

Edwards Aquifer Authority

Aquifer Science Research Program Plan

2008-2013

MANAGE
ENHANCE
PROTECT



January 2009

Report No. 09-01



EDWARDS AQUIFER
AUTHORITY

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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 Edwards Aquifer, the primary source of water for approximately 1.7 million people in the region (<http://quickfacts.census.gov/qfd/>), also provides most of the water for agriculture and industry. In addition, the aquifer discharges through a series of large springs that provide aquatic habitat for a number of threatened and endangered species. Springflow also provides a significant portion of water to 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 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 effectively manage the resource 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 the 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" [The Edwards Aquifer Authority Act (Act), as amended].

The ASRP

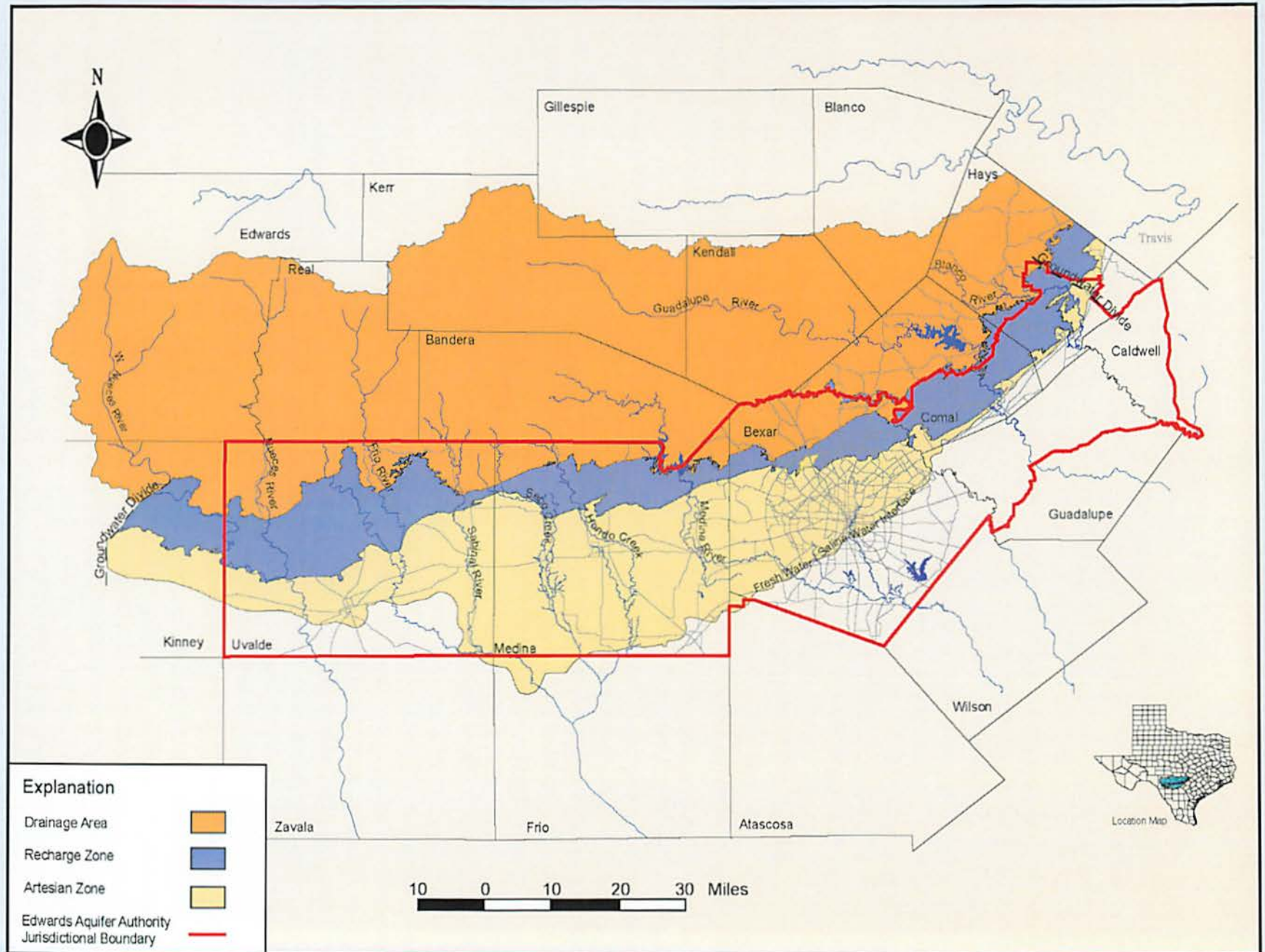
The Edwards Aquifer is a complex system, and to understand the aquifer adequately requires accurate and timely research and data collection. This report summarizes the inception of the Authority's Aquifer Science Research Program (ASRP), which is a natural outgrowth of the Authority's former research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

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 received input from the TAG and the ASAP in relation to research project development and review. The ASRP is also limited to research projects related directly to the Authority's Aquifer Science Program, whereas the OTS included projects outside the scope of the Aquifer Science Program. The Authority's board of directors has final approval over all projects prior to initiation.

The Edwards Aquifer Authority Aquifer Science Research Program Plan 2006–2011 (ASRPP—2006), which was released in November 2006, documents the Authority's transition from the OTS to the ASRP. The Aquifer Science Research Program Plan 2008–2013 (ASRPP—2008), the first update and revision to the ASRPP—2006, contains information on the status of existing research programs, as well as new research initiatives.

The sections that follow in this ASRPP provide a discussion of the ASRPP—2008 in greater detail. In order for the various projects associated with the ASRP to be documented, summary tables are provided in each section, whereas detailed descriptions are provided in the appendices. Appendix A provides detailed descriptions of proposed and active ASRP projects (some of which began as OTS projects), and completed projects (ASRP and OTS) are summarized in Appendix B.

Figure 1. San Antonio Segment of the Edwards Aquifer and other Physiographic Features in the Region.



EDWARDS AQUIFER OPTIMIZATION PROGRAM (1999-2006)

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 for all users, to include threatened and endangered species and downstream interests. Although the mission of the Authority has not changed, many 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 are 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 development of a regional steering committee led by the Authority. As a result, a Technical Advisory Group (TAG) was formed to develop recommendations and priorities for work scopes for proposed studies, as well as to 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 to be granted by 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 as follows:

- Recharge Enhancement
- Flowpath Studies
- Springflow Augmentation
- Springflow Recirculation
- Biological Assessment of Endangered Species
- Range Management
- Saline Water Study

Identification of these issues led to development of nine specific questions as outlined in the Optimization Technical Studies Report (Todd Engineers, 1999):

1. Can significant additional recharge be provided for aquifer users and to maintain springflow?
2. Where should recharge dams, pumping centers, and injection wells be located for maximum efficiency?
3. Are accurate predictions of aquifer conditions being obtained from the 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 the 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 annual rainfall in the catchment and recharge zones of the aquifer be increased?

Initial efforts to answer these questions became the basis for addressing some of the 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, all of the original 17 OTS studies were either initiated or completed. Some of the studies have been conducted under a slightly altered title, whereas some studies were not specifically designated in the original OTS but either provided support for other OTS initiatives or became parts of a multiple phase study to accomplish a long-term objective. Table 1

summarizes accomplishments of the OTS by listing projects conducted under the OTS and the current status of each. Note that Table 1 has an additional category for studies (support projects) performed in support of the OTS. Until 2006, the Authority's Aquifer Science Program provided oversight for all OTS projects. However, with the inception of the ASRP in 2006, some of the listed OTS studies were transferred to other Authority programs. For clarity, distribution and status of the various studies and their relationship to the ASRP are summarized in chart format in Figure 2. The OTS studies that are not under the guidance of the ASRP are:

- Variable Flow Biological Monitoring Plan and Ongoing Monitoring
- Potential Water Quality Impacts (pertaining to biological studies of endangered species at Comal and San Marcos springs)
- 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

Table 1. Summary and Status of OTS Projects, May 1988–November 2008

OTS Study Category	Status	Study Title
Biological Assessment	Habitat Conservation Plan (HCP) Development	This study accounts for two of the original OTS studies: (1) Variable Flow Biological Monitoring Plan and Ongoing Monitoring and (2) Potential Water Quality Impacts Comprehensive and Critical-Period Monitoring of the Comal Springs and San Marcos Springs Aquatic Ecosystems*
	Removed from OTS	Texas Wild-Rice Mapping* (project performed by Texas Parks and Wildlife as an annual survey)
	Complete	Assessment of Factors Influencing Texas Wild Rice (<i>Zizania texana</i>) Sexual and Asexual Reproduction* (This is the OTS study originally titled <i>Texas Wild-Rice Growth and Reproduction</i>)
	Complete	Assessment of Instream Flow and Habitat Requirements for Cagle's Map Turtle (<i>Graptemys caglei</i>)* (this is the OTS study originally titled <i>Cagle's Map Turtle Flow Requirements</i>)
	Initiated 2008	Well Sampling of Aquifer Biota* (study oversight by Authority's Aquifer Science Program, part of ASRP)
	Complete Complete Complete Complete	These studies are in direct support of the OTS study <i>Management Model/ GIS Data Sets and Model Recalibration*</i> 1. USGS MODFLOW Management Model (this is the New MODFLOW model) GIS Data Sets 2. Model Recalibration (this was for the GWSIM IV model, which was replaced with the MODFLOW model) 3. MODFLOW Management Module (not in OTS) 4. Estimation of Hydraulic Parameters for the Edwards Aquifer Management Model
	Complete Complete Complete Complete	These studies are in direct support of the OTS study titled: <i>Saline Water Study</i> 1. Saline Water Study* (SAWS is continuing this project; Authority participation ended in August 2005) 2. Saline Water Use Feasibility Study (not in OTS) 3. Recharge/Flowpath (N. Medina Co.)* USGS 2006 4. Hydrologic Budget Analysis of Medina Lake and Diversion Lake (not in OTS)
Flowpath/ Modeling	Complete In Progress In Progress In Progress Initiated 2008 Complete Complete	Studies below are in direct support of the OTS study titled: <i>Focused Flowpath Studies: Knippa Gap, San Marcos Springs, and Comal Springs*</i> 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. Noble and Active Gas Sampling in the Knippa Gap Region Karst Aquifer Modeling Research (Phase I) 7. Karst Aquifer Modeling Research (Phase I)
	Complete Complete Complete	Studies below are in direct support of the OTS study titled <i>Recharge Methodology*</i> 1. HSPF Pilot Study 2. HSPF Model for Region 3. HSPF Model for Region NEXRAD Calibrated Rainfall Input Refinement/GUI Development
	Complete	Statistical Analysis of Hydrologic Data*
	Complete Complete Complete Complete Complete	Studies below are in direct support of the OTS study titled <i>Fracture/Conduit Study*</i> 1. Helicopter Electromagnetic Survey of Northern Bexar County Helicopter Electromagnetic Survey in the Vicinity of Seco Creek Sinkhole 2. Analysis of Structural Controls on the Edwards Aquifer/Trinity Aquifer in North Bexar County— Camp Bullis Quadrangle 3. Analysis of Structural Controls on the Edwards Aquifer/Trinity Aquifer in North Bexar County—Helotes Quadrangle 4. Leona Formation Geophysical Survey 5. 3-D Visualization (Phase I)*

Table 1. (continued)

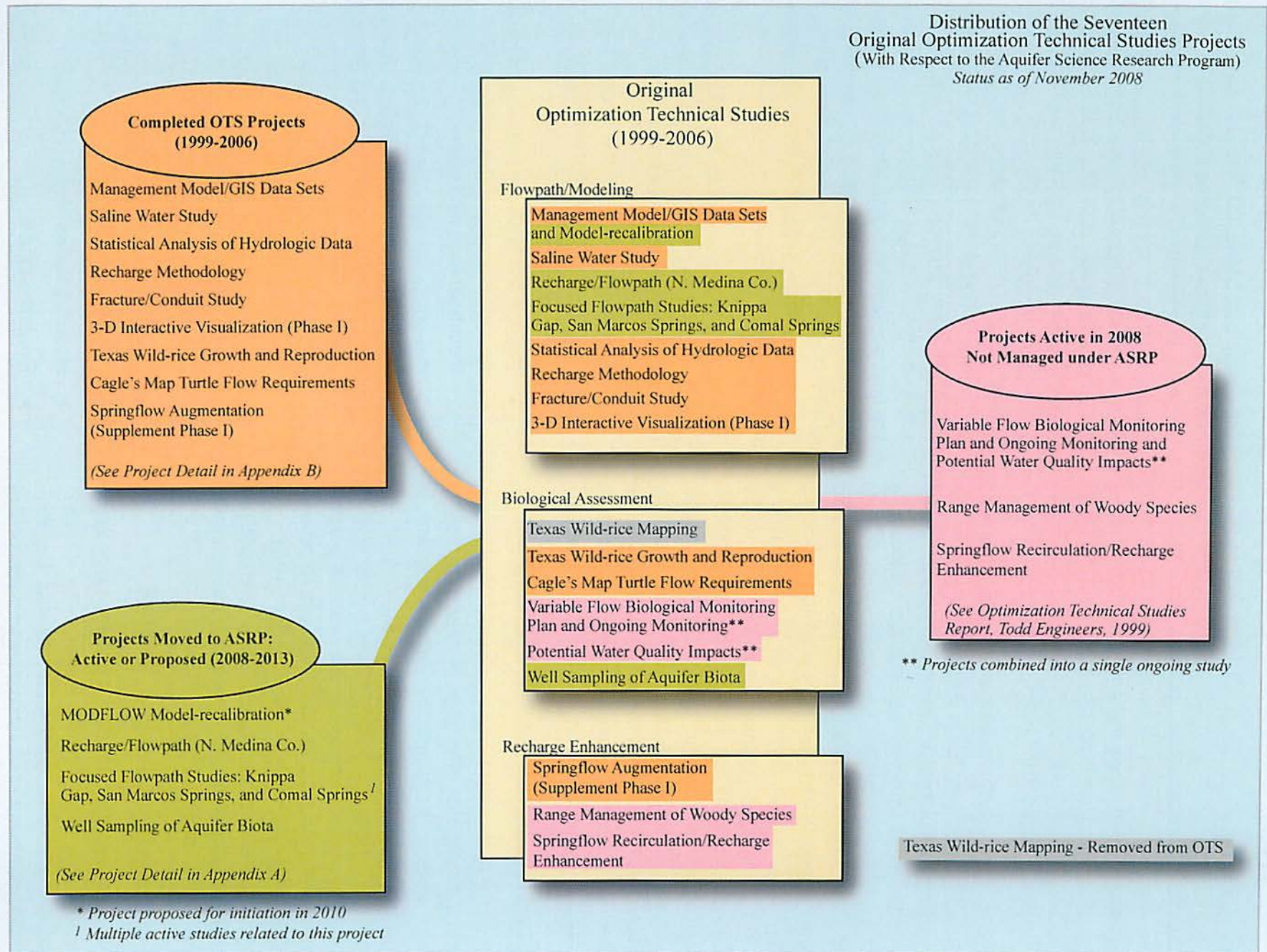
OTS Study Category	Status	Study Title
Recharge Enhancement	In Progress	Studies 1 and 2 below are in direct support of the OTS study titled <i>Range Management of Woody Species</i>* 1. Paired Watershed Study—Honey Creek and Government Canyon State Natural Area 2. Augmenting Groundwater Recharge through Brush Control: A Feasibility Study
	In Progress	
	Complete	Springflow Recirculation and Recharge Enhancement* 1. Phase I 2. Phase II 3. Phase III/Phase IV
	Complete 2008/2009	
	Complete	Augmentation Study (Supplement Phase I)* Study title <i>Evaluation of Augmentation Methodologies in Support of In-Situ Refugia at Comal and San Marcos Springs, Texas</i>
Support Projects		Each of the studies listed below provides basic data collection in support of the ASRP/OTS
	Ongoing	1. Synoptic Water Level Program (report for 1999–2004, completed in 2006)
	Complete	2. Synoptic Water Level Well Survey Project
	Ongoing	3. Focused Synoptic Water Level Program
	Ongoing	4. Water Quality Sampling
	Ongoing	5. Water Level and Conductivity/Temperature Monitoring

* = One of the 17 OTS studies proposed in 1999.

Active ASRP projects listed above are detailed in Appendix A.

Completed projects are detailed in Appendix B.

Figure 2. Relationship and Status of OTS Projects to the ASRP, November 2008



AQUIFER SCIENCE RESEARCH PROGRAM (2006 TO PRESENT)

Introduction

The ASRP became the guidance document for the Authority's Aquifer Science related research in September 2006. Since that time, research initiatives have been conducted under the guidance of the ASRP process through input from the TAG and ASAP, with oversight provided by the Authority's board of directors.

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

Basis for Development of the ASRP

The OTS were 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 internal expertise regarding management of the Edwards Aquifer, the ASRP became a more efficient guidance vehicle. Refocusing the research program has allowed the Authority to pursue a more mission-directed approach to conducting aquifer research and prioritizing research needs. Development and continued implementation of the ASRP are also in agreement with the current Authority Strategic Plan.

Goals and Objectives of the ASRP

Although a substantial body of knowledge exists for the hydrogeology of the Edwards Aquifer, many unknowns remain regarding 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.

The overall goal of the ASRP 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 investigative data, the ASRP is poised to make further advances in the areas of aquifer modeling, recharge modeling, flowpath understanding, recharge methodology, and water quality monitoring. In Figure 3, the relationship between the OTS and ASRP is summarized graphically. Original OTS projects applicable to the ASRP (nine projects total) provide the ASRP research objectives that ultimately lead to providing the best available technical information to decision makers. Many objective projects required completion of other research prior to their completion or initiation. Furthermore, many support studies have grown out of the OTS.

To accomplish its overall goal, the ASRP has been tasked with fulfilling OTS project initiatives, along with four additional objectives to

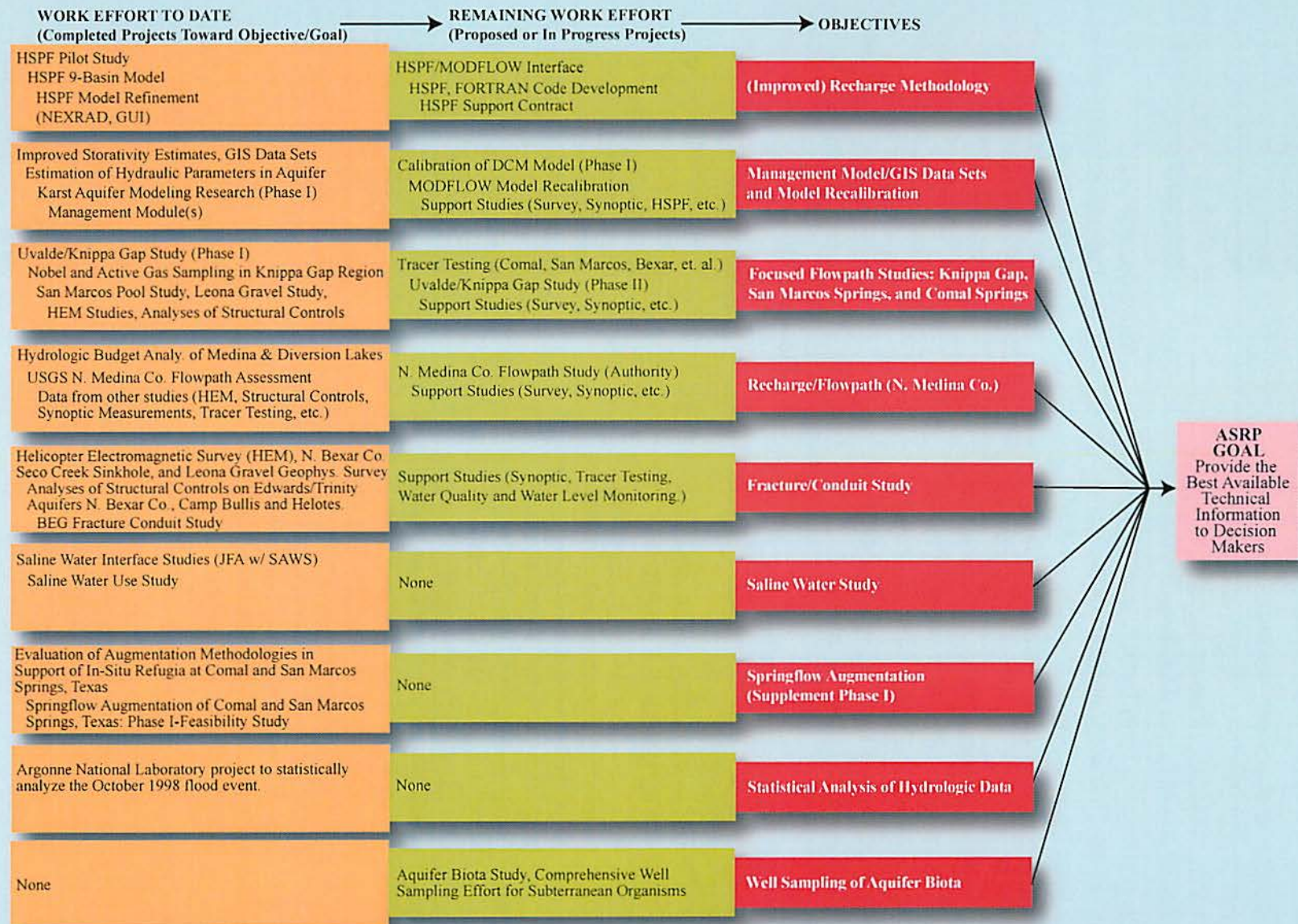
- Respond to directives of the board such that the program will provide adequate, sound information as needed.
- Develop and implement refinement plans for computer models that will prevent them from becoming obsolete.
- Continue basic data collection (water levels, water quality, and other basic data)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

The 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

Figure 3. OTS Project Objectives as Related to the ASRP Goal, November 2008

ASRP 2009-2013: Summary of Efforts To Achieve the Applicable OTS Objectives and Accomplish the Goal of the ASRP



Projects listed herein provide a basis for accomplishing the goal of the ASRP. Detailed descriptions of these projects are provided in the appendices to this document.

Research Needs and Project Development

Much historical and current research regarding the Edwards Aquifer has been aimed at answering basic research questions. However, in order to fully optimize the aquifer such that it will benefit all users adequately and equally, many basic research needs still exist. In the following bulleted items, some remaining basic research needs are listed by ASRP study category. For some listed needs, projects have been identified and studies either implemented or proposed, whereas for others, appropriate studies will be proposed in the future. Research needs without an active project (proposed studies) are summarized in Table 2; research needs with an active ASRP project (active studies) are summarized in Table 3.

- **Modeling studies/ model refinement:**

- Model refinement*

- As technology evolves and refinements are made to MODFLOW and Hydrologic Simulation Program-Fortran (HSPF) models, the refinement process for these computer models must be continued. For example, to maximize the abilities of these models, they will need to communicate directly through a common interface. In addition, continued support work is needed to update the HSPF model with scripts and modified code development to incorporate new data for variables such as improved mapping and streamflow measurements, updated rainfall data, and improved evapotranspiration data, and other data will be needed. Other model refinements include calibration of the dual conductivity module (DCM) model.

- 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 and subsequently implemented into the research plan, as well as into computer models, on a periodic basis. Studies in this category are implemented on the

basis of newly obtained knowledge from completed studies. Examples of proposed projects pertaining to this category include hydrogeology of north Medina County, detailed study of Cibolo Creek, well hydrophysics, analyses of well-plugging methods, and continuation of tracer-testing activities.

- Recharge variables*

- Recharge estimates indicate that more variables need to be refined and accounted for to achieve improved estimates. For example, evapotranspiration (ET) and stream loss at high flow volumes are both poorly characterized regionally. Improved water balance will require refinement of these data sets. Non-ASRP projects are planned to address these questions.

- **Flowpath studies:**

- Flowpath behavior*

- Primary flowpaths and their flow characteristics need further investigation. Some 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 flow components of the aquifer? Projects such as tracer testing, passive sampling, and water level monitoring will contribute solutions to the questions.

- Vulnerability*

- Karst 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. Water quality monitoring, tracer testing, and passive sampling will all contribute to addressing these research needs.

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. Research needs will be addressed partly by continued tracer testing, passive sampling, and water quality monitoring.

Pool delineation and identification

- Continued data collection is recommended in the 2008 San Marcos Pool study to obtain more definitive data regarding conclusions of the study. Other potential pools may exist in Uvalde and Kinney counties. Additional investigations need to be performed to further identify and delineate these potential pools. Water level monitoring, synoptic program measurements, tracer testing, and water quality analyses all contribute to answering questions in this category.

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. Improved gauging of streams and springs, as well as geophysical studies of gravels will help address some of these unknowns.

Data collection and retrieval

- Because of the large volume of data collected and the need for even more data, efforts to properly and effectively collect, store, and retrieve aquifer data need to be increased. Improvements to Aquifer Science Programs database software are ongoing.

The Authority's fiscal year coincides with the calendar year. As such, budget planning for ASRP projects generally begins between June and August of each year and is finalized in the month of November. The scope of proposed ASRP projects

is developed by consulting with Authority staff, the ASAP, and the TAG. On the basis of this process, Aquifer Science staff subsequently developed the proposed projects listed in Table 2. These projects are intended to address recommendations from completed 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 descriptions of proposed and active projects). Table 2 also provides a rough order of magnitude (ROM) cost for each proposed project. ROM costs—estimates in current dollars—represent approximate costs. The project listing in Table 2 is subject to modification annually, depending on budgetary limitations, time constraints, or development of new directives. Calendar year 2008 and 2009 projects are programmed into the Authority's annual budget. However, Authority staff will continue to seek joint funding opportunities for these projects.

In each coming year, aquifer science staff will meet with the advisory panel, TAG, and other Authority staff prior to the budgeting process to refine proposed ASRP studies. Proposed studies planned for initiation in calendar years 2008 and 2009 but not yet under way are summarized in Table 2. In addition, Table 2 lists part of the currently anticipated project needs for calendar years 2009 through 2012. As further research and planning take place, ASRP studies will be added and amended for years beyond 2008 in order to accommodate "unknowns" or new developments in the program, as well as improvements in technology.

Other Aquifer Science Programs that support the ASRP also require annual budgeting and planning. For example, the Authority monitors water quality in wells annually, springs quarterly, and several surface water sites semiannually. 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 water quantity data collection at springs and surface water sites.

Table 2. Summary of Proposed ASRP Studies, Calendar Years 2008–2013

ASRP Category	Estimated Initiation-Completion Year	Basic Research Need	Rough Order of Magnitude Costs/Year	Study Title
Modeling	2008–2009	Modeling refinements	\$21,000/2009	DCM Implementation Feasibility Test Technical Support
	2008–2009	Modeling refinements	\$19,500/2009	Compilation of Management Module with MODFLOW-DCM
	2009–2010	Modeling refinements	\$21,000/2008	HSPF-MODFLOW Interface
	2009–2010	Modeling refinements	\$24,000/2008	FORTTRAN Code Development to Load HSPF Output into MODFLOW Recharge File
	2009–2010	Modeling refinement	\$24,000/2009	HSPF Support Work (model updates, script development, Nueces River updates)
	2009–2010	Modeling refinement	\$80,000/2009	Calibration of DCM Model (Phase I)
	2010-2013	Modeling refinement	TBD	Recalibration of the MODFLOW Model
Flowpath	2009–2012	Conceptual model refinement	TBD Non-Contract	Cibolo Creek Study (defining extent of recharge zone along Cibolo Creek)
	2008–2010	Conceptual model refinement	\$60,000/2008 \$60,000/2009 \$50,000/2010	Well Hydrophysics Study
Recharge Methodology	2009–ongoing	Recharge variables	TBD	(Planning for these projects will be initiated in 2009 or later)
Support Studies	2008–2009	Conceptual model refinement	\$30,000/2008 \$35,000/2009	Well Plugging Study in Support of Regulatory Well Program
	2008–2009	Representative GW monitoring	\$30,000/2008 \$40,000/2009	Pharmaceuticals, Personal Care Products, and Bacterial Study

TBD = To be determined

Projects that are currently active are listed in Table 3, whereas projects completed under the ASRP since its inception in calendar year 2006 are listed in Table 4. Ongoing or active studies are detailed in Appendix A. Completed studies are detailed in Appendix B. With the completion of each project, improvements

in overall understanding of the system as a whole occur. This improved understanding provides one of the basic tools needed to direct development of future projects. Specifically, using new information to direct future research is one of the keys to ASRP project development.

Table 3. Active ASRP Studies, November 2008

ASRP Study Category	Status	Study Title
Flowpath Studies	Ongoing	Aquifer Biota Study
	Ongoing	Tracer Testing (Comal and San Marcos springs and Bexar County)
	Ongoing	Hydrogeology of North Medina County
	Ongoing	Phase II of the Uvalde County Study (geophysical study of gravel aquifers to improve water balance)
	Ongoing	Bacteria Source Tracking
Support Studies	Ongoing	Pilot Study to Improve Analytical Water Quality Data through Use of Passive Sampling Techniques
	Ongoing	Synoptic Water Level Program (report for 1999–2004 completed in 2006)
	Ongoing	Water Quality Sampling
	Ongoing	Water Level and Conductivity/Temperature Monitoring
	Ongoing Ongoing	Hydrologic Data Collection 1. Water quantity data collection 2. Addition of new stream gauges

Table 4. Completed ASRP Studies, November 2008

ASRP Study Category	Status	Study Title
Modeling Studies	Complete	Edwards Aquifer Computer Model (MODFLOW model)
	Complete	Water Resources Management Module for the Edwards Aquifer MODFLOW Model
	Complete	Enhanced Characterization and Representation of Flow through Karst Aquifers
	Complete	Hydrologic Simulation Program Fortran (HSPF) Model Refinement
	Complete	MODFLOW Model—Improved Storativity Estimates
	Complete	Estimation of Hydraulic Parameters for the Edwards Aquifer Management Model
	Complete	Water Resources Management Module for the Edwards Aquifer MODFLOW Model
	Complete	Conversion of the Water Resources Management Module for MODFLOW 2000
	Complete	Karst Aquifer Modeling Research (Phase I)
	Complete	Recharge Methodology
	Complete	Recharge Methodology (Pilot Study)
Flowpath Studies	Complete	Definition and Delineation of San Marcos Pool
	Complete	Augmentation Study (In Situ Refugia)
	Complete	Hydrologic Assessment of Flowpaths—North Medina County
	Complete	Noble and Active Gas Sampling in the Knippa Gap Region
	Complete	Investigation of Groundwater Systems in Uvalde County
	Complete	Hydrologic Budget Analysis of Medina Lake and Diversion Lake
	Complete	North Medina County Flowpath—Helicopter Electromagnetic Survey in the Vicinity of Seco Creek Sinkhole
	Complete	Leona Formation Geophysical Survey
	Complete	Analysis of Structural Controls on the Edwards Aquifer/Trinity Aquifer in North Bexar County—Camp Bullis Quadrangle
	Complete	Analysis of Structural Controls on the Edwards Aquifer/Trinity Aquifer in North Bexar County—Helotes Quadrangle
	Complete	Saline Water Study
	Complete	Statistical Analysis of Hydrologic Data
	Complete	Fracture/Conduit Study
	Complete	Helicopter Electromagnetic Survey of Northern Bexar County
Support Studies	Complete	Improved Gauging at Comal Springs and San Marcos Springs
	Complete	Guadalupe River Gain / Loss Study
	Complete	Edwards Aquifer Well Survey Project

AQUIFER SCIENCE ADVISORY PANEL

In accordance with the Authority's Strategic Plan, an ASAP was formed to provide advice to the Aquifer Science Program and technical oversight of 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, with the exception of reimbursement of members'

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 5 lists 2008 ASAP members.

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

Table 5. 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	Independent Hydrologist
Dr. Sue Hovorka Austin, Texas	Research Scientist, The University of Texas at Austin, 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, Department of Geological Sciences
Dr. George Veni San Antonio, Texas	Executive Director, National Cave and Karst Research Institute

AQUIFER SCIENCE RESEARCH PLAN REVIEW AND UPDATE (2008)

This document will be reviewed annually and updated approximately every two years as new developments unfold 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 quarterly meetings. Summaries of ASRP studies will be presented to the TAG, with final study reports being made available through the Authority website (www.edwardsaquifer.org) to the TAG and other interested parties.

Appendix A

Detailed Descriptions of Proposed and Active ASRP Projects

PROPOSED ASRP PROJECTS

ASRP CATEGORY: MODELING

Proposed Project Title:

DCM Implementation Feasibility Test, Technical Support

1. Purpose:

To assist Authority staff in revising current Edwards Aquifer steady-state model to implement and test a conduit layer using MODFLOW-DCM.

2. Background:

This project represents the early phase of an attempt in future recalibration of the Edwards Aquifer model with the MODFLOW-DCM, which addresses conduits with dual conductivity treatment.

3. Aquifer Management Issue to be Addressed:

Gaining experience in using the newly developed MODFLOW-DCM software and evaluating its usability in the Edwards Aquifer model.

4. Estimated Costs:

\$21,200.

5. Time Line:

Project is scheduled to begin in late 2008 and finish in 2009.

6. Status Report:

Pending contract approval.

ASRP CATEGORY: MODELING

Proposed Project Title:

Compilation of Management Module with MODFLOW-DCM

1. Purpose:

To use the aquifer management module with the newly developed dual-conductivity model MODFLOW-DCM; the software needs to be revised.

2. Background:

The consultant will incorporate the Groundwater Management Package developed by HydroGeoLogic, Inc. (HGL), for the Authority's MODFLOW ground water model into the MODFLOW-DCM model developed by Southwest Research Institute (SwRI®).

3. Aquifer Management Issue to be Addressed:

Current MODFLOW-DCM does not have the management module incorporated.

4. Estimated Costs:

\$19,500.00.

5. Time Line:

Project is scheduled to begin in late 2008 and finish in early 2009.

6. Status Report:

Pending contract approval.

ASRP CATEGORY: MODELING

Proposed Project Title:

MODFLOW / HSPF Interface

1. Purpose:

To revise postprocessing functions of the current HSPF interface in order to address differences in HSPF subbasins, as compared with MODFLOW recharge zone cells boundaries.

2. Background:

The goal of this research is to ensure that recharge estimates from the HSPF model can be used by the Authority MODFLOW model.

3. Aquifer Management Issue to be Addressed:

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

4. Estimated Costs:

Total estimated cost is \$21,000, which was included in the 2008 budget.

5. Time Line:

Research is scheduled to begin in early 2009 and be completed by the end of the same calendar year.

6. Status Report:

Research is currently in the proposal stage.

ASRP CATEGORY: MODELING

Proposed Project Title:

FORTTRAN Code Development for HSPF to MODFLOW Model Coupling

1. Purpose:

To develop FORTTRAN code for converting HSPF output to MODFLOW RCH files efficiently (both modeling platforms are based on FORTTRAN code).

2. Background:

The goal of this research is facilitate the interface between MODFLOW and HSPF, such that recharge data can ultimately be imported directly into MODFLOW from the HSPF model.

3. Aquifer Management Issue to be Addressed:

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

4. Estimated Costs:

Total estimated cost is \$24,000, which was included in the 2008 budget.

5. Time Line:

Research is scheduled to begin in early 2009 and be completed by the end of the same calendar year.

6. Status Report:

Research is currently in the proposal stage.

ASRP CATEGORY: MODELING

Proposed Project Title:

HSPF Technical Support

1. Purpose:

To

- Update the current HSPF model with the latest data sets,
- Update the HSPF model by incorporating the latest improvements related to the U.S. Army Corps of Engineers Nueces basin work effort, and
- Develop scripts that can export results with different output formats.

2. Background:

The goal of this research is to improve and refine the HSPF model.

3. Aquifer Management Issue to be Addressed:

Refinement of the accuracy of the Authority's recharge estimates.

4. Estimated Costs:

Total estimated cost is \$24,000, which was included in the 2009 budget.

5. Time Line:

Research is scheduled to begin in early 2009 and be completed by the end of the same calendar year.

6. Status Report:

Research is currently in the proposal stage.

ASRP CATEGORY: MODELING

Proposed Project Title:

Calibration of the Dual Conductivity Module (DCM) Model Phase I

1. Purpose:

To implement conduits within MODFLOW-DCM, revise boundary conditions in accordance with the latest data sets, and provide a preliminary calibration of steady-state and transient models.

2. Background:

The goal of this research is to provide a pioneering effort in incorporating the conceptual model of conduits into MODFLOW estimations. The end result will provide a better understanding of how groundwater flows in the aquifer. If the model performs successfully, the management module will be applied to simulate aquifer management scenarios.

3. Aquifer Management Issue to be Addressed:

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

4. Estimated Costs:

Total estimated cost is \$80,000, which was included in the 2009 budget.

5. Time Line:

Research is scheduled to begin in early 2009 and be completed by the end of the same calendar year.

6. Status Report:

Research is currently in the proposal stage.

ASRP CATEGORY: MODELING

Proposed Project Title:

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 input data sets and conceptual model need to be revised. The Authority has generated new data for the model:

- 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, and
- Target well information.

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

3. Aquifer Management Issue to be Addressed:

Refinement in accuracy of the Authority's ground-water model.

4. Estimated Costs:

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

5. Time Line:

Task is projected for 2010 through 2013.

6. Status Report:

Project is planned for 2010.

ASRP CATEGORY: MODELING

Proposed Project Title:

Cibolo Creek Study

1. Purpose:

To define extent of the recharge zone along Cibolo Creek.

2. Background:

The USGS has developed an HSPF model for quantifying recharge in the Cibolo Creek channel. The model shows that during 1992–2004, average groundwater recharge in the watershed was 79,800 acre-feet per year. Recharge was distributed between stream channel infiltration (74 percent) and upland areas (26 percent). Principal recharge areas were

- Trinity Aquifer outcrop: 77 percent,
- Area of transition from the Trinity aquifer outcrop to the Edwards aquifer outcrop: 13 percent,
- Edwards Aquifer recharge zone: 6.4 percent, and
- Area of transition from the Edwards Aquifer recharge zone (outcrop) to the Edwards Aquifer upper confining unit: 3.6 percent.

This project will include tracer tests, aquifer tests, water quality sampling, and other techniques to verify findings of the HSPF model.

3. Aquifer Management Issue to be Addressed:

According to the model, the Cibolo Creek watershed contributes more than 10 percent of the total annual recharge to the Edwards Aquifer. Consequently, the Authority is interested in verifying model findings to protect water quality and potentially enhance the quantity of recharge.

4. Estimated Costs:

Project will be completed by Authority staff.

5. Time Line:

Project is planned for initiation in 2009 and completion in 2012.

6. Status Report:

Authority staff will prepare a work plan for the project in 2009.

ASRP CATEGORY: MODELING

Proposed Project Title:

Well Hydrophysics Study

1. Purpose:

To 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. A pilot hydrophysics study was performed for the Authority by RAS Consultants in 2005, indicating that discrete conduits within a monitoring well bore account 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.

4. Estimated Costs:

Authority staff estimates that this study will cost approximately \$120,000 for calendar years 2008 and 2009. Calendar year 2008 costs are estimated at \$60,000, and calendar year 2009 costs are estimated at \$60,000. On the basis of results of initial data sets, further research may be carried into year 2010.

5. Time line:

Project is proposed for implementation in 2008 and completion in 2010.

6. Status Report:

Project is scheduled for initiation in late 2008 or early 2009.

ASRP CATEGORY: SUPPORT STUDY

Proposed Project Title:

Well Plugging Study

1. Purpose:

To evaluate a well-plugging case for completeness and resulting protection of water quality.

2. Background:

Authority regulations currently require plugging of abandoned wells, which includes either removal or perforation of any well casing and sealing of the annular space. Before 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 create a number of groundwater contamination problems.

This study is proposed to evaluate the effectiveness of a well-plugging case by geophysical logging of the well before abandonment, perforation 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:

Study will evaluate effectiveness of current well-plugging practices for the protection of water quality.

4. Estimated Costs:

\$65,000 over calendar years 2008 and 2009.

5. Time Line:

Project reinitiation is scheduled for late 2008.

6. Status Report:

Project work was initiated in early 2008 at a well in Hays County; however, upon further examination and limited geophysical testing, the candidate well was deemed unsatisfactory to the study, and work was placed on hold until a suitable well could be located. Currently the Authority is looking for a candidate well with the potential of study-cost sharing with the well owner or other public agency.

ASRP CATEGORY: SUPPORT STUDY

Proposed Project Title:

Bacterial and Pharmaceutical Study

[Also see page 42]

1. Purpose:

To identify emerging water quality issues in the Edwards Aquifer.

2. Background:

This study involves two potential contaminants of the Edwards Aquifer—(1) bacteria and (2) pharmaceuticals and personal care products (PPCPs). Bacteria wash into the aquifer during stormwater 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 revealed chronic bacterial contamination in some areas. Identifying bacterial sources (human or animal) will help determine whether regulatory controls are necessary. Groundwater from the Edwards Aquifer has never been sampled or tested for PPCPs, so the purpose of the second part of this study is to determine whether PPCPs are present in the Edwards Aquifer.

The most likely source of PPCPs is excretion by humans at on-site sanitary systems (OSSS). It is unlikely that routine grab samples from any well will contain PPCPs. Consequently, one or more wells will

be identified that have a relatively high probability of PPCPs. For example, wells that are located close to a large drain field, in a development with septic tanks, or near an area that disposes of treated effluent by spray irrigation. 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 stormwater.

3. Aquifer Management Issue to be Addressed:

Study will prepare a baseline evaluation of PPCPs in the aquifer.

4. Estimated Costs:

\$30,000 is in the 2008 budget for this study. \$14,000 is designated for the bacterial part of the study, and the remainder is for use in the PPCP analyses. The 2009 budget allocates \$40,000 for continuation and completion of this study.

5. Time Line:

Study is planned for 2008 and 2009.

6. Status Report:

The bacteria part of this study is active via a letter agreement with Dr. Adria Bodour at The University of Texas at San Antonio. PPCP sampling will be initiated in late 2008 or early 2009 after identification of a suitable laboratory for performance of analytical work.

ACTIVE ASRP PROJECTS

ASRP CATEGORY: FLOWPATH

Active Project Title:

Aquifer Biota Study

Background Information

The Aquifer Biota Study is a comprehensive well-sampling program to expand and update information regarding subterranean aquifer-dwelling organisms. For this monitoring program, Zara Environmental will collect data as prescribed in "Well Sampling for Aquifer Biota Monitoring Plan," which was prepared by the Edwards Aquifer Research and Data Center at Texas State University in 2001. The plan describes methods of selecting sampling locations, sampling methodology, data management, identification methodology, and other information related to the project. Biota samples will be collected throughout the Authority's jurisdictional area. Zara Environmental will install traps in selected wells, springs, and caves for long-term collection of specimen. The project

began in November 2007 and will conclude in November 2010. The following tasks will be completed for this project:

- Task 1. Project Initiation and Work Plan Review
- Task 2. Collection of Samples from Wells, Springs, and Caves
- Task 3. Sample Identification and Report Generation

Status Report

The study is in progress. The Authority and Zara Environmental met with San Antonio Water System for access to some of its wells for sample collection. Zara Environmental will continue to collect specimen from other area wells.

Project Budget Status

Total project budget:	\$ 209,100
Authority's share:	\$ 209,100

ASRP CATEGORY: FLOWPATH

Active Project Title:

***Tracer Testing of Aquifer Flowpaths—Comal Springs,
San Marcos Springs, Northern Bexar County***

General Background Information

The Authority conducted its first tracer test at Comal Springs in March and April of 2002 with the help of staff, cooperating agencies, and volunteers. In July 2003, the board approved a contract with George Veni and Associates (GVA) for tracer testing, stormwater monitoring, and water sampling at several sites, including Comal Springs. In September 2004, the board approved a one-year renewal of the contract. The GVA contract was subsequently renewed in 2005 and 2006. However, as of March 2007 the GVA contract had been completed, and a new scope of work for tracer testing was subsequently advertised.

On September 15, 2007, the board approved a \$120,000 contract with Zara Environmental LLC for support of the Authority's tracer tests in Kinney County and near San Marcos Springs. In both areas, Zara will act as the Authority's representative for directing and implementing field activities; participate in planning and implementing additional tracer tests; coordinate access to sampling and injection points with property owners; transfer water samples from the Authority's automatic samplers to sample containers; reprogram automatic water samplers; collect grab samples of water from wells, springs, and other surface water; collect and replace charcoal and cotton receptors; manage and document samples with chain of custody forms; deliver samples to the Authority's office in San Antonio; and assist with tracer injections. The contract was renewed by the Authority in September 2008, leaving one additional optional year.

Background Information— Comal Springs Tracer Testing

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 (UTSA), 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 in the Panther Canyon well appeared in Spring Run 3, rather than in Spring Runs 1 or 2, which are closer to the well. Dye injected in the LCRA well appeared in Spring 7, springs beneath the lake, and springs on Spring Island.

Status Report—Comal Springs

This study is in progress. The Authority has suspended tracer tests in the Comal Springs area until later in 2009.

Background Information— San Marcos Springs Tracer Testing

Authority staff injected dyes at Ezell's Cave and Primer's Fissure on September 16, 2002. Ezell's Cave and Primer's Fissure 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. The was in such a small amount to avoid visible dye detection in nearby private wells. Dye from Ezell's Cave was detected in Wonder Cave after two days, and 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 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.

GVA and Authority staff injected dyes at Ezell's Cave, Primer's Fissure, and Rattlesnake Cave in January 2004. 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. Zara Environmental and Authority staff injected dyes in Windy Cave and Dakota Ranch Cave just outside of San Marcos in fall of 2005 and measured relatively slow groundwater velocities (several hundred feet per day) to San Marcos Springs.

Status Report—San Marcos Springs

The study is in progress. In summer 2008, Zara Environmental, Authority, Barton Springs Edwards Aquifer Conservation District, and City of Austin staff

injected dyes in Bull Pasture Sink, Fritz's Cave, Halifax Sinkhole, and Two-Hole Sink to define springsheds for Barton and San Marcos springs. These traces are still in progress. The tracer tests are part of the follow-up work related to recommendations of the San Marcos Pool Study.

Background Information— Northern Bexar County Tracer Testing

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 in 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 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 Edwards and Trinity aquifers were monitored. Tracer test results showed that 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 faults having hundreds of feet of vertical displacement did not present a barrier to groundwater flow. Consequently, 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

The study is in progress. The Authority has suspended tracer tests in northern Bexar County until 2009.

Background Information— Uvalde and Kinney County Tracer Testing

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 test conclusions presented by SwRI® in its recent report on groundwater conditions in Kinney and Uvalde counties. 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. Tracer tests will be designed from findings of previous research in the area. The Authority will work with the Kinney County Groundwater Conservation District and the Uvalde Underground Water Conservation District to gain access to monitoring or injection points.

Status Report—Uvalde and Kinney County

The study is in progress. Authority staff members are planning the next phase of tracer tests in Kinney County under terms of the Memorandum of Understanding (MOU) with the Kinney County Groundwater Conservation District.

Status Report Zara Environmental Tracer Testing Contract

Work with Zara was initiated in September 2008 and will continue at locations as described herein.

2008 Project Budget Status

Total project budget:	\$ 120,000
Authority's share:	\$ 120,000

ASRP CATEGORY: FLOWPATH

Active Project Title:

Hydrogeology of North Medina County

Background Information

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 installation of numerous water management projects, such as recharge dams. Understanding flowpaths and, therefore, 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 tracer tests, synoptic water level measurements, continuous water level measurements, groundwater

analyses, and other techniques. Authority staff or contractors will conduct tracer tests to assess whether large scale faults act as barriers to groundwater flow. Test sites will be selected at 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. This project will contribute to conceptual understanding of groundwater flow in northern Medina County and northwestern Bexar County to improve groundwater management strategies, as well as the Authority's groundwater model.

Status Report

The study is in progress. Authority staff members have started to identify potential injection sites and monitoring wells in the area of the tracer test. The project budget will be used for materials and supplies needed to complete the 2008 part of the study. In addition, the Authority solicited proposals for a consultant to work on this project.

2008 Project Budget Status

Total project budget: \$ 50,000

Authority's share: \$ 50,000

Estimated cost for this study is \$160,000 over a three-year period.

ASRP CATEGORY: FLOWPATH

Active Project Title:

Evaluating Floodplain Hydraulics of the Frio River Where It Overlies the Edwards Aquifer

*(Formerly Listed as: Evaluation of the
Edwards Aquifer in Kinney and Uvalde Counties, Phase II)*

Background

Southwest Research Institute (SwRI®) completed a study in June 2006 that updated the conceptual model of 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 and San Antonio pools 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 principal aquifers in Uvalde and Kinney counties. Phase II has been 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.

Discharge from the Edwards Aquifer via floodplain flow is recognized as potentially significant and needs further evaluation. Integrated investigations using geophysical surveys of the subsurface are well suited to provide key information for evaluating the hydraulic relationship between river floodplain sediments and underlying aquifers. The objective of this study is to measure the hydraulic relationship between floodplain sediments of the Frio River where it traverses and exits the Edwards Aquifer. The project will consider

studies completed in the last several years, particularly floodplain flow studies of Leona and Nueces rivers and Elm and Turkey creeks. These recent studies are of particular interest because they provide direct evidence of hydraulics and hyporheic exchange of rivers, floodplain sediments, and subsurface flow near the southern edge of the Edwards Aquifer.

This project will help delineate the western boundary of the Edwards Aquifer in the Kinney County/Uvalde County area.

The following tasks will be performed:

- Task 1. Assessment of Surface Water Losses within the Floodplain
- Task 2. Assessment of Subsurface Flow through River Floodplain Sediments
- Task 3. Water Chemistry Analysis
- Task 4. Analysis of the Hydraulic Relationship between Floodplain Sediments and the Edwards Aquifer
- Task 5. Final Report

Status Report

The study is in progress. SwRI® has begun field reconnaissance for the geophysical survey site.

2008 Project Budget Status

Total project budget: \$40,577
Authority's share: \$40,577

This project is estimated to cost approximately \$40,000 in 2008 and \$50,000 in 2009. Total estimated costs are \$90,000 over two calendar years.

ASRP CATEGORY: FLOWPATH

Active Project Title:

Bacterial and Pharmaceutical Study (Bacterial Source Tracking)

(Also see page 33)

Background Information

The goal of this research is to perform microbial source tracking of fecal pollution in the San Antonio segment of the Edwards Aquifer. Microbial source tracking (MST) has sparked interest as a way to identify microbial sources for potential remediation of impaired surface water and groundwater systems. By knowing the microbial source, such as wild or domesticated animals, concentrated feed lots, or human activities, the Authority will be able to target regulatory and investigative efforts. The objective is to use several MST methods to determine the origin of fecal contamination in the Edwards Aquifer as follows:

- Use the *esp* protein from *Enterococcus faecium* as a screening index of human fecal pollution. Research has confirmed that the presence of culturable *enterococci* and detection of the *esp* gene in a water sample indicate the presence of human fecal contamination and potential human health risk.
- Create a fecal host-origin database that will "fingerprint" *E. coli* and *Bifidobacteria* of known fecal pollution in San Antonio. Development of this database will allow us to distinguish between human and nonhuman origin of fecal pollution. For instance, this fingerprint will distinguish whether the fecal source was animal (bird, domesticated animal, raccoon, etc.) or human based

All of these MST methods use a combination of culturing and molecular biology tools, such as polymerase chain reaction (PCR), ribotyping (RT), and electrophoresis. Fecal samples will be obtained from animal and human sources, cultivated, DNA extracted,

subjected to PCR, digested, visualized, and compared so that unique fingerprints can be identified.

Approximately 30 water samples from surface streams, water wells, and springs will be collected by Authority staff and provided to the Center for Water Research (CWR) at UTSA for evaluation. CWR staff will also collect samples from respective target animals, including human sources, for comparative studies. The Principal Investigator is Dr. Adria Bodour, Ph.D., Associate Professor, Department of Earth and Environmental Sciences, UTSA. Dr. Bodour holds a Ph.D. in environmental microbiology from the University of Arizona. She will be the project administrator and lead microbiologist for this proposed project, which will involve one or more graduate students.

Status Report

The study is in progress. Dr. Bodour is researching alternative methods for screening to discriminate between contamination sources. One method that shows promise is use of fecal *Bacteriodes* rather than *Enterococcus faecium*. Of the 33 samples collected this year from Edwards Aquifer springs and wells, seven contain *E. coli* and will be used for culture and subsequent examination of DNA fingerprints. Thus far, however, because bacteria counts have been somewhat low, additional samples or additional sample volumes will be collected to increase bacteria counts.

Project Budget Status (2008)

Total project budget: \$ 14,000
Authority's share: \$ 14,000

Project Budget Status (2009)

Total project budget: \$ 40,000
Authority's share: \$ 40,000

The pharmaceutical part of this study will begin in late 2008 or early 2009 and will have \$20,000 in 2009 funding, whereas the other \$20,000 will be for bacterial study in 2009.

ASRP CATEGORY: SUPPORT

Active Project Title:

Pilot Study to Improve Analytical Water Quality Data through Passive Sampling

Background Information

This project is designed to evaluate use of passive sampling devices in making improvements to the Authority's water quality sampling program. Historically the Authority's water quality sampling has been limited to collection of "grab" type samples, from wells, streams, or springs. Because of the karstic nature of the Edwards Aquifer, however, grab samples may not be fully representative of aquifer conditions. After all, grab samples provide only an instantaneous or snapshot representation of water quality at the sample point rather than a cumulative representation of changes in water quality conditions over time. As such, the Authority is seeking to examine the efficacy of sample collection techniques other than the historical *purge and sample* method. Passive sampling allows for samples to be collected without purging, through the process of diffusion across a membrane or by sorption onto applicable media. For the purposes of this study, three passive sampling devices have been selected for evaluation during the study. Two of the devices collect samples by diffusion across a membrane, whereas one sampler works by diffusion and sorption to media. They are the Rigid Porous Polyethylene Sampler (RPPS), the Polyethylene Diffusion Bag (PDB), and the Gore Sorber Module (GSM).

The Authority hopes to evaluate these technologies systematically to determine what role passive sampling may play in improving the Authority's water quality sampling program. Use of passive samplers may help to improve our understanding of contaminant flux in the system. Ideally wells and springs will both be tested for applicability of this technique. The project work plan is designed to accommodate changes to this approach as more information is gained throughout the study.

Status Report

The study is in progress. A project kickoff meeting was held on July 18, 2007, at which contractors and applicable Authority staff shared information and expertise regarding the project. Hydrophysical testing and packer placement were completed in July 2007 at well AY 68-28-608. As of August, 2007, testing with GSMs in well AY 68-28-608 had begun. The total 2007 budget for the project was \$50,000 to be utilized for all vendors, contractors, and supplies needed to perform the 2007 part of the study. Additional hydrophysical testing was completed on two wells in late August 2007, with one of the wells selected as a candidate for passive sampling. The selected well is referred to as the "Crystal Clear" well. Testing using all three passive devices was begun in this well in October 2007.

As of May 2008, additional grab sample collection had begun to further validate the passive sample data. Grab samples will be collected for every two out of three passive sample collection events. Testing at well AY 68-28-608 and Crystal Clear was continuing as of June 2008, utilizing RPPS and GSM samplers. The study cannot be completed as planned until weather patterns change and allow for sample collection impacted by significant rainfall. As such, beginning in June 2008, sample modules have been retained in wells for four-week intervals rather than two-week intervals, until major changes in weather patterns occur.

For 2008, additional funding for the purchase of passive samplers is included in the Authority budget. The first purchase of passive samplers was made for this calendar year in April with W. L. Gore for GSMs and with Columbia Analytical for RPPSs. Additional RPPS and GSM modules were ordered in mid-June.

Project Budget Status (Calendar Year 2008)

Total project budget:	\$ 48,500
Authority's share:	\$ 48,500

ASRP CATEGORY: SUPPORT

Active Project Title:

Synoptic Water Level Program

Background Information

The Authority currently coordinates the synoptic water level program in support of the MODFLOW aquifer model and Hydrologic Simulation Program Fortran (HSPF) recharge model. The Authority also coordinates the focused synoptic water level program in support of these modeling efforts and to develop a better understanding of aquifer flowpaths. In association with these synoptic water level programs, the Authority has completed two well survey projects—the first in December 2003 and the second in August 2007.

Synoptic Water Level Program (SWLP) and Focused Synoptic Water Level Program (FSWLP)

The SWLP was conceived by the OTS Technical Advisory Group (TAG) to create potentiometric surface maps to assist with modeling and aquifer flowpath studies. Staff from the Authority, San Antonio

Water System (SAWS), USGS, and Barton Springs/Edwards Aquifer Conservation District (BS/EACD) measured aquifer water levels in approximately 220 wells over the Edwards Aquifer region, between one and three times annually within a one-week period. The most recent regional event was performed in October 2008.

Recent efforts to improve overall understanding of groundwater gradients in the aquifer include “focused” synoptic measurements. Focused synoptic events are essentially synoptic studies limited to a smaller geographic area, in which detail can be enhanced by increasing the number of data points for a subset of the region. The next focused event is scheduled for 2009.

Synoptic measurements made between 1999 and 2004 have been published in report format titled Edwards Aquifer Authority Synoptic Water Level Program 1999–2004 Report. The report is available through the Authority’s website.

Project Budget Status

Project work was performed by Authority staff.

ASRP CATEGORY: SUPPORT

Active Project Title:

Analytical Water Quality Monitoring Program

Background Information

The Authority, in cooperation with the USGS and Texas Water Development Board (TWDB), has conducted a systematic program of water quality data collection since 1968. Five major spring groups are sampled regularly every year (springflow permitting): San Antonio, San Pedro, Hueco, Comal, and San Marcos. However, it is not uncommon for the Authority to collect additional samples from other springs in Uvalde or Kinney counties. For example in 2007, the Authority collected samples from Las Moras (Fort Clark) and Pinto springs in Kinney County, in addition to the five major spring groups that the Authority samples regularly. Through this cooperative effort, the Authority has maintained a network of groundwater and surface water monitoring sites, including major springs, for gathering water quality data across the Edwards Aquifer area. Analyses of these data have been used by the Authority to assess aquifer water quality.

Each year the Authority monitors the quality of water in the aquifer by sampling approximately 80 wells, eight surface water sites, and major spring groups across the region. Because of the extent of the aquifer and the large number of wells within it, the annual data set provides only limited resolution with regard to aquiferwide conditions. The sampling program provides a representative "snapshot" of water quality conditions relative to the location, time, and date that the sample was collected. As such, annual water quality data often provide further insight for identification of areas that may be problematic with regard to the presence of compounds that are not indigenous to the system. As a result, these areas may subsequently be sampled with higher frequency or greater density, if warranted.

In 2007, the Authority collected 84 routine water quality samples from 76 wells (six wells were sampled twice, and two wells were sampled at two different depth intervals inside the well). Also, a bacteria sample was collected from one well in addition to the 76 routine wells. The Authority also collected 51 routine water quality samples from seven spring groups (major spring groups were sampled monthly from January through May), with an additional round of sampling from the major spring groups collected in June for bacteria only. The Authority collected 16 routine water quality samples from eight streams (each stream was sampled twice) in 2007. In addition, the Authority analyzed more than 3,000 special samples from 90 wells in response to a large debris fire in Helotes, Texas, between January and May.

Routine water quality samples are typically analyzed in the field for selected water quality parameters and in the laboratory for inorganic and organic chemical constituents. Field analyses included temperature, pH, conductivity, and alkalinity. In general, most routine water samples were analyzed in the laboratory for common major ions, minor elements (metals), total dissolved solids (TDS), hardness, bacteria, and nutrients. In calendar year 2007, routine water quality samples collected from 48 wells and eight spring groups were also analyzed for volatile organic compounds (VOCs). Semivolatile organic compounds (SVOCs) were included in the analyses of water samples from 48 wells and eight spring groups, whereas water samples collected from 38 wells, eight spring groups, and eight stream locations were also analyzed for pesticides, herbicides, and polychlorinated biphenyls (PCBs).

Project Budget Status

Project work was performed by Authority staff.

Funding for analytical laboratory in 2008:

Anacon	\$165,000
San Antonio River Authority	\$ 25,000

ASRP CATEGORY: SUPPORT

Active Project Title:

Water Level Monitoring Program

Background Information

The Authority currently maintains a groundwater level monitoring network from eastern Kinney County to central Hays County. The water level observation network includes both the water table (unconfined) and the artesian (confined) zones of the Edwards, Trinity, and Leona Gravel aquifers. Water levels are monitored through periodic manual measurements (tape down) and continuous recorders. All water level measurements are recorded in feet above mean sea level (msl). Many wells have at least partial historical records dating back to the 1930s. Water levels were measured manually until the USGS introduced continuous water level recorders in

some of the observation wells in the 1930s. In more recent years, electronic data loggers, installed and maintained by the Authority, are replacing older style recorders.

As of August 2008, the Authority's Water Level Data Collection Program consisted of 51 continuous recorder-equipped observation wells and 16 periodically manually measured observation wells. The continuous recorders measure water levels at 15-minute intervals using a float or a pressure transducer. Data are recorded by equipment at the site and then downloaded during site visits or by modem. The continuous recorders are calibrated during each download using a steel tape to ensure data quality. Water level data collected by the Authority are forwarded to interested federal, state, and regional agencies.

Project Budget Status

Project work was performed by Authority staff.

ASRP CATEGORY: SUPPORT

Active Project Title:

Hydrologic Data Collection and Addition of new Stream Gauges

Background Information

The Authority contracts with the USGS annually to perform water quantity measurements at the springs in Uvalde, Bexar, Comal, and Hays counties, as well as streamflow measurements at major streams crossing the recharge zone of the aquifer. These data are used to estimate discharge from and recharge to the aquifer each year. In addition to these tasks, the Authority has recently added the installation

and monitoring of four new stream gauges on the Nueces and Blanco rivers in an effort to improve understanding of the systems water balance.

Status Report

The study is in progress. The Authority and the USGS work together annually to utilize water quantity data. The USGS is working to install and monitor new stream gauges.

Project Budget Status (2008)

Total project budget:	\$ 317,440
Authority's share:	\$ 317,440

MODELING STUDIES

ASRP CATEGORY: MODELING

Project Title:

Edwards Aquifer Computer Model

Background Information

In April 2000 the board approved a Joint Funding Agreement (JFA) with the USGS for construction of a new computer model of the Edwards Aquifer. The model was 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. SwRI® used geostatistical techniques to prepare the hydraulic conductivity data set.

To develop an improved model, the USGS and BEG conducted a study in cooperation with the U.S. Department of Defense (DOD) and the Authority. The objective of the 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.

So that this goal could be accomplished, 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 the initial phases of project planning and implementation, a Ground-Water-Model Advisory Panel (GWMAP) was formed to provide technical input, primarily for conceptualization, but also for 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, SAWS, TWDB, DOD, and contractors. Three employees of the Authority are 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 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 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).

A series of sensitivity tests was made to ascertain how model results were affected by variations greater 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 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 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 the Authority on March 2, 2005.

The model was submitted to the TWDB and has been approved as an official Groundwater Availability Model (GAM) for the San Antonio segment of the Edwards Aquifer.

ASRP CATEGORY: MODELING

Project Title:

*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, Inc., was retained in April 2006 to upgrade management modules to simulate junior/senior rights that were being considered by the Authority board.

Status Report

HydroGeoLogic, Inc., submitted the 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 with rules. Project was completed in August 2006.

ASRP CATEGORY: MODELING

Project Title:

*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 II of the project titled *Enhanced Characterization and Representation of Flow through Karst Aquifers*. The purpose of phase II is to continue testing MODFLOW-DCM (dual conductivity module) to enable MODFLOW to simulate groundwater flow in karst aquifers. The project was jointly funded by the Southwest Florida Water Management District and the Authority.

The project consisted of

- Task 1. Code Refinement
- Task 2. Barton Springs Demonstration Simulations
- Task 3. Floridan Aquifer Demonstration Simulations
- Task 4. Subtask 4.1 (Option 1): 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

Status Report

This study is complete. SwRI® solved dry cell issues associated with MODFLOW by using a solver based on the Newton-Raphson method instead of the Picard method. The project was completed in March 2007.

ASRP CATEGORY: MODELING

Project Title:

*Hydrologic Simulation Program
Fortran (HSPF) Model Refinement*

Background Information

The Authority contracted with Clear Creek Solutions, Inc., in November 2006 to evaluate potential refinements to the current HSPF recharge model and develop a graphical user interface (GUI) to simplify model use. Potential refinements consisted of assessing improvements in model output by using ground-calibrated NEXRAD radar data for each four square kilometers of the entire region. The original model was constructed using a limited series of existing National Weather Service (NWS) rainfall gauges across the region, resulting in limitation on input (rainfall) data sets. Calibrated NEXRAD data are available for calendar years 2003–2006.

Status Report

Conclusions of the final report were somewhat surprising regarding use of NEXRAD data sets for model rainfall input. Although NEXRAD data provide comprehensive coverage of the area, the timestep is daily rather than hourly. As such, use of the limited number of NWS rainfall gauges with hourly data appears to provide a more complete assessment of recharge than do daily NEXRAD data because of the need to have information for rainfall intensity. Rainfall events that result in a high degree of runoff affect modeled recharge output more significantly than rainfall events that do not. Daily rainfall amounts from NEXRAD do not provide this information. Future assessments may include evaluation of hourly NEXRAD data sets or incorporation of the Authority's real-time network of rainfall gauges. This project is complete, although, given the results of this study, one more iteration of model refinement is probably needed. The project was completed in September 2007.

ASRP CATEGORY: MODELING

Project Title:

MODFLOW Model—Improved Storativity Estimates

Background

The goal of this research was to refine storativity estimates of the Edwards Aquifer using a new method that is based on 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 measurements of storativity from aquifer tests are preferred, but a few data sets are available for the Edwards Aquifer. Consequently, indirect measurements, such as seismic efficiency, are used to fill data gaps.

Status Report

This research began in October 2006 and was completed in December 2007.

ASRP CATEGORY: MODELING

Project Title:

Estimation of Hydraulic Parameters for the Edwards Aquifer Management Model

Background Information

In May 2000 the board approved a two-year JFA with the U.S. Army Corps of Engineers (COE) to statistically model hydraulic conductivity measurements and create an input data set for the MODFLOW model being prepared by the 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 measured values to grid cells in the model. Results were refined in subsequent models using Bayesian statistics and incorporating groundwater levels, as well as hydraulic conductivities.

Status Report

The study is complete. The final report and 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.

ASRP CATEGORY: MODELING

Project Title:

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 was 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 was to simulate effects of the Authority's demand management/critical period rules that were enacted in 2002. The new modules enabled MODFLOW to accept trigger levels, a variety of recharge and pumping schedules, and other conditions.

Status Report

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

ASRP CATEGORY: MODELING

Project Title:

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. 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. This project required 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 reference manual that were prepared for the MODFLOW 96 version.

Status Report

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

ASRP CATEGORY: MODELING

Project Title:

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 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. 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

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.

Appendix B

Detailed Descriptions of Completed ASRP Projects

ASRP CATEGORY: MODELING

Project Title:

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 modeled were

- (1) Frio/Dry Frio River Basin
- (2) Sabinal River Basin
- (3) The area between Sabinal and Medina River Basins
- (4) Medina River Basin
- (5) The area between Medina River and Cibolo/Dry Comal Creek Basins
- (6) Cibolo Creek and Dry Comal Creek Basin
- (7) Guadalupe River Basin
- (8) Blanco River Basin
- (9) Nueces River Basin

The LBG-Guyton team consists of AQUA TERRA Inc., Espey Consultants, Freese and Nichols, and Dr. Bradford Wilcox (TAMU). Methodology for this project is similar to that of 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

The study is complete. HSPF recharge models for the nine basins were constructed and run using input (rainfall) data for the period 1950–2000. Model results indicate slightly higher cumulative recharge for the model period than do historical methods. The project final report was submitted on January 31, 2005. The final deliverable, a set of HSPF output data files formatted for use in the MODFLOW model, was submitted prior to the end of the contract period (March 30, 2005).

ASRP CATEGORY: MODELING

Project Title:

Recharge Methodology (Pilot Study)

Background Information

In April 2001, the board approved a contract between the Authority and HDR Engineering, Inc. (HDR), for development of pilot recharge models for the Nueces and Blanco River basins. Under the contract, HDR provided daily recharge estimates as far back as 1950 for the Nueces basin and 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 TWDB, produce different volumes of recharge for some basins, the largest differences between the two methods occurring in the Nueces and Blanco River basins. HDR's work updated recharge estimating methods and generated 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 estimating recharge to the aquifer annually.

Status Report

The study is complete. Final models were presented to Authority staff in February 2002. HDR delivered its final report to the Authority in June 2002. Because the pilot models generated more representative volumes of recharge than the previous methods, the updated methodology will be applied to remaining drainage basins in the recharge zone.

ASRP CATEGORY: MODELING

Project Title:

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 data provided by the Authority and described its approach to the study.

Status Report

The study is complete. ANL submitted its final report in November 2001, which completed its involvement in the project.

FLOWPATH STUDIES

ASRP CATEGORY: FLOWPATH

Project Title:

Define and Delineate San Marcos Pool

Background Information

Section § 702.1 of Authority rules currently defines two pools in the Edwards Aquifer, the San Antonio and the Uvalde. Although San Marcos Springs is currently included within the San Antonio Pool, the habitat provided by spring discharge may not be protected properly by trigger levels utilizing the Bexar County Index Well (J-17) or Comal Springs discharge. A high correlation exists between J-17 and Comal Springs; however, correlation is rather poor between J-17 and San Marcos Springs. Consequently, demand management and critical period management rules for the San Antonio Pool may have a limited effect on San Marcos Springs discharge. This project investigated methods and tasks to determine whether creation of a San Marcos Pool is technically justified. In addition, the conceptual model of the San Marcos Springs was evaluated and updated.

The study utilized information from a variety of sources, including water levels (Focused Synoptic Water Levels), water quality analyses, well logs, geologic data, tracer test results, and other information for making a determination.

Status Report

The study is complete. Although the report was issued in February 2008, some work continues on the basis of recommendations (in the report) to characterize groundwater flowpaths near the springs. Authority and Zara Environmental staff members are continuing tracer testing in the Blanco River area in Hays County. Thus far, the Authority has injected small quantities of nontoxic dyes into three sinkholes in the Blanco River Basin. No dye was detected in nearby wells. Additional dye was injected June 10–12, 2008, to trace groundwater flowpaths to San Marcos and Barton springs. Zara Environmental staff will monitor many wells and the springs over several weeks to detect arrival of the dyes.

ASRP CATEGORY: FLOWPATH

Project Title:

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 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 insufficient to maintain critical habitat, then threatened and endangered species will have to be moved to traditional refugia under controlled conditions. This project investigates 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 to obtain additional support services from the contractor as needed by the Authority.

Status Report

The study is complete. The final report was submitted in June 2004.

ASRP CATEGORY: FLOWPATH

Project Title:

Hydrologic Assessment of Flowpaths— North Medina County

Background Information

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

Status Report

The study is complete. The USGS finalized the report in February 2006

ASRP CATEGORY: FLOWPATH

Project Title:

Noble and Active Gas Sampling in the Knippa Gap Region

Background Information

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 help identify 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 predict hydrologic and geochemical responses in major flowpaths down gradient of the Knippa Gap region.

Status Report

The study is complete. The USGS has drafted a report of its findings.

ASRP CATEGORY: FLOWPATH

Project Title:

Investigation of Groundwater Systems in Kinney and Uvalde Counties

Background Information

In July 2004 the board approved a contract with SwRI® to investigate groundwater systems in Kinney and Uvalde counties. The purpose of the project was 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 groundwater systems in Uvalde County, a discrepancy seems to exist 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 pilot recharge models is less than the amount calculated by previous methods. Consequently, recent studies have revealed a lack of precision in existing estimates of the water budgets in Uvalde County. Because water resources of Uvalde County are an important part of the Edwards Aquifer, continued study of the sources of error in the water balance is important.

The project consists of the following tasks:

- Task 1. Well Inventory
- Task 2. Focused Synoptic Water Level Survey
- Task 3. Water Chemistry Evaluation
- Task 4. Geologic Structural Analysis
- Task 5. Data Analysis and Reporting

Status Report

The 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's website under the reports section at http://www.edwardsaquifer.org/pages/research_optimization.htm.

ASRP CATEGORY: FLOWPATH

Project Title:

Hydrologic Budget Analysis of Medina Lake and Diversion Lake

Background Information

In August 2000 the board approved a three-year, eight-month JFA with the USGS for a hydrologic budget analysis (water balance) of Medina and Diversion lakes. Bexar Metropolitan Water District (Bexar Met) is also cooperating 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. This study was conducted with high lake levels. The USGS monitored lake levels, meteorological conditions, inflows, and outflows from the lakes to calculate groundwater losses.

Status Report

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

ASRP CATEGORY: FLOWPATH

Project Title:

North Medina County Flowpath—Helicopter Electromagnetic Survey in the Vicinity of 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. A helicopter electromagnetic (HEM) survey was completed for an 81-square-mile area in northwestern Medina County and northeastern Uvalde County. HEM data were collected by towing an airborne magnetometer over predetermined flight lines, which were flown in a north-south and east-west grid pattern centered on Seco Creek Sinkhole. 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 report concluded that survey data are effective from near surface down to approximately 100 meters and that the data show more structural detail and precise locations than do 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.

ASRP CATEGORY: FLOWPATH

Project Title:

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 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 Edwards Aquifer hydrologic budgets. The project report concludes that as much as 100,000 acre feet of water may be leaving the Edwards Aquifer near Leona Springs.

Status Report

The study was completed in February 2004.

ASRP CATEGORY: FLOWPATH

Project Title:

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 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 percent of the cost of this study, which was initiated in June 2002 and 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 of this study was to analyze potential hydraulic communication across the interface between Edwards and Trinity aquifers, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

Status Report

The 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.

ASRP CATEGORY: FLOWPATH

Project Title:

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 COE and the Authority for analysis of structural controls on the Edwards Aquifer/Trinity Aquifer interface in the area of the Helotes Quadrangle. The COE Planning Assistance to States program is paying 50 percent of the cost of this study, and the CNWRA 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 of 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

The study is complete. SwRI® submitted the final geologic framework model and report in February 2005.

ASRP CATEGORY: SUPPORT

Project Title:

Saline Water Study

Background Information

Between mid-1998 and August 15, 2005, the Authority and SAWS cooperatively funded the construction, operation, and maintenance of Edwards Aquifer freshwater/saline water interface monitoring wells. The purpose of the multiyear study was 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 monitoring well transects. Prior to 1994, the USGS and EUWD 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 to not 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.

ASRP CATEGORY: FLOWPATH

Project Title:

Fracture/Conduit Study

Background Information

In November 2001 the board approved a JFA between the Authority and BEG to investigate the influence of faults and conduits on groundwater flowpaths in both recharge and artesian zones of the aquifer. Dr. Sue Hovorka will lead 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

The study was completed in February 2004.

ASRP CATEGORY: FLOWPATH

Project Title:

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 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. 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

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

SUPPORT STUDIES

ASRP CATEGORY: SUPPORT

Project Title:

Improved Gauging at Comal Springs and San Marcos Springs

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 to support the Authority's groundwater model.

The purpose of this study was to evaluate a new gauging system for Comal and San Marcos springs. The springflow quantification pilot project involved

selection of a new gauging location, as well as installation of a new generation of gauging equipment, to improve accuracy and precision of discharge measurements from Comal and San Marcos springs. Work on the project was performed through a joint funding agreement between the Authority and the USGS.

Work was performed in three phases:

Phase I—initial equipment installation and operation using up to 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 I evaluation period, up to two ADVMs at each spring system were placed permanently at the most favorable locations and connected by telemetry to obtain real-time data capabilities.

Phase II—data collection and system validation, which included collection of continuous velocity index data for an entire water year as a velocity–discharge rating curve is developed.

Phase III—study report and recommendations for improving the discharge measurement system at both springs.

Status Report

The USGS completed the study in 2008.

ASRP CATEGORY: SUPPORT

Project Title:

Guadalupe River Gain / Loss Study

Background

This study was intended to build on previous work on 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. The study also updated the amount of water that is estimated to recharge the Edwards Aquifer from the Guadalupe River. Ultimately this study should assist in determining the contribution of Comal and San Marcos springs to the Guadalupe River.

Status Report:

The USGS completed the work, and the first draft of the final report addressing all comments should be available in late 2008 or 2009.

ASRP CATEGORY: SUPPORT

Project Title:

Edwards Aquifer Well Survey Project

Background Information

In April 2002 the board approved a letter agreement with Ford Engineering, Inc. (FEI), to collect 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 from May 1, 2002, through December 31, 2003. The 403 wells surveyed include

- 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 Authority archives,
- Wells in Hays County necessary to evaluate the location of the Edwards Aquifer groundwater divide, and
- Eight permanently installed benchmarks and numerous spring-related features near Comal and San Marcos springs.

Status Report

The study is complete. Survey project deliverables received by the Authority include

- 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 hardcopy format sealed by RPLS, guaranteeing accuracy, as well as in MS Excel format.