5A.19 Conjunctive Use of the Brazos River Alluvium Aquifer

5A.19.1 Description of Option

The Brazos River Alluvium Aquifer is (Figure 5A.19-1) composed of unconsolidated clays, silts, sands, and gravels deposited by the Brazos River.[1,2] The alluvium covers approximately 694 square miles within Region G. The alluvial aquifer starts at Whitney Dam and occurs in Bosque, Hill, McLennan, Falls, Milam, Robertson, Brazos, Burleson, Washington, and Grimes Counties before continuing downstream to counties in Region H. The lateral width of the alluvium in the region ranges from 1 to 6 miles. The thickness of the alluvium ranges from approximately 10 feet to 80 feet, increasing with distance downstream. No continuous confining layer exists above the water table, and the primary source of recharge to the aquifer is direct precipitation onto the aquifer. Groundwater discharge from the alluvium contributes to the base flow of the Brazos River. Groundwater irrigation pumpage from 1980-1993 from the alluvium in Regions G was estimated at 27,850 acft. The estimated groundwater availability on a sustained basis in both Regions G and H is 66,700 acft. The Brazos River Alluvium is the most prolific of any alluvial aquifer of a major river in the state.

The concept of conjunctive use involves managing groundwater and surface water resources in tandem such that the net quantity of available water is greater than if the two resources were managed separately. The conjunctive use approach that is considered in this option entails directing high flows from the Brazos River that would otherwise flow to the Gulf of Mexico to infiltration basins located over the alluvium. This water would then be allowed to collect in the infiltration basins and percolate through the unsaturated zone to recharge the aquifer, thereby enhancing recharge to the aquifer.

The source of the water to be diverted to the infiltration basins is unappropriated flows from the Brazos River. Previous work performed by the Texas Water Resources Institute at Texas A&M University identified the quantity of unappropriated flows on the Brazos River that passed the river gauging station at Bryan. An analysis of the period between 1950 and 1984 revealed that for 62 percent of the months in the period, unappropriated flows passing the Bryan Gage exceeded 10,000 acft/month.

[1] Ashworth, J.B. and J. Hopkins, "Aquifers of Texas," Texas Water Development Board Report 345, 69 p., 1995.
[2] Cronin, J.G. and C.A. Wilson, "Ground Water in the Flood-Plain Alluvium of the Brazos River, Whitney Dam to Vicinity of Richmond, Texas," Texas Water Development Board Report 41, 206 p., 1967.

An examination of boring logs and well records in the region between the City of Calvert and State Highway 21, primarily in Robertson and Brazos Counties, indicate that on average the depth to the water table ranges from approximately 25 to 45 feet. Assuming that the water table may only rise to within 10 feet of ground surface, this equates to a potential of 15 to 35 feet of aquifer storage available for use through enhanced recharge.

Aquifer storage can be filled during periods of above-normal precipitation and high river flows, then pumped out from wells during drought to meet downstream water needs. The unconfined and unconsolidated geology of the Brazos River Alluvium Aquifer and the available supply of water from the Brazos River offer potential for enhanced recharge, supplemental water supplies from the aquifer, and conjunctive use with the Brazos River.

Although the area of the Brazos Alluvium has not been projected as having a water deficit, several potential uses for the water have been identified:

- Steam Electric – A steam electric plant in Bosque County is under construction and will have an annual demand of approximately 5,600 acft/yr.
- Water Trades/System Operations – Currently, a large portion of the yield of the BRA System that is in Region G is used to supply downstream needs in Region H. Development and utilization of the aquifer in conjunction with the BRA reservoir system could potentially make water available from upstream reservoirs (i.e. Lake Granbury, Lake Whitney, and Possum Kingdom Lake) for Region G needs.
- Downstream Needs – Any water developed through the implementation of the Brazos River Conjunctive Use Option will be new yield. Development of this supply could be used to meet water demands downstream in Region G and Region H.

5A.19.2 Available Yield

The Brazos River Alluvium has similar characteristics to a traditional surface reservoir, with water stored in the pore spaces of the aquifer materials. Like a surface reservoir, it has a definable length, width, and depth, and its volume can be calculated by factoring porosity into the calculations. The groundwater level is analogous to the pool level in a surface reservoir, and it fluctuates according to groundwater withdrawals from pumping and natural recharge to the aquifer through precipitation. Therefore, the Brazos River Alluvium may be modeled as a reservoir.

In order to calculate available yield of the aquifer, the aquifer system was modeled using RESSIM, a Fortran computer program that simulates reservoir operations in order to determine the firm yield over a given historical period of record. Input parameters for RESSIM were

adjusted to account for differences between aquifer and reservoir storage as follows. A flow chart depicting the difference in input is included as Figure 5A.19-2.

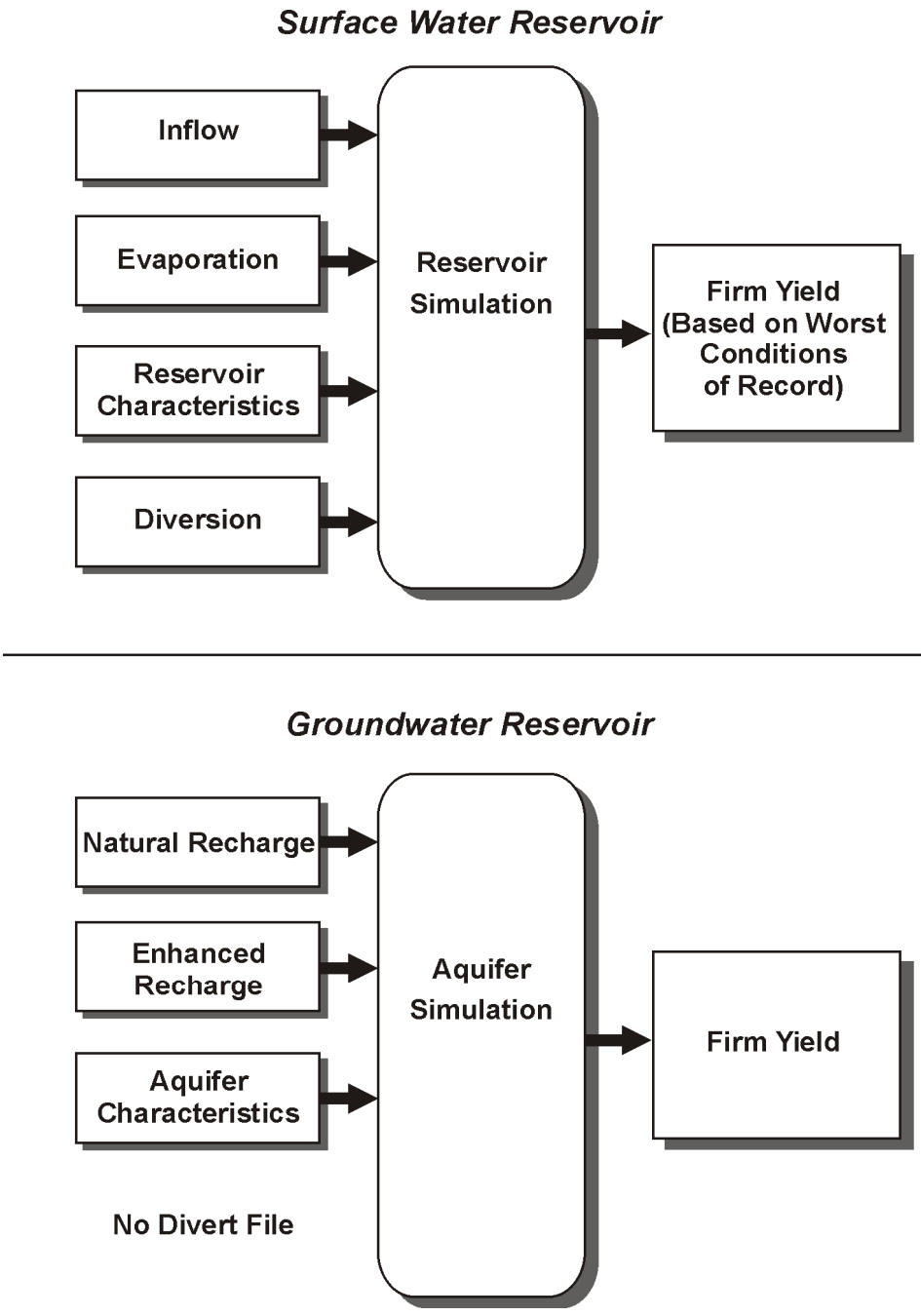

Figure 5A.19-2. RESSIM Model

The EVAP input file for RESSIM represents evaporative losses from surface reservoirs. However, negative values may be assigned in this file to represent direct rainfall onto the lake area. For simulation of the aquifer system, the EVAP file was used to simulate natural recharge to the aquifer. As previously mentioned, direct precipitation onto the aquifer is the primary source of recharge. Based on information in the TWDB report, the proportion of rainfall that reaches the aquifer as recharge was assumed to be 8 percent. Therefore, recharge was estimated as 8 percent of monthly rainfall values, and entered as negative numbers in the EVAP file.

The INFLOW file for RESSIM was designed to represent streamflow into the surface reservoir. For simulation of the aquifer system, the INFLOW file was used to represent enhanced recharge to the aquifer through the infiltration basin(s). Monthly quantities of artificial recharge were assigned based on the data for unappropriated flows at the Bryan Gage. If monthly unappropriated flows exceeded 10,000 acft/month, the enhanced recharge input was capped at 2,500 acft/month as an estimated practical limit. If unappropriated flows were less than 10,000 acft/month, enhanced recharge was assigned at 10 percent of the unappropriated flows. If there were no unappropriated flows, no enhanced recharge was assigned to the model.

The RESVR file for RESSIM defines the physical dimensions of the surface reservoir in terms of an elevation-area-capacity (EAC) table. The inputs for this file were altered in the following ways to represent the aquifer storage system. The aquifer was idealized as a "tank" of uniform thickness and surface area. Thus, for the EAC Table, the area value remained constant. The value for "dead storage" elevation in reservoir simulations refers to the pool elevation at which storage is unavailable for practical use (i.e., pool elevation below the penstock elevation). For the aquifer simulation, dead storage elevation referred to storage in the aquifer below the elevation of the river channel. The conservation storage elevation was set at 10 feet below the ground surface elevation. Finally, a porosity or storage capacity value needed to be included in determining capacity volumes for the EAC table, since unlike a surface reservoir, only pore spaces within the calculated aquifer volume is actually available for groundwater storage. Thus, capacity volumes were calculated by multiplying surface area (constant) by groundwater elevation (based on heights in idealized "tank") by this storage capacity factor. TWDB conservatively estimated storage capacity of the alluvium at 15 percent. In order to account for the fact that no more than 25 percent of the surface of the Study Area would be utilized for any proposed project, the storage capacity factor was reduced (from 15 to 3.75 percent) as a

surrogate for reduced area. The area factor could not be reduced because recharge calculations would be affected.

The DIVERT file in RESSIM has no analogy in the aquifer system, so was not utilized. Irrigation well pumpage could be represented using this file but was set to zero for this analysis, due to lack of specific data regarding pumpage in the individual areas that were examined.

Little information is currently available on other minor inflows to and outflows from the alluvium, such as groundwater inflow to the alluvium from other aquifers and groundwater discharge to the river channel. For purposes of this analysis, these flows were set approximately equal to each other in quantity, and were not considered in this analysis. Further study is needed to verify this.

After setting up the model as described, the model was run for three different areas: from the Falls/McLennan County Line to the City of Calvert; from Calvert to State Highway 21; and from Highway 21 to the Brazos/Grimes County Line. RESSIM was run for the period 1950 to 1977 to determine the annual firm yield available from the aquifer system. (This period was chosen because of the availability of uninterrupted precipitation data, and because it contains the longest drought of record in the early 1950s.)

The model was run for conditions of no enhanced recharge, and for conditions with an enhanced recharge maximum of 2,500 acft/month. Results are summarized in Table 5A.19-1. With no enhanced recharge, the annual firm yield for the area between Calvert and Highway 21 was approximately 20,360 acft/yr. With enhanced recharge capped at 2,500 acft/month, the calculated firm yield was approximately 30,000 acft/yr, representing an increase in firm yield of 9,640 acft/yr for the area between Calvert and Highway 21, despite having a smaller surface area than the other segments. The area between Calvert and Highway 21 appeared to offer the most favorable conditions for this enhanced recharge.

5A.19.3 Environmental Issues

Diverting unappropriated flows from the Brazos River to infiltration basins along the adjacent Brazos River Alluvium Aquifer would raise several environmental issues related to environmental water needs/instream flows, fish and wildlife habitat, cultural resources, and threatened and endangered species. These include:

- Diverting flood flows could reduce the beneficial effects of overbank flooding on downstream aquatic and riparian communities;

Table 5A.19-1.
Available Yield from Brazos River Alluvium
with Enhanced Recharge

Aquifer Segment	Area (sq. miles)	Average Pumpage[1] (acft/yr)	Available Yield (acft/yr)		Increase in Available Yield
			No Enhanced Recharge	With Enhanced Recharge	
Falls/McLennan County to Calvert	141	6,076	22,420	29,820	7,400
Calvert to Hwy 21	115	12,462	20,360	30,000	9,640
Hwy 21 to Brazos/Grimes County	142	9,306	26,320	36,070	9,750
Total	398	27,844	66,740	95,890	29,150

[1] Based on average values from 1980 to 1993.

- Construction of new diversion channels and infiltration ponds could impact wetlands and riparian bottomland habitat;
- Construction of new diversion channels and infiltration ponds could impact existing cultural sites;
- Construction of new diversion channels and infiltration ponds in the Brazos River Alluvium could impact the habitats of the Houston toad, and two plant species, all federally listed as endangered;
- Pumping stored water back to the Brazos River could improve or sustain ecological conditions by increasing base flows;
- Using existing sand and gravel pits as infiltration basins would reduce impacts identified above.

Table 5A.19-2 summarizes environmental issues for this option.

5A.19.4 Engineering and Costing

Infrastructure needs for this project system will include

- Pump station(s) and intake structure(s) to divert water from the Brazos River;
- Construction of multiple infiltration basins;
- Installation of multiple wells for recovery of stored water, and;
- Construction a two-way pipeline to carry the water from the river to the infiltration ponds and from the recovery wells back to the river.

The proposed project was sized to utilize 25 percent of the alluvial storage volume between Calvert and Highway 21, in order to correspond with the results of the RESSIM firm yield analysis. To reduce the incidence of groundwater being lost through seepage to river channels, the project should be sited as far as possible from the Brazos and Little Brazos Rivers. The area selected for the project is the center of the alluvium between the Brazos and Little Brazos Rivers.

Because of the large area covered, an initial project of reduced size was examined that would utilize one-third of the surface area between Calvert and Highway 21, and produce an increased yield of one-third of 9,640 acft, or 3,215 acft/yr. A preliminary cost estimate was generated for this project. In order to utilize the entire area between Calvert and Highway 21, it is envisioned that two additional and essentially identical projects could be built. The total project cost would then be three times the estimate generated for the initial project. The unit cost of water for the total project would be essentially the same as for the smaller project.

The target delivery rate for the initial project, therefore, is one-third of the total of 2,500 acft/month, or 833 acft/month. This was rounded up to 1,000 acft/month, or 17.5 cubic feet per second, to account for transmission and evaporative losses. A system of 16 recovery wells, each yielding 500 gallons per minute, would have the capacity to return flow to the river at approximately the same rate.

The total project costs for a project sized to utilize one-third of the area between Calvert and Highway 21 and increase yield by 3,215 acft/yr, would be approximately $9,843,000, as detailed in Table 5A.19-3. If the project were sized to utilize the entire area between Calvert and Highway 21 and increase yield by 9,640 acft/yr, the total project costs would be approximately $29,520,000. In either case the unit cost of water incremental benefit would be on the order of $305 per acft (or 93 cents per 1,000 gallons of water). These costs were generated assuming that land purchase would be restricted to land necessary for construction of the infiltration basins. If it is necessary to purchase all land beneath which water will be stored, the unit cost of water would rise to $690 per acft (or $2.12 per 1,000 gallons). These are raw water costs for transmission to and from the Brazos River. Diversion, treatment, and transmission costs must be added for comparison to other specific options for municipal or industrial use.

5A.19.5 Implementation Issues

This water supply option has been compared to the plan development criteria, as shown in Table 5A.19-4 and the option meets each criterion.

In order for this option to be implemented, the following issues will need to be addressed.

- Land Acquisition – An area of land extending along the central axis of the alluvial valley between the Brazos River and the Little Brazos River needs to be acquired for siting of infiltration basins and canals.

Table 5A.19-3.
Cost Estimate Summary
Brazos Alluvium Conjunctive Use Project Option
Second Quarter 1999 Prices

Item	*Estimated Costs for Facilities*
Capital Costs	
Infiltration Ponds	$651,000
Intake and Pump Station	1,538,000
Well Field	1,576,000
Transmission Pipeline	2,198,000
Total Capital Cost	**$5,963,000**
Engineering, Legal Costs and Contingencies	$1,977,000
Environmental & Archaeology Studies and Mitigation[1]	503,000
Land Acquisition and Surveying	345,000
Interest During Construction	1,055,000
Total Project Cost	**$9,843,000**
Annual Costs	
Debt Service	$715,000
Operation and Maintenance:	
Intake, Pipeline, Pump Station	76,000
Infiltration Ponds	98,000
Pumping Energy Costs	90,000
Total Annual Cost	**$979,000**
Available Project Yield (acft/yr)	**3,220**
Annual Cost of Raw Water ($ per acft)	**$305**
Annual Cost of Raw Water ($ per 1,000 gallons)	**$0.93**

[1] No mitigation is included for existing irrigation wells
[2] 200 acres purchased for infiltration basins and canal siting.

Table 5A.19-4.
Comparison of Brazos Alluvium Conjunctive Use Option to Plan Development Criteria

Impact Category	*Comment(s)*
A. Water Supply: 1. Quantity 2. Reliability 3. Cost	 1. Potentially significant quantities to meet regional or other region's needs 2. High reliability 3. Low to moderate
B. Environmental factors 1. Environmental Water Needs 2. Habitat 3. Cultural Resources 4. Bays and Estuaries	 1. Possible low impact 2. Low impact 3. Possible low impact 4. Possible low impact
C. Impact on Other State Water Resources	• No apparent negative impacts on state water resources; no effect on navigation
D. Threats to Agriculture and Natural Resources	• Possible impact to agriculture if agriculture groundwater is converted to other use
E. Equitable Comparison of Strategies Deemed Feasible	• Option is considered to meet municipal and industrial shortages
F. Requirements for Interbasin Transfers	• Not applicable
G. Third Party Social and Economic Impacts from Voluntary Redistribution	• None

- Groundwater District – The formation of a groundwater district has been proposed that would encompass Robertson and Brazos Counties. If this district becomes authorized by the state legislature, all project activities may have to be coordinated and permitted with this district.
- Water Rights Easements – Negotiations will need to be conducted with landowners in the area of the projected aquifer storage. In areas outside groundwater districts, no regulations restrict the quantity of groundwater any landowner within this area may pump. Easements will need to be purchased to utilize aquifer storage beneath private property, and contracts will need to be in place limiting these landowners to groundwater withdrawals necessary for the operation of their property (i.e., preventing them from withdrawing the recharge water). The proposed groundwater district may assist in these negotiations.
- Surface Water Rights – A surface water right permit must be obtained to collect unappropriated flows from the Brazos River.
- Environmental/Water Quality Issues – TNRCC concerns regarding raw water quality from the Brazos River and potential mobilization of contaminants from the unsaturated zone to the aquifer will need to be addressed prior to permitting of the project.
- Pilot Project – Prior to full implementation, a bench scale pilot project will need to be implemented in order to determine hydraulic loading rates in the vicinity of the

project more accurately. Effective hydraulic loading rates will determine the final area of infiltration ponds necessary to deliver the specified recharge rate, and could affect the costs significantly.

- Mitigation Funding and Other – Mitigation requirements would vary depending on impacts, but could include vegetation restoration, wetland creation or enhancement, or additional land acquisition.

Requirements Specific to Pipelines:

1. Necessary permits:
   a. U.S. Army Corps of Engineers Section 10 and 404 dredge and fill permits for stream crossings impacting wetlands or navigable waters of the United States.
   b. GLO easement for use of state-owned streambeds.
   c. TPWD Sand, Gravel, and Marl permit for construction in state-owned streambeds.
2. Right-of-way and easement acquisition.
3. Crossings:
   a. Highways and Railroads.
   b. Creeks and Rivers.
   c. Other Utilities.

Requirements Specific to a Well Field:

1. Easements for water well sites and water transmission pipelines.
2. Updated inventory of existing wells.
3. Test drilling and aquifer testing.
4. Chemical analysis.

Requirements Specific to Infiltration Basins:

1. TNRCC permitting.
2. Unsaturated zone environmental characterization.
3. Detailed soil mapping and infiltration testing of infiltration basin sites.
4. Continuing O&M of pre-sedimentation basins for infiltration basins.
5. NPDES Storm Water Pollution Prevention Plan.