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REPORT IN BRIEF

WATER SCIENCE AND TECHNOLOGY BOARD
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Review of the Edwards Aquifer Habitat Conservation Plan

THE EDWARDS AQUIFER IS THE PRIMARY SOURCE OF WATER for drinking and irrigation in the San Antonio area, and supplies the two largest freshwater springs in Texas, Comal Springs and San Marcos Springs. Both springs are used for recreation and are home to several species of fish, amphibians, insects, and plants found nowhere else. Seven Edwards Aquifer species are on the federal Endangered Species List because they are vulnerable to reduced spring flows caused by drought and pumping. To protect these species, the Edwards Aquifer Authority and four other local entities have created a 15-year Habitat Conservation Plan. This report is the first product of a three-phase study to provide advice to the Edwards Aquifer Authority on various scientific aspects of the Habitat Conservation Plan to help improve the management of the aquifer.

The report finds that overall, the Edwards Aquifer Authority is doing an excellent job in implementing many aspects of a complex habitat conservation plan, and that addressing several overarching scientific and modeling issues would further strengthen the plan.

Underlain by porous, permeable limestone rock known as "karst," large volumes of water can move through the Edwards Aquifer's 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 and springflow (see Box 1).

Rapid declines in springflow can be catastrophic to the species that live in the Edwards Aquifer and its springs. The seven species listed under the federal Endangered Species Act (ESA) are the fountain darter, the San Marcos gambusia (presumed extinct), the Texas blind salamander, the Comal Springs dryopid beetle, the Comal Springs riffle beetle, Peck's Cave amphipod, and Texas wild rice.

To protect the ESA-listed species, the Edwards Aquifer Authority (EAA) and four other local entities applied for an incidental take permit under the Endangered Species Act, creating a 15-year Habitat Conservation Plan (HCP) as part of the application process. The average annual costs of the HCP are between $15 and $20 million. Given

Figure 1 The Edwards Aquifer underlies several Texas counties and covers an area about 180 miles long and from five to 40 miles wide. The primary water source for San Antonio and its surrounding communities, an area that is home to over 2.3 million people, the aquifer also supplies irrigation water to thousands of farmers and livestock operators in the region, as well as supplying the Comal and San Marcos Springs. In this map, the red line indicates the jurisdiction of the Edwards Aquifer Authority.

Box 1. A Drought of Record at Edwards Aquifer

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 pumping levels, 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.

the uniqueness of the two spring ecosystems, the many diverse projects that make up the HCP, and the persistence of drought conditions across the region, the EAA requested the input of the National Research Council. This report is the first product of a three-phase study to provide advice to the EAA on various scientific aspects of the HCP that will ultimately lead to improved management of the aquifer (see Box 2).

Figure 2. Karst aquifers are made of highly porous, permeable limestone and are characterized by fractures, conduits, and cavities that can transport water miles per day. Photo by Dr. Steven J. Taylor and Dr. Jean K. Krejca, Zara Environmental LLC.

HYDROLOGIC MODELING

Hydrologic modeling is used to create 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.

The Edwards Aquifer is underlain by rock of varying porosity and permeability, and has physical features such as conduits, faults, and barriers that complicate modeling efforts. There have been many efforts to characterize and model the Edwards Aquifer, most based on the MODFLOW code. The HCP calls for refinement of the MODFLOW program and development of a second finite element model.

Box 2. The Scope of This Report

The Edwards Aquifer Authority asked the National Research Council to provide advice on the scientific initiatives underway to support the Habitat Conservation Plan. This first report from the three-phase study focuses on improving modeling efforts for the Edwards Aquifer, specifically reviewing four scientific initiatives within the HCP:

1. ecological modeling,
2. hydrologic modeling,
3. biological and water quality monitoring, and
4. applied research.

Later reports will review the performance of minimization and mitigation measures found in the HCP, including the four spring flow protection measures, as well as the adequacy of biological goals and objectives to protect endangered species.

The report's authoring committee found that EAA could gain efficiency by moving toward a single model that incorporates the best concepts from existing modeling efforts. Continued development of "competing" models (i.e., having both a MODFLOW model and a finite element model) is inefficient and unnecessary and cannot be used for assessing model uncertainty. Furthermore, model uncertainty needs to be quantitatively assessed and presented in formal EAA documents, for example via explicit sensitivity analysis, validating the groundwater model, and using additional calibration and validation metrics. Quantifying model uncertainty increases a model's defensibility and can provide a reasonable estimate of model error, which is important information when using a model for management decisions.

ECOLOGICAL MODELING

The HCP calls for the development of new ecological models to predict species population metrics under a variety of potential future conditions. 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. Currently, population dynamics models for fountain darter and submersed aquatic vegetation are under development.

The individual-based model for fountain darter is a scientifically sound approach for modeling population dynamics that will require extensive data for model formulation, calibration, and validation. Suggestions for improving the modeling effort include (1) hosting workshops to define the questions, formulate the model, and present preliminary results, (2) making clearer links between the monitoring data and the Applied Research projects and how both will be used to inform the modeling, and (3) engaging modelers with experience in developing similar individual-based models.

If the Comal Springs riffle beetle is to be an adequate indicator of some of the other ESA-listed species, it is critical to have a much deeper understanding of its spatial distribution, range of potential habitats, and natural history. The degree to which the beetle is a reliable indicator of other species not being monitored is presently not well understood nor has it been objectively tested.

Developing an ecosystem-based conceptual model, or a series of models of increasing resolution, should be a top priority for the EAA. The conceptual models should show how water quality and quantity, other biota, and restoration and mitigation activities are expected to interact with the indicator species, as well as with all covered species.

MONITORING

The HCP requires the development and implementation of a monitoring plan 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. The committee found the monitoring programs to be strong and comprehensive. Nonetheless, it cautioned that results from the monitoring program cannot be scaled to the entire spring and reach system because the sampling locations were not selected using randomization procedures. If the EAA finds it is necessary to provide system-wide estimates of population densities of target species rather than relying on trends at index sites, it will need to carry out special studies or conduct sampling using randomization techniques.

Figure 3. Texas wild rice. Source: Laura Ehlers

Annual algal blooms suggest that enhanced sampling for nutrients is needed to better monitor the role of nutrient loading in the spring and river systems of the Edwards Aquifer. The current detection limits for nutrients such as soluble reactive phosphorus, nitrate and nitrite, and total nitrogen are so high that significant changes in nutrient concentrations could go undetected. Analytical methods should be changed to lower the detection limits for phosphorus, nitrate and nitrite, and total nitrogen.

APPLIED RESEARCH PROGRAM

Critical to the protection of all aquifer species is knowledge of the species-specific demography and ecology, including knowledge of natural population fluctuations. 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 report evaluates the 15 projects that have been funded to date and identifies new study topics that could inform the ecological modeling efforts.

The report's authoring committee also found that the Applied Research Program could be restructured to help increase the program's efficiency and usefulness, and to ensure that the limited funds available are targeted to priority research needs. For example, more widely disseminated solicitations for research under the Applied Research Program would help foster greater collaboration and increase the diversity of thought, understanding, and perspective. The program would benefit from a more transparent process for prioritizing and funding the projects that includes stakeholder involvement and peer review. Finally, the program should offer some longer (e.g., two- to five-year) projects in order to maximize interest and collaboration from the region's leading researchers.

OVERARCHING ISSUES

The EAA is at the beginning stages of implementing a complex HCP and is doing an excellent job in many respects. Nevertheless, there are a number of overarching issues that, if considered now, could help ensure the success of the HCP.

There is a need for more formal integration both within the HCP and between the HCP programs and other relevant EAA programs to enable clear explanation of the many sets of results emanating from the monitoring, modeling, and research efforts. Developing an overall conceptual model of the system including hydrological, climate, and biological community components (as discussed above) would be a first important step to achieving integration. A second way to achieve integration would be to develop a comprehensive data/information management system. The EAA could also convene an annual science meeting to discuss results, discover gaps in understanding, and help plan future activities.

Figure 4. (top) *Comal Springs dryopid beetle. Source: John Abbot.* (bottom) *Fountain darter. Source: U.S. Fish and Wildlife*

There is an urgent need to monitor the performance of the HCP's minimization and mitigation measures that are being implemented at both Comal and San Marcos Springs. These include control of recreational activities, removal of exotic species, riparian restoration and bank stabilization projects.

Finally, the Committee recommends that the EAA begin to think now about possible worst case scenarios and their potential implications for both modeling and implementation of the HCP over the next decade. Examples of potential future "worst case" scenarios worth considering include:

- Increased groundwater pumping from exempt or unregulated wells that undermines the HCP's minimum flow requirements;
- Drought conditions that exceed the drought of record from the 1950s;
- Climate change impacts that become significant faster than expected;
- High court affirmation of the Bragg constitutional takings decision, which found that limiting landowners ability to pump water from Edwards Aquifer could result in a constitutional taking of their property rights, requiring payment from EAA;
- Subjugation to Aransas National Wildlife Refuge Endangered Species Act issues, including the Whooping Crane.

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The National Academies appointed the above committee of experts to address the specific task requested by the Edwards Aquifer Authority. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

For more information, contact the Water Science and Technology Board at (202) 334-3422 or visit http://dels.nas.edu/wstb. Copies of *Review of the Edwards Aquifer Habitat Conservation Plan* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.