campus sports. Design plans are underway with construction expected to begin early in 2019. A meeting will be set for a discussion on continuing to follow a Management Plan and IPMP guidelines based on both the EAHCP (EAHCP §5.4.9) and the Spring Lake Management Plan.

Proposed Activities for 2019:

Texas State will finish construction of recreation fields and discuss continuation of its Grounds Management Plan and IPMP.

3.4.11 Boating in Spring Lake and Sewell Park (EAHCP §5.4.10)

EAHCP Obligations:

Boating at Spring Lake will be restricted to areas treated with the harvester, operators will enter and exit boats at designated access points, and all boats will follow USFWS standards for proper cleaning.

2018 Compliance Actions:

The canoe/kayak classes are limited to no more than two classes per day with a maximum duration of one hour and limited to 20 students in ten canoes. In addition, the glass-bottom boats are restricted to areas in Spring Lake that are mowed for aquatic vegetation control. Boat access into Spring Lake must follow the USFWS decontamination process as outlined in the Spring Lake Management Plan and only enter at specific controlled locations that minimize potential impacts to listed species or their habitats. A total of 7,616 glass-bottom boat tours and 924 canoe/kayak tours were conducted in 2018.

Canoeing/kayak classes in Sewell Park were limited to the region between Sewell Park and Rio Vista Dam as specified in the EAHCP. Access to the river was confined to the floating boat dock adjacent to the recreation center downstream of the walking bridge in Sewell Park. No more than three classes/day with a maximum of 20 students in ten canoes are permitted and not to exceed two hours in duration.

Proposed Activities for 2019:

Texas State will continue to implement the boating program in Spring Lake and Sewell Park consistent with the protocols identified in the EAHCP.

3.4.12 Reduction of Non-Native Species Introduction (EAHCP §5.4.11)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.5** – Reduction of Non-Native Species Introduction.

3.4.13 Control of Non-Native Plant Species (EAHCP §5.4.12)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.8** – Control of Harmful Non-Native Plant Species.

3.4.14 Control of Harmful Non-Native and Predator Species (EAHCP §5.4.13)

For discussion related to Texas State's *EAHCP Obligations*, *2018 Compliance Actions* and *Proposed Activities for 2019* related to this Conservation Measure, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.8** – Control of Harmful Non-Native and Predator Species.

3.4.15 Challenges Observed and Identified Solutions

For discussion of challenges observed and identified solutions by Texas State, please refer to the discussion under **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **subsection 3.3.15** – Challenges Observed and Identified Solutions.

3.5 San Antonio Water System

SAWS, with involvement by the EAA in certain Edwards water rights acquisition, is responsible for the following measure under the EAHCP:

- Use of the San Antonio Water System Aquifer Storage and Recovery for Springflow Protection (EAHCP §5.5.1 and §5.5.2)

SAWS is one of the largest municipally-owned water and wastewater systems in the United States, serving a population of 1.8 million. SAWS serves most of Bexar County and the surrounding area. The population within the SAWS service area is growing by an estimated 40,000 persons per year.

SAWS' H_2Oaks ASR Project (formerly known as the Twin Oaks SAWS ASR) in southern Bexar County is a key Conservation Measure for the EAHCP. This Conservation Measure, among other things, involves the injection, storage, and potential recovery of Edwards Aquifer water produced under EAA-issued groundwater withdrawal permits leased by the EAA. Under certain conditions — more fully described in

the EAHCP and the Interlocal Contract between the EAA and SAWS for the Use of the H_2Oaks ASR Project for Contribution to Springflow Protection (ILC) — this water may be recovered from storage to serve SAWS customers during certain drought conditions as specified in the EAHCP. The day-to-day operation of the SAWS' H_2Oaks ASR Project (SAWS ASR) is managed by SAWS. A twelve-person Regional Advisory Group composed of diverse stakeholders advises SAWS on the implementation of this Conservation Measure.

The EAHCP broadly outlines how SAWS, with the advice of the Regional Advisory Group, will report its injection, storage, and recovery activities (EAHCP §5.5.1, page 5-38). The ILC provides additional detail on these activities, as well as the other activities necessary to implement the SAWS ASR Program.

3.5.1 Use of the San Antonio Water System Aquifer Storage and Recovery for Springflow Protection (EAHCP §5.5.1 and §5.5.2)

EAHCP Obligations:

SAWS will utilize the H_2Oaks ASR Facility as a contributing springflow protection measure during defined times of extreme drought. The SAWS ASR Program under the EAHCP and the ILC consists of four primary components: (1) injection, storage, and potential recovery of "EAHCP Groundwater"[11] in and from the SAWS ASR; (2) acquisition by the EAA of leases of EAHCP Groundwater for delivery to SAWS for injection and storage into the SAWS ASR, (3) acquisition by the EAA of forbearance agreements that require the contracting permit holder to forbear the right to make withdrawals from the Edwards Aquifer pursuant to EAA Groundwater Withdrawal Permits during certain prescribed drought conditions; and (4) forbearance by SAWS during times of certain defined drought conditions of its right to make withdrawals from the Aquifer under its EAA-issued groundwater withdrawal permits. The EAA has the obligation to acquire 50,000 ac-ft/year of EAHCP Groundwater through leases and forbearance agreements. The EAA is then required to sublease to SAWS (through a Notice of Availability [NOA]) any EAHCP Groundwater it may acquire through leases for SAWS to inject and store in the SAWS ASR. SAWS may then potentially recover such stored EAHCP Groundwater under the terms and conditions of the ILC to offset any forbearance obligation it may have relative to its EAA-issued groundwater withdrawal permits under the EAHCP and the ILC. SAWS has the general duty to inject and store in the SAWS ASR and credit to the EAA any EAHCP Groundwater that the EAA may present to SAWS through a NOA.

When the level of the Edwards Aquifer index well J-17 is less than 630 ft msl and the ten-year rolling recharge average of the Aquifer is less than or equal to 500,000 ac-ft/year, SAWS will forbear making withdrawals from the Aquifer from designated wells on the northeast side of its service area equivalent to certain forbearance schedules prescribed in the ILC, or an alternative schedule prescribed by processes detailed in the ILC, and instead, at its option and discretion, to offset its forbearance from Edwards pumping, recover EAHCP Groundwater from the SAWS ASR for distribution to its customers.

[11] EAHCP Groundwater is essentially defined by the ILC as the leases acquired by the EAA of EAA-issued groundwater withdrawal permits for the purpose of supplying SAWS with a water supply to inject and store in the SAWS ASR for the purposes of Section 5.5.1 of the EAHCP.

SAWS will make every effort to meet the presumptive forbearance schedule identified in the ILC; however, the EAHCP recognizes that future droughts may not exactly mimic the drought of record, so flexibility will be afforded to SAWS through processes outlined in the ILC to provide for alternative forbearance schedules.

Section 5.5.2 of the EAHCP includes a discussion on the use of the SAWS Water Resources Integration Program (WRIP) as the Phase II presumptive action for the EAHCP. To date, Phase II is not yet in effect and has not yet been discussed by the committees of the EAHCP, so it is not discussed at length in this report. Phase 1 of the WRIP has been constructed and is operational between the H_2Oaks ASR Facility and the newly-commissioned Old Pearsall Road pump-station. Interconnects between these two facilities have been constructed, enhancing the water distribution capacity of the WRIP. WRIP Phase 2 will allow for additional distribution/recharge capacity to and from the Anderson Pump Station and is to be completed in 2021.

2018 Compliance Actions:

In 2013, the ILC was developed between the EAA and SAWS over a seven-month period. The ILC translates the conceptual elements of SAWS ASR commitment in Section 5.5.1 of the EAHCP into measurable activities related to both parties' responsibilities. Summaries of SAWS and EAA actions related to fulfilling these responsibilities in 2018 are provided below in subsections 3.5.1.1 through 3.5.1.4.

SAWS is responsible for organizing and facilitating an ASR Advisory Group. The ILC also required formation of a Staff Work Group. This subject will also be discussed further in this section of the Annual Report.

Under the ILC, SAWS is required to credit to the EAA as being in storage any permitted Edwards Aquifer groundwater for which it receives a NOA from the EAA by certain dates.

3.5.1.1 San Antonio Water System Aquifer Storage and Recovery Regional Advisory Committee and Staff Work Group

The EAHCP and the ILC provide for continued dialog and interaction. Under the ILC, SAWS has the responsibility to facilitate two groups. The first group is the SAWS ASR Regional Advisory Group as described in the EAHCP. Per the requirement on page 5-39 of the EAHCP, a twelve-person Regional Advisory Group consisting of four representatives of SAWS, the EAHCP Program Manager, and one representative each from the EAA, an EAA permit holder for irrigation purposes, a representative of small municipal aquifer users, a representative of the COSM and CONB, an environmental representative (including TPWD), a representative of industrial aquifer users, and downstream interests provides advice to SAWS regarding the implementation of the program. **Table 3.5-1** lists the members of the SAWS ASR Regional Advisory Group for 2018.

Table 3.5-1. Members of the SAWS Aquifer Storage and Recovery Regional Advisory Group in 2018

Entity	Appointee	Alternate
SAWS	Darren Thompson	Patrick Shriver/Roger Placencia
SAWS	Matthew Diggs	Patrick Shriver/Roger Placencia
SAWS	Karen Guz	Patrick Shriver/Roger Placencia
SAWS	Roger Placencia	Patrick Shriver
EAA	Roland Ruiz	Marc Friberg
Irrigator	Rader Gilliland	Adam Yablonski
Small Municipal	Bruce Alexander	No alternate named
Springs Communities	Roger Biggers	Trino Pedraza
Environmental Interest	Cindy Loeffler	No alternate named
Industry	Buck Benson	Louisa Eclarinal
Downstream Interest	Tommy Hill	Charlie Hickman
EAHCP Program Manager	Scott Storment	No alternate named

The second group is a Staff Work Group. SAWS is responsible for organizing and facilitating the Staff Work Group between staffs of SAWS and the EAA. Per the requirement on pages 44 and 45 of the ILC, an eight-person Staff Work Group consisting of four members of SAWS' staff and four members of the EAA's staff. The members are to have experience in evaluating drought conditions, factors affecting Aquifer levels and springflows at Comal Springs, meteorology, Aquifer and springflow modeling, or related expertise, and provides advice to each agency regarding their respective duties and obligations under the ILC for the implementation of the program.

In 2018, both groups met in compliance with the EAHCP and the ILC. The SAWS ASR Regional Advisory Group met on January 19, 2018.

3.5.1.2 Status of EAA Lease Acquisition

The EAA will acquire a total of 16,667 ac-ft of Edwards Aquifer permitted water through leases and maintain such leases on an annual basis for use in the SAWS ASR Program. During 2018, the EAA acquired and maintained lease rights to 39,893.924 ac-ft of EAA Groundwater Withdrawal Rights.

3.5.1.3 Status of EAA Notices of Availability to SAWS

Of the total 39,893.924 ac-ft under lease by the EAA in 2018, EAA transferred to SAWS 16,667 ac-ft in 2018 (**Table 3.5-2**). The EAA issued one NOA to SAWS in the amount of 16,667 ac-ft on March 9, 2018.

Table 3.5-2. SAWS Aquifer Storage and Recovery Notices of Availability in 2018

NOA #	Date Effective (through December 31, 2018)	Total Ac-ft Acquired	Total Ac-ft Authorized
2018 NOA #1	03/9/18	39,893.924	16,667

3.5.1.4 Injection and Storage of EAHCP Groundwater by SAWS in 2018

In 2018, SAWS recharged through injection and stored 16,667 ac-ft of EAHCP Groundwater into the SAWS ASR Project. Through 2018, SAWS has recharged through injection and has in storage a total of 99,375 ac-ft of EAHCP Groundwater as shown in **Figure 3.5-1**. Beneficial rainfall in 2018 enabled

injection and storage of EAHCP Groundwater throughout the year. The balance remaining for injection and storage to meet the storage goal of 126,000 ac-ft of EAHCP Groundwater is 26,625 ac-ft. It is anticipated this completion of storage of this remaining amount will be in 2021.

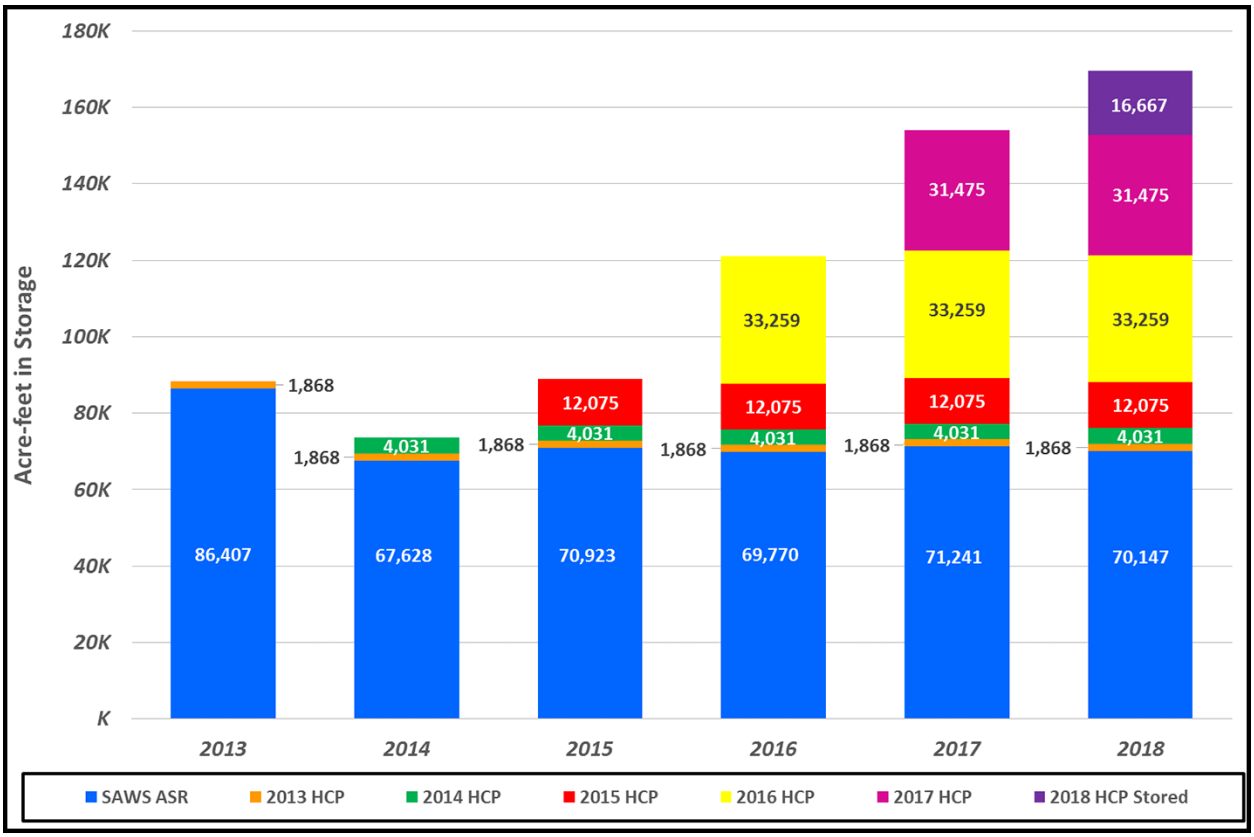

Figure 3.5-1. Total SAWS and EAHCP water stored at the SAWS ASR (2013 – 2018).

3.5.1.5 Recovery of EAHCP Groundwater by SAWS and SAWS Forbearance in 2018

The applicable drought triggers authorizing recovery by SAWS from the SAWS ASR Project and requiring forbearance by SAWS were not met in 2018. Those triggers are: (1) for Well J-17 – less than 630 ft mls, and (2) for the Ten-Year Average Annual Aquifer Recharge – equal to or less than 500,000 ac-ft. Therefore, SAWS did not recover any EAHCP Groundwater from the SAWS ASR Project in 2018, nor was it required to forbear making withdrawals under its EAA Groundwater Withdrawal Permit during 2018 under this program.

3.5.1.6 Status of EAA Forbearance Agreement Acquisition

As amended in February 2018, the EAA will acquire a total of 33,333 ac-ft of forbearance agreements for springflow protection related to EAA Groundwater Withdrawal Permits and maintain such agreements on an annual basis. In 2018, the EAA acquired and maintained forbearance agreements in the amount of 18,672.662 ac-ft of EAA Groundwater Withdrawal Rights to be effective in 2019.

3.5.1.7 Groundwater Rights Pooling Program for Aquifer Storage and Recovery

By a "master agreement," the EAA has created a program whereby EAA permit holders may contribute any "unpumped amount" under their permits into a "pool" administered by the EAA for the purpose of transfer to SAWS so that SAWS may recharge through injection such water into the SAWS ASR for the purpose of springflow protection under Section 5.5.1 of the EAHCP. This "pooling" program is complementary to the formal EAA ASR leasing/forbearance agreement program. No groundwater withdrawal rights were made available to SAWS under this program in 2018.

Proposed Activities for 2019:

In 2019, SAWS and the EAA will continue to manage this Conservation Measure as described in the EAHCP and consistent with the terms of the ILC. The EAA will devote resources to continue marketing the ASR Program to EAA permit holders and enroll additional groundwater withdrawal rights into the program through forbearance agreements. Water rights enrolled as forbearance agreements will remain unpumped when the ten-year rolling recharge average of the Edwards Aquifer is at or below 500,000 ac-ft. Newly-enrolled forbearance agreements will replace expiring leases beginning in 2019 that were previously used as water for injection and storage into the SAWS ASR.

3.5.2 Challenges Observed and Identified Solutions

Relative to SAWS' operation and maintenance of the SAWS ASR to accomplish the purposes of Section 5.5.1 of the EAHCP and the ILC, there were no unauthorized or unexpected activities at the SAWS H_2Oaks Facility in 2018.

As discussed in **subsection 3.5.1.2** of this chapter, the EAA has faced Edwards water market headwinds in acquiring the 50,000 ac-ft of leases and lease options (and now forbearance agreements) in support of the SAWS ASR Program. In 2018, the EAHCP completed an AMP Proposal initiated by the EAA to resolve some of the program's structural issues with regard to the "tiering" of such leases/lease options and creating market products that will be better received.

3.6 Texas Parks & Wildlife Department

The TPWD serves as the state agency with primary responsibility for conserving, protecting and enhancing the state's fish and wildlife resources. In this role, TPWD has the authority to establish a state "scientific area" (SSA) for the purposes of education, scientific research, and preservation of flora and fauna of scientific or educational value (Texas Parks & Wildlife Code §81.501). To minimize the impacts of recreation, TPWD has designated a 2-mile segment of the public waters of the San Marcos River as a SSA in the San Marcos Springs ecosystem (31 TAC §57.910).

To protect existing and restored fountain darter habitat, TPWD, in coordination with the CONB, may pursue creation of a SSA in the Comal Springs ecosystem. The goal of these regulations is to minimize impacts to habitat from recreation activities.

3.6.1 State Scientific Areas (EAHCP §5.6.1)

EAHCP Obligations:

The TPWD will pursue the establishment of a SSA in the San Marcos Springs ecosystem for expanded protection of Texas wild-rice within a 2-mile segment. TPWD will pursue an ILC with the COSM and Texas State regarding enforcement of the SSA.

To protect extensive aquatic and riparian restoration, TPWD, in coordination with the CONB, will also pursue a SSA within the Comal River system. Once a SSA is established, TPWD will pursue an ILC with the CONB regarding enforcement of the area.

2018 Compliance Actions:

The EAHCP requires that TPWD pursue creation of SSAs in the San Marcos and Comal rivers. To preserve Texas wild-rice during low flows and to minimize the impacts of recreation, TPWD designated and maintains a 2-mile segment of the public waters of the San Marcos River as a SSA in the San Marcos Springs ecosystem (31 TAC §57.910). This SSA is designed to protect Texas wild-rice by restricting recreation in these areas during flow conditions below 120 cfs. The rule makes it unlawful for any person to: (1) move, deface, alter, or destroy any sign, buoy, boom, or other such marking delineating the boundaries of the area; (2) uproot Texas wild-rice within the area; and (3) enter an area that is marked. The regulations are intended to preserve at least 1,000 m^2 of Texas wild-rice (**Appendix M**).

In cooperation with the COSM and Texas State, signs and information kiosks were designed, produced, and installed during the summer of 2013. The purpose of the signs and information kiosks is to educate the public about protecting the San Marcos River and its endangered biota, especially during prime recreational season. In 2016, the COSM produced new signs, in cooperation with TPWD.

When the flows within the San Marcos River SSA are 120 cfs or less, physical barriers may be placed within the SSA to help recreational users avoid vulnerable stands of Texas wild-rice while enjoying the river and to protect areas where habitat has been restored. During late August through early September 2018 streamflow hovered around 120 cfs with periods below 120 cfs, triggering the placement of exclusion zones to protect Texas wild-rice. Fortunately, streamflows recovered and exceeded 120 cfs by September 4, 2018.

Proposed Activities for 2019:

In 2019, TPWD will work to expand its public education efforts to include signage in Spanish. In addition, TPWD may pursue an ILC with the COSM and Texas State regarding enforcement of the SSA. As had also been planned for 2016 and 2017, TPWD will also initiate discussion with CONB regarding creation of a SSA for the Comal River.

3.6.2 Challenges Observed and Identified Solutions

Efforts to expand education outreach by translating SSA signage into Spanish were initiated but not completed due to staff resource limitations. As in 2016 and 2017, a formal ILC between TPWD, the COSM, and Texas State regarding enforcement of the SSA was not completed in 2018 either, but the three entities communicated as needed.

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4.0 ADAPTIVE MANAGEMENT ACTIVITIES FOR 2018

4.1 Adaptive Management Process Decisions for 2018

Article 7 of the FMA outlines the procedural steps and responsibilities of the Permittees for making AMP decisions. It also identifies three different AMP decisions the Permittees may make – Routine, Nonroutine, and SAMP decisions.

Routine decisions are decisions involving ongoing, day-to-day matters related to the management and administration of existing Conservation Measures and Phase II Conservation Measures implemented through the SAMP that do not require an amendment to the ITP. Nonroutine AMP decisions are decisions related to existing Conservation Measures, which are not Routine AMP decisions. SAMP decisions are decisions that relate to the selection of Phase II Conservation Measures that are to be implemented by the Permittees in Phase II.

The Year 2018 marked the first year of SAMP decisions as the program transitions from Phase I (2013 – 2020) into Phase II (2020 – 2028). SAMP decisions in 2018 revolved around four sources: lessons learned from implementation of Phase I Conservation Measures, MODFLOW DOR simulations, recommendations from the NAS *Report 3* and the Phase II Work Group. The Permittees continued to implement monitoring, research and modeling activities to provide information that help inform SAMP decisions. These activities are summarized in **Chapter 3.0** – PLAN IMPLEMENTATION IN 2018, **Section 3.1** – Edwards Aquifer Authority, of this Annual Report.

4.1.1 Routine Decisions

There were no Routine AMP Decisions made in 2018.

4.1.2 Nonroutine Decisions

In 2018, the Permittees conducted an analysis of the SAWS ASR for Springflow Protection leasing structure. In this analysis, Nonroutine AMP Proposals were brought forward and ultimately reviewed by the EAHCP Committee members.

The Nonroutine AMP Decisions included one modification to the EAHCP:

1) SAWS ASR for Springflow Protection leasing structure
   The EAHCP includes a springflow protection program that utilizes the SAWS ASR Facility for storage and recovery of leased Edwards Aquifer water. A proposal to replace the three-tiered lease option with a simplified two-tiered leasing agreement structure and to revise the 10-Year Rolling Average of Estimated Recharge threshold to 500,000 ac-ft was presented and approved by the IC, SH, and SC.

4.1.3 Strategic Adaptive Management Process Decisions

There were no SAMP Decisions made in 2018.

4.2 Strategic Adaptive Management Process

As previously discussed, the EAHCP SAMP represents the transition between Phase I and Phase II of the EAHCP, and SAMP are encapsulated by the selection of Phase II Conservation Measures. Activities that occurred during the SAMP in 2018 centered around four aspects of the program: evaluation of the Phase I Conservation Measures, recent groundwater modeling simulations, the NAS *Report 3* and the Phase II Work Group recommendations.

In May and August 2018, the Program Manager presented the EAHCP SAMP Whitepaper to the IC, SH and SC (**Appendix I1**), which provided a comprehensive framework for the SAMP and included four potential outcomes that guide the direction of the Phase II Conservation Measures:

1) Continuation of Phase I Conservation Measures without changes;
2) Continuation of Phase I Conservation Measures with changes or expansion;
3) Continuation of Phase I Conservation Measures, plus new Phase II Conservation Measures;
4) Continuation of Phase I Conservation Measures with changes, plus a new Phase II Conservation Measure.

In October 2018, the NAS produced their NAS *Report 3* that reviewed the effectiveness of the Phase I Conservation Measures meeting the Biological Objectives and the likelihood of the Biological Objectives meeting the LTBGs. The NAS *Report 3* determined the following: 1) Phase I Conservation Measures and activities are achieving the Biological Goals; and 2) the NAS/SRP was unable to reach a determination on the effectiveness of the Conservation Measures relating to the CSRB.

At the October 18, 2018 EAHCP Joint IC and SH meeting, a Phase II Work Group was created to review and discuss a draft of the Comprehensive Phase II Work Plan. The charge of the Phase II Work Group consisted of the following tasks (**Appendix I3**):

- To review the draft Comprehensive Phase II Work Plan;
- To participate in coordination conference calls and attend Work Group meetings;
- To provide comments and recommendations on the draft Comprehensive Phase II Work Plan to the EAHCP Program Manager;
- To review and approve the Phase II Work Group Report.

On November 29, 2018, a meeting of the Phase II Work Group was held to review and discuss the draft Comprehensive Phase II Work Plan. A second Comprehensive Phase II Work Group meeting was held on December 5, 2018, as a continuation of the draft Phase II Work Plan review and to address the comments and recommendations made during the initial Work Group meeting.

The members of the Phase II Work Group agreed that the development of the Comprehensive Phase II Work Plan will consist of the second option listed within the SAMP Whitepaper: continuation of Phase I Conservation Measures with changes or expansion.

Additionally, EAHCP staff presented a summary of the draft MODFLOW simulation results to the Phase II Work Group. Results of the draft MODFLOW DOR simulations – with EAHCP activities "as implemented" and VISPO forbearance – demonstrated 29.6 cfs springflow at the Comal Springs, which is short of the 30.0 cfs target. However, the final MODFLOW DOR simulations and conclusions are to be completed and presented in Spring 2019.

One item important to note, as described in NAS *Report 3*, the NAS/SRP arrived at an 'effective' ranking for the ability of the springflow protection measures to meet the springflow objectives. This evaluation was provided given the examination of aquifer and springflow response during the 2013-2014 drought, the conservative nature of the MODFLOW model and the review of the MODFLOW DOR, calibration, and validation. Final MODFLOW results will be presented to the IC, SH, and SC in Spring 2019.

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5.0 2018 ANNUAL TAKE ESTIMATES

The EAHCP ITP requires a Net Disturbance and Incidental Take assessment to be conducted at the conclusion of each year for incorporation into the ITP Annual Report. Condition M (1a and 2a) of the ITP specifically addresses minimization and mitigation activities associated with the EAHCP. This requirement stipulates that over the course of any given year no more than 10 percent of a Covered Species occupied habitat can be affected by EAHCP Conservation Measure activities. Following quantification of net disturbance specific to these activities, incidental take was calculated for the disturbed areas. However, that is only part of the overall incidental take assessment. Incidental take associated with implementation of all other applicable EAHCP Covered Activities was then characterized and quantified to the degree practical. For a more detailed description of methodologies and species-specific results please refer to the "Item M Net Disturbance and Incidental Take Assessments for 2018 EAHCP ITP Annual Report" technical memorandum dated December 26, 2018, located in **Appendix N**. As in previous years, all 2018 assessments were performed in accordance with ITP requirements.

Table 5.0-1 provides an overview of net disturbance percentages and a summary of incidental take for 2018. As shown in **Table 5.0-1**, only the fountain darter in the Comal system had a net disturbance when considering the project footprint for EAHCP Conservation Measure activities overlaid on occupied habitat. The net disturbance was approximately 2 percent of the total occupied habitat for the fountain darter in the Comal system. In the San Marcos system, only the fountain darter and San Marcos salamander had net disturbances calculated at approximately 5 percent and less than 1 percent, respectively, of their total occupied habitat. In summary, the net disturbance in 2018 was under the 10 percent disturbance rule as outlined in ITP Condition M[a].

Table 5.0-1 also shows the calculated incidental take on the Comal system with respect to the EAHCP Covered Species. The calculated value for the fountain darter in the Comal system was slightly higher in 2018 than observed during 2017. The primary cause for the increase for the fountain darter in the Comal system was lower discharge conditions in 2018, which resulted in larger spring to fall aquatic vegetation (habitat) reductions primarily in the Upper Spring Run section. In 2018, all invertebrate restoration activities occurred on shore resulting in no calculated incidental for the listed Comal invertebrates. For the San Marcos system, incidental take for the fountain darter also went up slightly in 2018 compared to 2017. The slight increase in the San Marcos system was due to a larger footprint for EAHCP mitigation primarily native aquatic vegetation restoration in 2018 relative to 2017. The Texas wild-rice exclusion zone implemented for 21 days in the summer below Spring Lake Dam resulted in the minor amount of incidental take being calculated for the San Marcos salamander.

When examining 2018 results, conditions are in line with those characterized in the Biological Opinion as an average year. As such, the incidental take numbers summarized in **Table 5.0-1** and documented in **Appendix N** continue to justify the data sets used and methodologies employed in 2018 relative to performing an incidental take assessment within the context of the Biological Opinion. It is understood that adjustments to data sets and/or methodologies may be employed based on feedback from the USFWS, SC, EAHCP participants, or others as deemed appropriate by the EAHCP.

Table 5.0-1. Summary of Impacted Habitat and Net Disturbance and Incidental Take for EAHCP Covered Species Compared Against ITP Maximum Permit Amounts

Covered Species Per System	EAHCP Mitigation/Restoration		EAHCP Measures/ Drought	Combined Impacted Habitat 2018 TOTAL (m^2)	Incidental Take		2018 Incidental Take Total	ITP Maximum Permit Amount	ITP Permit Maximum Minus (Combined First Six Years)
	Impacted Habitat (m^2)	Net Disturbance % Of Total Occupied Habitat	Impacted Habitat (m^2)		EAHCP Mitigation/ Restoration	EAHCP Measures/ Drought			
COMAL SYSTEM									
Fountain Darter	1,599	1.5%	3,356	**4,955**	2,399	5,034	**7,432**	797,000	736,334
Comal Springs Riffle Beetle	0	0%	0	**0**	0	0	**0**	11,179	8,887
Comal Springs Dryopid Beetle	0	0%	0	**0**	0	0	**0**	1,543	1,527
Peck's Cave Amphipod	0	0%	0	**0**	0	0	**0**	18,224	18,057
SAN MARCOS SYSTEM									
Fountain Darter	4,763	5%	3,188	**7,951**	7,145	4,783	**11,927**	549,129	474,024
San Marcos Salamander	15	< 1%	0	**15**	45	0	**45**	263,857	261,183
Texas Blind Salamander	0	0%	0	**0**	0	0	**0**	10	10
Comal Springs Riffle Beetle	0	0%	0	**0**	0	0	**0**	N/A	N/A
Comal Springs Dryopid Beetle	0	0%	0	**0**	0	0	**0**	N/A	N/A

Table 5.0-2 provides an estimate of the accumulated take totals so far in the implementation of the EAHCP. Reduced springflow in both the Comal and San Marcos springs systems resulted in an increased take of the Covered Species in 2018. In the Comal system in 2018, incidental take for fountain darters (7,432) was almost double that in 2017 (4,620). In the San Marcos system in 2018, incidental take for fountain darters (11,927) was about 1,688 more than that in 2017 (10,239). Overall, the incidental take that has occurred since the implementation of the EAHCP is within a proportional level to assume compliance for the remainder of the ITP.

Table 5.0-2. Incidental Take Summary (2013-2018)

Spring System	Species (Common Name)	ITP Take Limit	2013 Take	2014 Take	2015 Take	2016 Take	2017 Take	2018 Take	TOTAL Take	Remaining ITP Take*
Comal	Fountain Darter	797,000	10,482	23,060	5,115	9,959	4,620	7,432	**60,668**	736,334
	Comal Springs Riffle Beetle	11,179	681	1,564	0	0	46	0	**2,291**	8,887
	Comal Springs Dryopid Beetle	1,543	13	2	0	0	1	0	**16**	1,527
	Peck's Cave Amphipod	18,224	81	82	0	0	3	0	**166**	18,057
San Marcos	Fountain Darter	549,129	16,698	11,909	13,295	11,023	10,239	11,927	**75,091**	474,024
	San Marcos Salamander	263,857	1,053	482	1,059	0	36	45	**2,675**	261,183
	Texas Blind Salamander	10	0	0	0	0	0	0	**0**	10
	Comal Springs Riffle Beetle	N/A	0	0	0	0	0	0	**0**	N/A
	Comal Springs Dryopid Beetle	N/A	0	0	0	0	0	0	**0**	N/A

* The accumulation of annual totals from previous take report numbers show a difference by one or two individuals. Calculation discrepancies are due to rounding to the whole number. The discrepancy found in the San Marcos fountain darters occurs due to a change that happened after the 2013 ITP was created. In early 2014, the San Marcos fountain darter numbers were recalculated to account for Texas wild-rice, increasing the 2013 take by 14 fountain darters.

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6.0 RECOMMENDATIONS FOR MOVING FORWARD

The Permittees are now in their seventh year of implementing the EAHCP. With the benefit of experience—including during wide-ranging weather conditions—and time, the Permittees continue to gain perspective and practical insights into implementation of the EAHCP. The Permittees recommend the following as priorities for 2019 based upon this knowledge and experience.

6.1 Edwards Aquifer Authority

Refugia (EAHCP §5.1.1)

Per the terms of the contract approved in November 2016, the USFWS will preserve the capacity for the Covered Species to be re-established at the Comal and San Marcos rivers if extirpation in the wild were to occur. This effort will be achieved through duplicated off-site refugia populations of the Covered Species. The primary off-site refugia is located at the SMARC with the second being located at the UNFH.

The USFWS completed construction of EAA physical infrastructure used to house the Covered Species at SMARC in 2018. They also continue to collect species for their standing-stock population. Construction at UNFH will continue into 2019 while salvage refugia populations are already intact at both facilities.

Strategic Adaptive Management Process

As discussed in **Chapter 4.0** – ADAPTIVE MANAGEMENT ACTIVITIES FOR 2018, SAMP program activities will focus on completion of the MODFLOW modeling, addressing NAS *Report 3* recommendations, and approval of the Comprehensive Phase II Work Plan. Under the direction of the EAHCP Program Manager (FMA §7.13.7), a resolution to address the EAHCP program activities as they relate to the NAS/SRP's determinations provided in the NAS *Report 3* will be presented to the IC in spring 2019.

6.2 City of New Braunfels

Habitat Protection and Restoration (EAHCP §§5.2.2, 5.2.5, and 5.2.8)

In 2019, the CONB will continue efforts to maintain and enhance endangered species habitat in the Comal River system. The CONB will continue existing programs to increase native aquatic vegetation coverage and remove non-native animal species. The CONB will also continue their riparian restoration program along the banks of the Old Channel of the Comal River, Landa Lake and Spring Run 3. Non-native plant species will continue to be systematically removed along the banks of the Old Channel downstream of Elizabeth Street through the Old Channel LTBG Reach and along the banks of Landa Lake. Native plants will be planted along the Old Channel in areas where non-native plants were removed.

In order to continue efforts to protect CSRB habitat within Spring Run 3, supplemental riparian vegetation will be planted within riparian buffer areas established in 2018 along the southeast bank of the spring run.

Water Quality Protection (EAHCP §5.7.6)

Habitat protection efforts in 2019 will also include the design and construction of stormwater treatment infrastructure identified in the CONB's WQPP. The CONB will move forward with construction of a bioretention basin at the end of North Houston Avenue that will help to infiltrate and filter urban stormwater runoff prior to entering the Upper Spring Run area of Landa Lake. The CONB will also perform engineering design for an underground stormwater treatment vault, to be installed in 2019, that will filter stormwater runoff from Fredericksburg Road and adjacent streets prior to discharging to Spring Run #1 and the Comal River system. Both water quality protection projects are expected to remove stormwater-related contaminants prior to reaching the Comal River system.

6.3 City of San Marcos/Texas State University

Water Quality Protection (EAHCP §§5.7.4 and 5.7.6)

The intent of the COSM's WQPP is to provide a holistic, integrated approach in regard to water quality concerns associated with impervious cover and urban development. The WQPP has mapped and prioritized sources of pollution in the San Marcos River watershed within city limits and developed conceptual solutions in partnership with the Upper San Marcos River Watershed Protection Plan. In 2018, the COSM/Texas State will complete construction of the Downtown Pond to minimize the impacts from stormwater runoff. Also, in 2019, the COSM/Texas State will complete designs and start construction of several stormwater control structures along the middle reach of Sessom Creek. This work is to capture and treat stormwater runoff from a heavily developed watershed.

Riparian Restoration (EAHCP §5.7.1)

The riparian buffer of the San Marcos River has undergone non-native invasive plant removal, followed by plantings of native trees, shrubs and vines from the headwaters to IH-35. This buffer has also been expanded wherever possible to increase infiltration and treatment of stormwater runoff. Work done over the past seven years has improved the water quality buffer from the headwaters to IH-35. In 2019, the COSM/Texas State will focus on maintenance of previously restored areas to reduce the re-colonization of non-native plants.

7.0 LITERATURE REVIEW

The following list of articles and reports represent a review of literature related to the protected species, aquatic features, and management actions associated with the EAHCP and the EARIP. This review includes journal articles, study reports, and theses and dissertations published or approved from December 1, 2017 to November 30, 2018 and any additional literature from 2017 found to have been undocumented in last year's report. The literature search was accomplished by conducting online searches of academic databases (such as EBSCO and JSTOR), Google Scholar, Texas State Dissertations and Theses, and the EAA document library.

7.1 Literature from 2017

Bollwahn, B. J. 2017. Changing the way we look at water: A soft path approach to groundwater management in San Antonio, Texas. Thesis, Texas State University, San Marcos, Texas, USA.

This thesis discussed potential alternatives to groundwater management strategy with the potential to greatly reduce or eliminate San *Antonio's projected water deficit for the future. The study discussed the roadblocks and potential successes that might occur to implement a soft path approach to groundwater management in San Antonio.*

Hamilton, J. M., and J. Boenig. 2017. Re-conceptualizing the Edwards Aquifer Authority recharge program: Staff recommendations to optimize and protect the Edwards Aquifer. EAA Staff Report, San Antonio, Texas, USA.

This report outlined staff recommendations on optimizing the EAA Recharge Program. There were specific recommendations under the categories of: Water Quantity Enhancement, Water Quality Protection, and Regional Collaboration. One of the bullet points under regional collaboration was "continue to support and demonstrate the value and benefits of the EAHCP and related management and conservation strategies to achieve targeted water levels and springflows during critical drought scenarios."

Liu, A., N. Troshanov, J. Winterle, A. Zhang, and S. Eason. 2017. Updates to the MODFLOW groundwater model of the San Antonio segment of the Edwards Aquifer. EAA Staff Report, San Antonio, Texas, USA.

This report documented the recent updates and recalibration of the MODFLOW groundwater model of the San Antonio segment of the Edwards Aquifer. The original model was utilized in the analysis to demonstrate the effectiveness of various springflow conservation measures. This particular analysis had been used in the EARIP process, which resulted in the EAHCP. The EAA will repeat the analysis with the revised and updated model to evaluate whether or not there are any new conclusions about the effectiveness of the Conservation Measures of the original analysis.

National Academies of Sciences, Engineering, and Medicine. 2017. Review of the Edwards Aquifer Habitat Conservation Plan: Report 2. Washington, DC: The National Academies Press. https://doi.org/10.17226/23685.

This report is the second of three phases of reports that are evaluating the effectiveness of the EAHCP. This report reviews the progress the EAA has made in implementing the suggestions and recommendations established in the first report. It also reviewed selected research projects and minimization and mitigation measures to ensure the effectiveness of these projects in meeting the goals outlined in the EAHCP. The third report is anticipated to determine whether or not these research projects and minimization and mitigation measures are adequate to meet the goals of the EAHCP.

Oates, R. P., G. Longley, P. Hamlett, and D. Klein. 2017. Pharmaceutical and endocrine disruptor compounds in surface and wastewater in San Marcos, Texas. Water Environment Research: 89-11: 2021-2030. https://doi.org/10.2175/106143017X14902968254584

This article discusses the presence of pharmaceuticals and endocrine disrupting compounds (EDCs) in aquatic environments. The study investigated the removal of theses EDCs in the San Marcos Water resource recovery facility (WRRF) to determine what treatment process was most effective at removal and how effective the overall treatment process was at removing the 23 known or suspected EDCs. The study revealed that the San Marcos WRRF is removing more than 92 percent of these compounds except for two. The preliminary results can be used to guide future improvements in the WRRF.

Pierce, S. A., J. Collins, and J. Banner. 2017. Dynamic data analysis of climate and recharge conditions over time in the Edwards Aquifer, Texas. American Geophysical Union, Fall Meeting 2017.

This article discusses the temporal patterns in the datasets related to climate, recharge, and water resource conditions as tools necessary to inform water management and policy decisions. This article specifically addresses the Edwards Aquifer as it is a karstic aquifer more susceptible to climate change and contaminants, and an increasingly larger population is coming to rely on the aquifer. Additionally, the University of Minnesota Global Surface Water Monitoring System was utilized to show the surface water bodies over the Edwards are declining except for some dam-controlled lakes.

Shannon, W. L. 2017. An ecological case against development: Remote sensing analysis of ecology and vegetation around Spring Lake, Texas, USA. Thesis, Texas State University, San Marcos, Texas, USA.

This thesis studied the ecological health of the terrestrial ecosystem around Spring Lake utilizing remote sensing of the vegetation and then offers a comparative analysis of outcomes for land management practices, namely either wildland versus recreation field. The study concluded that the preferred option for protection of the ecosystem around Spring Lake was in returning the study area to a wildland, which provides more protection for the lake and river, provides more

biodiversity, can be used for future academic ecological studies, and increases the overall ecosystem services which support human health.

Slattery, R. N., and L. D. Miller. 2017. A water-budget analysis of Medina and Diversion lakes and the Medina/Diversion lake system, with estimated recharge to Edwards Aquifer, San Antonio area, Texas (ver. 1.1, February 2017): U.S. Geological Survey Scientific Investigations Report 2004–5209, 41 p., https://doi.org/10.3133/sir20045209.

This USGS Scientific Investigations Report attempted to better quantify the relationship between the stage in water level in Medina and Diversion lakes with the recharge to the Edwards Aquifer. This study computed monthly estimates of recharge for average stage levels, rising-lake stage conditions, and falling-stage conditions and found that this study calculated rates that were between 44 and 60 percent of the rates previously calculated using the Lowry method, suggesting recharge rates from Medina and Diversion lakes may have been overestimated.

7.2 Literature from 2018

Bohannon, A. Z., C. Adcosk, A. R. MacLaren, M. L. Kiehne, and M. R. J. Forstner. 2018. *Eurycea nana* (San Marcos salamander). Herpetological Review Natural History Notes 49: 296-297.

This brief note discussed recent research on the San Marcos salamander. It discusses finding a San Marcos salamander in a floating mat of introduced Water Sprite. It suggests that more research needs to be conducted to see if these salamanders might be found in other non-native, invasive, floating macrophytes that occur within the habitat of the San Marcos salamander to ensure that incidental take does not occur.

Carroll, A. 2018. Consequences of long-term changes in fish community structure on ecosystem function in a subtropical spring-fed river. Thesis, Texas State University, San Marcos, Texas, USA.

This thesis examined the patterns of long-term changes in the composition of the fish community in the spring-influenced upper San Marcos River and the ecosystem implications due to changes in the fish community. It determined that the occurrence of the fish species changed dramatically throughout the 78 years covered by the study. Non-native fish increased considerably from 1959 to 1989. Since 1990-onward there has been a decline in the non-native species that was attributed to some combination of the relocation and upgrade of the San Marcos wastewater treatment plant and the creation of the Edwards Aquifer Authority. This has led to the conclusion that more intense regulation of water usage from the aquifer and habitat protection and restoration efforts starting in the late 1980s may have facilitated declines in non-native species and the recovery of native species.

Cole, S. A., B. Johnson, S. Neises, and D. Christiansen. 2018. Modeling the future: Utilizing SAWS' All-pipes Model to develop a Phased CIP. Proceedings of the Water Environment Federation, Utility Management p.402-206. https://doi.org/10.2175/193864718823773832

This article discusses the ways in which SAWS may meet future water needs in order to decrease the reliance on the Edwards Aquifer. This study conducted hydraulic modeling that evaluated the following elements: timing and magnitude of future water supplies, existing system capacity to meet projected demands in growth areas, infrastructure required to distribute water throughout the system, and usefulness of aging or inadequate facilities. The resulting capital plan and hydraulic model will serve as a baseline for future water system infrastructure needs.

Delices, L. R. 2018. Variation in minimum temperature tolerance of two invasive snails in Central Texas, USA. Thesis, Texas State University, San Marcos, Texas, USA.

This thesis looked at the thermal tolerance of two invasive snails in Central Texas to predict the likely spread of the species in waterways throughout the state. It determined that survival of the snail species varied significantly between the temperature treatments, species, and river of origin.

Earl, R.A., J. Bosarge, H. Wooten, S. Hedgepeth, and J. Sherrouse. 2018. Relationship of flood peaks to 24-hour rainfall in the eastern Texas Hill Country, south-central Texas. The Geographical Bulletin 59:87-102.

This article discusses the research on the relationship between rainfall greater than four inches in 24 hours and peak discharge that results in four streams west of San Marcos, Texas. It was determined that approximately 370 ac-ft of runoff was produced by each 1,000 ft^3/second of peak stream flow. They determined that about fifteen percent of the runoff associated with these flooding events provides recharge to the Edwards Aquifer, while the remaining 85 percent of this runoff remains in streams with flood detention dams.

EAA. 2018. Universal passive samplers and the aliasing problem in groundwater sampling.

This report delineates the experiment the EAA conducted on the viability of passive sampling devices versus grab sampling as a potential improvement for collecting samples for the water quality monitoring program. The findings indicated that universal passive samplers can detect contaminants at lower concentrations than grab samples. Ultimately, the passive samplers only partially overcame the aliasing also present in grab samples by indicating the presence or absences of contaminants in groundwater.

Gates, A. Y., T. M. Guerra, F. B. Morrison, M. J. R. Forstner, T. B. Hardy, and D. Hahn. 2018. Detection of *Salmonella* in the intestine of *Hypostomus plecostomus* from the Upper San Marcos River, Texas. Journal of Water and Health. 16.3: 460-471.

This article discusses the results of sampling for Salmonella *bacteria in the intestines of fish in the San Marcos River and Spring Lake over time. It determined that there is a high prevalence of*

different serotypes of Salmonella *in intestine samples of the suckermouth catfish across different sampling events during 2014. The prevalence of* Salmonella *and the diversity of serotypes was ruled to be independent of precipitation events and runoff, which indicated that there are strains of environmental Salmonella able to persist in the long term in the environment.*

Iwanowicz, L. R., D. D. Iwanowicz, C. R. Adams, T. D. Lewis, T. M. Brandt, L. R. Sanders, and R. S. Cornman. 2018. Isolation, characterization and molecular identification of a novel aquareovirus that infects the endangered fountain darter *Etheostoma fonticola*.

This article discusses the novel aquareovirus *that was isolated from wild fountain darters inhabiting the San Marcos River. The genome sequencing was completed for this virus. Analysis suggests this virus belongs to the* Aquareovirus A *genus. This research is the initial step in providing data critical to support the hatchery and refugia biosecurity measures for the endangered fountain darter.*

Johnson, S., G. Luevano, and M. Hamilton. 2018. Field and laboratory tests of passive sampling techniques. Report No. 18-01.

This report is a longer version of the EAA report Universal Passive Samplers and the Aliasing Problem in Groundwater Sampling *that delineates the experiment the EAA conducted on the viability of passive sampling devices versus grab sampling as a potential improvement for collecting samples for the water quality monitoring program. The findings indicated that universal passive samplers can detect contaminants at lower concentrations than grab samples. Ultimately, the passive samplers only partially overcame the aliasing also present in grab samples by indicating the presence or absences of contaminants in groundwater. This report also detailed the sampling program under the EAA jurisdiction that is prescribed in the EAHCP.*

Kloesel, K., B. Bartush, J. Banner, D. Brown, J. Lemory, X. Lin, G. McManus, E. Mullens, J. Nielsen-Gammon, M. Shafer, C. Sorenson, S. Sperry, D. Wildcat, and J. Ziolkowska, 2018: Southern Great Plains. In Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D. R., C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, pp. 987–1035. doi: 10.7930/NCA4.2018.CH23

The overall assessment for Chapter 23 discusses the Southern Great Plains and its experiences with extreme weather events, climate change, and changes to human infrastructures that could help lessen the impacts of climate change. Within Chapter 23 there is a case study on the Edwards Aquifer that examines the susceptibility of the aquifer to extreme weather events such as drought and the pressures from increasing population over the aquifer leading to an increase in consumption of the water within the aquifer. It also lauds the efforts of the EARIP HCP and its innovative solutions to attempting to balance human consumption with the requisite water needs of the endangered species that live in the aquifer.

Marvin, G. A., and P. V. Crupp Jr. 2018. Chemical detection of intraguild predators (*Gyrinophilus*, *Pseudotriton*) by streamside plethodontid salamanders (*Eurycea*). Southeastern Naturalist 17-1: 166-175.

This article discusses the examination of whether Eurycea *salamanders will change their microhabitat selection based on chemical cues from intraguild predators. It determined that the* Eurycea *salamanders in this study avoided the habitat with the potential predatory salamander species and determined that individuals of different* Eurycea *species and populations distinguish the odors of salamander species that are potential predators.*

Mendyk, R. W., M. Litton, and C. Windsor. 2018. *Eurycea rathbuni* (Texas blind salamander). Herpetological Review Herpetoculture Notes 49: 485-486.

This brief note discussed oophagy and cannibalism of larvae in captive bred Texas blind salamanders. It suggests that this could occur in the natural habitat for Texas blind salamander, and that this has implications for successfully captive breeding programs in the future for this species as programs attempt to prevent their decline.

National Academies of Sciences, Engineering, and Medicine. 2018. Review of the Edwards Aquifer Habitat Conservation Plan: Report 3. Washington, DC: The National Academies Press. doi: https://doi.org/10.17226/25200.

This report is the final of three phases of reports that are evaluating the effectiveness of the EAHCP. This report evaluates the likelihood of whether the EAHCP and mitigation and minimization measures will meet the biological objectives. The committee also made recommendations on potential alterations or modifications to the biological goals and objectives to ensure the continued protection of the listed species, and not just the accomplishment of the biological goals as outlined in the EAHCP.

Nissen, B. D, T. J. Devitt, N. F. Bendik, A. G. Gluesenkamp, and R. Gibson. 2018. New occurrence records for stygobiontic invertebrates from the Edwards and Trinity aquifers in west-central Texas, USA. Subterranean Biology 28: 1–13. https:// doi.org/10.3897/subtbiol.28.29282

This article discusses the new occurrences for stygobiontic invertebrates located in the Edwards and Trinity aquifers in Blanco, Hays, and Travis counties. The collection includes seven species: Caecidotea reddelli*,* Crangonyx *nr.* pseudogracilis*,* Stygobromus balconis*,* Stygobromus bifurcates*,* Stygobromus russelli*,* Sphalloplana mohri*,* Caecidotea reddelli*, and* Crangonyx *nr.* pseudogracilis*.*

Norman, D. E. 2018. Groundwater management zones for conjunctive water conservation in Hays County and the Hill Country Region of central Texas. Thesis, the University of Texas, Austin, Texas, USA.

This thesis discussed Groundwater Management Zones in Texas, specifically studying the Barton Springs Edwards Aquifer Conservation District and Hill Country Underground Water Conservation District. It discusses the overall management of Groundwater Management Area (GMA) 9 and the challenges GMA 9 will face with the interconnectivity between the Trinity and Edwards aquifers in the EAA district and varied regulation of the Trinity Aquifer.

Opsahl, S. P., M. Musgrove, B. J. Mahler, and R. B. Lambert. 2018. Water-quality observations of the San Antonio segment of the Edwards Aquifer, Texas, with an emphasis on processes influencing nutrient and pesticide geochemistry and factors affecting aquifer vulnerability, 2010–16: U.S. Geological Survey Scientific Investigations Report 2018–5060, 67 p., https://doi.org/10.3133/sir20185060.

This report studied how water quality changes under a range of hydrologic conditions and contrasting land-cover settings (rural and urban) in the Edwards Aquifer. Overall it was determined that the Edwards Aquifer is vulnerable to contamination, and that there is greater vulnerability in urban areas relative to rural areas. Additionally, there was more vulnerability to contamination in the shallow and unconfined groundwater sites relative to the deeper, confined groundwater sites.

Romero, F. S. 2018. San Antonio's Edwards Aquifer Protection Program: review and analysis. Texas Water Journal 9-1: 1-15. https://journals.tdl.org/twj/index.php/twj/article/view/7063

This article reviewed the City of San Antonio's Edwards Aquifer Protection Program (EAPP) that utilizes land and conservation easement acquisitions to protect water quality and quantity for Edwards Aquifer recharge. The review focused on four components of viability for the program. The analysis in this review concluded that the program has been successful in protecting the recharge and contributing zones for the City of San Antonio. Additionally, it suggests that the EAPP model could be utilized by other cities in Texas.

Schindel, G. M. 2018. Recommended strategies for the response to hazardous materials releases in karst. *In*: W. White, J. Herman, E. Herman, and M. Rutigliano (eds.) Karst groundwater contamination and public health. advances in karst science. Springer, Cham. https://doi.org/10.1007/978-3-319-51070-5_30

This article first discusses the inherent vulnerabilities for karstic aquifers to contamination. The results of the paper are intended to identify potential strategies to implement to properly contain and mitigate for the potential impacts from the release of hazardous materials in karst terrains.

Smith, B. A., B. B. Hunt, D. A. Wierman, and M. O. Gary. 2018. Groundwater flow systems in multiple karst aquifers of Central Texas. NCKRI Symposium 7. 15th Sinkhole Conference.

https://bseacd.org/uploads/Smith-et-al.-2018-GW-Flow-Systems-in-Multiple-Karst-Aquifers-Sinkhole-Conference.pdf

This article discusses the Middle Trinity Aquifer specifically as it relates to the transition from the Hill Country portion of the Middle Trinity Aquifer into the Balcones Fault Zone portion of the Middle Trinity Aquifer and the inherit similarities and differences of these aquifers. It also discusses potential hydrogeologic connections between the Edwards Aquifer, Upper Trinity Aquifer, and Middle Trinity Aquifer.

Thomas, E. D. 2018. Hyrologic trends in the Upper Nueces River Basin of Texas – Implications for water resource management and ecological health. Thesis. 2018. Tarleton State University, Stephenville, Texas, USA.

This thesis discussed the Nueces River Basin, an ecologically significant watershed that recharges the Edwards Aquifer. The study analyzed the hydroclimatic trends of the Nueces River Basin from 1970 to 2014 and the impact on the ecologically significant stream segments. The study demonstrated statistically significant decreasing trends for certain low-flow indicators in the streamflow gauges over various timeframes, which is presumably due to water rights owners and minimal land use changes. The declining flows would be problematic in the region due to the increase in demand.

Uddameri, V., S. Singaraju, and E. A. Hernandez. 2018. Is standardized precipitation index a useful indicator to forecast groundwater droughts? — Insights from a karst aquifer. Journal of the American Water Resources Association 1–19. https://doi.org/10.1111/1752-1688.12698.

This article tried to answer the question on what the relationships are between meteorological and groundwater droughts on the water levels and spring discharges in the Edwards Aquifer. The results were that spring flow had a stronger and quicker response to meteorological droughts than changes in storage. It also recommended that in aquifers with spring discharges, such as the Edwards, groundwater monitoring programs must make the effort to inventory and monitor the spring discharges.

Udita, T. S. 2018. Land use/land cover change detection and analysis of the Upper Guadalupe River, Central Texas. Thesis, Texas State University, San Marcos, Texas, USA.

This thesis examined the land use/land cover changes of the Upper Guadalupe River Basin from 1987 to 2017. Results showed a clear decline through time in the water bodies and riparian vegetation due to rapid urbanization and expansion of agricultural lands. Overall, water and urbanization demonstrated gradual changes, while vegetation and agriculture demonstrated very rapid changes. The thesis postulated that improved management relative to land use/land cover changes may reduce the impacts on the riparian corridors and water resources.

United States Department of the Interior, Fish and Wildlife Service. 2018. Biological Opinion for the Proposed Repairs to the Spring Lake Dam. Austin, Texas, USA.

This is the Biological Opinion from the USFWS on how to mitigate for endangered species protection on the proposed repairs to the Spring Lake Dam. The work is being conducted by Texas State and funded in part by the Federal Emergency Management Agency (FEMA). The U.S. Army Corps of Engineers also must authorize the activity under Section 404 of the Clean Water Act. This Biological Opinion is the response to the Biological Assessment submitted by FEMA.

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