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Edwards Aquifer Authority Aquifer Science Research Program Plan 2006–2011

UNDERSTAND
CONSERVE
PROTECT



EDWARDS AQUIFER
AUTHORITY
November 2006

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INTRODUCTION

The Balcones Fault Zone Edwards Aquifer in south central Texas is one of the most permeable and productive aquifers in the United States. The San Antonio segment of the aquifer extends from the groundwater divide near Brackettville in Kinney County, east to the city of San Antonio in Bexar County, then northeast to the groundwater divide near Kyle in Hays County—a distance of approximately 180 miles (**Figure 1**). The aquifer, the primary source of water for approximately 1.7 million people in the region (<http://quickfacts.census.gov/qfd/>), provides most of the water for agriculture and industry. In addition, the aquifer discharges through a series of large springs that provide aquatic habitat to a number of endangered species. Springflow also provides a significant portion of water for downstream interests in the Guadalupe River basin.

The Edwards Aquifer Authority (the Authority) was created by the Texas Legislature in 1993 to replace the Edwards Underground Water District (EUWD) as a special regional water management district in charge of the San Antonio segment of the Edwards Aquifer. The Authority's jurisdictional area encompasses all or parts of eight counties, including Uvalde, Medina, Atascosa, Bexar, Comal, Guadalupe, Hays, and Caldwell (**Figure 1**). The Authority is governed by a 17-member board of directors, with voting members elected to represent 15 districts across the Authority's region and two nonvoting members appointed by other entities. Directors represent agricultural, industrial, domestic, municipal, spring, and downstream user groups. The Legislature also created the South Central Texas Water Advisory Committee (SCTWAC) to interact with the Authority when issues related to downstream water rights are being addressed.

The Legislature mandated that the Authority take all necessary measures to manage the resource effectively in order to ensure domestic and municipal water supplies, to promote the operation of existing agriculture and industry, to protect terrestrial and aquatic habitat, and to sustain economic development of the region. To accomplish these goals, the Authority is vested with all of the "powers, rights, and privileges

necessary to manage, conserve, preserve, and protect the aquifer, and to increase the recharge of, and prevent the waste or pollution of water in, the aquifer" [Edwards Aquifer Authority Act, as amended].

The Edwards Aquifer is a complex system and to understand the aquifer adequately requires accurate and timely research and data collection. This report summarizes the inception of the Authority's Aquifer Science Research Program (ASRP), which is a natural outgrowth of the Authority's initial research program known as Optimization Technical Studies (OTS). The OTS were performed under the Edwards Aquifer Optimization Program (EAOP), as summarized by Todd Engineers, 1999.

This report will serve as the document for transitioning from the OTS to the ASRP. The ASRP is managed by the Authority, with input from an outside panel of experts referred to as the Aquifer Science Advisory Panel (ASAP), as well as continued input from the Technical Advisory Group (TAG), which helped the Authority develop the original OTS. The ASRP differs from the OTS in that the Authority receives input from the TAG and the new ASAP in relation to research project development and review. The ASRP is also limited to research projects directly related to the Authority's Aquifer Science Program, whereas the OTS included projects outside the Aquifer Science Programs scope. As with the OTS, the board of directors has final approval over all projects prior to initiation.

The document sections that follow provide a discussion of the EAOP, OTS, and the new ASRP in greater detail. In order to document the various projects associated with the ASRP and OTS, summary tables are provided in each respective section, and detailed descriptions are provided in the appendices. Appendix A provides detailed descriptions of proposed ASRP projects. Detailed descriptions and status summaries of active OTS projects (many of which will be absorbed into the ASRP) are provided in Appendix B. Projects completed under the OTS are listed in Appendix C.

EDWARDS AQUIFER OPTIMIZATION PROGRAM (EAOP)

The EAOP was conceived as the umbrella program under which a series of multidiscipline, mission-directed studies (the OTS) would be performed with the objective of optimizing the Edwards Aquifer with regard to all users, to include threatened and endangered species and downstream interests. Although the mission of the Authority has not changed, many of the projects originally conceived under the EAOP are either complete or of a nature more directly related to the mission of other programs within the Authority. As such, OTS projects related to nonaquifer science studies will be managed by other Authority programs.

Although many studies related to the Edwards Aquifer have been conducted over the last 100 years, data gaps remain. In 1996, the San Antonio Mayor's Citizens Advisory Committee on Water Policy identified some of the known data gaps. With the help of technical advisors, the committee subsequently proposed the concept of developing aquifer optimization strategies for implementation on a regional basis. This committee recommended specific technical studies for aquifer management to include continuation of the saline/freshwater interface study, recharge enhancement, and aquifer optimization. The next step in this process led to the development of a regional steering committee, which was headed by the Authority. Hence, a Technical Advisory Group (TAG) was formed. At that time it was envisioned that the TAG would develop recommendations and priorities for proposed studies, as well as review results of the studies.

The Authority became the lead agency for the TAG, with the responsibility of providing technical oversight through its Research and Technology Committee and staff, with final approval of all projects through the board of directors. The original TAG was composed of more than 30 members, with representatives from federal, state, regional and local agencies, aquifer users, and academe. The group included experts in the fields of hydrology, geology, biology, and

engineering. The TAG was charged with addressing several issues identified by the Citizens Committee:

- Recharge enhancement
- Flowpath studies
- Springflow augmentation
- Springflow recirculation
- Biological assessment of endangered species
- Range management
- Saline water study

Identification of these issues led to the development of nine specific questions (Todd Engineers, 1999):

1. Can significant additional recharge be provided to aquifer users and maintain springflow?
2. Where should we put recharge dams, pumping centers, and injection wells for maximum efficiency?
3. Are we receiving accurate predictions of aquifer conditions from our current flow model?
4. Can the "bad water" line move during extended periods of low aquifer levels?
5. Can springflow be augmented during extended periods of low aquifer levels?
6. What are actual minimum flow requirements of the various endangered species and habitats?
7. Can excess springflow be captured and returned to the aquifer during wet periods?
8. Will control of *Ashe juniper* in the recharge zone increase recharge to the aquifer?
9. Can we increase annual rainfall in the catchment and recharge zones of the aquifer?

Initial efforts to answer these questions became the basis for addressing some technical uncertainties

associated with making technically sound aquifer optimization decisions. Addressing these questions led to development of three areas of specialization within the TAG, resulting in the forming of the following subgroups:

- Biological Assessment
- Flowpath/Modeling
- Recharge Enhancement

The OTS grew out of this process and developed into a research program of 17 technical studies recommended for adoption by the Authority. The 17 studies were composed of six biological assessments, eight aquifer flowpath and modeling studies, and three recharge enhancement studies. The 17 original OTS projects are summarized in Table 1.

Between May 1999 and September 2006, almost all of the original 17 OTS studies were either initiated or completed. Some studies have been conducted under a slightly altered title, whereas some studies were not specifically designated in the original OTS but provided support for other OTS initiatives. Table 1 summarizes accomplishments of the OTS by provid-

ing a listing of projects conducted under the OTS and the current status of each. Note that Table 1 has an additional category for studies performed in support of the OTS. To date, the Authority's Aquifer Science Program has provided oversight for all OTS efforts. However, some of the listed studies will transfer to other Authority programs as they move from their research phase to either long-term monitoring or to feasibility studies for consideration of implementation. As such, these particular studies will not be included in the ASRP. These nonaquifer science studies are:

- Variable Flow Biological Monitoring Plan and Ongoing Monitoring
- Well Sampling of Aquifer Biota
- Springflow Recirculation/Recharge Enhancement Phases III and IV
- Precipitation Enhancement Program
- Paired Watershed Study: Honey Creek and Government Canyon State Natural Area
- Augmenting Groundwater Recharge through Brush Control: A Feasibility Study

Table 1. Summary and Status of OTS Projects May 1999–September 2006

OTS Study Category	Status	Study Title
Biological Assessment	Continuous study in support of Habitat Conservation Plan (HCP)	Comprehensive and Critical-Period Monitoring of the Comal Springs and San Marcos Springs Aquatic Ecosystems ("Variable Flow" study)
	Removed from OTS	Texas Wild-Rice Mapping (Project being performed by Texas Parks and Wildlife)
	Complete	Assessment of Factors Influencing Texas Wild-Rice (<i>Zizania texana</i>) Sexual and Asexual Reproduction (Texas Wild-Rice Growth and Reproduction)
	Complete	Assessment of Instream Flow and Habitat Requirements for Cagle's Map Turtle (<i>Graptemys caglei</i>)
	On hold	Well Sampling of Aquifer Biota (Work plan initiated, study not funded)
Flowpath/ Modeling	1) Complete 2) Complete 3) 2009 4) Complete 5) Complete	Management Model/GIS Data Sets and Model Recalibration 1) Management Model (This is the New MODFLOW model) 2) GIS Data Sets 3) Model Recalibration 4) MODFLOW Management Module (Not in OTS) 5) Estimation of Hydraulic Parameters for the Edwards Aquifer Management Model
	1) Complete 2) Complete	1) Saline Water Study (SAWS is continuing this project; Authority participation ended in August 2005)) 2) Saline Water Use Study
	1) USGS 2006 2) Complete	Recharge/Flowpath (N. Medina Co.) Hydrologic Budget Analysis of Medina Lake and Diversion Lake
	1) Complete 2) In progress 3) In progress 4) In progress 5) Proposed 6) 2007 7) 2006	Focused Flowpath Studies: Knippa Gap, San Marcos Springs, and Comal Springs 1) Uvalde/Knippa Gap Study (Phase I) 2) Tracer Testing at Springs (Comal and San Marcos) 3) Tracer Testing Bexar County 4) Tracer Testing in Kinney and Uvalde Counties 5) Uvalde/Knippa Gap Study (Phase II) 6) Karst Aquifer Modeling Research (Phase 1) 7) Noble and Active Gas Sampling in the Knippa Gap Region
	1) Complete 2) Complete 3) 2007	Recharge Methodology Pilot Study HSPF Model for Region HSPF Model for Region NEXRAD Calibrated Rainfall Input Refinement/ GUI Development
	Complete	Statistical Analysis of Hydrologic Data

Table 1. (continued)

Recharge Enhancement		
	1) In progress 2) In progress	Range Management of Woody Species 1) Paired Watershed Study – Honey Creek and Government Canyon State Natural Area 2) Augmenting Groundwater Recharge through Brush Control: A Feasibility Study
	Complete Complete 2007 2007	Springflow Recirculation and Recharge Enhancement Phase I Phase II Phase III Phase IV
	Complete	Augmentation Study (Supplement Phase I) Project title: <i>Evaluation of Augmentation Methodologies in Support of in situ Refugia at Comal and San Marcos Springs, Texas</i>
Support Projects		
	Ongoing	Synoptic Water Level Program (Report for 1999–2004 due in 2006)
	Complete	Synoptic Water Level Well Survey Project
	Initiation stage	Focused Synoptic Water Level Program
	On-going	Water Quality Sampling
	On-going	Water Level and Conductivity/Temperature Monitoring

AQUIFER SCIENCE RESEARCH PROGRAM

Introduction

To date, Authority research initiatives have been conducted under the guidance of the OTS process, with oversight provided by the Authority's Aquifer Science Program. The OTS process began in 1996 and culminated in the production of the OTS in May 1999. During this development, the Authority was in transition from the former Edwards Underground Water District to the Edwards Aquifer Authority. In April 1999, the Authority hired a Chief Technical Officer and other technical staff to implement the studies identified in the OTS and enhance the Authority's knowledge and expertise by expanding the Aquifer Science Program. The Authority's Aquifer Science Program, through the hiring of experienced staff and completion of numerous studies, has gained the technical expertise necessary to revise, define, and direct the Aquifer Science Research Program for the Authority. Because most of the OTS studies have been completed, the Authority recognized the need to update and revise the OTS document and EAOP process to address new technical issues for the region such as groundwater quality.

The Authority has recognized the need to modify and expand some of its programs, as well as to create new programs such as resource protection. Therefore, research related directly to hydrogeologic issues will be the responsibility of the Authority's Aquifer Science Program. Results of some studies have shown the need to create expanded investigations not directly related to the Aquifer Science Program. As such, those projects will be managed by other Authority programs. Since the inception of the OTS, the Authority has grown in size and expertise, leading to the need for staff reorganization and ultimate redistribution of responsibilities. The Aquifer Science Program and staff will concentrate their efforts and expertise on research initiatives applicable to the hydrogeology of the Edwards Aquifer.

Basis for Development of the ASRP

The OTS was used to implement the EAOP. However, with the completion or initiation of most of the original OTS projects, along with the Authority's growth in size and collective internal expertise regarding management of the Edwards Aquifer, a refocus of the research program is appropriate. Refocusing the research program will allow the Authority to pursue a more mission-directed approach to conducting aquifer research and prioritizing research needs. Revising the Authority's research approach is also in agreement with the current Authority Strategic Plan.

Goals and Objectives of the ASRP

Although a substantial body of knowledge exists for hydrogeology of the Edwards Aquifer, many unknowns remain with regard to the aquifer's characteristics. Therefore, continued research must concentrate on supplementing and refining that knowledge to provide policy makers with adequate information to make decisions that assist in implementation of the Act. Because the Authority has implemented and managed the OTS projects, it has built a sound corporate knowledge of the research needed to continue the aquifer optimization process by implementing the ASRP.

The overall goal of the revised research program is to provide the best available technical information to decision makers as efficiently as possible. Using the current knowledge base derived from the OTS and other investigational data, the ASRP is poised to make further advances in the areas of aquifer modeling, recharge modeling, flowpath understanding, water quality monitoring, and recharge methodology.

In order to accomplish its overall goal, the ASRP is tasked with these objectives:

- To respond to the directives of the board such that the program will provide adequate, sound information as needed.
- To develop and implement refinement plans for models that will prevent them from becoming obsolete.
- To continue basic data collection (water levels, water quality, rainfall, and other basic data) such that data quality represents the best available technology and store that data such that they do not become obsolete or irretrievable in the future.
- To continue to conduct and oversee research initiatives regarding hydrogeology of the Edwards Aquifer.

Projects or research initiatives conducted under the ASRP fall into one of four basic categories:

- Modeling studies/Model refinement
- Flowpath studies
- Recharge methodology studies
- Support studies

Research Needs and Project Development

Much of the historical and current research regarding the Edwards Aquifer has been aimed at answering basic research questions. However, in order to fully optimize the aquifer so that it will benefit all users adequately and equally, many basic research needs still exist. In the bulleted items below, some of the remaining basic research needs are listed by ASRP study category. For some of the listed needs, projects have been identified and studies proposed, whereas for others, appropriate studies will be proposed in the future.

- **Modeling studies/model refinement: Conceptual model refinement**
 - As new and refined data become available for the Edwards Aquifer, the conceptual model of the system will need to be refined

periodically and subsequently implemented into the research plan, as well as into computer models.

- **Flowpath studies: Flowpath behavior**
 - Identification of primary flowpaths and their flow characteristics need further investigation. Some of the questions in need of further investigation are: Do individual flowpaths respond to rainfall or pumping events? Do they have an identifiable surface signature? Are they representative monitoring sites? Does cross-communication from other aquifers occur? Are there water supply implications for vertical and horizontal components of the aquifer?

Vulnerability

- Karst groundwater aquifers are highly susceptible to contamination from surface activities. Basic research is needed to assess the vulnerability of the Edwards Aquifer, especially in the recharge zone and drainage area.

Contaminant transport

- Contamination in karst aquifers is difficult to determine with regard to vertical and horizontal extent, as are rate of contaminant movement and direction of flow. Basic research is needed to explain contaminant behavior and transport in the Edwards Aquifer.

Pool delineation and identification

- Recent aquifer conditions indicate a disconnect between the "San Antonio Pool" and San Marcos Springs discharge. Other potential pools may also exist in Uvalde and Kinney counties. Additional investigations need to be performed to identify and delineate these pools.

- **Modeling studies/model refinement:**

Recharge variables

- Computer recharge estimates indicate that variables need to be refined and accounted for to achieve improved estimates. For example, evapotranspiration (ET) and streamloss at high flow volumes are poorly

characterized on a regional basis. Improved water balance will require refinement of these data sets.

- **Support studies:**

Water balance

- Basic imperfections remain in the water balance. Improved recharge and discharge estimates are needed to close this data gap and improve modeling confidence.

Representative groundwater monitoring systems

- Karst aquifers often transmit contaminants in a pulse-type flux, making accurate detection difficult when samples are taken at random. Research needs to be performed on continuous samples collected at key locations, using cost-effective measures.

Data collection and retrieval

- Because of the large volume of data collected and the need for even more data, efforts to collect, store, and retrieve aquifer data properly and effectively need to be increased.

Currently active (OTS) projects, moving from the OTS to the ASRP, are listed in Table 2. The table lists only projects that transfer from the OTS into the ASRP. Projects moving under the oversight of other Authority programs are not listed. With the completion of each project, overall understanding of the

system as a whole improves slightly. This improved understanding provides one of the basic tools needed to direct development of future projects. Specifically, new information to direct future research is one of the keys to ASRP project development. In addition, obtaining input from the Aquifer Science Advisory Panel (discussed later) is another key to project refinement.

The Authority's fiscal year coincides with the calendar year. As such, budgeting for proposed projects typically occurs between June and August of each year, whereas planning for future projects is a continual process. After consulting with Authority staff, the ASAP, and the TAG, Aquifer Science staff developed the proposed projects listed in Table 3. Proposed projects are intended to provide follow-up information for previous studies, continue existing studies (i.e., support projects), or provide information aimed at addressing one of the basic research needs of the ASRP (see Appendix A for detailed project descriptions). Table 3 also provides a rough order of magnitude (ROM) cost for each proposed project. The ROM costs are estimates in current dollars and represent approximate costs. The project listing in Table 3 is subject to modification annually, given budgetary limitations, time constraints, or development of new directives. Calendar year 2006 and 2007 projects are programmed into the Authority's annual budget. However, Authority staff will continue to seek joint funding opportunities for these projects.

Table 2. Active Projects Moving from the OTS to the ASRP

OTS Study Category	ASRP Study Category	Study Title
Flowpath/Modeling	Modeling Studies	MODFLOW Management Module
Flowpath/Modeling	Flowpath Studies	Tracer Testing at Springs (Comal and San Marcos)
		Noble and Active Gas Sampling in the Knippa Gap Region
		Tracer Testing, Bexar County
N/A	Support Studies	Synoptic Water Level Program (Report for 1999–2005 due in 2006)
		Water Quality Sampling
		Water Level and Conductivity/Temperature Monitoring
		Hydrologic Data Collection

In each coming year, aquifer science staff will meet with the advisory panel, TAG, and other Authority staff before the budgeting process to refine the proposed ASRP studies prior to budgeting. Studies planned for calendar years 2006 and 2007 but not yet under way are summarized in Table 3. In addition, Table 3 lists part of the currently anticipated project needs for calendar years 2008 through 2011. As further research and planning take place, ASRP studies will be added and amended for years beyond 2006 and 2007 to accommodate "unknowns" or new developments in the program, as well as improvements in technology.

Other Aquifer Science Programs that support the ASRP studies also require annual budgeting and planning. For example, the Authority annually

monitors water quality in wells, springs, and several surface water sites. This monitoring requires the continual use of a contract analytical laboratory. In addition, the Authority maintains an agreement with the United States Geological Survey (USGS) for hydrologic data collection at springs and surface water sites. Other data collection activities, such as the Authority's real-time network (automated rain gauge system), well-logging activities, and recharge structure maintenance all require budgeting and staff time annually. Other support items include costs associated with microwave and telephone line rental for sending and receiving real-time information from remote instrumentation. Support programs and costs such as these are not detailed herein but, with future revisions of this document, may warrant inclusion.

Table 3. Summary of Proposed ASRP Studies—Calendar Years 2006–2011

ASRP Category	Estimated Initiation–Completion Year	Basic Research Need	Rough Order of Magnitude Costs/Year	Study Title
Modeling	2006–2007	Recharge Variables/Modeling	\$30,000/2006 \$50,000/2007	HSPF Model refinement—Inclusion of calibrated NEXRAD rainfall data sets + GUI development Anticipated project completion in 2007
	2007-on- going	Conceptual Model Refinement	\$70,000/2007 \$20,000/2008	MODFLOW model, improved storativity estimates
	2009–2011	Modeling Refinement	\$30,000/2009 \$30,000/2010 \$30,000/2011	MODFLOW model recalibration
Flowpath	2008–2010	Conceptual Model Refinement	\$50,000/2008 \$80,000/2009 \$20,000/2010	Hydrogeology of North Medina County
	2007–2008	Conceptual Model Refinement and Flowpath Behavior	\$60,000-2007 \$30,000-2008	Phase II of the Uvalde County Study (geophysical study of gravel aquifers to improve model balance/water balance)
	2008–2009	Conceptual Model Refinement and Flowpath Behavior	\$70,000/2007 \$20,000/2008	Well hydrophysics study
	2007–on-going	Conceptual Model Refinement and Flowpath Behavior	\$100,000/2007	Tracer testing of flowpaths
Recharge Methodology	2007–on-going	Recharge Variables	TBD	Planning for these projects will be initiated in 2007 or later
Support Studies	2006–2007	Conceptual Model Refinement and Flowpath Behavior	\$50,000/2006 \$15,000/2007	Well-plugging study in support of regulatory well program
	2006–2007	Water Balance	\$83,000/2006	Improvement of gauging systems at Comal and San Marcos springs
	2006–2008	Pool Delineation	\$120,000/2007	Definition and delineation of San Marcos Pool through focused synoptic and other studies
	2006–2007	Water Balance	\$20,000/2006 \$30,000/2007	Stream-gauging improvements (Nueces and Blanco rivers)
	2007–2009	Recharge Variables	\$75,000/2007	Guadalupe River gain/loss studies
	2006–2007	Representative GW Monitoring	\$50,000/2006 \$30,000/2007	Bacterial and pharmaceutical study
	2007–2008	Representative GW Monitoring	\$50,000/2007	Pilot study to improve analytical water quality data through use of passive sampling techniques
	2006–2007	Recharge Variables	\$15,000/2006	Weather station installations to determine improved evapotranspiration rates in region

TBD—To be determined

Aquifer Science Advisory Panel

In accordance with the Authority's Strategic Plan, an Aquifer Science Advisory Panel (ASAP) was formed to provide advice to the Aquifer Science Program and technical oversight for the ASRP. Panel members are selected on the basis of their expertise and experience from within and outside the region. The panel is composed of experts in the fields of karst hydrology, geochemistry, geology, computer modeling, structural geology, and hydrology. Panel members are not compensated for their participation, except for reimbursement of member expenses directly related to meeting attendance. Projects initiated under the ASRP process will be presented to the Edwards Aquifer Authority Research and Technology Committee and subsequently to the board of directors for approval prior to initiation. Table 4 below lists the 2006 ASAP members.

The ASAP will convene as needed to discuss the state of the aquifer, review current research, and make recommendations for future studies.

Aquifer Science Research Plan Review and Update

This document will be reviewed annually and updated approximately every two years on the basis of new developments within the ASRP. Changes to membership in the ASAP will be reflected in future updates, along with changes to ASRP studies, or initiation of new studies. This document will serve as the mechanism for summarizing the Authority's research program.

In addition, Authority staff will remain active in the Technical Advisory Group (TAG) by providing updates to its members at the quarterly meetings. Summaries of ASRP studies will be presented to the TAG, with final study reports made available through the Authority Website (www.edwardsaquifer.org) to the TAG and other interested parties.

Table 4. Aquifer Science Advisory Panel Members for Calendar Year 2006

Member Name	Background
Dr. E. Calvin Alexander, Jr., Minneapolis, Minnesota	Professor of Hydrogeology and Geochemistry, University of Minnesota
Dr. Stephen Worthington, Hamilton, Ontario, Canada	President, Worthington Groundwater
Dr. Charles Kreidler, Austin, Texas	Vice President, LBG-Guyton Associates
Dr. Robert Mace, Austin, Texas	Director of Groundwater Resources Division, Texas Water Development Board
Mr. Andrew Donnelly, Austin, Texas	Hydrologist III, Texas Water Development Board
Dr. Sue Hovorka, Austin, Texas	Research Scientist, Texas Bureau of Economic Geology
Dr. Alan Dutton, San Antonio, Texas	Professor of Hydrogeology, The University of Texas at San Antonio
Dr. Alan Shapiro, Washington D.C.	Research Scientist, USGS
Dr. Ronald Green, San Antonio, Texas	Research Scientist, Southwest Research Institute
Dr. Brad Wilcox, College Station, Texas	Professor of Rangeland Hydrology, Texas A&M University
Dr. John (Jack) Sharp, Austin, Texas	Professor of Geosciences, The University of Texas at Austin
Dr. George Veni, San Antonio, Texas	President, Veni and Associates, Inc.

Appendix A

Detailed Descriptions of Proposed ASRP Projects as of November 2006 (Projects Initiated in Calendar Year 2006 or to be Initiated in 2007)

MODELING STUDIES/ MODEL REFINEMENT

PROPOSED ASRP PROJECT:

HSPF Model Refinement

1) Purpose:

To refine existing Hydrologic Simulation Program Fortran (HSPF) computer model used to estimate surface water recharge to the Edwards Aquifer.

2) Background:

This project will refine the existing Hydrologic Simulation Program Fortran (HSPF) computer model, which is designed to estimate recharge in the nine sub-basins applicable to the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer. This project has two phases; the first phase will require analysis of potential improvements in model calibration by using refined precipitation data. The second phase will initiate development of a graphical user interface (GUI) designed to facilitate use of the model.

The model was developed and implemented with calibrated results (recharge estimates) completed for the period 1950–2000. These initial estimates were made using 32 National Weather Service (NWS) rain gauges across the region. Since completion of the model, improved rainfall data for calendar years 2003–2005 have been developed. These improved data utilize the Authority's real-time network as a calibration tool for NEXRAD radar. The calibrated NEXRAD data provide rainfall on a regionwide basis at four square kilometer grid cell spacing on a daily time step. As such, Phase I of this project will analyze potential improvements in model calibration that may be obtained using the NEXRAD rainfall data set, as opposed to the NWS rainfall stations.

In order for Phase I to be accomplished, the model will need to be run for calendar years 2001–2005 utilizing the

NWS data set and subsequently rerun for calendar years 2003–2005 utilizing the NEXRAD data. The model's input structure will require modification before the NEXRAD data may be accommodated. Upon completion of these efforts, model outputs will be compared for improvements in calibration, and the most cost-effective rainfall data set will be selected for model runs beyond calendar year 2005.

Phase II of the project will deal with development of a user-friendly GUI for the HSPF model, as well as site-based training for Authority staff. HSPF is a complex and highly specialized computer model, which does not feature a user-friendly or intuitive interface. Typically, HSPF is operated by modeling specialists familiar with the various aspects of the model code and calibration controls. The Authority's objective is to be able to use the calibrated model via an intuitive GUI that will facilitate in-house use of the model by staff, as well as allow for modeling of hypothetical scenarios, which is not currently possible with the existing model structure.

3) Aquifer Management Issue to be Addressed:

The HSPF provides surface water recharge estimates by basin, which are used as input files for the Authority's MODFLOW groundwater model. The effort is to update the data files and refine the estimates using weather radar. In addition, the HSPF data will be used to estimate annual recharge amounts for the Authority's annual Hydrologic Data Report.

4) Estimated Costs:

The total estimated cost of this project is \$80,000, with \$30,000 budgeted for 2006 and \$50,000 budgeted for 2007.

5) Time Line:

The project was initiated in October 2006 and is scheduled for completion in September 2007.

6) Status Report:

This project was initiated in October 2006.

MODELING STUDIES/ MODEL REFINEMENT

PROPOSED ASRP PROJECT:

MODFLOW Model—Improved Storativity Estimates

1) Purpose:

To help refine storativity parameters for use in the Authority's MODFLOW groundwater model.

2) Background:

The goal of this research is to refine the storativity estimates of the Edwards Aquifer using a new method that is based on the seismic efficiency of the aquifer matrix. The approach will be validated by comparison with an indirect estimate of storativity using barometric efficiency. The research is being conducted by Evelyn Mitchell, a Ph.D. student at The University of Texas at San Antonio, and her advisor, Dr. Alan Dutton.

Storativity is a basic hydrogeologic property of aquifers that describes the volume of water that can be recovered from a unit column of an aquifer, given a unit decline in hydraulic head. The accuracy of numerical models is particularly sensitive to uncertainty in storativity. Direct mea-

surements of storativity from aquifer tests are preferred, but there are few data sets available for the Edwards Aquifer. Consequently, indirect measurements, such as seismic efficiency, are used to fill the data gaps.

3) Aquifer Management Issue to be Addressed:

Research will help refine the estimates of storativity, an important parameter in the Authority's groundwater model. The model is used to evaluate the potential impacts of groundwater transfers and management scenarios

4) Estimated Costs:

Total estimated cost is \$20,000–\$10,000, of which was included in the 2006 budget. The remainder has been included in the proposed 2007 budget.

5) Time Line:

This research began in October 2006 and will be completed in December 2007.

6) Status Report:

This research began in October 2006 and will be completed in December 2007. A technical report will be prepared, detailing the numerical methodology, data, calculations, results, and interpretations.

MODELING STUDIES/ MODEL REFINEMENT

PROPOSED ASRP PROJECT:

MODFLOW Model—Recalibration of the MODFLOW Model

1) Purpose:

To recalibrate the Authority's MODFLOW Model.

2) Background:

When the USGS completed the MODFLOW model in 2004, tentative plans were in place to recalibrate it in five years. Recent studies have shown that the input data sets and the conceptual model need to be revised. The Authority's optimization technical studies have generated new data for the model, such as:

- Recharge data generated by HSPF models
- Pumping data based on meter readings at all wells in the aquifer
- Storativity estimates
- Water budget estimates in the western counties
- Barrier fault locations and effects
- Trinity Aquifer underflow
- Target well information

Authority staff will develop a program for updating, checking, and installing the new input data sets and formulating a new conceptual model of the aquifer. The new package will be reviewed by the Aquifer Science Advisory Panel (ASAP).

3) Aquifer Management Issue to be Addressed:

Refinement in the accuracy of the Authority's groundwater model.

4) Estimated Costs:

Estimated cost of model recalibration is \$90,000 over three years.

5) Time Line:

This task is projected for 2009 through 2011.

6) Status Report:

This project is planned for 2009. More details will be developed as the five-year deadline approaches.

CONCEPTUAL MODEL REFINEMENT AND FLOWPATH BEHAVIOR

PROPOSED ASRP PROJECT:

Hydrogeology of North Medina County

1) Purpose:

Evaluate groundwater flowpaths in northern Medina County.

2) Background:

The USGS has developed a conceptual model for groundwater flow in northern Medina County and northwestern Bexar County. This model assumes that a series of large displacement faults, striking northeast/southwest, act as barriers to groundwater flow and result in groundwater in this area flowing from northeast to southwest before it merges with the regional flowpath of the aquifer to emerge at Comal and San Marcos springs. This conceptual model was incorporated into the Authority's groundwater flow model. However, tracer testing in northern Bexar County indicates that large faults in the study area exert no control on the direction of groundwater flow.

The northern Medina County area is being considered for the installation of numerous water management projects such as recharge dams. Understanding the flowpaths and, therefore, the retention of groundwater in the aquifer is important for proper evaluation of recharge structures and management of the aquifer.

The purpose of this project is to initiate investigation of groundwater flowpaths in north Medina County using tra-

cer tests, synoptic water level measurements, continuous water level measurements, groundwater analyses, and other techniques. Authority staff or Authority contractors will conduct tracer tests to assess whether large-scale faults act as barriers to groundwater flow. Test sites will be selected in which injection points are located across faults from monitoring wells. Other wells will be monitored to intercept dye that may flow parallel to the faults.

3) Aquifer Management Issue to be Addressed:

Conceptual understanding of groundwater flow in northern Medina County and northwestern Bexar County to improve groundwater management strategies, as well as to improve the Authority's groundwater model will be addressed.

4) Estimated Costs:

Estimated costs for this study are \$50,000 in 2008; \$80,000 in 2009; and \$30,000 in 2010; for a total of \$160,000 over a three-year period.

5) Time Line:

This project is planned for initiation in 2008 and completion in 2010.

6) Status Report:

Authority staff will prepare a request for qualifications with a scope of work to solicit qualified consultants in 2007. Recommendations for contractor selection based on submitted statements of interests and qualification will be presented to the Research and Technology Committee and the Board of Directors for consideration in late 2007 or early 2008.

CONCEPTUAL MODEL REFINEMENT AND FLOWPATH BEHAVIOR

PROPOSED ASRP PROJECT:

Evaluation of the Edwards Aquifer in Kinney and Uvalde Counties, Phase II

1) Purpose:

Given the recommendations contained in the 2006 Kinney County/Uvalde County Groundwater Study, further study is needed in the Kinney County/Uvalde County area to delineate flowpaths and refine understanding of the conceptual model in this area.

2) Background:

In June 2006, Southwest Research Institute (SWRI) completed a study that updated the conceptual model of the groundwater systems in Uvalde County, with existing and recently collected data on hydrology, geochemistry, and structural geology, and described the hydrogeologic relationship between the Uvalde pool and the San Antonio pool of the Edwards Aquifer. The area of investigation consisted of Kinney and Uvalde counties and included the groundwater divide in Kinney County to the west and the Knippa Gap to the east. It included all of the principal aquifers in Uvalde and Kinney counties. Phase II is planned to fill data gaps that were identified in the SWRI report. Specifically the purpose of this project is to investigate floodplain flow in the Nueces River, evaluate recharge in Uvalde County, and estimate groundwater flow in the Knippa Gap. Additional tasks may be added in Kinney County, depending on the outcome of tracer tests planned there for 2006.

Floodplain Flow. Flow in the Nueces River and Frio River floodplains will be measured at locations where the rivers leave the Edwards Aquifer recharge zone. In the case of the Frio River, it is important that floodplain recharge of the Austin Chalk Aquifer be taken into consideration

when measuring floodplain flow down gradient from the Edwards Aquifer recharge zone. The floodplain flow may require a combination of surface and subsurface geophysical characterization and aquifer testing.

Evaluation of Recharge. A focused evaluation of the recharge zone at the points where the Dry Frio and Frio rivers leave the Edwards Aquifer would help resolve what parts of recharge from the Dry Frio River and Frio River basin contribute to the Uvalde pool and the San Antonio pool of the Edwards Aquifer. This evaluation would help resolve whether there is a southwest component to groundwater flow in the recharge zone east of the Frio River.

Knippa Gap. Measurement or estimation of the quantity of water flowing through the Edwards Aquifer immediately down gradient from the Knippa Gap should be refined. This refinement will require a focused structural geological analysis, water chemistry assessment, and synoptic water level survey.

3) Aquifer Management Issue to be Addressed:

Delineation of the west boundary of the Edwards Aquifer in the Kinney County/Uvalde County area will be addressed.

4) Estimated Costs:

This project is estimated to cost approximately \$60,000 in 2007 and \$30,000 in 2008. Total estimated costs are \$90,000 over two calendar years.

5) Time Line:

This project is planned for 2007. Authority staff will prepare a request for qualifications with a scope of work to solicit qualified consultants. After the Research and Technology Committee and the board of directors have approved a consultant, the staff will negotiate a contract.

6) Status Report:

This project has not been initiated.

CONCEPTUAL MODEL REFINEMENT AND FLOWPATH BEHAVIOR

PROPOSED ASRP PROJECT:

Well Hydrophysics Study

1) Purpose:

Define the range of well hydrologic properties in the karstified Edwards Aquifer.

2) Background:

Water wells in karst aquifers are noted for intersecting preferential flow features, such as fractures, faults, conduits, and caves. These flow features can affect the quantity and quality of water entering the borehole, thereby having a significant impact on design and interpretation of water quality monitoring system data, preparation and interpretation of potentiometric surface maps, and our understanding of hydrologic properties of various geologic units. In 2005 a pilot hydrophysics study was performed for the Authority by RAS Consultants indicating that discrete conduits within a monitoring well bore accounted for most water entering the well bore. In addition, even under "static" conditions, more than 300 gallons a minute of water

passed vertically down the borehole, creating a depression in the potentiometric surface of more than 20 feet.

On the basis of results of the hydrophysics pilot study, a more extensive hydrophysics program is proposed to quantify the occurrence of preferential flow features in boreholes in the aquifer and whether they are related to geologic formations or structure.

3) Aquifer Management Issue to be Addressed:

Understanding of local groundwater flow dynamics on a well-bore scale will be addressed.

4) Estimated Costs:

Authority staff estimate that this study will cost approximately \$90,000 over two years. Calendar year 2008 costs are estimated at \$50,000, and calendar year 2009 costs are estimated at \$40,000.

5) Time line:

This project is proposed for implementation in 2008 and completion in 2009.

6) Status Report:

The project is scheduled for initiation in 2008; funding will be programmed into the 2008 budget in calendar year 2007.

SUPPORT STUDIES

PROPOSED ASRP PROJECT:

Well-Plugging Study in Support of Regulatory Well Program

1) Purpose:

To evaluate effectiveness of the Authority's well-plugging regulations for the protection of water quality.

2) Background:

Authority regulations currently require the plugging of abandoned wells, which includes either the removal or perforating of any well casing and sealing of the annular space. Before the implementation of Authority regulations, wells were commonly abandoned by merely filling the well bore and casing with cement or grout and ignoring the annular space. Poor sealing of the annular space of wells, either during drilling or plugging, may be responsible for a number of groundwater contamination problems in the country.

This study proposes to evaluate the effectiveness of well-plugging methods by geophysical logging of the well before abandonment, perforating of the well casing using mechanical and chemical methods, sealing of the well bore and annular space, drilling of the annular space, geophysical logging of the well, and final abandonment of the well.

3) Aquifer Management Issue to be Addressed:

This study will evaluate the effectiveness of the Authority's well-plugging protection programs and water quality.

4) Estimated Costs:

\$60,000 in 2006.

5) Time Line:

Project initiation is scheduled for late 2006.

6) Status Report:

The project is in the initial stages of planning. Suitable wells are being identified, access privileges examined, and preliminary schedules and contracts drafted.

WATER BALANCE

PROPOSED ASRP PROJECT:

Improved Gauging at Comal Springs and San Marcos Springs

1) Purpose:

To improve discharge measurement accuracy at Comal and San Marcos springs.

2) Background:

Comal and San Marcos springs, the two largest spring systems in Texas, are critically important resources for a number of reasons. Both springs flow from the Edwards Aquifer, which supplies water to more than 1.7 million people. Also, federally listed endangered species exist in the springs and surface streams immediately fed by the springs. Because discharge numbers from Comal and San Marcos springs are incorporated into the Authority's Demand Management Critical-Period Management Rules, accurate estimation of discharge from both of these spring systems is essential for management of the aquifer to protect the federally endangered spring-dependant species. In addition, discharge data from Comal and San Marcos springs are important data sets for supporting the Authority's groundwater model.

The purpose of this study is to evaluate a new gauging system for Comal and San Marcos springs. The spring-flow quantification pilot project will involve selection of a new gauging location, as well as installation of a new generation of gauging equipment to improve the accuracy and precision of discharge measurements from Comal and San Marcos springs. Work on the project will be performed through a joint funding agreement between the Authority and USGS.

Work will be performed in three phases. Phase 1 will include initial equipment installation and operation using as many as five Acoustic Doppler Velocity Meters (ADVMs) at different locations in each spring system for a period of six to eight months. At the conclusion of the Phase 1 evaluation period, as many as two ADVMs at each spring system will be permanently placed at the most favorable locations and connected by using telemetry to obtain real-time data capabilities.

Phase 2 of the project will involve data collection and system validation and include collection of continuous velocity index data for an entire water year as a velocity-discharge rating curve is developed. Discharge at the spring lake outflows will be measured directly on periodic visits every four weeks to calibrate discharge/velocity-index ratings of each outflow site.

Phase 3 of the project will be to prepare a study report and recommendations for improving the discharge measurement system at both springs.

3) Aquifer Management Issue to be Addressed:

Improvement in discharge measurement of Comal and San Marcos springs, which are incorporated into the Authority's Demand Management Critical-Period Management Rules, and improvement of discharge data sets in support of the Authority's groundwater model will be addressed.

4) Estimated Costs:

This project is jointly funded over three years by the Authority and the USGS. Funding by year is as follows:

Year	Authority Funding	USGS Funding
2006	\$76,250	\$18,750
2007	\$60,000	\$11,250
2008	\$3,750	\$0

5) Time Line:

The USGS initiated work on this project in the spring of 2006. The project is expected to be completed in the first quarter of 2008.

6) Status Report:

The Board of Directors approved a joint funding agreement between the Authority and the USGS at the March 2006 Board meeting. The USGS has initiated Phase I of the study and installed the ADVMs at the springs and is collecting data on applicability of the ADVMs and monitoring locations. Funding has been included in the proposed 2007 budget for this project.

POOL DELINEATION

PROPOSED ASRP PROJECT:

Define and Delineate San Marcos Pool

1) Purpose:

Determine the need for a separate San Marcos Pool.

2) Background:

The Authority implements its Demand Management Critical-Period Management Rules by dividing the aquifer into pools that have their own index wells, well trigger levels, spring discharge triggers, and withdrawal reduction requirements. Authority rules currently define two pools, San Antonio and Uvalde. However, recent drought conditions have shown that Bexar County Index Well and Comal Springs discharge do not have a high correlation to discharge at San Marcos Springs, and, therefore, the potential need for a San Marcos Pool should be investigated. Currently, habitat provided by San Marcos Springs discharge may not be properly protected by trigger levels utilizing the Bexar County Index Well (J-17) or Comal Springs discharge. Consequently, Demand Management Critical-Period Management Rules for the San Antonio Pool may have a limited effect on San Marcos Springs discharge. The purpose of this project is to define and delineate a San Marcos Pool that could be the basis for rules for maintaining discharge at the springs.

Principal criteria for determining whether a San Marcos Pool is technically justified are

- Hydrogeologic conditions or geologic features indicating that a significant part of the discharge from San Marcos Springs is isolated from other pools (e.g., groundwater divide, barrier fault)
- Distance from the springs beyond which withdrawals do not appreciably affect springflow.

San Marcos Springs are the second-largest spring group in Texas, with an average historical discharge of approximately 175 cfs. Groundwater issues from six major orifices and numerous smaller openings beneath Spring Lake, which is as much as 40 feet deep. Tracer tests by the Authority show that groundwater follows discrete

flowpaths to the spring orifices. Groundwater flowing from the southwest discharges from Deep Hole, whereas groundwater flowing from the northeast discharges from Weissmuller, Hotel, Diversion, Cabomba, and others. Groundwater velocities between 1,000 and 2,500 feet per day have been measured near the springs.

San Marcos Springs discharges groundwater that bypasses Comal Springs on the upthrown side of the Comal Springs Fault and local flow from the recharge area of the Blanco River, Sink Creek, Purgatory Creek, York Creek, and Alligator Creek basins, the Guadalupe River basin east of the river that is south of the Hueco Springs Fault, and parts of Dry Comal Creek and Cibolo Creek basins.

The San Marcos Pool will be defined using a variety of hydrologic data, including continuous water levels, focused synoptic surveys, Blanco River characteristics, tracer tests, water quality analyses, and modeling. A potentiometric surface map will be developed using focused synoptic surveys and tested using tracer tests. Water quality analyses will be used to fingerprint groundwater and surface water and track its movement through the aquifer to the springs. Modeling will be used to test hypotheses, and a water balance will be developed as part of a conceptual model of the new pool.

3) Aquifer Management Issue to be Addressed:

Need for a San Marcos Pool to better manage groundwater withdrawals from the eastern parts of the aquifer will be addressed.

4) Estimated Costs:

The 2007 proposed budget includes \$120,000 for this task.

5) Time Line:

This project is planned for 2007.

6) Status Report:

Authority staff have prepared a work plan for the project and will prepare a request for qualifications with a scope of work to solicit qualified consultants in the fourth quarter of 2006. After the Research and Technology Committee and the Board of Directors have approved a consultant, the staff will negotiate a contract.

WATER BALANCE

PROPOSED ASRP PROJECT:

Guadalupe River Gain/Loss Study

1) Purpose:

To better understand the hydrologic characteristics of the Guadalupe River, including gains and losses from each aquifer, contributions of tributary streams, contributions of Comal and San Marcos springs, and recharge to the Edwards Aquifer.

2) Background:

This study is intended to build on previous work on the gains and losses along the Guadalupe River and will incorporate data being generated from existing river and spring gauging systems, as well as performing streamflow measurements where appropriate. Finally, the study will update the amount of water that is estimated to recharge the Edwards Aquifer from the Guadalupe River.

3) Aquifer Management Issue to be Addressed:

Determination of the contribution of Comal and San Marcos springs to the Guadalupe River and the amount of recharge to the Edwards Aquifer originating from the Guadalupe River will be addressed.

4) Estimated Costs:

The 2007 proposed budget includes \$75,000 for this study.

5) Time Line:

This project is proposed for implementation in 2007 and tentative completion in 2009.

6) Status Report:

Staff will begin the contracting and approval process for this study upon approval of the 2007 budget.

REPRESENTATIVE GROUNDWATER MONITORING

PROPOSED ASRP PROJECT:

Pilot Study to Improve Analytical Water Data through Passive Sampling

1) Purpose:

To evaluate the use of passive sampling devices to improve the Authority's water quality sampling program.

2) Background:

This project will examine the possibility that improvements may be made to the quality and accuracy of the Authority's analytical water quality sampling data by using passive sampling techniques. One of the problems with obtaining representative samples from the Edwards or similar aquifers is the difficulty of collecting a sample concurrent with the presence of a potential contaminant. Often in a karst system, groundwater velocities may be high (compared with those of porous media systems) and depend on flowpaths associated with the observation point. Tracer studies have indicated groundwater velocities to several thousand feet per day in parts of the Edwards Aquifer. For example, many times when a contaminant of concern is detected at a well or spring location, subsequent confirmation samples conducted weeks later frequently do not detect a continued presence of the compound in question. Tracer studies indicate contaminant behavior in many locations to resemble that of a flood hydrograph, in which, after the contaminant is first detected, its concentration will increase quickly, and drop drastically soon thereafter. Frequently this behavior (breakthrough) will occur over as little as 24 to 48 hours.

Exceptions do occur at times, depending on the type and concentration of the contaminant, aquifer characteristics, etc. Compounds that have a density greater than water and that do not readily dissolve in water will often provide a continuous source of contamination in an area. For example, tetrachlorethylene (PCE) commonly behaves

this way. PCE will tend to collect as "free product" in a location and provide a continuous contaminant source by slowly dissolving into the water column.

For purposes of this proposed study, several existing innovative technologies may apply in improving the "representativeness" of the Authority's water quality samples. Sampling techniques utilizing media that will "sorb" contaminants, such as the Goresorber®, will be deployed in hopes that contaminants passing through the system will be detected. Other technologies will also be examined for their applicability to this study, such as:

- passive diffusion bags
- regenerated-cellulose dialysis membranes
- nylon-screen passive diffusion samplers
- rigid porous polyethylene samplers
- semipermeable membrane devices
- Goresorber® modules

This study will examine and field test the efficacy of various passive sampling technologies with the goal of a better understanding of contaminant behavior in the Edwards Aquifer.

3) Aquifer Management Issue to be Addressed:

Design of a representative water quality sampling program for the Edwards Aquifer will be addressed.

4) Estimated Costs:

The proposed 2007 Authority budget includes \$50,000 for this study.

5) Time Line:

This project is scheduled for initiation early in 2007, with completion anticipated in early 2008.

6) Status Report:

Authority staff have installed a limited number of passive samplers in northern Bexar County and have tested them to determine whether they are suitable for use in the Edwards Aquifer. Results are pending.

REPRESENTATIVE GROUNDWATER MONITORING

PROPOSED ASRP PROJECT:

Bacterial and Pharmaceutical Study

1) Purpose:

To identify emerging water quality issues in the Edwards Aquifer.

2) Background:

This study involves two potential contaminants of the Edwards Aquifer—bacteria and pharmaceuticals and personal care products (PPCPs). Bacteria wash into the aquifer during storm water recharge events, and both bacteria and PPCPs are likely to enter the aquifer with septic tank effluent. Both bacteria and PPCPs may also originate from either human or animal waste. Samples of groundwater collected after recent sewage spills have revealed chronic bacterial contamination in some areas. Identifying the sources will help us determine whether regulatory controls are necessary. Because groundwater from the Edwards Aquifer has never been sampled and tested for PPCPs, the purpose of the second part of this study is to determine whether PPCPs are present in the Edwards Aquifer.

Recently, raw sewage leaked from a lift station and entered the aquifer in the recharge zone. Subsequent sampling did not identify it conclusively, but some well samples contained high counts of total coliform and fecal strep. Routine analyses do not identify the source of the bacteria, but doing so may be possible through recent advances in microbiology to determine whether it originated from humans or animals. Researchers will utilize groundwater samples to enumerate bacteria populations and examine the DNA to determine the origin.

The most likely source of PPCPs is their excretion by humans in on-site sanitary systems (OSSS). Because of the unlikelihood that routine grab samples from any well will contain PPCPs, one or more wells will be identified that have a relatively high probability of PPCPs. For example, wells close to a large drain field, in a development with septic tanks, or near an area that disposes of treated effluent by spray irrigation. The wells may be sampled and analyzed for nitrate or bacteria to determine whether they are intercepting effluent. Samples may be collected during a runoff event to intercept contaminated storm water.

3) Aquifer Management Issue to be Addressed:

This study will prepare a baseline evaluation of PPCPs in the aquifer.

4) Estimated Costs:

There is \$10,000 in the 2006 budget for this study and an additional \$10,000 included in the proposed 2007 budget.

5) Time Line:

This study is planned for 2006 and 2007.

6) Status Report:

Staff is preparing a letter agreement with Dr. Adria Bodour at The University of Texas at San Antonio.

RECHARGE VARIABLES

PROPOSED ASRP PROJECT:

Weather Station Installations to Calculate Evapotranspiration Rates in the Region

1) Purpose:

To calculate evapotranspiration rates in the Edwards Aquifer region for improving agricultural irrigation efficiencies.

2) Background:

Conservation is and has been an important program component at the Edwards Aquifer Authority since its creation. Various programs have been developed and promoted as part of that commitment. Installation of weather stations to calculate evapotranspiration rates is one of these programs whose goal is to help regional farmers to improve conservation practices.

In recent years, the Authority has encouraged irrigators to install pivot irrigation systems as a best management practice to conserve groundwater when irrigating crops. In addition, the Authority has funded research at the Texas A&M Research Station in Uvalde, Texas, to develop crop coefficients for optimizing irrigation water. Providing

potential evapotranspiration (PET) for regional irrigators will optimize pivot systems in the region. The Authority has provided funding in this fiscal year to establish three stations in Uvalde, Medina, and Bexar counties.

3) Aquifer Management Issue to be Addressed:

Improvement of irrigation efficiencies among irrigators will be addressed.

4) Estimated Costs:

For 2006, approximately \$15,000. Additional costs of approximately \$5,000 are anticipated in late 2006 or early 2007.

5) Time Line:

This project is scheduled for implementation in 2006 and 2007.

6) Status Report:

Purchase of the sensors required at the sites is under way and is being facilitated by Global Water, Inc. Software work is needed to integrate weather station sensors into the EAA's real-time system. Software bids are currently being solicited, with selection projected to be completed by the end of September 2006. Software implementation (programming of software to facilitate instrument use) should take approximately four weeks. Hardware installation will occur as soon as instrumentation is delivered.

Appendix B

Detailed Descriptions of Active OTS Projects

COMPREHENSIVE AND CRITICAL-PERIOD MONITORING OF THE COMAL STRINGS AND SAN MARCOS SPRINGS AQUATIC ECOSYSTEMS ["VARIABLE FLOW" STUDY]

Background Information

In February 2005, the board approved a three-year contract with a consulting team headed by BIO-WEST, Inc., for continuation of aquatic ecosystem monitoring. The comprehensive monitoring work for Comal and San Marcos springs aquatic ecosystems is designed to gather data pursuant to a schedule prescribed in an established monitoring plan. The critical-period monitoring work is designed to collect data during extreme high and extreme low flow conditions. The Authority's ongoing monitoring provides the most current and comprehensive data set for the Comal and San Marcos aquatic ecosystems.

The consulting team consists of members of the BIO-WEST team that completed the previous contract in February 2005. In addition, BIO-WEST has added ZARA Environmental (a historically underutilized business) to the team to provide additional support during monitoring for aquatic invertebrate and salamander work. Contract 05-194-GM continues the comprehensive and critical-period monitoring of the Comal and upper San Marcos springs/river aquatic ecosystems through February 2008.

Status Report

This study is in progress. Critical-period monitoring was triggered in July when reduced flows in the San Marcos River reached the first level previously agreed to with the U.S. Fish & Wildlife Service and Texas Parks & Wildlife. The BIO-WEST team has been in the field monitoring habitat and the threatened and endangered species and water quality parameters. As flow approached 100 cfs in the San Marcos River, low flow and recreation appeared to be having an impact in shallow areas. Judging by observation (data not analyzed at this time), threatened and

endangered animal species do not seem to have been significantly impacted by the decreased flow, but some endangered Texas wild-rice clumps are showing signs of stress.

The Texas wild-rice clumps that are showing stress are those that are growing in areas that have been filled in by large amounts of sediments washed into the river during rainfall runoff. The sediments have decreased the depth of the stream bed, causing the Texas wild-rice clumps to be closer to the surface, where they are more vulnerable to low flows, drying, sunlight intensity, sexual reproduction (the plant dies after sexual reproduction), and unintentional recreational impacts (trampling, tearing, etc.). The BIO-WEST team is carefully monitoring springflows at both spring ecosystems in the event that additional critical-period sampling is necessary.

EDWARDS AQUIFER COMPUTER MODEL* CONTINUING SUPPORT WORK

WATER RESOURCES MANAGEMENT MODULE FOR THE EDWARDS AQUIFER MODFLOW MODEL

Background Information

Under previous contracts with the Authority, HydroGeoLogic, Inc., developed the Groundwater Management Package to enable MODFLOW to simulate the Authority's critical-period rules and subsequently modified the modules to be compatible with MODFLOW 2000 (see Section 3). HydroGeoLogic was retained in April 2006 to upgrade the management modules to simulate the junior/senior rights being considered by the Authority's board. HydroGeoLogic will prepare addenda to the quality plan and the reference manual that were prepared for the MODFLOW 2000 version.

*Model Construction by USGS: Please see Completed Studies in Section 3.

Status Report

HydroGeoLogic submitted revised code for modeling junior rights. It creates two records in the WEL file for each well, one for the junior right and one for the senior right, that can be controlled independently by rules. Authority staff will test the new code. Revised documentation will be submitted by August 2006.

MODEL-RELATED SUPPORT WORK BY THE EDWARDS AQUIFER AUTHORITY

Background Information

The Authority currently coordinates the synoptic water level project in support of the modeling effort. The Authority also completed a well survey project in December 2003 in support of the model (see description in completed projects).

Synoptic Water Level Project (SWLP)

The SWLP was conceived by the OTS Technical Advisory Group (TAG) to create potentiometric surface maps for assisting with modeling and aquifer flowpath studies. Staff from the Authority, SAWS, USGS, and Barton Springs/Edwards Aquifer Conservation District (BS/EACD) measure aquifer water levels in approximately 220 wells over the Edwards Aquifer region, usually within one week. For 2006, two regional and three focused events were performed. The focused events are in the early stages of development and are limited to Comal and Hays counties at this time.

ENHANCED CHARACTERIZATION AND REPRESENTATION OF FLOW THROUGH KARST AQUIFERS

Background Information

On June 14, 2005, the Board of Directors approved the contract with SwRI® for phase 2 of the project titled *Enhanced Characterization and Representation of Flow through Karst Aquifers*. The purpose of phase 2 is to con-

tinue testing MODFLOW-DCM (dual conductivity module) in order to enable MODFLOW to simulate groundwater flow in karst aquifers. This is a jointly funded project by the Southwest Florida Water Management District and the Authority.

The project consists of

- Task 1. Code Refinement. SwRI® will add transitioning between laminar and turbulent flow and adaptive time-stepping modeling into MODFLOW-DCM and create a user's manual and modeling package.
- Task 2. Barton Springs Demonstration Simulations. MODFLOW-DCM will be tested by modeling a karst aquifer having a relatively well characterized conduit system.
- Task 3. Floridan Aquifer Demonstration Simulations. MODFLOW-DCM will be tested by modeling a karst aquifer having relatively high matrix permeability.
- Task 4. Subtask 4.1 (Option 1): Preparation of a Graphical User Interface with Environmental Simulations International or
Subtask 4.2 (Option 2): Evaluation of the Costs and Benefits of Developing a Three-Dimensional MODFLOW-DCM.
- Task 5. Technical Exchanges, Reporting, and Meetings. This task includes quarterly status report, final technical report, team meetings, and support for the Authority and SWFWMD staff for using MODFLOW-DCM. The final report is due September 1, 2006.

Status Report

This study is in progress. SwRI® has made progress on solving dry cell issues associated with MODFLOW. The solution involves using a solver based on the Newton-Raphson method instead of the Picard method. The Authority is extending the contract period to March 31, 2007, to allow additional time to solve these problems.

HYDROLOGIC ASSESSMENT OF FLOWPATHS—NORTH MEDINA COUNTY

In December 2000, the SAWS board approved a contract with the USGS to perform data collection and evaluation tasks for the Northern Medina County Flowpath Study. The Authority is not involved as a cooperator in the SAWS/USGS agreement; however, Authority staff provide support as requested. As part of the study, the USGS installed new monitoring wells in Medina County on the recharge zone. The Authority is not aware of budget information for this project.

Status Report

This study is in progress. The USGS is finalizing the report.

FOCUSED FLOWPATH STUDIES

TRACER TESTING OF AQUIFER FLOWPATHS—COMAL SPRINGS, SAN MARCOS SPRINGS, NORTHERN BEXAR COUNTY

Background Information—Comal Springs

Authority staff, cooperating agencies, and volunteers completed a tracer test in the Comal Springs area between March 22 and April 12, 2002. The test was directed by the Authority with assistance from New Braunfels Utilities, City of New Braunfels—Parks and Recreation Department, USGS, University of Minnesota, The University of Texas at Austin, The University of Texas at San Antonio, Texas A&M University—College Station (TAMU), and others. The test showed that discrete groundwater flowpaths to each of the major springs are in the Landa Park area. Dye injected into the Panther Canyon well appeared in Spring Run 3 rather than in Spring Runs 1 and 2, which are closer to the well. Dye injected into the LCRA well appeared in Spring 7, springs beneath the lake, and springs on Spring Island.

In July 2003, the board approved a contract with George Veni and Associates (GVA) for tracer testing, storm water monitoring, and water sampling at several sites, including Comal Springs. In September 2004, the board approved a one-year renewal of the contract.

Status Report—Comal Springs

This study is in progress. The Authority and GVA are focusing on tracer tests in Bexar County and will resume in Comal County later in the year.

Background Information—San Marcos Springs

On September 16, 2002, Authority staff injected dyes at Ezell's Cave and Primer's Fissure, which are located just southwest of San Marcos. No dye from Primer's Fissure was detected at San Marcos Springs probably because insufficient dye was used in order to avoid causing visible dye detection in nearby private wells. Dye from Ezell's Cave was detected in Wonder Cave after two days, after six days at an artesian well at Texas State University—San Marcos, and after 11 days at Spring Lake. Dye was detected at Diversion and Deep Hole springs in Spring Lake, but not in Weissmuller, Salt & Pepper, or Crater springs. These findings represent groundwater velocities of about 1,000 feet per day, which is not unusual for karst conditions.

In January 2004, GVA and Authority staff injected dyes at Ezell's Cave, Primer's Fissure, and Rattlesnake Cave. Dye from Primer's Fissure and Ezell's Cave was subsequently detected at Deep and Catfish springs in Spring Lake. Dye from Rattlesnake cave was detected at other springs in Spring Lake, and all three dyes were detected in the lake outfall. The test revealed that there are discrete flowpaths to each of the spring orifices and groundwater flows of almost 3,500 feet per day to the springs.

Status Report—San Marcos Springs

The study is in progress. GVA staff restarted autosamplers at San Marcos springs after dye from the Dakota Ranch Cave that was injected on October 25, 2005, was detected in May 2006 at Weissmuller, Diversion, and Ossified Forest springs. However, no additional dye was detected. Authority staff and GVA staff will initiate the next injection near Sink Creek when the Authority receives permission from the property owner.

Background Information—Northern Bexar County

During the first year of the GVA contract, preliminary information such as identifying potential dye injection and monitoring points was obtained; however, no dye injections were performed. The first group of tracer tests, under the

second year of the GVA contract, was performed in the Panther Springs Creek basin in northern Bexar County. The purpose of these tests was to measure groundwater velocity and to identify groundwater flowpaths in a part of the recharge zone. Seven tracer tests were performed in three phases in the area of Blanco Road and Loop 1604. Wells in both the Edwards and the Trinity aquifers were monitored. Tracer test results showed that the dye traveled at apparent velocities of up to 13,000 feet per day in flowpaths associated with Panther Springs Creek. In addition, dyes crossed several northeast-southwest-trending faults in which members of the Edwards and Glen Rose formations are juxtaposed. Some of the faults have hundreds of feet of vertical displacement but did not present a barrier to groundwater flow. Consequently, the tracer tests show excellent communication between groundwater in the upper Glen Rose Limestone (Trinity Aquifer) and the Edwards Limestone in northern Bexar County.

Status Report—Northern Bexar County

Dye was injected into Stealth Cave and Lewis Valley Cave at Camp Bullis on July 27, 2006. A small amount of dye was injected to avoid coloring the Camp Bullis water supply wells. Because no dye has been detected to date, a larger amount will be injected soon. The objective of these tests is to trace dye to Shavano Park water supply wells. Uranine that was placed on the ground surface near Dynamite Cave was detected in an Edwards water supply well at the Club at Sonterra in June 2006. Eosin from the injection in Dynamite Cave had already been detected in that well. George Veni and Associates continue to monitor wells downgradient from the injection points.

Background Information—Uvalde and Kinney County

The purpose of this project is to identify groundwater flowpaths and velocities near Pinto, Las Moras, and Leona Springs. In addition, the Authority would like to identify the basin boundaries, as well as boundaries for these springs and for the groundwater divide between Uvalde and Kinney County pools. Dye will be injected in karst features or wells upgradient from the springs, and groundwater samples will be collected from the springs and other wells in the area. The tracer tests will be designed from findings of previous research in the area. The Authority will work with the Kinney County Groundwater and Uvalde Underground Water Conservation Districts to gain access to monitoring or injection points.

Status Report—Uvalde and Kinney County

Authority and GVA staff are planning a tracer test near Grass Valley and Pinto Springs in Kinney County for late 2006 to test the hypotheses presented by SWRI® in their recent report (see Completed Studies below).

NOBLE AND ACTIVE GAS SAMPLING IN THE KNIPPA GAP REGION

In March 2005, the board approved a joint funding agreement with the USGS to perform analyses of noble gases, active gases, and groundwater dating geochemistry to better understand groundwater flow in the Knippa Gap region of the Edwards Aquifer. These techniques will assist in identifying multiple water sources, recharge areas, groundwater mixing, and unique elemental and isotopic "signatures" of groundwater sources and groundwater-rock interactions. In addition, these data will help in predicting hydrologic and geochemical responses in major flowpaths downgradient of the Knippa Gap region.

To perform the study, the Survey will perform the following tasks:

Task 1. Inventory of Wells

Wells suitable for the study will be inventoried. During the well-inventory task, the USGS will obtain permission to access the wells, determine well-construction details, and identify any unique requirements for connecting sampling equipment to the study wells. Study wells will be identified as early as possible in 2005, prior to irrigation pump activation in the spring or early summer.

Task 2. Water Well Sampling

A total of 15 well-water gas samples will be collected for laboratory analysis. Water samples will be collected from each study well after the appropriate volume of water has been purged and after field parameters have stabilized. Field parameters measured during well purging will include pH, ORP (oxidation-reduction potential) conductivity, dissolved oxygen (barometric pressure corrected dissolved oxygen), and temperature. Samples collected will be appropriately containerized, preserved, and shipped to the Survey's Noble Gas Laboratory and Geochronology Laboratory (Isotopic/Geochronology Core Operations) located in Denver, Colorado, for analysis.

With one exception noted below, selected wells will penetrate only the uppermost freshwater parts of the Edwards Aquifer, providing a common baseline for regional comparison of the upper part of the aquifer. In addition to samples from the uppermost freshwater part of the Edwards Aquifer, the study will also include fluid logging and discrete interval sampling of one well fully penetrating the aquifer. The 15 well-water gas samples will be collected from the following well sites:

- five samples and fluid logging: Uvalde No. 2, a freshwater monitoring well in the Uvalde freshwater/saline water monitoring well transect (Well No. YP-44-50-902)
- one sample: Uvalde Index Well (Well No. YP-69-50-302, *note: well has no pump*)
- nine samples: nine well locations to be determined by the USGS pursuant to Task 1. The nine water samples from these wells will be collected from the upper part of the Edwards Aquifer. In addition, wells will be selected to provide regional coverage of flow and will be located south of the recharge zone west of the Knippa Gap and to the south of the recharge zone on the east side of the Knippa Gap.

Task 3. Laboratory Analysis

Laboratory analysis will include the following noble gas and active gas molecular and isotopic compositions: He, Ne, Ar, CO₂, CH₄, N₂, O₂, (and, possibly, C_nH_m, H₂S, SO₂), as well as ³H, ³He, ⁴He, ²⁰Ne, ²¹Ne, ²²Ne, ³⁶Ar, and ⁴⁰Ar. Apparent ³H-³He age, excess air, and recharge temperature will be computed, as well as radiogenic and nucleogenic isotopic contributions to helium and neon.

Analytical work and laboratory data results will be completed in 2006.

Task 4. Final Report

A final report of all data, including an interpretation, will be provided by December 31, 2006. Recommendations for further investigations will be offered in the final report on the basis of results of this study.

Status Report

This study is in progress. The USGS has received most of the analyses and is drafting a report of their findings.

RANGE MANAGEMENT STUDIES

PAIRED WATERSHED STUDY— HONEY CREEK AND GOVERNMENT CANYON STATE NATURAL AREAS

Background Information

In October 1998, the board approved an eight-year joint funding agreement with the Natural Resource Conservation Service (NRCS) to assess the water quality and water quantity effects of removing *Ashe juniper* trees from the Edwards Aquifer drainage area and recharge zone. Two drainage basins in the Honey Creek State Natural Area (HCSNA) and one drainage basin in the Government Canyon State Natural Area (GCSNA) are being utilized for the study.

The Authority contributes \$25,000 per year to this \$300,000 per year study. The NRCS, USGS, SAWS and the Authority have been primary cooperators on the project. The Texas Parks and Wildlife Department (TPWD) is cooperating in the study by providing access to the study sites. The board considers funding for the project annually. On February 8, 2005, the board approved Authority participation in the project for 2005. The cooperative agreement for funding is through fiscal year 2006. This is the last year of Authority participation in the project, which is scheduled to be completed in 2006.

STATUS REPORT

Government Canyon Site

This study is in progress. Monitoring activities at the GCSNA were delayed because of concerns of the USFWS regarding habitat for the golden-cheeked warbler (GCW). USFWS was concerned that brush clearing (treatment) for the project would diminish GCW habitat. In October 2003, the USFWS provided a letter of review to TPWD approving the selective clearing of 192 acres of *Ashe juniper* in the 480-acre Laurel Canyon watershed part of GCSNA. The selective brush removal will reduce the canopy by 50 percent and leave the mature, single-stem *Ashe juniper*.

A treatment method proposal has been submitted by TPWD to USFWS, which specifies the method of treatment. Location of the critical bird habitat has been marked

so that monitoring may be conducted for an additional year before brush treatment begins. A meeting was held at GCSNA on December 5, 2005, with the USGS, NRCS, and the GCSNA staff. During the meeting NRCS members said that they were planning to start treatment in October 2006. Additional time for post-treatment monitoring may be required because of the delayed start date for pretreatment monitoring and brush treatment.

According to the USGS and NRCS, all monitoring equipment indicated in the project work plan is installed and operational, and data collection is on going. Some equipment has been damaged because of weather, but it has been repaired or replaced with little data loss. All weather stations were serviced and updated. Data collection is continuing on schedule, but unfortunately, because of the lack of rain, no runoff has been measured. TPWD and NRCS staff will be working at Government Canyon to mark brush management sites this month, and selective brush management was begun at Government Canyon in September 2006.

Honey Creek Site

This study is in progress. According to the USGS and NRCS, all weather and watershed monitoring equipment indicated in the project work plan is installed and operational and data collection is on-going. The USGS continues to collect baseline data from the monitoring equipment. Brush removal in the treatment watershed was initiated in November 2003. As of July 25, 2005, selective brush management was complete on the Honey Creek site and post-treatment is now being done. Rainfall, streamflow, and ET data were collected from two major rain events that occurred during 2005.

The University of Texas at San Antonio, Center for Water Research, is assisting the USGS with data storage from both research sites and with data distribution. In 2005, the USGS plans to complete its data quality assurance review and release all pretreatment data. NRCS reports that all work for this site is on schedule, and pretreatment data have been compiled. A report was provided to all project partners in December 2005. At present, the study is going through the process of collecting post-treatment data. All weather stations were serviced and updated. Data collection is continuing on schedule, but unfortunately, because of the lack of rain, no runoff has been measured.

AUGMENTING GROUNDWATER RECHARGE THROUGH BRUSH CONTROL: A FEASIBILITY STUDY

Background Information

On September 9, 2003, the board approved a four-year, three-month (51-month) interlocal cooperation agreement (ICA) between the Authority and Texas Agricultural Experiment Station—Texas A&M University (TAMU). The purpose of the ICA is to determine whether recharge in the Edwards Aquifer Recharge Zone may be enhanced through reduction of *Ashe juniper* and other woody species (brush), and, if so, to what extent. The study will accomplish the following:

- Establish a quantitative link between the dynamics of precipitation and groundwater recharge through monitoring recharge in shallow caves prior to brush removal. Doing so will require approximately one year of monitoring several natural or artificial rainfall simulation tests, limited tracer testing, and geochemical analyses.
- After removing brush from the ground surface in the watershed of the cave, determine the extent to which the precipitation/recharge relationship has changed. Any difference in recharge should be directly attributable to changes in brush cover at the surface.
- If a change is noted, an attempt will be made to establish natural grass to determine what, if any, change occurs in recharge.

Two caves at Camp Bullis (Headquarters Cave and Bunny Hole Cave) have been selected as study sites. The caves were selected because of their accessibility and shallow depth.

Status Report

The study is in progress. Continuous monitoring of precipitation and recharge is on-going at both cave sites. Within the caves are several different tipping buckets that measure the amount of water captured by the collection systems. Because several of the tipping buckets have malfunctioned in the harsh cave environment, they have now all been redesigned so that all of the moving parts are made out of stainless steel. On the surface above Bunny Hole Cave, tree stem flow and canopy through-fall collectors are installed and attached to rain gauges. All of

the instruments are connected to data loggers. Work continues to refine and modify the water collection systems in the caves. Solar panels were installed in September 2005 for the surface water collection system.

In September 2004, a weather station and additional equipment required to simulate a rain event were installed at Bunny Hole Cave. The equipment consisted of water storage tanks and rainfall simulation masts, and a rainfall simulation experiment was conducted using the additional equipment. During this experiment, a total of 3,895 gallons, or 14.744 cubic meters, of water was sprayed above the cave area. Analysis of the data revealed that approximately 10.372 cubic meters, or 70.35% of the total rainfall applied reached the land surface as the through-fall component. Stem flow was measured at 0.123 cubic meters, or 0.89% of the total rainfall applied. Recharge collected inside the cave from the drip collectors accounted for 0.428 cubic meters, or 2.9% of the total rainfall applied.

November 2004 was an exceptionally wet month. Data collected during the end of 2004 are being evaluated to determine how well the data collection system performed and how responsive the site is to recharge from natural precipitation. Staff has been experiencing problems with the air temperature/relative humidity probes, in that readings have been drifting and giving false readings. In February 2005 a new type of air temperature probe was installed in both caves. An original temperature probe was left in Headquarters Cave in order to compare the trends of the two types of probes. Data were collected and downloaded in May 2005 from Bunny Hole and Headquarters caves. Because 2005 ended as a dry year with few rain events, there are very few collection data. A detailed analysis of the field data collected during 2004 and 2005 is being conducted.

Rainfall has been simulated at both sites as late as August 2005. The August rainfall simulation replicated an actual rain event, which had occurred on site. A preliminary evaluation of the data indicates a close correlation of measurements between a natural rain event and a simulation. A simulation at Headquarters Cave demonstrated that water infiltrates into Headquarters Cave from areas where there are no surface indications of the cave's presence. A simulation at Bunny Hole Cave indicated significant water infiltration into the cave within ten minutes. Surface runoff collectors were installed in July 2005 at Bunny Hole Cave and at Headquarters

Cave, which will measure the amount of runoff water entering the caves. Water budgets are currently being developed for each cave. Solar panels have been upgraded to help provide more power for the amount of monitoring equipment.

Pilot-study tracer tests were also conducted (at an off-site location) to determine the appropriate amount of dye needed to demonstrate infiltration of water in settings similar to those of the study sites.

Field activities during March and April 2006 include site inspections, data download, and planning summer rainfall simulations. On April 26, 2006, Dr. Brad Wilcox discussed the current status of the project, described current data collection, and briefed the Research and Technology Committee on preliminary findings. A comprehensive data analysis and summary were prepared and submitted to EAA for evaluation.

Current Activities:

- 1) Rainfall simulation: A large-scale simulation experiment was conducted at Headquarters Cave from July 24 through July 28. More than three tanker-loads of water was applied above the cave to gain a better understanding of contributing areas, travel times, and recharge as a percent of the water budget.
- 2) Site maintenance and downloading data.
- 3) Data management: programming is being completed to allow for easier and more efficient management of the data.

RECHARGE AND RECIRCULATION

Background Information

In April 2004, the board approved a contract between the Authority and Todd Engineers for analysis of the concept of recharge and recirculation (R&R). A principal tool of the analysis is the MODFLOW model of the Edwards Aquifer that has been prepared by the USGS. Application of this model will enable multiple scenarios to be investigated regarding how recharge locations and volumes impact water levels and springflows. With these data it will then be possible to evaluate the feasibility of various water-collection, storage, and transport facilities.

The study will be conducted in four phases over a period of approximately three years:

- | | |
|---------|---|
| Phase 1 | Definition of R&R Alternatives
(completed in September 2004) |
| Phase 2 | Computer Modeling of R&R
Alternatives (completed in
mid-May 2005) |
| Phase 3 | Sizing of R&R Facilities |
| Phase 4 | Summary, Recommendations, and
Report Preparation |

Status Report

The SAWS Water Resources Committee voted on August 10, 2006, to send the Phase 3 contract to their board for consideration. The Authority Board of Directors heard a presentation about R&R from Director Carol Patterson on August 8, 2006, and discussed it further during their workshop later in the month.

Appendix C

Detailed Descriptions of Completed OTS Projects

ASSESSMENT OF FACTORS INFLUENCING TEXAS WILD-RICE (*ZIZANIA TEXANA*) SEXUAL AND ASEXUAL REPRODUCTION

Background Information

In December 2000, the board approved a three-year joint funding agreement (JFA) with the U.S. Fish and Wildlife Service (USFWS), San Marcos National Fish Hatchery & Technology Center (NFHTC) to assess reproduction requirements for Texas wild-rice and to assist in the evaluation of potential impacts from aquifer optimization strategies. The JFA was amended in November 2003 to extend the completion date to June 2004. The NFHTC performed the necessary laboratory and field analyses to identify factors that influence sexual and asexual reproduction in Texas wild-rice.

It was shown that Texas wild-rice does not self-pollinate and that the pollen does not travel long distances. This fact is significant because it means that genetic diversity is required in the wild-rice stands to assure that there will be opportunities for sexual reproduction. It was also found that viable seeds might sink immediately, providing the opportunity for new plants in the general area of the stand. Some viable seeds were found to float downstream, an activity essential to the production of wild-rice stands in other areas of the river.

Status Report

This study is complete. The final report was submitted in June 2004. Results of the final report were presented to the Research and Technology Committee in August 2004 and to the board in October 2004.

ASSESSMENT OF INSTREAM FLOW AND HABITAT REQUIREMENTS FOR CAGLE'S MAP TURTLE (*GRAPTEMYS CAGLEI*)

Background Information

In April 2000, the board approved a two-year contract with West Texas A&M University (WTAMU) for this study.

The study investigated instream flow requirements and basic habitat characteristics of the turtle, which may be warranted for listing on the Endangered Species List. In February 2001, USFWS staff indicated that the Cagle's Map Turtle (Cagle's) is still a candidate for listing as an endangered species, although listing the species is not a priority. The USFWS may propose the turtle for listing at a later date.

Status Report

This study is complete. The Cagle's Map turtle team submitted their final report in April 2002. The Research and Technology Committee received a report on the project at their June 2002 meeting.

(Note: Dr. Flavius Killebrew, the primary investigator for this study is no longer at WTAMU. Dr. Killebrew is now the president of Corpus Christi-A&M.)

The final report indicates that the team found Cagle's Map turtles in their historical range in the Guadalupe River from the upper Guadalupe River (near Ingram) to the lower Guadalupe River (near Tivoli). Populations in the upper and lower Guadalupe River vary according to the specific area. The turtle's population appears to be steady (declining in one area), judging by comparisons of population data from this study with those of other studies. Cagle's Map Turtle appears to be impacted by physical obstructions in the river (low-water crossings and dams) more than varying flow regimes. The turtle populations are isolated even further by obstructions in the upper Guadalupe River. The turtles were not found in large reservoirs.

COMPREHENSIVE AND CRITICAL-PERIOD MONITORING OF THE COMAL SPRINGS AND SAN MARCOS SPRINGS AQUATIC ECOSYSTEMS ("VARIABLE FLOW" STUDY)

Background Information

In February 2001, the board approved a two-year contract with a consulting team headed by BIO-WEST, Inc., for continuation of aquatic ecosystem monitoring. The consulting team consists of the members of the PBS&J team, which

initiated the work (Phase 1) in 2000. Phase 1 involved development of the original variable flow-monitoring plan. Phase 2 (the current phase) is for the implementation of the monitoring plan. The current contract for continuation of the comprehensive and critical-period monitoring of the Comal and upper San Marcos Springs/River aquatic ecosystems extends through February 2005.

The current contract was amended eight times as follows:

- | | |
|-------------|--|
| Amendment 1 | Added work to examine the potential habitat of the Comal Springs riffle beetle (June 2001). |
| Amendment 2 | Added high-flow trigger levels for critical-period monitoring work (September 2001). |
| Amendment 3 | Added laboratory studies for the effects of temperature on fountain darter and Comal Springs riffle beetle response to flow variations (October 2001). |
| Amendment 4 | Extended a report deadline (June 2002). |
| Amendment 5 | Extended the contract through February 2004 (February 2003). |
| Amendment 6 | Modified the Monitoring Plan on the basis of the past two years of data collection, to ensure efficient and cost effective data collection (April 2003). |
| Amendment 7 | Added laboratory studies on the effect of low flows on aquatic vegetation that is the prime habitat for endangered species (May 2003). |
| Amendment 8 | Extended the contract through February 2005 (December 2003). |

The comprehensive monitoring work for the Comal and San Marcos springs aquatic ecosystems is designed to gather data pursuant to a schedule prescribed in the monitoring plan. The critical-period monitoring work is designed for data to be collected during extreme high and extreme low flow conditions. The monitoring work is an ongoing project and has been extended through February 2005 (Amendment 8). The Authority's ongoing monitoring provides the most current and comprehensive data set for the Comal and San Marcos aquatic ecosystems. The data collected over the first two years of the contract were used to modify the monitoring plan in 2003 (Amendment 6) to assure that the project be cost efficient while the best available data were being collected. Under the modified sampling plan, nets placed over several of

the major Comal Springs orifices have collected Peck's Cave amphipods and Comal Springs dryopid beetles. This collection is important because it indicates that the endangered invertebrates are living within the aquifer and not just in associated surface waters.

Amendment 1 added work to evaluate potential habitat for the Comal Springs riffle beetle (CSRB) in Landa Lake. The work was initiated in June 2001 and completed in January 2002. This work is significant because it documents an increase in the known range for the CSRB in Landa Lake. The CSRB was once thought to be found only in major spring runs. BIO-WEST found CSRB in other springs and spring runs, on the shore of Landa Lake (in an area of additional springs), and at spring orifices in the lake as deep as approximately six feet. CSRBs have been found in areas that were dried out as recently as 1996. Additional research conducted by the U.S. Fish & Wildlife Service's San Marcos National Fish Hatchery & Technology Center (NFHTC) has revealed numerous CSRBs in the spring orifices in Spring Lake (San Marcos Springs aquatic ecosystem). This discovery expands the known range of the CSRB.

Amendment 3 added laboratory studies to evaluate the impact of temperature on fountain darter reproduction and possible low-flow survival tactics of the CSRB. This study was initiated in September 2001 and completed in August 2002. The study of temperature impacts on fountain darter reproduction was conducted on healthy fish, as well as heavily parasitized fish (gill parasites). Presence of the gill parasites did not have an apparent effect on fountain darter reproduction. Fluctuating temperatures did have some effect on fountain darter reproduction, with a significant reduction when the water temperature was 28° to 30° Celsius (approximately 82.4°–86.0° Fahrenheit). The laboratory studies on possible low-flow survival tactics of the CSRB found that the beetle tends to move toward the source of water flow, either downward or laterally through diverse substrates. The CSRB was found to move through very small, interstitial spaces in the substrate. This research suggests that it is possible that the beetles burrowed into the streambed and spring upwellings during drought conditions.

Amendment 7 added laboratory studies to evaluate the effect of low flow on the aquatic vegetation that is the prime habitat of the endangered species. The work was completed in February 2004, and the results were reviewed with the Research and Technology Committee on April 28, 2004. The experiment used plants from the San Marcos and the Comal Springs aquatic ecosystems. The major aquatic plant species that were found to compose

the preferred habitat of the fountain darter were evaluated by controlling the flow of water through raceways at the NFHTC. The experimental design was the result of consultation between BIO-WEST staff and other aquatic biologists, including those on the staff of the NFHTC. Laboratory testing showed that free carbon dioxide in the water column greatly influenced the aquatic plants' growth.

Amendment 8, approved by the board in December 2003, extended the aquatic ecosystem monitoring contract through February 2005.

Status Report

The BIO-WEST team completed all required 2004 monitoring events and is in the process of analyzing data and writing the 2004 annual report that was due February 28, 2005. A briefing on the 2004 monitoring work was scheduled to be provided to the Research and Technology Committee in March 2005. The monitoring contract expired February 28, 2005. On February 8, 2005, the board approved a new three year monitoring contract with BIO-WEST. Under the new contract, spring monitoring events for both systems began in April 2005.

AUGMENTATION STUDY (IN SITU REFUGIA)

Background Information

In November 2002, the board approved a contract between the Authority and LBG-Guyton Associates, Inc., to perform a study titled *Evaluation of Augmentation Methodologies in Support of In-Situ Refugia at Comal and San Marcos Springs, Texas*. The purpose of the project is to assess the feasibility of introducing water directly to critical habitat areas of the Comal and San Marcos springs ecosystems to extend the viability of the habitat during low springflow. If augmentation, in conjunction with other water management programs, is not sufficient to maintain critical habitat, then the threatened and endangered species will have to be moved to traditional refugia under controlled conditions. This project investigates some of the recommendations presented by The University of Texas at Austin, Center for Research in Water Resources (CRWR), in its report titled *Springflow Augmentation of Comal Springs and San Marcos Springs, Texas: Phase I-Feasibility Study* (Technical Report CRWR 247, February 1995). A project amendment was approved in June 2004 to extend the contract performance period to December 31, 2004, in order for additional support services to be obtained from the contractor as needed by the Authority. The latest contract amendment (Amendment 3) also

provides additional project funding up to a maximum of \$10,000 for support work.

Status Report

This study is complete. The final report was submitted in June 2004. Results of the final report were presented to the Research and Technology Committee in August and to the board in September.

ESTIMATION OF HYDRAULIC PARAMETERS FOR THE EDWARDS AQUIFER MANAGEMENT MODEL

Background Information

In May 2000, the board approved a two-year Joint Funding Agreement (JFA) with the U.S. Army Corps of Engineers (COE) to model hydraulic conductivity measurements statistically and create an input data set for the MODFLOW model being prepared by USGS. The COE subcontracted the work to SwRI. The purpose of the project was to create a hydraulic conductivity data set for the management model of the Edwards Aquifer being built by the USGS for the Authority. SwRI used geostatistical techniques to upscale specific capacity data and hydraulic conductivities measured in pumping tests to each grid cell in the model. The initial geostatistical model involved a stochastic simulation and co-kriging techniques to upscale and interpolate the measured values to the grid cells in the model. Results were refined in subsequent models using Bayesian statistics and incorporating groundwater levels, as well as the hydraulic conductivities.

Status Report

This study is complete. The final report and the final hydraulic conductivity model were delivered to the Authority in May 2002. The USGS is using this data set for calibration work for the aquifer model.

EDWARDS AQUIFER WELL SURVEY PROJECT

Background Information

In April 2002, the board approved a letter agreement with Ford Engineering, Inc. (FEI), for collecting survey-grade GPS data at well sites directed by the Authority. The main goal of the project was to obtain professionally surveyed locations and elevations at Edwards Aquifer wells with historical water level data, as well as to install and survey benchmarks and numerous features near Comal and San

Marcos springs. The joint survey work of the Authority and FEI staff was performed in the period from May 1, 2002, through December 31, 2003; 403 wells were surveyed, including

- Target wells used in steady-state calibration of the model (SSCW)
- Target wells used in transient calibration of the model (TCW)
- All wells included in the Synoptic Water Level Program (SWLP)
- Other wells with water level information available in the Authority archives
- Wells in Hays County necessary to evaluate the location of the Edwards Aquifer groundwater divide
- Eight permanently installed benchmarks and numerous spring-related features near Comal and San Marcos springs.

Status Report

The study is complete. Survey project deliverables were received by the Authority, including

- Latitude, longitude, and elevation data for each surveyed location and
- Data in decimal degrees in NAD83 horizontal coordinate system and NAVD88 vertical coordinate system.

All data are presented in a hardcopy format sealed by RPLS, guaranteeing accuracy as well as MS Excel format.

EDWARDS AQUIFER COMPUTER MODEL

Background Information

In April 2000, the board approved a Joint Funding Agreement (JFA) with the USGS for the construction of a new computer model of the Edwards Aquifer. The model is being constructed using MODFLOW software. In December 2004, the JFA was amended to extend the project completion date to March 1, 2005. The University of Texas at Austin, Bureau of Economic Geology (BEG), served as a subcontractor to the USGS to prepare input data sets. Southwest Research Institute (SwRI) used geostatistical techniques to prepare the hydraulic conductivity data set (see Completed Studies).

To evaluate the hydrologic response to various alternative proposals for managing the Edwards Aquifer, the Authority, along with other San Antonio water-resource managers and planners, expressed the need for an improved numerical groundwater-flow model. Rather than attempt to update, modify, or recalibrate existing models, the Authority decided that a new, comprehensive groundwater-flow model, using contemporary user-friendly, pre- and post-processing software that incorporated important components of the latest conceptualization of the aquifer, was needed. To develop an improved model, a study was conducted from 2000 to 2003 by the USGS and the BEG, in cooperation with the U.S. Department of Defense and the EAA. The objective of this study was to improve understanding of the complex hydrogeologic processes that control water availability of the Edwards Aquifer in the San Antonio area through development, calibration, and testing of a numerical groundwater-flow model that could be used in decision processes to optimize resource management.

To accomplish this objective, all available and pertinent hydrogeologic data were compiled and organized into a comprehensive, digital-based system of data storage and retrieval. The new Edwards Aquifer numerical groundwater-flow model developed in this study (hereinafter, the Edwards Aquifer model) incorporates improvements over previous models by using (1) a user-friendly interface, (2) updated computer codes (MODFLOW96 and MODFLOW2000), (3) a finer grid resolution, (4) less-restrictive boundary conditions, (5) an improved discretization of hydraulic conductivity, (6) more accurate estimates of pumping stresses, (7) a long transient simulation period (54 years, 1947–2000), and (8) a refined representation of zones of large hydraulic conductivity, or conduits. In addition, the Edwards Aquifer model produces a closer match between simulated and measured hydraulic heads for a larger area of the San Antonio segment of the Edwards Aquifer, and between simulated and measured springflows, than do previous numerical groundwater-flow models.

During initial phases of project planning and implementation, a Groundwater-Model Advisory Panel (GWMAP) was formed to provide technical input, primarily for conceptualization, but also for the construction and calibration of the Edwards Aquifer model. The GWMAP was a group of individuals with expertise in modeling, karst hydrology, and the Edwards Aquifer, including the Chief Technical Officer/Program Manager of the Authority's Aquifer Science Program, USGS, San Antonio Water System (SAWS), TWDB, Department of Defense (DOD), and

contractors. Three employees of the Authority were included as GWMAP staff. The intent was to deliver an end product (Edwards Aquifer model) that had been critiqued, as it was developed, by the groundwater community concerned with the Edwards Aquifer in the San Antonio region, as represented by the GWMAP. The GWMAP met periodically during development of the model, providing comments, suggestions, and technical direction. The GWMAP's final meeting was on September 29, 2005, to discuss the future of the model.

The new numerical groundwater-flow model (Edwards Aquifer model) that incorporates important components of the latest information and plausible conceptualization of the Edwards Aquifer was developed. The model includes both the San Antonio and Barton Springs segments of the Edwards aquifer in the San Antonio region, Texas, and was calibrated for steady-state (1939–1946) and transient (1947–2000) conditions, excluding Travis County. Transient simulations were conducted using monthly recharge and pumpage (withdrawal) data. The model incorporates conduits simulated as continuously connected (other than being separated in eastern Uvalde and southwestern Medina counties), one-cell-wide (1,320 feet) zones with very large hydraulic-conductivity values (as much as 300,000 feet per day). Locations of the conduits were based on a number of factors, including major potentiometric surface troughs in the aquifer, presence of sinking streams, geochemical information, and geologic structures (for example, faults and grabens).

The simulated directions of flow in the Edwards Aquifer model are most strongly influenced by the presence of simulated conduits and barrier faults. The simulated flow in the Edwards Aquifer is influenced by the locations of the simulated conduits, which tend to facilitate flow. The simulated subregional flow directions generally are toward the nearest conduit and subsequently along the conduits from the recharge zone into the confined zone and toward the major springs. Structures simulated in the Edwards Aquifer model influencing groundwater flow that tend to restrict flow are barrier faults. The influence of simulated barrier faults on flow directions is most evident in northern Medina County.

A water budget is an accounting of inflow to, outflow from, and storage change in the aquifer. For the Edwards Aquifer model steady-state simulation, recharge (from seepage losses from streams and infiltration of rainfall) accounts for 93.5 percent of the sources of water to the Edwards Aquifer, and inflow through the northern and

northwestern model boundaries contributes 6.5 percent. The largest discharges are springflow (73.7 percent) and groundwater withdrawals by wells (25.7 percent).

The principal source of water to the Edwards Aquifer for the Edwards Aquifer model transient simulation was recharge, constituting about 60 percent of the sources of water (excluding change in storage) to the Edwards Aquifer during 1956, a drought period, and about 97 percent of the sources (excluding change in storage) during 1975, a period of above-normal rainfall and recharge. Principal discharges from the Edwards aquifer for the transient simulation were springflow and withdrawals by wells. During 1956, representing drought conditions, the change in storage (net water released from storage) was much greater than recharge, accounting for 75.9 percent of the total flow compared with 14.5 percent for recharge.

Conversely, during 1975, representing above-normal rainfall and recharge conditions, recharge constituted 79.9 percent of the total flow, compared with 7.1 percent for the change in storage (net water added to storage).

A series of sensitivity tests was made to ascertain how the model results were affected by variations greater than and less than the calibrated values of input data. Simulated hydraulic heads in the Edwards Aquifer model were most sensitive to recharge, withdrawals, hydraulic conductivity of the conduit segments, and specific yield and were comparatively insensitive to spring-orifice conductance, northern boundary inflow, and specific storage. Simulated springflow in the Edwards Aquifer model was most sensitive to recharge, withdrawals, hydraulic conductivity of the conduit segments, specific yield, and increases in northern boundary inflow and was comparatively insensitive to spring-orifice conductance and specific storage.

Status Report

This study has been completed. Final paper copies and a pdf-format copy of the Scientific Investigations Report "Conceptualization and Simulation of the Edwards Aquifer, San Antonio Region, Texas," were delivered to EAA on March 2, 2005.

A briefing on the MODFLOW model project was scheduled to be provided to the Research and Technology Committee in April 2005, followed by a presentation to the board in May.

The USGS revised the model in late 2005 as part of the National Water Quality Assessment Transport of Anthropogenic and Natural Contaminants to Supply Wells project. The revisions included replacing the single-cell-wide conduits with a broader zone of high-transmissivity to simulate aquifer conditions in the confined part of the aquifer region.

WATER RESOURCES MANAGEMENT MODULE FOR THE EDWARDS AQUIFER MODFLOW MODEL

Background Information

In December 2003, the board approved a contract with HydroGeoLogic, Inc., to develop water resource management modules in MODFLOW for the Edwards Aquifer model that is under construction by the USGS. The project was completed on May 31, 2005, after the original contract schedule was extended. The purpose of the modules is to simulate the effects of the Authority's Demand Management Critical-Period Management Rules that were enacted in 2002. The new modules enable MODFLOW to accept trigger levels, a variety of recharge and pumping schedules, and other conditions.

Status Report

This study has been completed. HydroGeoLogic, Inc., has submitted all of the deliverables required by the contract including a users manual, reference manual, and software.

CONVERSION OF THE WATER RESOURCES MANAGEMENT MODULE FOR MODFLOW 2000

Background Information

Under a previous contract with the Authority, HydroGeoLogic, Inc., developed the Groundwater Management Package to enable MODFLOW to simulate the Authority's critical-period rules (see Section 3). According to the scope of work, HydroGeoLogic, Inc., wrote the software to be compatible with the Edwards Aquifer model in MODFLOW 96, which was under construction by the USGS. The USGS subsequently converted the model

to MODFLOW 2000. The scope of work for the current project describes the requirements for the Consultant to modify the Groundwater Management Package to be compatible with MODFLOW 2000. HydroGeoLogic, Inc., modified the existing graphical user interface (GUI) for WPM1 to include the capability to generate the trigger rule and managed pumping well files for the modified MODFLOW 2000 code. HydroGeoLogic, Inc., prepared addenda to the quality plan and the reference manual that were prepared for the MODFLOW 96 version.

Status Report

HydroGeoLogic, Inc., submitted the management modules for MODFLOW 2000 in December 2005. The modules performed satisfactorily with the test cases, and Authority staff is testing them with the entire model data-set. Authority staff completed the tests in April 2006.

INVESTIGATION OF GROUNDWATER SYSTEMS IN UVALDE COUNTY

Background Information

In July 2004, the board approved a contract with SwRI® to investigate the groundwater systems in Uvalde County. The purpose of the project is to further characterize the Edwards Aquifer flow system in Uvalde County and to refine the estimated contribution of the Uvalde Pool to the San Antonio Pool and to the Leona Aquifer. The study is considered a focused flowpath study to better understand the effect of the "Knippa Gap" on flow within the aquifer.

As more information is collected regarding the groundwater systems in Uvalde County, there appears to be a discrepancy in the estimated water budget for the Edwards Aquifer in Uvalde County. For example, groundwater discharges from the aquifer and recharges the Leona Aquifer at a significant but unknown rate. Also, the amount of recharge from the Nueces River estimated from the pilot recharge models (see Completed Studies below) is less than the amount calculated by previous methods. Consequently, recent studies have revealed the lack of precision in existing estimates of the water budgets in Uvalde County. Because the water resources of Uvalde County are an important part of the Edwards Aquifer, it is important to continue to study the sources of error in the water balance.

The project consists of the following tasks:

- Task 1. Well inventory: Available well records for Uvalde County, western Medina County and eastern Kinney County will be reviewed and compiled. The objective is to add 200 wells to the Authority's network of wells for data collection.
- Task 2. Focused Synoptic Water Level Survey: Three focused water level measuring events will be conducted using wells in existing data collection networks and new wells identified in Task 1.
- Task 3. Water Chemistry Evaluation: Available groundwater and surface water chemistry data will be evaluated to identify flowpaths and relationships between major aquifers in the study area.
- Task 4. Geologic Structural Analysis: An analysis will be performed to characterize the geologic structure beneath Uvalde County and to evaluate the potential for hydraulic communication between the principal water-bearing units.
- Task 5. Data Analysis and Reporting: An analysis will be conducted to assimilate all collected data and information to characterize the Edwards Aquifer flow system in Uvalde County and to refine the estimated contribution of the Uvalde Pool to the San Antonio Pool and to the Leona Aquifer. Draft and final reports will be prepared.

The original project performance period was 16 months, and it was extended because the initial synoptic event was not completed. The project was completed in May 2006.

Status Report

This study is complete. SwRI® presented its findings to the Research and Technology Committee on June 28, 2006, and to the Board of Directors on July 11, 2006. The project final report is currently posted on the Authority Website under the reports section at http://www.edwardsaquifer.org/pages/research_optimization.htm.

KARST AQUIFER MODELING RESEARCH (PHASE 1)

Background Information

In August 2003, the board approved a cooperative funding agreement with the American Water Works Association Research Foundation (AWWARF) to initiate development of modeling software that will accommodate the hydraulic characteristics of groundwater in karst aquifers. Karst aquifer modeling requires specific modeling capabilities such as turbulent flow in discrete conduits, which are not included in widely used groundwater modeling software such as MODFLOW. AWWARF contracted the work to SwRI in San Antonio. SwRI developed software for MODFLOW to accommodate karst groundwater conditions. Draft code was completed at the conclusion of the first year of the study. SwRI conducted initial tests on the code by modeling the Barton Springs segment of the Edwards Aquifer. The cooperative funding partners in the project were the Authority, AWWARF, and the Southwest Florida Groundwater Management District. These three agencies provided \$100,000 each in cooperative funding for the project. An additional \$102,000 was provided to the project in in-kind services from the following entities:

- Miami-Dade Water and Sewer Department
- Oklahoma State University
- Water Resources Authority of Jamaica
- Barton Springs/Edwards Aquifer Conservation District
- University of West Indies
- University of Manitoba
- University of South Florida
- University of Connecticut
- The University of Texas at Austin, Bureau of Economic Geology

Status Report

The study is complete. SWRI submitted the final report in December 2004. SWRI developed the scope of work for 2005 activities, although AWWARF was not involved.

RECHARGE METHODOLOGY

Background Information

In October 2002, the board approved a contract with a team led by LBG-Guyton Associates to develop

Hydrologic Simulation Program-Fortran (HSPF) models for seven basins, including areas upstream of the Edwards Aquifer Recharge Zone. In March 2004, the contract was amended to extend the performance period from April 30, 2004 through March 30, 2005. The contract amendment also increased the project work scope to create equivalent models for the Blanco and Nueces river basins. The river basins being modeled are

- Frio/Dry Frio River Basin
- Sabinal River Basin
- The Area between Sabinal and Medina River Basins
- Medina River Basin
- The Area between Medina River and Cibolo/Dry Comal Creek Basins
- Cibolo Creek and Dry Comal Creek Basin
- Guadalupe River Basin
- Blanco River Basin
- Nueces River Basin

The LBG-Guyton team consists of AQUA TERRA Inc., Espey Consultants, Freese and Nichols, and Dr. Bradford Wilcox (TAMU). The methodology for this project is similar to that of the pilot HSPF models prepared for the Nueces and Blanco basins in 2002; however, this project also includes the basin area upstream of the recharge zone.

Status Report

This study is complete. HSPF recharge models for the nine basins listed above were constructed and run using input (rainfall) data for the period 1950 through 2000. Model results indicate slightly higher cumulative recharge for the model period than do the historical methods. The project final report was submitted on January 31, 2005. The contractor provided a presentation, summarizing findings of the study at the February 2005 meeting of the Research and Technology Committee. The final deliverables, a set of HSPF output data files formatted for use in the MODFLOW model, were submitted prior to the end of the contract period (March 30, 2005).

RECHARGE METHODOLOGY (PILOT STUDY)

Background Information

In April 2001, the board approved a contract between the Authority and HDR Engineering, Inc. (HDR), for the development of pilot recharge models for the Nueces and Blanco River basins. Under the contract, HDR provided

daily recharge estimates back to 1950 for the Nueces basin and back to 1956 for the Blanco basin. Recharge is currently estimated by two methods that provide annual recharge estimates only. The two existing methods, prepared by the USGS and the Texas Water Development Board (TWDB), produce different volumes of recharge for some basins, and the largest differences between the two methods are in the Nueces and Blanco River basins. HDR's work will update the recharge estimating methods and generate daily recharge values for a future update of the Edwards Aquifer model being prepared by the USGS. The new models eventually will be adopted for annually estimating recharge to the aquifer. HDR submitted the work plan for the modeling in August 2001 and presented its plans to Authority Staff in September 2001.

Status Report

This study is complete. The final models were presented to Authority staff in February 2002. HDR delivered a presentation of the Pilot Recharge Models to the Technical Advisory Group and submitted its final report to the Authority in June 2002. The Research and Technology Committee received a report regarding the completed project at its July 2002 meeting. Because the pilot models generated more representative volumes of recharge than the previous methods, the updated methodology will be applied to the remaining drainage basins in the recharge zone.

HYDROLOGIC BUDGET ANALYSIS OF MEDINA LAKE AND DIVERSION LAKE

In August 2000, the board approved a three-year and eight-month JFA with the USGS for a hydrologic budget analysis (water balance) of Medina Lake and Diversion Lake. Bexar Metropolitan Water District (Bexar Met) is also a cooperator with the USGS in the project. The study is a continuation of the water balance prepared by the USGS in 1996 that was limited to low lake levels. The current study is being conducted with high lake levels. The USGS is monitoring lake levels, meteorological conditions, inflows, and outflows from the lakes to calculate groundwater losses.

Status Report

This study is complete. The USGS submitted the final Water Resource Investigations (WRI) Report in December 2004.

Project Budget Status (Water Balance)

Total project budget: \$417,200

Authority's share: \$268,900

NORTH MEDINA COUNTY FLOWPATH— HELICOPTER ELECTROMAGNETIC SURVEY NEAR SECO CREEK SINKHOLE

Background Information

In April 2002, the board approved a JFA with the USGS for an airborne electromagnetic survey of northern Medina County near Seco Creek Sinkhole. The helicopter electromagnetic and magnetic (HEM) survey was completed for an 81-square-mile area in northwestern Medina County and northeastern Uvalde County. The HEM data were collected by towing an airborne magnetometer over predetermined flight lines. Flight lines were flown in a north-south and east-west grid pattern centered on Seco Creek Sinkhole. The survey data were processed to produce apparent resistivity maps—maps that delineate different geologic materials at various depths. Geologic structure and its effect on groundwater flow can be interpreted from the data.

Status Report

The part of the study funded by the Authority is complete. In July 2003, the USGS finalized *Helicopter Electromagnetic and Magnetic Survey Data and Maps, Seco Creek Area, Medina and Uvalde Counties, Texas, Open-File Report (03-226)*. The Research and Technology Committee received a briefing on the report, and electronic copies were provided to all board members. The report concluded that the survey data are effective from near surface down to approximately 100 meters and that the data show more structural detail and precise locations than previously prepared geologic maps. The USGS may produce a follow-up report in the future that will contain conductivity profiles correlated to stratigraphy and geologic structure using existing well logs.

LEONA FORMATION GEOPHYSICAL SURVEY

Background Information

In February 2003, the Authority and SwRI signed a letter agreement authorizing SwRI to perform geophysical

investigations to determine the lateral extent of the Leona Formation in the Leona River floodplain south of the City of Uvalde. The purpose of this study was to evaluate the depth and lateral extent of the Leona Formation. These data were combined with previously determined Leona Aquifer parameters to estimate of the amount of water that may be flowing from the Edwards Aquifer in the area of Leona Springs. This information will improve overall understanding of the Edwards Aquifer hydrologic budgets. The project report concludes that there may be as much as 100,000 acre feet of water leaving the Edwards Aquifer near Leona Springs.

Status Report

This study is complete. The board was briefed on results of the study in February 2004.

ANALYSIS OF STRUCTURAL CONTROLS ON THE EDWARDS AQUIFER/TRINITY AQUIFER IN NORTH BEXAR COUNTY— CAMP BULLIS QUADRANGLE

Background Information

In March 2002, the board approved a one-year JFA between the COE and the Authority for the analysis of structural controls on the Edwards Aquifer/Trinity Aquifer interface in the area of the Camp Bullis Quadrangle map. The COE's Planning Assistance to States program is paying 48% of the cost of this study. The study was initiated in June 2002 and was completed in December 2003. The purpose of this project was to generate a three-dimensional computer model and predictions of localized fault-related deformation in the Edwards and Trinity aquifers in the study area. A second major objective for this study was to analyze potential hydraulic communication across the interface between the Edwards and the Trinity aquifers, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

Status Report

This study is complete. The Center for Nuclear Waste Regulatory Analyses (CNWRA) at SwRI, the COE's contractor for the project, submitted its final report on December 8, 2003. The board was briefed on results of the study in February 2004.

ANALYSIS OF STRUCTURAL CONTROLS ON THE EDWARDS AQUIFER/TRINITY AQUIFER IN NORTH BEXAR COUNTY— HELOTES QUADRANGLE

Background Information

In June 2003, the board approved a one-year JFA between the Corps of Engineers (COE) and the Authority for analysis of structural controls on the Edwards Aquifer/Trinity Aquifer interface in the area of the Helotes Quadrangle. The U.S. Army Corps of Engineers Planning Assistance to States program is paying 50% of the cost of this study. The Center for Nuclear Waste Regulatory Analysis at SwRI is the contractor. The study began in the fall of 2003 and was completed in February 2005. The purpose of this project was to generate a three-dimensional computer model and predictions of localized fault-related deformation in the Edwards and Trinity aquifers in the study area. A second major objective for this study was to analyze potential hydraulic communication across the interface between the Edwards and Trinity aquifers, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

Status Report

This study is complete. SWRI submitted the final geologic framework model and report in February 2005.

SALINE WATER STUDY

Background Information

Between mid-1998 and August 15, 2005, the Authority and San Antonio Water System (SAWS) cooperatively funded the construction, operation, and maintenance of Edwards Aquifer freshwater/saline water interface monitoring wells. The purpose of the multiyear study is to conduct a regional investigation and data collection program to assess the likelihood of saline water encroaching across the currently mapped Edwards Aquifer freshwater/saline water interface during periods of extended drought. SAWS is currently installing the monitoring well transects. Prior to 1994, the USGS and the Edwards Underground Water District installed monitoring-well transects for the program. To date, monitoring-well transects have been installed in the following ten areas:

- Area of Artesia Pump Station in San Antonio—completed in 1986
- Area of Comal Springs–New Braunfels—completed in 1989
- Area of San Marcos Springs–San Marcos—completed in 1991
- Southwest Medina County (one exploratory well only)—completed in 1993
- Area of Kyle and IH-35—completed in 1998
- Southeast Uvalde County—completed in 1999
- Area of confluence of Bexar–Comal–Guadalupe county lines—completed in 2000
- Area of San Marcos Federal Fish Hatchery–Hays County—completed in 2001
- Area of Mission Road Pump Station in San Antonio—completed in 2002
- Area of Pitluk Road in San Antonio—completed in 2005

During approval of the Authority's 2005 budget, the board voted not to participate in the study after expiration of the 2004–2005 agreement. The 2004–2005 Interlocal Cooperation Agreement (ICA) between the Authority and SAWS expired August 15, 2005. SAWS plans to continue the project without Authority participation.

Status Report

The study is ongoing without Authority cooperative funding for new monitoring-well transects. SAWS continues to monitor water levels and water quality in transect monitoring wells.

STATISTICAL ANALYSIS OF HYDROLOGIC DATA

Background Information

In June 2000, the board approved a JFA with the COE to perform this study. COE subcontracted the work to Argonne National Laboratory (ANL). ANL reviewed the Edwards Aquifer data that were provided by the Authority from the major storm event on October 17–18, 1998. ANL submitted a Phase I Memorandum in December 2000 that assessed the data provided by the Authority and described its approach to the study.

Status Report

This study is complete. ANL submitted its final report in November 2001, which completed its involvement in the project. Authority staff presented ANL's findings to the Authority's board of directors in December 2001.

FRACTURE/CONDUIT STUDY

Background Information

In November 2001, the board approved a JFA between the Authority and the BEG to investigate the influence of faults and conduits on groundwater-flow paths in both the recharge and artesian zones of the aquifer. Dr. Sue Hovorka led the BEG team to test the following hypotheses:

- Karst conduits are strongly controlled by structures such as fracture zones and fault displacements of the aquifer.
- Conduits are preferentially developed and most active beneath streams.
- Conduits preferentially develop in some stratigraphic horizons within the Edwards Group.
- Hydrogeologic characteristics such as transmissivity, travel times, and others can be estimated for groundwater flow in regions or domains of the aquifer.

Project deliverables included a final report and GIS files of geologic structure, fault locations, water levels, and water chemistry.

Status Report

This study is complete. The board was briefed on results of the study in February 2004.

HELICOPTER ELECTROMAGNETIC SURVEY OF NORTHERN BEXAR COUNTY

Background Information

An airborne helicopter electromagnetic (HEM) survey, funded by the U.S. Army, was flown over the Camp Stanley Storage Facility (CSSA) and Camp Bullis areas in northern Bexar County. The Authority contributed funding to extend the survey to the south and west of the Army facilities on undeveloped areas of the recharge zone. The survey area is east of I-10, north of Loop 1604, south of Cibolo Creek, and west of Blanco Road. The geophysical information collected from the survey will be used to map geologic and hydrologic features in the subsurface. Information from the airborne survey will be useful in a variety of groundwater studies being conducted in the Bexar County area. Of particular interest is the contact between the Edwards and Trinity aquifers in that area. A similar survey was completed in 2002 in the Seco Creek area north of Hondo in northwestern Medina County.

Status Report

This study has been completed. The USGS submitted a report and map in June 2005.