Re-Conceptualizing the Edwards Aquifer Authority Recharge Program:

Staff Recommendations to Optimize and Protect the Edwards Aquifer

An Edwards Aquifer Authority Technical White Paper

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I. BACKGROUND & INTRODUCTION OF SUBJECT

Since the 1970s, the Edwards Aquifer Authority (EAA) and its predecessor agency, the Edwards Underground Water District (EUWD), have operated and maintained four recharge dams located on the recharge zone of the Edwards Aquifer (Aquifer) in Medina County. These structures were constructed by the EUWD on private properties through negotiated easement agreements with landowners within the Nueces River and San Antonio River basins for the purpose of artificially enhancing natural occurring recharge to the Aquifer. The Edwards Aquifer Authority Act (Act) further recognized the aquifer's recharge capability by granting the EAA the authority to enter into cooperative contracts with political subdivisions of the State of Texas for artificial recharge and to own, finance, and construct recharge dams. To date, however, there have not been any new dams constructed.

Over time, with the advent of new technologies and improved understanding of the hydraulic nature of the Aquifer, the EAA "Recharge Program" has evolved beyond the concept of enhanced recharge (or dams) and has developed into a more comprehensive initiative focused on enhancing the available yield of and protecting the water quality in the Aquifer. As a result, today, enhanced recharge is only one of a multitude of tools available to the EAA in its mission to optimize the yield and protect the long-term sustainability of the Aquifer for its beneficial use.

Accordingly, this report is presented to communicate the updated scope and priorities of the EAA "Recharge Program" as they have evolved over time. Included is background information on the aquifer and its geologic and hydraulic attributes, summaries of various regional supply strategies and, finally, staff recommendations for the program's future direction. Background information used to develop this document is derived from previous EAA staff presentations to the Board of Directors (two presented as Technical Briefings and three as reports to the Aquifer Management Planning Committee), which are summarized in the Appendix and available as electronic or hardy copy on request.

II. REVIEW OF AQUIFER HYDRAULICS

As evidenced by extensive historical water level data, the Aquifer system is highly responsive to both recharge and discharge, thus resulting in a relatively short retention time for water in the system. These data validate that karst systems like the Edwards, because of their porous and high transmissivity nature, provide a poor medium for storing water over extended periods of time, as water is always moving through and exiting the system naturally.

Specifically, the Aquifer demonstrates rapid rises of water levels when rainfall is abundant and rapid declines during extended dry periods as demonstrated in **Figures 1a and b**. The data in these figures demonstrate that the aquifer can rise as much as 51-feet over a period of just 12 months, yet it can decline as much as 61-feet in as little as 22 months.

The ability of the system to recharge efficiently by natural means is also well demonstrated in historical water level and stream gauging data. In 1956, during the peak of the drought of record, the all-time low recharge amount was just 43,700 acre-feet (acft). Conversely, the all-time high recharge amount occurred in 1992 at 2,485,700 acft. Stream gauges upstream and downstream of the recharge zone indicate that natural recharge typically captures 80 to 100 percent of stormwater runoff which is ideal for both recharge capture efficiency and conveyance of sediment. As such, these data indicate the importance of preserving historical, natural, recharge as well as how responsive the system is to taking naturally occurring recharge during wet periods.

Based on water level behavior (**Figures 1a-b**) and recorded estimates of natural recharge, it appears the predominant factors that limit optimization efforts are rainfall and retention time of water in the aquifer. For an optimization scheme to be effective, it must provide adequate retention time to benefit the region during a repeat of the drought of record which lasted 10-years. Water level data analysis indicates that enhanced recharge does not significantly increase firm yield if the Aquifer is used as the storage container.

Figure 1a, Bexar County Index Well J-17, Response to Recharge September 2006-September 2007.

Figure 1b, Bexar County Index Well J-17, Response to Drought and Discharge September 2007-July 2009.

III. REVIEW OF THE REGION-WIDE WATER PLANNING PROCESS

Based on aquifer hydraulics, and changes in State water planning legislation, the region-wide water planning process for South Central Texas (Region L in the State Water Plan) has shifted from aquifer-centered enhancement projects to a combination of alternative strategies that ensure higher firm yields for water supply planning purposes.

The Region L planning process itemizes the demands and additional needs of all regional user groups every 5 years with stakeholders recommending a prioritized list of capital projects that best meet future water needs over the next 50 years. Proposed projects are evaluated based on firm yield, using the criteria of the Drought of Record (DOR) from 1947 to 1956. The additional needs for Region L by year 2070 are estimated to be 482,943 acre-feet per year (acft/yr). Proposed projects in the 2016 Region L plan are estimated to produce new water supplies of 787,000 acft/yr. The categories for new water supply sources are:

- Storage Strategies *(off-channel reservoirs, ASRs)* 26%
- Seawater Desalination 23%
- Conservation & Drought Management 22%
- Non-Edwards Groundwater (fresh and brackish) 17%
- Water Reuse 12%

The following is a summary of important regional water planning topics:

- Region L stakeholders propose and prioritize projects to meet anticipated regional water demands. They do not create policy nor ensure the connection of new sources to future customers.
- Region L has a plan to meet projected demands through 2070 at an average cost of $1,291/acft/yr without additional increases to the firm yield of the Aquifer.
- Due primarily to the EAA Act, water planning emphasis has shifted from Aquifer-centered enhancement projects to viewing the available water in the Aquifer as well established and set due to the cap and permitting system.
- Long-term storage projects in the 2016 Region L water plan account for 26% of the new water supplies over the next 50 years. The strategy is to store water captured during normal and wet years to withstand longer periods of drought.
- Edwards groundwater management strategies increase the firm yield of the Aquifer by over 62,000 acft/yr.
- The EAA may seek, but is not obligated, to enhance the firm yield of the Aquifer.

IV. REVIEW OF AQUIFER OPTIMIZATION STRATEGIES

The following ongoing and potential aquifer optimization strategies are provided for informational and comparison purposes. **Table 1** summarizes current EAA initiatives that contribute to optimization or protection of the Edwards Aquifer. As illustrated below, these storage and management strategies provide as much or more benefit to the aquifer than the existing recharge dams, especially during drought conditions.

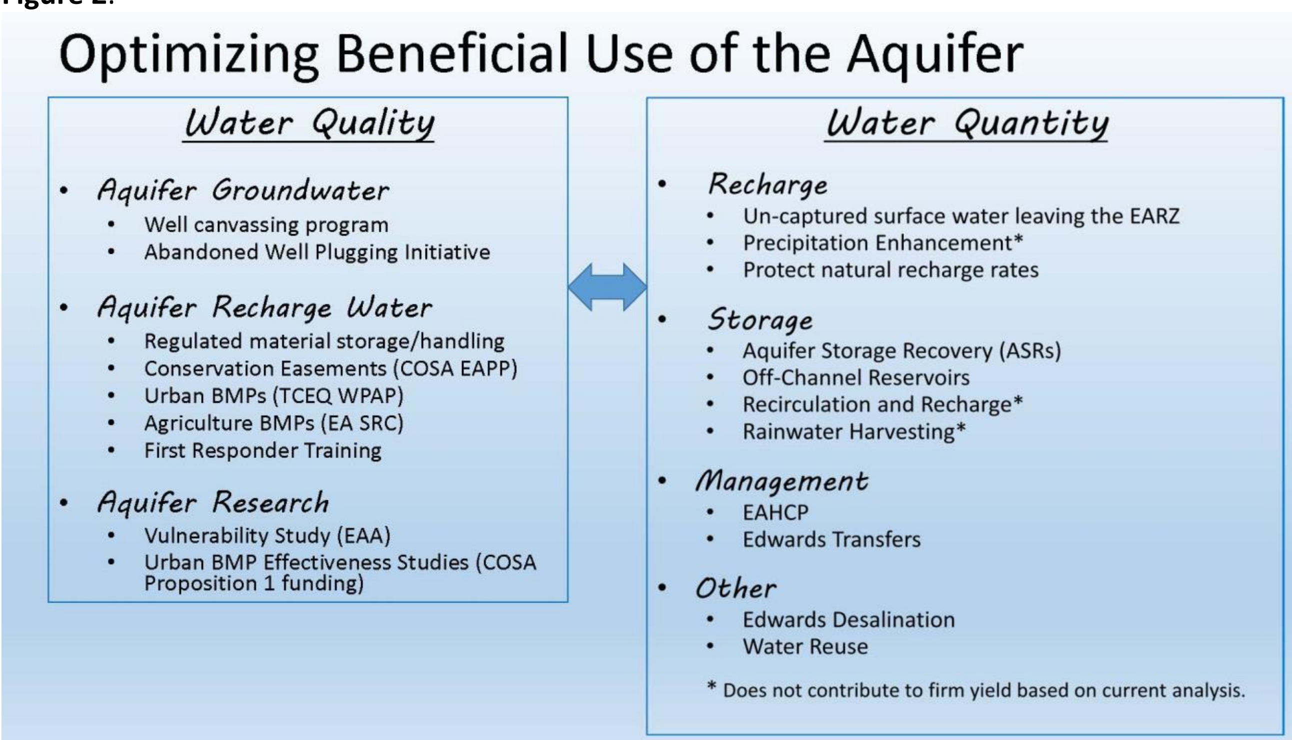
Table 1, Current Optimization and Protection Tools and Related Benefits

Optimization/Protection Tool	Benefit to Aquifer
The EAA Act	Staff estimates the Act effectively saved an average of 153,000 acft/yr of water from being pumped between 1997 and 2014. (*see The EAA Act a Success Story)*
San Antonio Water System (SAWS) ASR in conjunction with Edwards Aquifer Habitat Conservation Plan (EAHCP)	Approximately 80,000 acft of demand reduction distributed over a period of time during a critical drought scenario.
VISPO	40,000 acft of irrigation water use reduction during a critical drought scenario.
New Braunfels Utilities (NBU) ASR Pilot Study (EAA collaboration)	Goal to provide 7,000 acft of demand reduction in Comal Springs area during high demand periods or critical drought.

EAA Recharge Dams	3,300 acft/yr of enhanced recharge during average weather conditions; 200 acft/yr (estimated) during drought conditions.
Precipitation Enhancement	3,200 acft/yr of enhanced recharge during average weather conditions; unknown benefit during drought conditions.
City of San Antonio Edwards Aquifer Protection Program (EAPP)	Protecting natural recharge quantity and quality with 145,000 acres of conservation easements (program is still expanding).
EA SRC Program (see page 7)	Collaborative effort with Natural Resource Conservation Service (NRCS) to fund prioritized conservation activities within Edwards Aquifer system.
EAA Abandoned Well Program	Identification and risk prioritization of abandoned wells to protect water quality.

Figure 2 lists both current and potential aquifer optimization strategies into categories under the main topics of water quality protection and water quantity enhancement. This comprehensive list encompasses the current scope of the EAA "recharge" program.

Figure 2.



A. Water Quality Strategies

Water Quality Protection is essential to ensure the long-term sustainability of the Aquifer and faces increased challenges with increased development and population. The aquifer's rapid responses to runoff emphasize the importance of maintaining high water quality levels in recharge water since natural filtering and biological processes to reduce contaminants are limited at such high rates of recharge.

Groundwater Protection includes locating and assessing all Edwards wells and prioritizing a list of known abandoned wells for reducing potential risks to groundwater quality. Aquifer Recharge Water quality protection includes storage and handling requirements for regulated materials, assessing and monitoring conservation easements, improving the implementation and maintenance of rural and urban best management practices, and training First Responders to reduce potential Edwards Aquifer Recharge Zone (EARZ) impacts resulting from accidents and emergencies. Additionally, the Aquifer Research Team is obtaining data to better understand the water quality relationships between surface water and groundwater. The EAPP and Edwards Aquifer State Resource Concern (EA SRC) programs also protect natural recharge rates.

B. Water Quantity Strategies

While the EAA is not obligated to enhance the historical yield of the aquifer, the agency serves as a liaison and technical advisor to others that provide proposals for consideration. Proposals must be deemed legally and technically sound and sustainably beneficial e to the long-term health of the aquifer to be viable.

The following staff analysis is provided for informational purposes to explain the potential benefits and concerns of various aquifer yield enhancement strategies:

1. Recharge Dams

During average conditions, the enhanced recharge from the four EAA operated recharge dams adds 0.3 percent to annual natural recharge. Generally, recharge dams provide larger volumes of recharge in wet years when recharge is not critical and limited or no recharge during drought when needs are most critical.

Staff updated the comprehensive 1998 Trans-Texas Recharge Enhancement Feasibility Study to current costs and capacities at the April 25, 2017 Aquifer Management and Planning Committee. Based on the report and updated site information, the most feasible remaining project sites are in the Nueces River Basin; and include the Lower Frio, Lower Sabinal, Lower Hondo and Lower Verde projects, labeled as Package 2c in **Figure 3**. The graph in **Figure 3** summarizes updated capacities and costs of all proposed Trans-Texas projects. The criteria for project prioritization includes the anticipated benefit to spring flow and consumption in addition to the unit cost of enhanced recharge. Package 2c projects would require estimated annual expenditures of $12M at a cost of $1,413/acft/yr. These projects are estimated to add 6.4% (44,600 acft/yr) during average conditions, and 3.7% (8,500 acft/yr) during the Drought of Record (DOR), to natural recharge rates.

Recharge projects involving dams have significant levels of risk including project approval, project operation and economic viability. Obtaining approval to construct Package 2c projects is not certain and would require significant funding, years of environmental studies, and strong political will to meet regulatory requirements and overcome strong public and landowner opposition. Operational risks include the uncertainty of the volume of recharge available for capture during critical periods and how much of that recharged water would be physically available for withdrawals or spring flow when needed. Accelerated sediment loading of natural recharge features is also a concern. Economic viability risk includes the lack of certainty to receive administrative approval for additional withdrawals during drought conditions.

*2. **Additional System Storage***

The aquifer is more storage limited than recharge limited. That is to say that when the level of groundwater in the Aquifer is high, springflow rates increase significantly due to higher pressure in the system pushing more water through the Aquifer and out of the springs. On the other hand, efficient external storage projects such as ASRs or Off-Channel Reservoirs (OCRs) improve the firm yield of the aquifer by storing water outside of the aquifer when the rate of spring flow is very high and storing the water in locations where losses are significantly reduced. Therefore, this strategy could substantially increase the water available to supplement the Aquifer and therefore diminish demand during critical periods. As long as per capita consumption remains constant, more efficient storage will increase the firm yield of the system.

The chart in **Figure 4** shows the huge potential supply of water available for long-term storage using natural recharge rates and historical system demands. The chart shows 25-years of annual Groundwater Discharge by Use from the Aquifer and the historical mean and the minimum sustainable long-term springflows, as determined by the EAHCP. Flow that exceeds the average and minimum springflow rates, is a potential source of water for long-term system storage, whether extracted from a well or diverted from downstream surface water. Based on this assumption, the accumulated storage volume for the past 25 years is 3.1 million acft (springflow above historical mean) or 4.4 million acft (springflow above long-term minimum flow). For comparison, 2.5 million acft is a 10-year supply for the current municipal demand.

*a. **Established Long-Term Storage Strategies***

ASRs and OCRs are established long-term strategies that store large volumes of interruptible diversions/supplies more efficiently than the Aquifer when spring flowrates are high. As demonstrated by the SAWS ASR into the Carrizo, the sand aquifer is holding 100,000 acft of Edwards water in a relatively static location over the long-term that does not require treatment upon removal. The NBU ASR Pilot Study is expected to answer questions over the next several years regarding the feasibility of utilizing the saline portion of the Edwards Aquifer as an ASR. ASR projects listed in the 2016 Region L State Water Plan comprise 9% (67,355 acft/yr) of the additional water resources for the region over the next 50 years.

OCRs have less environmental impacts than in-channel reservoirs. OCRs can be designed to accept large rates of flow such as scalping peak stormwater flows from a river but treatment of stored water is required before potable use. OCR projects listed in the 2016 Region L State Water Plan comprise 16% (93,800 acft/yr) of the additional water resources for the region over the next 50 years.

b. ***Conceptual Long-Term Storage Strategies***

Recharge & Recirculation (R&R) and Rainwater Harvesting are not considered established storage strategies, but are considered conceptual long-term storage strategies because their contributions to firm yield have not been established. The 2008 Todd R&R study did not find a benefit to the firm yield of the aquifer. Concerns related to R&R are uncertainties in modeling and the residence time of water in the aquifer. Rainwater harvesting is an effective storage strategy for individual properties to reduce water consumption during average weather conditions. However, the strategy does not have the storage volume or certainty of operation in a watershed scale application to impact the firm yield of the aquifer.

Figure 3.

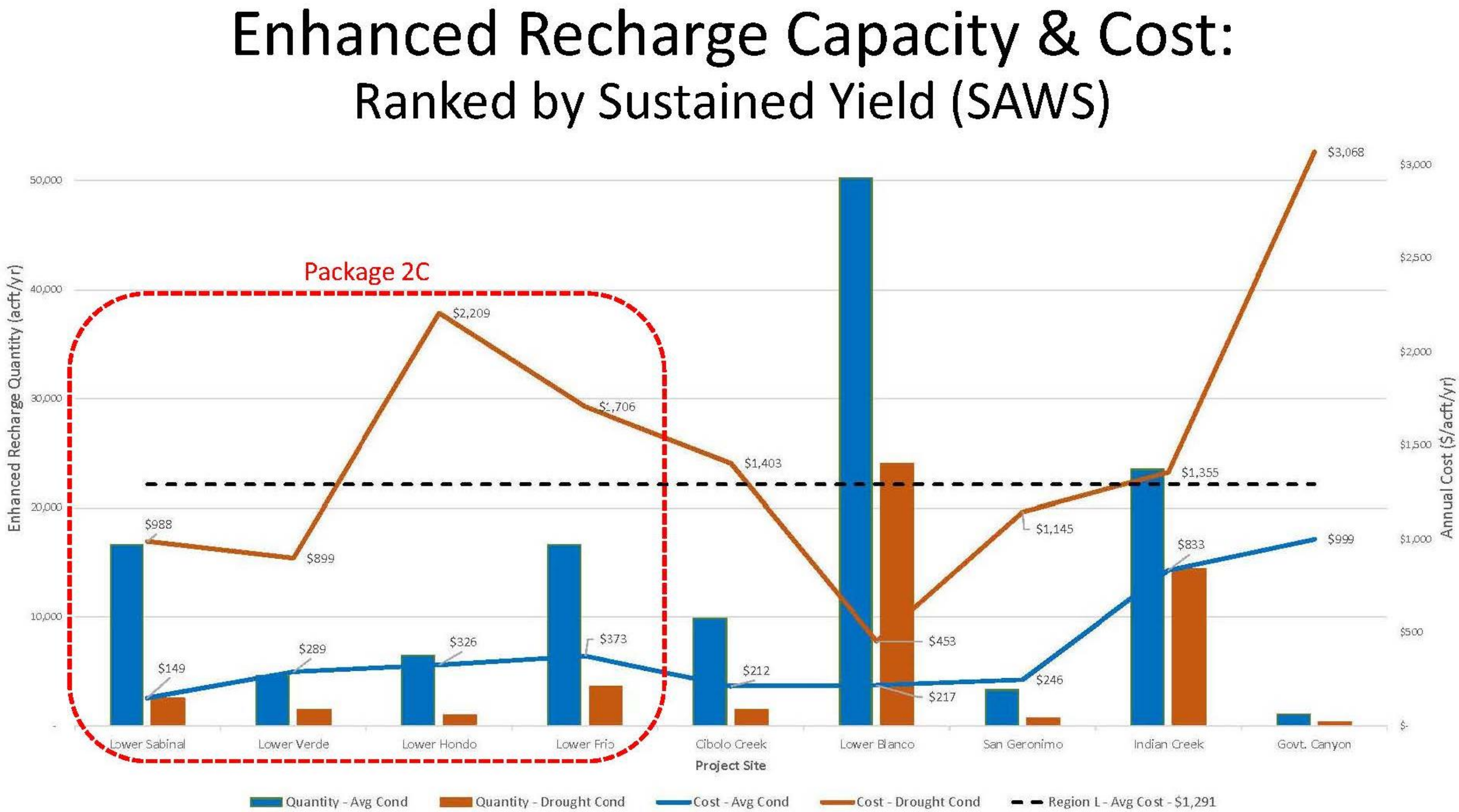
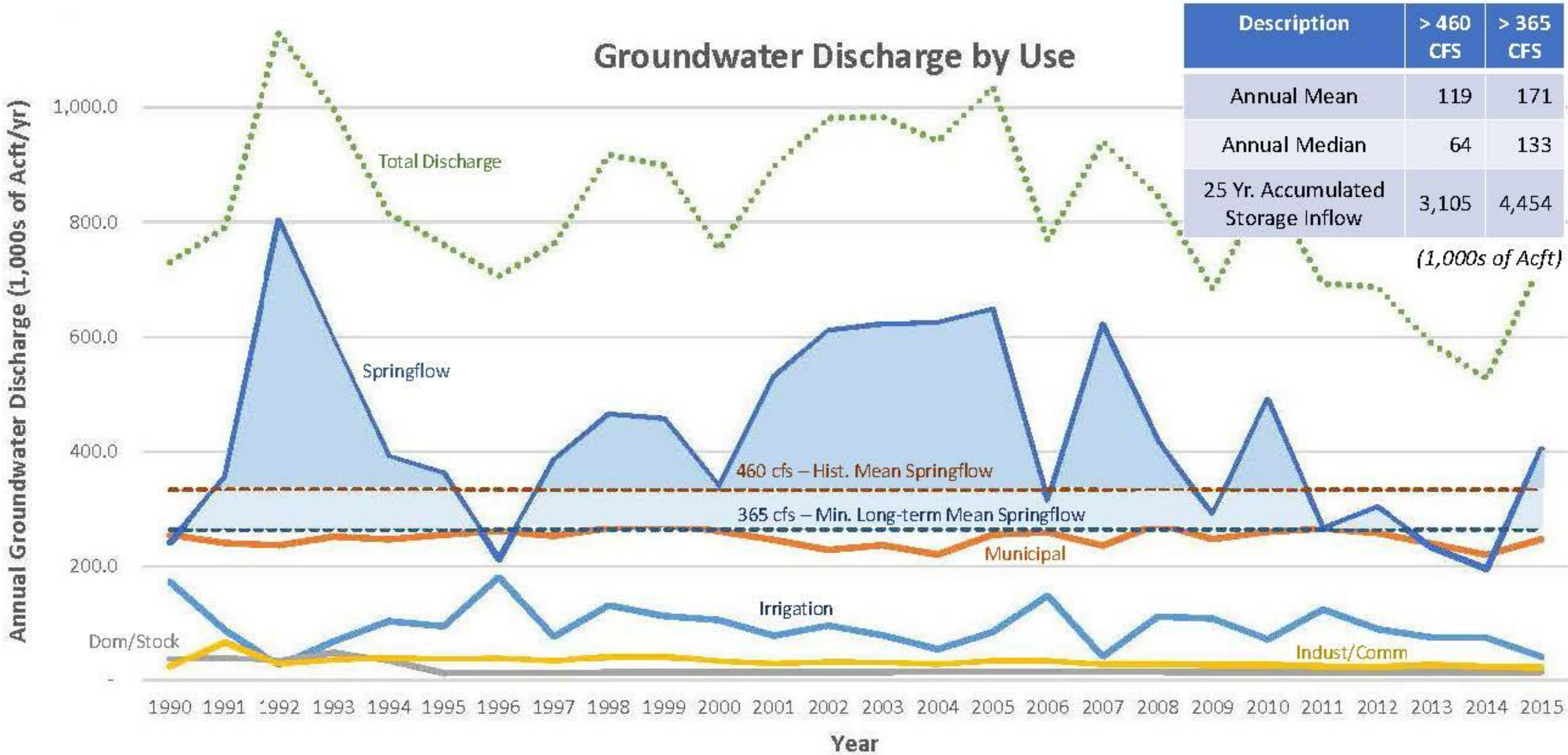

Enhanced Recharge Capacity & Cost:
Ranked by Sustained Yield (SAWS)
Package 2C
Enhanced Recharge Quantity (acft/yr)
Annual Cost ($/acft/yr)
50,000
40,000
30,000
20,000
10,000
-
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$-
$988
$899
$2,209
$1,706
$1,403
$453
$1,145
$1,355
$3,068
$149
$289
$326
$373
$212
$217
$246
$833
$999
Lower Sabinal
Lower Verde
Lower Hondo
Lower Frio
Cibolo Creek
Lower Blanco
San Geronimo
Indian Creek
Govt. Canyon
Project Site
Quantity - Avg Cond
Quantity - Drought Cond
Cost - Avg Cond
Cost - Drought Cond
Region L - Avg Cost - $1,291

Figure 4.

Quantifying “Additional” Supply for Potential Storage



Description	> 460 CFS	> 365 CFS
Annual Mean	119	171
Annual Median	64	133
25 Yr. Accumulated Storage Inflow	3,105	4,454

(1,000s of Acft)

3. Groundwater Management Strategies

The EAA Act has helped to dramatically reduce trends of Aquifer demands and spur efficient use of water by capping withdrawals, issuing permits and providing critical period conservation measures. Reducing demand on the aquifer during critical periods is equally effective to increasing supply. Using Region L criteria, the EAHCP conservation measures (VISPO, Regional Conservation, SAWS ASR, Stage V) add 50,600 acft/yr to the firm yield of the Aquifer at a cost of $345/acft/yr. Note that the SAWS ASR is a storage strategy that is classified as a groundwater management strategy in this scenario. Edwards transfers are trades of groundwater rights initially permitted for irrigation use that have been converted to non-agriculture. These transfers are projected to add 12,000 acft/yr of firm yield for municipal supply by year 2070 at a cost of $1,415/acft/yr.

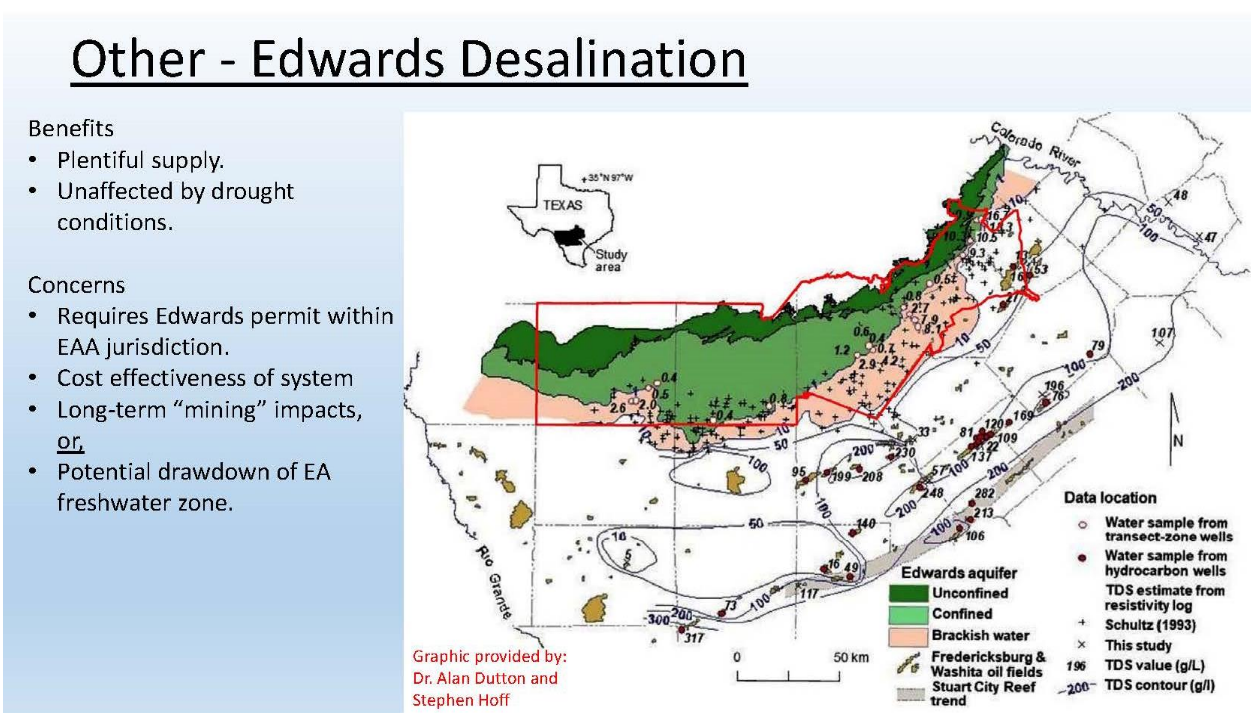
4. Other Strategies to Increase Firm Yield

The following firm yield water supply strategies are indirectly related to the freshwater zone of the Aquifer.

*a. **Edwards Desalination***

The saline Edwards portion of the aquifer as show in **Figure 5**, has a large volume of water, with TDS concentrations ranging from 500 to 10,000 ppm, that can be treated or blended for use. Withdrawals within EAA jurisdiction require a permit while areas outside of EAA jurisdiction are not regulated. A potential benefit of this strategy is the large volume of water available to contribute to firm yield when needed.

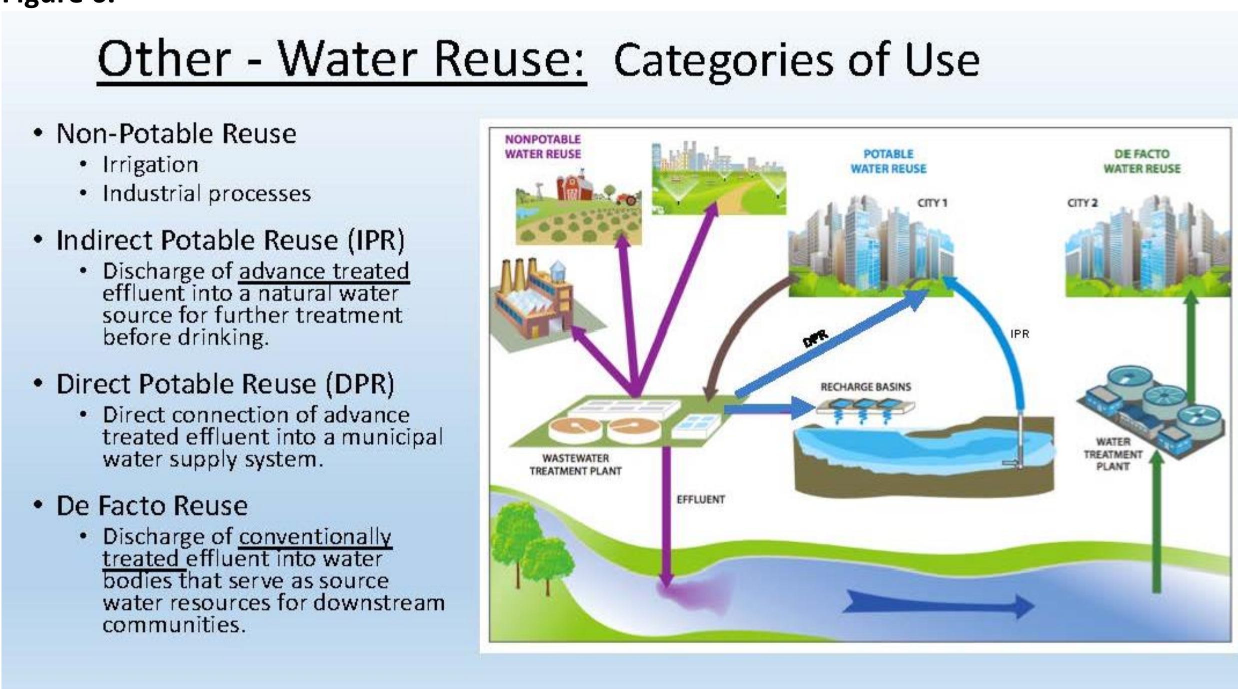
Figure 5.



b. ***Water Reuse***

As a result of advances in technology and increasing water demands of a growing regional population, sewage treatment plant effluent continues to gain more acceptance as a valuable resource instead of a waste product. In addition to non-potable reuse, advanced treatment of wastewater effluent for direct and indirect potable reuse is currently implemented in Texas. Potable reuse has sustainable benefits of reducing pollutant loading while providing a reliable source of water in times of drought that increases with population growth. De Facto reuse of conventionally treated wastewater is becoming commonplace as streams and rivers become dominated by effluent contributions. Continued population growth may eventually cause State regulations to increase the treatment standards of all discharge permits in urbanized areas. Water reuse categories are defined in **Figure 6**.

Figure 6.



V. CONCLUSIONS

Recharge is defined in the EAA Act as: *Increasing the supply of water to the aquifer by naturally occurring channels or artificial means*. Based on this definition, the EAA recharge program previously consisted of four recharge dams initially sponsored by the EUWD and Medina County Commissioners Court until calendar year 2004, when participation in the regional Precipitation Enhancement Program (PEP) was added to the program.

As shown in **Figure 2**, the EAA Recharge Program has evolved to include a comprehensive set of aquifer optimization and protection strategies. Protection strategies include enforcing EAA Act regulations, monitoring Edwards Aquifer Protection Programs (easements and stormwater basins) sponsoring the EA SRC, canvassing and assessing wells, and conducting water quality research. Management strategies resulting from the EAA Act, such as the EAHCP and Edwards transfers make the use of existing water resources more efficient. Storage strategies, such as the SAWS ASR, are an effective tool to supplement pumping demands during critical periods. These "non-recharge" optimization strategies combined with protective measures that address equally important water quality components add to the long-term sustainability of the aquifer system. In **Figures 7a-b**, the benefits of current aquifer optimization and protection strategies are summarized and quantified, where possible.

In addition to listed existing activities, EAA staff collaborates with regional entities and reviews the technical and legal merit of proposed projects to increase the firm yield of the aquifer. In the future, part of that collaboration could include hosting a workshop to bring regional planners, managers, purveyors, and scientists together to share thoughts regarding new optimization strategies. Although, hosting this type of event would require staff resources and funding to accomplish, it may provide a valuable forum for sharing optimization strategies between interested parties.

Note: EAA resources required to review project proposals can be a significant investment due to the complexity of issues and length of time involved. Based on past performance, staff believe that resources are adequate to continue this process without impacting our management fee. This could change, however, if the number or complexity of proposed projects increase.

VI. STAFF RECOMMENDATIONS

Staff recommends re-conceptualizing the EAA "Recharge Program" into a more comprehensive optimization and protection program that takes into account historical efforts to enhance recharge, but that also includes new technologies and known Aquifer hydraulics to enable exploration of ways to further maximize firm yield of the Aquifer for beneficial use while also protecting historic recharge and water quality. Specifically, staff recommends the following actions moving forward:

<u>Water Quantity Enhancement</u>

- Continue to maintain the existing recharge structures and pursue permit amendments that more accurately account for the range of enhanced recharge that occurs when these structures operate.
- Do not pursue the design, construction or operation of any additional recharge structures due to the risks and minimal contributions to firm yield when compared to other strategies.

- Continue to participate in the PEP to achieve demand reductions and additional recharge in affected areas.
- Continue to monitor the science behind measuring the benefits of the PEP program during average and drought conditions to further analyze benefits associated with this developing methodology.
- Encourage development of, but do not pursue lead sponsorship responsibilities of ASR or OCR projects.

Water Quality Protection

- Continue participation in the City of San Antonio and Texas Commission on Environmental Quality Edwards Aquifer Protection Programs and NRCS State Resource Concern Program to bolster stewardship and maintenance of natural recharge rates and water quality.
- Continue to refine existing regulatory and science programs and studies such that both programs are better informed, benefiting stakeholders and the aquifer.
- Continue to pursue research that will inform the optimization and protection process, in hopes of providing more certainty for the future.

Regional Collaboration

- Continue to demonstrate the value and benefits of the EAA Act to the public and stakeholders so support for Act related measures grows.
- Continue to support and demonstrate the value and benefits of the EAHCP and related management and conservation strategies to achieve targeted water levels and springflows during critical drought scenarios.
- Continue to facilitate regional collaboration as a liaison to water supply projects sponsored by others (for example, the NBU ASR pilot project).
- Develop and facilitate an annual or biennial workshop to bring regional stakeholders together to explore new technologies for increasing firm yields (ASR, desalinization, OCR) and protecting water quality.

Figure 7a.

Water Quantity Optimization Summary	Contributions: Average Conditions	Contributions: Drought Conditions (Firm Yield)	Status
I. Management Strategies **A. EAA Act** **(Cap on groundwater withdrawals, permit system)** **(Stage 1-4, critical period/drought management)** **Savings based on forward modeling of anticipated increased Edwards Aquifer demand resulting from population growth in region from 1997-2014, if Act were not in place.*	153,000 acft/yr* (on average 1997-2014)	Increases certainty of maintaining water levels and spring flows during drought (historical yield)	In Progress
B. Edwards Aquifer Habitat Conservation Plan (EAHCP) **-VISPO 40,000 acft** (applies in severe drought scenario) **-Regional Conservation 10,000 acft** **-SAWS ASR (storage strategy) 80,000 acft** (HCP-related storage by 2018) **-Stage 5, Critical Period Measure, additional 5-percent permit reductions**		Estimated 50,600 acft/yr of firm yield during severe drought (Region L estimate)	In Progress
C. Permit Transfers		12,000 acft/yr (by 2070)	In Progress
II. Recharge Strategies **A. Existing EAA Recharge Dams**	3,300 acft/yr	200 acft/yr	In Progress
B. Existing NRCS Dams on Recharge Zone	14,162 acft/yr	4,928 acft/yr	In Progress
C. Package 2c Recharge Dams	44,600 acft/yr	8,500 acft/yr	Not Recommended
III. Storage Strategies **A. NBU ASR (Proposed)**	7,000 acft	Unknown	To be determined
IV. Protecting Natural Recharge Rate *Based on recharge for Period of Record (1934-2016)*	700,000 acft/yr	229,000 acft/yr	In Progress

Figure 7b.

Water Protection Summary	Contribution	Status
I. Maintaining Natural Recharge and Water Quality		
A. Edwards Aquifer Protection Program, Conservation Easements	145,000 acres of protected lands (expected to increase by 15-20% by 2022)	In Progress
B. State Resource Concern with NRCS	Funding source for conservation and water quality on agricultural properties	In Progress
II. Maintaining Water Quality		
A. Well Canvassing Program	ID wells, assign water quality risk to abandoned wells	In Progress
B. Vulnerability Assessment Study	Develop science to assess impacts to groundwater that emanate from surface waters, in karst setting	In Progress
III. New Strategies for Existing Programs		
A. Amended Water Quality Rules *(Program under development)*	Holistic approach, combining regulatory and science teams to achieve greater effectiveness through: -Information sharing -Training to prevent pollution -Database development combining spill, karst features, wells, and water chemistry data to help inform sampling and improve understanding of the system	In Progress Under Development/ Refinement

APPENDIX

Technical Briefing, March 14, 2017: ***The EAA Recharge Program***

- Purpose of the Recharge Program
- The EAA Recharge Program – 1997
- Recharge as a Component of Optimization – Program Evolution
- The Edwards Aquifer and Karst Hydraulics
- Can we Make Enhanced Recharge more Effective?
- EAA Science Program Contributions
- Conclusions
- Future Discussions
- Handout: *The EAA Act: A Success Story*

AMP Committee, March 28, 2017: **EAA' Role in Region-Wide Water Planning**

- Overview of EAA Water Planning History
- Region L Planning Criteria
- Region L – Summary of Proposed Water Supply Projects
- Edwards Groundwater Management Strategies
- Trends in Region-wide water planning
- Future Management Considerations

AMP Committee, April 25, 2017: **Updating Recharge Enhancement Feasibility Studies – Capacities, Costs, & Risks**

- Definitions and Evaluation Criteria
- Updated Costs and Capacities of Recharge Projects
- Proposed Project Site Updates
- Contributions of Existing Dams in the EARZ
- Project Sponsorship Responsibilities
- Conclusions – Understanding Risk Analysis

AMP Committee, June 27, 2017: **Alternative Strategies to Maximize Beneficial Use of the Aquifer**

- Quantifying Benefits of Long-Term Storage
- Long-Term Storage Strategies
- Edwards Desalination and Water Reuse Strategies
- Water Quality Protection Strategies
- Recommended Program Priorities

Technical Briefing, July 11, 2017: ***Re-conceptualizing the EAA Recharge Program for Optimizing and Protecting the Beneficial Use of the Edwards Aquifer***

- Physical Characteristics of the Edwards Aquifer
- History and Evolution of the Recharge Program
- Status of Region-wide Water Planning
- Aquifer Optimization Strategies
- Staff Recommendations