

**Evaluation of the Availability of
Additional Water Supplies
From the Edwards Aquifer**

June 25, 2004



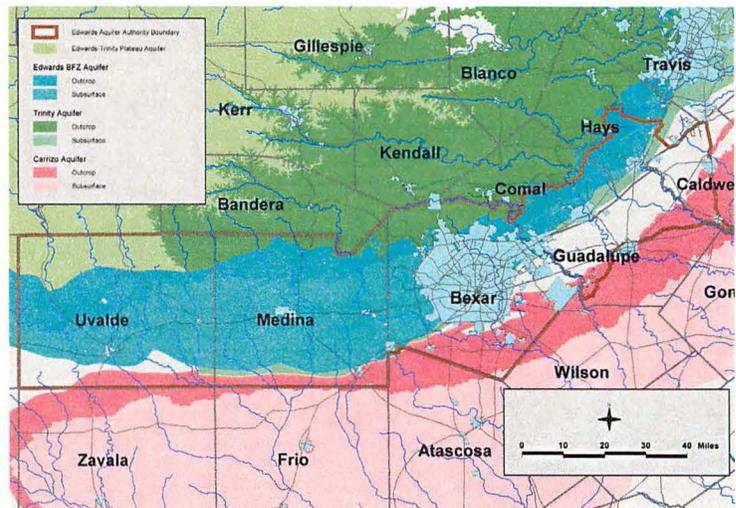
***Daniel B. Stephens
& Associates, Inc.***

Evaluation of the Availability of Additional Water Supplies From the Edwards Aquifer

Prepared for

Edwards Aquifer Authority
San Antonio, Texas

June 25, 2004



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Table of Contents

Section	Page
Executive Summary.....	ES-1
1. Purpose and Scope.....	1
2. Evaluation Process	2
2.1 Characterization and Screening Process.....	3
2.2 Information Write-up on Studies and Strategies.....	6
2.3 Decision Analysis Process.....	6
2.3.1 Objectives and Performance Measures.....	7
2.3.2 Scales, Analysis, and Weights	8
2.3.3 Evaluation of Alternative Strategies.....	11
3. Conclusions	14
4. Recommendations	15



List of Figures

Figure		Page
1	Objectives and Performance Measures Decision Hierarchy	8
2	Relative Overall Scoring of Precipitation Enhancement Program and SAWS ASR Project to Ideal Case for Recommending an Increase to the Cap	11
3	Relative Contributions of the Objectives to the Overall Performance of the Precipitation Enhancement Program and SAWS ASR Project.....	12
4	Radar Chart of Weighted Performance Scores for Each Objective of the Precipitation Enhancement Program and SAWS ASR Project.....	13

List of Tables

Table		Page
1	Board Approved List of Studies and Strategies	2
2	Relative Importance of Objectives	10
3	Relative Importance of Performance Measures.....	10

List of Attachments

Attachment

- A Results of Characterization and Screening Process of Studies and Strategies
- B Section 711.296 Write-ups of the Studies and Strategies
- C Detailed Description of the Weights and Ratings Used in the Decision Model for Precipitation Enhancement Program and SAWS ASR Project



Executive Summary

The project team consisting of Daniel B. Stephens & Associates, Inc., Freese and Nichols, Turner, Collie and Braden, and George Veni and Associates has screened 25 studies and 8 strategies through a decision analysis process to identify any study or strategy that could be used to justify an adjustment of the Edwards Aquifer withdrawal cap. At present, two implemented water management strategies, The Edwards Aquifer Authority's (Authority's) Precipitation Enhancement Program and the San Antonio Water System's (SAWS) Aquifer Storage and Recovery (ASR) project, passed the water-budget based screening process. These strategies currently appear to fall somewhat short of meeting some of the objectives required to justify adjusting the withdrawal cap. The ASR strategy appears to be the more promising of the two. As the SAWS ASR project goes forward, and an operational track record is established, it may well provide the basis for a cap adjustment in the future.

In addition to the SAWS ASR project and the Precipitation Enhancement Program, the project team identified several other studies and strategies that have the potential to support an adjustment to the withdrawal cap once more conclusive information is developed or more reliable performance records are developed.



1. Purpose and Scope

The purpose of this scope of work is to develop information for the Edwards Aquifer Authority Board of Directors so that they can determine if there is justification for changing the volume of water that may be withdrawn from the aquifer by permittees each year. The evaluation will be performed pursuant to the relevant citations in the Edwards Aquifer Authority Act (the Act) and Edwards Aquifer Authority Rules Chapter 711 (Groundwater Withdrawals), subchapter K (Additional Groundwater Supplies).

Article 1, Section 1.14(d) of the Edwards Aquifer Authority Act indicates that, "If through studies and implementation of water management strategies, including conservation, springflow augmentation, diversions downstream of Comal and San Marcos springs, reuse, supplemental recharge, conjunctive management of surface and subsurface water, and drought management plans, the Authority determines that additional supplies are available from the aquifer, the Authority, in consultation with appropriate state and federal agencies, may review and may increase the maximum amount of withdrawals provided by this section and set a different maximum amount of withdrawals.

These rules require that the General Manager of the Authority provide periodic reports, titled additional water supply reports, to the board. This report was completed June, 2004. Section 711.294 of the rules indicates the types of water management strategies that should be considered. Section 711.296 outlines the required steps for evaluating ongoing (incomplete) or completed studies or implemented water management strategies. Section 711.298 indicates that the board may issue an order determining that additional supplies are present and they are available for withdrawal. These rules also outline processes for the board to consult with state and federal agencies on increasing the permitted withdrawal cap and allocating any additional groundwater supplies.



2. Evaluation Process

The studies and strategies approved by the Authority Board of Directors, as well as their completion status, are listed in Table 1.

Table 1. Board Approved List of Studies and Strategies

Study / Strategy	Status
Studies	
Texas Wild Rice Mapping	Incomplete
Texas Wild Rice Growth and Reproduction	Incomplete
Aquatic Ecosystem Monitoring at Comal and San Marcos springs	Incomplete
Cagle's Map Turtle Habitat	Complete
Edwards Computer Model (Modflow)	Incomplete
Parameter Estimation for MODFLOW Model	Complete
Management Modules for MODFLOW Model	Incomplete
Karst System Computer Model	Incomplete
Saline Water Study	Incomplete
Use of Aquifer Saline Water	Incomplete
N. Medina Co. Flowpath, Hydrologic Budgets	Incomplete
N. Medina Co. Flowpath, Hydrogeologic Assessment	Incomplete
N. Medina Co. Flowpath, HEM Survey, Seco Sinkhole	Complete
Structural Controls, Edwards-Trinity, Camp Bullis Quad	Complete
Structural Controls, Edwards-Trinity, Helotes Quad	Incomplete
Leona Formation Geophysical Survey and Aquifer Test	Complete
N. Bexar Co. Flowpath, HEM Survey, Camp Bullis	Incomplete
Tracer Testing of Comal and San Marcos Springs	Incomplete
Recharge Models of River Basins	Incomplete
Statistical Analysis, 1998 Flood	Complete
Fracture/Conduit Study	Complete
Range Management - Woody Species BMPs	Incomplete
Range Management - Groundwater Recharge by Brush Control	Incomplete
Analysis of Recharge and Recirculation	Incomplete
Springflow Augmentation in Support of In-situ Refugia	Incomplete
Strategies	
Conservation	
Authority's Agricultural Water Conservation Loan Program	Implemented
Region L's Population and Water Demand Revisions	Implemented



Table 1. Board Approved List of Studies and Strategies (Continued)

Study / Strategy	Status
<i>Strategies (continued)</i>	
Springflow Augmentation	None
Diversions Downstream of Springs (Pursuant to Sect. 1.30)	None
Reuse: SAWS & NBU Recycled Water Programs	Implemented
Supplemental Recharge: Authority's Precipitation Enhancement Program	Implemented
Conjunctive Management of Surface and Groundwater : Bexar Met, San Marcos, New Braunfels, Canyon Regional	Implemented
Drought Management Plans:	
Water Purveyors Drought Plans and Authority's Demand Management and Critical Period Management Rules	Implemented
Other Water Management Strategies	
SAW's ASR Project	Implemented
SAW's Use of Trinity and Carrizo Aquifers	Implemented
Bexar Met Use of Trinity and Carrizo Aquifers	Implemented
Tri-County Area Cities Use of Carrizo Aquifer	Implemented

2.1 Characterization and Screening Process

The project team recognized that studies and strategies need to meet certain threshold conditions before it made sense to evaluate in more detail whether they could justify adjustment of the withdrawal cap.

The withdrawal cap itself derives largely from a water budget calculation. It is based on estimates of the amount of inflow into the aquifer (recharge) and the amount of outflow from the aquifer required for downstream uses and endangered species. So it follows that increases to the withdrawal cap can be justified if supported by new studies or strategies which prove:

- Springflow requirements for listed species are less than previously
- More water is available for use from the aquifer than previously estimated (as determined through research or the implementation of alternative management strategies)



- Natural recharge to the aquifer is greater than previously estimated or recharge can be artificially increased

Studies and strategies that result in the development of better aquifer management tools and studies that improve the basic understanding of the aquifer, while important, will generally not lead to recommended withdrawal cap adjustments. Studies and strategies that improve the efficiency of current uses or change the place or purpose of use, while important, will generally not lead to recommended cap adjustments unless they can be shown to limit withdrawals during drought to preserve springflows.

New sources of supply that affect the water budget of the region, but not the aquifer, will generally not lead to recommended cap adjustments unless they can be shown to help limit withdrawals during drought to preserve spring flows. Effective and reliable management strategies that can be shown to be reliable methods to limit pumping impacts on springflows will have the potential to support recommended cap adjustments.

Based on this approach, the project team judged that the following studies represented primarily data collection or management tool efforts:

- Texas wild-rice mapping
- Texas wild-rice growth and reproduction
- Cagle's Map Turtle habitat
- Groundwater modeling, parameter estimation, management modules, and karst-system computer models
- Saline water study
- North Medina County - Seco Creek HEM study
- Structural controls, Edwards-Trinity
- North Bexar County flowpath, HEM survey
- Tracer testing of Comal and San Marcos springs
- Statistical analysis, 1998 flood
- Fracture/conduit study



The following studies were judged to have the potential to support cap adjustments:

- Aquatic ecosystem monitoring
- Use of aquifer saline water
- North Medina flowpath studies
- Leona formation geophysical survey and aquifer test
- Recharge models of river basins
- Range management studies (woody species BMPs and increased recharge by brush control)
- Recharge and recirculation study
- Springflow augmentation in support of in-situ refugia

At present, these studies are either incomplete or have generated results that are not conclusive enough to support a recommended withdrawal cap adjustment.

The following strategies include those that improve efficiency in the use of aquifer water, new supplies, and uses that will affect the regional water budget but not the Edwards Aquifer water budget. For the purpose of this evaluation, these strategies are considered management tools and do not currently have a sufficient operational record to justify specific adjustments to the withdrawal cap. Future withdrawal cap evaluations may include some of these strategies if they can be shown to limit withdrawals during drought to preserve springflows. These strategies include:

- Conservation (Authority's agricultural water conservation loan program and Region L's population and demand revisions)
- Reuse (SAWS and NBU recycled water programs)
- Conjunctive management (Bexar Met, San Marcos, New Braunfels, and Canon Regional surface water plants)
- Drought management plans (water purveyors drought plans and Authority's demand management and critical period management rules)



- Other water management strategies (SAWS and Bexar Met use of Trinity and Carrizo aquifers, Tri-County area cities' use of Carrizo aquifer.

Pursuant to the previously described project screening criteria, the strategies that have apparent potential to support cap adjustments include:

- Supplemental recharge (precipitation enhancement)
- Other water management strategies (SAWS ASR Project)

Attachment A presents the results of the characterization and screening process.

2.2 Information Write-up on Studies and Strategies

Section 711.296 outlines the required steps for evaluating ongoing (incomplete) or completed studies or implemented water management strategies. Attachment B presents the write-ups for each of the 25 studies and 8 strategies. The write-ups are presented in a format consistent with the steps outlined in Section 71.296. After compiling and reviewing the write-ups, the project team found that the precipitation enhancement program and SAWS ASR project are far enough along to allow a more detailed evaluation using a decision analysis approach as described below.

2.3 Decision Analysis Process

The project approach relied on decision analysis, a decision making method often applied in situations involving selection among competing alternatives. The idea is to integrate what one can do (alternatives) with what one knows (data and assumptions), along with what decision makers want (values and objectives). This tool helps to focus the discussions on the elements of the problem that most directly affect the decision.

During a series of workshops involving Authority staff and managers and the consulting team, commencing in January, 2004, we constructed a decision-making framework to help Authority staff implement § 711.296 (12)-(14) to determine whether to recommend an increase to the permitted withdrawal cap, and if, so, by how much; and to provide a reasoned analysis supporting the recommendation.



2.3.1 Objectives and Performance Measures

The first step was to consider what objective would need to be satisfied in order to support a recommendation to raise the withdrawal cap. The project team concluded that the most important objectives to be satisfied were:

- Environmental protection
- Economic feasibility
- Quantity of supply
- Regulatory feasibility
- Reliability

That is, for an implemented strategy (or study) to be the basis for a recommended cap increase, the project team would desire that the strategy be, at the same time, protective of the environment, economically feasible, produce a significant new supply, be feasible from a regulatory standpoint, and be reliable from a physical standpoint.

For each objective, the project team identified one or two *performance measures*, or attributes that could be rated or scored on a quantitative or qualitative basis. With regard to environmental protection, the performance measures included:

- Protect endangered species/water levels
- Maintain aquifer water quality

Economic feasibility was judged to be a reflection of:

- Project costs
- Protect economies of region

Quantity of supply was measured in terms of average yield, with consideration to yield under drought conditions.



Regulatory feasibility evaluations reflected:

- Number of jurisdictions
- Regulatory availability

Reliability of the strategy was considered in terms of:

- Value, precision, and accuracy of data
- Technical basis and feasibility

The objectives and performance measures form the *decision hierarchy*, as shown in Figure 1.

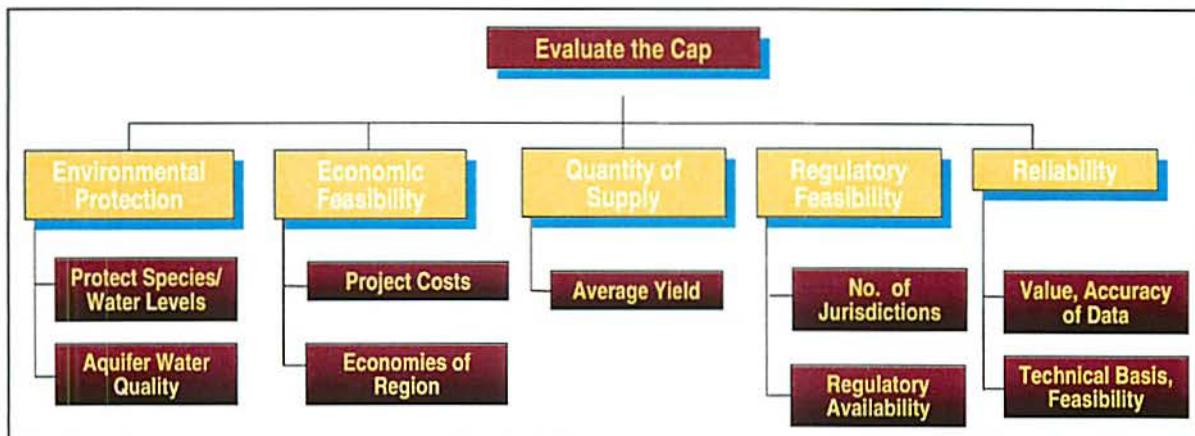


Figure 1. Objectives and Performance Measures Decision Hierarchy

For each performance measure, the project team developed a scale with which to rate or score the performance of the two strategies that survived the screening process.

2.3.2 Scales, Analysis, and Weights

For each performance measure, we adopted a rating scale of 0 (worst) to 100 (best) and described qualitatively the features that would merit high, medium, and low ratings. The two alternative strategies were then scored according to that scale. The following



paragraphs briefly describe the relative performance of the two strategies. Attachment C includes a detailed description of the weights and ratings used in the decision model for the precipitation enhancement program and the SAWS ASR project.

2.3.2.1 Environmental Protection

Both strategies were judged to be favorable with regard to the protection of endangered species and water levels, with somewhat higher rating scores going to the SAWS ASR project because of its higher effectiveness during dry periods. No significant water quality issues were anticipated for either strategy.

2.3.2.2 Economic Feasibility

Project costs are at present difficult to quantify. In the case of precipitation enhancement, the relationship between increased rainfall, increased recharge, and decreased pumping demand has not been quantified. Although long-term operating costs of the ASR project have not been firmly established the project team judged that it would be somewhat more cost-effective than the precipitation enhancement strategy. A similar relationship was found for protection of the economies of the region, as the ASR project provide higher water levels during dry periods to the benefit of all who pump from the aquifer.

2.3.2.3 Quantity of Supply

The precipitation enhancement program is assumed to be less effective during drought, where as the planned average yield from the ASR is 22,500 acre feet per year during dry periods, the ASR strategy is judged to perform much better with regard to quantity of supply.

2.3.2.4 Regulatory Feasibility

Both of the strategies were judged to perform very well for this objective. They are already implemented (or in the process of being implemented) with limited if any resistance.



2.3.2.5 Reliability

The link between slightly increased rainfall and recharge is not well quantified. In addition, because of the dependence on variable climatic conditions, the precipitation enhancement program was judged to significantly less reliable than the ASR strategy.

2.3.2.6 Weights

To apply the decision model, it is necessary to identify the relative importance of the objectives and performance measures. The project team considered the intrinsic importance of the objectives and performance measures as well as the range of performance for all the alternatives for each objective and performance measure. Table 2 shows the weights assigned to each objective.

Table 2. Relative Importance of Objectives

Objective	Weight (%)
Environmental protection	20
Economic feasibility	21
Quantity of supply	23
Regulatory feasibility	18
Reliability	18

The relative importance of the performance measures is listed in the Table 3.

Table 3. Relative Importance of Performance Measures

Performance Measure	Weight (%)
Protect endangered species/water levels	11
Maintain aquifer water quality	8
Project costs	7
Protect economies of region	14
Average yield	23
Number of jurisdictions	6
Regulatory availability	12
Value, precision, and accuracy of data	8
Technical basis and feasibility	11



2.3.3 Evaluation of Alternative Strategies

With the ratings and weights in place, the evaluation of the alternatives was completed and is summarized in Figure 2, which illustrates the overall performance of the alternatives on a scale of 0 to 1 (1 being perfect). An ideal alternative is a perfect score for all performance measures.

It is clear that although the two alternative strategies provide significant benefits with regard to the identified objectives, they also fall significantly below the ideal case for recommending an increase to the cap.



Figure 2. Relative Overall Scoring of Precipitation Enhancement Program and SAWS ASR Project to Ideal Case for Recommending an Increase to the Cap

Figure 3 shows how relative contributions of the objectives to the overall performance. Economic feasibility, quantity of supply, and reliability appear to be the factors than drive the better performance of the ASR alternative.

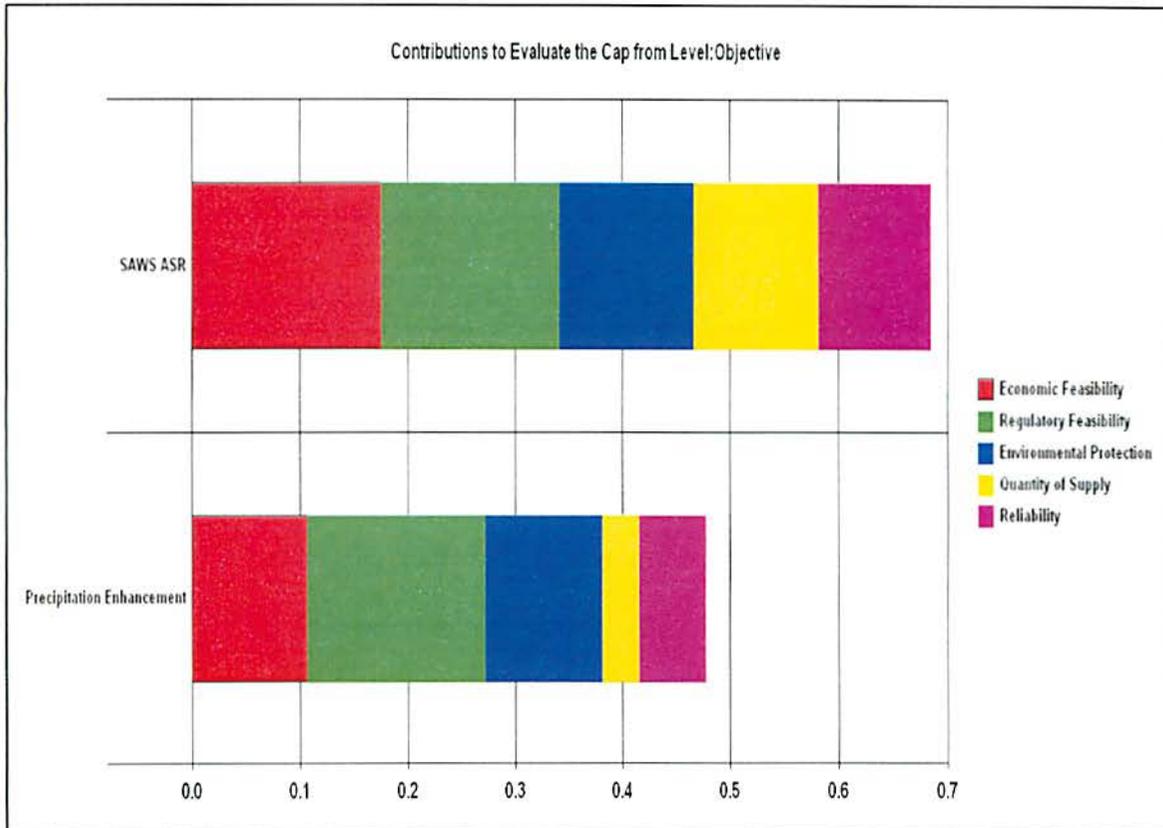


Figure 3. Relative Contributions of the Objectives to the Overall Performance of the Precipitation Enhancement Program and SAWS ASR Project

Figure 4 shows the same results in a different format, called a *radar chart*. In this view, the weighted performance scores for each objective are plotted along the “spokes” of the wheel. Because the ASR scores are always on the outside, it can be readily seen that this strategy performs as well or better than the precipitation enhancement for all the objectives.

The Project team then evaluated whether the scores were sensitive to the weights assigned to the objectives. This analysis determines whether small shifts in weights assigned to a particular objective would change the scores received by each alternative. This analysis demonstrated that changes in weights assigned to the objectives did not significantly affect the scores. In other words, no one objective leads to the selection of one alternative versus another. In fact, it is exactly because the ASR strategy performs



the best for each objective that it rises to the top—and stays at the top—for pretty much any reasonable distribution of weights among the multiple objectives.

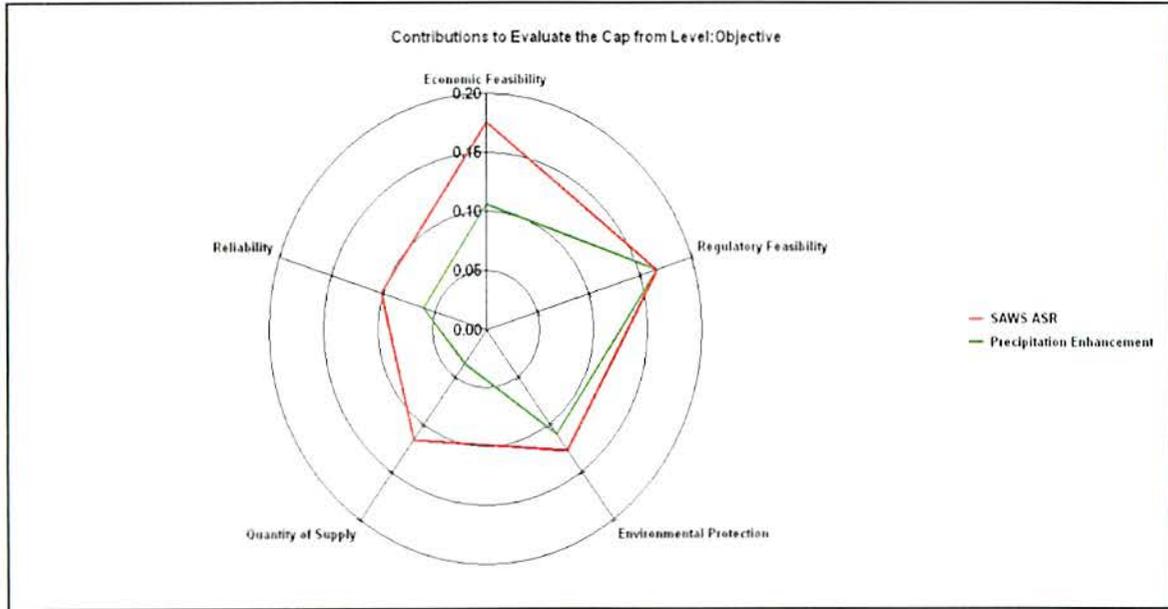


Figure 4. Radar Chart of Weighted Performance Scores for Each Objective of the Precipitation Enhancement Program and SAWS ASR Project



3. Conclusions

The project team created a decision-analysis tool that has provided useful insights into the evaluation of the withdrawal cap as called for in § 711.296 of the Authority's rules. It seems appropriate that a recommendation to adjust the cap should be based on studies or strategies that meet the multiple objectives identified: environmental protection, economic feasibility, quantity of supply, regulatory feasibility, and reliability.

At present, the two implemented strategies that pass the water-budget based screening process appear to fall somewhat short in meeting some of the objectives. However, the ASR strategy appears to be the more promising of the two that were evaluated. As the project goes forward and an operational track record is established, it may well provide the basis for a cap adjustment.

In addition to the SAWS ASR project and the precipitation enhancement program, the project team identified several other studies and strategies that have the potential to support an adjustment to the cap once more conclusive information is developed or more reliable performance records are developed.



4. Recommendations

The decision model developed during this work assignment represents a useful framework for ongoing evaluation of potential cap adjustments. In addition to providing a means to evaluate studies and strategies, it also serves the useful purpose of creating an audit trail of the thinking and conclusions of the Authority staff.

There are several potential applications of the decision model:

- It could be used to help explain the findings of the *Evaluation of Available Supplies Study* to the Edwards Aquifer Authority Board of Directors (BOD) and other interested stakeholders
- The BOD and appropriate stakeholders could be involved in review and update of the decision model, particularly with regard to the value judgments involved
- This process could allow Authority staff and management to obtain agreement at this stage that this process will be the decision framework that will be used in subsequent evaluations of the cap
- As studies are completed and more "hard data" is available, the decision model could be refined to include more quantitative scales for the performance measures
- The decision model could also be applied to make a preliminary evaluation of the studies and strategies that are in their early stages (and thus not fully evaluated here); this preliminary evaluation could be used to prioritize these activities and set priorities for funding and scheduling

In addition to extending and applying the decision model, the next evaluation should consider assembling several alternatives that consist of combinations of several studies and strategies. It is possible that when several studies and strategies are taken together, performance with regard to achieving the objectives could be improved.

Attachment A

**Results of Characterization and
Screening Process of
Studies and Strategies**

ATTACHMENT A

Project Screening Process

EDWARDS AQUIFER AUTHORITY RULES ch. 711 (Groundwater Withdrawals), subch. K (Additional Water Supplies).

On December 16, 2003, the board approved a contract between the Authority and Daniel B. Stephens & Associates, Inc. (DBS&A) to develop and implement a process to evaluate the availability of additional water supplies from the Edwards Aquifer. The information developed through this contract will be incorporated into the 2004 additional water supply report. The report will be provided to the board by June 30, 2004.

On February 10, 2004, the board approved a list of ongoing and completed studies and implemented water management strategies to be considered in the preparation of the report. Over the last two months, Authority staff and the DBS&A team have been compiling information regarding the board-approved studies and strategies and have developed a project screening process. The project screening process is presented below.

Screening Criteria:

I. Is the study complete or is the strategy implemented?

No: Because of incomplete information, incomplete studies and non-implemented strategies will not be evaluated for their potential to support an adjustment to the Edwards Aquifer withdrawal cap. Background information regarding the incomplete studies or non-implemented strategies will be prepared pursuant to Authority rules 711.296(a)(1)–(12).

Yes: Completed studies and implemented strategies are categorized by their potential to support an adjustment to the aquifer withdrawal cap as follows:

Project Category:

1. Does the study or strategy identify reduced flow requirements for listed species? **(RF)**
2. Does the study or strategy identify additional water in the aquifer? **(AW)**
3. Does the study or strategy identify increased recharge to the aquifer? **(IR)**
4. Study or strategy does not support adjusting the withdrawal cap at this time. **(NSA)**

If the answer to questions 1 through 3 is no, the study or strategy is considered as a **low potential** for supporting an adjustment to the aquifer withdrawal cap and will not receive further evaluation at this time. If the answer is yes to at least one of questions 1 through 3, the project is considered to have potential to support an adjustment to the aquifer withdrawal cap; therefore, each project has a potential rating as follows:

Project Potential:

- A. Potential **(P)**; or
- B. Low potential **(LP)**.

II. Will the study or strategy directly function as a project that may be used to support an adjustment to the Edwards Aquifer withdrawal cap?

All studies and strategies, regardless of their state of completeness or implementation, were categorized by their function. While all studies and strategies on the board-approved list are considered important, some projects will not directly serve to adjust the aquifer withdrawal cap and some, upon further evaluation, may support an adjustment to the aquifer withdrawal cap. All studies and strategies were categorized by the following functions:

Project Function:

1. Data collection effort (DC).

These studies will improve the conceptual understanding of how the aquifer works and will lead to future improvements in aquifer modeling; however, they do not specifically address obtaining additional water supplies from the aquifer.

2. Management Tool (MT).

These studies and strategies will serve to better manage the water currently available from the aquifer but do not have the potential to create additional water supplies.

3. Projects that may, upon further evaluation, potentially support adjusting the withdrawal cap. (PSA).

Studies and strategies with a function of DC or MT are considered as a low potential for supporting an adjustment to the aquifer withdrawal cap and will not receive further evaluation at this time.

Projects that indicate that further evaluation is warranted, pursuant to the project screening process, will be subjected to a decision analysis process to evaluate if a recommendation to adjust the aquifer withdrawal cap is feasible. The decision analysis process is being constructed around a projects merit relative to the following objectives:

- Environmental concerns
- Quantity of water supply
- Economic considerations
- Regulatory feasibility
- Reliability

Results of Project Screening Process

The results of this screening process for the board-approved list of studies and strategies are summarized below.

<u>Status</u>	<u>Category</u>	<u>Potential</u>	<u>Function</u>	<u>Study (S) or Strategy (ST)</u>
Incomplete	N/A	N/A	DC	Texas Wild Rice Mapping (S)
Incomplete	N/A	N/A	DC	Texas Wild Rice Growth (S)
Incomplete	N/A	N/A	DC, PSA	Aquatic Ecosystem Monitoring (S)
Complete	RF	LP	DC	Cagle's Map Turtle Habitat (S)

<u>Status</u>	<u>Category</u>	<u>Potential</u>	<u>Function</u>	<u>Study (S) or Strategy (ST)</u>
Incomplete	N/A	N/A	MT	Edwards Model (MODFLOW) (S)
Complete	NSA	LP	MT	Parameter Estimation for Model (S)
Incomplete	N/A	N/A	MT	Management Modules for Model (S)
Incomplete	N/A	N/A	MT	Karst System Computer Model (S)
Incomplete	N/A	N/A	DC	Saline Water Study (S)
Incomplete	N/A	N/A	DC, PSA	Use of aquifer Saline Water (S)
Incomplete	N/A	N/A	DC, PSA	N. Medina Co. Flowpath, Hydrologic budgets (S)
Incomplete	N/A	N/A	DC, PSA	N. Medina Co. Flowpath Hydrogeologic Assessment (S)
Complete	NSA	LP	DC	N. Medina Co. Flowpath, HEM Survey, Seco Sinkhole (S)
Complete	NSA	LP	DC	Structural Controls, Edwards-Trinity Camp Bullis Quad (S)
Incomplete	N/A	N/A	DC	Structural Controls, Edwards-Trinity Helotes Quad (S)
Complete	NSA	LP	DC, PSA	Leona Formation Geophysical Survey and Aquifer Test (S)
Incomplete	N/A	N/A	DC	N. Bexar Co. Flowpath, HEM Survey, Camp Bullis (S)
Incomplete	N/A	N/A	DC	Tracer testing of Comal & San Marcos Springs (S)
Incomplete	N/A	N/A	MT, PSA	Recharge Models of River Basins (S)
Complete	NSA	LP	DC	Statistical Analysis, 1998 Flood (S)
Complete	NSA	LP	DC	Fracture/Conduit Study (S)
Incomplete	N/A	N/A	DC, PSA	Woody Species Management (S)
Incomplete	N/A	N/A	DC, PSA	Groundwater Recharge by Brush Control (S)
Incomplete	N/A	N/A	DC, PSA	Analysis of Recharge and Recirculation (S)

<u>Status</u>	<u>Category</u>	<u>Potential</u>	<u>Function</u>	<u>Study (S) or Strategy (ST)</u>
Incomplete	N/A	N/A	PSA	Springflow augmentation in support of in-situ refugia (S)
Implemented	NSA	LP	MT	<u>Conservation</u> , Authority's agricultural water conservation program (ST)
Implemented	NSA	LP	MT	<u>Conservation</u> , Region L's population and water demand revisions (ST)
Not Imp.	N/A	N/A	N/A	<u>Springflow Augmentation</u> (ST)
Not Imp.	N/A	N/A	N/A	<u>Diversions Downstream of Springs Pursuant to Sect. 1.30</u> (ST)
Implemented	NSA	LP	MT	<u>Reuse</u> , SAWS & NBU recycled water programs (ST)
Implemented	AW, IR	P	PSA	<u>Supplemental Recharge</u> , Authority's precipitation enhancement (ST)
Implemented	NSA	LP	MT	<u>Conjunctive Management of Surface Water and Groundwater</u> , Bexar Met, San Marcos, New Braunfels, and Canon Regional Surface plants (ST)
Implemented	NSA	LP	MT	<u>Drought Management Plans</u> , Water purveyor's drought plans and Authority's critical period management rules (ST)
Implemented	AW	P	PSA	<u>Other water management strategies</u> , SAWS' ASR Project (ST)
Implemented	NSA	LP	MT	<u>Other water management strategies</u> , SAWS use of Trinity and Carrizo Aquifers (ST)
Implemented	NSA	LP	MT	<u>Other water management strategies</u> , Bexar Met use of Trinity and Carrizo Aquifers (ST)
Implemented	NSA	LP	MT	<u>Other water management strategies</u> , Tri-County area cities use of Carrizo Aquifer (ST)

N/A = Not Applicable.

The results of the screening process for the studies and strategies as of May 25, 2004 indicate that no completed studies and two implemented water management strategies warrant further evaluation by the decision analysis process. The two implemented strategies are:

1. Authority's Precipitation Enhancement Program
2. San Antonio Water System's Aquifer Storage and Recovery Project (this project may not be implemented, pending further evaluation)

Attachment B

**Section 711.296 Write-ups of the
Studies and Strategies**

Studies

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Texas Wild-Rice Mapping

(1) **Name of study or strategy:**

Texas Wild-Rice Mapping

(2) **Name of entities providing funding:**

Texas Parks & Wildlife Department (\$ not disclosed)
United States Fish and Wildlife Service (\$25,000)

(3) **Cost of study or strategy:**

The cost of the study was originally estimated to be \$50,000. An interlocal cooperation contract was prepared in February 2000 that would result in the Edwards Aquifer Authority (Authority) and the United States Fish and Wildlife Service (USFWS) each contributing \$25,000 to the Texas Parks and Wildlife Department (TPWD) for the study. The contract for the Authority's contribution was cancelled at the request of the TPWD. The USFWS funding contribution remained in place. The Authority understands that the TPWD will fund the remainder of the costs necessary to complete the work.

(4) **Study completion date, or strategy implementation date:**

The completion date for the study was proposed to be March 2001. December 2001 was the last proposed completion date provided to the Authority. TPWD initiated the study, however a firm completion date has not been provided.

(5) **Name of entity preparing the study or implementing the strategy:**

Texas Parks & Wildlife Department

(6) **Name and title of Authority liaison, if any:**

Ms. Jackie Poole - TPWD Biologist.

(7) **A statement of the purpose of the study or strategy:**

Texas wild-rice is a federally listed, endangered species endemic to the San Marcos Springs and upper San Marcos River in San Marcos, Texas. The range of Texas wild-rice has been noted and logged by hand since approximately 1989. This study will convert TPWD handwritten field notes from 1989 through 1999 into an electronic format.

The purpose of the study is to facilitate the documentation of historical Texas wild-rice

distribution in relation to changes in flow conditions. This documentation will allow future analysis of the data to address Texas wild-rice flow requirements in support of proposed aquifer management strategies that may impact springflows at San Marcos Springs and flows in downstream river segments.

(8) An identification of the data used in performing the study, or implementing the strategy:

The basic data used in the project will consist of TPWD hand written field notes regarding Texas wild-rice stand locations, densities, orientation, areal coverage and any remarks noted. The field notes to be converted to are from 1989 through 1999. Springflow records collected for San Marcos Springs by the United States Geological Survey (USGS) will be used to identify the flow conditions present when the field notes were prepared.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

Field survey benchmarks referenced in TPWD handwritten notes will be surveyed using global positioning system (GPS) equipment. The benchmark data, field drawings, and bearings and distances to plant stand limits will be converted to electronic maps using geographic information system (GIS) software. The Texas wild-rice stand distribution maps will be combined with flow regime information to produce annual maps of plant distribution from the San Marcos Springs downstream to the confluence of the San Marcos and Blanco Rivers. Extent and percent cover of Texas wild-rice will be provided on the available data. An accuracy assessment of the final maps will also be provided.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

The study will provide historic Texas wild-rice range data and a comparison with historic streamflow conditions. The data can be used in future analysis of springflow flow management alternatives.

(11) If completed, an abstract of the study or strategy:

The study is not complete. TPWD has not provided a firm study completion date.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits):

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC).

ATTACHMENT B

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

(14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board;

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

**Assessment of Factors Influencing Texas Wild-Rice (*Zizania texana*)
Sexual and Asexual Reproduction**

(1) Name of study or strategy:

Assessment of Factors Influencing Texas Wild-Rice (*Zizania texana*) Sexual and Asexual Reproduction

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$81,211)
United States Fish & Wildlife Service, San Marcos National Fish Hatchery & Technology Center (\$38,700)

(3) Cost of study or strategy:

\$119,911 over three years

(4) Study completion date, or strategy implementation date:

Joint-funding agreement extended to June 2004.

(5) Name of entity preparing the study or implementing the strategy:

United States Fish & Wildlife Service - National Fish Hatchery & Technology Center (USFWS-NFHTC)

(6) Name and title of Authority liaison, if any:

Ms. Paula Power - USFWS-NFHTC Biologist.

(7) A statement of the purpose of the study or strategy:

Texas wild-rice is a federal and state listed, endangered species endemic to the San Marcos Springs and upper San Marcos River in San Marcos, Texas. The range of Texas wild-rice has been steadily decreasing. It has been postulated that the decrease in Texas wild-rice is related to less than optimum reproductive conditions in the plant's aquatic environment. However, the Texas wild-rice reproductive requirements in the wild are not known. The purpose of the study is to determine the optimum conditions for Texas wild-rice reproduction in its natural habitat in order to better understand the possible impacts of proposed aquifer management strategies.

(8) An identification of the data used in performing the study, or implementing the strategy;

The basic data used in the project will consist of previous work conducted by the USFWS-NFHTC, Texas Parks & Wildlife Department, Southwest Texas State University, North Texas State University, Colorado State University and the National Seed Storage Laboratory Agricultural Research Service. In addition, the USFWS-NFHTC will be conducting new studies specifically designed to help determine the factors and optimum conditions for Texas wild-rice sexual and asexual reproduction.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The project will incorporate basic botanical techniques for investigating reproduction including pollen viability and dispersal, stigma viability and receptivity, self-pollination, numbers of spikelets per inflorescence and plant, numbers and quality of seeds produced, seed dispersal, distances between stands, and numbers of asexual tillers produced per plant. Existing botanical methodologies will be utilized, in addition to the development of new techniques – such as individual plant florescence bags to isolate individual Texas wild-rice flowers for sexual reproduction studies.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The study will provide needed information on the requirements of Texas wild-rice for sexual and asexual reproduction. The data may be used in the analysis of possible impacts on Texas wild-rice from springflow management alternatives.

(11) If completed, an abstract of the study or strategy;

The study is not complete. The final report is scheduled to be completed June 2004.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC).

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

(14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Comprehensive and Critical Period Monitoring Program to Evaluate the Effects of Variable Flow on Biological Resources in the Comal and San Marcos Springs Aquatic Ecosystems

(1) Name of study or strategy:

Comprehensive and Critical Period Monitoring Program to Evaluate the Effects of Variable Flow on Biological Resources in the Comal and San Marcos Springs Aquatic Ecosystems

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$2,007,662)
Southwest Texas State University & U.S. Fish & Wildlife Service (providing \$193,929 in in-kind services)

(3) Cost of study or strategy:

The total project budget is \$2,201, 591.

(4) Study completion date, or strategy implementation date:

This ongoing study was implemented in February 2001 and is scheduled to be completed in February 2005.

(5) Name of entity preparing the study or implementing the strategy:

BIO-WEST, Inc.
Southwest Texas State University (SWTSU)
United States Fish & Wildlife Service - National Fish Hatchery & Technology Center (USFWS - NFHTC)

(6) Name and title of Authority liaison, if any:

Mr. Ed Oborny – BIO-WEST Project Manager.

(7) A statement of the purpose of the study or strategy:

The San Marcos and Comal springs and their associated aquatic ecosystems provide the natural habitat for eight species listed as threatened or endangered by the United States Fish & Wildlife Service (USFWS). The amount of water flowing from these Edwards Aquifer springs is dependent upon rainfall, recharge, natural discharge (through spring orifices) and discharge through wells. The USFWS has established minimum Comal and San Marcos springflow requirements for the threatened and endangered species, based primarily on

individual opinions and observations. Currently, the only available management technique to meet the USFWS's minimum flow requirements is the reduction of aquifer discharge through wells. Since the Edwards Aquifer is the primary source of water for the region, the minimum flow numbers must be based on current scientific data to be defensible. This project will develop the scientific data required to establish minimum Comal and San Marcos springflow requirements for the threatened and endangered species.

(8) An identification of the data used in performing the study, or implementing the strategy:

The study will be based on data obtained while monitoring flora and fauna in the San Marcos and Comal Springs aquatic ecosystem pursuant to the project monitoring plan. The monitoring will be conducted by BIO-WEST, Inc., the USFWS-NFHTC, and SWTSU. Previous observations by the USFWS-NFHTC, Texas Parks & Wildlife Department (TPWD), SWTSU, and the University of North Texas will also be used in the study. In addition, laboratory studies regarding the impact of low springflow levels and temperature variations on aquatic vegetation that is prime habitat and on two species (Comal Springs riffle beetle and the fountain darter) will be used in the study.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

The project will utilize standard statistical, limnological and biological techniques, including (but not limited to) turbidity, conductivity, pH, dissolved oxygen, nutrients, and temperature analysis. Biological samples will be observed, photographed and mapped in addition to being collected by net, dredge, and hand for identification and population density estimates. Parametric and non-parametric statistical analysis, including descriptive statistic will be used to evaluate the data collected. The specific methodology is described in detail in the project monitoring plan.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

The study will provide scientific data on which to base flow requirements for the threatened and endangered species in the Comal Springs and San Marcos Springs aquatic ecosystems.

(11) If completed, an abstract of the study or strategy:

The study is not complete. The final report is scheduled to be completed February 2005.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits):

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC) and upon further evaluation may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

(14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

**Assessment of Instream Flow and Habitat Requirements for
Cagles' Map Turtle (*Graptemys caglei*)**

(1) Name of study or strategy:

Assessment of Instream Flow and Habitat Requirements for Cagles' Map Turtle
(*Graptemys caglei*)

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$100,000)
West Texas A&M University (\$248,022).

(3) Cost of study or strategy:

\$348,022 over two years.

(4) Study completion date, or strategy implementation date:

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

(5) Name of entity preparing the study or implementing the strategy:

West Texas A&M University (WTAMU).

(6) Name and title of Authority liaison, if any:

Dr. Flavius Killebrew – WTAMU Provost/Vice President for Academic Affairs.

(7) A statement of the purpose of the study or strategy:

The purpose of this study is to evaluate the current population, range, and preferred habitats of the Cagle's Map Turtle and to provide an assessment of the instream flow and habitat requirements of the species. The Cagle's Map Turtle is endemic to the Guadalupe River and its tributaries in south central Texas. The decline in the population and range of the Cagle's Map Turtle is suspected to be linked to the loss of habitat and stream flow management practices. The decline has caused the Cagle's Map Turtle to be proposed for listing by the United States Fish & Wildlife Service (USFWS).

The study also provided Cagle's Map Turtle expertise for the Guadalupe River Instream Flow (GRIF) study currently being conducted by the Texas Parks and Wildlife Department

(TPWD), Texas Natural Resource Conservation Commission (TNRCC), Guadalupe-Blanco River Authority (GBRA), and Texas Water Development Board (TWDB). The GRIF study is evaluating the instream flow requirements for the entire Guadalupe River aquatic community. The GRIF study will result in the development of a hydrological and physical habitat model of the Guadalupe River system to be used to evaluate the effects of proposed water management alternatives on instream uses.

(8) An identification of the data used in performing the study, or implementing the strategy:

Data for the study was from new and previous Cagle's Map Turtle population and habitat surveys conducted by WTAMU (directed by Dr. Flavius Killebrew). These data were collected by dredging, snorkeling, netting, trapping, and hand catching from the bank or by boat. Other habitat and stream condition data collected by the GRIF team was considered. River flow data collected by the United States Geological Survey (USGS) were also used in the study.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

Standard biological models used for population estimates and instream flow requirements were utilized. Physical locations were verified with global positioning system (GPS) equipment and were plotted using geographic information system (GIS) equipment. WTAMU identified the specific habitat requirements of the Cagle's Map Turtle and coordinated with the GRIF team to ensure that the habitat input parameters were considered in the selected GRIF model. A final report containing data, maps, and detailed descriptions of habitat and instream flow requirements were delivered to the Authority.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

The study provided necessary baseline data on the current status of the Cagles Map Turtle, its habitat and its flow requirements. This data may be utilized by surface water managers as a component for consideration in the management of the Guadalupe River and its tributaries.

(11) If completed, an abstract of the study or strategy:

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

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted

withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study does not make a recommendation or provide technical basis for increasing the withdrawal cap. The project function determined for this study was a data collection effort (DC) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

(14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Edwards Aquifer Computer Modeling Project (MODFLOW)

(1) Name of study or strategy:

Edwards Aquifer Computer Modeling Project (MODFLOW)

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$319,000), United States Geological Survey (\$212,818), and United States Department of Defense (\$264,000).

(3) Cost of study or strategy:

\$795,818 over five years (budget and time frame amended March, 2003 and May, 2004).

(4) Study completion date, or strategy implementation date:

This ongoing study was implemented in March 2000 and is scheduled to be completed in September 2004.

(5) Name of entity preparing the study or implementing the strategy:

The United States Geological Survey (USGS) is preparing the computer model with the University of Texas – Bureau of Economic Geology (BEG) serving as a subcontractor to the USGS. A Ground-Water Model Advisory Panel (GWMAP) has been established by the Authority that meets to discuss project methodologies and progress. The Southwest Research Institute (SWRI) also supported the project with parameter estimation work as described in a separate 711.296 study write-up.

(6) Name and title of Authority liaison, if any:

Mr. George Ozuna – USGS San Antonio Subdistrict Chief.

(7) A statement of the purpose of the study or strategy:

The purpose of the model is to characterize groundwater flow conditions in the Edwards Aquifer (the aquifer) and to serve as the basis for predicting impacts of water-supply management alternatives by the Authority. The project statement-of-work (SOW) only describes the groundwater modeling requirements; the resulting model will be adapted by others to simulate management alternatives.

(8) An identification of the data used in performing the study, or implementing the strategy;

The model project is using existing groundwater level data, geological structural data, aquifer parameter data, and aquifer recharge and discharge data for model construction and calibration. These data have been collected by the Authority, USGS, San Antonio Water System (SAWS), and other agencies over the past fifty plus years.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The ground-water flow model is being constructed using the MODFLOW computer program developed by the USGS. Proprietary software called Groundwater Vistas (developed and supplied by Environmental Simulations Inc.) is being used for efficient, graphically based development of model input files and analysis of model output. Supporting data sets will be supplied in the ARCView geographic information system (GIS) format.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The model project will provide a state-of-the-art groundwater model of the Edwards Aquifer using industry-standard software. Once the model is complete, it will allow operators to simulate various aquifer management scenarios and predict the results of implementing those scenarios.

(11) If completed, an abstract of the study or strategy;

The study is not complete. Draft versions of the modeling report and the users manual have been completed and were reviewed by the GWMAP in December, 2003. Additional review comments and suggestions of GWMAP members were provided to the USGS during April, 2004. The draft modeling report provides a detailed description of the groundwater flow model and supporting rationale for model construction. The model has been calibrated to water level and spring flow observations for both steady-state (1939-1946) and transient (1947-2000) conditions. Model sensitivity analyses are presented, as are simulated water budgets for below normal (May through November, 1956) and above normal (November 1974 through July 1975) precipitation conditions.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a management tool (MT).

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

(14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

Edwards Aquifer Computer Model Parameter Estimation Project

(1) **Name of study or strategy:**

Edwards Aquifer Computer Model Parameter Estimation Project.

(2) **Name of entities providing funding:**

Edwards Aquifer Authority (\$67,355) and the United States Army Corps of Engineers (\$67,355).

(3) **Cost of study or strategy:**

\$134,710 for the two-year study.

(4) **Study completion date, or strategy implementation date:**

This ongoing study was implemented in May 2000 and was completed in May 2002.

(5) **Name of entity preparing the study or implementing the strategy:**

Southwest Research Institute (SWRI)
SWRI served as a subcontractor to the United States Army Corps of Engineers (COE). The work was performed under a joint funding agreement (JFA) between the Authority and the COE under the COE's planning assistance to states program. The Texas Water Development Board (TWDB) provided dataset expertise as in-kind services at no charge to the project. The Edwards Aquifer Modeling project advisory panel established by the Authority also provided oversight for the Parameter Estimation project by discussing project methodologies and progress.

(6) **Name and title of Authority liaison, if any:**

Dr. Scott Painter with SWRI.

(7) **A statement of the purpose of the study or strategy:**

The purpose of the Parameter Estimation project is to support the development of the groundwater model being prepared by the United States Geological Survey (USGS) by providing an improved representation of the aerial distribution of vertically averaged hydraulic conductivity at a scale appropriate for the model. Several geostatistical techniques and empirical data were used to formulate initial estimates of hydraulic conductivity, upscaled from observed data points to model blocks, for input to the groundwater flow model. These "initial estimates" of hydraulic conductivity are meant to be

a starting point for model calibration; they have been adjusted in some cases during the model calibration process.

(8) An identification of the data used in performing the study, or implementing the strategy:

The study reviewed available aquifer test data to identify an empirical relationship between aquifer transmissivity and the specific capacity of wells. Observed data from over 1,000 aquifer and specific capacity tests were reviewed. Where multiple values existed for the same well, the geometric mean of the values was computed. Once the averaging was completed, 653 and 108 values of transmissivity were used for the confined and unconfined portions of the aquifer, respectively. Transmissivity was converted to hydraulic conductivity by dividing by the screened interval of the well. In addition, 153 values of steady-state hydraulic head were also applied during the final estimation of the hydraulic conductivity field.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

The Parameter Estimation Project used existing data sets and statistical modeling to analyze the spatial statistical characteristics of the highly heterogeneous Edwards Aquifer. Geostatistical techniques were applied to upscale specific capacity data and hydraulic conductivities measured in pumping tests to each grid cell in the model. The initial geostatistical model used stochastic simulation and co-kriging techniques to upscale and interpolate the measured values to the grid cells in the model. The initial results were refined in subsequent models using a Bayesian statistical approach that incorporates steady-state groundwater levels and the initial upscaled estimates of hydraulic conductivity.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

The Parameter Estimation project assisted the computer modeling project by providing improved estimates of hydraulic model input parameters at the start of the ground water flow model calibration process. The project also provided an improved understanding of the spatial distribution and range of hydraulic parameters, thus leading to a more efficient and defensible method of model calibration.

(11) If completed, an abstract of the study or strategy:

Two versions of an estimated Edwards Aquifer hydraulic conductivity field were provided for implementation into the groundwater flow model under construction by the USGS. The first version was developed based on observed hydraulic conductivity data (deduced primarily from specific capacity tests) at wells. A summary of the procedure is as follows:

1. Spatial correlation functions were developed from the observed values of hydraulic conductivity at wells
2. The correlation functions were used to estimate hydraulic conductivity for a series of 20 meter by 20 meter cells within the groundwater model domain. This scale was assumed to be commensurate with the scale of field estimates. Twenty

unconditional stochastic simulations of the hydraulic conductivity field were developed.

3. An effective hydraulic conductivity for the larger groundwater flow model cells (1/4 mile square, or 402 meters on a side) was computed using numerical simulation where a hydraulic gradient was imposed across the larger grid block area, and the effective (upscaled) hydraulic conductivity at the larger grid block scale was back calculated from the simulated flux for each of the 20 stochastic simulations.
4. The resulting values of upscaled hydraulic conductivity were analyzed statistically and a cross-covariance model was fitted to the values.
5. Final (first version) best estimates of hydraulic conductivity for use in the model were developed by cokriging block estimates based on local-scale hydraulic conductivity observations.

The second and final estimate of model-scale hydraulic conductivity is based on a recently developed approach to automated groundwater flow model calibration based on Bayesian statistics. This approach uses statistical methods to pick from the universe of potential hydraulic conductivity fields the one that minimizes deviation from a preconceived prior model, which in this case is the first version of the hydraulic conductivity field described above. This approach required utilization of a groundwater flow model so that information concerning hydraulic conductivity evident from steady state hydraulic head observations could be utilized. For example, high hydraulic gradients may indicate regions of low hydraulic conductivity, while low hydraulic gradients may indicate regions of high hydraulic conductivity. The groundwater flow model used during this study was based on some initial parameter estimates provided by the USGS for steady state conditions only, and should not be confused with the more comprehensive groundwater flow model still under development (see Edwards Aquifer Computer Model Project status report).

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is complete but does not provide a technical basis for increasing the withdrawal cap. The purpose of the study was to provide updated estimates of aquifer hydraulic properties for application in the groundwater flow model, which will in turn be used to evaluate the hydrologic effects of alternative water management strategies. The project function determined for this study was a management tool (MT) with low potential (LP) for supporting additional water supplies.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

- (14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Management Modules for the MODFLOW Model Development

(1) Name of study or strategy:

Management Modules for the MODFLOW model development

(2) Name of entities providing funding:

Edwards Aquifer Authority

(3) Cost of study or strategy:

\$108, 522.63

(4) Study completion date, or strategy implementation date:

August 2004

(5) Name of entity preparing the study or implementing the strategy:

HydroGeoLogic Inc

(6) Name and title of Authority liaison , if any:

Dr. Varut Guvanasen, HydroGeoLogic Inc

(7) A statement of the purpose of the study or strategy:

The purpose of this study is to develop a water resource management module for the MODFLOW model of the Edwards Aquifer that is currently under development by the United States Geological Survey. The water resources management module will enable the model to simulate the effects of the Edwards Aquifer Authority Demand Management/Critical Period Rules.

(8) An identification of the data used in performing the study, or implementing the strategy:

The management module applies the Authority rules so that the model will respond to trigger levels in index wells and spring discharges, pumping reductions, and other requirements. The rules and the other input files define the water management scenario designed by the user.

- (9) An identification of the methodology used in performing the study, or implementing the strategy;

The input files created by the management module enable the model to identify the types and locations of pumpage, change pumpage volumes and rates during model runs based on trigger levels, and control recharge and recirculation systems independently of the recharge and well packages of the Edwards Aquifer model.

- (10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The management module will provide Authority staff with the ability to simulate the effects of aquifer management scenarios such as recharge or recirculation based on a variety of demand management/critical period conditions.

- (11) If completed, an abstract of the study or strategy;

This study is not yet complete.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a management tool (MT).

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

\$711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Karst Aquifer Modeling Research

(1) Name of study or strategy:

Karst Aquifer Modeling Research

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$100,000), American Water Works Association research Foundation (AWWARF) (\$100,000), and the Southwest Florida Water management District (\$100,000). An additional \$102,000 will be provided to the project in in-kind services from the following entities:

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

(3) Cost of study or strategy:

\$402,000 over 1.5 years

(4) Study completion date, or strategy implementation date:

April 1, 2005

(5) Name of entity preparing the study or implementing the strategy:

Southwest Research Institute (SWRI) is preparing the study in conjunction with other participants is provided in item 2 above.

(6) Name and title of Authority liaison , if any:

Dr. Scott Painter - SWRI

(7) A statement of the purpose of the study or strategy;

The purpose of this study is to develop enhanced capabilities for karst aquifer characterization and flow representation to support the quantitative evaluation and management of the water resources of karst systems. Specifically, modeling software will be developed that will simulate the hydraulic characteristics of groundwater flow in karst aquifers (e.g. turbulent flow in discrete conduits), and the software will be tested using at least one field site.

(8) An identification of the data used in performing the study, or implementing the strategy;

Data from one or more field sites, such as water levels, estimates of recharge and discharge, and aquifer parameters, will be used to assess the performance of the selected existing or newly developed karst flow groundwater code.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The methodology that will be applied to conduct this study is evaluation of existing finite element (FEFLOW) and finite difference (MODFLOW) groundwater flow models for adequacy with regard to simulation of steady-state and transient groundwater flow in a representative karst flow system. Depending on the results of this testing, the next step was to either (1) adopt the existing FEFLOW code which purports to have the capability to simulate conduit flow, or (2) develop a new computer code or specialized module for simulating conduit flow that can be used with an existing code. It has been determined that option 2 applies, and the next step in the study involves writing code that is compatible with MODFLOW-2000 that can simulate karst flow conditions. Once the code is written, it will be tested (validated) and applied to one or more field sites.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The benefit of this study to the Authority will be the availability of new modeling software that will allow for more accurate simulation of groundwater flow in karst aquifers, which should lead to more accurate predictions of the effects of alternative water management strategies.

(11) If completed, an abstract of the study or strategy;

This study is not yet completed.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a management tool (MT).

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004**Incomplete Study****Saline Water Study - Edwards Aquifer Freshwater/Saline Water Interface Monitoring Wells and Aquifer Modeling Project****(1) Name of study or strategy:**

Saline Water Study - Edwards Aquifer Freshwater/Saline Water Interface Monitoring Wells and Aquifer Modeling Project

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$150,000 per year), San Antonio Water System (\$500,000 per year - varies by year), and Texas Water Development Board (unspecified non-reimbursed drilling costs).

(3) Cost of study or strategy:

\$700,000 per year (approximate) A San Antonio Water System (SAWS) work plan calls for wells to be installed over an eleven year period and monitoring of the wells to continue for decades. An Optimization Technical Studies planning document indicates that the costs of the well installation phase of the project will be approximately \$9,742,000.

(4) Study completion date, or strategy implementation date:

This ongoing study was implemented in March 1997. The well installation phase of the project is scheduled to be complete in 2007 or 2008, depending on funding.

(5) Name of entity preparing the study or implementing the strategy:

SAWS is installing the monitoring wells. SAWS will subcontract the freshwater/saline water interface modeling component.

(6) Name and title of Authority liaison, if any:

Mr. John Waugh – SAWS Source Protection and Management Project Manager

(7) A statement of the purpose of the study or strategy:

The purpose of the study is to conduct a regional investigation and data collection program to assess the likelihood of saline water encroaching across the currently-mapped Edwards Aquifer freshwater/saline water interface during times of low water levels or during periods of extended drought. A long-term monitoring program is also being established using these monitoring wells. A geochemical and groundwater flow model will also be developed to further characterize the freshwater/saline water interface within the aquifer.

(8) An identification of the data used in performing the study, or implementing the strategy;

Data regarding the physical character of the Edwards Group limestone and the distribution of total dissolved solids near the freshwater/saline water interface will be collected during this study. Water level and water quality monitors will be installed in the monitoring wells as they are installed. These data will also form the basis for a geochemical and flowpath computer model of the interface.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Monitoring wells are being installed using conventional rotary drilling techniques. Water level and water quality monitors are being installed in the wells. The primary analysis technique will be monitoring water quality, primarily dissolved solids, as water levels fluctuate over time. The geochemical and flowpath modeling methodologies have not been finalized.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The study will benefit the Authority by providing long-term monitoring for saline water encroachment into the freshwater portion of the aquifer. Data collected during drilling, long-term monitoring, and computer modeling will further the understanding of the southern boundary of the freshwater aquifer. Monitoring for saline water encroachment into the area of the major springs of the aquifer may also help protect aquatic ecosystems at those springs during an extended drought.

(11) If completed, an abstract of the study or strategy;

The study is not complete. Monitoring data collected to date in the existing monitoring wells has not indicated movement of the freshwater/saline water interface. A final report on the monitoring well installation phase of the project is not scheduled to be provided until 2007 or 2008.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC).

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable.

(14) A reasoned analysis supporting the recommendation;

Not applicable.

(15) Supporting documentation as appropriate; and

Not applicable.

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable.

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Assessment of Using Edwards Aquifer Saline Water as a Potable Water Supply

(1) **Name of study or strategy:**

Preliminary Feasibility Assessment of Edwards Aquifer Saline Water Treatment and Use and Related Future Studies.

(2) **Name of entities providing funding:**

Edwards Aquifer Authority

(3) **Cost of study or strategy:**

\$14,990 for the preliminary feasibility study, costs for future studies are to be determined.

(4) **Study completion date, or strategy implementation date:**

The preliminary feasibility study project report was delivered on January 2003. Future studies are planned to be initiated in 2004.

(5) **Name of entity preparing the study or implementing the strategy:**

Southwest Research Institute Center for Nuclear Waste Regulatory Analyses

(6) **Name and title of Authority liaison , if any:**

Dr. Bobby Pabalan, Southwest Research Institute
Dr. Ron Green, Southwest Research Institute

(7) **A statement of the purpose of the study or strategy:**

The study is a preliminary investigation of the feasibility of the two most widely used treatment technologies (reverse osmosis and electro dialysis) used in desalination of saline waters and applicability of these technologies to desalination of Edwards Aquifer saline water. Future studies will investigate specific technical issues regarding the feasibility of treating Edwards Aquifer saline water.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

The study used data available from desalination industry sources, case histories and experience of other municipalities, previous publications, data from existing desalination

plants, and data from investigations of the fresh-saline water interface by San Antonio Water System (SAWS) and Edwards Underground Water District (EUWD). Future studies by the Authority will primarily focus on the availability of supply.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The preliminary feasibility study uses industry and published sources to describe current desalination and effluent stream disposal technologies. A summary of existing desalination plants in North America and planned facilities in Texas is presented. Estimated annual costs are calculated for several desalination technologies over a range of product outflow rates and feed and product water qualities using the United States Bureau of Reclamation Water Treatment Estimation Routine (WaTER). The results of an HDR survey of existing desalination plant operating costs are presented as well as estimated costs from published and industry sources. Potential well yields of saline-water zone wells are estimated from aquifer test data from EUWD saline-zone well transects and specific-capacity data from SAWS well transects.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The study provides estimates of the relative costs of the available desalination technologies and the numbers of wells that would be needed to supply feed-water for a desalination facility. Future studies will answer questions regarding the availability of supply.

(11) If completed, an abstract of the study or strategy;

The preliminary feasibility study presents an assessment of using brackish water from the saline-zone of the Edwards (BFZ) aquifer to produce potable water. Background material is given on reverse osmosis and electro-dialysis reversal technologies. A summary of existing and planned desalination facilities using similar technologies is presented. Preliminary cost curves for desalination as a function of operating parameters are compared to cost data from existing plants and estimates from other sources. Preliminary estimates for the potential yields of saline-zone wells are made and include a projection on the number of wells that may be needed to supply a desalination facility.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

The scope of work of this study is not sufficiently broad to provide a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap. The project function determined for this study was a data collection effort (DC) and will be the basis for future studies. At this time, the assessment of treating saline water is not sufficient to support adjusting the withdrawal cap. The treatment of saline water has the potential to adjust the withdrawal cap, depending on the findings of future studies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

North Medina County Flow Path Hydrologic Budgets
Medina and Diversion Lakes

(1) **Name of study or strategy:**

North Medina County flow path and hydrologic budgets of Medina and Diversion Lakes

(2) **Name of entities providing funding:**

Edwards Aquifer Authority (\$268,900)
United States Geological Survey (\$148,000)

(3) **Cost of study or strategy:**

\$416,900 over 3 years, 8 months

(4) **Study completion date, or strategy implementation date:**

This study was implemented in August 2000, and is scheduled to be completed in June 2004.

(5) **Name of entity preparing the study or implementing the strategy:**

United States Geological Survey (USGS)

(6) **Name and title of Authority liaison, if any:**

Mr. Richard Slattery – USGS Project Chief, San Antonio Subdistrict Office.

(7) **A statement of the purpose of the study or strategy:**

The purpose of the flow path study is to characterize groundwater flow conditions in the North Central Flow Unit of the Edwards Aquifer that extends across northern Medina County. The hydrologic budget analysis of Medina and Diversion lakes is to calculate groundwater losses.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

Hydrographs of wells, Medina Lake levels, rainfall and evaporation measurements, stream inflows and outflows, and geologic maps.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

This study is a continuation of a 1995-96 USGS project that was limited by low water levels in Medina Lake. The USGS will measure all inflows and outflows to Medina Lake and Diversion Lake and collect daily weather data to calculate evaporation.

The water balance study will consist of the following activities:

- Quantify seepage losses from Medina Lake and Diversion Lake by calculating hydrologic budgets over a range in stage,
- Determine the spatial distribution of ground-water inflow (GW_{in}) from Medina Lake along the reach of the Medina River downstream of Medina Dam to the Haby Crossing fault, and
- Determine the relative proportion of water lost from Medina and Diversion Lakes that enters the Eastern Medina and Western Medina storage units.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This study will complement other investigations of flow paths in the Edwards Aquifer. The findings will evaluate the recharge potential of the Medina Lake system and the storage potential of the recharge zone in northern Medina County. The study results will assist calibration of the modeling project.

(11) If completed, an abstract of the study or strategy;

This study is not complete. The data collection for the study is complete and the USGS is currently revising the Water Resources Investigation (WRI) Draft Report after receiving Edwards Aquifer Authority comments.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC) and upon further evaluation may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

North Medina County Flowpath - Hydrogeologic Assessment

(1) Name of study or strategy:

North Medina County Flowpath - Hydrogeologic assessment

(2) Name of entities providing funding:

San Antonio Water System and U.S. Geological Survey: (information available does not include costs)

(3) Cost of study or strategy:

Unknown (Edwards Aquifer Authority does not provide funding for this project)

(4) Study completion date, or strategy implementation date:

This study was implemented in August 2000 and the report is currently being completed, with a target completion date of late 2004.

(5) Name of entity preparing the study or implementing the strategy:

U.S. Geological Survey

(6) Name and title of Authority liaison , if any:

Rebecca Lambert - USGS

(7) A statement of the purpose of the study or strategy:

The purpose of the project is to study and better delineate groundwater movement and properties of the Edwards Aquifer in northern Medina County, particularly in the Medina Lake area.

(8) An identification of the data used in performing the study, or implementing the strategy:

The study will compile and evaluate available geologic, well, geochemical, and hydrologic data for the study area, and establish a network of monitoring sites to collect new and high quality data.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Eight new wells were drilled in northern Medina County. Geophysical and other data from other concurrent or recently completed studies will be included. A network of wells will be established to develop synoptic water level maps. Aquifer pump tests will be conducted to determine hydraulic parameters for those sites. Potentiometric data and chemical modeling will be used to evaluate groundwater evolution and movement.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This study will provide information on the characteristics of a hydrogeologically important part of the Edwards Aquifer where few precise data currently exist. It will be especially useful in better understanding the aquifer recharge occurring at Medina Lake and its influence of groundwater levels and flowpaths in that area, and potentially into Bexar County.

(11) If completed, an abstract of the study or strategy;

The study is not complete. A report is in preparation with an estimated completion date of late 2004.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project functions determined for this study was a data collection effort (DC) and a project upon further evaluation that may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

**North Medina County Flowpath
Helicopter Electromagnetic (HEM) Survey in the Vicinity of Seco Sinkhole**

(1) Name of study or strategy:

North Medina County Flowpath - Helicopter Electromagnetic (HEM) survey in the vicinity of Seco Sinkhole.

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$45,000)
U.S. Geological Survey (\$100,000)

(3) Cost of study or strategy:

\$145,000 for 1 year

(4) Study completion date, or strategy implementation date:

This study was completed in May 2003.

(5) Name of entity preparing the study or implementing the strategy:

U.S. Geological Survey

(6) Name and title of Authority liaison, if any:

Bruce Smith, U.S. Geological Survey

(7) A statement of the purpose of the study or strategy:

The purpose of this study was to conduct a low-altitude, helicopter-based, electromagnetic geophysical survey in the area of Valdina Farms Sinkhole (Seco Creek Sinkhole), in western Medina County, to capture information on the subsurface fractures and conduits that potentially control local groundwater flow.

(8) An identification of the data used in performing the study, or implementing the strategy:

The RESOLVE © airborne electromagnetic survey system was used to gather geophysical data from a helicopter flown as a series of parallel transects over the study area. The results were compiled into a set of apparent resistivity maps for interpretation.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

The survey was conducted by flying 1,534 km of geophysical transect lines over an area of 209 km² at a target elevation of 30 m above ground level. The transects were flown along north-south bearings and spaced 200 m apart. The resulting geophysical maps were plotted at various frequencies to interpret hydrogeologic features at various depths within the Edwards Limestone Group and surrounding formations.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

This study assessed the potential of helicopter-based electromagnetic surveys to locate and evaluate subsurface geologic features and their influence on groundwater movement in the Edwards Aquifer.

(11) If completed, an abstract of the study or strategy:

The study is complete. Following is the abstract from the report:

"A helicopter electromagnetic and magnetic (HEM) survey was completed of a 209 square kilometer (81 square miles) area of the central Edwards aquifer. This open-file report is a release of the airborne geophysical data and a summary of the hydrologic application. The survey area was centered on the Valdina Farms sinkhole along the Seco Creek drainage in western Medina County, Texas. Flight lines were flown north south with three east west tie lines to aid in leveling the magnetic data. Additional lines were flown on each side of the Seco and Little Seco Creek drainages. A five kilometer (4 mile) extension of 15 lines was flown north of the main survey block centered on Seco Creek. This digital data release contains the flight line data, grids, and maps of the HEM survey data.

The Edwards aquifer in this area consists of three hydrologic zones: catchment, recharge, and confined. The Glen Rose Formation is exposed in the catchment area. The recharge zone is situated in the Balcones fault zone where the Devils River Group of the Edwards aquifer has been exposed by normal faults. The magnetic data is not discussed in depth here, but does have high amplitude closed anomalies caused by shallow igneous intrusives. The Woodard Cave Fault that separates the recharge and catchment zones is in places associated with a weak linear magnetic low.

The HEM data has been processed to produce apparent resistivities for each of the six EM coil pairs and frequencies. Maps of the apparent resistivity for the five horizontal coil pairs show that the catchment, recharge, and confined zones all have numerous linear features that are likely caused by structures, many of which have not been mapped. The distribution of high resistivity areas reflects the lithologic differences within the Trinity and Edwards aquifers."

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is complete but does not provide a technical basis for increasing the withdrawal cap. However, when results of this study is integrated with future research which better delineates groundwater flow conditions within the Edwards Aquifer, this information will improve the quantification of the Edwards Aquifer's water budget and groundwater modeling effort of the Edwards Aquifer. The project function determined for this study was a data collection effort (DC) with low potential (LP) for supporting additional water supplies.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

**Analysis of Structural Controls on the Edwards/Trinity Aquifers
Camp Bullis Quadrangle**

(1) **Name of study or strategy:**

Analysis of structural controls on the Edwards/Trinity Aquifers – Camp Bullis Quadrangle

(2) **Name of entities providing funding:**

Edwards Aquifer Authority (\$37,750)
U.S. Army Corps of Engineers, Ft. Worth District (\$35,000)

(3) **Cost of study or strategy:**

\$72,750 for 1 year

(4) **Study completion date, or strategy implementation date:**

This study was completed in December 2003.

(5) **Name of entity preparing the study or implementing the strategy:**

Center for Nuclear Waste Regulatory Analysis at Southwest Research Institute

(6) **Name and title of Authority liaison, if any:**

Dr. David Ferrill, Southwest Research Institute

(7) **A statement of the purpose of the study or strategy:**

The purpose of this project was to generate a three-dimensional computer model and predictions of localized fault-related deformation in the Edwards Aquifer and Trinity Aquifer in the area of the Camp Bullis 7.5' topographic quadrangle, in north-central Bexar County. A second major objective for this study was to analyze potential hydraulic communication across the interface between the Edwards Aquifer and the Trinity Aquifer, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

Existing geologic mapping of faults were supplemented with additional field observations and analyzed by various methods, but primarily with the 3D Stress™ and 3D Earthvision™ structural analysis software.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The study was conducted in a series of six tasks:

- a. 3D Stress™ was used to assess the consistency, orientations, and anomalies of major faults in the study area in order to identify probable secondary faults and their slip directions from their development relative to the major faults.
- b. 3D Earthvision™ structural framework model was developed for the ground surface, and the Edwards and Trinity hydrostratigraphic units in the study area.
- c. Fault block deformation analysis was conducted.
- d. Accessible outcrops were examined for a field analysis of fault zone materials and deformation mechanisms
- e. 3D Earthvision™ structural framework model was used to evaluate the cross-fault juxtaposition of Edwards and Trinity hydrostratigraphic units to assess the potential for cross-formational groundwater flow.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This study resulted in a three-dimensional hydrostratigraphic computer model of the Camp Bullis Quadrangle that can be used to predict areas and types of unobserved deformation and analyze the potential for groundwater flow between the Edwards and Trinity aquifers in that area. The model can be applied in future studies for detailed analysis of the entire aquifer area.

(11) If completed, an abstract of the study or strategy;

This study is complete. Following is the abstract from the project report:

“The purpose of the project reported here is to characterize the, structural architecture of the Edwards and Trinity Aquifers for the area of the Camp Bullis 7 ½ minute quadrangle, and extending north to include Cibolo Creek in the southern part of the Bergheim 7 ½ minute quadrangle. Included in this analysis are tasks to generate a three-dimensional computer model of the Trinity and Edwards Aquifer, and perform field investigations to characterize the mechanisms and products of localized fault-related deformation in the Edwards and Trinity Aquifers in and near the study area. An important objective is to analyze the potential for communication between the Edwards Aquifer and the Trinity Aquifers, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

Results of the project show the aquifer architecture throughout the study area, the location and interpreted geometry of the most important mapped faults in the study area, and the deformation mechanisms and deformation style in fault zones in the rocks of both the Edwards and Trinity Aquifers. The three-dimensional geologic framework model of the Camp Bullis area reveals (i) juxtaposition of permeable and relatively impermeable

hydrogeologic units, (ii) structural thinning of the Edwards Aquifer and Trinity Aquifers, (iii) potential for cross-fault communication between the Trinity and Edwards Aquifers, (iv) faults expressed on the surface as potential infiltration pathways, and (v) maximum offset concentrated along a small number (two or three) fault systems. This information, along with an understanding of fault zone deformation mechanisms and the role of fault zones as barriers or conduits, can assist in locating environmentally sensitive areas. It is useful for aquifer water flow path studies and contributes to the identification of areas where communication between the Trinity and the Edwards Aquifers is suspected.

In this geologic framework model, the Edwards and Trinity Aquifers are subdivided into seven stratigraphic horizons which are offset by a network of 40 faults. Vertical offset (fault throw) ranges from near zero to an approximate maximum of 110 meters (361 ft). Displacement sense is normal, commonly down to the southeast, and lateral displacement gradients are small. In map view, fault blocks are elongate, with the long axis oriented NE-SW. Maximum offset is concentrated along three fault systems, the southernmost of which forms the northern boundary of the aquifer recharge zone, where rocks of the Edwards Group are in faulted juxtaposition with rocks of the Glen Rose Formation.

Fault displacements within the Camp Bullis study area are too small to place the base of the Edwards Aquifer (Basal Nodular layer) against the permeable Lower Glen Rose layer. However, each fault decreases the effective aquifer thickness. This structural thinning of aquifer layers can cause flow constrictions, which in turn diverts flow and causes fluctuations in the local water table from fault block to fault block. Areas of such flow constrictions can be identified using a map of fault throw distribution; constriction is greatest where fault throw is greatest.

In the Castle Hills quadrangle, immediately south of the Camp Bullis quadrangle, several faults offset the Edwards Aquifer by distances equal to or greater than its full thickness. Smaller fault displacements in the Camp Bullis area and the northern part of the Castle Hills quadrangle reduce the amount of direct juxtaposition of Kainer against Lower Glen Rose in these areas to a minimum. The lack of fault juxtaposition of the recognized highly permeable units of the Edwards Group and Glen Rose Formation in the Camp Bullis and Castle Hills areas suggests that simple juxtaposition is not likely to be a major source of aquifer communication in this area.

3DStress™ analysis of measured faults, and regional stratigraphic thicknesses based on published maps yield a stress system during faulting of: vertical effective stress = 15 MPa; minimum horizontal effective stress (σ_3) = 4 MPa with an azimuth of 150°; and an intermediate principal effective stress = 9.5 MPa. When applied to the fault surfaces exported from the three-dimensional geologic framework model, this stress tensor indicates that the dominant, NE-SW striking faults experience high slip tendencies and are well oriented to have accommodated regional strains developed within the inferred stress system. A few NW-SE trending faults experience low slip tendencies and probably formed in response to local stress perturbations, indicating that local perturbations resulting from such effects as displacement-gradient-driven fault block deformation were not widely developed in this area. In addition to experiencing high slip tendencies in the inferred stress system, the predominant faults are also subject to high dilation tendencies. This combination of high slip and dilation tendencies implies that the major faults could have been effective fluid transmission pathways at the time of faulting. If a similar stress system were extant today, the faults would be in favorable orientations for fluid transmissivity.

Fault block deformation calculated using cutoff lines generated from the three-dimensional geologic framework model results in cutoff line elongations that rarely exceed 2% (positive or negative). These small cutoff elongations reflect the low displacement gradients on faults within the Camp Bullis study area. At the scale of the three-dimensional model, competent units exhibit gentle dips, which is consistent with relatively rapid lateral and vertical fault propagation, until intersection with other faults occurs (laterally) or intersection with a weaker mechanical layer occurs. This lack of steep lateral displacement gradients suggests rapid fault propagation with respect to the rate of displacement accumulation on the faults.

Field work reveals interesting contrasts between faults in the Edwards and Trinity Aquifers. Faults with displacements of 5 m (16 ft) to tens of meters in the Glen Rose Formation (Trinity Aquifer) commonly have damage zones with widths on the order of meters, within which small faults and rotated fault blocks are common. Although faults with displacements of 5 m (16 ft) to tens of meters in the Edwards Group limestones typically have numerous associated small faults, block rotation and bed tilting is not common. This characteristic difference in structural style between the Edwards Group limestones and the Glen Rose Formation appears to be related to lithologic differences and the resulting differences in mechanical behavior of the two stratigraphic sections. The Glen Rose Formation contains both competent massive limestone beds and incompetent argillaceous limestone and shale beds. Incompetent beds tend to arrest fault propagation during fault growth. Consequently, with increasing fault displacement, fault tips (terminations) episodically propagate then arrest. Continued displacement on a fault with an arrested fault tipline will produce fault tipline folding and associated local deformation such as intense small scale faulting. Resulting fault damage zones can be quite complex and variable along a fault, related to the structural position (including displacement magnitude) and the associated mechanical stratigraphy. Permeability in fault zones and fault blocks is likely to be strongly influenced by the different deformation styles in mechanical layers, and the deformation progression with increasing fault displacement.

The large fault surfaces that cut multiple layers depicted in the Camp Bullis geologic framework model provide potential pathways for both vertical and lateral movement of water and hydraulic communication between aquifers. These fault surfaces along with localized zones of relatively intense small scale faulting and extension fracturing, and limestone solution (karst conduit formation) provide likely communication pathways between the Trinity and Edwards Aquifers. The structural analyses presented in this report provide the framework for more detailed investigations of groundwater levels, multiwell pumping (drawdown) tests, tracer studies, and geochemical investigations to further investigate potential groundwater communication between the Trinity and Edwards Aquifers in the Camp Bullis and Castle Hills Quadrangles.”

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is complete but does not provide a technical basis for increasing the withdrawal cap. However, when results of this study is integrated with future research which better delineates groundwater flow conditions within the Edwards Aquifer, this information will improve the quantification of the Edwards Aquifer's water budget and groundwater

modeling effort of the Edwards Aquifer. The project function determined for this study was a data collection effort (DC) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

**Analysis of Structural Controls on the Edwards/Trinity Aquifers
Helotes Quadrangle**

(1) **Name of study or strategy;**

Analysis of structural controls on the Edwards/Trinity Aquifers - Helotes Quadrangle

(2) **Name of entities providing funding;**

Edwards Aquifer Authority (\$32,375)
U.S. Army Corps of Engineers, Ft. Worth District (\$32,375)

(3) **Cost of study or strategy;**

\$72,750 for 1 year

(4) **Study completion date, or strategy implementation date;**

This study was implemented on 8 July 2003 and is scheduled to be completed in July 2004.

(5) **Name of entity preparing the study or implementing the strategy;**

Center for Nuclear Waste Regulatory Analysis at Southwest Research Institute

(6) **Name and title of Authority liaison , if any;**

Dr. David Ferrill, Southwest Research Institute

(7) **A statement of the purpose of the study or strategy;**

The purpose of this project is to generate a three-dimensional computer model and predictions of localized fault-related deformation in the Edwards Aquifer and Trinity Aquifer in the area of the Helotes 7.5' topographic quadrangle, in northwest Bexar County. A second major objective for this study is to analyze potential hydraulic communication across the interface between the Edwards Aquifer and the Trinity Aquifer, taking into account fault-related deformation and juxtaposition of the aquifers across key faults.

(8) **An identification of the data used in performing the study, or implementing the strategy;**

Existing and geologic mapping of faults will be supplemented with additional field observations and analyzed by various methods, but primarily with the 3D Stress™ and 3D Earthvision™ structural analysis software.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The study will be conducted in a series of six tasks:

- a. D Stress™ will be used to assess the consistency, orientations, and anomalies of major faults in the study area in order to identify probable secondary faults and their slip directions from their development relative to the major faults.
- b. 3D Earthvision™ structural framework model will be developed for the ground surface, and the Edwards and Trinity hydrostratigraphic units in the study area.
- c. Fault block deformation analysis will be conducted.
- d. Accessible outcrops will be examined for a field analysis of fault zone materials and deformation mechanisms.
- e. 3D Earthvision™ structural framework model will be used to evaluate the cross-fault juxtaposition of Edwards and Trinity hydrostratigraphic units to assess the potential for cross-formational groundwater flow.
- f. Report preparation

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This study will develop a three-dimensional hydrostratigraphic computer model of the Helotes Quadrangle that will predict areas and types of unobserved deformation and analyze the potential for groundwater flow between the Edwards and Trinity aquifers in that area. If the model is successful, it could be applied in future studies for detailed analysis of the entire aquifer area.

(11) If completed, an abstract of the study or strategy;

The study is not complete. A final report is scheduled for submission in October 2004.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC).

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

Leona Formation Geophysical Survey and Aquifer Test

(1) Name of study or strategy:

Leona Formation Geophysical Survey

(2) Name of entities providing funding:

Edwards Aquifer Authority (EAA)

(3) Cost of study or strategy:

\$14,900

(4) Study completion date, or strategy implementation date:

The final report was submitted on December 8, 2003 and the EAA board was briefed on the results of the study in February 2004. The study was approved in February 2003.

(5) Name of entity preparing the study or implementing the strategy:

Southwest Research Institute (SwRI)

(6) Name and title of Authority liaison, if any:

Dr. Ronald T. Green

(7) A statement of the purpose of the study or strategy:

The purpose of this study was to evaluate the depth and lateral extent of sand and gravel deposits that form the Leona Formation. The characterization of the aquifer's dimensions would allow for the calculation of groundwater flow through the Leona River Floodplain.

(8) An identification of the data used in performing the study, or implementing the strategy:

A dipole-dipole DC electrical resistivity survey was conducted in March 2003 which consisted of five transects (total distance of 3 miles) across the Leona Floodplain in Uvalde County. The resistivity survey results were used to create lithologic interpretations which were compared to driller's lithologic descriptions of (clays, silts, sands, gravels) from local wells to confirm the resistivity interpretations of lithology. Local geological maps and reports, USGS stream gage data, local water well lithologic descriptions and pump tests results were also used during this study.

A ten day aquifer pump test five days pumping and five days recovery monitoring) was conducted in January 1998 within 400 feet of the UVAL4 transect. The 16-inch irrigation well was pumped at 1,176 gpm the duration of the pump test. Six wells were monitored which provide a consistent assessment of the hydraulic properties of the Leona Aquifer.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The resistivity survey was generated by an AGI R8 SuperSting™ resistivity system using a continuous "roll-along" survey method to provide continuous coverage along each transect. Electrical resistivity is an effective geophysical technique to perform this evaluation because the target sand and gravel composition of the Leona aquifer has a distinctly different electrical signature (i.e., more resistive) relative to the electrically conductive (less resistive) clay-rich aquitard portions of the Leona Formation. The five transects provide interpretation to a depth of slightly more than 100 feet, which is deeper than the base of the Leona River floodplain.

The transition from silt/clay to sand/gravel is estimated to occur at approximately 25 to 50 ohm-meters in the Leona River Floodplain. The cross-sectional area of the sand/gravel from each transect was calculated using Surfer 8™. The total corresponding cross-sectional area generated along the five transects is 697,000 ft² (25 ohm-meters, 58% of floodplain cross-section) and 311,000 ft² (50 ohm-meters, 25% of floodplain cross-section).

The drawdown data was plotted in terms of feet versus time in log-log space for the conventional Theis-curve analysis. Theis curves were matched to the log-log plots of drawdown data to determine transmissivity and storage. The recovery data were plotted in terms of residual drawdown versus dimensionless time (total time after the onset of pumping divided by the time of recovery) in semi-log space to determine transmissivity. Values of transmissivity ranged from 80,000 ft²/day (hydraulic conductivity is 2,425 ft/day) to 215,000 ft²/day (hydraulic conductivity is 14,300 ft/day), and the values of the storage coefficient ranged from 0.00062 to 0.05 indicating a confined or semi-confined aquifer system. A significant hydraulic connection between the Leona River and the Leona Formation was not observed in the drawdown of LMW6 (along the reach of the river). The local groundwater gradient was determined from six wells and five days after the pump test and was approximately 0.0023 to the southeast.

The total groundwater discharge through the Leona River floodplain was estimated using Darcy's Law (equation):

$$Q = AKVh$$

Q = total discharge (ft³/day),
 A = cross-sectional area (700,000 ft²),
 K = average hydraulic conductivity (6,500 ft/day)
 Vh is the hydraulic gradient (0.0023)

$$Q = 10,500,000 \text{ ft}^3/\text{day} \text{ or } 87,000 \text{ acre/feet/year}$$

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

The accurate assessment of the groundwater resources of the Edwards Aquifer require that major sources of water recharge into and discharge from be adequately determined. The quantity of surface water that is discharged from the Edwards Aquifer into the Leona River has been measured by a USGS stream gage since 1939. However, the subsurface-groundwater discharge from the Edwards Aquifer into the Leona River Floodplain has only been previously estimated. To determine the quantity of groundwater flow through the Leona River Floodplain (Aquifer), the depth, later extent, hydraulic properties and groundwater gradient must be known or at least reasonably estimated. This Edwards Aquifer discharge into the Leona River Floodplain may be an additional available water supply.

(11) If completed, an abstract of the study or strategy:

An electrical resistivity survey was conducted during March 2003 on the Leona River Floodplain to determine the lateral and vertical extent of the Leona Aquifer at the survey site located 4.5 miles south of Uvalde, Texas. The resistivity survey results illustrate the transition from the electrically conductive clay and silt portion of the floodplain sediments to the electrically resistive sands and gravel deposits which form the Leona Aquifer.

Some difficulty was encountered when assigning a specific electrical resistivity contour value to the transition from silt/clay to sand/gravel sediments. This difficulty arose from the lack of accurate geologic logs for wells located near the resistivity transects. Additional insight as to the appropriate resistivity value to assign to the transition from silt/clay to sand/gravel was gained by using results from a comparable floodplain (Colorado River, near Columbus, Texas).

Specific conductance values for formational water was identified as a potential cause for slightly lower transition resistivity values. Consequently, a range of resistivity of 25 to 50 ohm-meters was assigned to the transition from silt/clay to sand/gravel in the Leona Formation. The corresponding cross-sectional areas associated with these resistivities are 697,000 and 311,000 ft² respectively.

A ten day aquifer pump test (five days pumping and five days recovery monitoring) was conducted in January 1998 within 400 feet of the UVAL4 transect. The 16-inch irrigation well was pumped at 1,176 gpm the duration of the pump test. Six wells were monitored which provide a consistent assessment of the hydraulic properties of the Leona Aquifer. Not all well data collected during the aquifer test was conclusive. Insufficient drawdown was observed in two monitor wells. The recovery data for three wells was masked by the local pumping of an unidentified well.

The drawdown data from the monitor wells was plotted in terms of feet versus time in log-log space for the conventional Theis-curve analysis. Theis-curves were matched to the log-log plots of drawdown data to determine transmissivity and storage. The recovery data were plotted in terms of residual drawdown versus dimensionless time (total time after the onset of pumping divided by the time of recovery) in semi-log space to determine transmissivity. Values of transmissivity ranged from 80,000 ft²/day to 215,000 ft²/day, and the values of the storage coefficient ranged from 0.00062 to 0.05 indicating a confined or

semi-confined aquifer system. The local groundwater gradient was determined from six wells and was approximately 0.0023 to the southeast.

Using the available data, the estimated combined surface water (Leona River, 14,500 acre/feet/year) and groundwater (subsurface flow, using Darcy's equation, 87,000 acre/feet/year) originating from the Edwards Aquifer and that flows annually through the Leona Floodplain is approximately 100,000 acre/feet/year.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is complete but does not provide a technical basis for increasing the withdrawal cap at this time. Additional studies and aquifer tests are needed to confirm the subsurface flow through the Leona River Floodplain. If future research can scientifically verify and quantify the subsurface groundwater flow through the Leona River Floodplain, then this water may be considered in future withdrawal cap evaluations. At present, the project function determined for this study was a data collection effort (DC) that may, upon further evaluation, potentially support adjusting (PSA) the withdrawal cap.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

**North Bexar County Flowpath
Helicopter Electromagnetic (HEM) Survey in the Vicinity of Camp Bullis**

(1) **Name of study or strategy:**

North Bexar County Flowpath - Helicopter Electromagnetic (HEM) survey in the vicinity of Camp Bullis

(2) **Name of entities providing funding:**

Edwards Aquifer Authority (\$14,546)
U.S. Army (\$17,300)

(3) **Cost of study or strategy:**

\$31,846 for 1 year

(4) **Study completion date, or strategy implementation date:**

This study was implemented on 27 August 2003 and is scheduled to be completed in August 2004.

(5) **Name of entity preparing the study or implementing the strategy:**

U.S. Geological Survey

(6) **Name and title of Authority liaison , if any:**

Dr. Victor F. Labson, U.S. Geological Survey

(7) **A statement of the purpose of the study or strategy:**

The purpose of this study is to conduct a low-altitude, helicopter-based, electromagnetic geophysical survey in the Camp Bullis and Camp Stanley area in north-central Bexar County to capture information on the subsurface fractures and conduits that probably control local groundwater flow.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

An airborne electromagnetic survey system was used to gather geophysical data from a helicopter flown as a series of parallel transects over the study area. The results will be compiled into a set of apparent resistivity maps for interpretation.

- (9) An identification of the methodology used in performing the study, or implementing the strategy;

The survey was conducted by flying geophysical transect lines over portions of the Edwards Aquifer recharge and contributing zones in both urbanized and rural areas. Transects were flown along east-west bearings and spaced 200 m apart. The resulting geophysical maps will be plotted at various frequencies to interpret hydrogeologic features at various depths within the Edwards Limestone Group and surrounding formations.

- (10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This study further assesses the potential of helicopter-based electromagnetic surveys to locate and evaluate subsurface geologic features and their influence on groundwater movement in the Edwards Aquifer. It provides comparisons between urban and rural areas and thus tests the survey methods' effectiveness around sources of potential electromagnetic interference.

- (11) If completed, an abstract of the study or strategy;

The study is not complete. A final report is scheduled for submission in August 2004.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC).

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

**Tracer Testing of Aquifer Flowpaths at Comal and San Marcos Springs
Storm Water Monitoring and Hueco Springs**

(1) Name of study or strategy:

Tracer testing in the vicinity of Comal, San Marcos and Hueco springs, and storm water monitoring.

(2) Name of entities providing funding:

Edwards Aquifer Authority

(3) Cost of study or strategy:

\$181,600

(4) Study completion date, or strategy implementation date:

Existing contract will terminate July 14, 2004 with an option to renew for two one year renewals.

(5) Name of entity preparing the study or implementing the strategy:

George Veni and Associates

(6) Name and title of Authority liaison , if any:

Dr. George Veni, George Veni & Associates

(7) A statement of the purpose of the study or strategy:

The purpose of dye trace studies is to identify groundwater flow paths and flow velocities through the Edwards aquifer in the vicinity of Comal and San Marcos Springs. This study will also provide important insights of this karst system for the conceptual model for future computer modeling and information regarding the dominant subsurface pathways and travel times of groundwater and/or contamination.

(8) An identification of the data used in performing the study, or implementing the strategy:

Data used in this study includes previously mapped locations of local karst features and selected injection points, and monitoring points consisting of spring discharge points and

water wells. Dye traces performed by the Authority and others will also be used to guide in the design of future traces.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The monitoring points will consist of main springs, the injection points will consist of caves, surface stream sinks or wells. After the dyes, injection and monitoring points have been approved by the EAA staff, dyes will be introduced into the injection points. Staff will monitor the selected monitoring points, collect samples, submit the samples for dye concentration analysis and determine when until the dye slug has passed by or a pre-determined number of days. Data will be processed by the EAA staff to determine groundwater flow velocities and aquifer flow paths.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The study will provide accurate and detailed information on the dominant conduit/fracture systems within the Edwards Aquifer karst in the vicinity of the study areas. The studies will provide groundwater flow velocities, flow directions and travel time information. This information is critical in the construction of an accurate groundwater flow model.

(11) If completed, an abstract of the study or strategy;

Study is not complete.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. However, the study will improve the present understanding of subsurface flow directions and velocities. The project function determined for this study was a data collection effort (DC).

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Recharge Models of Nine Basins

(1) Name of study or strategy:

This strategy consists of two studies: Pilot Recharge Models of the Nueces and Blanco River Basins and Prepare Recharge Models of Seven Basins Using the HSPF Computer Model

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$168,416) for pilot models.
Edwards Aquifer Authority (\$701,502) after March 2004 amendment for the seven basins contract to include two additional basins.

(3) Cost of study or strategy:

\$168,416 for the pilot models of the Nueces and Blanco River basins
\$701,502 over two years, five months for the seven basins

(4) Study completion date, or strategy implementation date:

Pilot models of the Nueces and Blanco River basins were completed by HDR Engineering in July 2002.

The study of the remaining seven basins was initiated in October 2002. LBG-Guyton Associates will submit the final report for the model for all nine basins in March 2005.

(5) Name of entity preparing the study or implementing the strategy:

HDR Engineering built the pilot models for the Nueces and Blanco River basins.

LBG-Guyton Associates (Guyton) is building the recharge models for seven basins and the contributing zone. The Guyton team consists of AQUA TERRA Inc., Espey Consultants, Freese and Nichols, GlynData and Bradford Wilcox Ph.D. with Texas A&M University.

(6) Name and title of Authority liaison, if any:

- Mr. Sam Vaughn, P.E. – HDR Engineering (Pilot Models)
Mr. Charles W. Kreidler, Ph.D. – LBG-Guyton Associates (Seven Basins)

(7) A statement of the purpose of the study or strategy:

The purpose of this strategy is to develop Hydrologic Simulation Program-Fortran (HSPF) models of the nine drainage basins crossing the Edwards aquifer recharge zone to estimate the volume of daily recharge to the Edwards Aquifer. The recharge estimates will be input into the Edwards Aquifer computer model when it is recalibrated to a daily time step. The drainage basins being modeled are:

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

HDR Engineering built pilot models of the Nueces and Blanco River basins to test the concept. The LBG-Guyton team is building models of the remaining seven basins, the drainage area of the Nueces and Blanco River basins, and refining incorporating the pilot models into one model.

(8) An identification of the data used in performing the study, or implementing the strategy:

Data for the models consist of precipitation and evaporation measurements from the National Climatic Data Center and National Oceanographic and Atmospheric Agency Hydrologic Data Systems Group, stream discharges from the USGS, watershed characteristics from the National Resource Conservation Service (NRCS), surface water use records from the Texas Commission on Environmental Quality (TCEQ), and water well records from the Texas Water Development Board (TWDB).

(9) An identification of the methodology used in performing the study, or implementing the strategy:

Both contractors collected and compiled the data listed above and prepared work plans that included modeling assumptions and calibration procedures for the HSPF software. The objective of the models is to create a water balance for the basins and match the stream discharge measured at the gauges at the upstream and downstream edges of the recharge zone. Recharge to the aquifer is the residual volume of water after water has been allocated to all the other components of the water balance. The models will generate daily recharge estimates for the nine basins. The model output files will be compatible with the input data files being used for the new Edwards Aquifer simulation model being prepared by the USGS.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

Updating the method for estimating recharge to the Edwards Aquifer will provide more accurate recharge data than the two methods currently used. The existing methods, one

developed by the USGS and the other by HDR Engineering, Inc, provide only annual estimates of recharge, while the HSPF models will provide daily estimates. Compared to the current methods, the HSPF models will use fewer assumptions and more consistent watershed representations, and they will generate input data files for the new Edwards Aquifer model.

(11) If completed, an abstract of the study or strategy:

The pilot study was completed in 2001. The final report and model for all nine basins will be submitted in March 2005.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits):

The models are not complete so they cannot provide a technical basis to increase the permitted withdrawal cap. The project function determined for this study was a management tool (MT), and upon further evaluation may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any:

Not applicable

(14) A reasoned analysis supporting the recommendation:

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

Statistical Analysis of Hydrologic Data from the October 1998 Flood Event

(1) **Name of study or strategy:**

Statistical Analysis of Hydrologic Data from the October 1998 Flood Event

(2) **Name of entities providing funding:**

Edwards Aquifer Authority (\$27,500)
United States Army Corps of Engineers (\$27,500)

(3) **Cost of study or strategy:**

\$ 55,000 over 1.5 years

(4) **Study completion date, or strategy implementation date:**

This study was implemented in June 2000, and was completed in November 2001.

(5) **Name of entity preparing the study or implementing the strategy:**

Argonne National Laboratory (ANL)

ANL served as a subcontractor to the United States Army Corps of Engineers (COE). The work was performed under a joint funding agreement (JFA) between the Authority and the COE under the COE's planning assistance to states program.

(6) **Name and title of Authority liaison, if any:**

Mr. David Tomasko – ANL Project Manager

(7) **A statement of the purpose of the study or strategy:**

The major storm that occurred over South Texas during October 17-18, 1998 offers a unique opportunity to analyze the flow of water through the Edwards Aquifer. Intense rainfall occurred over parts of Medina, Guadalupe, Bexar, Comal, and Hays counties, and large volumes of water entered the aquifer from the major streams and tributaries in the recharge zone. As the water moved through the aquifer, water levels in wells rose, and eventually springflows increased. By analyzing how the aquifer responded to this unique recharge event, the study evaluated the rate at which water flowed through the aquifer from throughout the recharge zone to the springs.

The purpose of this study was to interpret groundwater flowpaths by assessing the response of the aquifer to the storm event. A secondary objective of the study was to identify the sources of water that issue from San Marcos Springs based on evidence from the hydrologic records during the October 1998 event. Records of several wells and streams in the San Marcos area were correlated with springflow to evaluate the relationship between surface water flow, groundwater levels, and spring discharge.

(8) An identification of the data used in performing the study, or implementing the strategy;

Data for this study consists of precipitation measurements from the National Climatic Data Center, stream discharges from the US Geological Survey, and water well records from the Edwards Aquifer Authority.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

ANL studied the movement of the stormwater through the aquifer by cross-correlating responses in wells, springs, and streams. That is, by comparing the timing of the response to the storm by surface water and groundwater levels, ANL tried to track the position of the water as it moved through the system. Cross-correlation coefficients were calculated between discharges from Comal and San Marcos Springs; between river flows in the same body of water at upstream and downstream gauges; and among the responses in 12 monitoring wells, rivers, and springs.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This is a foundational study that will complement other investigations of groundwater flowpaths in the Edwards Aquifer. It provided estimates of residence time of water in the aquifer that may be used to evaluate the success of aquifer storage projects. In addition, this review and analysis of empirical data will assist calibration decisions for the Edwards Aquifer modeling project. The findings revealed evidence of preferential flowpaths through the aquifer that were considered in model development.

(11) If completed, an abstract of the study or strategy;

The October 1998 storm was a major hydrologic event that occurred on the drainage and recharge zones of the Edwards Aquifer. Intense rainfall fell on parts of Medina, Guadalupe, Bexar, Comal, and Hays counties, and large volumes of water entered the aquifer from the major streams and tributaries on the recharge zone. The highest rainfall, at least 30 inches, fell in southern Hays County just south of San Marcos. The second highest area of rainfall, with about 22 inches of rain, was in western Comal County.

Rivers and streams immediately filled with runoff, and many had record-breaking flows. Most streams and rivers reached peak flows within a day and then returned to pre-storm flows within about four days. San Marcos Springs peaked at about 400 cubic feet per second (cfs) about nine days after the storm, and Comal Springs peaked at about 400 cfs about 11 days after the storm. Discharge returned to pre-storm levels after 166 days at San Marcos Springs and after one year at Comal Springs.

Groundwater levels rose throughout the Edwards Aquifer. The Bexar County index well (J-17) water level rose almost 30 feet and peaked at an elevation of 689 feet 17 days after the storm. Other wells in the artesian zone such as the Hondo index well, responded similarly. Water levels at J-17 and Hondo returned to pre-storm elevations after about 230 days.

Cross-correlation coefficients were calculated between discharges from Comal and San Marcos Springs; between river flows in the same body of water at upstream and downstream gauges; and among the responses in 12 monitoring wells, rivers, and springs. San Marcos and Comal Springs revealed limited correlation. Although their discharges peaked two days apart, San Marcos Springs received inflow about 20 days after the storm that sustained the discharge for about 35 days, while the Comal Springs discharge continued receding. This is consistent with the prevailing interpretation that at least two sources of recharge contribute to San Marcos Springs. The Blanco River, which probably contributes to San Marcos Springs, correlated slightly with the springs with a time difference or lag of nine days. Discharges from gauges on the same river, such as the Blanco River, correlated very highly because both upstream and downstream gauges received the storm flow on the same day. Similarly, most of the well responses in the artesian zone showed high correlations with a lag of zero days because the pressure wave produced by infiltrating stormwater propagated rapidly through the aquifer. Responses among recharge zone wells correlated to a limited extent, but there was less correlation with artesian zone wells.

The statistical analysis clearly showed a major flowpath from the artesian zone to San Marcos and Comal Springs. Other specific flowpaths could not be traced because the storm event of October 17 and 18, 1998 produced rainfall over the entire area, and impacted all flowpaths nearly simultaneously. Groundwater elevations and springflows, reflecting the amount of water stored in the Edwards Aquifer system, returned to pre-October 1998 levels within about one year after the storm event.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

By itself, the study is not sufficient to support a recommendation to increase the permitted withdrawal cap. This foundational study supports the Edwards Aquifer modeling project that will be completed in 2004 and will be used to evaluate various aquifer management scenarios with increased permitted withdrawal caps. The project function determined for this study was a data collection effort (DC) with low potential (LP) for supporting additional water supplies.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Completed Study

Fracture/Conduit Study - Improve the Conceptual Model of Fracture/Conduit Flow in the Recharge Zone of the Edwards Aquifer

(1) Name of study or strategy:

Fracture/Conduit Study - Improve the Conceptual Model of Fracture/Conduit Flow in the Recharge Zone of the Edwards Aquifer.

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$75,000)
University of Texas at Austin - Bureau of Economic Geology (\$15,202)

(3) Cost of study or strategy:

\$90,202 of 1.5 years

(4) Study completion date, or strategy implementation date:

This study was completed in January 2004.

(5) Name of entity preparing the study or implementing the strategy:

University of Texas at Austin - Bureau of Economic Geology (BEG)

(6) Name and title of Authority liaison, if any:

Dr. Susan Hovorka – BEG Project Manager

(7) A statement of the purpose of the study or strategy:

Although a large volume of empirical data has been collected regarding the Edwards Aquifer, the conceptual model of groundwater flow in the recharge zone has been defined only on a regional basis. Current management scenarios require more localized detail regarding the movement of groundwater as it travels from the recharge zone to the artesian zone and the springs. The purpose of this study is to integrate and analyze a number of existing and in-progress data sets to improve the conceptual model of structurally influenced karst flow in the recharge zone.

(8) An identification of the data used in performing the study, or implementing the strategy;

BEG used a variety of data sets for this study, including but not limited to structure maps; cave maps; hydrographs of streams, wells, and springs; water levels; and natural, contaminant, or introduced tracers.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The study tested the following hypothesis:

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

To test these hypotheses, the study included the following tasks:

- An update of the fault locations in the Edwards Aquifer
- An update of the Edwards Aquifer stratigraphy to reflect new well data and recent mapping by the BEG, USGS, and SAWS
- A compilation of published cave information as it relates to the development of karst features in the Edwards Aquifer
- An analysis of surface water-groundwater interactions, especially rainfall events
- A recreation of historical water level maps, especially droughts
- An investigation of the relationships between water chemistry, flow mechanisms, and conduit development.

The final report presented and the analysis of the project tasks discusses the implications of the findings of the study for aquifer management, aquifer protection, and further research.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

This is a foundational study that will complement other investigations of groundwater flowpaths in the Edwards Aquifer, especially in the recharge zone. The benefit of this study is its holistic approach to the Edwards Aquifer, taking into account geologic structure of the Balcones faults, stratigraphy of the Edwards Group, hydrogeology, geochemistry, hydraulic response rainfall events, and the evolution of karst features. It investigated the influence of fractures and conduits on groundwater flowpaths. Like other Edwards Aquifer Optimization Program (EAOP) studies, this review and analysis of Edwards Aquifer data will assist calibration decisions for the modeling project. The findings will be used to interpret the locations of preferential flowpaths through the aquifer that will be considered in the model.

(11) If completed, an abstract of the study or strategy:

This study is complete. Following is the abstract from the project report:

"The Balcones Fault Zone Edwards Aquifer of South Texas exhibits multimodal permeability. High matrix porosity and permeability are overshadowed by high permeability developed in structurally influenced karstic conduit systems. High permeability is developed in the confined part of the aquifer at depths greater than 4,000 feet below sea level, as well as in the unconfined zone. Optimization of use of this heavily subscribed aquifer requires accurate quantification and realistic mapping of the relationships between the limestone matrix, which stores most of the water, and the conduit system, which transmits water into, through, and out of the aquifer. This balance between storage and drainage is a key variable needed for predicting sustainability of flow during periods of low recharge and heavy use.

The purpose of this study was to interpret and integrate a selection of the existing diverse data to better characterize the conduit system. Data sets selected to feed into this interpretation included (1) water-level data, (2) structural information, (3) cave maps, (4) existing water-chemistry data, and (5) well hydrographs. It is intended that analysis of the existing data will supply hypotheses that will then be tested using field-based follow-up studies. These might include injected tracers; high frequency, closely spaced water level monitoring; conductivity monitoring; and well testing to better define flow systems.

A regionally extensive system of high-permeability zones is defined by broad troughs in the potentiometric surface in the confined zone. Indications of connections of the confined aquifer to the recharge zone are weakly defined by troughs in the available water-level data. Intersection of the Edwards/Trinity merged potentiometric surface maps with base Edwards's structure maps to show that the Edwards Formation is saturated over only a part of the Edwards outcrop zone. This fact suggests that recharge flows through the Edwards into the upper beds of the underlying Glen Rose Formation before returning to the Edwards. Steep gradients of 100 ft/mi are mapped where flow crosses between the Glen Rose and the Edwards Formations, showing that the cross-formational flowpaths are much less transmissive than those in the Edwards confined zone. Spring discharge at the Edwards-Glen Rose contact suggests that perched water tables or flood-stage perched conduits might have a significant role in transmitting water through the recharge zone.

Cave maps show a persistent overprint of vadose-zone karst development, forming near-vertical shafts; however, in the horizontal segments, cave elongation shows that about half the caves are elongated along the principal fault direction. This orientation documents the role of opening-mode fractures parallel to the Balcones Fault Zone trends in controlling permeability. The other half of the horizontally elongated caves trend in other directions, reflecting multiple fracture systems in this structurally complex system. Local gradient toward a local discharge point is interpreted to be a possible contribution to elongations of some cave patterns.

Water chemistry from Texas Water Development Board (TWDB) files is used as an indicator of flowpath geometry. High-salinity water (>3000 mg/L total dissolved solids [TDS]) indicative of long residence times is found in the deep part of the Edwards aquifer and in parts of the Glen Rose (Trinity) Aquifer. These areas are therefore interpreted as regions bypassed by low-TDS recharge water moving through conduits. Other Trinity samples have salinities in the same range as that of average Edwards's water (200 to 500

mg/L) and may indicate faster flowpaths that communicate from the Trinity to the Edwards and from the Edwards recharge zone through the Trinity and back into the Edwards. About 5% of the Edwards waters in the confined Edwards are strongly undersaturated with respect to calcite, interpreted as an indicator of rapid conduit flow that has limited reactions between rock and water. Undersaturated samples are not strongly clustered in the major conduits zones defined by troughs in the potentiometric surface, suggesting that a network of conduits is active, with groundwater velocities adequate to impact chemistries. Samples with reported high (more than 30 mg/L) nitrate in the confined aquifer are tentatively interpreted as indicators of fast flowpaths from surface sources of nitrate; however, well leakage and sample contamination are alternative explanations.

Separation of representative well hydrographs recession curves shows variability in the ratio of matrix to fracture storativity. However, strong rapid drainage characteristic of conduits was not observed in the small population of hydrographs analyzed.”

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is complete but does not provide a technical basis for increasing the withdrawal cap. However, when results of this and related present and future research that better delineate groundwater flow conditions within the Edwards Aquifer are sufficiently quantified, they eventually must be considered in groundwater modeling and determining the Edwards Aquifer’s water budget. The project function determined for this study was a data collection effort (DC) with low potential (LP) for supporting additional water supplies.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

**Range Management - Evaluation of Woody Species
Best Management Practices in Relation to
Water Quality and Quantity Studies on Watersheds in the
Government Canyon State Natural Area and Honey Creek State Natural Area**

(1) **Name of study or strategy:**

Range Management - Evaluation of Woody Species Best Management Practices in Relation to Water Quality and Quantity Studies on Watersheds in the Government Canyon State Natural Area and Honey Creek State Natural Area.

(2) **Name of entities providing funding:**

Edwards Aquifer Authority (\$25,000 per year)
San Antonio Water System (\$25,000 per year)
United States Geological Survey (\$125,000 per year)
Texas Soil and Water Conservation Board, in cooperation with the United States Department of Agriculture Natural Resource Conservation Service (\$125,000 per year)
Guadalupe-Blanco River Authority (\$25,000 total)
Edwards Region Grazing and Lands Conservation Initiative (\$1,000 total) to this approximately \$300,000 per year study.

(3) **Cost of study or strategy:**

\$2,426,000 over eight years

(4) **Study completion date, or strategy implementation date:**

This ongoing study was implemented in late 1998 at the beginning of the 1999 federal fiscal year. The final report is scheduled to be completed by September 2006.

(5) **Name of entity preparing the study or implementing the strategy:**

The United States Department of Agriculture – Natural Resource Conservation Service (NRCS) manages the study. The United States Geological Survey (USGS) is collecting data for the study.

(6) **Name and title of Authority liaison, if any:**

Mr. Phillip Wright – NRCS office in Hondo, Texas

(7) A statement of the purpose of the study or strategy:

The purpose of the study is to quantify the effectiveness of phreatophyte (cedar, *Juniperus ashei*) management and plant community restorations as a model best management practice (BMP) for increasing water yields while protecting water quality on a watershed scale, while avoiding adverse impacts on Golden-cheeked Warbler and other endangered species habitat.

(8) An identification of the data used in performing the study, or implementing the strategy:

Rainfall data, evapotranspiration data, and water quality data will be collected during the study. The data will be collected from three watersheds, two at the Honey Creek State Natural Area (HCSNA) and one at the Government Canyon State Natural Area (GCSNA). Baseline data will be collected for at least two years from the drainage basins before cedar tree removal is implemented. Cedar removal (cedar management) should occur over approximately one year. Data collection will continue during and after the cedar management is performed. Selective species removal began in the Honey Creek site in November 2003 and is on-going. Selective brush removal is planned to begin during the fall of 2005 at GCSNA.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

The data will be evaluated to determine if statistically-significant differences exist between the three watersheds prior to cedar removal. These statistical tests will be the basis for evaluating changes in the watersheds after cedar is removed. Data will be evaluated on a storm event and continuous time-series basis. Precipitation will be taken into consideration when determining differences between the three watersheds to assure that the differences are not due to precipitation variability. A final report is scheduled to be prepared by September 2006. Significant project delays have occurred at the GCSNA due to concerns about damage to Golden-Cheeked Warbler habitat.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy:

The study will provide the Authority with an assessment of the benefits of cedar management over the Edwards Aquifer Recharge Zone and Contributing Zone in regards to recharge quantity and water quality. Research conducted in the San Antonio area has shown that the removal of woody vegetation followed by the establishment of perennial grass cover will result in increased water yields from rangeland watersheds. The documented increased surface-water yield has ranged from 40,000 to 140,000 gallons per acre treated per year depending on the percentage of woody plant removed. This information is based on field scale studies. Additional research would determine if the field scale results are applicable on a watershed scale.

(11) If completed, an abstract of the study or strategy:

The study is not complete. A final project report is due in September 2006.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC) and upon further evaluation may potentially support adjusting (PSA) the withdrawal cap.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Range Management - Study of Augmenting Groundwater Recharge Through Brush Control

(1) Name of study or strategy:

Range management - study of augmenting groundwater recharge through brush control (reduction of Ashe Juniper)

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$300,000), National Science Foundation and SAWS (\$100,000)

(3) Cost of study or strategy:

\$400,000 over four years and three months; contract was signed on September 9, 2003.

(4) Study completion date, or strategy implementation date:

The final report is scheduled to be completed by December, 2007.

(5) Name of entity preparing the study or implementing the strategy:

Texas A & M University (TAMU)

(6) Name and title of Authority liaison, if any:

Dr. Brad Wilcox, TAMU, College Station, Texas

(7) A statement of the purpose of the study or strategy:

The purpose of the study is to determine if recharge in the Edwards Aquifer Recharge Zone may be enhanced through the reduction of Ashe Juniper and other woody species (Brush) and if so, to what extent. Two cave locations (Headquarters and Bunny Hole Caves) at Camp Bullis have been selected for the study. The study will:

1. Establish a quantitative link between the dynamics of precipitation and groundwater recharge through monitoring recharge in shallow caves prior to brush control.
2. After brush removal, determine the extent to which the precipitation/recharge relationship has changed due to brush removal.

3. If a change is noted, determine the impact to recharge with planted native grasses that have replaced the brush.

(8) An identification of the data used in performing the study, or implementing the strategy;

Data used in this study includes precipitation, evapotranspiration, surface runoff, soil moisture and collected recharge water from within the caves. Both naturally occurring precipitation events and staged man made rainfall events (soaker hoses or elevated sprinkler system) will be monitored. There will be two data collection periods, the first is baseline data collection prior to brush removal, the second period would be after the designated brush has been cleared.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The data will be evaluated to determine if statistically significant differences exist for recharge before and after brush (Ashe Juniper) removal. These statistical tests will be the basis for quantifying the impacts on recharge by brush removal. A better understanding of the hydrogeologic water budget before and after brush removal will also be developed.

(10) (10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

Research has previously documented increased surface-water yield from 40,000 (0.12 acre/feet per year) to 140,000 (0.43 acre/feet per year). This study will provide the authority with a semi-quantitative assessment of the impacts of brush (Ashe Juniper) removal and the potential volume of ground water recharge to the Edwards Aquifer. This study may also provide insights to the temporal and spatial distribution of recharge with regards to the impact of different magnitudes and durations of precipitation events.

(11) If completed, an abstract of the study or strategy;

The study is incomplete. A final project report is due in December, 2007.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. However, the study when completed, may indicate that brush clearing could statistically increase a quantifiable volume of recharge to the aquifer under given circumstances. The project function determined for this study was a data collection effort (DC) and with further evaluation may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Analysis of Recharge and Recirculation

(1) Name of study or strategy:

Analysis of Recharge and Recirculation

(2) Name of entities providing funding:

Edwards Aquifer Authority (EAA)

(3) Cost of study or strategy:

\$330,000 over four years

(4) Study completion date, or strategy implementation date:

This study was implemented on May 11, 2004 and is scheduled for completion in April 2006.

(5) Name of entity preparing the study or implementing the strategy:

Todd Engineering

(6) Name and title of Authority liaison, if any:

Dr. David Todd, Todd Engineering

(7) A statement of the purpose of the study or strategy:

The purpose of this study is to perform an independent analysis of the recharge and recirculation concept. The recharge and recirculation concept is described as "an integrated and coordinated approach to water management that combines groundwater and surface water sources and storage units, taking advantage of a large variety of supply options to store water so as to optimize the availability of water to users in the Edwards Aquifer pumping region during drought of record and to accommodate water requirements of endangered species at Comal and San Marcos Springs."

(8) An identification of the data used in performing the study, or implementing the strategy:

The study is expected to use work related to the recharge and recirculation model runs conducted for the South Central Texas Regional Water Planning Group by HDR, Inc along

with other Recharge and Recirculation related research efforts conducted by HDR, Inc and the EAA.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The USGS MODFLOW model of the Edwards Aquifer will be used to simulate multiple scenarios to investigate different recharge sites and how various volumes of recharge from these sites affect water levels and spring flows. The results of the model simulations will be used to evaluate the feasibility of various water collection, storage and transportation facilities.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The study will provide information on the conjunctive management of the Edwards Aquifer, surface water sources and water storage options to optimize the availability of the Edwards Aquifer during a repeat of the drought of record and address the needs of spring-based endangered species.

(11) If completed, an abstract of the study or strategy;

This study is incomplete.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was a data collection effort (DC) and upon further evaluation may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Incomplete Study

Evaluation of Augmentation Methodologies in Support of In-Situ Refugia at Comal and San Marcos Springs, Texas
Augmentation Study (In Situ Refugia)

(1) Name of study or strategy:

Evaluation of Augmentation Methodologies in Support of In-Situ Refugia at Comal and San Marcos Springs, Texas (In Situ Refugia)

(2) Name of entities providing funding:

Edwards Aquifer Authority (\$157,750)

(3) Cost of study or strategy:

\$157,750 over 1 year 7 months

(4) Study completion date, or strategy implementation date:

This ongoing study was implemented in November 2002. LBG-Guyton will submit the final report by June 30, 2004.

(5) Name of entity preparing the study or implementing the strategy:

LBG-Guyton and Associates

(6) Name and title of Authority liaison, if any:

Charles W. Kreitler, Ph.D. - LBG-Guyton and Associates

(7) A statement of the purpose of the study or strategy:

The purpose of this project is to assess the feasibility of introducing water directly to critical habitat areas of the Comal and San Marcos springs ecosystem to extend the viability of the habitat during low springflow.

(8) An identification of the data used in performing the study, or implementing the strategy:

Data for this study consists of field work including a bathymetric survey of Landa Lake and Spring Lake along with collection of samples of the water and sediments from the major spring orifices at Comal and San Marcos springs. It is based in part on recommendations presented by the University of Texas, Center for Research in Water Resources (CRWR) in

the report: Springflow Augmentation of Comal and San Marcos Springs, Texas: Phase I-Feasibility study. Other resources include evaluation of existing well information including logs, historic records, prior research, and it includes research and an evaluation of the history of the springs from various sources.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The project team led by LBG-Guyton will collect data for this study consisting of field work including a bathymetric survey of Landa Lake and Spring Lake along with the collection of sediment and water samples from the major spring orifices at Comal and San Marcos springs and Landa and Spring lakes. From the data collected it will be determined what conditions are necessary to support the endangered species and which are critical to the developing and maintaining an in-situ refugia to protect the threatened and endangered species during low springflow (e.g. drought) conditions.

There is a continuum of strategies is expected to be necessary to protect the species. This study will look at viable alternatives including supplementing available supplies with alternative water supplies including finding, treating the water supply when necessary and delivery of water of appropriate quality to current habitat area in the spring complexes to support the various threatened and endangered species habit in the spring complexes at both Comal and San Marcos springs.

LBG-Guyton will also characterize the hydrogeologic conditions within one mile of the springs and lakes to help determine the potential impact of drought on strategies proposed for augmentation. Five potentially "most feasible" strategies will be identified along with data gaps that are identified in the course of the study and the evaluation of the strategies along with cost and potential sources of water supply.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

Augmentation in the context of this project is an attempt to create in situ refugia for the species. If augmentation in conjunction with other water management programs is successful and sufficient to maintain critical habitat, then the endangered species should not have to be moved to traditional refugia under controlled conditions.

(11) If completed, an abstract of the study or strategy;

The study is not complete. A final report and model will be submitted in June 2004.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This study is incomplete; therefore it does not provide a technical basis to increase the permitted withdrawal cap at this time. The project function determined for this study was

that upon further evaluation that the study may potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

Strategies

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Conservation
Agricultural Water Conservation Loan Program

(1) **Name of study or strategy:**

Agricultural Water Conservation Loan Program

(2) **Name of entities providing funding:**

Edwards Aquifer Authority
Texas Water Development Board (TWDB)

(3) **Cost of study or strategy:**

Administrative costs only. This strategy is implemented with loan money that is repaid. A \$250 non-refundable application fee serves to defray the Authority's administrative costs.

In September 1998, the TWDB approved a \$3,000,000 loan request by the Authority to make low interest loans available to irrigators to purchase equipment to improve agricultural water use efficiency. In May 2001, the TWDB approved an additional \$1,000,000 loan request by the Authority. To date, the Authority has issued 28 loans, totaling approximately 2.5 million dollars. In 2001, the Authority will loan \$207,638 for this program. According to TWDB, the Authority did not make any loans in 2002 or 2003 using this program.

(4) **Study completion date, or strategy implementation date:**

The Agricultural Water Conservation Loan Program is an ongoing program that has been administered by the Authority since 1998.

(5) **Name of entity preparing the study or implementing the strategy:**

Edwards Aquifer Authority implements the strategy with low interest loan money provided by the TWDB.

(6) **Name and title of Authority liaison, if any:**

Mr. Michael Smith, Texas Water Development Board

(7) **A statement of the purpose of the study or strategy:**

The purpose of the Agricultural Water Conservation Loan Program is to encourage water conservation by providing low-interest loans. The primary use of the loan money provided

to date has been for the purchase of high efficiency irrigation pivot systems to replace flood irrigation on cropland.

(8) An identification of the data used in performing the study, or implementing the strategy;

Data developed by the TWDB and the United States Department of Agriculture-Natural Resource Conservation Service (NRCS) indicates that a significant water savings can be realized if crop irrigation is performed with high efficiency sprinkler systems in lieu of flood irrigation. The NRCS estimates that a high efficiency sprinkler system, center pivot or linear system, can result in a 30 percent water savings over flood irrigation. To date, an analysis of the amount of water saved by the Authority's Agricultural Water Conservation Loan Program has not been performed. The amount of savings per system installed depends on the acreage, crop type, and type of sprinkler system installed.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The Agricultural Water Conservation Loan Program represents the Authority's commitment to accomplishing the board's goal to "conduct research and develop additional sources of water." The Edwards Aquifer Authority Act, Article 1, Section 1.24, Loans and Grants, indicates that:

- (a) Notwithstanding any other provision of law, the Authority is eligible as a lender district to receive loans from the TWDB under the Agricultural Water Conservation Loan Program under Subchapter J, Chapter 17, Water Code;
- (b) The Authority may apply for, request, solicit, contract for, receive, and accept gifts, grants, and other assistance from any source for the purpose of this article; and
- (c) The Authority may issue grants or make loans to finance the purchase or installation of equipment or facilities. If the Authority issues a grant for a water conservation, reuse, or water management project, the Authority may require the beneficiary to transfer to the Authority permitted rights to Aquifer water equal to a portion of the water conserved or made available by the project.

Individual loans are available for new capital materials and equipment for irrigation water delivery and application mechanisms. Loan amounts up to 90% of the value of eligible expenses are available if security pledged is equal in value to the amount of the loan. Loans are secured by a first lien on the equipment and/or other forms of collateral equal to or exceeding in value the loan amount in favor of the Authority and the TWDB. Permitted water rights may also be pledged as additional collateral. The Authority will pay back the TWDB loan over a period of eight years through the revenue generated from individual loans to irrigators.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The program results in improved water use efficiency averaging approximately 30% water savings for participating irrigators. The saved water may be leased or sold to others in

need of Edwards Aquifer withdrawal rights or used to increase the irrigated acreage of the well owner.

(11) If completed, an abstract of the study or strategy;

As of November 13, 2001, the Authority has issued 28 loans, totaling about 2.5 million dollars.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Conservation programs are important tools for improving the efficient use of available water in the region but they do not increase the total amount of water available in the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Conservation
Region L's Population and Water Demand Revisions

(1) **Name of study or strategy:**

South Central Texas (Region L) Regional Water Plan (SCTRWP) population and water demand revisions

(2) **Name of entities providing funding:**

Texas Water Development Board (TWDB) and SCTRWP Group Members

(3) **Cost of study or strategy:**

\$82,000 was appropriated to Task 2 of the SCTRWP plan to review, develop, and approve population and water demand projections.

(4) **Study completion date, or strategy implementation date:**

Approval of initial population projections from the SCTRWP 2000-2060 were approved by the Texas Water Development Board on March 19, 2003. Revised population projections were adopted on February 17, 2004. Water demand projections for Region L were approved on September 17, 2003 by the TWDB.

(5) **Name of entity preparing the study or implementing the strategy:**

HDR Engineering, Inc. is under contract to SCTRWP

(6) **Name and title of Authority liaison, if any:**

Mr. Ralph Boeker, Texas Water Development Board
Mr. Sam Vaughn, HDR Engineering

(7) **A statement of the purpose of the study or strategy:**

The purpose of the population and water demand projections are to provide a quantitative basis for regional water planning. The primary use of these projections is in the forecasting of future water demands for the region and is the foundation of input data for planning.

(8) An identification of the data used in performing the study, or implementing the strategy;

Data is developed by the Census Bureau, the TWDB, and the State Data Center using the 2000 Census. Initial data releases are reviewed by the regional water planning groups and adjustments are made according to local, changed conditions.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Consultant utilized revised population and water demand data for the planning region from TWDB and then develops and analyzes projected water demands for water user groups and wholesale water providers. Detailed summary tables were prepared for each water user group, including historical and projected population, water use, per capita water use, and other relevant information used to populate the TWDB database with required data.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The program will provide the most accurate assessment of future population and water demand projections for the region. The TWDB-approved population and water demand will provide the official future water demands to be used in assessing supplies and future water supply conditions used in the regional water plan.

(11) If completed, an abstract of the study or strategy;

On February 5, 2004, the South Central Texas Regional Water Planning Group (Region L) approved the population and demand for its planning region. The primary difference in the revised population and water use projections compared to the original estimates (Senate Bill 1, projections made in 2000) are reduced urban population and municipal water demand. The overall population of the planning area is now projected to increase by 90 percent from 1.36 million to 2.59 million by 2030, 12 percent less than the originally projected 2.95 million people.

Projected water demand also decreased for two reasons, first because of the projected population adjustment, and secondly, because of more accurate per capita use rates determined during the dry year of 2000. The updated water demand projections are 24 percent below projections made during the Senate Bill I planning period. Projected municipal water demand projections for the year 2030 decreased from approximately 524,000 acre-feet/year to approximately 401,000 acre-feet/year. By the year 2030, municipal water demand is projected to be 60 per cent of the total demand for the region.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Adjustment of projected population growth and municipal water demand assists in managing the resources of the Edward Aquifer. However, they do not

increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

\$711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Reuse

San Antonio Water System (SAWS) Recycled Water Program

(1) **Name of study or strategy:**

San Antonio Water System Recycled Water Program

(2) **Name of entities providing funding:**

San Antonio Water System (SAWS)

(3) **Cost of study or strategy:**

\$22,968,300 by the end of 2003 when the strategy is scheduled to be fully implemented.

(4) **Study completion date, or strategy implementation date:**

The strategy concept was formalized in 1989 when the City of San Antonio established a wastewater reuse district. The SAWS board authorized implementation of the strategy in 1994. Construction began in 1996 and the first customers began receiving water from the project in 1999

(5) **Name of entity preparing the study or implementing the strategy:**

San Antonio Water System (SAWS).

(6) **Name and title of Authority liaison, if any:**

Ms. Susan Butler, Director of Water Resources, SAWS
Pablo Martinez and Steve Fletcher, SAWS

(7) **A statement of the purpose of the study or strategy:**

The purpose of this strategy is a conservation measure to reduce demand on the Edwards Aquifer. The Recycled Water Program began in 1989 when the City of San Antonio requested that the State Legislature pass a bill to permit the creation of a district devoted to reuse of the municipality's effluent. Senate Bill 1667, which established the Alamo Water Conservation and Reuse District (AWCRED), was signed by the Governor on June 16, 1989. In 1991, the District applied for a permit to divert water from the Leon Creek Wastewater Treatment Plant for reuse purposes. In December 1991 the San Antonio City Council voted to establish a single utility responsible for water, wastewater, stormwater, and reuse. As a result, SAWS was created in May 1992. In 1994, the SAWS board authorized SAWS staff to initiate a recycled water program as a conservation measure to reduce

demand on the Edwards Aquifer. The program supplies SAWS commercial and irrigation customers with a non-potable source of water that is not subject to drought restrictions.

(8) An identification of the data used in performing the study, or implementing the strategy;

SAWS staff surveyed potential commercial and irrigation customers regarding their interest in participating in a recycled water program. In 1996, SAWS sent out request for service letters to targeted potential customers. By identifying potential customers, SAWS was able to begin designing infrastructure for the project. Potential customers were identified by the type of use, proximity to water treatment plants, and the volume of water used. The Recycled Water Program will eventually distribute approximately 35,000 acre-feet of treated waste water to appropriate customers for use in landscape irrigation, cooling towers, and agricultural irrigation.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Treated wastewater is delivered to customers through transmission lines that extend from two wastewater treatment plants in southern Bexar County to the areas of use. Customers contract for the service and connect to the transmission line. SAWS offers their recycled water program users incentives that will reimburse them for the cost of the connection.

The Salado Creek Treatment Plant (eastern distribution, capacity of 13,000 acre-feet/year) and the Leon Creek Treatment Plant (western distribution, capacity of 22,000 acre-feet/year) are currently used to supply water for the project. The Dos Rios Treatment Plant and the Medio Creek Treatment Plant could provide future needs of recycled water. Currently, there are 74 miles of transmission lines that carry the treated wastewater from the two treatment plants. Storage towers for the treated wastewater are located on Hildebrand, Coliseum Drive, Highway 151 and Pearsall Road.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The amount of treated wastewater delivered by the system generally replaces Edwards Aquifer water that would have been pumped if the treated wastewater was not available. By supplying treated wastewater to customers that can use it, SAWS is able to reduce its Edwards Aquifer pumpage. Use of the treated wastewater is not subject to drought restrictions.

(11) If completed, an abstract of the study or strategy;

SAWS's Recycled Water Program is installing the infrastructure required to deliver treated, non-potable water to customers who have a need for water but do not require potable water. SAWS obtains contractual commitments from entities that would otherwise use Edward Aquifer groundwater if the treated wastewater was not available. As of June 2004, SAWS has contracts to supply 14,260 acre-feet/year of non-potable water per year to various customers (5,100 stream maintenance, 3,183 Mitchell Lake, 5,977 commercial contracts). Another 6,111 acre-feet/year is contracted and waiting for hookups and 720

acre-feet/year is in negotiations. The recycled water system capacity is 35,000 acre-feet per year, a volume that is approximately equal to 20% of San Antonio's drinking water needs.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Recycled water is an important resource management tool for the region. Recycled water does reduce demand from the Edwards Aquifer; however, recycled water does not increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Reuse
New Braunfels Utilities (NBU) Recycled Water Program

(1) **Name of study or strategy:**

New Braunfels Utilities Recycled Water Program

(2) **Name of entities providing funding:**

Capital costs for the currently implemented and operating project were funded by Sundance golf course. Funding details of a second reuse project for an industrial customer have not yet been discussed.

(3) **Cost of study or strategy:**

The golf course reuse project had a capital cost of \$125,000. The additional potential reuse project being evaluated by NBU has costs estimated in the \$6,000,000 to \$7,000,000 range.

(4) **Study completion date, or strategy implementation date:**

The contract for the first recycled water project was signed in late 1994 and water has been delivered for the past several years. A second potential project is being studied for an industrial customer and would be implemented within the next few years.

(5) **Name of entity preparing the study or implementing the strategy:**

New Braunfels Utilities (NBU)

(6) **Name and title of Authority liaison, if any:**

Roger Biggers, Executive Director of Water Services, NBU

(7) **A statement of the purpose of the study or strategy:**

Treated wastewater delivered to Sundance Golf Course generally replaces water that would otherwise have come from the Edwards Aquifer. Regarding the potential project, reuse water would be provided to an industrial customer in exchange for that industry's pumping water rights from the Edwards Aquifer. This would benefit both NBU and its customer by providing additional potable supply for NBU and providing an expandable, drought resistant supply for the industrial customer.

(8) An identification of the data used in performing the study, or implementing the strategy;

Water deliveries under the reuse project are measured by an in-line meter at the treatment plant's diversion point. These data provide an isolated quantitative measure of the water being delivered to the reuse water user.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Treated wastewater is delivered to a customer through a one mile transmission line that extends from Gruene Treatment Plant to the area of use. North and South Kuehler Treatment Plants could potentially supply reuse water to additional and potential future customers. The second potential reuse customer would receive water from these two treatment plants via a five mile delivery line.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The amount of treated wastewater delivered by the system generally replaces Edwards Aquifer water that would have been pumped if the treated wastewater was not available. The amount of reuse water delivered to the Sundance Golf Course from the system replaces water that would otherwise come from the Edwards Aquifer if the reuse water was not available. However, there is little potential benefit to the Authority expected from the implementation of the second project since there will be limited reduction in pumping from the Edwards Aquifer due to the assumption of the water right.

(11) If completed, an abstract of the study or strategy;

New Braunfels Utilities currently supplies treated wastewater from the Gruene Treatment Plant to Sundance Golf Course for purposes of golf course irrigation. The amount of treated wastewater delivered is based on the needs of the customer and is metered. Approximately 100 acre-feet of reuse water has been used by the customer in the past 12 months. New Braunfels Utilities is looking at a second water recycling project for an industrial customer. This reuse project would supply up to 5,000 acre-feet per year of reuse water for purposes of dust control and aggregate washing. The water for this project would be delivered from the North and South Kuehler Treatment Plants through a five mile transmission line.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Recycled water is an important resource management tool for the region. Recycled water does reduce demand from the Edwards Aquifer; however, recycled water does not increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004**Implemented Strategy****Supplemental Recharge**
Edwards Aquifer Authority's Precipitation Enhancement Program**(1) Name of study or strategy:**

Precipitation Enhancement Program (PEP)

(2) Name of entities providing funding:

Edwards Aquifer Authority (EAA)
Texas Department of Agriculture (TDA)

(3) Cost of study or strategy:

The Edwards Aquifer Authority has operated a cloud seeding or Precipitation Enhancement Program (PEP) since 1999 through a "turn-key" contract with a private contractor. This program cost the Authority approximately \$500,000 per year and continued through the end of the 2001 PEP season. In an effort to enhance services and reduce costs, the Authority contracted with the South Texas Weather Modification Association (STWMA) in Pleasanton, Texas, and the Southwest Texas Rain Enhancement Association (SWTREA) in Carrizo Springs, Texas for its 2002, 2003, and 2004 PEP program. The Authority's cost for the 2002-2004 PEP programs has been \$124,776 per year, at a cost of approximately \$0.4 per acre within the service area. The service area includes Bandera, Bexar, Medina and Uvalde counties. The STWMA is responsible for cloud-seeding over Bandera, Bexar and Medina counties and the SWTREA is responsible for cloud-seeding over Uvalde County for the Authority.

(4) Study completion date, or strategy implementation date:

Precipitation Enhancement Program (PEP) has been operational in the EAA service area since 1999. PEP strategies are implemented annually between May 1st and October 31st.

(5) Name of entity preparing the study or implementing the strategy:

Weather Modification, Inc. performed cloud seeding activities for the PEP in 1999, 2000, and 2001. Woodley Weather Consultants completed an assessment of the effects of cloud seeding for the 1999, 2000, and 2001 operating period. STWMA and SWTREA have provided cloud seeding for the PEP since 2002 and summarizes the cloud seeding activities for each season in reports to the Authority.

(6) Name and title of Authority liaison, if any:

Mike Mahoney - STWMA
Ed Walker – SWTREA

(7) A statement of the purpose of the study or strategy:

The purpose of the program is to increase rainfall over the Edwards Aquifer region to increase recharge to the aquifer and to reduce crop irrigation and lawn watering demands. The Authority obtained a four-year permit to conduct precipitation enhancement from the Texas Natural Resource Conservation Commission (TNRCC) on October 21, 1998. The permit was issued by the Texas Department of Licensing and Regulation and was valid through 2002. The permit allowed the Authority to conduct precipitation enhancement anytime during the year, although the traditional cloud-seeding season is from May through October. In 2002, STWMA and SWTREA modified their cloud seeding permits to include the appropriate counties within the Authority's area (Bandera, Bexar, Medina, and Uvalde).

The PEP sponsored by the Authority is designed to put additional water on the ground and into the Edwards Aquifer. The target area for 1999 through 2001 included 6.37 million acres in all or parts of twelve counties including Real, Kerr, Kendall, Bandera, Blanco, Uvalde, Medina, Bexar Comal, Hays, Guadalupe, and Caldwell. The target area for 2002 through 2004 includes 3.1 million acres in four counties including Uvalde, Bandera, Medina, and Bexar.

(8) An identification of the data used in performing the study, or implementing the strategy:

Data for the precipitation enhancement program consists of rainfall data, radar images, and seeding aircraft flight tracks.

(9) An identification of the methodology used in performing the study, or implementing the strategy:

The program targets the counties that comprise large portions of the recharge and drainage areas and large portions of high irrigation demand. Licensed meteorologists with STWMA and SWTREA monitor weather systems that may be candidates for cloud seeding. Once a target cloud is identified, seeding aircraft are deployed to inject tiny particles of silver iodide into the base of the cloud. Moisture accumulates around the silver iodide particles to form raindrops. Unseeded clouds generally have approximately a 20-30 minute life span. The objective of this program is to extend the life span of clouds with seeding agent and increase the amount of precipitation that may fall from the cloud.

Specially equipped aircraft place the seeding agent into convective cloud towers to induce those clouds to produce more rainfall. The seeding is achieved by burning either ejectable flares or wing-mounted flares just below the cloud base. Some "base" seeding is also accomplished by operating seeding agent generators that are wing-mounted on the aircraft. The seeding aircraft fly below the cloud base in the updraft region of growing convective clouds. The aircraft pilots are directed to the target clouds by a licensed meteorologist that uses weather radar identify clouds that need a "nudge" from the seeding effort.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

Research indicates that precipitation enhancement can result in increased rainfall from a seeded cloud by about 10 to 20 percent. A study by Woodley Weather Consultants, Inc. for the 1999-2001 seasons indicated that seeded clouds produced 21% more rainfall than similar clouds that were not seeded. The total amount of additional rain produced by seeding in 1999 through 2001 was approximately 60,000 acre-feet per year. A study of the 2003 PEP by Arquimedes Ruiz, a meteorologist for the West Texas Weather Modification Association, indicates that the 2003 precipitation enhancement activities produced approximately 123,000 acre-feet of rainfall in the four county area funded by the Authority. This amount of increased rainfall could add a significant amount of increased recharge to the Edwards Aquifer. Benefits are also realized from increased rainfall even if the rain doesn't fall over the Edwards Aquifer Recharge Zone because the rainfall reduces aquifer pumping demand by decreasing the need for lawn watering and crop irrigation.

(11) If completed, an abstract of the study or strategy;

Several PEP studies have been completed by Authority contractors and others between 1999 and 2004. Research funded by the Authority indicates that precipitation enhancement can result in increased rainfall from seeded clouds by approximately 20% to 50% with the later figure now appearing to be the most probable. The present benefit of the PEP program is increased rainfall and recharge to the Edwards Aquifer. Additional benefits would be seen even if the rain doesn't fall over the recharge zone because rainfall keeps homeowners from having to water lawns and farmers from having to irrigate crops.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

At this time, Authority staff does not recommend that the board of directors consider increasing the permitted withdrawal cap based on this strategy. While this program has the potential to support adjusting the withdrawal cap, a specific recommendation can only be made once the correlation between cloud seeding, decreased demand, and increased recharge is further refined. The project function determined for this strategy was that upon further evaluation, this strategy can potentially support adjusting (PSA) the withdrawal cap.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

**Conjunctive Management of Surface Water and Groundwater
Bexar Metropolitan Water District Surface Water Plant**

(1) **Name of study or strategy:**

Bexar Metropolitan Water District (BMWD) Surface Water Plant

(2) **Name of entities providing funding:**

Bexar Metropolitan Water District (BexarMet/BMWD)

(3) **Cost of study or strategy:**

\$30,000,000 for design and construction of the treatment plant and infrastructure (plant, 30" transmission line, storage tank).

(4) **Study completion date, or strategy implementation date:**

The surface water plan became operational on December 7, 1999.

(5) **Name of entity preparing the study or implementing the strategy:**

BexarMet

(6) **Name and title of authority liaison, if any:**

Mr. Chuck Ahrens – BexarMet Water Resource Manager

(7) **A statement of the purpose of the study or strategy:**

Purpose of the strategy is to provide an alternative water source in place of Edwards Aquifer water and to supplement the Edwards Aquifer permitted withdrawal amount that will be proposed for BexarMet. The project will enable BexarMet to meet future water supply demands.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

BexarMet projected demand and pending limitations on Edwards Aquifer permitted withdrawals.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

The ultrafiltration water purification plant was built in southwestern Bexar County near the Medina River to provide additional supplies of potable water for customers in southeastern San Antonio. A 30-inch water transmission line and water storage tank were also constructed specifically for the project.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

The strategy will benefit the Authority by helping BexarMet to meet current and future water demands with non-Edwards Aquifer water and decreasing their need to purchase or lease additional Edwards Aquifer withdrawal rights.

(11) If completed, an abstract of the study or strategy;

BexarMet's Surface Water Plant provides treated surface water from the Medina River water to their service area in southeast San Antonio. This is their largest contiguous service area. The project represents the first non-Edwards Aquifer potable water source in Bexar County. The plant is a state-of-the-art facility that provides approximately 10,000,000 gallons per day (11,200 acre-feet per year) of water that is comparable in quality to Edwards Aquifer water.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Meeting current and future water demands from sources other than the Edwards Aquifer is an important resource management tool for the region. However, the conjunctive use of groundwater and surface water resources may reduce demand of the Edwards Aquifer; conjunctive use does not increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

\$711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Conjunctive Management of Surface Water and Groundwater
San Marcos Regional Surface Water Plant

(1) **Name of study or strategy:**

San Marcos Regional Surface Water Plant

(2) **Name of entities providing funding:**

City of San Marcos (CSM)
Edwards Aquifer Authority (EAA/Authority)

The Authority will provide \$1,119,000 to the CSM to offset costs for the purchase of surface water from the Guadalupe-Blanco River Authority (GBRA). Authority payments to the CSM will total \$223,800 per year for five years commencing in 2000. The CSM and the Authority also agreed to suspend 3,000 acre-feet per year of CSM Edwards Aquifer withdrawal rights for the years 2001 through 2007.

(3) **Cost of study or strategy:**

\$20,000,000 for design and construction of the surface water treatment plant.

(4) **Study completion date, or strategy implementation date:**

The plant became operational in January 2000.

(5) **Name of entity preparing the study or implementing the strategy:**

City of San Marcos.

(6) **Name and title of Authority liaison, if any:**

Mr. Tom Taggart – CSM Director of Water and Wastewater Utilities

(7) **A statement of the purpose of the study or strategy:**

The San Marcos Regional Water Treatment Plant was constructed to reduce the reliance of the City of San Marcos on Edwards Aquifer water.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

CSM projected demand and pending limitations on Edwards Aquifer permitted withdrawals.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

A CSM contractor performed a 50-year surface water supply study in 1992. Plant design contracts were awarded in 1996 and the plant was constructed between June 1998 and December 1999. The plant became operational in January 2000 using Guadalupe River water as a source.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

The strategy will benefit the Authority by helping the CSM to meet current and future water demands with non-Edwards Aquifer water and decreasing their need to purchase or lease additional Edwards Aquifer withdrawal rights. As part of the contract for Authority funding for the project, the CSM agreed to suspend 3,000 acre-feet of permitted Edwards Aquifer withdrawal rights for 6 years (2001 through 2007).

(11) If completed, an abstract of the study or strategy;

The project is an advanced surface water treatment plant that uses conventional coagulation techniques and enhanced coagulation techniques in addition to sedimentation and filtration methods. With the current plant configuration, the CSM has reduced its Edwards Aquifer water demand by two-thirds since the plant came on-line. The plant has a capacity of 6 million gallons per day (6,720 acre-feet per year) and can be expanded to 24 million gallons per day. The plant uses Guadalupe River water as source water. The source water is delivered from the Guadalupe River to the plant via a pipeline constructed by GBRA.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Meeting current and future water demands from sources other than the Edwards Aquifer is an important resource management tool for the region. However, the conjunctive use of groundwater and surface water resources may reduce demand of the Edwards Aquifer; conjunctive use does not increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Conjunctive Management of Surface Water and Groundwater
New Braunfels Surface Water Plant

(1) Name of study or strategy:

New Braunfels Utilities Surface Water Plant.

(2) Name of entities providing funding:

New Braunfels Utilities (NBU)
Edwards Aquifer Authority

An interlocal agreement between the Edwards Underground Water District (predecessor agency to the Edwards Aquifer Authority) and New Braunfels Utilities was executed in 1989. The agreement resulted in the Edwards Underground Water District providing \$1,424,509 over a five year period for the purchase of surface water for the plant.

(3) Cost of study or strategy:

\$8,400,000 for design and construction of the surface water treatment plant.

(4) Study completion date, or strategy implementation date:

The plant became operational in November 1991.

(5) Name of entity preparing the study or implementing the strategy:

New Braunfels Utilities (NBU)

(6) Name and title of authority liaison, if any:

Mr. John Richardson - Plant Manager, NBU

(7) A statement of the purpose of the study or strategy:

The NBU Surface Water Treatment Plant was implemented to provide the City of New Braunfels with an alternate water source and reduce their dependency on the Edwards Aquifer. The plant also provides potable water to Green Valley Special Utility District, which also uses the treated surface water to supplement their permitted withdrawal from Edwards Aquifer.

(8) An identification of the data used in performing the study, or implementing the strategy;

The City of New Braunfels projected demand and pending limitations on Edwards Aquifer permitted withdrawals.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

NBU contracted to have the surface water treatment plant constructed using water from the Guadalupe River as source water. The plant was placed on line in November 1991.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

The strategy will benefit the Authority by helping NBU to meet current and future water demands with non-Edwards Aquifer water and decreasing their need to purchase or lease additional Edwards Aquifer withdrawal rights. The plant currently provides the majority of the City of New Braunfels water needs.

(11) If completed, an abstract of the study or strategy;

NBU operates a surface water treatment plant using Guadalupe River water as a source. The plant is located in New Braunfels. In its current configuration, the plant is the primary source of water for the City of New Braunfels with a capacity of 8.0 million gallons per day (8,964 acre-feet per year) of potable water. The plant also supplies treated surface water to Green Valley Special Utility District (GVSUD). In 2000, the NBU plant provided approximately 298 acre-feet of treated surface water to GVSUD. The plant became operational in November 1991.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Meeting current and future water demands from sources other than the Edwards Aquifer is an important resource management tool for the region. However, the conjunctive use of groundwater and surface water resources may reduce demand of the Edwards Aquifer; conjunctive use does not increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004**Implemented Strategy****Conjunctive Management of Surface Water and Groundwater
Canyon Regional Surface Water Plant****(1) Name of study or strategy:**

Canyon Regional Water Authority Surface Water Plant

(2) Name of entities providing funding:

Canyon Regional Water Authority (CRWA)

CRWA is a subdivision of the State of Texas created by the Texas Legislature in 1989. The agency does not have taxing authority and raises funds by performing services. Its services are sold to member entities, most of which are pumpers from the Edwards Aquifer that are regulated by the Edwards Aquifer Authority (Authority). The member entities include: Crystal Clear Water Supply Corporation (WSC), East Central WSC, Bexar Metropolitan Water District, Green Valley Special Utility District, Springs Hill WSC, City of Cibolo, City of Marion, City of La Vernia, Maxwell WSC, County Line WSC, and Martindale WSC.

(3) Cost of study or strategy:

\$5,090,000 for design and construction of the surface water treatment plant

(4) Study completion date, or strategy implementation date:

The plant became operational in 1994.

(5) Name of entity preparing the study or implementing the strategy:

Canyon Regional Water Authority (CRWA).

(6) Name and title of authority liaison, if any:

David Davenport - CRWA General Manager

(7) A statement of the purpose of the study or strategy:

CRWA surface water plant operates to provide non-Edwards Aquifer water to its members that are in need of potable water supplies. CRWA is mandated to "encourage water conservation, to reduce reliance on a future uncertain supply of groundwater and to protect, preserve, and restore the purity of water".

(8) An identification of the data used in performing the study, or implementing the strategy;

Projected demand of CRWA member entities and pending limitations on Edwards Aquifer permitted withdrawals.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

CRWA constructed the surface water treatment plant and related infrastructure. The plant currently uses sand filtration and will be upgrading to membrane technology in the future.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

The CRWA surface water plant will benefit the Authority by helping CRWA member entities to meet current and future water demands with non-Edwards Aquifer water and decreasing their need to purchase or lease additional Edwards Aquifer withdrawal rights.

(11) If completed, an abstract of the study or strategy;

The CRWA surface water treatment plant is located adjacent to Lake Dunlap on the Guadalupe River southeast of New Braunfels. According to CRWA, the plant currently serves 5,200 connections in the Green Valley Special Utility District, Springs Hill WSC, Crystal Clear WSC, and the East Central WSC service areas. The plant uses Guadalupe River water as source water and sand filtration treatment technology. In its current configuration, the plant provides approximately 2.0 million gallons per day (2,240 acre-feet per year) of potable water to its users. CRWA plans to increase the plant capacity to a 12 million gallon per day and upgrade to membrane filter treatment technology.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Meeting current and future water demands from sources other than the Edwards Aquifer is an important resource management tool for the region. However, the conjunctive use of groundwater and surface water resources may reduce demand of the Edwards Aquifer; conjunctive use does not increase the total amount of water available from the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

**Drought Management Plans
Enacted by Edwards Aquifer Water Purveyors**

(1) **Name of study or strategy:**

Drought management plans enacted by water purveyors in the Edwards Aquifer region.

(2) **Name of entities providing funding:**

Water purveyors that are required to obtain a permit from the Edwards Aquifer Authority to withdraw Edwards Aquifer water.

(3) **Cost of study or strategy:**

The cost of this strategy has not been quantified. Costs to administer drought management plans are incurred by the water purveyors. Costs will be highly variable depending on the complexity of individual drought management plans and the enforcement mechanisms that result from the plan.

(4) **Study completion date, or strategy implementation date:**

Implementation dates vary. Some area water purveyors, such as the City of San Marcos, New Braunfels Utilities, and San Antonio Water System (SAWS) have ordinances and rules in place to deal with drought conditions. Some area water purveyors are currently developing drought management plans. Many area water purveyors implement emergency drought management measures only when drought conditions develop. All drought management plans must comply with EDWARDS AQUIFER AUTHORITY RULES, ch. 715 (Comprehensive Water Management Plan Implementation), subch. D (Demand Management and Critical Period Management). These rules became effective in 2003.

(5) **Name of entity preparing the study or implementing the strategy:**

Water purveyors within the boundaries of the Edwards Aquifer Authority.

(6) **Name and title of Authority liaison, if any:**

The Authority liaison for individual drought management plans is generally the city manager or water utility manager. In some cases, water purveyors have retained a consultant to serve as a liaison for their drought management plan.

(7) A statement of the purpose of the study or strategy;

The purpose of this strategy is to reduce Edwards Aquifer withdrawals by water purveyors during drought conditions that have resulted in low water levels and low springflows. Reducing aquifer withdrawals during drought conditions will prolong springflows as long as possible or until a recharge event occurs to increase water levels. Prolonged periods of low springflows are believed to present a significant danger to the aquatic ecosystems that depend on flow from the major Edwards Aquifer springs. Significantly reduced Edwards Aquifer water levels and springflows also have a negative economic impact by increasing aquifer pumping costs, decreasing recreation-related commerce in the areas of major springs, and decreasing downstream flows in rivers that receive water from the major springs.

(8) An identification of the data used in performing the study, or implementing the strategy;

The data used to implement the drought management plans will vary with the individual water purveyor's plans. Drought management plans are normally implemented by demand management/critical period trigger levels such as water levels at an aquifer index well. Springflow amounts have not routinely been used for drought management plan trigger levels.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Methodologies for implementing this strategy will vary. It is the responsibility of the individual water purveyor to devise a drought management plan that is achievable in their service area, and yet still meets the necessary reduction of water use as determined by the Edwards Aquifer Authority.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

The Authority will benefit from this strategy by having Edwards Aquifer withdrawal reduction plans in place during periods of drought. The withdrawal reductions are intended to minimize water level declines and prolong springflows as long as possible or until the next recharge event occurs.

(11) If completed, an abstract of the study or strategy;

Individual drought management plans can be obtained from the various water purveyors in the Authority's region. As noted previously, some purveyors have existing plans and some are in the process of developing plans. A comprehensive listing of the current status of the drought management plans of each water purveyor has not been compiled. All drought management plans must comply with EDWARDS AQUIFER AUTHORITY RULES, ch. 715 (Comprehensive Water Management Plan Implementation), subch. D (Demand Management and Critical Period Management).

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted

withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy is being implemented but does not provide a technical basis for increasing the withdrawal cap at this time. Drought management plans are important tools for the management of the aquifer during a drought and maintaining minimum flows to meet environmental requirements. However, they do not increase the total amount of water available in the Edwards Aquifer. The project function, at this time, determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004**Implemented Strategy****Demand Management and Critical Period Management Rules of the Edwards Aquifer Authority****(1) Name of study or strategy:**

Demand Management and Critical Period Management Rules of the Edwards Aquifer Authority.

(2) Name of entities providing funding:

Funding is provided by all users of the Edwards Aquifer that pay aquifer management fees to the Edwards Aquifer Authority.

(3) Cost of study or strategy:

The cost of these rules on the regulated community is not precisely known. When the rules were considered by the Edwards Aquifer Authority Board of Directors, a regulatory impact assessment was prepared that included various cost scenarios. The actual cost can not be predicted because the length and severity of a drought can not be predicted. The costs to the regulated community would depend on the length of time that water use restrictions are in effect and the severity of the restrictions will depend on the amount that water levels and springflows actually decline. The regulatory impact assessment generally indicates that because of the large size and diverse economies of the planning area, the effect of the early stages of water use restrictions would not have substantial negative impacts. As more severe water use restrictions are imposed, the largest negative impact would be to agriculture-related employment and income.

(4) Study completion date, or strategy implementation date:

The Demand Management and Critical Period Management Rules of the Edwards Aquifer Authority were implemented in 2003.

(5) Name of entity preparing the study or implementing the strategy:

The Edwards Aquifer Authority has implemented this strategy.

(6) Name and title of Authority liaison, if any:

The Authority liaison for the Demand Management and Critical Period Management rules is the contact person listed in the Authority database of authorized use permits and owners of wells that are exempt from aquifer use permitting.

(7) A statement of the purpose of the study or strategy;

The purpose of this strategy is to authorize the maximum aggregate withdrawals from the aquifer from wells with groundwater withdrawal permits, interim authorizations status, or exempt well status balanced against the Authority's aquifer management strategy to slow the rate of decline of springflows in Comal or San Marcos springs. Slowing the rate of decline of springflows will allow more time for the return of normal precipitation events resulting in the maintenance or increase of aquifer levels which would concomitantly result in the maintenance or increase in spring levels.

(8) An identification of the data used in performing the study, or implementing the strategy;

The volume of groundwater that may be withdrawn by any party authorized to withdraw water from the aquifer during a stage of the Demand Management or Critical Period Management is determined by Chapter 715 (Comprehensive Water Management Plan Implementation), Subchapter D (Demand Management and Critical Period Management rules). Aquifer withdrawals are provided on the Quarterly Allocation Form that is required under rule 715.204 (Authorized Withdrawals) and are adjusted by the interruption coefficient that is determined by 715.218 (Interruption of Withdrawals During Demand Management and Critical Periods). Each user must also file a monthly groundwater withdrawal report with the Authority containing withdrawal data in weekly increments when a demand management or critical period is in effect.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Each of the identified users shall file with the Edwards Aquifer Authority a quarterly Demand Management/Critical Period withdrawal schedule on a form provided by the Authority. This schedule shall include the Initial Regular Permit application number or permit number for each permit or transfer and the total volume of groundwater authorized to be withdrawn, the date of the effective transfer, the pool from which the withdrawal or transfer is to be made, and the volume of groundwater proposed to be withdrawn for each quarter of the year.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

The Authority will benefit from this strategy by having Edwards Aquifer withdrawal demand management and critical period plans in place during periods of drought. The withdrawal reductions will maintain water levels and prolong springflows as long as possible or until the next recharge event occurs.

(11) If completed, an abstract of the study or strategy;

The Edwards Aquifer Authority has developed and implemented demand management and critical period management rules as section 715 subchapter D.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted

withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy is being implemented but does not provide a technical basis for increasing the withdrawal cap at this time. Critical Period Management Rules are important tools for the management of the aquifer during a drought and maintaining minimum flows to meet environmental requirements. However, they do not increase the total amount of water available from the Edwards Aquifer. The project function, at this time, determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Other Water Management Strategies
San Antonio Water System (SAWS)-Aquifer Storage and Recovery (ASR)
Project in
South Bexar County

(1) Name of study or strategy:

San Antonio Water System's Aquifer Storage and Recovery (ASR) Project in South Bexar County

(2) Name of entities providing funding:

San Antonio Water System (SAWS)

(3) Cost of study or strategy:

Full cost of implementation and construction of this strategy is approximately \$215,000,000.

Recently revised cost estimate is \$190,000,000.

(4) Study completion date, or strategy implementation date:

A phased-in operation was initiated in May 2004. Full implementation is scheduled to be in 2005.

(5) Name of entity preparing the study or implementing the strategy:

SAWS is implementing the strategy.

(6) Name and title of Authority liaison, if any:

Mr. Mike Brinkman, Project Manager, SAWS

(7) A statement of the purpose of the study or strategy:

The purpose of an aquifer storage and recovery (ASR) project is to use water from a source other than the receiving aquifer, treat it to drinking water standards if necessary, and inject it into an aquifer for subsequent recovery. Water can be injected during periods of excess supply and recovered during periods of peak demand. The SAWS ASR Project will store water in a portion of the Carrizo Sand Aquifer in southern Bexar County, where SAWS has acquired land for the infrastructure for the project, and use the Edwards Aquifer for source water.

(8) An identification of the data used in performing the study, or implementing the strategy;

Research began in 1996 using a Texas Water Development Board (TWDB) Planning Grant to study the feasibility of an aquifer storage and recovery project in Bexar County. Various aquifers in the county were evaluated for their ability to accept water from another source, store it for a period of time, and allow for the recovery of that water when demands were greater. Of the aquifers evaluated, the Carrizo Sand Aquifer was identified as the most favorable aquifer for the project. The feasibility study was completed in October 2000. Phase I of the implementation phase was completed with the installation of production wells and a treatment plant in May 2004.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Approximately 3,200 acres of land in southern Bexar County was purchased by February 2000. A feasibility study was completed in October 2000. In November 2001, the Texas Natural Resource Conservation Commission (TNRCC) (now the Texas Commission of Environmental Quality, TCEQ) authorized SAWS to construct and operate the ASR project in South Bexar County. The TCEQ authorization allows SAWS to use the Carrizo Sand Aquifer for the storage and recovery of Edwards Aquifer water. SAWS will also be able to produce groundwater from the Carrizo Sand Aquifer in the same location as the ASR facility. SAWS will be able to store and recover approximately 22,500 acre-feet of Edwards Aquifer water from the current ASR project.

Phase I of drilling included seventeen injection/recovery wells which were completed in 2003. The construction of 29 miles of pipelines, pumps and a water treatment plant (treatment of Carrizo groundwater) to treat and transport ASR water began in August, 2002 and was completed in May 2004. No treatment of the injected Edwards Aquifer water will be necessary. Phase II includes the drilling of seventeen additional injection/recovery wells which will be completed by 2005.

Presently (June, 2004), 6,400 acre-feet of Carrizo Aquifer groundwater is being pumped from the Phase I ASR well field into the distribution pipelines to San Antonio. In the following months, excess Edwards Aquifer water will be injected into the ASR well field for storage and to determine both injection and production capacities for final assessment of project capabilities.

(10) A statement of the benefit or potential benefit to the Authority expected from the study or strategy;

When the ASR project is fully implemented, it will enable SAWS to decrease its Edwards Aquifer withdrawals during dry periods when Edwards Aquifer demand reductions become mandatory. This will benefit the Authority by decreasing aquifer pumping and prolonging springflows during periods of low water level conditions.

(11) If completed, an abstract of the study or strategy;

The strategy is in the implementation phase and a complete strategy description is not available. Testing is underway to determine both injection and production capacities for

final assessment of project capabilities with the existing well field. The strategy implementation date is presently scheduled to be in 2005.

- (12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

At this time, the Authority staff does not recommend that the board of directors consider increasing the permitted withdrawal cap based on this strategy. The strategy is in its implementation phase and does not have a sufficient operational record for evaluation. The project function determined for this strategy was that upon further evaluation, this strategy may potentially support adjusting (PSA) the withdrawal cap.

- (13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

- (14) A reasoned analysis supporting the recommendation;

Not applicable

- (15) Supporting documentation as appropriate; and

Not applicable

- (16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Other Management Strategies

San Antonio Water System (SAWS) Use of Trinity and Carrizo Aquifer Water

(1) Name of study or strategy:

SAWS use of Trinity and Carrizo Aquifer water

(2) Name of entities providing funding:

San Antonio Water System (SAWS)

(3) Cost of study or strategy:

Project costs for the development of supplies in the Trinity Aquifer are estimated to be \$7,800,000. Costs for the development of supplies in the Carrizo Aquifer are estimated to be around \$250,000,000.

(4) Study completion date, or strategy implementation date:

The two Trinity Aquifer sites came on-line in February 2002. Strategies that utilize water from the Carrizo Aquifer are currently being evaluated and supplies are expected to be delivered by 2007.

(5) Name of entity preparing the study or implementing the strategy:

San Antonio Water System (SAWS)

(6) Name and title of Authority liaison, if any:

Darren Thompson, Project Manager, SAWS

(7) A statement of the purpose of the study or strategy:

This strategy was implemented by SAWS in order to reduce their dependency on Edwards Aquifer water and to supply their customers with an alternate water source.

(8) An identification of the data used in performing the study, or implementing the strategy:

The Texas Water Development Board has contracted with various consultants to develop Groundwater Availability Models (GAM) to determine aquifer supplies and availabilities. This includes models for both the Carrizo and Trinity aquifers. An accurate groundwater model requires a tremendous amount of information about the aquifer. The general steps in

developing a groundwater model include: (1) developing the conceptual model, (2) defining the model architecture, (3) calibrating and verifying the model, and (4) making predictions. The conceptual model represents our best idea of how the aquifer works. Developing a good conceptual model requires compiling detailed information on the geology, precipitation, water quality, recharge, rivers, water levels, hydraulic parameters, and pumping.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Hydrologic studies were performed prior to the development of the two Trinity well sites and are currently being performed on the development of Carrizo supplies. These studies include the running of groundwater models and implementation of monitoring wells.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

This strategy benefits the Authority by helping SAWS to meet current and future water demands with non-Edwards Aquifer water, decreasing their need to purchase or lease additional Edwards Aquifer withdrawal rights.

(11) If completed, an abstract of the study or strategy;

SAWS has developed two locations in North Central Bexar County, namely the Oliver Ranch and BSR sites that draw water from the Trinity Aquifer. These two sites provide approximately 5,000 acre-feet of water to SAWS customers per year. SAWS is currently evaluating a strategy in Gonzales County that would supply water from the Carrizo Aquifer to SAWS customers. This strategy is still in the feasibility stages with delivery of the supplies expected in 2007. This strategy would provide a minimum of 20,000 acre-feet of non-Edwards water.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Groundwater derived from other aquifers can be used to supplement and decrease demand for Edwards Aquifer water but water from other aquifers does not increase the total amount of water available in the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Other Management Strategies
Bexar Metropolitan Water District (BMWD)
Use of Trinity and Carrizo Aquifer Water

(1) **Name of study or strategy:**

BMWD use of Trinity and Carrizo Aquifer water

(2) **Name of entities providing funding:**

Bexar Metropolitan Water District (BexarMet), possibly Schertz-Seguin Water System

(3) **Cost of study or strategy:**

Cost of this strategy will vary depending on BexarMet's decision to contract with Schertz-Seguin or not. Costs are estimated in the range of \$40,000,000 to \$50,000,000, if BexarMet chooses to complete the project alone. This includes costs of conveyance, storage, and treatment facilities.

(4) **Study completion date, or strategy implementation date:**

BexarMet has acquired numerous water supply systems located over the Trinity and Carrizo Aquifers between the years of 1995 and 2000. The proposed Carrizo project in Gonzales and Guadalupe Counties would be expected to come on-line in 2007 or 2008.

(5) **Name of entity preparing the study or implementing the strategy:**

Bexar Metropolitan Water District

(6) **Name and title of Authority liaison, if any:**

Mike Albach, Deputy General Manager, Bexar Metropolitan Water District

(7) **A statement of the purpose of the study or strategy:**

This strategy will be implemented by BexarMet in order to obtain additional supplies for municipal use and to supply their customers with an alternate non-Edwards water source.

(8) **An identification of the data used in performing the study, or implementing the strategy:**

The Texas Water Development Board has contracted with various consultants to develop Groundwater Availability Models (GAM) to determine aquifer supplies and availabilities.

This includes models for both the Carrizo and Trinity aquifers. An accurate groundwater model requires a tremendous amount of information about the aquifer. The general steps in developing a groundwater model include: (1) developing the conceptual model, (2) defining the model architecture, (3) calibrating and verifying the model, and (4) making predictions. The conceptual model represents our best idea of how the aquifer works. Developing a good conceptual model requires compiling detailed information on the geology, precipitation, water quality, recharge, rivers, water levels, hydraulic parameters, and pumping which will be utilized to determine potential groundwater availabilities.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Investigative studies will be conducted prior to the development of the new well sites. These studies must be done in order to determine how water levels will be affected by additional pumping of the aquifer, analyze water quality, and comply with local groundwater conservation district rules and requirements. These studies consist of running groundwater models, implementing monitoring wells, and coordinating with regional regulatory entities.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

This strategy is beneficial to the Authority by helping BexarMet to meet municipal water demands with non-Edwards Aquifer water. Obtaining additional supplies from the Carrizo and Trinity Aquifers reduces the amount of water needed from the Edwards Aquifer to meet current and future demands.

(11) If completed, an abstract of the study or strategy;

BexarMet has acquired wells in both the Trinity and Carrizo Aquifers in North and South Bexar County. They have also acquired 4,500 acres of land from a single landowner in Gonzales and Guadalupe Counties. BMWd is looking to drill three wells for additional municipal supply. It is still not known if Schertz-Seguin will contract with BexarMet to participate in the project. The quantity available from the additional acreage will be determined by local groundwater district rules.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Groundwater derived from other aquifers can be used to supplement and decrease demand for Edwards Aquifer water but water from other aquifers does not increase the total amount of water available in the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

§711.296 - General Manager's Annual Additional Water Supply Report for 2004

Implemented Strategy

Other Management Strategies
Tri-County Area Cities Use of Carrizo Aquifer Water

(1) Name of study or strategy:

Tri-County area cities use of Carrizo Aquifer water

(2) Name of entities providing funding:

Regional water suppliers in Atascosa, Bexar, and Wilson counties and the cities of Selma, Schertz, and Converse

(3) Cost of study or strategy:

The cost of the Carrizo Aquifer well field funded by the cities of Schertz & Seguin was \$51 million dollars.

(4) Study completion date, or strategy implementation date:

This strategy has been implemented by the cities of Schertz and Selma. The anticipated implementation date for Converse is unknown.

(5) Name of entity preparing the study or implementing the strategy:

The strategy consists of a cooperative venture by Schertz and Seguin to develop a well field in the Carrizo Aquifer.

(6) Name and title of Authority liaison, if any:

None

(7) A statement of the purpose of the study or strategy:

The purpose of this strategy is to develop groundwater supplies from the Carrizo Aquifer for municipal customers located in the Schertz and Seguin area to provide non-Edwards aquifer water.

(8) An identification of the data used in performing the study, or implementing the strategy:

Regional groundwater studies included detailed information such as geology, recharge estimates, precipitation, water quality, and historical pumping of the aquifer to site the well field. Additional information of the Carrizo Aquifer hydraulic properties and water quality

were obtained from drilling and geophysical logs. Information was integrated to create a well field computer model.

(9) An identification of the methodology used in performing the study, or implementing the strategy;

Aquifer data from state agencies and local drilling provided the needed information to select the location of the well field and assist in designing well construction.

(10) A statement of the benefit or potential benefit to the authority expected from the study or strategy;

This strategy benefits the Authority by helping municipalities in the Tri-County area to meet current and future water demands with non-Edwards Aquifer water. This strategy decreases these cities' need to purchase or lease additional Edwards Aquifer rights.

(11) If completed, an abstract of the study or strategy;

A cooperative venture by Schertz and Seguin to develop a planned 30,000 acre-feet/year well field in the Carrizo Aquifer occurred during 1999 to 2002. LBG-Guyton and Associates and Roming, Parker and Kasberg Engineering located, designed and constructed a well field consisting of eight wells (maximum yield approximately 1,000 gpm per well) in Gonzales County from 1999 to 2002. A 37.5 mile pipeline was built to deliver the groundwater to the Schertz and Seguin cooperative. Since the completion of the well field in 2002, the Schertz and Seguin cooperative has sold Carrizo groundwater to Selma and Universal City (each 800 acre-feet/year). Presently, Schertz is consuming approximately 300 acre-feet per year of Carrizo aquifer groundwater.

(12) A recommendation whether the study or strategy provides a technical basis for the board to determine that additional supplies are available from the aquifer to increase the permitted withdrawal cap established in section 711.164(a) and (b) of this chapter (relating to Groundwater Available for Permitted Withdrawals for Initial and Regular Permits);

This strategy has been implemented but does not provide a technical basis for increasing the withdrawal cap. Groundwater derived from other aquifers can be used to supplement and decrease demand for Edwards Aquifer water but water from other aquifers does not increase the total amount of water available in the Edwards Aquifer. The project function determined for this strategy was a management tool (MT) with low potential (LP) for supporting additional water supplies.

(13) A recommendation as to the specific amount of additional supplies in acre-feet per annum that are available for withdrawal from the aquifer, if any;

Not applicable

(14) A reasoned analysis supporting the recommendation;

Not applicable

(15) Supporting documentation as appropriate; and

Not applicable

(16) Any other appropriate information as may be determined by the general manager or the board.

Not applicable

Attachment C

**Detailed Description of the
Weights and Ratings Used in the
Decision Model for Precipitation
Enhancement Program and
SAWS ASR Project**

ATTACHMENT C
Decision Model Weights and Ratings for the Precipitation Enhancement Program and the SAWS ASR Project

Objective	Objective Weight	Performance Measure	Performance Measure Weight	Precipitation Enhancement Program		SAWS ASR Project		Rating Scale		
				Rating	Rationale	Rating	Rationale	100	50	0
Environmental protection	85	Protect endangered species/ water levels	100	60	Increase of available water to ecosystem, also may increase local water levels	75	Project is expected to enhance spring flow during dryer periods. During wetter periods, excess permitted water in the aquifer will be diverted to storage in the Carrizo Aquifer. During dryer periods, the stored water will be pumped from the Carrizo Aquifer instead of the Edwards Aquifer.	Significantly reduces risk that water levels and spring flows could drop below minimum levels necessary to protect endangered species.	Risk that water levels and spring flows could drop below minimum levels necessary to protect endangered species remains about the same as under current conditions.	Potential to significantly increase the risk that water levels and spring flows could drop below minimum levels necessary to protect endangered species.
		Maintain aquifer water quality	75	50	No significant water quality impact anticipated	50	No significant water quality impact anticipated	Some improvement in aquifer water quality would be expected.	No significant change in aquifer water quality expected.	Significant deterioration in aquifer water quality could be expected.
Economic feasibility	90	Project costs	50	35	Cost per ac-ft is difficult to quantify because of the unknown relationship between increased rainfall and increased recharge.	75	The infrastructure costs are unknown. Operational costs have been calculated but because no operational record is available, the operating costs are not firm.	Strategy or study costs are judged to be minimal compared with expected benefits.	Costs appear to be reasonable, given expected benefits.	Costs appear to not be cost-effective, given expected benefits.
		Protect economies of region	100	60	Costs for crop irrigation and urban landscape irrigation will be lower due to increased soil moisture. Spring flows and their related economies will also benefit from placing more water in storage.	90	All who pump from the aquifer will benefit from higher aquifer water levels during dryer periods. Spring flows and their related economies will also benefit from higher spring flows during dryer periods.	Significant improvement in economies of the region can be expected.	Will not significantly affect economies of region.	Slight to moderate adverse effect can be expected.
Quantity of supply	100	Average yield	100	15	The strategy is very susceptible to drought conditions in that little to no additional water will be produced when there are limited cloud seeding opportunities.	50	Permitted withdrawals from the aquifer are considered a reliable source. Drought restrictions on pumping could limit the source during extended dry periods. The planned average yield is 22,500 ac-ft.	Around 50,000 AFY could be expected.	Around 25,000 AFY could be expected.	Little additional yield can be expected.
Regulatory feasibility	80	Number of jurisdictions	50	90	Already implemented, minor resistance to activity	90	In the process of being implemented, regulatory permits are in place, minor resistance to activity	Only 1 or 2 jurisdictions would need to approve.	4 or 5 jurisdictions might need to be involved.	6 or more jurisdictions with vastly different perspectives would need to be involved.
		Regulatory availability	100	90	Necessary regulatory structures are in place (Program is implemented)	90	Necessary regulatory structures are in place (Program implementation is planned to start June 2004).	All necessary regulatory structures and programs are already in place.	Existing regulatory programs would need to be changed somewhat.	An entirely new regulatory structure would be necessary.
Reliability	80	Value, precision, and accuracy of data	75	25	Evaluations performed to date indicate that much work remains to correlate enhanced rainfall to aquifer recharge.	50	The amount of water available to be pumped from the aquifer to the Carrizo Aquifer is precisely known. The Carrizo Aquifer storage and recovery parameters have been calculated; however, no operational record is available.	Extremely valuable and reliable new data expected.	Some level of uncertainty in results; moderately reliable data.	Significant interpretation challenges leave much uncertainty in the results.
		Technical basis & feasibility	100	40	Precipitation enhancement technology is well understood and well documented; however, it is difficult to quantify increases in aquifer storage that result from this technology.	60	The ASR infrastructure is a tested and reliable technology. The SAWS ASR project is planned to store and recover approximately 22,500 ac-ft. of aquifer water; however, until an operational record is established some feasibility questions will remain.	Feasibility and reliability of techniques or projects well demonstrated	Some level of uncertainty with regard to the technical basis and/or feasibility	Limited track record causes concern about technical basis or reliability.

ac-ft = Acre-feet

AFY = Acre-feet per year