The National Academies of
SCIENCES · ENGINEERING · MEDICINE

Review of

The Edwards Aquifer Habitat Conservation Plan

Project Summary

Contents

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The plentiful waters of the Edwards Aquifer have played a major role in helping people and ecosystems in the San Antonio region thrive. However, as the population continues to grow, the Edwards Aquifer Authority (EAA) is challenged to meet human water needs while protecting ecosystems and the many services they provide. Working with regional stakeholders, the EAA and four local entities crafted a 15-year Habitat Conservation Plan that charts a course for managing water supplies while maintaining the health of indigenous species. To ensure that the scientific aspects of the plan were as strong as possible, the EAA asked the National Academies of Sciences, Engineering, and Medicine to provide a rigorous 5-year scientific review.

The Edwards Aquifer

The Edwards Aquifer is one of the most prolific artesian aquifers in the world. More than 2.3 million people in the San Antonio region rely on it for drinking water. Because the aquifer is under pressure, its water rises to the surface in several places to form natural springs. Two of the largest springs are the San Marcos Springs and Comal Springs to the northeast of San Antonio, both of which provide recreation on their associated river systems and house several species of fish, amphibians, insects, and plants found nowhere else in the world.

The Edwards Aquifer is underlain by porous, permeable limestone rock known as “karst,” so that large volumes of water can move through its fractures, conduits, and cavities in just days. As a result, the aquifer responds quickly to both rainfall events that recharge the groundwater, and to drought and pumping that reduce the groundwater levels. If groundwater levels drop too low the water pressure can drop enough to stop the springs from flowing.

In the 1950s, central Texas experienced what is now called the “drought of record,” the most severe drought recorded in the region. During this drought, flows at Comal Springs ceased for four months, and flows at San Marcos Springs were severely reduced. At current water pumping levels in the region, a similar drought today could result in complete cessation of flow at Comal Springs for more than three years, and near cessation of flow at San Marcos Springs.

Rapid declines in spring flow can be catastrophic to the species that live in the Edwards Aquifer and its springs. Eight Edwards Aquifer species are on the federal Endangered Species List because they are vulnerable to reduced spring flows caused by drought and pumping. Those species include the fountain darter, the San Marcos gambusia (presumed extinct), the Texas blind salamander, the San Marcos salamander, the Comal Springs dryopid beetle, the Comal Springs riffle beetle, Peck’s Cave amphipod, and Texas wild rice.

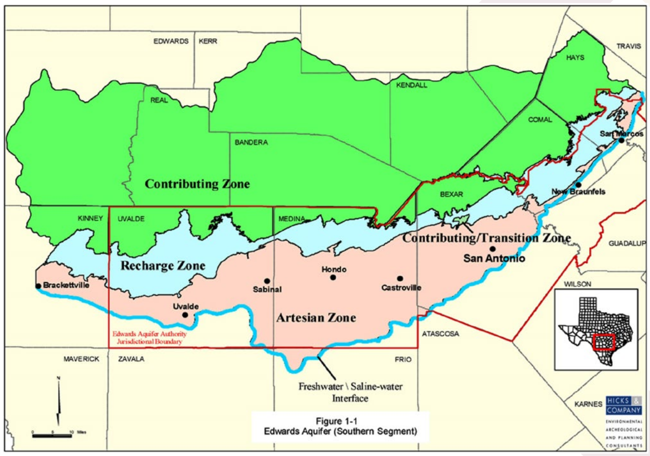


Figure 1-1
Edwards Aquifer (Southern Segment)

Crafting a State-Led Plan

Stakeholders in the Edwards Aquifer region comprise a wide range of water users, including agriculture, industry, utilities, and municipalities, as well as environmental groups, state regulators, academia, recreators, and at-large citizens. While many stakeholders focus mainly on meeting human water needs, others, including environmentalists and downstream towns that rely on the springs for recreation and economic value, are more concerned about disrupting spring flow. In 1993, the Sierra Club brought a lawsuit against the U.S. Fish and Wildlife Service (FWS), alleging that FWS was not protecting the species in the San Marcos springs.

In response to stakeholder concerns, the EAA tried to develop a habitat conservation plan in the late 1990s and early 2000s, but did not succeed in moving it forward. One area of agreement among the regional stakeholders was the desire for the region to craft its own plan rather than wait for federal regulators to impose a plan. After listening to the concerns of the stakeholders, the Texas Legislature created the Edwards Aquifer Recovery Implementation Program, which resulted in a 5-year consensus-based planning effort that resulted in the Edwards Aquifer Habitat Conservation Plan (HCP), approved by the FWS in 2013.

Essentials of the Plan

Essential parts of the HCP include establishing biological goals for the endangered species and then determining biological objectives to meet those goals.

Fountain Darter
Fountain darters are fish that live in submerged aquatic vegetation (SAV) in the river systems of the Comal and San Marcos springs. Biological goals include maintaining coverage of submerged aquatic vegetation and minimum numbers of fountain darter per square meter of the vegetation. To reach these goals, the HCP set out objectives including restoring native vegetation, maintaining a certain minimum spring flow, and maintaining water quality parameters such as dissolved oxygen, conductivity, temperature, and pH within certain limits.

Texas Wild Rice
Texas wild rice is an aquatic perennial grass found only in the headwaters of the San Marcos River in

Hays County, Texas. The installation of dams and recreation, including kayaking and tubing, has changed water flows and damaged habitat. Biological goals include maintaining certain acreages of Texas wild rice in the different reaches of the river. The objectives include maintaining a certain minimum spring flow and controlling recreation, especially at low flows.

Comal Springs Riffle Beetle

The Comal Springs riffle beetle lives near spring orifices, where it feeds on leaves and other detritus. The beetle is sensitive to silt accumulations from sediment runoff, thus, biological goals are focused on maintaining silt-free conditions near spring openings, and on maintaining certain population abundances. The biological objectives are to maintain minimum flows and stable water quality, and to restore riparian habitat adjacent to spring openings to reduce silt accumulation.

San Marcos Salamander

The San Marcos salamander is a small, fully aquatic salamander that hides under rocks, gravel, and SAV. Its biological goals include maintaining silt-free gravel and specific populations at three sites where the salamander has been shown to occur over the past 50 years. Biological objectives include aquatic gardening at these sites, the regulation of recreational activity, and maintaining flow above certain levels. There is no water quality objective for the salamander.

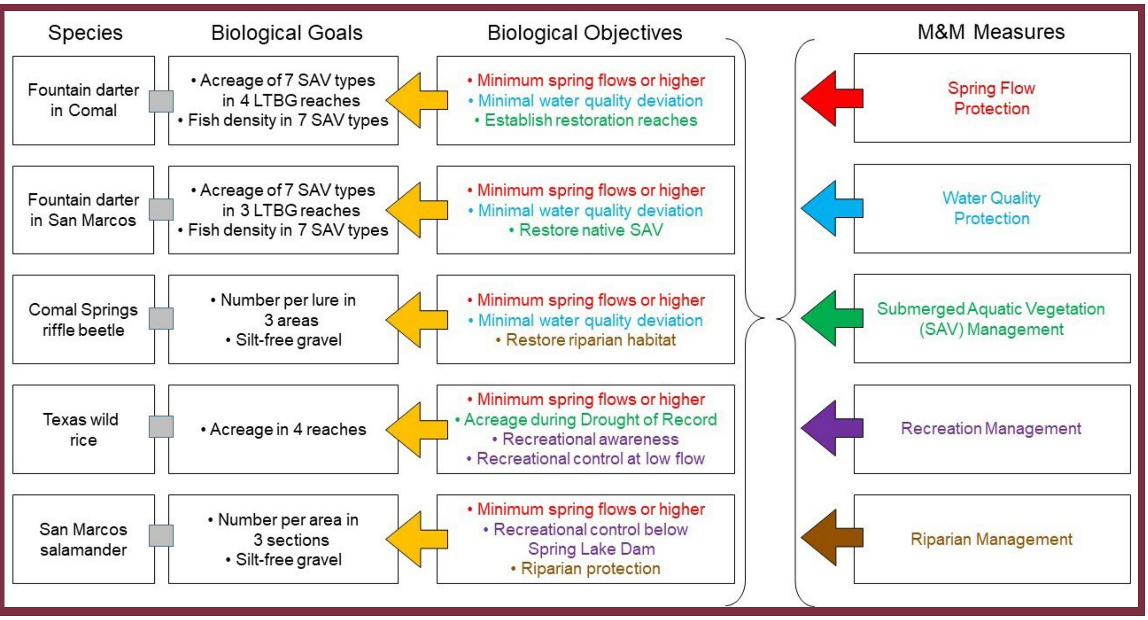
The HCP proposes minimization and mitigation measures, also known as conservation measures, in five categories meant to meet the biological objectives identified for each target species. Figure 2 shows the linkages, for four of the target species, between the biological goals, the biological objectives, and the minimization and mitigation measures. These measures include:

- *Flow Protection Measures*, including a water conservation program, aquifer storage and recovery, and a voluntary suspension of irrigation pumping to help maintain the minimum flows required in the Comal and San Marcos systems. They comprised 71 percent of the HCP expenses.
- *Restoration and Maintenance of Native Submerged Aquatic Vegetation* is particularly important for creating fountain darter habitat. Related measures include planting Texas wild rice and removing nonnative SAV.
- *Recreation Management Measures* include creating permanent river access points and preventing access at other locations, controlling recreational activities that might damage Texas wild rice, and educational efforts.
- *Water Quality Measures* include stormwater control, golf course management, and the management and removal of floating litter and vegetation.
- *Riparian Management Measures* include restoring native vegetation along streambanks, stabilizing river banks, and preventing shoreline erosion and sedimentation.

Figure 2

Linkages between the four listed “sentinel” species, their biological goals and objectives, and the minimization and mitigation (M&M) measures.

LTBG = long-term biological goal



Modeling and Monitoring Efforts

Another essential part of the HCP are plans to use models to help project the results of various actions. There have been many efforts to characterize and model the Edwards Aquifer over the last 20 years, and the HCP calls for refinements of those models.

The HCP makes use of groundwater models that reproduce known spring flows and can predict: (1) the effects of potential future hydrologic conditions such as climate change and droughts on spring flow, and (2) how management actions will affect water levels and spring flows. Because the Edwards Aquifer is underlain by porous rock, its physical features complicate modeling efforts.

A major effort set forth by the HCP is the creation of predictive ecological models for the Comal and San Marcos spring systems. The models are designed to predict species populations in response to a variety of conditions brought about by such things as groundwater withdrawal, recreation activities, and restoration actions. Three endangered species—the fountain darter, the Comal Springs riffle beetle, and Texas wild rice—have been designated as indicator species within the HCP, and, along with submerged aquatic vegetation, are the initial targets of modeling efforts.

Finally, the HCP requires the development and implementation of biological and water quality monitoring plans to (1) evaluate compliance; (2) determine if progress is being made toward meeting the HCP’s long-term biological goals and objectives; and (3) provide scientific data and feedback information for the adaptive management process. This aspect of the HCP builds upon the strong monitoring capabilities that have been in place for the Comal and San Marcos Spring systems since 2000.

Checking the Science

As the plan was being developed, officials recognized the value of seeking outside expertise to review the scientific basis of the HCP. The review was designed to accomplish many goals These included getting advice to refine the ongoing modeling and monitoring efforts that are critical to ensuring the success of the HPC. The review was also directed at ensuring that biological goals and objectives were appropriate and attainable. The EAA also wanted to incorporate insights from relevant new research, such as dealing with uncertainties in groundwater modeling. An overall goal of seeking outside expertise was to increase the faith that citizens and stakeholders have in the process and the plan.

After considering several options, the EAA chose the National Academies of Sciences, Engineering, and Medicine (NASEM) to conduct the review. A nonprofit that operates outside the framework of government, NASEM produces its studies by recruiting top scientists and other professionals who have expertise on the questions at hand. Instead of opting for a single study, the EAA requested that NASEM conduct a series of studies over a 5-year period. The plan was for the EAA to incorporate advice as it was provided and to adjust the HCP as appropriate.

The first two in the series of NASEM reports focused on providing scientific input to the hydrological modeling and the ecological modeling, as well as to the biological and water quality monitoring. The third and final phase of the NASEM study was to evaluate whether or not biological objectives would effectively meet the biological goals and whether the conservation measures can meet the biological objectives. The study found that the objectives are adequate to meet the goals, with some improvements to be made. Similarly, the study found the conservation measures to be generally adequate to meet the objectives, providing many specifics to make the measures even better. The total "report card" on the conservation measures is shown in Table 2.

Responding to Advice

The EAA has already been responsive to the advice in the NASEM reports and has outlined plans for continuing to improve the HCP, as the reports recommend.

Hydrological Modeling

As described above, the HCP makes use of groundwater models to project spring flows in response to future climate conditions and various management actions. The 2015 report

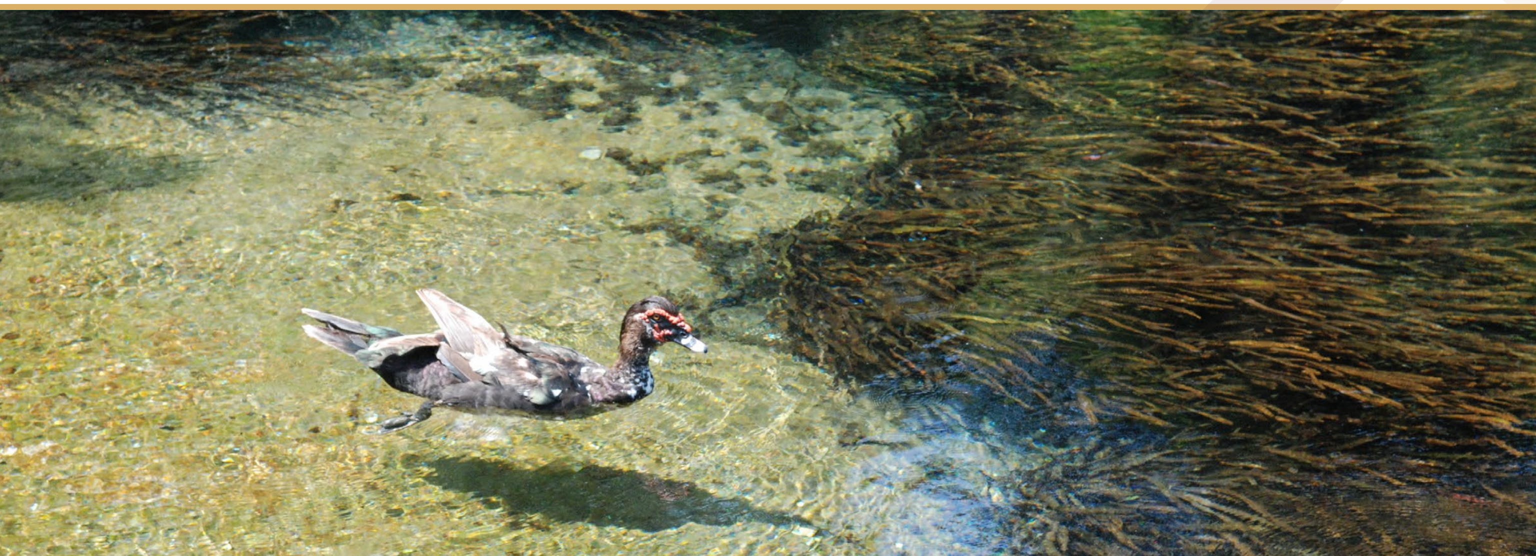


Table 2

Measure	Rating	Issue
Spring flow protection	Effective	Recent drought triggered 3 measures—flow maintained; validation of MODFLOW Model
Water quality protection	Somewhat effective	Stormwater control measures not yet implemented, hard to monitor, but have worked elsewhere
SAV management	Effective	Texas Wild Rice gaining acreage, removing nonnative SAV both good and bad; overreliance on bryophytes
Recreation management	Effective	Access now well controlled; structures built; need to enroll more outfitters in Certificate of Inclusion program; area below dam still vulnerable
Riparian management	Cannot be determined	No monitoring to demonstrate link between riparian plantings and reduction of siltation; need to maintain erosion control structures; negative consequences of removing nonnative plants

recommended more careful evaluation of recharge estimation, uncertainty analysis, incorporation of conduits, and improved descriptions of the modeling plans. The EAA has begun implementing these recommendations. The 2017 report recommended testing the groundwater model for the 2011 to 2015 period, which was not used in model calibration. This period, which includes both very dry and wet years, offers a remarkable opportunity to validate the model and enhance confidence in the model for future applications. Such a test was recently completed with excellent agreement between model predictions and observations.

Ecological Modeling

The initial efforts of the ecological modeling team—guided in part by the 2015 report and by an interim report from the National Academies produced in mid-2016—have focused on modeling the population dynamics of the fountain darter and key submerged aquatic vegetation species. In general, the NASEM reports found that ecological modeling efforts have made good progress and that scientifically sound frameworks and approaches for the submerged aquatic vegetation and fountain darter models are in place. However, the model has not reached a state of development that allows it to be used to predict the consequences of conservation measures on the listed species.

Biological and Water Quality Monitoring

The biological and water quality monitoring programs are intended to provide the observational data needed to assess whether the HCP is meeting its goals of protecting the covered species. Monitoring in the Edwards Aquifer spring systems has been ongoing since 2000 and is now even more comprehensive as a result of the HCP.

The 2015 report raised concerns about the lack of integration between the water quality and biological monitoring programs, insufficient detection limits for phosphorous and nitrogen, and the inability to determine population densities of invertebrates such as the Comal Springs riffle beetle. In response, the EAA established two working groups to assess the water quality and biological monitoring programs, respectively, and make necessary modifications. The EAA immediately acted on one of the most important recommendations to create a database for housing and analyzing the data and information being collected by the monitoring programs and the Applied Research Program. In additional it has begun doing more sophisticated analysis of its biological data sets, as recommended in the 2015 report.

Applied Research Program

The Applied Research Program is intended to fill knowledge gaps about the endangered species in the Comal and San Marcos systems, particularly under low-flow conditions, and to provide data and information that can be used to calibrate and validate the ecological methods. The 2015 and 2017 reports evaluated every project that had been funded to date and identified new study topics. As a result, and the Comal Springs riffle beetle was made the subject of all Applied Research for 2016. The EAA also acted on the NASEM's recommendations to (1) have more widely disseminated solicitations for research, (2) have a more transparent process for prioritizing and funding the projects, and (3) offer some longer (e.g., two- to five-year) projects in order to maximize interest and collaboration from the region's leading researchers.

Going Forward

The overall conclusion of the NASEM study is that the EAA is at the beginning stages of implementing a complex HCP and is doing an excellent job in many respects. Throughout the study, NASEM identified a number of overarching issues that go beyond the HCP, but that if considered now, could help ensure the success of the HCP in the future. These include:

- Developing and implementing a plan for early detection of invasive species and rapid response to eradicate them before they become established. If a high-impact nonnative species were to become established, these systems could be permanently uninhabitable for one or more covered species.

- Considering the potential effects of catastrophic events, such as floods and droughts worse than the Drought of Record, on the Edwards Aquifer system. For example, an event the size of Hurricane Harvey could completely destroy the SAV in the Comal and San Marcos rivers, directly affecting Texas wild rice and fountain darter habitat and leading to erosion and sedimentation in some areas, affecting silt-sensitive species. The report recommends evaluating such catastrophic events for possible inclusion in future HCP planning.

With the reassurance and advice from the NASEM study, the EAA is well on the path towards protecting the endangered species over the long term.

The Committees to Review the Edwards Aquifer Habitat Conservation Plan

PHASE 1

Danny D. Reible (Chair), Texas Tech University; **Jonathan D. Arthur**, Florida Department of Environmental Protection; **M. Eric Benbow**, Michigan State University; **Robin K. Craig**, University of Utah; **K. David Hambright**, University of Oklahoma; **Timothy K. Kratz**, University of Wisconsin; **Andrew J. Long**, U.S. Geological Survey; **Laura Murray**, University of Maryland; **Jayantha Obeysekera**, South Florida Water Management District; **Kenneth A. Rose**, Louisiana State University; **Laura Toran**, Temple University; and **Greg D. Woodside**, Orange County Water District. Staff from the National Academies of Sciences, Engineering, and Medicine: **Laura J. Ehlers** (Study Director) and **Michael J. Stoever** (Research Associate).

PHASE 2

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PHASE 3

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For More Information . . . This booklet was prepared by the National Academies of Sciences, Engineering, and Medicine based on the series of Consensus Study Reports Review of the Edwards Aquifer Habitat Conservation Plan: Report 1 (2015); Review of the Edwards Aquifer Habitat Conservation Plan: Report 2 (2017); Review of the Edwards Aquifer Habitat Conservation Plan: Report 3 (2018). The study was sponsored by the Edwards Aquifer Authority. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Reports are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Water Science and Technology Board web page at http://www.nationalacademies.org/wstb.

Image sources:

Cover & Pages 3/4 : Fountain Darter; Comal Springs Riffle Beetle; and San Marcos Salamander. Abbott Nature Photography; Texas Wild Rice photographed by Laura Ehlers.

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