Alternative Water Supplies for the Barton Springs Segment of the Edwards Aquifer and for the Region

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1.0 Background and Purpose

The Barton Springs/Edwards Aquifer Conservation District (District) is working within its statutory authority and regulatory purview to find ways to reduce dependence on the Barton Springs segment of the Edwards Aquifer. This white paper identifies additional sources of water for the area that should be further evaluated as to their efficacy for replacing some of the historically permitted Edwards water to such other alternative sources, while at the same time likely providing additional water for the region (Figure 1). Potential sources include: the Edwards saline zone for desalination and aquifer storage and recovery (ASR), Middle and Lower Trinity Aquifers, ASR in the Middle and Lower Trinity Aquifers, surface water, groundwater from outside the District (e.g., Carrizo-Wilcox), reclaimed wastewater, rainwater harvesting, natural recharge enhancement, recharge enhancement with externally sourced water, and weather modification. Some of these alternative sources are beyond the authority or other capability of the District to promote directly.

The need for considering such alternatives derives from statutory requirements and the District's regulatory program to implement those requirements.. Maximum pumping rates that are currently authorized under permits during extreme drought conditions may not allow for sufficient flow at Barton Springs to ensure the survival of the endangered salamanders that live in the four spring outlets, nor to minimize the impacts to pumping wells due to low water levels. To bridge the gap between the Desired Future Conditions (DFC) of 6.5 cfs of flow during an extreme drought and the predicted amount of flow based on the Extreme Drought Withdrawal Limit (EDWL), other sources of water need to be made available so that the amount of pumpage from the freshwater Edwards by District permittees can be reduced further. With a required reduction in pumping during an Emergency Response Period (ERP) of 50%, flow from Barton Springs will still likely be smaller than the DFC; therefore, other sources of water will be needed to replace some of the fresh Edwards groundwater, as well as to enable the 50% curtailments for some permittees.

The alternative source of water most likely to produce a substantial quantity of "new" water from the District is the saline zone of the Edwards Aquifer. The Middle and Lower Trinity Aquifers are also alternative sources of interest, both as a direct replacement and additional supply in the western part of the District and as a supply of brackish water in the eastern part of the District. These sources are in the District's regulatory sphere within its geographic jurisdiction. Groundwater in the saline Edwards is considered to be brackish with total dissolved solids (TDS) values between 1,000 and 15,000 milligrams per liter (mg/L). The Trinity Aquifers range from freshwater to the west to increasingly more brackish to the east. Desalination technologies have advanced considerably in recent years, and in many areas the cost of desalinated water is becoming cost-competitive on an as-delivered basis with additional traditional water sources. The Edwards saline zone and the Middle and Lower Trinity Aquifers could also serve as reservoirs for fresh Edwards groundwater that could be retrieved during periods of drought. Such systems are known as aquifer storage and recovery (ASR).

As part of this process of evaluating alternative sources of water, the District intends to form an *ad hoc* Stakeholder Advisory Committee (SAC) to review and comment on this document. A Board work session is recommended to be held in early February 2013 to provide input that will guide future Board actions regarding alternative sources of water.

1.1 Necessity of Alternative Sources of Water

The sustainable yield studies conducted by the District (BSEACD, 2004) have demonstrated the need for a reduction in pumpage from the Barton Springs segment of the Edwards Aquifer during periods of extreme drought to protect water wells from going dry and to maintain the quantity and quality of flow at Barton Springs for endangered species and for recreational purposes. Studies for the Habitat Conservation Plan (HCP) grant (BSEACD, 2007; and in preparation) have further demonstrated the need for alternative sources of water. The District's conditional permitting policies have addressed the limitations on the amount of additional water that can be pumped from the freshwater Edwards. Large amounts of water will be needed for growth that is expected in the District, particularly in the southeastern portion along IH 35, SH 45 Southeast, and SH 130. With limitations placed on the amount of Edwards water that can be pumped, other sources will be needed to supply these developments.

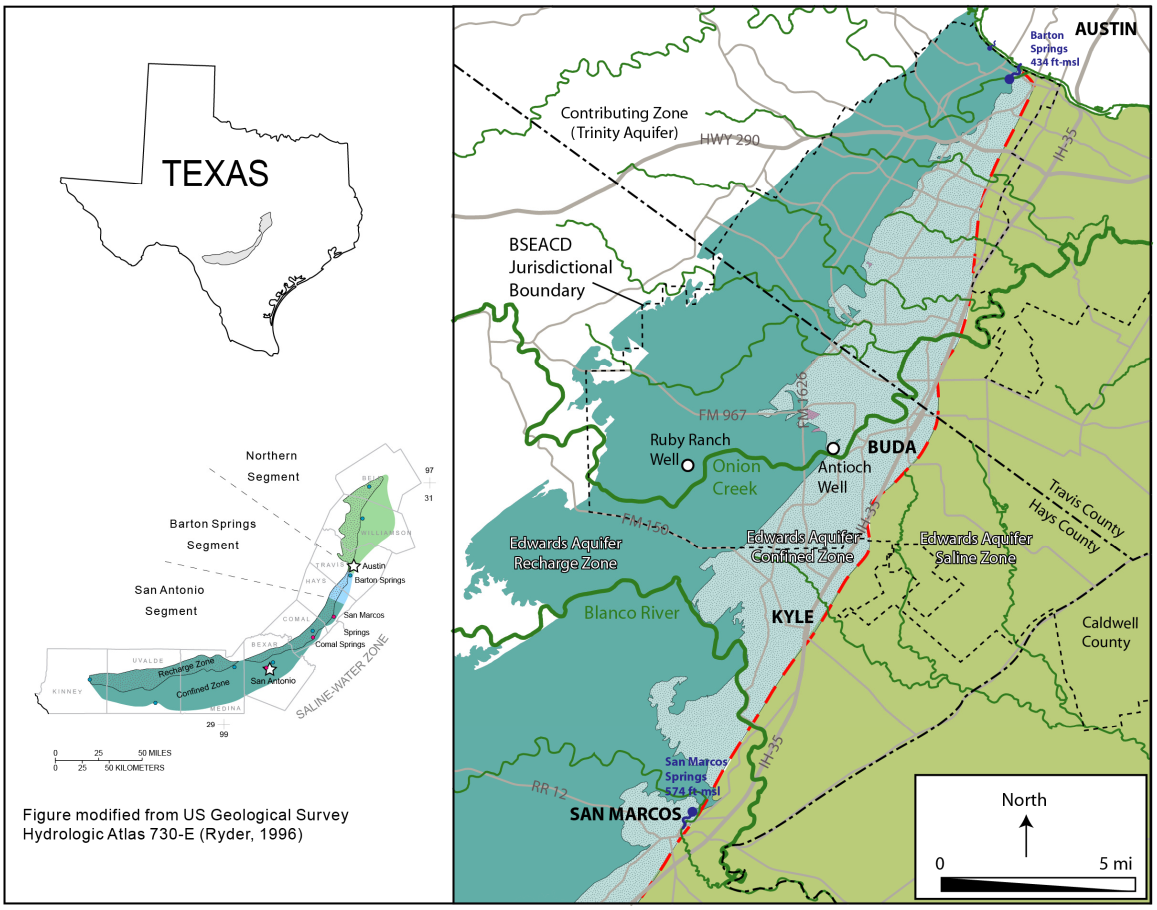

Figure 1. Location map of the part of the Edwards Aquifer of interest, its hydrologic zones, and the District's jurisdictional boundaries (dotted lines)

With additional regional supplies available and within an appropriate regulatory setting, current historical-use groundwater permittees and their end-users may be willing to switch to other, less constrained sources during periods of extreme drought or to forego some portion of their permitted amount of groundwater. A decrease in the quantity of permitted historical groundwater will lead to increased flows at Barton Springs and increased water levels during periods of extreme drought.

2.0 Potential Alternative Sources of Water

There are a number of alternative sources of water available with or near the District. However, each one has limitations for groundwater users. Some of these limitations are costs, regulatory issues, distance between the source and the users, and technical implementation. And some will only yield small amounts of water. Further, the District *per se* is restricted in its ability to mandate and/or otherwise make available the use of some of these sources. A brief summary of each alternative is listed below.

- Edwards saline zone- Desalination of saline groundwater in the Edwards saline zone has the potential to provide substantial water for the area.
- Edwards saline zone- Aquifer storage and recovery (ASR) could provide a means of storing excess groundwater or surface water in the Edwards saline zone for use during periods of extreme drought.
- Middle and Lower Trinity Aquifers- Available and currently being used in western parts of District, but wells are more costly because of depth and protective well construction, and yields are considerably less that the Edwards and water quality is poorer.
- ASR in the Middle and Lower Trinity Aquifers- Under wet conditions when there is "excess" Edwards water, the Middle and Lower Trinity Aquifers could be used to store this water as an ASR system (Figure 2). If successful, it could provide additional water that could increase the MAG for the Trinity Aquifers. Has similar issues to direct use of such aquifers as reported above.
- Surface water- Currently providing water to users within the District, but because the nearby surface water sources are also oversubscribed, it is not likely that this will provide any significant additional water for this area, especially for those not already using such sources.
- "Outside the District" groundwater (e.g., Carrizo-Wilcox)- Currently being developed as a source of water along the IH-35 corridor, but is not yet available to users within the District. Long-distance water transport cost will be expensive. Water chemistry differences may inhibit ability for blending with water from other sources without further treatment
- Reclaimed wastewater- Could be a viable alternative source with sufficient treatment that satisfies stringent quality standards, careful site characterization, and best management practices to reduce risk of water quality degradation. Indirect and direct potable re-use of wastewater could serve as a substitute or incremental supply, for either direct use in the generating area or as additional recharge. Use of treated wastewater for residential and common-area lawn irrigation can reduce largest single use of groundwater in District.. Some acceptability barriers exist, and some regulatory mechanisms are missing.
- Rainwater harvesting- Could eventually be a significant component of the area's water supply using individual or community-scale systems, but start-up costs are high and it is not extreme-drought proof,
- Natural recharge enhancement- This is being done at Antioch Cave on Onion Creek, but during extreme drought there is no water available for recharging

unless surface impoundments are built. Impoundments would be very costly and it would difficult to obtain sufficient land.

- Recharge enhancement with externally sourced water- Water from the Colorado River could be diverted to Barton or Onion Creeks to provide recharge to the aquifer. This would be costly and water rights would need to be obtained; moreover, the diversions would be subject to legal riparian interception before the water reached the recharge zone. Most of diverted water in Barton Creek would discharge at Cold Springs, and therefore not provide much benefit to Barton Springs. Diversions to Onion Creek would benefit Barton Springs, but would be even more costly and would be subject to more riparian interception.
- Weather modification- Cloud seeding, but the benefit, if any, is not likely to be able to be targeted in the small area where benefit to the Barton Springs aquifer would be obtained. It is considered impractical in this setting.

Only the first three of these alternatives will be addressed in this document, as provision of these sources will likely require some District involvement and oversight. Moreover, these sources also might represent the best opportunity for providing appreciable amounts of additional regional water supply beyond the amount required for achieving and maintaining the Extreme Drought DFC of the Edwards. The other sources are largely decisions and commitments made by individual water supply providers and/or individual well owners, without much impetus or approval from the District required. Some of these other alternatives are already being pursued or considered and will possibly develop further in the near future, while others will not likely to be significant contributors until the economics of water supply in the area change significantly. Conservation measures are not considered to be alternative *sources* of water in the context of this paper, but they are and are expected to continue to be a major component of the District's efforts to reduce pumping from the freshwater Edwards.

With a required 50% reduction in pumping during an ERP, the District is very close to reaching the current MAG. However, additional sources of water are needed to reduce the amount of pumping during an ERP so that the probability of negative impacts from severe drought can be reduced considerably, and so that compliance with ERP curtailments in the future is more readily achieved. Regardless of sources employed and of how much additional water might or might not be provided, the District's involvement in alternative water supplies derives from and is authorized by this statutory need to assure compliance with its applicable DFCs.

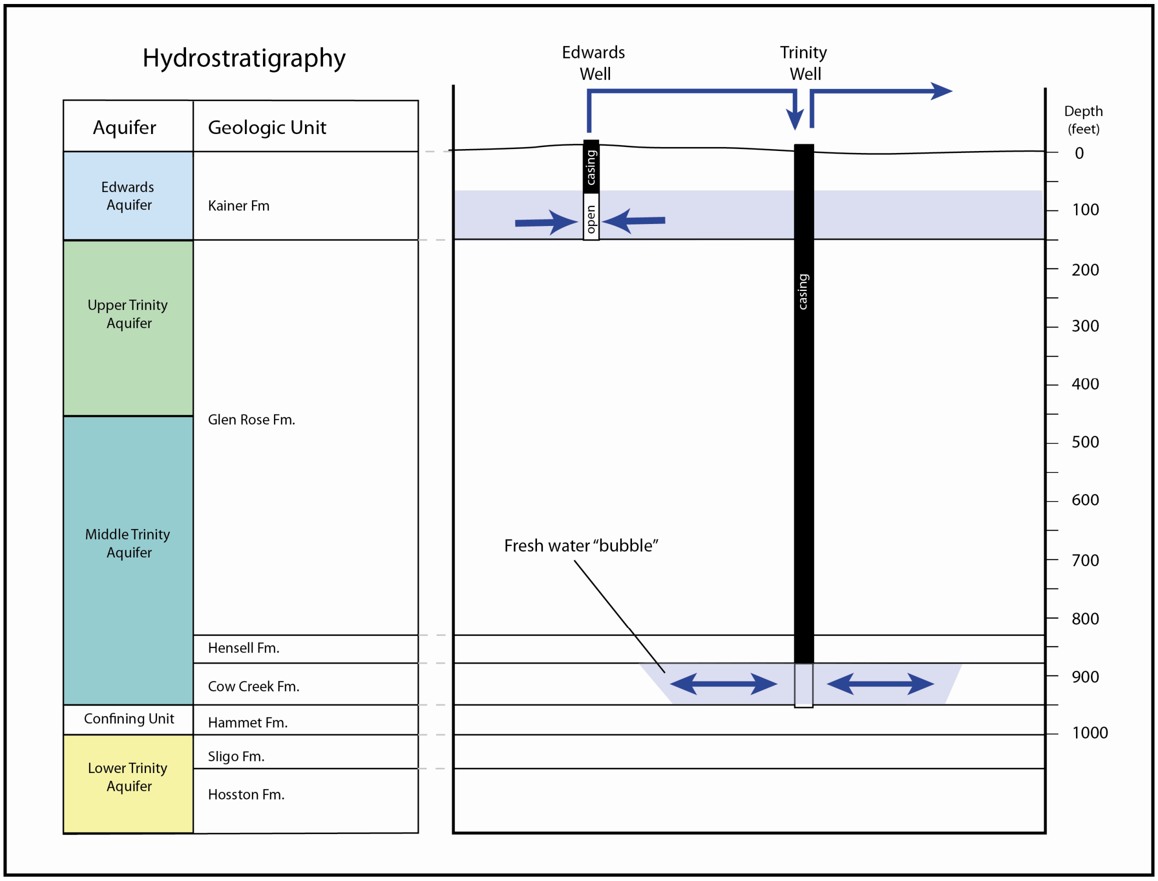

Figure 2. Edwards Aquifer to Middle Trinity aquifer storage and recovery scenario.

3.0 Providing Other Water Supplies for BSEACD Historical Users

This section discusses the role and potential for the Edwards saline zone (and analogously, the brackish Middle and Lower Trinity Aquifers underlying the Edwards) to be used for replacement supplies to the District's firm-yield users and for additional supplies for other water users in the region. Desalination of brackish and saline water is a proven and widely used technology. Aquifer storage and recovery systems are common throughout the world, and many of these use brackish-water aquifers as the storage host. The Middle and Lower Trinity Aquifers in the District, in addition to their use directly as water sources, could also be employed as part of an ASR system that uses unaltered freshwater Edwards water as a stored water in either freshwater or brackish portions of the Trinity host, or even as a source for a desalination facility.

3.1 The Saline Zone

3.1.1 Background on Use of the Edwards Saline Zone

The Edwards saline zone has often been mentioned as a source of water for desalination or ASR, but because of limitations in the Edwards Aquifer Authority's jurisdictional area on use of the Edwards regardless of whether the water if fresh or saline, the resource was not considered by the large water suppliers such as SAWS and Bexar Metropolitan Water District. These limitations do not apply in the Barton Springs area, but with limited financial resources of both the District and the local water purveyors and with Austin Water Utility's being dependent exclusively on surface water, little has been done to study the potential for use of the Edwards saline zone. There is no current beneficial use of the Edwards saline zone in the District, other than negligible incidental/accidental use.

3.1.2 Hydrogeology of the Saline Zone and the Saline/Freshwater Interface

Hydrogeologic characteristics of the saline zone and the saline/freshwater interface of the Edwards Aquifer have been studied for some time. Maps and cross sections have been generated that indicate the salinity of Edwards groundwater east and west of the saline/freshwater interface (Flores 1990; SWRI, 2003; LBG-Guyton, 2003; Brune and Duffin, 1983; Baker, et al., 1986) (Figure 1). Some fairly detailed delineation of the saline zone in the San Antonio area has been done by Shultz (1993).

San Antonio Water System (SAWS), in partnership with the U.S. Geological Survey (USGS), has installed about 20 monitor wells across the saline/freshwater interface to provide "conclusive" data about possible movement of the "bad water line" (Waugh, 2005). These wells have been installed from as far north as Kyle to as far west as Uvalde (Lambert, 2009). An additional 16 wells will be installed as part of this program. The drilling and installation part of the study is expected to last about 15 years with long-term monitoring over a 50-year period.

Lithologies of Edwards units east of the saline/freshwater interface are similar to the lithologies to the west. All of these sediments were deposited on a broad, shallow, carbonate shelf. The main difference between Edwards units on either side of the saline/freshwater interface is the degree of dissolution of the rocks and the amount of void space created by dissolution. Flux of fresh water has been high in the portion of the aquifer between the recharge zone and Barton Springs. This flow of slightly acidic water has dissolved a considerable amount of limestone and dolomite along faults, fractures, bedding planes, and even within the matrix. Significant conduits have developed along some of these zones that facilitate flow of even greater quantities of water. To the east of this zone of high flux, the amount of water flowing through the rock is less and therefore less dissolution takes place. However, there is some dissolution, but the minerals that are dissolved from the rock are not carried away from the zone of dissolution as quickly as the area to the west, and therefore concentrations of dissolved minerals increase and the water is then considered to be saline or brackish.

Another factor that has contributed to the isolation of the saline zone from the freshwater zone is faulting that has offset similar units by tens to hundreds of feet, with the units on the eastern side of the faults mostly being down-dropped relative to the western side. The combination of horizontal separation from the main flow paths and vertical faulting has limited flow in the saline zone such that salinities increase to the east of the saline/freshwater interface.

One theory that has been proposed to explain the high salinity of the saline zone is that the mineral constituents are from the original formation water from the time of deposition. Another theory suggests that saline fluids from deeper in the basin have migrated into this area and have dissolved portions of the rock due to mixing of fluids. Zones of caves and karst have developed by this mechanism in some parts of the world (Klimchouk, 2007; George Veni, personal communication), but studies have not been conducted to prove or disprove the theory in the Edwards. The chemistry of some parts of the saline Edwards is sodium-sulfate water, which indicates that the dissolved constituents are from dissolution of the host rock, rather than primary formation fluids.

3.2 Desalination

3.2.1 Overview of Desalination Technologies

Desalination is the process of removing dissolved solids from water. The most common techniques for desalination are distillation and membrane processes. About half of the world's desalination facilities are based on distillation (TWDB, 2004). The two most common membrane-based technologies are electro-dialysis reversal (EDR) and reverse osmosis (RO). EDR uses an electric current and a semi-permeable membrane to separate the dissolved solids from the water. This technique is most effective for TDS values of 3,000 mg/L or lower. RO processes use high pressure to drive water through a semi-permeable membrane that leaves most of the dissolved solids on the high pressure side of the membrane. RO is commonly used for waters with TDS values greater than 3,000 mg/L. Another technique that works well with high-TDS source water is enhanced vapor extraction, although this technique has had very limited use with groundwater. All of these techniques produce a highly concentrated by-product that can require costly disposal. Desalination plants near oceans or other bodies of saline water can discharge this concentrate directly into the saline surface water. In arid climates, evaporation ponds might be cost effective if land costs are low. In other areas, deep-well injection might be the only option. One technique that does not require disposal of a concentrate liquid is zero-liquid discharge technology. This technique uses high heat to turn the total dissolved solids in the water into solids that are either incinerated or disposed as a solid waste, or stored for later recovery of valuable chemical components. All of the techniques mentioned above require high amounts of energy. TWDB (2004) estimates that one-third of the operational costs of a desalination plant are for power.

3.2.2 Desalination in Texas

There are an estimated 2.7 billion acre-feet of brackish groundwater in Texas (LBG-Guyton 2003). Brackish water aquifers vary from coastal aquifers to bolsons (alluvial basins) in West Texas to aquifers like the Edwards that have high TDS values due to low circulation and long residence time of the groundwater. Desalination of saline water is not new to Texas. The Texas Commission on Environmental Quality (TCEQ) estimates that there were 101 permitted desalination facilities in Texas in 2003 (TWDB, 2004). The sources of water and the purposes of the plants are quite varied. A number of these plants treat saline groundwater for municipal and industrial purposes. TWDB (2004) lists 12 membrane plants sourced from groundwater with capacities greater than 0.025 million gallons per day (MGD) that were built before 2003. The largest of these plants has a capacity of 3 MGD. All of these plants discharge concentrate to either surface waters or evaporation ponds.

In a more recent study (TWDB, 2006), TWDB estimated that the state has a desalination capacity of about 50 MGD from public water supply (PWS) entities. This includes both groundwater and surface water. The capacity of non-PWS desalination facilities is between 50 to 100 MGD (Figure 6b).

Since 2003, some notable advances have been made with planning or construction of desalination plants in Texas. Groundbreaking took place on August 31, 2005 in El Paso for a 27.5 MGD RO desalination plant that cost about $87 million. The plant officially began operation on August 8, 2007. Water from this plant is being used for the City of El Paso and the Fort Bliss Army Base. When operated at full capacity, this will be the country's largest inland desalination facility. Groundwater to supply the plant comes from the saline portion of the Hueco Bolson Aquifer. Concentrate from the plant is injected into three wells 20 miles northeast of the plant site. Total depths of the wells are about 4,000 ft where the concentrate is injected into bedrock of Ordovician age. At full capacity, 18.5 MGD of saline water will be run through the RO system (Hutchison, 2007). About 3 MGD of concentrate will be generated and the 15.5 MGD of treated water will be blended with 12 MGD of groundwater from the freshwater portion of the Hueco Bolson Aquifer.

Costs of the El Paso plant are divided into: production wells and collectors ($30 million); RO plant and near plant pipes ($40 million); and concentrate disposal ($17 million). Annual operation and maintenance (O&M) is estimated to be about $4.8 million. About 5% of annual O&M is for concentrate disposal (Hutchison, 2007). Hutchison estimates that the cost of desalinated water is about $534 per acre-foot (AF) compared to $163/AF for groundwater, $300/AF for surface water, $706/AF for reclaimed water, and $1,400/AF for imported water. Considering that there is very little, if any, additional groundwater or surface water for the El Paso area, $534/AF of desalinated groundwater is a bargain compared to the other options.

TWDB is partially funding several groundwater desalination projects (TWDB, 2006). One of these projects is for the City of San Angelo to study the Whitehorse Aquifer as a source of saline water. The City of Kenedy (Karnes County) has an existing desalination plant that has been in operation since 1995. With partial funding from TWDB, the City is testing the efficiency of a newer membrane technology to determine the cost saving for upgrading to a newer generation of membranes. The North Cameron Regional Water Supply Corporation (Cameron County) designed and built a 2.3 MGD desalination facility. TWDB provided financial assistance so an engineering facility roadmap can be developed for other organizations to use as they plan and implement desalination plants. TWDB has funded 12 brackish groundwater desalination demonstration projects for a total of about $2.6 million.

SAWS is constructing a desalination system in southern Bexar County to use water from the Wilcox Aquifer. When completed, the plant should be able to provide up to 20 MGD of treated water to San Antonio. Test results, so far, indicate that this would be a very viable source of saline water (John Waugh, personal communication). The project is so promising that SAWS is considering not doing any testing of the saline Edwards as a potential source water that was supposed to be a part of this project. The saline Edwards would be used for desalination concentrate disposal across the county line, in Wilson County, where such injection would be allowable.

3.2.3 Implementation of a Desalination System in the Saline Zone

One possible scenario for use of the brackish Edwards as a source of water for a desalination facility would be to pump brackish water from the Edwards, treat it with a reverse osmosis (RO) plant or other treatment systems, and inject the concentrate that is derived from the process into a formation with TDS values of greater than 10,000 mg/L (Fig. 3A). However, if the underlying formations have TDS values of less than 10,000 mg/L, the concentrate could be sent by pipeline a few miles to the east where it could be injected for permanent disposal into a portion of the brackish Edwards that is hydraulically isolated from the Edwards where the water is being produced. On the basis of limited information, the Middle and Lower Trinity Aquifers beneath the saline Edwards in this area may have TDS values below 10,000 mg/L, and its use as a disposal zone is problematic.

A second scenario involves use of the Middle or Lower Trinity as a source of brackish water for a desalination facility (Fig. 3B). Concentrate from this system would need to be piped farther to the east for disposal where isolation in a separate fault block could be ensured and where such injection would be compliant with current regulations. Yields from the Middle and Lower Trinity would likely be less than from the Edwards and therefore require larger well fields, but the potentially lower TDS values would make the Middle and Lower Trinity groundwater more cost-effective for treatment.

3.3 Aquifer Storage and Recovery

ASR is a technique that has been used worldwide to store excess water in an aquifer for later recovery (Pyne, 1995). Different types of aquifers have been used for storage and the water to be stored comes from various sources. In some areas, the aquifer being used for storage is also used for production of fresh groundwater. So the storage of additional water in the aquifer is a way to "top off" the aquifer. Saline-water aquifers are also used for storage. Fresh water is injected into the aquifer so that a "bubble" of fresh water develops surrounded by saline water (Figures 3C and 4). Some amount of fresh water mixes with the saline water and is not usable. Confined and unconfined aquifers have been used for ASR. Surface water and groundwater have been used as ASR source water. Some waters need to be treated to prevent fouling of the injection well and the formation.

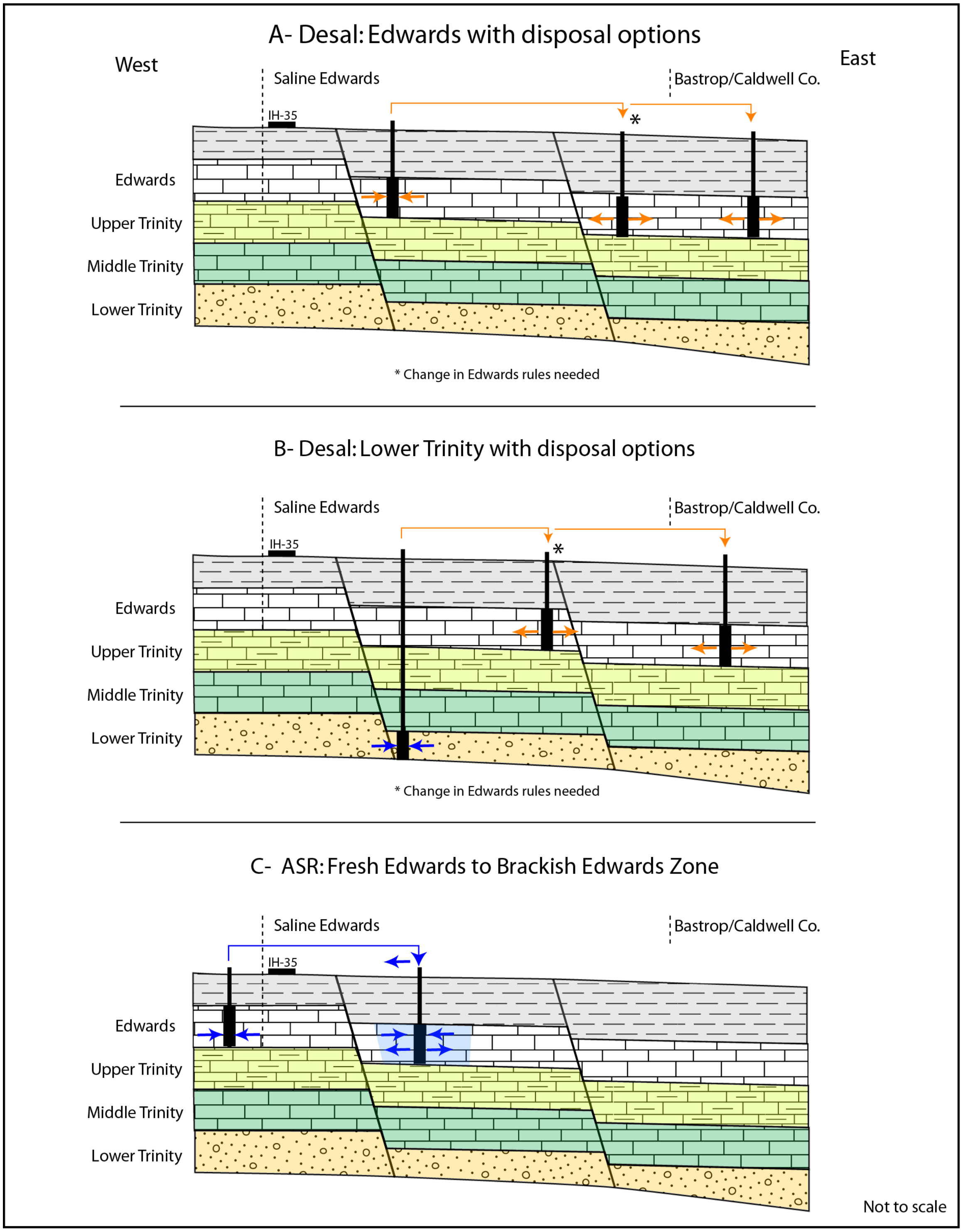

Figure 3. Various desalination and ASR scenarios for the saline Edwards.

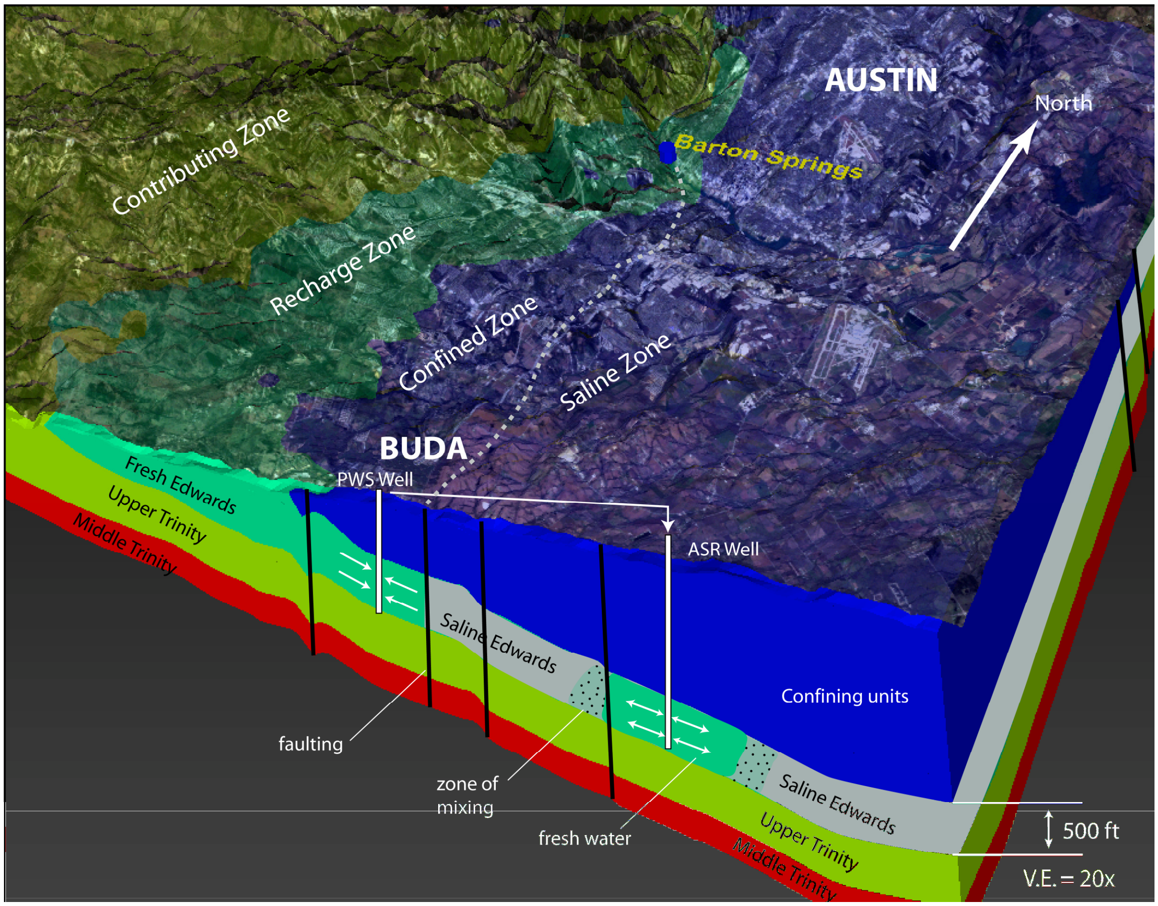

Figure 4. Schematic diagram of how an aquifer storage and recovery system could be implemented in the saline Edwards.

More than 60 operational ASR systems have been identified in the United States as of 2005 (EBMUD, 2005). There are at least three ASR systems currently in operation in Texas. The largest system is operated by SAWS in southern Bexar County. This system, which has been in operation since 2004, injects excess Edwards water in the Carizzo Formation. Full injection capacity of the SAWS ASR system is about 60 MGD. During the drought of 2005-2006, the system was able to supply some of this stored water to the SAWS distribution system. This allowed SAWS to reduce production of fresh Edwards water, thereby staying within their drought pumping limits.

El Paso Water Utilities has operated an ASR system since 1987. Approximately 3 MGD of treated waste water are injected into the Hueco Bolson Aquifer through ten injection wells. The City of Kerrville has operated an ASR system since 1998. Treated water from the Guadalupe River is injected into the Hosston and Sligo units of the Trinity Aquifer through three injection wells. The rate of injection is about one MGD. The goal of the system is to store about one billion gallon of injected water; the amount of water used by the city in one year.

Limited studies of the saline Edwards suggest that there is adequate storage capability in this zone. Many wells in the saline Edwards are capable of yielding more than 1,000 gallons per minute (gpm) when pumped (SWRI, 2003). This suggests that in at least some zones, storage and permeability values are high enough for water to enter the formation and to be stored. David Pyne (personal communication), the author of Groundwater Recharge and Wells (1995), believes that the saline Edwards would serve as a very effective reservoir for ASR. High salinity in the eastern portion of the Edwards Aquifer indicates that there is very little circulation in that part of the aquifer. Therefore, fresh water injected into the saline Edwards is not likely to migrate far from the injection point.

4.0 Regulatory and other Institutional Considerations

The BSEACD, as a Texas Groundwater Conservation District, is enabled by Chapter 36 of the Texas Water Code and Chapter 8802 of the Special District Local Laws Code with the authority to manage all the groundwater resources within its jurisdiction. This authority is manifested through the development and implementation of the District's Management Plan and the Rules and Bylaws. As a political subdivision of the State, the conventional approach to groundwater management is through permitting of nonexempt wells and the imposition of production limits with an emphasis on further production limits or curtailments imposed during drought conditions. The District has implemented its authority by capping firm-yield historical permitted pumpage and by developing drought management rules requiring substantial pumping curtailments and prohibiting waste and proscribed use. Curtailing pumping through demand management and water use restrictions, however, addresses only one side of the equation. Development of new supplies may have the potential to allow replacement or substitution of the demand that is currently being satisfied by over-allocated historical freshwater Edwards permits, especially under even more stringent curtailment requirements. A corollary benefit likely attendant to developing these alternative supplies for regulatory purposes is making available additional regional water for all users, in an area where other traditional supplies are essentially fully subscribed.

4.1 Current and Future BSEACD Regulatory Aspects

The current regulatory structure was developed in anticipation of the need to facilitate, or at the least, to remove obstacles to development of alternative supplies. This was largely accomplished through the creation of management zones and through certain permit reservations within the District's limit on permitted pumpage during non-drought conditions, also known as the "All-Conditions MAG."

4.1.1 Management Zones

Management Zones (MZ) were created in the District to recognize the distinguishing characteristics between the Districts' aquifers and the need to manage them accordingly. For example, the distinction between the freshwater Edwards MZs (Western and Eastern) and the other MZs allowed the District to create unique and separate rules for each. The key difference is that, where the freshwater Edwards aquifer is currently permitted beyond the MAG, there is room for additional permits authorizing production from wells producing from the saline and Trinity MZs within their respective MAGs. Therefore, these permits are not subject to the deeper pumping curtailments of the freshwater zones which allow access to permits providing more firm-yield supplies. This distinction has already served to foster the development of deeper Middle Trinity wells in the southwestern parts of the District in the Ruby Ranch and Oak Forest subdivisions where other supplies are limited. While Lower Trinity and saline wells have not yet been completed for production in the District, the MZ regulatory structure removes regulatory obstacles associated with interruptible permits to allow future development of these aquifers as potential alternatives to the freshwater Edwards.

4.1.2 Class D Conditional Production Permits

The District's permitting structure allows continued permitting of interruptible pumpage within the all-conditions MAG of 16 cfs through the issuance of Conditional Production Permits (Figure 7). The District has four classes of conditional permits (Class, A, B, C, and D) with each class having progressively more restrictive conditions and curtailment requirements. The most restrictive class, Class D, requires 100% curtailment upon the declaration of Stage II Alarm Drought but more importantly, it is only available for groundwater production from wells associated with aquifer storage and recovery (ASR) projects <u>where stored water is recovered and used to supplement or substitute freshwater Edwards supplies during District-declared drought</u> (District Rule 3-1.24.F). This rule serves to ensure that there will always be room for permitting ASR projects. However, the rule is most notable as an indicator of the District's deliberate efforts to implement policies to accommodate such projects when it provides potential relief to the over-allocated freshwater Edwards. The rule might serve to be a model for development of similar strategies to encourage the use of newly developed alternative supplies for replacement purposes.

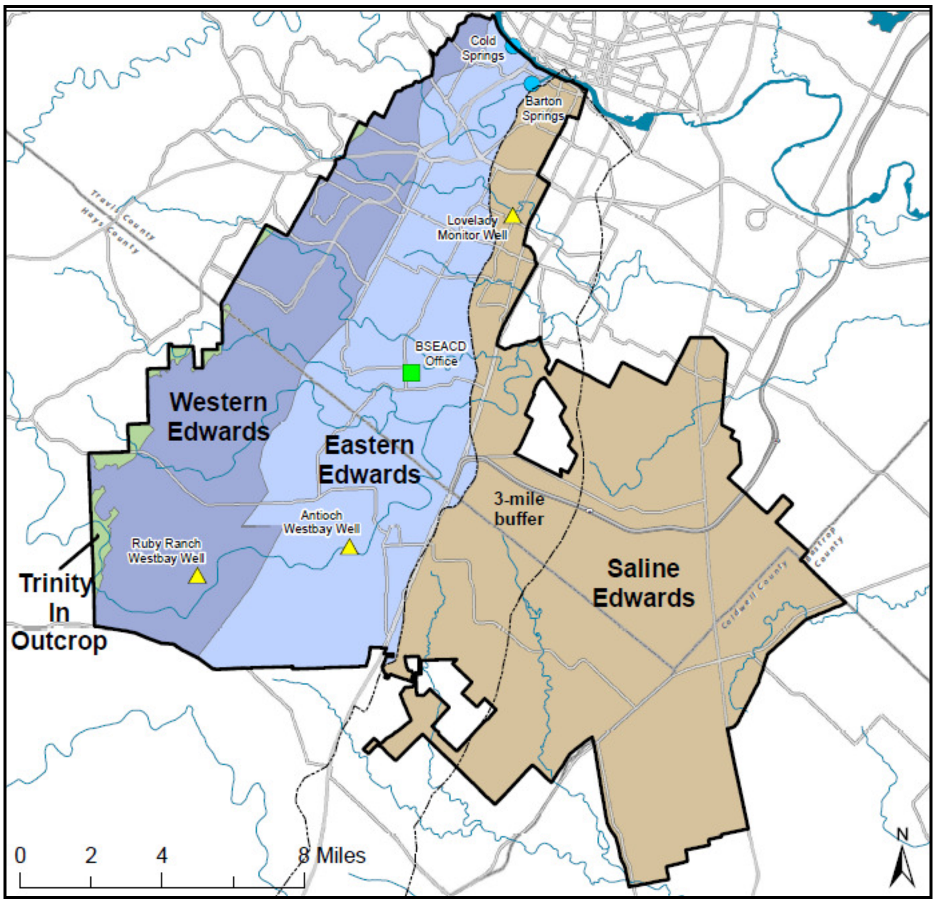

Figure 5. Map view of the District showing the three Edwards management zones.

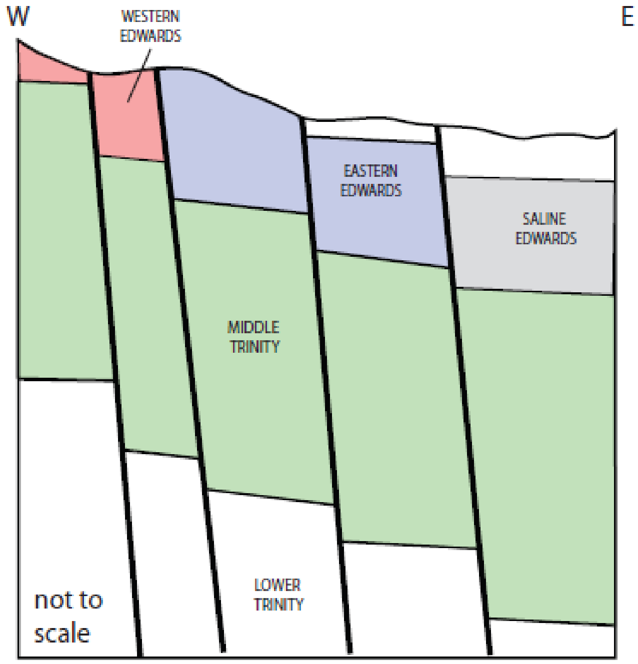

Figure 6. Cross-section view showing the Middle and Lower Trinity management zones beneath the three Edwards management zones.

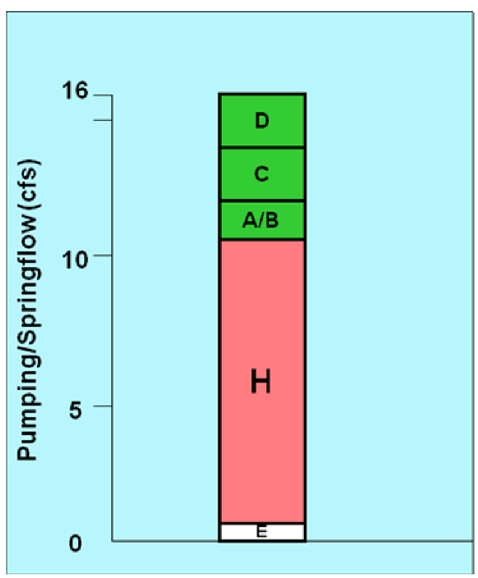

Figure 7. Allocations of permitted pumpage within the all-conditions MAG by permit type where (H) denotes historical permitted pumpage and A, B, C, and D denote the respective classes of conditional permitted pumpage. 2 cfs of a total of 16 cfs are reserved for ASR projects authorized under Class D production permits.

4.2 Pertinent State and Federal Regulations

The District has made a deliberate effort to pave the way towards alternative-supply development by implementing policies that remove certain regulatory obstacles as described above. However, certain state and federal regulations are in place that were either unintended obstacles or that did not anticipate an interest in development of the more marginal quality supplies (saline Edwards) or the deeper aquifers (Middle and Lower Trinity). These state and federal regulatory issues require attention to facilitate alternative water-supply development.

4.2.1 Texas Water Code

The most significant regulatory hurdle for alternative-supply development involves restrictions on injection wells that transect or terminate in the Edwards Aquifer. Section 27.051(i) of the Texas Water Code states:

> *The commission may not authorize by rule or permit an injection well that transects or terminates in the Edwards Aquifer. The commission by rule may authorize injection of groundwater withdrawn from the Edwards Aquifer, or injections of storm water, flood water, or groundwater through improved sinkholes or caves located in karst topographic areas. For purposes of this subsection, "Edwards Aquifer" has the meaning assigned by Section 26.046(a.*

This provision of the Texas Water Code applies to all of Hays and Travis Counties and also to the saline Edwards since the statute makes no distinction between fresh and saline zones of the Edwards Aquifer. These restrictions do not apply to the Edwards in Bastrop and Caldwell Counties. This obstacle potentially affects the economic viability of saline Edwards desalination projects because it complicates the option of deep well injection as one of the more conventional disposal methods for desalination concentrate. Further, since the TCEQ interprets "groundwater withdrawn from the Edwards" as groundwater that has not been "physically, chemically, or biologically altered", this provision would also be an obstacle to the injection of any treated Edwards water for ASR purposes. In order to encourage both ASR and saline Edwards desalination as a cost-effective alternative supply, the intent of this restriction needs to be recognized as unnecessary in the saline Edwards (with an appropriate exclusion zone in place to limit proximity to the springs), and then modified through legislation to allow for such projects.

4.2.2 Federal Underground Injection Control Regulations

The TCEQ's underground injection rules implement the federal UIC program, and it utilizes the federal definition of (potential) Underground Source of Drinking Water (USDW) to be water that is less than 10,000 mg/L total dissolved solids. There is a state-wide prohibition on injection of essentially anything other than native water, or water meeting drinking water standards, into or above such aquifers, including concentrate or other residuals from a desalination facility. The hydrogeologic setting of a well injection component for desalination residuals disposal must be characterized sufficiently to demonstrate compliance with these regulations.

Further, this requirement also connotes that the injection wells must be far enough down-gradient so that their native water is more saline than just moderately brackish groundwater. For example, the TDS of the deep Trinity Aquifer underlying the saline Edwards is only poorly known regionally and is unknown in the District; if it is brackish but less than 10,000 mg/L, as is indicated on the basis of very limited data, then it would be considered a USDW and be off-limits as a target for injection of desalination concentrate. On the other hand, parts of the saline Edwards in the District are known to have waters that are quite saline and would not be considered USDW, and therefore could be utilized as an injection zone for a desalination facility, if the more local prohibition discussed in the preceding subsection is removed.

4.3 Statutory Considerations

While a detailed legal analysis is beyond both the scope of this white paper and the knowledge domain of the staff preparing it, there are some statutory considerations that potentially could affect, either positively or negatively, the efficacy of some alternative water-supply programs. Generally, these would be employed in concert with each other for a District-sponsored supply.

By its statutory authority under Texas Water Code §36.105, the District does have limited eminent domain authority, subject to fair market compensation and the stipulation it would be for a public purpose. For example, the District *could* acquire land by eminent domain necessary for conservation purposes including recharge and reuse. The District may not condemn land for the purpose of production, sale, or distribution of groundwater or surface water. If the District pursued acquisition of land in the District's jurisdictional area, the market price for land may well be prohibitive for the District's relatively meager existing financial resources, which exist primarily for other purposes that would then be put at risk.

The District statutorily has the authority to issue bonds to support its programs under Texas Water Code §36.171. Because the District's current operational income is barely enough to support its ongoing operations, re-payment of the bonds plus interest would require such bonds to be revenue bonds, such as might be enabled by the District's being a wholesale water supplier itself or part of a public-private partnership for that purpose. Otherwise, the bonding capacity of the District is likely negligibly small.

On a related note, the District is statutorily authorized to purchase, sell, transport, and distribute surface water or groundwater under Texas Water Code §36.104. To date, it has resisted essentially going into competition with some of its water-supply permittees. But because many of its permittees are seeking additional water supplies from third parties, perhaps this would not be considered the same constraint that it has heretofore. For example, the District *could* install a Middle (and/or Lower) Trinity well on the land that it already owns near the Antioch recharge facility, and operate it as a wholesale water supplier to, say, Centex for some of its quarrying operations, or, depending on the quality of the water produced, as a blend for the public water supply of Buda. It is unknown whether this would require financial resources beyond the District's capability or the assumption of risk that is beyond the District's intent. As a water purveyor, water provided by the District could be contracted with terms that would serve the ultimate objective of providing a benefit to the District aquifers. Such terms, for example, may (but are not required to) require that those new water supplies be used in place of permitted Edwards Aquifer water, particularly during District-declared drought.

5.0 Possible Mechanisms/Strategies for Replacing Existing Historical Use While Increasing Regional Water Supplies

The BSEACD staff has identified a number of potential mechanisms and strategies for promoting the replacement or substitution of permitted historical use water of the Barton Springs aquifer and the likely concomitant provision of additional regional water supplies, which are the focus of this white paper. Underlying these possibilities is the necessary, but not sufficient, condition of alternative supplies being available to the historic use permittees. This section of the white paper is addressing what one or more additional strategies within BSEACD's purview may then be sufficient to promote the development and use of replacement supplies.

It should be emphasized that the District is not likely to be able to do all of these at present, either because it may lack the financial resources, the statutory and/or legal authority, the political will, or a combination of these things to implement one or more of them. At the same time, this set of possibilities is not intended to be exhaustive, and one of the purposes of this white paper is to be a vehicle for soliciting additional ideas and strategies from the Stakeholders Advisory Committee (SAC) to promote additional replacement and substitution of historical use water of the Barton Springs aquifer and to provide additional regional water supplies.

For now, the District is simply identifying in broad strokes, for discussion purposes only, some *possibilities* below.

1) Require switching some portion of historical use water to alternative supplies by geographic area, including developing new regional supplies, by some certain date(s). This has been a strategy successfully employed by Lone Star GCD in moving some 30% of its overall current production off groundwater to surface water supplies in order to meet its DFCs. That GCD is working in active partnership with the San Jacinto River Authority to make that happen.

2) Link switching some portion of historical use water under a particular permit to some replacement supply, including developing new regional supplies, by some date(s) certain, in lieu of even more draconian additional curtailments being applied to that permittee during severe drought. This is something of a carrot and stick approach. For example, a historical use permittee could be indemnified from future curtailments during ERP greater than 50 % only if it commits to using existing or new alternative water supplies in lieu of Barton Springs aquifer groundwater for some material part of its authorized production on a full-time basis, thereby reducing the authorized groundwater withdrawals during an ERP.

3) Push for legislative change to allow prioritization among uses and geographies once the DFC is reached. Current law prevents a GCD from prioritizing among types of use of groundwater, although surface-water supplies are allowed this management flexibility. No distinction between in-District and exported use is necessarily being suggested. It supports the concept of local groundwater management. Agricultural irrigation use could be exempted; this would not affect the District as there is no such use.

4) Push for legislative change to alter or remove the ceiling on groundwater use fees once the applicable DFC is reached, so use of alternative supplies is not economically disadvantaged *vis a vis* existing groundwater use rights. Rather than an unrestricted rate structure, the ceiling could be made equivalent to or otherwise indexed to the existing rates of raw, untreated, undelivered surface water supplied by local river authorities and primary water wholesalers. The District is considering a somewhat similar bill in the upcoming legislative session, and it is being discussed among other GCDs.

5) Have BSEACD develop new water supplies and become a water purveyor/broker for that new supply, furnishing replacement supplies for existing permittees and others in the District. This would connote that BSEACD itself would acquire groundwater rights. For example, BSEACD owns some 37 acres at the Antioch site, and it could develop a Middle Trinity and/or Lower Trinity well and sell that water to nearby historical user permittees at some rate that would allow and facilitate a reduction in the authorized historical use water production amount.

6) Consider public-private partnerships (PPP) with those entities that have or have access to new regional water supplies and that in turn could be used, among other uses, to provide replacement water; as part of the terms of the PPP, the District could provide the regulatory driver for preferential use of that replacement water by nearby historical use permittees and could participate in the benefit provided by fees collected by the partnership. PPPs are often problematic on both legal and practical grounds, and this requires further articulation.

7) Have BSEACD conduct studies of the saline zone and the Lower and Middle Trinity Aquifers that would generate data that could be used in feasibility studies for desalination and ASR as new regional water supplies.

8) Encourage permittees, developers, and other stakeholders to conduct studies and form partnerships that could finance and operate such plants and systems if their feasibility was determined.

9) Other strategies identified by the Board and/or SAC.

6.0 Summary and Next Steps

This white paper has identified and discussed the statutory and regulatory need for providing alternative water supplies to replace freshwater Edwards groundwater that is currently authorized to be pumped by District historical-use permittees, especially during extreme drought. While a number of potential alternative water sources are available to individual end users and even individual permittees and have been briefly characterized in the white paper, the sources that are most likely to produce sufficient new supplies on a large scale relate to the use of the Edwards saline zone and, probably to a lesser extent, the Middle and Lower Trinity Aquifers, for supplying desalination facilities of various scales and for hosting aquifer storage and recovery systems. The deployment of such new supply systems to satisfy regulatory-driven requirements will likely also produce (or at least demonstrate the efficacy of producing) additional water to be used by other water users in the region and even beyond, regardless of whether they are currently District permit holders.

The District's regulatory program requirements, policies, and in-kind investments can provide an impetus for developing replacement water supplies and by extension additional regional supplies. This white paper has identified several types of specific approaches that the District could conceivably use to provide that impetus. The District Board will be seeking public input on the efficacy and issues associated with these various possibilities.

Toward that end, an *ad hoc* Stakeholder Advisory Committee (SAC) is being formed that will be representative of the interests that may affect and be affected by various alternative supply strategies and mechanisms. The SAC will be charged with providing the Board inputs on those approaches and activities, and any others that the SAC identifies and considers. This white paper is designed to be a point of departure for the SAC members in providing their review and recommendations to the Board. The Board will select approaches and strategies for possible pursuit, if any, only after the SAC completes its advisory mission. And any change in the regulatory framework that would accompany a selected strategy would require a structured rulemaking process, including formal communications with the permittees, end-users, and the public at-large, a public hearing, and a comment and response period.

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