APPENDIX G

STRATEGY DESCRIPTIONS

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Appendix G – Strategy Descriptions

Potential water management strategies were identified for users in the West Central Brazos study area with supply needs due to quantity, quality and/or reliability issues over the planning period (2000 to 2060). The strategies are described below and are grouped into the following categories:

- Agreements between water suppliers to maximize available yield within the study area,
- Interconnections and strategies identified for emergency or back-up supplies,
- Interconnections and movement of existing supplies to meet needs,
- New supply strategies, and
- General projects that provide additional water supply to the region.

These strategies were developed to assess potential alternatives for providing water supplies to the regions. Detailed cost tables for the strategies are included in Appendix H. A description of how the costs were developed and assumptions for sizing infrastructure is also included in Appendix H. Generally, the amount of water provided by a strategy was based on the average yearly use. Infrastructure was sized for peak day capacities, with peaking factors typically ranging from 1.5 to 2 times the average demand.

The identification and recommendation of certain strategies do not replace or circumvent local control and direction. This assessment provides information that can be used by the entities within the region as they seek to develop reliable water supplies. Implementation of any alternative will require appropriate agreements between the respective entities.

1. Water Agreements

Under Texas water law surface water rights are granted on a priority system based on the seniority of the right (first in time is first in right). Water rights with early priority dates are allowed to divert first, increasing their reliability during drought. The water supplies within the West Central Brazos study area were evaluated under a priority system analysis using the Brazos Water Availability Model (WAM). For some reservoirs located upstream of large downstream senior water rights, the firm yields were considerably less than permitted amounts. This is partly due to the assumed pass through of inflows for senior water rights during drought. Retaining these inflows in the upstream reservoir generally resulted in higher yields for that reservoir. For several reservoirs, it is recommended that agreements be considered with downstream water rights holders to allow the storage of inflows that would otherwise need to be passed through

under drought conditions. Specifically, the city of Graham, NCTMWA and WCTMWD may want to consider entering into such agreements with the BRA to avoid the necessity of passing priority inflows to Possum Kingdom Lake from Lake Graham, Millers Creek and Hubbard Creek reservoirs, respectively. There could be an increase in firm yield to the upstream reservoirs with agreements regarding pass throughs for senior downstream water rights. The effects of enforcing the senior water rights can be significant and critical to local and regional planning. A summary of the projected yield increase and impacts to the yield of Possum Kingdom Lake is shown in Table G-1. For this analysis only impacts associated with priority inflows identified for Possum Kingdom Lake are evaluated. No costs were assigned to these agreements.

Table G-1

Impacts of Holding Priority Releases to Possum Kingdom Lake

Reservoir	2000 firm yield, priority analysis (acre-ft/yr)	2000 firm yield, holding priority inflows to PK (acre-ft/yr)	Increase in upstream reservoir's firm yield (acre-ft/yr)	Reduction of Possum Kingdom's firm yield (acre-ft/yr)
Hubbard Creek	22,000	41,690	19,690	8,500
Millers Creek[1]	3,640	7,200	3,560	1,900
Lake Graham	7,050	7,600	550	1,100

1. Millers Creek Reservoir has a permitted diversion of 5,000 ac-ft/yr. The firm yield holding releases for Possum Kingdom in 2000 is greater than the permitted diversion. However, by 2060 the firm yield is less than the permitted amount.

Permit modifications could also be used to increase available water supply if there is unpermitted yield associated with a reservoir. This potentially applies to Lake Brownwood and Possum Kingdom Lake. Brown County WID #1 is currently pursuing several permit changes to their permit for Lake Brownwood. The modifications being pursued include:

- Change to combine all use types into total permit amount. Current permit specifies amounts for each use type.
- Eliminate the loss clause in the permit. Change permit such that the consumptive use equals the diversion.

2. Strategies for Emergency or Back-up Supplies

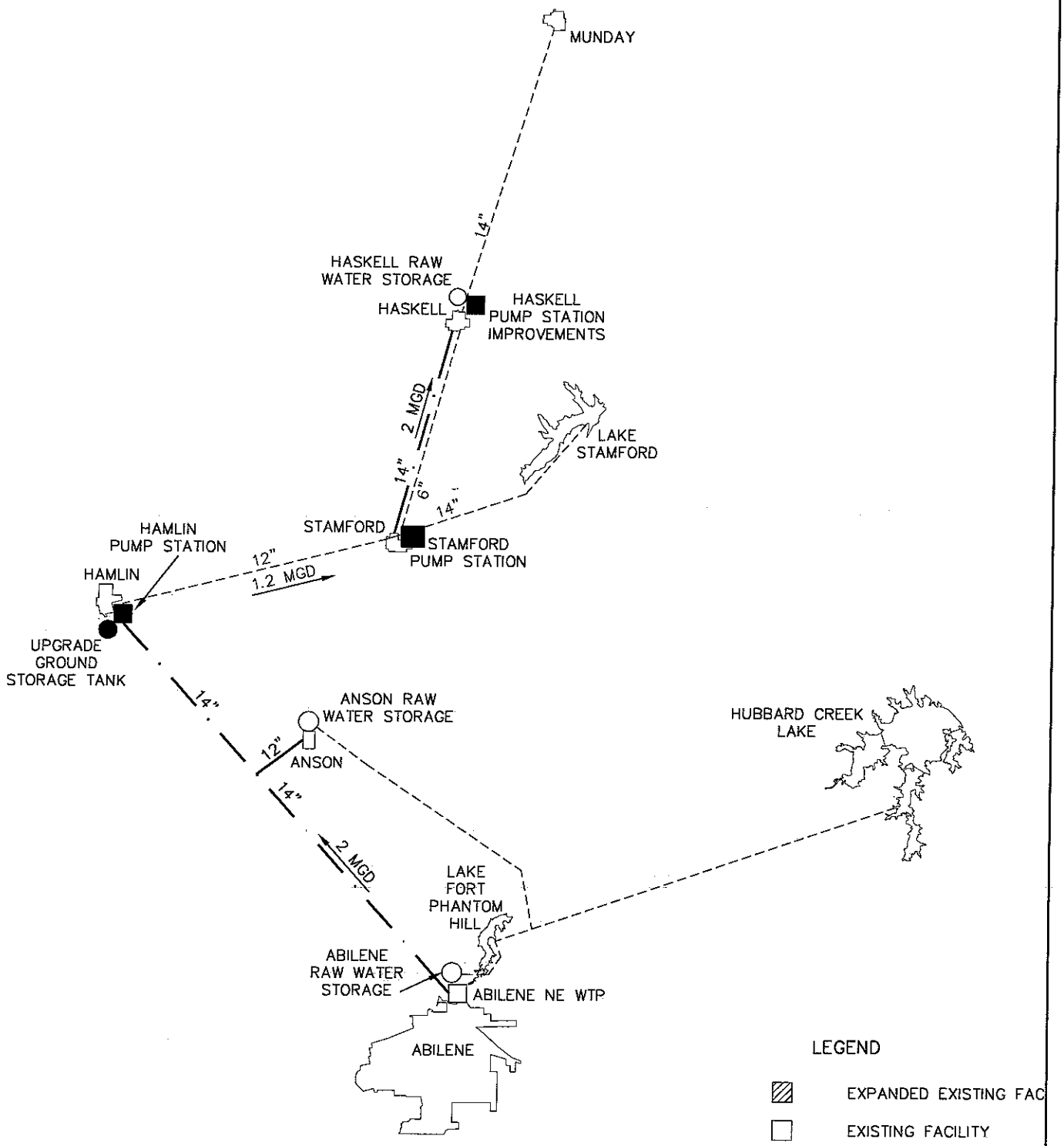
These alternatives provide a secondary source of water to the users to increase the reliability of their water supplies during drought and/or catastrophic event. For most entities, these strategies are not needed to meet a specific need but would provide back-up water supplies for emergencies. Generally, the strategies in this section include water from existing surface water sources. Groundwater is another potential source for emergency or back-up supplies, which is discussed in Section 6.

Abilene to North Central Texas MWA

This strategy would provide the means to move water between Abilene and NCTMWA, via the cities of Hamlin and Stamford, effectively increasing the reliability of water supplies to a four-county area. Where possible, this strategy would utilize existing and planned facilities. There is an existing 12-inch pipeline between Hamlin and Stamford and a proposed 14-inch pipeline from Abilene to Hamlin. To complete the connection, a new pipeline between Stamford and Haskell and necessary pumping facilities are proposed. There is an existing 6-inch pipeline between these cities as part of the Paint Creek WSC system, which could be used for a small amount of emergency supply. For long-term supplies, a new 14-inch pipeline would be needed between Stamford and Haskell.

As shown on Figure G-1, there are three distinct conveyance segments that could be used in various scenarios, depending on the demands and available supplies. Segment 1, the pipeline from Abilene to Hamlin, has a capacity of 2.0 mgd. Segment 2, the existing line from Hamlin to Stamford, can provide 1.2 mgd from Hamlin to Stamford or 1.3 mgd in reverse, and Segment 3 (the proposed new pipeline from Stamford to NCTMWA) would have a capacity of 2.0 mgd. Water sources include the sources for Abilene (currently Hubbard Creek, Fort Phantom Hill and O.H. Ivie reservoirs), Lake Stamford and Millers Creek Lake. This strategy does not create new supplies, but allows the movement of existing supplies in a variety of scenarios to best meet regional needs. With the recent completion of the Ivie Pipeline to Abilene and the California Creek diversion project at Lake Stamford[(1, 2)i], there is a greater amount of supply available in the region.

[i] Superscripted numbers in parenthesis refer to the corresponding reference listed at the end of this Appendix.



WEST CENTRAL BRAZOS STUDY

ABILENE TO NCTMWA INTERCONNECTION W/ EMERGENCY CONNECTION TO ANSON

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G-1
FIGURE

The water quality of the proposed water sources is generally good. Water from Abilene would most likely come from the Northeast water treatment plant, which receives water from Lake Fort Phantom Hill and Hubbard Creek Lake. The contract between Abilene and Hamlin is to provide treatment of water from Hubbard Creek Lake contracted through the city of Albany. Additional treated water to NCTMWA could be obtained from Abilene's system. Hubbard Creek Lake has a wide range of reported chloride and total dissolved solids levels. On occasion these constituents exceed the state's secondary drinking standards, but the median values meet the state standards. Mixing of the two sources also helps reduce potential elevated concentrations of salts. Lake Stamford has similar water quality to Hubbard Creek Lake, which is typical for west Texas. Miller Creek Lake is the third potential water source for this strategy and its water quality is generally good. There have been reported elevated concentrations of total organic carbon in Millers Creek Lake, which can increase treatment costs.

The potential environmental impacts are expected to be low. It is assumed that the new and proposed pipelines will be routed around environmentally sensitive areas if needed. Most of the pipeline is proposed to follow existing roadways. Impacts to the water sources are expected to be low since there is no significant increase in use from these sources.

The costs for this scenario will vary depending on the source of water and recipient. The limiting factors are the 12-inch pipeline between Hamlin and Stamford and the amount of water available from Abilene after Hamlin has taken their share. Assuming that approximately 1.2 MGD (average 700 acre-feet per year) could be moved from Abilene to NCTMWA on a regular basis, the cost per 1,000 gallons of treated water would be $3.36. Costs would be higher for emergency supplies only.

Anson Connection to Abilene-Hamlin Pipeline

An option of the Abilene to NCTMWA strategy is to provide an emergency connection to Anson. The 14-inch Abilene-Hamlin pipeline will pass approximately four miles from Anson. As previously discussed, the capacity of this line is 2.0 mgd. At this capacity, Anson could take 1.0 mgd from Abilene on an emergency basis. There would be no additional capacity to move water to NCTMWA from Abilene. NCTMWA could still receive water from Stamford. To provide water to both Anson and NCTMWA from Abilene, the Abilene-Hamlin pipeline would need to be upgraded to 18 inches. Since the pipeline is currently in design, this decision would

be needed soon. Alternatively, a small amount of water could be pumped from Stamford to Hamlin to Anson. This alternative is limited by the 1.3 mgd capacity of the Stamford-Hamlin pipeline.

The additional capital costs to upgrade the Abilene-Hamlin pipeline and provide a connection would be $2.5 million. These costs include upgrading approximately 21.5 miles of the Abilene-Hamlin pipeline to 18-inches and providing a 14-inch connection to Anson. This strategy could provide Anson with 1.4 mgd of treated water on a regular basis at a cost of $2.36 per 1,000 gallons.

If only a 12-inch connection to Anson is provided, with no upgrades to the Abilene-Hamlin line, the capital costs would be approximately $890,000. This could provide 1.0 mgd of emergency water. However, this supply would only be available on a limited basis.

The potential environmental impacts of the Anson connection are expected to be low. It is assumed that the Anson pipeline would follow existing roadways (County Road 707). Impacts to Abilene's water sources are expected to be low since this supply amount is small and Abilene has sufficient supplies to meet these demands.

An alternative to the Abilene-Hamlin pipeline (with the connection to Anson) is to utilize the existing WCTMWD raw water line to Anson. This alternative would have Abilene treat approximately 3.5 mgd of Hubbard Creek water and transport it to the junction of the WCTMWD-Anson pipeline. From there, the treated water would be conveyed to Anson through the existing 14-inch pipeline and to Hamlin through a new 14-inch pipeline. This alternative would require conversion of the raw water pipeline to treated water and would result in Anson receiving 100 percent treated water. This strategy is similar to proposals previously evaluated for Hamlin, Stamford and Anson, before the city of Stamford constructed the California Creek Diversion. At the time of the previous studies, the city of Anson declined to participate in the project in favor of operating their own water treatment system. It is uncertain whether Anson would be interested in a treated water strategy now. Preliminary cost estimates indicate that the capital costs for this alternative (3.5 mgd of treated water to Anson and Hamlin, using the WCTMWD pipeline) is approximately $2 million more than the direct Abilene to Hamlin pipeline with full upgrades for Anson.

Lake Creek to Millers Creek Lake (NCTMWA)

A strategy to divert water from Lake Creek into the Millers Creek watershed was evaluated to increase inflows to Millers Creek Lake. A previous study looked at diverting water by a pipeline from Lake Creek to Brushy Creek, a tributary of Millers Creek upstream of Millers Creek Lake[(3)]. Water would then flow by gravity into Millers Creek Lake. This diversion site was used to assess the viability of this strategy.

The drainage area at the diversion point was estimated at 112 square miles. The Brazos WAM was used to determine monthly inflows at Millers Creek Lake and the diversion point. Channel losses were applied from the discharge point to the lake. Using priority analysis, the available flows at the diversion point were nearly zero during drought conditions. Therefore, this analysis assumed all flows were available for diversion with appropriate compensation to downstream water rights holders. This assumption was also used for inflows into Millers Creek Lake.

To determine how much flow is available for diversion, the monthly inflows generated by the Brazos WAM were converted to daily flows by using nearby gages. The median daily flow at the Lake Creek diversion point was only 2.5 cfs. To protect instream flows needs, it was assumed that water would be diverted only if flows were above 5 cfs. Several diversion capacities were evaluated, and it was found that 10 mgd was the optimum capacity. Capacities greater than 10 mgd (15.5 cfs) had minimal impacts to the increase of reservoir yield.

Using this criterion (diverting all available flow above 5 cfs and below 15.5 cfs), the increase in firm yield of Millers Creek Lake was estimated at 800 acre-feet per year. A diversion structure, 24-inch pipeline and 350 HP pump station would be needed to transport the water to Brushy Creek. Outlet works and channel protection would also be needed at the discharge point. Further study would be needed to determine if flooding would increase along Brushy Creek. Agreements would also be needed with the BRA regarding the potential impact to Possum Kingdom Lake. No detailed assessment of these impacts was made at this time, but impacts to Possum Kingdom Lake are expected to be low due to the small amount of flow diverted.

The capital costs are estimated at $7.7 million for the diversion system. Using the increase in firm yield of 800 acre-feet per year, the cost for raw water is $2.76 per 1,000 gallons. Treated water costs are estimated at $3.11 per 1,000 gallons.

An alternative to this strategy would utilize an open channel to transport the water from Lake Creek to Brushy Creek. Assuming a minimum slope gradient of 0.25% for a gravity conveyance channel, the minimum elevation required at Lake Creek would be approximately 25 feet above the stream bank. For this scenario, a diversion structure, off-channel storage and pump station would be needed. Considerable excavation would be required for the gravity channel and there does not appear to be a cost advantage with this option. If this strategy is pursued by the NCTMWA, the costs and feasibility of a gravity channel could be reviewed at that time.

Eastland County WSD to Cisco

The city of Cisco obtains all its water from Lake Cisco. The estimated reliable yield of this lake is 1,300 acre-feet per year, including Battle Creek Diversion. This is sufficient to meet the projected demands for the city and the city's 2.1 mgd water treatment plant has sufficient capacity to provide Cisco with treated water. Lake Cisco is a single water source for Cisco and it has shown some vulnerability to drought during the 1980s. To reduce the risks associated with future drought or other possible catastrophic event, the city of Cisco could purchase treated water from Eastland County WSD for emergency supplies.

The city currently uses approximately 1.5 mgd of treated water. The Eastland County WSD system is capable of supplying 950 gpm (1.4 mgd) to Cisco through the city of Eastland without modification. A new 14-inch pipeline would be required between the city of Eastland standpipe and the city of Cisco's College Hill Pump Station to complete this scenario. No additional head pressure would be required from the District's water treatment plant. For smaller quantities of water, a smaller pipeline from Eastland to Cisco could be used. A schematic for this alternative is shown on Figure G-2.

A strategy for emergency or back-up supplies would provide 1 mgd or an average supply of approximately 500 acre-feet per year. For this strategy, a 10-inch pipeline would be needed, and the estimated annual cost would be $542,000. If Cisco were to develop the full 1.4 mgd from Eastland County WSD, with the 14-inch pipeline, the annual cost would be $787,000.

WEST CENTRAL BRAZOS STUDY

EASTLAND COUNTY WSD TO CITY OF CISCO

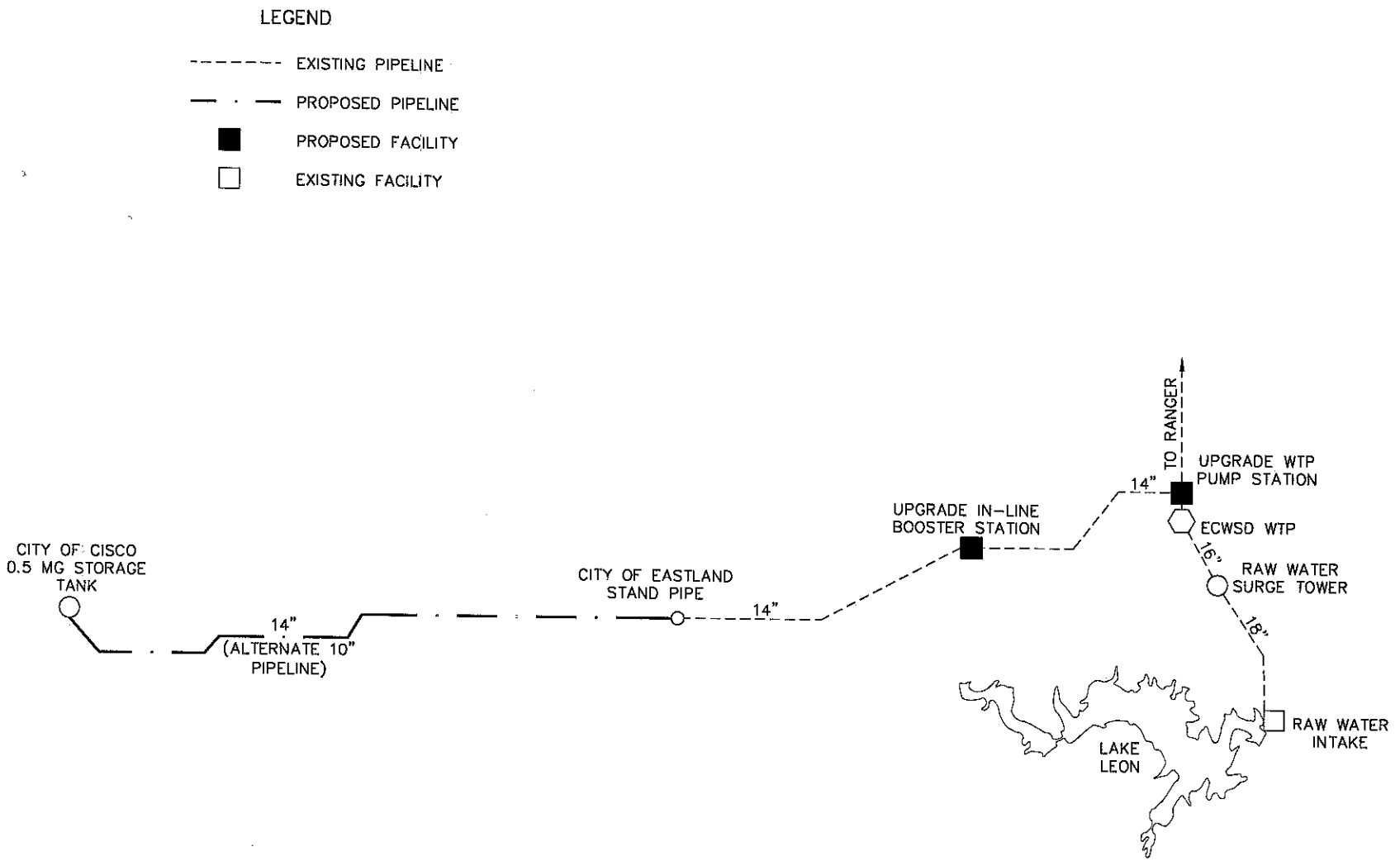

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FIGURE	G-2

West Central Brazos Water Distribution System (WCBWDS) Connection to Cisco

As an alternative supply source, Cisco could take raw water directly off of the WCBWDS pipeline and treat it at its water treatment plant on Lake Cisco. Water from Possum Kingdom Lake would be transported through the WCBWDS to the endpoint in Eastland County. From there, a new 10-inch pipeline would convey 500 acre-feet per year (1 mgd capacity) to Cisco's treatment plant. The plant would need to be upgraded with reverse osmosis to treat the water from Possum Kingdom. This would provide approximately 350 acre-feet per year of treated water. The water from Possum Kingdom could potentially be blended with Lake Cisco water at an approximate ratio of 1 to 3, but that would limit the quantity of water from Possum Kingdom to less than 0.5 mgd. It also would greatly reduce the quality of the finished water.

The total capital costs for the 1.0 mgd strategy are estimated at $8.7 million. More than half of this amount is associated with the expanded treatment facility. The estimated annual cost would be $788,100 for a potential emergency supply of 1 mgd. If the water from Possum Kingdom Lake were blended with water from Lake Cisco, the estimated annual cost would be $329,500 for a supply of 0.45 mgd. This cost reflects a smaller pipeline and pump station from the WCBWDS endpoint to transport 0.45 mgd and no treatment facilities. Both scenarios do not include a delivery fee for the use of the WCBWDS. It is likely that there would some fee, which would increase the annual costs for these scenarios.

Palo Pinto MWD Connection to Gordon

The city of Gordon relies on Lake Gordon for all of its water supply. Projected demands for the city are expected to nearly double over the planning period and the city is concerned about the reliability of their water source. To provide back-up supplies to Gordon, the city could potentially purchase raw water from Palo Pinto MWD, directly from Palo Pinto Lake. This strategy would include the construction of a 7.5-mile 6-inch raw water pipeline from Palo Pinto Lake to Gordon, along with a lakeside intake structure. Capital costs are estimated at $1.1 million, with treated water costs estimated at $4.07 per thousand gallons.

3. Interconnections to Meet Supply Shortages

These strategies utilize existing water sources to meet supply shortages that were identified over the planning period (2000 to 2060). For some entities, more than one strategy may be needed to achieve a safe level of supply.

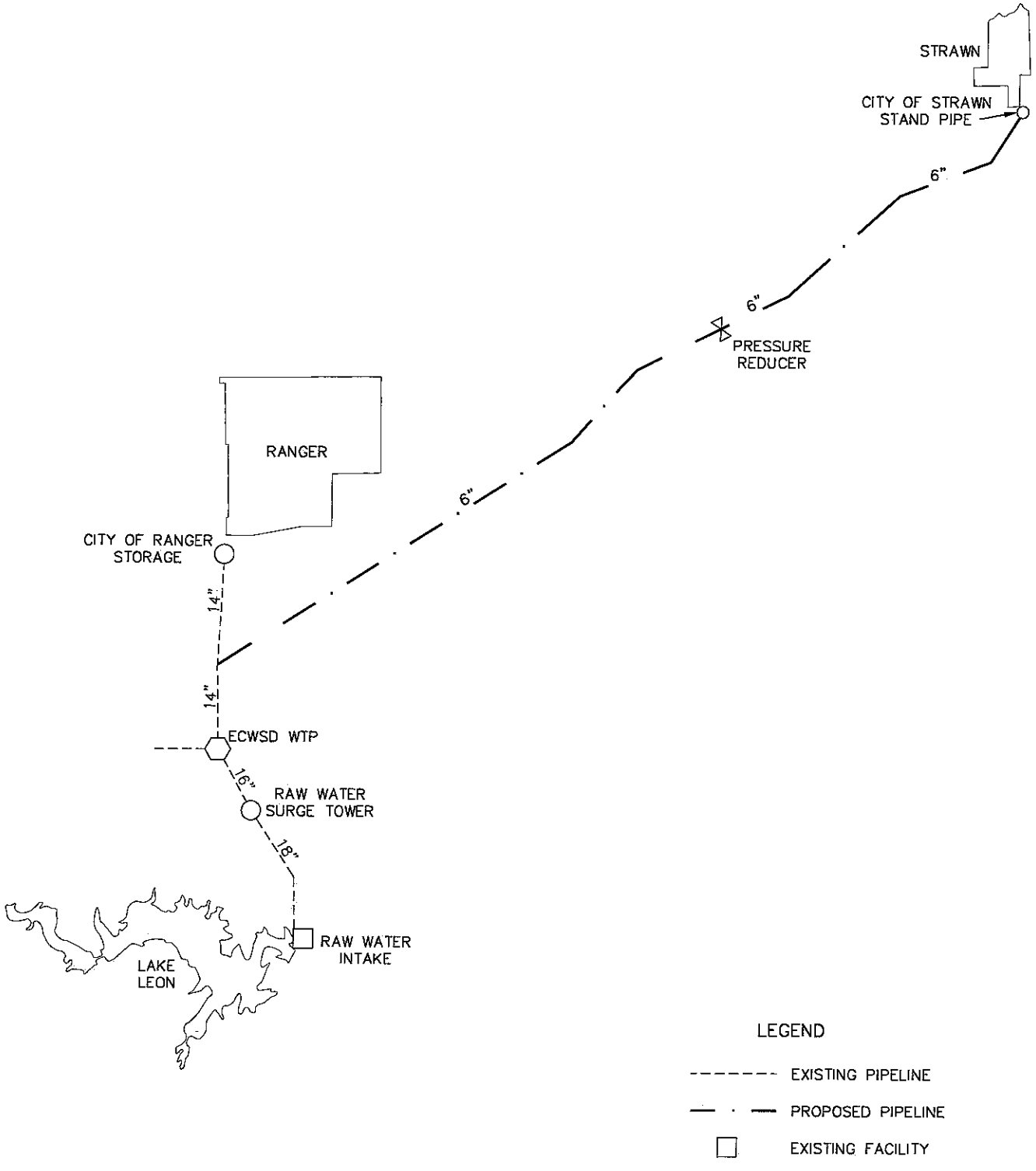
Eastland County WSD to the City of Strawn

The only water supply source for the city of Strawn is Lake Tucker, a small local lake. The reliability of this supply is unknown, but based on the performance of similar lakes in the area the reliability is probably low. The city treats its own water supply, and with new drinking water regulations, the cost of treatment is increasing. This strategy would supply Strawn with treated water from Eastland County WSD.

The source of water for Eastland County WSD is Lake Leon. This lake has historically responded well during drought and appears to have available supply. The projected long-term demands for Strawn are 196 acre-feet per year. Based on TCEQ requirements, the city is required to maintain a peak delivery capacity of approximately 0.25 mgd. The current Eastland County WSD system includes a 14-inch water line from the District's water treatment plant to the city of Ranger. To provide a supply of 0.25 mgd to the city of Strawn, approximately 13 miles of 6-inch line would be required from the 14-inch Ranger supply line to the city of Strawn. A pressure reducing valve is also required, using existing head pressure, due to the elevation of Ranger Hill to the east of the connection point. No other modifications to the District's system are necessary. The proposed improvements are shown on Figure G-3.

Water quality from Lake Leon is good. All reported chloride and TDS sampling concentrations were below the state's secondary drinking water standards. The potential environmental impacts are expected to be low. It is assumed that the proposed pipeline could be routed around environmentally sensitive areas. Environmental conditions at Lake Tucker could improve with reduced use. The city may need to periodically release water from Lake Tucker to avoid build up of salts due to evaporation. The small amount of additional demand on Lake Leon should have low to no environmental impacts.

The estimated cost is $3.33 per 1,000 gallons of treated water. This includes construction, operation and purchase costs.



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EASTLAND COUNTY WSD TO THE CITY OF STRAWN

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FIGURE

Eastland County WSD to 3P Water Group

The 3P Water Group is a group of water suppliers that includes the cities of Strawn and Gordon, Santo WSC, Sturdivant-Progress WSC, and North Rural WSC. Both Strawn and Gordon obtain their water supplies from local lakes. The three WSCs are current customers of Palo Pinto MWD and receive water from Palo Pinto Lake. During drought, water supplies from Palo Pinto MWD are sometimes restricted. With demands projected to nearly double over the planning period, these suppliers are looking for additional water sources. One strategy being considered by the group is purchasing treated water from Eastland County WSD and distributing the water through a regional pipeline.

This project proposes to supplement existing supplies with 850 acre-feet per year of treated water from Lake Leon. The assumed split of supplies is 61 acre-feet per year for Strawn, 92 acre-feet per year for Gordon and 232 acre-feet per year for each WSC. Water from Lake Leon would be treated at the Eastland County WSD's water treatment plant and transported through a new pipeline that would run east along Interstate 20 from Ranger to near the Palo Pinto County border. The suppliers would tap into the main trunk line at nearby connection points. An extension of the pipeline (as shown on Figure G-3A) would be needed for the North Rural WSC connection. To transport and treat the additional 850 acre-feet per year, additional improvements would be needed to the Eastland County WSD raw water line and treatment plant. The proposed improvements are shown on Figure G-3A.

The total capital costs for the strategy are estimated at $19.1 million. The estimated annual cost would be $1.9 million. The cost by user varies from $5.09 per 1,000 gallons for Strawn to $9.48 per 1,000 gallons for North Rural WSC. This split of cost by participant is shown in Appendix H following the cost table for the 3P Water Group.

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EASTLAND COUNTY WSD TO 3P WATER GROUP

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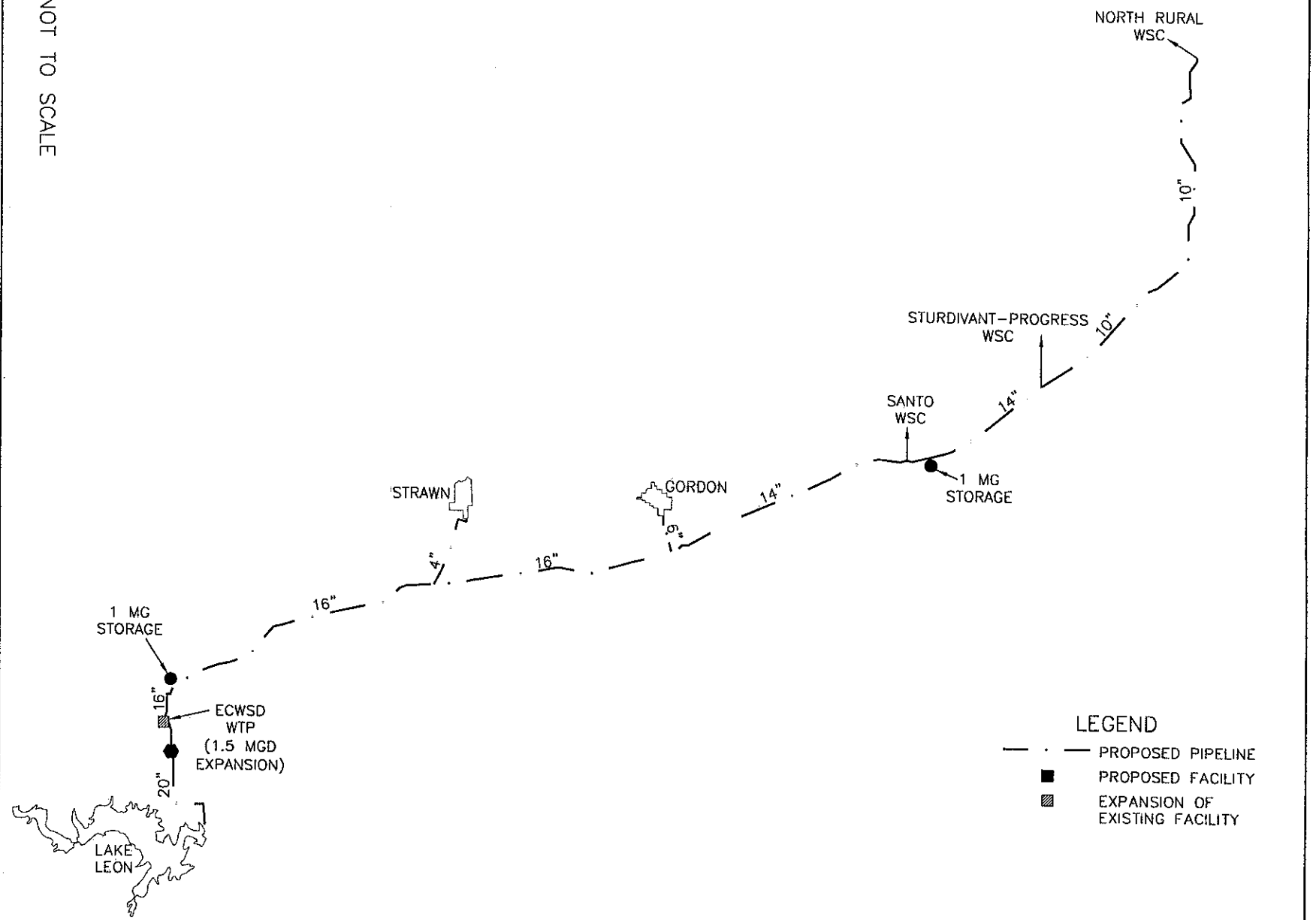

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FIGURE G-3A

Lake Stamford to Throckmorton

The city of Throckmorton is projected to need 338 acre-feet per year of additional supply by 2060. Its current source, Lake Throckmorton, is not reliable, and an emergency water supply contract with Fort Belknap WSC will expire in 2004. The city owns and operates a water treatment plant and has expressed interest in continuing to treat raw water. Two scenarios were evaluated to supply Throckmorton with water from Lake Stamford. The first scenario would supply Throckmorton with only the amount needed for the city, 340 acre-feet of raw water per year. The water would be treated at the city's existing water treatment plant. Water from Lake Throckmorton and/or Fort Belknap WSC could be used to supplement this supply. The second scenario would provide 800 acre-feet per year of water from Lake Stamford. The water could then be used to supplement the supplies of Shackelford WSC and Stephens County RWSC for customers near Throckmorton. This scenario would include an expansion of the Throckmorton water treatment plant or possibly a new facility operated by a WSC.

With the completion of the California Creek Diversion project at Lake Stamford [(1)] and the moth balling of the steam electric power plant on the lake, Lake Stamford has available supply. This strategy would include a new intake structure at Lake Stamford, pump station and 28-mile pipeline from the lake to Throckmorton as shown on Figure G-4. The pipeline would generally follow Highway 380.

Water from Lake Stamford tends to have slightly elevated chlorides and total dissolved solids when the content of the lake is low. With higher expected lake elevations due to the California Creek Diversion and reduced demands, the water should meet the state's secondary drinking water standards most of the time.

Potential environmental impacts are expected to be low. Most of the proposed pipeline will follow the right-of-way for Highway 380. It is assumed that the pipeline from the lake to Highway 380 can be routed to minimize impact on potentially sensitive areas if needed. Impacts to Lake Stamford should be negligible since the total demands on the lake are not expected to change significantly from current conditions and there should be additional supplies from the California Creek Diversion.

The cost for the 340 acre-feet per year scenario is $5.32 per 1,000 gallons of treated water. To transport and treat 800 acre-feet per year costs are $4.54 per 1,000 gallons.

WEST CENTRAL BRAZOS STUDY

LAKE STAMFORD TO THROCKMORTON

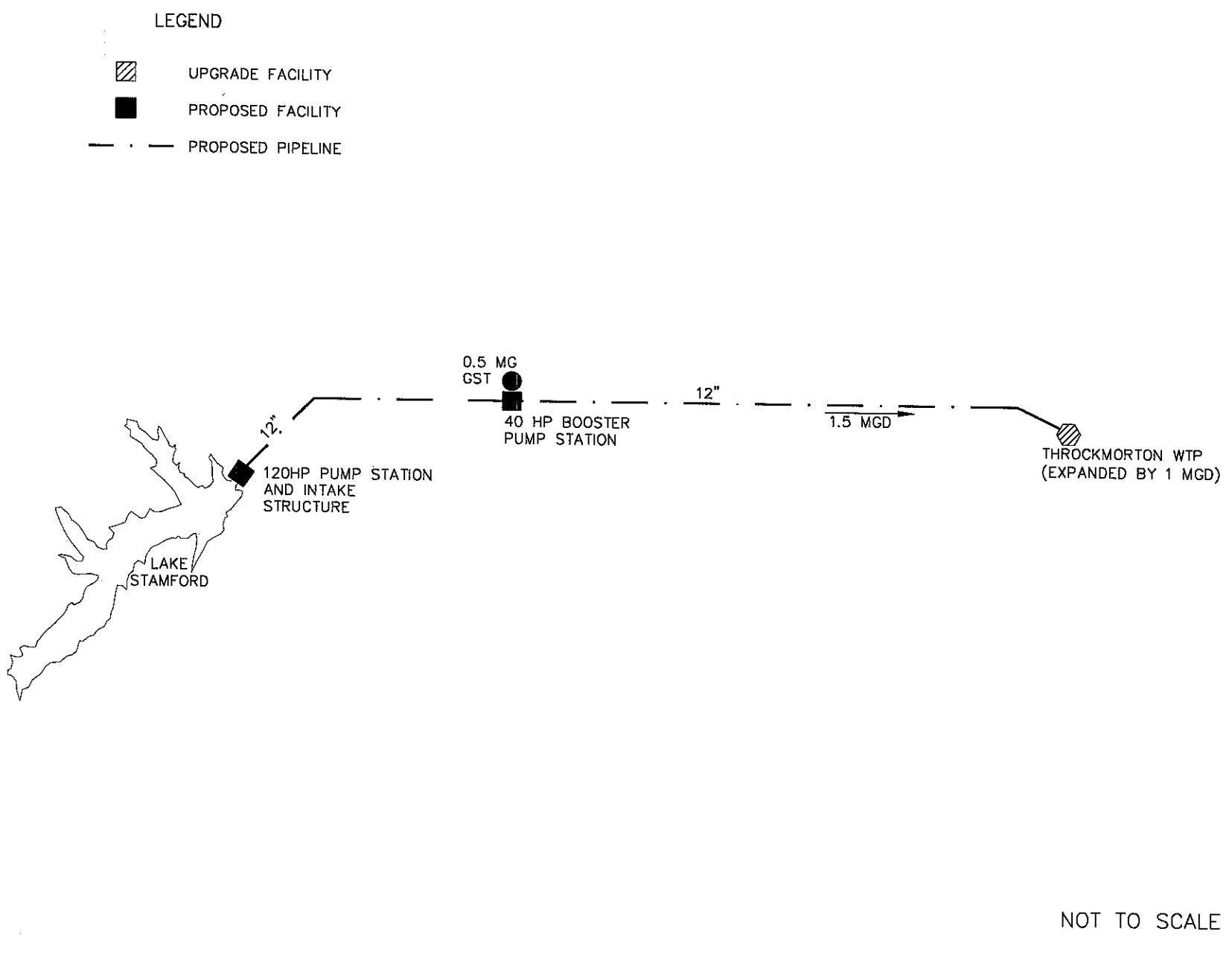

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FIGURE	G-4

Zephyr WSC to Northeast Brown County

Water supply corporations supply most of the water to rural Brown County from Lake Brownwood. A small area in northeast Brown County near the divide between the Colorado and Brazos river basins relies on groundwater from the Trinity Aquifer. Groundwater in this area is heavily used and the reliability of this water source is uncertain. The Region F Water Plan[4] shows this area to be in need of immediate and long-term supplies. The regional water plan recognizes that the most likely source of water for this area would be Lake Brownwood, either through a local WSC or a direct connection to Brown County WID #1. To estimate the cost of providing treated surface water to this area, a transmission line from the Brown County WID WTP to the city of May was evaluated. This strategy would provide 580 acre-feet per year of water at a cost of $5.30 per 1,000 gallons.

As an alternative to the Region F strategy, there is a current study to expand service from Zephyr WSC to provide water to northeast Brown County. Zephyr WSC receives water from Lake Brownwood through the cities of Early and Brownwood. The current Zephyr WSC service area boundaries extend within about seven miles of the area of concern. The WSC plans to expand its CCN boundaries and upgrade its distribution system, and the WSC has recently completed plans for water system improvements through a grant by USDA Rural. The proposed improvements with some additional expansion could serve approximately 140 customers in the area. Based on the hydraulic analyses, approximately 26.3 miles of new water lines, ranging in sizes from 2 inches to 6 inches, would be needed to serve this area. A new pump station would also be necessary. The capital costs for the infrastructure improvements are estimated at $2.8 million. The cost per 1,000 gallons of treated water would be approximately $5.47. Details of this strategy were analyzed as part of the hydraulic study and are shown on Figure F.9 in Appendix F.

Lake Brownwood has sufficient supplies to meet these demands and the water quality of this source is good. There should be minimal environmental impacts associated with a distribution expansion. The reduced pumping on the Trinity aquifer should improve water availability of this source for other uses.

Abilene to Lawn

The city of Lawn presently uses water from Lake Coleman and treats it at its own water treatment plant. The city is finding it difficult to meet treatment standards with its current plant. Also, the supply from Lake Coleman may not be reliable during drought, as demonstrated during the most recent drought. Potential supplies to Lawn include a direct pipeline from Abilene's south side distribution point or an interconnection with Steamboat Mountain WSC. Both scenarios were evaluated.

The Steamboat Mountain WSC system is located in close proximity to the city of Lawn. To meet Lawn's needs, Steamboat Mountain WSC would need to provide at least 180 gpm to the city. The hydraulic analysis evaluated the improvements required to provide 250 gpm to Lawn. These improvements included about 10.5 miles of 8-inch and 10-inch water lines, as well as an in-line pump station and elevated storage tank. See Appendix F, Figure F.4 for details of the proposed improvements. The total capital costs are estimated at $1.9 million. Assuming a water purchase cost of $2.00 per 1,000 gallons, the annual costs for 150 acre-feet per year are $255,400. This is $5.23 per 1,000 gallons.

If a pipeline were constructed directly from Abilene to Lawn, then approximately 13 miles of 8-inch line with one pump station would be needed. The total capital costs are estimated at $2.4 million, with an annual cost of $264,600. The cost per 1,000 gallons of treated water would be $5.41. Under current assumptions both costs are similar; however, depending on the negotiated water purchase cost there could be greater cost differences in the strategies.

Westbound WSC to Rising Star

Rising Star currently uses groundwater from the Trinity (Antlers) aquifer. This portion of the aquifer has elevated levels of nitrates. The city is considering installing reverse osmosis treatment to address the nitrate concerns. Alternatively, the city could supplement its current groundwater supply with water from Westbound WSC. This strategy would provide Rising Star with higher quality water and increase the reliability of its water supplies.

The projected demands for Rising Star are approximately 120 acre-feet per year over the planning period. Nine wells located within the city limits currently provide all of the city's water supply. A proposed expansion of Westbound's distribution system would place the WSC's

system very near the city limits of Rising Star. With some proposed pipeline upgrades and increased pumping capacity, the Westbound system could provide up to 200 gpm to Rising Star, which would meet all of Rising Star's projected demands. These improvements are shown on Figure F.5 in Appendix F, and include upsizing approximately 20 miles of water line between the proposed well field and Rising Star. All of these lines are proposed as part of Westbound's current Rural Development Project. Upsizing of the WSC's proposed Well Field pump station, the proposed FM 169 in-line pump station and the existing south Cisco pump station would also be necessary. With no improvements to the proposed Westbound WSC expansion, the WSC could provide Rising Star with only 40 gpm. Rising Star would need to continue using water from their existing wells and install advanced treatment for nitrates. A larger quantity of good quality water would be needed to blend with Rising Star's existing supply to meet the nitrate standards without additional treatment. However, the use of the 40 gpm from Westbound WSC would decrease the amount of water requiring treatment and would serve as an alternate water source to increase the reliability of the city's supply.

Most of the water from Westbound WSC to Rising Star would come from the new proposed well field northeast of Cross Plains. Groundwater in this area is generally good quality. The environmental impacts for this project are low to none. Irrigation production from the aquifer in this area has reportedly decreased due to the decline in peanut farming in the area, and therefore competing demands should be low. All of the proposed improvements are part of an existing project and there should be no additional impacts associated with the proposed upgrades. There would be no net increased demands on the Trinity aquifer.

To meet all of Rising Star's needs, the capital costs to upgrade Westbound's system would be approximately $1.47 million. This could provide Rising Star with an average of 150 acre-feet per year of treated water at $4.22 per 1,000 gallons. To treat Rising Star's existing supply with ion exchange and construct a backup connection to Westbound WSC for 50 acre-feet per year, the total capital costs would be $744,000. The costs per 1,000 gallons of treated water would be $1.86.

Midway Group Interconnections/ Regional WTP

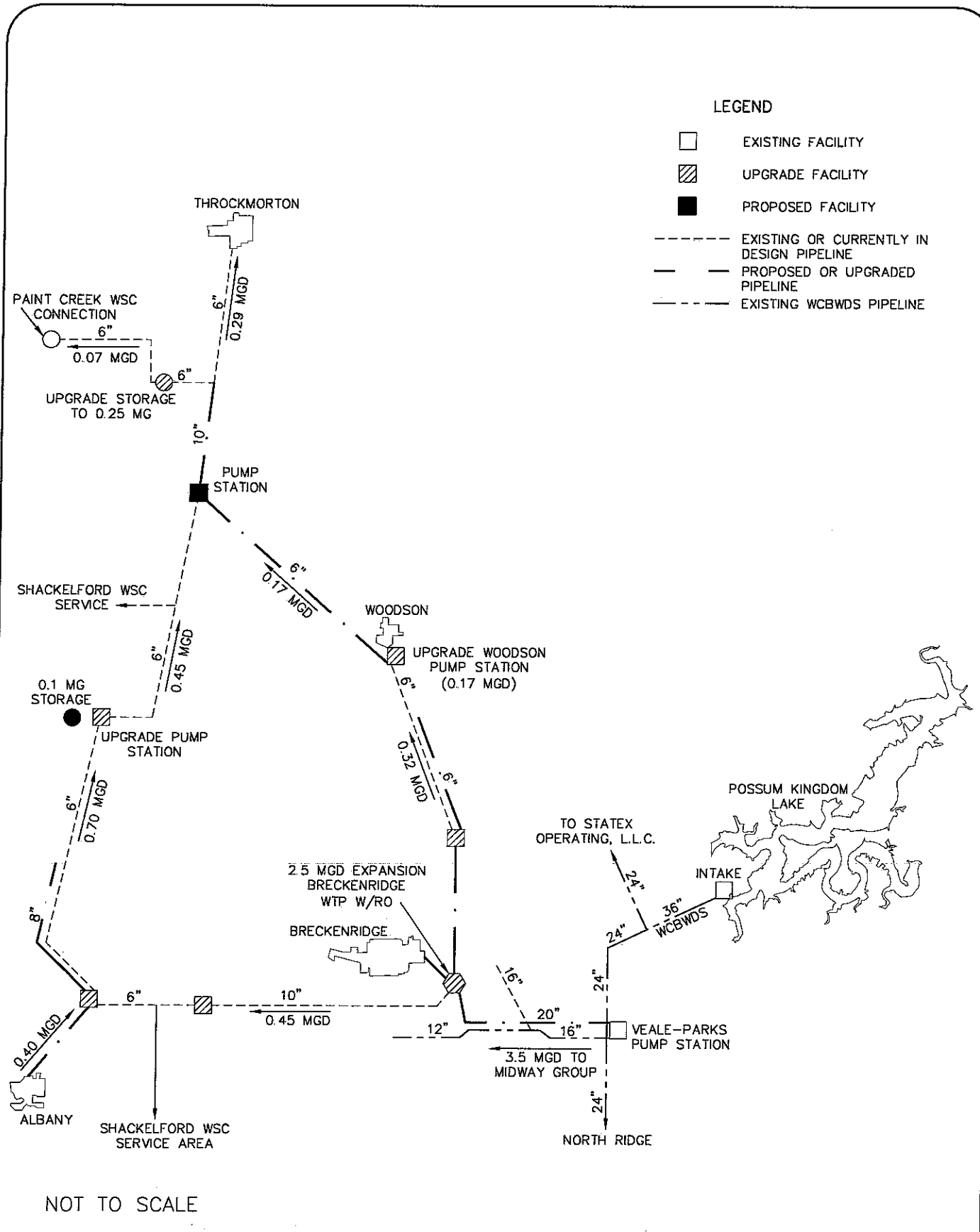
The Midway Group consists of Shackelford WSC, Stephens County RWSC, Breckenridge and Throckmorton. These four entities provide much of the water in Shackelford,

Stephens and Throckmorton Counties. Primary water sources for the group include Hubbard Creek Lake, Lake Daniel, Lake Throckmorton and a contract with the city of Albany, which receives water from Hubbard Creek Lake and Lake McCarty. Shackelford WSC and Stephens County RWSC do not have sufficient supplies to meet projected demands under current contract conditions, and Throckmorton's supply is unreliable. The city of Breckenridge has sufficient supplies for the short term, but Lake Daniel is currently very low and the amount of reliable supply from this source is uncertain.

To meet the needs of the Midway Group, this strategy proposes to use water from Possum Kingdom Lake. This water would be transported to a regional water treatment facility near Breckenridge via the WCBWDS, and distributed using existing facilities, upgraded proposed facilities and new facilities. Figure G-5 presents a general schematic of the proposed improvements required for this strategy. A more detailed evaluation of this strategy is included in Appendix F.

Shackelford WSC has a contract with BRA for 353 acre-feet per year of water from Possum Kingdom Lake. Requests for Possum Kingdom water from Stephens County RWSC and Breckenridge (via WCTMWD) are pending. This strategy assumes a raw water supply of 2,000 acre-feet per year (Shackelford's contract and other requests). Assuming 30 percent of this supply is lost as reject water during treatment, the available treated supply is approximately 1,400 acre-feet per year. The projected need for the group is nearly 800 acre-feet per year.

The WCBWSD would be used to move the 2,000 acre-feet of water from Possum Kingdom Lake to the regional water treatment plant. Hydraulic analyses of this pipeline found that a new 20-inch pipeline and some pump station improvements were needed to meet the peak demands of BRA's current customers and the Midway Group. To treat the water, the existing water treatment plant at Breckenridge would be expanded with a 2.5 mgd microfiltration and reverse osmosis facility. The reject water could possibly be discharged to evaporation beds, brine disposal well, to the WCBWDS pipeline for delivery to on-going oil field water flood operations or other means.



WEST CENTRAL BRAZOS STUDY

MIDWAY GROUP INTERCONNECTIONS WITH REGIONAL WATER TREATMENT PLANT

F&N JOB NO.	BRA02372
DATE	DEC. 2003
SCALE	AS SHOWN
DESIGNED	SFK
DRAFTED	CAM
FILE	MIDWAY GROUP.dwg

G-5
FIGURE

This strategy proposes to supply Throckmorton with 193 acre-feet per year (200 gpm) through upgrading Shackelford WSC's planned expansion into Throckmorton County and utilizing existing and new water lines in Stephens County RWSC system. To meet the city's full demands (340 acre-feet per year), a new water line from the water treatment plant to Throckmorton would be needed. This scenario assumes that Throckmorton will continue to use some water from Lake Throckmorton and/or extend its contract with Fort Belknap.

Of the remaining supply, approximately 250 acre-feet per year of treated water would be provided to Shackelford WSC, 400 acre-feet per year to Stephens County RWSC and 550 acre-feet per year to Breckenridge to supplement current contracted supplies. The water for Shackelford WSC would be taken south of Breckenridge and transported through the WSC's system to a proposed in-line pump station on Highway 180. The water would then be conveyed to the WSC's office pump station where it could be blended with water from the city of Albany and transported to an existing booster pump station near Ft. Griffin. From there, water would be distributed to Shackelford 's customers and the city of Throckmorton. This scenario requires approximately 11.5 miles of upgrades to existing or planned water lines, upgrades of 5 pump stations and several new facilities. Some of these improvements are already proposed to serve retail customers of Shackelford WSC.

Stephens County RWSC and Breckenridge would take treated water directly from the water treatment plant. New connections to their existing distribution facilities would be needed. Some upgrades to Stephens County RWSC system as shown on Figure G-5 are also necessary to move water to Throckmorton and expand service to retail customers. These improvements include nearly 13 miles of new 6-inch pipeline and upgrades to Stephens County RWSC's two existing pump stations. No additional improvements are proposed for Breckenridge.

The environmental impacts are expected to be low for the transmission improvements and system upgrades. Most of the upgrades are to existing or proposed pipelines. It is assumed that new pipelines can be routed around environmentally sensitive areas, if needed. Environmental impacts for the reject water from the treatment facility could be low to moderate, depending on the selected disposal method. Further study is needed on the disposal options and potential impacts. There should be minimal impacts to Possum Kingdom Lake from this

strategy. The quantity of water represents a small amount of the total yield of lake, and would have little impact on water levels.

The total capital costs for this strategy are estimated at $17.2 million, which includes upgrades to the WCBWDS pipeline and a 2.5 mgd water treatment facility. The cost for treated water would be $4.12 per 1,000 gallons. This does not include power costs to move the water to Throckmorton or other WSC customers.

Possum Kingdom Lake to WCTMWD

WCTMWD provides water from Hubbard Creek Lake to four member cities: Breckenridge, Albany, Anson and Abilene. Current contract obligations exceed the reservoir's firm yield under WAM analysis, and WCTMWD is looking for additional water to supplement its supply from Hubbard Creek Lake. The District has made a request to the BRA for water from Possum Kingdom Lake. This water would be transported to Hubbard Creek Lake using the existing WCBWDS, and possibly blended with water from Hubbard Creek Lake.

The water quality concerns at Hubbard Creek Lake include chlorides and total dissolved solids (TDS). Concentrations generally fall just below the secondary treatment standards, with higher levels recorded during low flow periods. Blending water from Possum Kingdom Lake with Hubbard Creek Lake would be limited without additional treatment to remove salts. Using the median values of chloride and TDS, the maximum blending ratio is 0.035:1.0. This greatly limits the amount of water from Possum Kingdom Lake that could be discharged into Hubbard Creek Lake and still treated with conventional treatment. Assuming that water from Possum Kingdom Lake is only blended with Hubbard Creek Lake when the volume of water in Hubbard Creek Lake is greater than 75,000 acre-feet, then the amount of water from Possum Kingdom Lake is limited to 2,500 acre-feet per year. When this amount is pumped evenly over the year, the firm yield of Hubbard Creek Lake increases by 1,475 acre-feet per year. However, continual pumping of Possum Kingdom Lake water during Hubbard Creek Lake's long critical period (11 years) will result in continual deterioration of water quality in the receiving reservoir, and most likely require advanced treatment of all water in Hubbard Creek Lake if the water is not blended with an additional high quality source. Due to the concerns of greatly impacting a significant water source, it is not recommended to blend water from Possum Kingdom Lake directly in Hubbard Creek Lake.

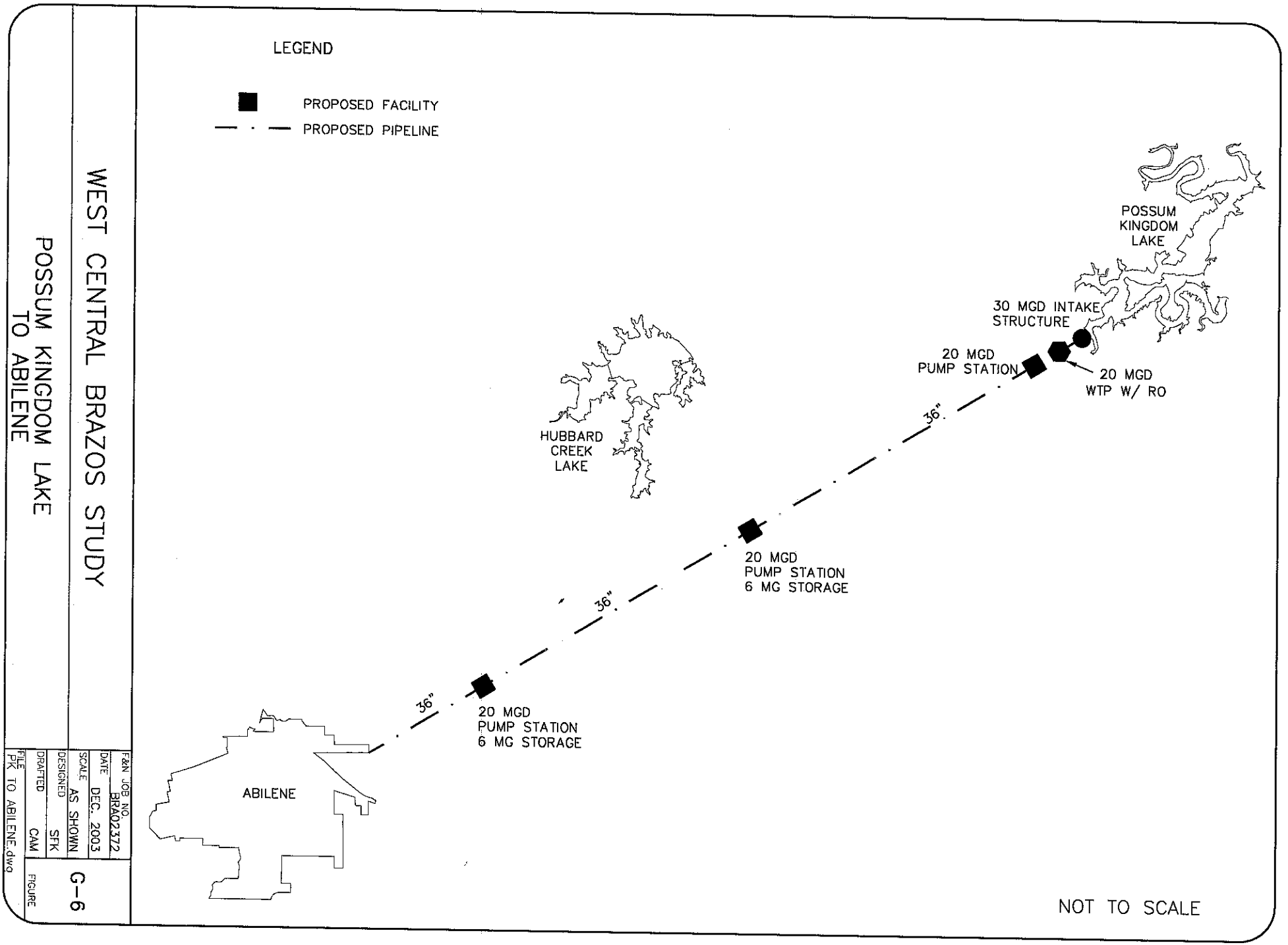
However, if WCTMWD pursues this strategy, improvements will be needed to the WCBWDS, including new 14-inch and 24-inch pipelines and upgrades to the existing pump stations. Upgrades to the WCBWDS necessitated by moving water for the Midway Group will also be needed for this strategy. The costs are estimated at $1.20 for raw water. Additional costs would apply for treatment and transmission to WCTMWD customers.

Possum Kingdom Lake to Abilene

The city of Abilene is a major water provider in the West Central Brazos study area. Current supply sources, including supply from Lake Ivie, appear to be adequate to meet the City's projected demands. However, the reliability of the supply from these sources, especially Lake Ivie, is uncertain. The upper Colorado River basin is currently in drought of record conditions, which means that the available supply from this reservoir is probably less than previously estimated. When the drought is over, the impact on supply will be assessed and it is likely that contract amounts will be reduced accordingly. This could have a significant impact on Abilene's long-range water planning. To ensure adequate supplies in the future, the WCTMWD has made a request on behalf of Abilene for 20,000 acre-feet per year of water from Possum Kingdom Lake. This water would be needed sometime after 2030, depending on the status of Abilene's other water sources.

The hydraulic analysis of the existing WCBWDS pipeline found that significant improvements would be needed to transport Abilene's request of 20,000 acre-feet per year to the existing WCTMWD pipeline. Since these improvements included new pipeline capable of handling all of Abilene's requested supply, there were few benefits in using the WCBWDS for Abilene. For this scenario, it is assumed that the water from Possum Kingdom Lake would be treated at the lake and transported approximately 71 miles through a new 36-inch pipeline to Abilene as shown on Figure G-6. This scenario would require a new intake structure at Possum Kingdom, a 20 mgd water treatment plant with reverse osmosis, 20 mgd pump station, and several booster pump stations. The pipeline would be routed around Hubbard Creek Lake and could possibly be used to supply other customers along the route.

The reject water from the treatment plant could possibly be discharged to Possum Kingdom Lake, disposed through a brine injection well or discharged to evaporation beds. For a facility of this size, the area needed for evaporation beds could be quite large. Discharging to the



WEST CENTRAL BRAZOS STUDY

POSSUM KINGDOM LAKE TO ABILENE

FAN JOB NO.	BRA02372
DATE	DEC. 2003
SCALE	AS SHOWN
DESIGNED	SFK
DRAFTED	CAM
FILE	PK TO ABILENE.dwg

FIGURE G-6

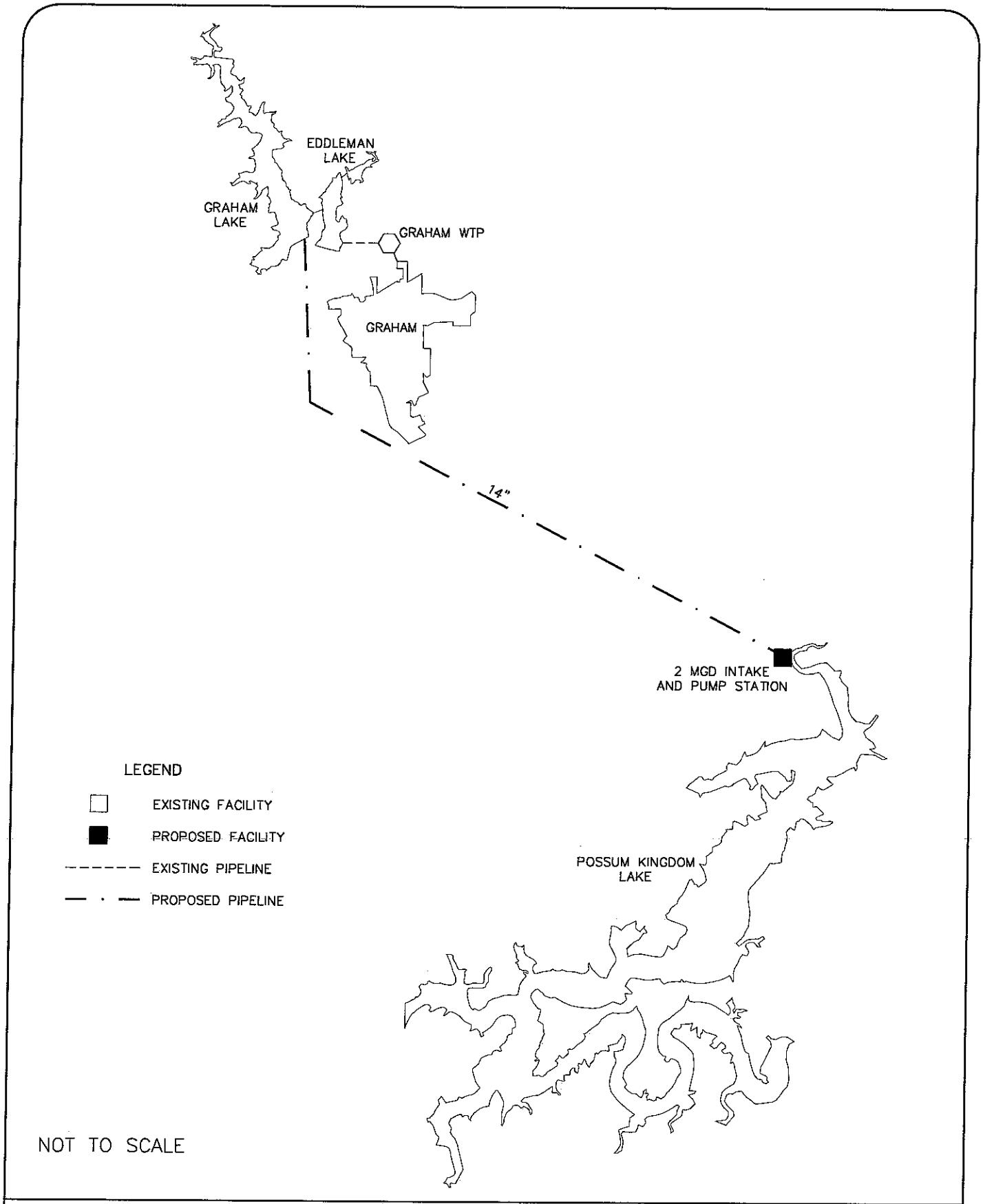
lake would require detailed water quality and impact studies before TCEQ would consider permitting this option. A brine disposal well would be permitted through the Railroad Commission. Existing disposal facilities may be available. The potential environmental impacts would depend on the disposal option selected and the findings of additional studies. For the pipeline, environmental impacts are expected to be low to moderate. The pipeline, where possible, could be routed to avoid environmentally sensitive areas. This strategy could lower lake levels, which may impact recreation at the lake.

The total capital costs for this scenario are estimated at $128 million. Approximately 40 percent of this cost is associated with the new water treatment plant. The cost for treated water at Abilene would be $3.39 per 1,000 gallons.

Direct Pipeline to Graham

The city of Graham is a provider for several WSCs and communities in Young and Throckmorton Counties. Graham's only water source is Lake Graham. The estimated firm yield of the lake is slightly more than 7,000 acre-feet per year. The current demands on Lake Graham are approximately 5,300 acre-feet per year, increasing to over 6,100 acre-feet per year by 2060. Over half of this demand is water for steam electric power, and steam electric use could be higher depending on future power needs. With the uncertainties associated with drought and increasing demands, the city of Graham is looking to supplement its current supplies. Graham has made a request to BRA for 1,000 acre-feet per year of water from Possum Kingdom Lake. This water would be transported 14 miles directly from Possum Kingdom Lake to Lake Graham through a new 14-inch pipeline as shown on Figure G-7. Use of the WCBWDS was determined unlikely since the distance from the WCBWDS endpoint to Graham was approximately the same as a direct line from Possum Kingdom Lake.

The pipeline would be capable of transporting 2.0 mgd, with an average use of 1,000 acre-feet per year. The water would be discharged directly to Lake Graham and used to supplement the yield of the reservoir. The water quality of Lake Graham is generally good, and could be blended with the poorer quality water from Possum Kingdom. Using the median values for chlorides and total dissolved solids, the maximum mixing ratio would be one part Possum Kingdom water to six parts Lake Graham water. The current capacity of Lake Graham is 45,000



WEST CENTRAL BRAZOS STUDY

POSSUM KINGDOM LAKE TO LAKE GRAHAM W/ BLENDING

F&N JOB NO.	BRA02372
DATE	DEC. 2003
SCALE	AS SHOWN
DESIGNED	SFK
DRAFTED	CAM
FILE	PKL_TO_GRAHAM.DWG

G-7
FIGURE

acre-feet, which provides a significant volume for blending. To maintain acceptable chloride concentrations in Lake Graham, it is assumed that the water from Possum Kingdom is only blended with Lake Graham when there at least 10,000 acre-feet of water in Lake Graham. To assess the impacts of this strategy on the firm yield of Lake Graham, a reservoir operation model was used. The model assumed that 1,000 acre-feet of Possum Kingdom water was pumped evenly over the year, with no water pumped when Graham was less than 10,000 acre-feet or greater than 35,000 acre-feet. This scenario increases the firm yield of Lake Graham by 700 acre-feet per year. However, continual pumping of Possum Kingdom water during Lake Graham's critical period without significant inflows would result in continual deterioration of water quality in Lake Graham. If blending is used, it will be necessary to monitor water quality in the lake. Due to these water quality concerns, the reliability of using water from Possum Kingdom during drought is low, and this scenario could greatly increase treatment costs for all of the water in Lake Graham.

The total capital costs for this blended strategy are estimated at $5.8 million. For a yield of 700 acre-feet per year, the cost per 1,000 gallons of treated water is $2.76. If additional treatment were needed, the costs would be much higher.

Alternatively, the 1,000 acre-feet of water from Possum Kingdom could be treated using reverse osmosis and blended with Graham's other treated water supplies. The amount of additional supply would be the same, 700 acre-feet per year. The total capital cost for this strategy is estimated at $11.8 million, which includes a 1.5 mgd water treatment plant upgrade with reverse osmosis. The cost for treated water would be $5.16 per 1,000 gallons.

The maximum amount of water from Possum Kingdom that could be blended with water from Lake Graham at the city's WTP and still allow conventional treatment (no reverse osmosis) is 360 acre-feet per year. This quantity is based on the total municipal demand of approximately 2,700 acre-feet per year, with a mixing ratio of one to six. Assuming a smaller pipeline (10-inch) and pump station to transport this quantity, the total capital costs would be $3.8 million. The cost for treated water would be $3.23 per 1,000 gallons. This scenario provides more control over the water quality of the raw water source and better protects the good water quality of Lake Graham than blending directly in the lake.

Palo Pinto County MWD and Mineral Wells

Palo Pinto County MWD provides water to Mineral Wells, several small communities, and an electric generating facility. The sole source of water for Palo Pinto County MWD is Lake Palo Pinto. The firm yield of the lake under WAM analysis is estimated at 12,890 acre-feet per year, reducing to 10,900 acre-feet per year by 2060 due to reduced capacity from sedimentation. The total demands on the lake are approximately 6,500 acre-feet per year, and are projected to increase to nearly 10,000 acre-feet per year by 2060. Presently, the electric power plant on Lake Palo Pinto is no longer operating. This has reduced the demands on Lake Palo Pinto, but it is uncertain whether the power company will renew its operations at Lake Palo Pinto and if so, at what capacity.

With the projected growth in Parker County and demands on Lake Palo Pinto, the District is looking for additional water supplies. Two strategies were identified for Palo Pinto County MWD: 1) releases of water from Possum Kingdom Lake for diversion at Mineral Wells, and 2) expansion of their current facilities with the construction of Turkey Peak Reservoir. Release of water from Possum Kingdom Lake is a strategy that uses existing sources to meet needs and is included in this section. Turkey Peak reservoir would provide a new water source and is discussed separately in Section 4 below.

Releases from Possum Kingdom Lake to Palo Pinto Co. MWD

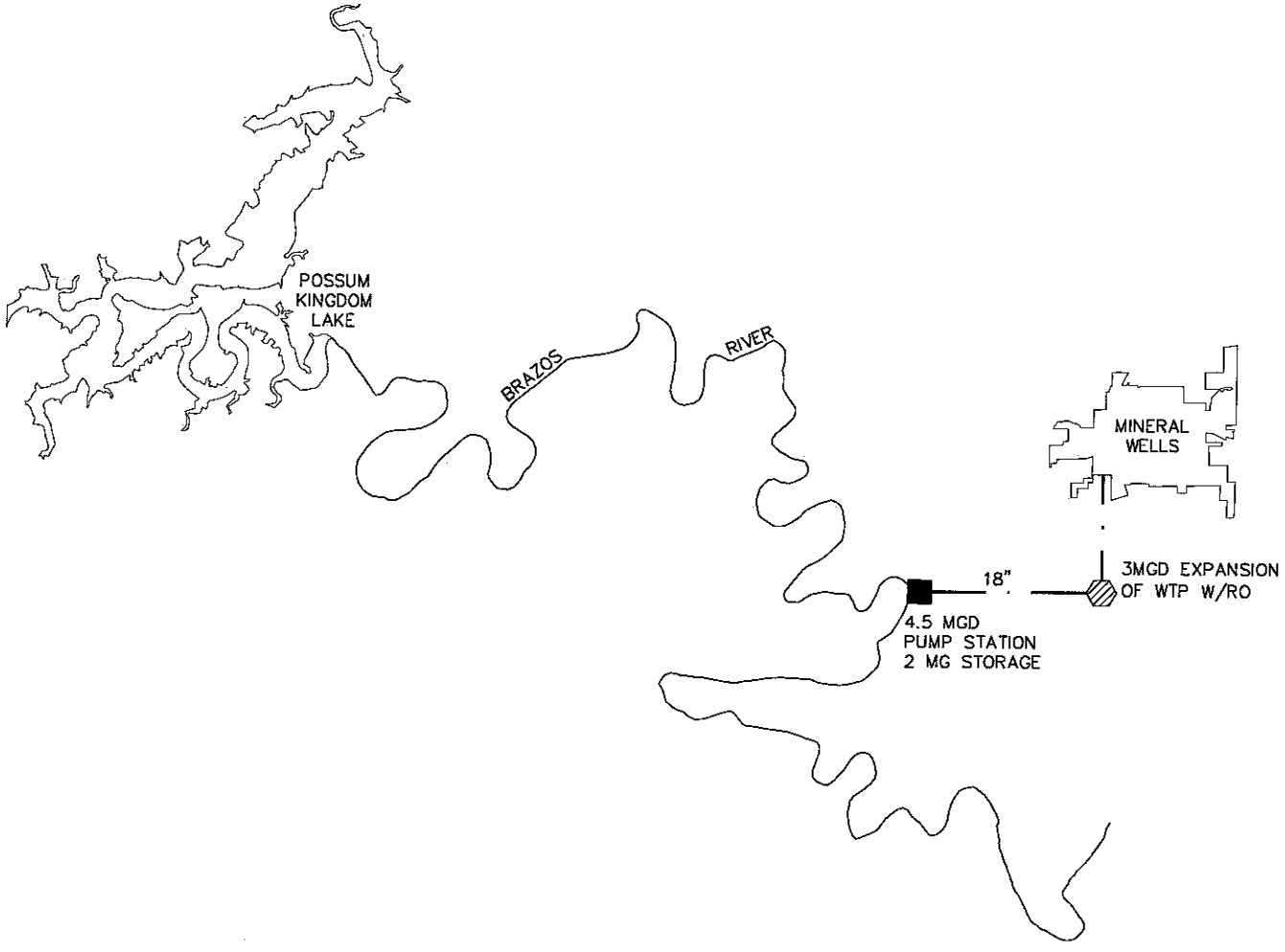
The city of Mineral Wells has a temporary permit to use water from the Brazos River on an emergency basis [(5)]. However, the amount of additional supply during drought is uncertain. To provide a more reliable supply, water could be released from Possum Kingdom Lake down the Brazos River to a diversion point near Mineral Wells. Approximately 2,500 acre-feet per year of raw water would be needed by 2060 to provide a safety factor of 25 percent above the projected demands. A small diversion structure, off-channel storage facility, pump station and 18-inch pipeline would be needed to convey the water from the Brazos River to a treatment facility in Mineral Wells. The water from Possum Kingdom would be treated at a new or expanded 3 mgd facility with reverse osmosis or similar technology, and then blended with water from Lake Palo Pinto. The reject water from treatment would be discharged to evaporation beds or to a brine disposal well. While the quality of the water in the Brazos River is marginal near

Mineral Wells, it is unlikely that a discharge permit directly to the river would be granted. A schematic of this scenario is shown on Figure G-8.

The quality of the water from Lake Palo Pinto is very good and could possibly be blended with water from Possum Kingdom. The maximum blending ratio would be one part Possum Kingdom water to 3.5 parts water from Lake Palo Pinto to meet State standards. Since water from Possum Kingdom would be used to meet the projected municipal demands (7,500 acre-feet per year by 2060), the amount of water from Possum Kingdom that could be blended would be 1,500 acre-feet per year. The median chloride concentration of the blended supply would be 261 mg/l, which is below secondary standards but considerably higher than the concentrations in Lake Palo Pinto. Most likely, a smaller amount of water would be used to maintain lower salt concentrations in the blended supply. If a greater supply from Possum Kingdom were needed, it would be treated with reverse osmosis.

The costs to blend 1,000 acre-feet per year of water from Possum Kingdom with Lake Palo Pinto supply would be $1.27 per 1,000 gallons. This is based on a diversion facility and 12-inch pipeline to transport the water to Mineral Wells' existing water treatment plant. No additional treatment facility is included. To utilize the full 2,500 acre-feet per year from Possum Kingdom, the capital costs would be $15.8 million, which is much higher due to the reverse osmosis treatment facility. The cost per 1,000 gallons of treated water would be $3.18. Costs for a partially blended, partially treated scenario would fall in between.

The environmental impacts for the blended scenario would be low to moderate. A more detailed study would be needed to site and design the diversion structure. An assessment of potential wetlands, endangered species, and archeological impacts would be needed as well as the impacts to stream flows. Releases from Possum Kingdom Lake will increase stream flows in the reach between the lake and the diversion point. Flows below the diversion point should not decrease.



LEGEND

- UPGRADE FACILITY
- PROPOSED FACILITY
- PROPOSED PIPELINE

NOT TO SCALE

WEST CENTRAL BRAZOS STUDY

RELEASES FROM POSSUM KINGDOM LAKE TO PALO PINTO MWD WITH TREATMENT

F&N JOB NO.	BRA02372
DATE	DEC. 2003
SCALE	AS SHOWN
DESIGNED	SFK
DRAFTED	CAM
FILE	PKL TO PP.dwg

G-8
FIGURE

Lake Alan Henry to Local Water Users

Lake Alan Henry is located in the upper Brazos River Basin in Kent and Garza County. The Authority owns and operates the dam, and the city of Lubbock has a Water Supply Agreement with the Authority for 100 percent of the water in the lake. There is no infrastructure in place for Lubbock to use the water at this time and there is the potential that water may be available to other users. The firm yield of Lake Alan Henry is estimated at 22,500 acre-feet per year. This estimate incorporates a subordination agreement between the Authority and Lubbock that allows Lake Alan Henry to impound inflows that otherwise would be released to meet senior water rights of Possum Kingdom Lake.

Water quality at Lake Alan Henry is relatively good and options to release water down the Brazos River to downstream users are limited because of impaired water quality concerns and stream losses over significant distances. As a result, the most likely recipients of water from Lake Alan Henry in the West Central Brazos study area include users in Kent and Scurry Counties. Currently there is not a large demand for municipal and manufacturing water in Kent County, and the demand is projected to decrease through 2060. Water supply for municipal and manufacturing use is from groundwater and conversion to surface water would be expensive. The major municipal center in Kent County is the city of Jayton, which is over 30 miles from Lake Alan Henry. If demands in the county were to increase, Lake Alan Henry may be a viable source.

Many of the municipal water users in Scurry County obtain their water from the Colorado Municipal Water District (CRMWD), which operates three water supply reservoirs and several groundwater well fields. The CRMWD has stated that they have sufficient supplies for their customers. The District could potentially use water from Lake Alan Henry to supplement their current supplies. However, at this time there is no defined need for water form Lake Alan Henry.

4. New Supply

There are limited opportunities for new water sources in the upper Brazos River basin. Several new reservoir sites have been studied and a few are recommended for further study. Much of the water in the upper portion of the basin has water quality concerns that make the development and use of this water for municipal purposes more costly than other sources. However, there are limited alternatives. This section presents a group of strategies that look at the feasibility of developing new water supplies, including new groundwater sources.

Turkey Peak Reservoir

Turkey Peak Reservoir is a proposed reservoir located immediately downstream of Lake Palo Pinto that would be operated in conjunction with Lake Palo Pinto. This reservoir site was recently evaluated for Palo Pinto County MWD by HDR Engineers, Inc. [(6)]. The proposed reservoir would have a storage capacity of 24,070 acre–feet and inundate approximately 663 acres of land at the normal pool elevation of 867 feet above msl. The spillway would be at the same elevation as Lake Palo Pinto, allowing the reservoirs to act as a single pool. The normal pool surface area of the proposed lake (663 acres) is about one fourth of the surface area of Lake Palo Pinto, making the new reservoir significantly less sensitive to evaporation loss.

Six different operation scenarios of the Lake Palo Pinto-Turkey Peak Reservoir system were evaluated by HDR, Inc. using the reservoir operation model SIMYLD-II [(6)]. These scenarios included different reservoir pool combination to determine maximum benefits for steam electric power use and municipal demands. This analysis concluded that the scenario with 100 percent combined storage pools generates the greatest yield of the system. The smallest benefit was for the scenario with a combined pool only above elevation 863 feet msl. For all scenarios, the construction and operation of Turkey Peak Reservoir provided a significant source of increased supply, nearly doubling the available supply from Lake Palo Pinto. The combined yields of Lake Palo Pinto and Turkey Peak Reservoir range from 14,800 to 16,900 acre-feet per year, with an assumed reserve supply equal to half of the system's yield (amount of water remaining in the reservoir at all times). Analysis of these reservoirs using the Brazos WAM confirmed these yield estimates.

The water quality of Turkey Peak Reservoir should be comparable to Lake Palo Pinto, which is generally very good. Environmental impacts are expected to be moderate. The impact

of the construction of Turkey Peak Reservoir would be the inundation of approximately 700 acres immediately downstream of the existing reservoir. There should be low to moderate impacts on downstream flows.

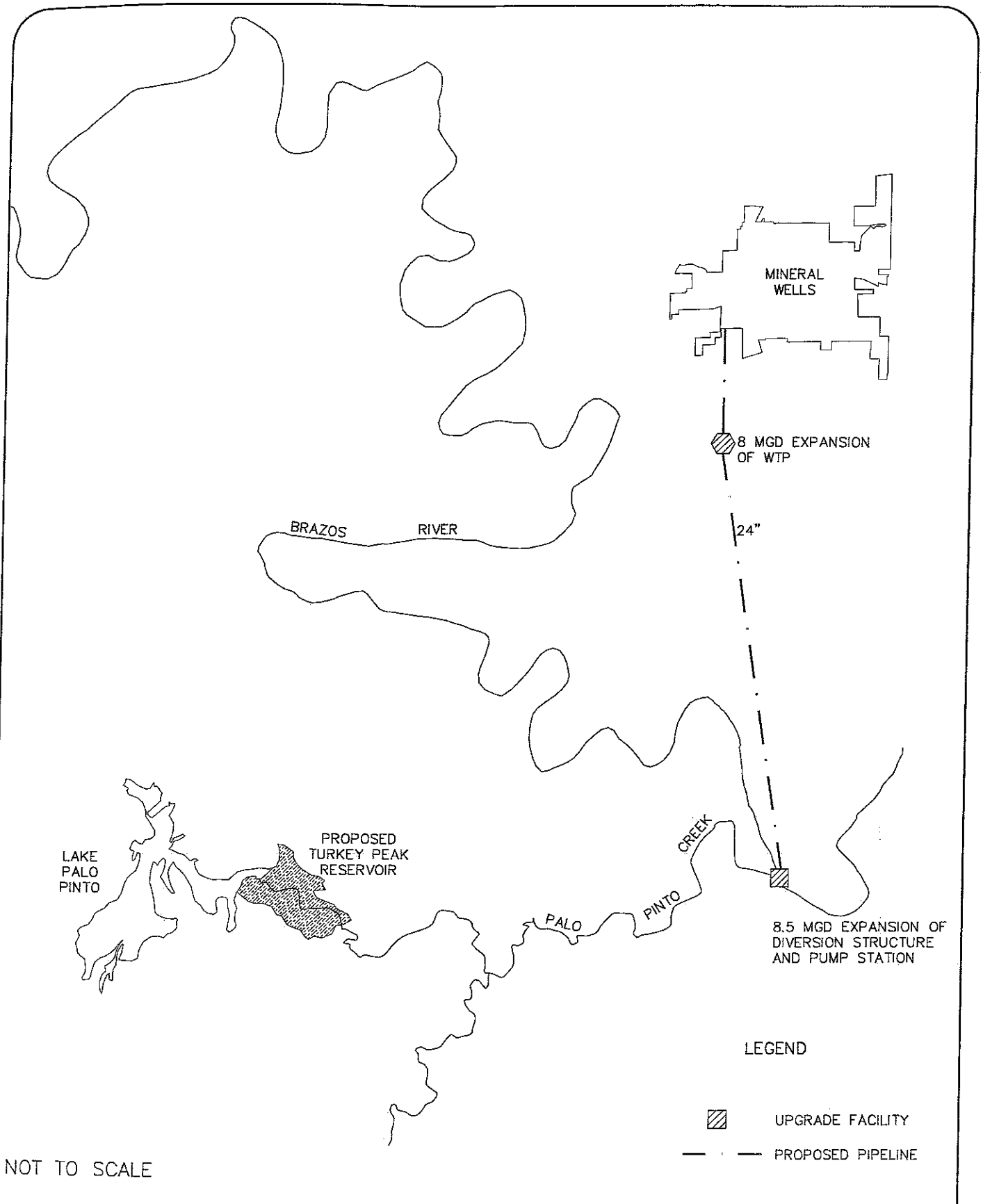
The estimated increase in yield of the Lake Palo Pinto – Turkey Peak Reservoir system is 7,600 acre-feet per year. For this study, it is assumed that 4,000 acre-feet per year of this amount would be used for municipal supply. The remainder would most likely be used for steam electric power or other lakeside demands. Using the costs developed by HDR, the capital costs for the reservoir are estimated at $41 million. Improvements needed to transport and treat the 4,000 acre-feet per year of municipal supply are estimated at $19 million. This results in a raw water cost of $1.15 per 1,000 gallons, and a treated water cost of $2.70. The schematic of this strategy is shown on Figure G-9.

Double Mountain Fork Reservoir

Two potential dam sites have been studied along the Double Mountain Fork of the Brazos River in Stonewall County for possible water supply to the city of Abilene. The potential dam sites are referred to as the East and West Dam Sites and are shown on Figure G-10. The East Double Mountain Fork Dam Site is located in the southeast portion of Stonewall County, upstream of Highway 1835. It has a conservation capacity of 280,400 acre-feet. The West Double Mountain Fork Dam Site is located in the southwest portion of Stonewall County, with a conservation capacity of 215,300 acre-feet.

Yield studies were conducted for these sites in 2001 and 2002 [7, 8]. These studies looked at the potential reservoir yields for several different reservoir capacities and also performed an assessment of projected reservoir water quality. The 2002 study evaluated the potential impacts of the sites on the yield of Possum Kingdom Reservoir. Based on these analyses, the firm yield of the West Reservoir site (conservation elevation 1790 feet msl) was estimated at 34,835 acre-feet per year. This yield includes releases under the Consensus Method for instream flows, but holding all other inflows. An evaluation of this site using the Brazos WAM inflows resulted in a firm yield of 8,225 acre-feet per year. The significant decrease in yield under WAM analysis is due to releases for senior downstream water rights holders.

A similar finding was made for the East Reservoir site. The estimated firm yield for the east site (elevation 1667 feet msl) from the 2001 study was 43,785 acre-feet per year. The yield



WEST CENTRAL BRAZOS STUDY

TURKEY PEAK RESERVOIR
W/ 4,000 AF/Y FOR MUNICIPAL USE

F&N JOB NO.	BRA02372
DATE	DEC. 2003
SCALE	AS SHOWN
DESIGNED	SFK
DRAFTED	CAM
FILE	TURKEY PEAK.dwg

G-9
FIGURE

Figure G-10

using the Brazos WAM inflows was 9,503 acre-feet per year. The greatest impact of holding inflows would be to Possum Kingdom Lake. The 2002 study found that construction of the Double Mountain Fork East reservoir would result in a reduction of Possum Kingdom Lake's firm yield by 24,620 acre-feet per year. The reduction in firm yield from the West Reservoir site would be 16,067 acre-feet per year.

Since the Brazos WAM priority analysis is the tool TCEQ uses to evaluate new permit requests, agreements would be needed with the downstream water rights holders to develop the full yield for either reservoir site.

The water quality of the proposed reservoir sites would be slightly poorer than Possum Kingdom Lake. The average total dissolved solids concentration estimated in the reservoirs would be 2,350 mg/l. This is greater than the recommended State secondary drinking water standard of 1,000 mg/l. Water from the Double Mountain Fork reservoir would require additional treatment or blending with higher quality water if it is used for municipal supply.

Environmental impacts for reservoir construction are expected to be moderate. The proposed reservoir sites are not within or adjacent to any designated environmentally sensitive areas. There are no listed endangered or threatened species in Stonewall and Fisher Counties. A site-specific assessment of potential environmental impacts would be needed as part of further study.

Another concern regarding these reservoir sites is the potential for gypsum at the dam site. The soil in this part of Texas has significant deposits of gypsum, which is water-soluble and would not be an appropriate material upon which to build a dam. Soil samples at the two dam sites are needed to determine whether or not gypsum poses a problem for either of the two proposed locations.

The costs for the construction of the reservoirs were estimated at $161 million for the East site and $113 million for the West site. Using the yields from the Brazos WAM, the estimated costs for 1,000 gallons of raw water at the reservoir is $3.64 for the East site and $3.06 for the West site. These costs are high for raw water, making the reservoir unfeasible at the WAM yield amount. This strategy would only be feasible if a subordination agreement was reached with downstream water rights holders. Using the higher yield amounts, the raw water cost is estimated at $0.87 per 1,000 gallons for the East site and $0.78 per 1,000 gallons for water from the West site.

Double Mountain Fork to Abilene

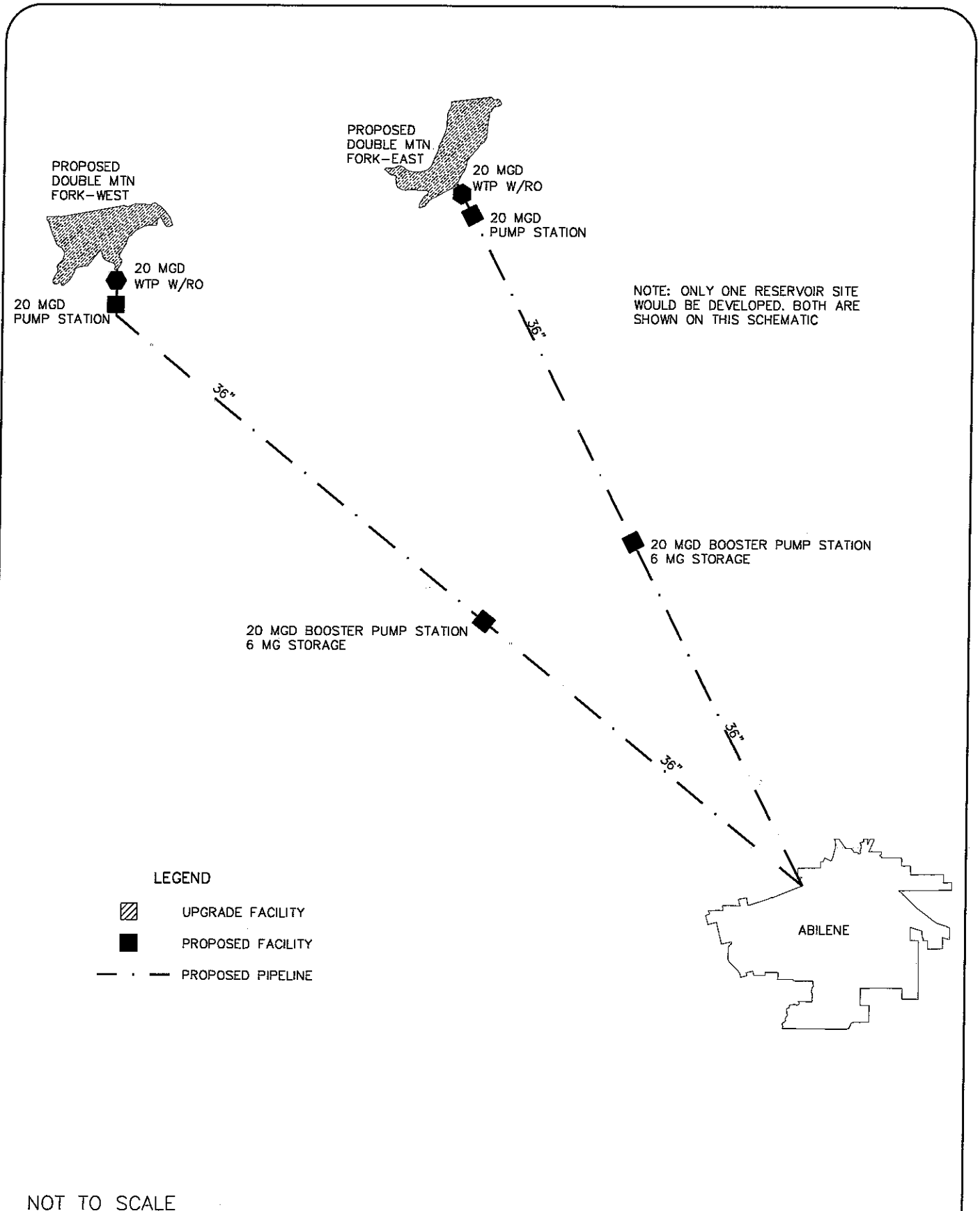
The Double Mountain Fork reservoir sites are potentially feasible only if the larger yields are obtainable. These yields (34,835 af/y for the West site and 43,785 af/y for the East site) are much greater than the local demands. This means that a large water supplier would need to commit to the project. Within the study area, a possible recipient for this water is Abilene. Abilene is looking for additional long-term supplies, and the Double Mountain Fork sites could provide the city with significant quantities.

For this strategy, it was assumed that 20,000 acre-feet per year of raw water would be treated at the reservoir site. The reject water from the treatment plant could possibly be discharged to the Double Mountain Fork downstream of the reservoir, disposed through a brine injection well or discharged to evaporation beds. There would be significant area to construct evaporation ponds. Discharging to the stream would require detailed water quality and impact studies.

Approximately 14,000 acre-feet of treated water would be transported through a new 36-inch pipeline to Abilene. If the Double Mountain Fork East site were developed, the pipeline would be approximately 44 miles to Abilene. A 50-mile pipeline would be needed from the West site. For either site, a new intake structure at the reservoir, a 20 mgd water treatment plant with reverse osmosis, 20 mgd pump station, and a booster pump station would be needed. The treated water pipeline would be routed directly to Abilene and could possibly be used to supply other customers along the route. Schematics of these alternatives are shown on Figure G-11.

The environmental impacts for the treatment and transmission system are expected to be low to moderate. Further review is needed to assess the potential environmental impacts along the pipeline route, but it is assumed that the pipeline could be routed around environmental sensitive areas if needed. Impacts associated with the reject water disposal would need to be assessed on a case-by-case basis.

The capital costs for the treatment and transmission systems are estimated at $95 million for the East site and $99 million for the West site. Assuming the costs per 1,000 gallons of raw water are the same as estimated above ($0.78 for the West site and $0.87 for the East site), the costs per 1,000 gallons of treated water at Abilene are $3.73 from the West site and $3.82 from the East site.



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WEST CENTRAL BRAZOS STUDY

DOUBLE MOUNTAIN FORK RESERVOIR WITH TRANSMISSION TO ABILENE

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SCALE	AS SHOWN
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G-11
FIGURE

Elm Creek Reservoir (Throckmorton)

A potential water management strategy for the city of Throckmorton is a new lake north of the city as shown on Figure G-12. The proposed dam site is on North Elm Creek is located approximately three miles northwest of Throckmorton [(9)]. Elm Creek Reservoir would have a storage capacity of 15,000 acre-feet and inundate 1,850 acres at the top of conservation pool elevation of 1355 feet msl. The contributing drainage area is approximately 82 square miles. The emergency spillway is proposed on the south side of North Elm Creek to avoid conflicts with Highway 283.

Estimates of reliable yield were made using the Brazos WAM under both priority and natural order analysis for the WAM period of record (1940 to 1997). For these initial assessments environmental flow releases were not determined. If the project goes forward, releases will need to be assessed, but the estimated release amounts and impacts during the reservoir's critical period under priority analysis are expected to be small. This is due to the low inflows and release of water for senior water right holders during the reservoir's critical period. The estimated firm yield of the reservoir under priority analysis is 220 acre-feet per year. This is less than the city's demands, and the analysis does not account for the recent drought. Based on the response of Lake Throckmorton, the yield could be much less.

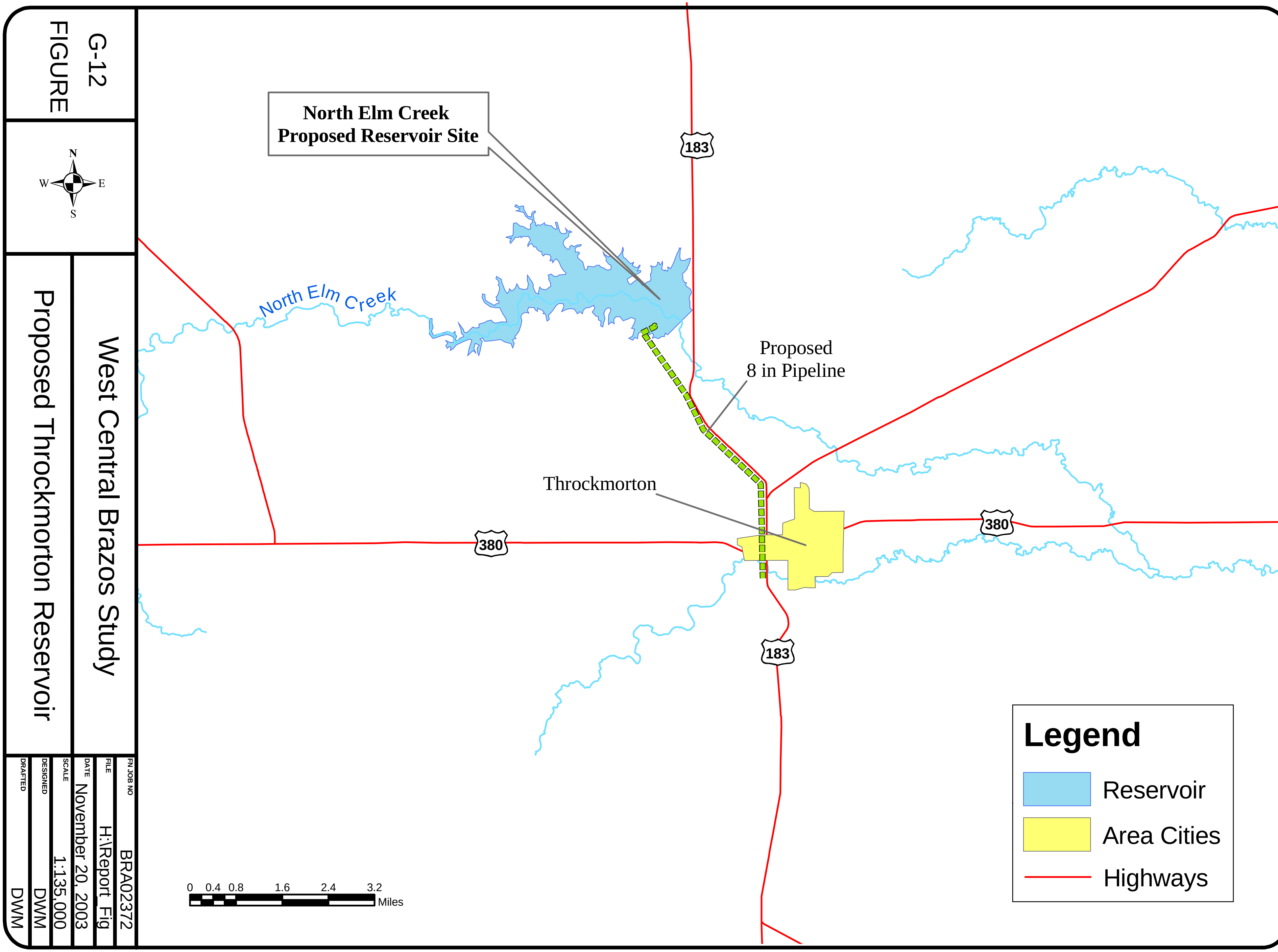
The natural order firm yield was estimated at 1,375 acre-feet per year, but this analysis also does not include instream flow releases or extended hydrology. Instream flow releases are expected to have a greater impact to the natural order yield. Based on the hydrologic analyses, the Elm Creek reservoir site has the potential to provide some water to Throckmorton, but it would require agreements with senior water rights holders.

There are no known water quality concerns in the watershed of the proposed reservoir that would require special treatment. The environmental impacts are expected to be moderate. It is a relatively small reservoir. Further review would be needed to assess the potential environmental impacts, including potential wetlands, endangered species, and archeological impacts. Instream flow requirements were not assessed at this time, but will be required for permitting.

FIGURE G-12

West Central Brazos Study

Proposed Throckmorton Reservoir



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DATE: November 20, 2003

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DESIGNED: DWM

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The costs for water from the reservoir are very high for amount of water that could be permitted with no agreements with downstream water rights holders. Using the available water supply under the Brazos WAM permitting scenario (220 af/y), the cost per 1,000 gallons of treated water for Throckmorton is over $18. If the firm yield of the reservoir is available, the raw water costs are estimated at $3.01 per 1,000 gallons. Treated water costs at Throckmorton for 340 acre-feet per year would be approximately $4.29 per 1,000 gallons. The city of Throckmorton would need to sell additional raw water to repay the debt service on the reservoir.

Cedar Ridge Reservoir (WCTMWD)

A potential water management strategy for WCTMWD is the Cedar Ridge Reservoir. This reservoir site (shown on Figure G-13) is located on the Clear Fork of the Brazos River in southern Throckmorton County. The reservoir was previously evaluated by Freese and Nichols, Inc. in 1980 [(10)] and was considered a potentially viable project in the 1991 Regional Water Supply Plan prepared for the WCTMWD [(11)]. An alternate site, the Breckenridge Reservoir, was a recommended strategy in the Brazos G Regional Plan [(12)]. The Breckenridge site is located immediately downstream of the confluence of the Clear Fork of the Brazos and Paint Creek. This site would have larger conservation storage than the Cedar Ridge site, but the inflows from Paint Creek generally have poorer quality than water in the Clear Fork. The Cedar Ridge site eliminates some of the poorer quality water, and therefore was retained for consideration in this study.

The Cedar Ridge Reservoir would have a conservation storage of 342,900 acre-feet at a top of conservation pool elevation of 1432 feet msl. The reservoir would inundate approximately 6,600 acres of fairly hilly land. The yield of the reservoir was determined using the Brazos WAM for both priority and natural order analyses. Instream flow releases were estimated using the consensus criteria and daily flow data from the USGS gage near Nugent. Under priority analyses (permitting scenario), the firm yield of Cedar Ridge was estimated at 14,700 acre-feet per year. Under natural order, the yield was 24,770 acre-feet per year. The critical period for both analyses is long, from 1942 to 1957.

Figure G-13

Recent historical water quality data of the Clear Fork at the Nugent gage (1993 to present) shows moderately high total dissolved solids and chlorides [13]. The median TDS concentration was 2,255 mg/l, with a maximum reported value of 4,020 mg/l. The median chloride concentration was greater than 500 mg/l. These values are comparable to the levels used in previous water quality modeling [10]. This modeling, conducted as part of the 1980 study, found that the median TDS concentration in the reservoir after 50 years would be 3,200 mg/l, with significant quality deterioration during drought conditions. At these levels, advanced water treatment would be needed for municipal use.

Construction of the Cedar Ridge Reservoir would have moderate to high environmental impacts. A detailed assessment of potential wetlands, endangered species, and archeological impacts would be required. Consensus-based instream requirements were used to develop the conceptual design, but instream flow requirements must be assessed. The development of a reservoir in this location will create wildlife and aquatic habitat. The addition of stored water may also create limited wetlands habitat at the fringes of the lake and will provide a source of water for wildlife as well.

The estimated total capital cost for the construction of the reservoir is $123 million. These costs reflect the assumed need for a gated spillway structure. This was recommended during previous studies of the site and the narrow gorge location of the dam suggests the need for this type of spillway. Further study would be needed to determine if a less costly alternative is feasible. With these costs, the raw water cost for the firm yield under the permitting analysis (14,700 af/y) would be $1.85 per 1,000 gallons. Assuming compensation is made to BRA for impacts to Possum Kingdom Lake, the raw water cost for the higher yield (24,700 af/y) would be $1.15 per 1,000 gallons. Since WCTMWD operates on a safe yield basis, the raw water cost for safe yield would be $1.26 per 1,000 gallons.

The most likely recipient of water from Cedar Ridge would be Abilene. Abilene has expressed interest in obtaining an additional 20,000 acre-feet per year by 2050. This would be nearly all of the new reservoir's safe yield (21,800 af/y). Since the water would require treatment at a new facility with reverse osmosis, it is recommended that the new plant be located at the reservoir. A new 36-inch pipeline and two pump stations would be needed to transport the treated water approximately 42 miles to Abilene as shown on Figure G-14. The capital cost for

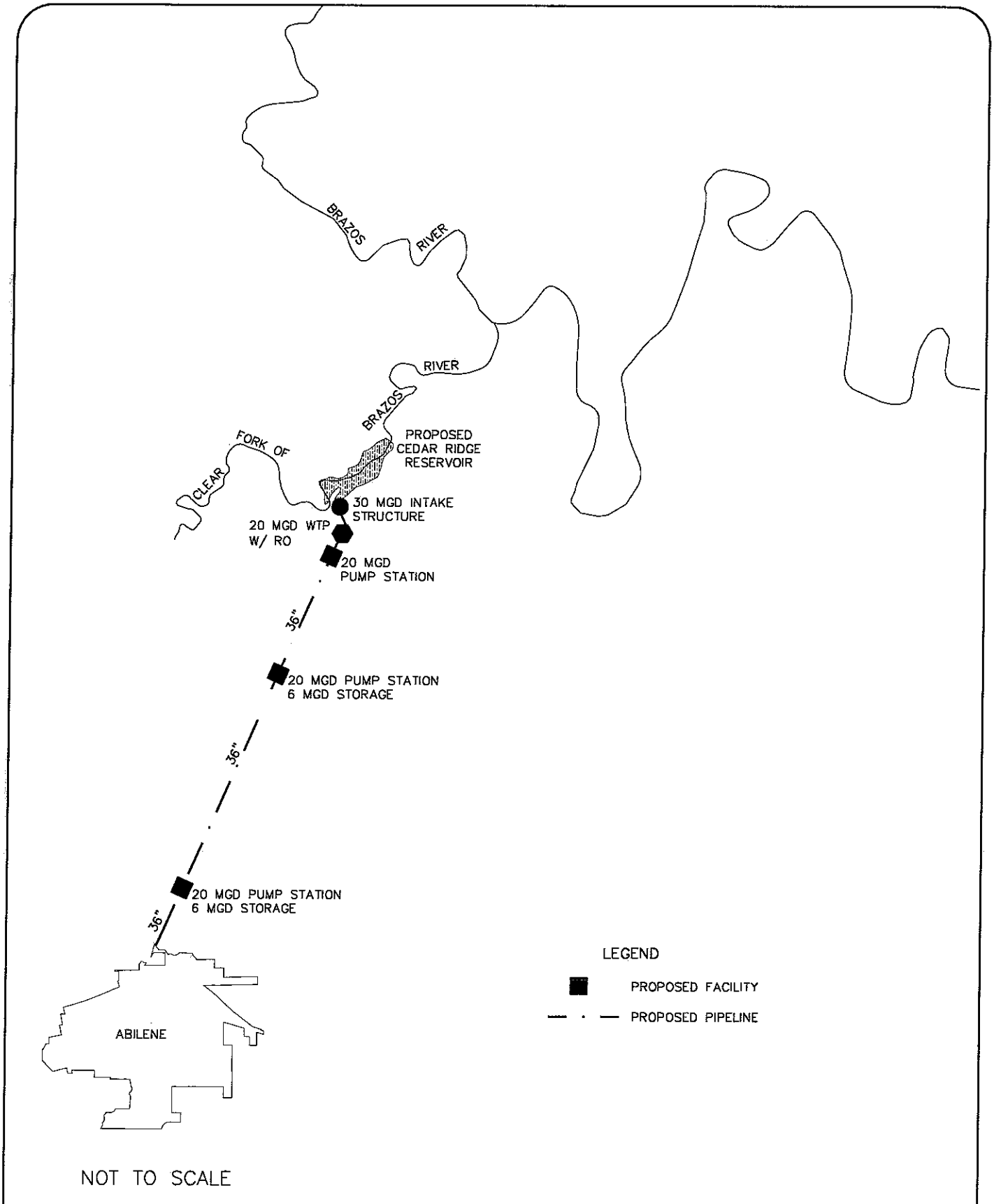
the treatment and transmission systems is estimated at $100 million. The cost per 1,000 gallons of treated water at Abilene would be $4.35.

Clear Fork Diversions to Hubbard Creek Lake

This strategy was first evaluated for WCTMWD in 1980 [(10)], and was recommended for further consideration at that time. It consists of diverting peak flows from the Clear Fork of the Brazos River into Hubbard Creek Lake. Flows above 300 cfs would be diverted via a diversion weir and channel and 650 MGD pump station, with a maximum diversion rate of 1,000 cfs. The water would be transported approximately five miles through two 120-inch pipelines to Hubbard Creek Lake. These diversions were then included in a reservoir operation model to assess the impact on the reservoir's firm yield.

The amount of available flow for diversion was determined using the results of the Brazos WAM and a daily flow analysis. The flows from the WAM model, which are reported on a monthly basis, were converted to daily flows by using the proportion of daily streamflows recorded on the Clear Fork at Fort Griffin (USGS gage #08085500). Diversions were made on a daily basis, following the minimum and maximum flow constraints. The available flow at the proposed Clear Fork diversion point includes both unappropriated flow (flow that could be permitted independently of existing water rights holders) and flows designated for downstream users. If only the unappropriated flow is diverted, the increase in yield of Hubbard Creek Lake is approximately 6,000 acre-feet per year. If all available flow (above 300 cfs and below 1,000 cfs) is diverted, the increase in Hubbard Creek Lake's yield is nearly 16,000 acre-feet per year. This is a similar finding to the evaluation in 1980.

The infrastructure needed to divert only the unappropriated flow is the same as needed for the larger amount. Therefore, it is more cost effective to be able to divert all of the available flows. For this scenario, WCTMWD would need a permit for the diversions of the unappropriated flows and most likely a contract with BRA for an upstream diversion of water from Possum Kingdom Lake. Alternatively, WCTMWD could enter into a subordination agreement with BRA, but TCEQ has been less favorable to such agreements. The impact to the firm yield of Possum Kingdom Lake is approximately 8,250 acre-feet per year using natural order analyses.



WEST CENTRAL BRAZOS STUDY

PROPOSED CEDAR RIDGE RESERVOIR WITH TRANSMISSION TO ABILENE

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DESIGNED	SFK
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G-14
FIGURE

Water quality of the Clear Fork at Fort Griffin (near the proposed diversion site) is similar to the quality in Hubbard Creek Lake. The median concentrations of TDS and chloride in the Clear Fork are slightly higher than the median values at Hubbard Creek Lake, but diverting during high flows should provide water of higher quality. Previous water quality modeling of this scenario found that the Clear Fork diversion would have a minimal impact to the quality in Hubbard Creek Lake. The modeling reported that over 90 percent of the time the concentration of TDS in Hubbard Creek Lake would be less than 1,000 mg/l (Freese and Nichols, Inc., 1980).

The environmental impacts for this strategy should be low to moderate. Most of the flow is diverted during flood events. A more detailed study would be needed to assess the potential impacts of the diversion weir and instream flows. The pipeline route, while short, is fairly inflexible due to the size of the pipes. If possible the placement of the transmission system should avoid environmentally sensitive areas.

The capital costs for the diversion system is estimated at $81 million. Using the firm yield increase of 16,000 acre-feet per year, the cost for raw water is $1.44 per 1,000 gallons. If only the unappropriated water is diverted, the raw water cost is $3.65 per 1,000 gallons.

Increase Supply from Hubbard Creek Lake

If WCTMWD proceeds with the Clear Fork diversion strategy, there would be available supply to Abilene and/or other WCTMWD customers. WCTMWD typically operates under a safe yield analysis and contracts are limited to this amount. As such, the available supply to WCTMWD customers would be 12,500 acre-feet per year. If Abilene were to increase its contract with WCTMWD by the full 12,500 acre-feet per year, the total amount of water committed to Abilene would be 29,300 acre-feet per year (average 26.5 mgd). Abilene's portion of the capacity of the existing pipeline from Hubbard Creek Lake to Lake Fort Phantom Hill is 31 mgd [(14)]. Utilizing this pipeline with no improvements would provide a peaking capacity of only 1.16 for the line. If peak needs could be met with supplies from Lake Fort Phantom Hill and/or water from Lake Ivie, an additional pipeline may not be needed. However, additional treatment capacity would most likely be needed. Abilene's total treatment capacity is 54.6 mgd. Of this amount, there is 44.8 mgd capacity to treat water from Fort Phantom Hill and Hubbard

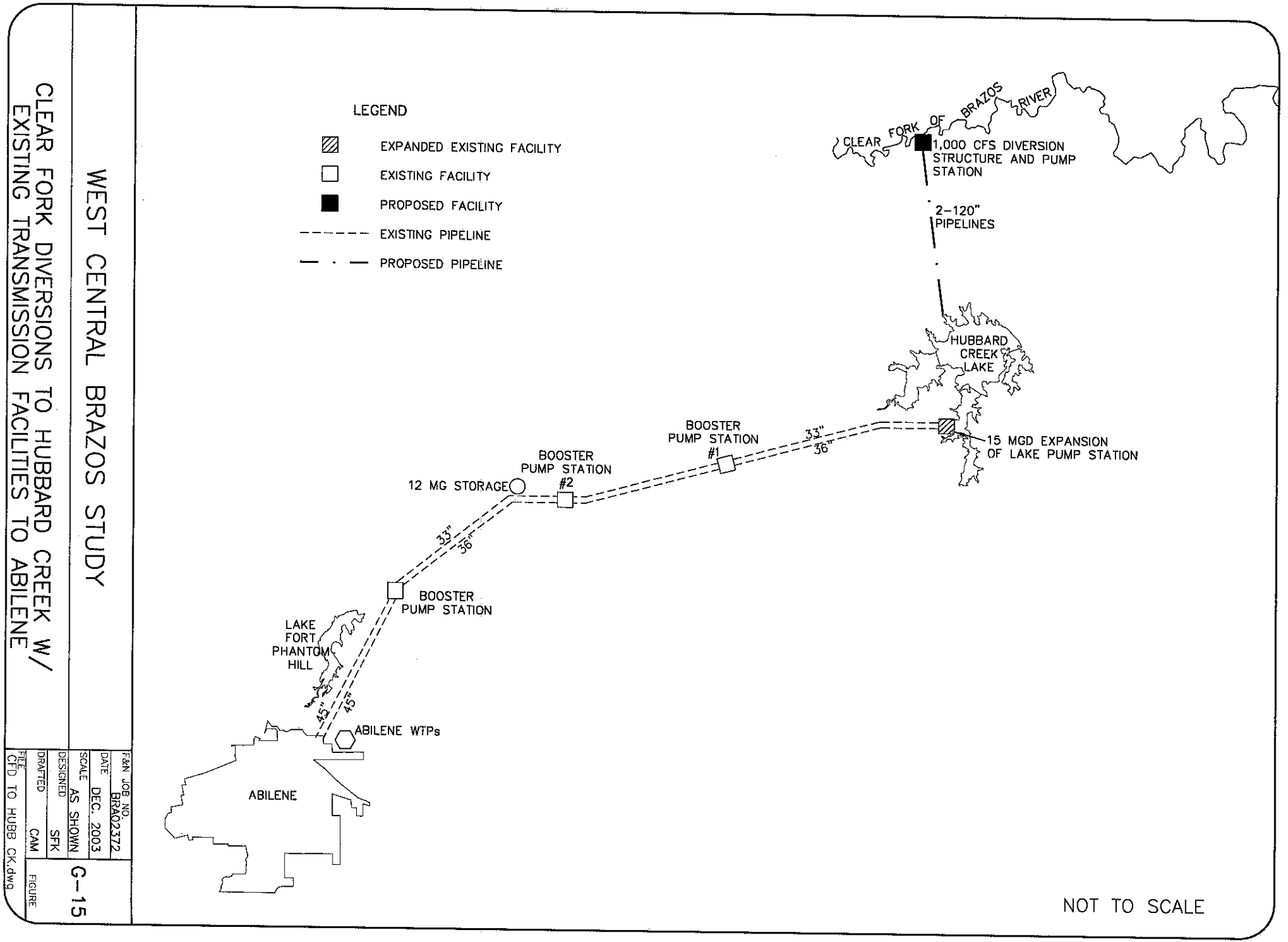
Creek Lake. Most of the remaining capacity is located on the south side of town and is used to treat water from Lake Ivie. To utilize any additional capacity at the south water treatment facility (Hargesheimer WTP), an interconnection with the Hubbard Creek pipeline is needed.

Since there is some uncertainty regarding the need for additional pipeline capacity for Abilene, two possible scenarios were reviewed: 1) 15 mgd conventional water treatment plant expansion with no transmission improvements, and 2) 15 mgd conventional WTP expansion, new 30-inch pipeline with a connection to the south WTP, and an 8 mgd expansion of the south WTP. Scenario 1 shown on Figure G-15 is strictly limited to increased supply from Hubbard Creek Lake with Clear Fork diversions. Scenario 2 as shown on Figure G-16 could be expanded to include some supply from Possum Kingdom Lake. The connection to the Hargesheimer water treatment plant with reverse osmosis provides a means to treat Possum Kingdom Lake water with existing or expanded facilities.

Scenario 1: No Transmission Improvements

For this scenario, it is assumed that no additional transmission improvements are provided. As previously stated, with the current pump and pipe configuration the maximum capacity of the existing Hubbard Creek pipeline is 31 mgd for Abilene. To be able to treat this full amount and peak supplies from Lake Fort Phantom Hill, Abilene would need approximately 60 mgd of treatment capacity for these sources. It is assumed that the two 45-inch pipelines from Lake Fort Phantom Hill and the end of the Hubbard Creek pipelines should be sufficient to convey these amounts. A 15 mgd conventional water treatment plant expansion is the only proposed capital improvement.

The environmental impacts for Scenario 1 are expected to be low. The water quality should be adequate. The estimated cost for treated water is $2.30 per 1,000 gallons, which includes the cost for raw water from the Clear Fork Diversion strategy.



WEST CENTRAL BRAZOS STUDY

CLEAR FORK DIVERSIONS TO HUBBARD CREEK W/ EXISTING TRANSMISSION FACILITIES TO ABILENE

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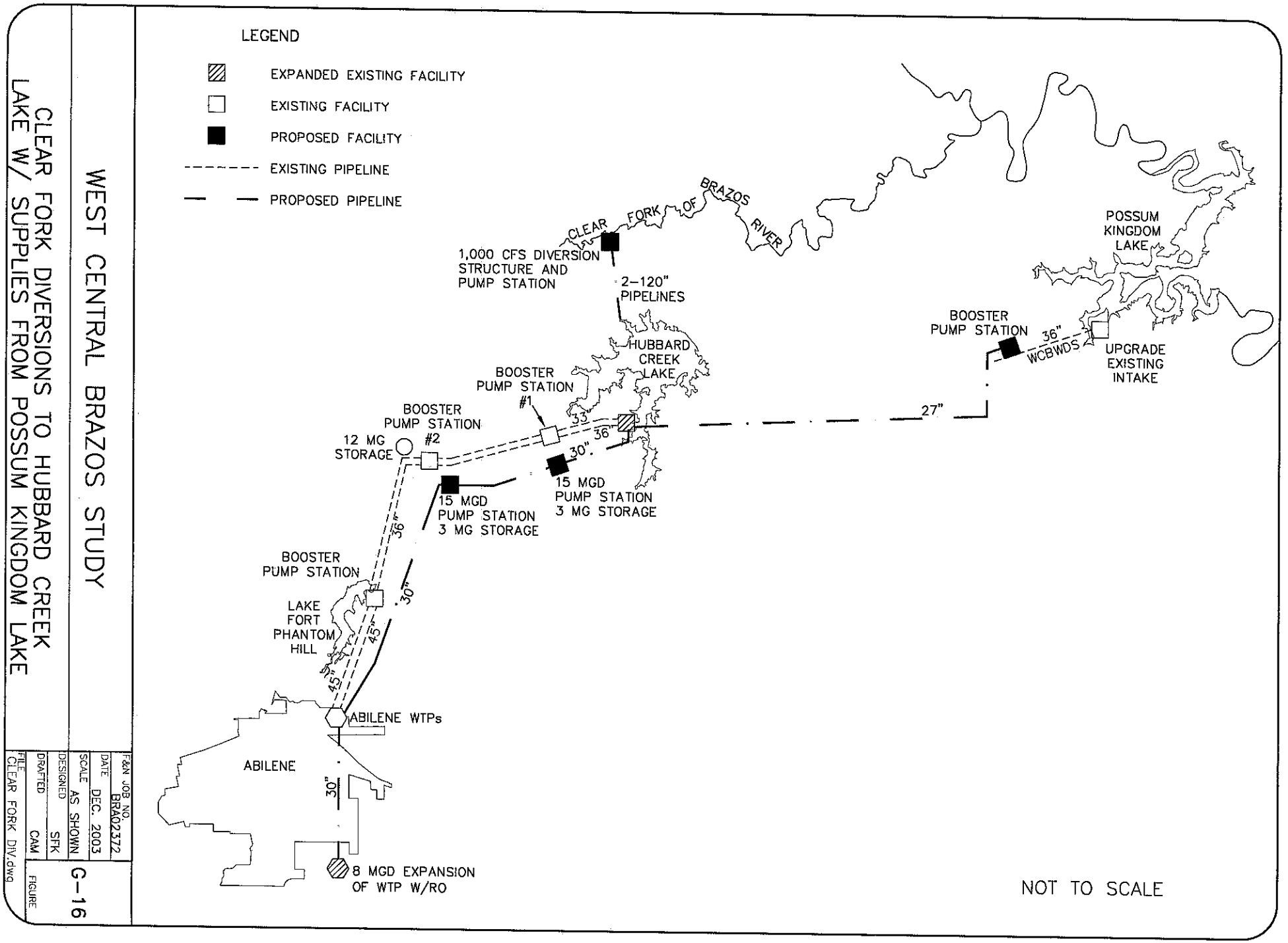
FIGURE	G-15



WEST CENTRAL BRAZOS STUDY

CLEAR FORK DIVERSIONS TO HUBBARD CREEK LAKE W/ SUPPLIES FROM POSSUM KINGDOM LAKE

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FIGURE	G-16

Scenario 2: Transmission Improvements with Water from Possum Kingdom

This scenario could provide the 12,500 acre-feet per year from Hubbard Creek Lake plus 8,000 acre-feet per year from Possum Kingdom Lake. It would require a new 30-inch pipeline from Hubbard Creek Lake and a 27-inch pipeline from Possum Kingdom Lake to the new pipeline. The 30-inch line would parallel the existing WCTMWD pipeline until the second booster station. From there it would go directly to Abilene's water treatment plant with a connection to the Hargesheimer plant. The 27-inch pipeline would parallel the WCBWDS and connect directly to the new 30-inch pipeline. The total peak capacity of the transmission system from Hubbard Creek Lake to Abilene that is dedicated to Abilene would be 46 mgd. The third pipeline enables flexibility in providing water from Hubbard Creek Lake and/or Possum Kingdom Lake.

It is assumed that a 15 mgd conventional water treatment plant would be constructed for the increased supply from Hubbard Creek Lake. At a minimum, an 8 mgd treatment facility with reverse osmosis would be needed for the water from Possum Kingdom Lake. The existing Hargesheimer plant can be expanded to 12 mgd. Additional expansion would be necessary if water from Lake Ivie is also treated at the same time. However, there may be some flexibility in the timing of the expansions.

The estimated capital cost for these improvements is $91 million. The cost per 1,000 gallons of treated water is $3.13. This provides the greatest flexibility in bringing large quantities of water to Abilene at the least cost. For smaller quantities, scenario 1 with no transmission improvements probably would be preferable.

5. New Groundwater Supplies

City of Sweetwater (Nolan County)

The City of Sweetwater is projected to need an additional 3,800 acre-feet per year by 2060. The city's current surface water sources, Lake Sweetwater and Oak Creek Reservoir, are at record lows, and the city is currently using groundwater to meet all supply needs. Currently, the only long-term supply alternative being considered is the expansion of the existing groundwater supply that produces water from the Dockum aquifer west of the city. It is anticipated that the surface water reservoirs will be able to supply water for the city again, which

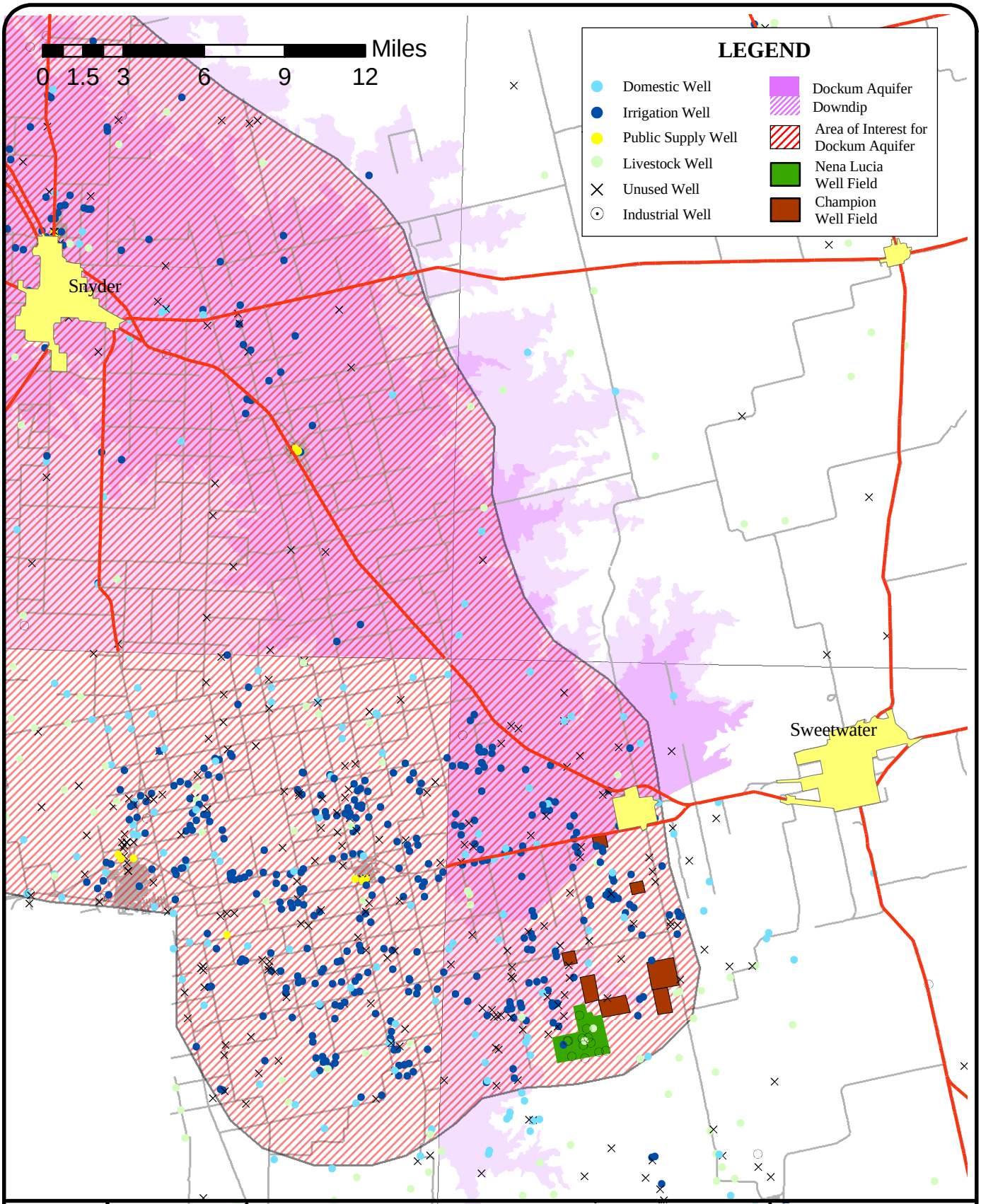
will reduce the demand on the well fields and extend the life of the field(s). However, for planning purposes it was assumed that groundwater is the only supply being considered. Therefore the estimated additional supply needed from groundwater is 5,100 acre-feet per year.

Existing wells in Sweetwater's Champion well field are between 160 to 322 feet deep, and produce between 20 and 225 gallons per minute (gpm), averaging a little over 100 gpm. The Dockum aquifer in the area has transmissivities of between 1,000 and 12,500 gpd/ft, and some wells in the area have been reported to produce as much as 500 gpm, although this would be an exceptional production rate from this aquifer. Based on this information, it is estimated that 50 additional wells will be required to increase the supply by 5,100 acre-feet. As can be seen in Figure G-17, there are significant areas of the Dockum aquifer north and west of the current well field, including large areas with numerous irrigation wells where reportedly the aquifer is very productive. Additional, largely undeveloped areas are located in Scurry County toward Snyder, which may be able to be developed as a long-term supply. However, because these areas are undeveloped, there are few wells upon which to base an evaluation, and therefore these must be evaluated independently before any production of groundwater can be relied upon.

Water quality is not currently an issue for the city because all groundwater produced is currently treated in the city's surface water treatment plan. Potential water quality problems in the region are mainly associated with nitrate concentrations in the groundwater, which reportedly is a problem for the city of Roscoe, which produces groundwater from the same aquifer a few miles to the north of the Champion well field.

Declining water levels are a potential concern if this area continues to be used as the city's sole source of groundwater. Declines of two to five feet per year are currently being observed in the city's well fields, although this is based on limited data. If the Dockum aquifer continues to be used at the current rate, the city may have to evaluate purchasing or leasing groundwater rights from additional properties as water levels in their current well fields decline to levels that make it economically impractical to continue production. However, as noted above, there are large areas for potential development of Dockum groundwater in western Nolan County.

Currently the city has 37 wells producing groundwater from eight different properties west of Sweetwater near the town of Champion. The current production from the Champion well field is between 3,100 and 3,900 acre-feet/year. The city currently leases water from the



G-17 FIGURE		West Central Brazos Study	FN JOB NO: BRA02372
			FILE: H:\Report_Fig
			DATE: November 20, 2003
		Potential Groundwater for Sweetwater	SCALE: 1:320,000
			DESIGNED: DWM
			DRAFTED: DWM

landowners, and produces groundwater from new wells installed by the city. The city pays $0.085/1,000 gallons ($27.60/acre-foot) per year for the groundwater. Figure G-17 shows the locations of the properties that are currently included in the Champion well field. Assuming similar wells will be able to be installed in new well fields, a total of $4 million is estimated for the well field with 50 wells. An annual operating cost for these new wells is estimated to be $465,300. Capital costs for the well field and a transmission system to convey the water approximately 15 miles to Sweetwater would be $17 million. The cost per 1,000 gallons of treated water would be $1.62. Costs would be higher if the well field is further than 15 miles from the city of Sweetwater.

Groundwater from the Dockum aquifer is a potential supply for the city of Sweetwater, both as a long-term supply and an emergency supply. Groundwater is currently the sole source of water for Sweetwater due to low reservoir levels. Once the reservoirs recover, production from the aquifer can be reduced, which will extend the life of the existing well fields. Additional areas are available for expansion of groundwater production, and wells in the area are relatively inexpensive to install. The city has successfully leased water rights for their current well field and should look to acquire additional leases or water rights purchases in the future to continue expanding their water supply.

Upper Leon MWD (Comanche County)

The Upper Leon MWD currently obtains all of its supply from Lake Proctor. Although existing contracts are projected to be sufficient for the municipal supply through the planning period, groundwater is being considered for long-term supply and to help meet other demands on Lake Proctor. An additional 1,000 acre-feet/year of supply is needed for this purpose.

A potential long-term groundwater supply for the Upper Leon MWD in Comanche County is groundwater from the Trinity (Twin Mountains) aquifer. Much of Comanche County is underlain by the Trinity aquifer, which can be very prolific and produces mostly fresh water. The aquifer consists of medium to coarse-grained sands, silts, clays, and conglomerates. Wells producing from the Trinity in this area are between 50 and 200 feet deep, with most wells being less than 100 feet deep, and produce 25 to 200 gpm, although most production rates are between 50 and 125 gpm. Higher production rates may be possible from properly completed municipal

wells. The Trinity aquifer in this area is fairly productive, with transmissivities between 9,000 and 14,000 gpd/ft. Specific capacities of wells producing from the Antlers range from less than one up to 20 gpm/foot of drawdown.

Water quality from the Trinity aquifer in this area is mostly fresh, although some wells in the area produce groundwater with between 1,000 and 3,000 mg/l of total dissolved solids. As with many other areas in this region, nitrate concentrations in groundwater can also be a problem. This issue must be examined for each site, because the nature of nitrate contamination makes its occurrence unpredictable on a regional basis.

The Trinity aquifer in northern Comanche County has historically been fairly heavily developed for irrigation purposes, but the amount of irrigation pumpage that is currently occurring has reportedly decreased. The amount of groundwater available for municipal supply purposes depends on water rights issues and competing water demands. If water rights can be obtained, the Trinity aquifer has the capability to supply entities with groundwater for extended periods of time, and the close proximity of productive areas of this aquifer to the district make it an attractive potential supply. Figure G-18 shows existing well locations and areas for potential groundwater development near the Upper Leon MWD.

Assuming that groundwater is available in this area, the cost for 12 new wells is estimated to be $637,500. An annual operating cost for these 12 wells is estimated at $78,000. Since the location of the potential well field is unknown, it is assumed that the well field would be located within 10 miles of Lake Proctor or major transmission line. The groundwater would be transported to supplement ULMWD's supply system (either into the lake or directly into an existing transmission facility). The total capital costs, including the wells, a 12-inch transmission pipeline, well field pump station, and storage facilities, would be $4.2 million. This would be $1.43 per 1,000 gallons of additional raw water for the ULMWD. These costs could be higher or lower depending on the location of the well field and the negotiated water lease cost.

Figure G-18

NCTMWA (Seymour Aquifer)

The NCTMWA currently uses water from Millers Creek Lake. With the recent drought, Millers Creek Lake entered a new critical period and to date has not fully recovered. The estimated yield of Millers Creek Lake is sufficient to meet the demands of its current customers provided the reservoir fully recovers. Continued drought or a more extreme drought will impact the water supply in Millers Creek Lake.

The Seymour aquifer shown on Figure G-19 is located within the counties that NCTMWA serves, and could be used for back-up or emergency supply during drought. The Seymour aquifer in this area is very shallow and highly productive. The thickness of the Seymour is typically less than 100 feet with saturated thickness averaging about 50 feet. Much of the Seymour is currently used for irrigation. It is mainly fresh water with some areas containing elevated levels of nitrates and TDS. Well yields average 200 gpm, but can be considerably higher.

For this strategy, ground water would be pumped from the Seymour and blended with lake water either at the lake or directly in a raw water transmission line. The location of the well field will depend on where water rights can be obtained and the productivity and quality of the area. It is assumed that blending of the water should reduce quality concerns such that no additional treatment would be needed. However, due to potentially high nitrate levels, blending would need to be carefully monitored to ensure that the treated water met drinking water standards. For costing purposes, it is assumed that the well field would be located within 10 miles of Millers Creek Lake or a major transmission line. It was assumed that three wells could provide an annual amount of 500 acre-feet per year (pumping at 200 gpm with a peaking factor of 1.5). This is approximately 30 percent of the total demands for NCTMWA.

The capital costs for the ground water wells and transmission system is estimated at $2.4 million. This would be $1.49 per 1,000 gallons of additional raw water for the NCTMWA. Treated water costs would be $1.84 per 1,000 gallons. These costs could be higher or lower depending on the location of the well field and the negotiated water lease cost.

Figure G-19

6. Other Groundwater Sources

Seymour Aquifer - The Seymour is comprised of numerous isolated alluvial pockets in Haskell, Knox, Jones, and Fisher Counties within the planning area, with some smaller pockets also occurring in Kent and Stonewall Counties. Currently most (>95%) of groundwater production from the Seymour is for irrigation purposes.

The Seymour aquifer in the study area is very shallow and highly productive. The Seymour is comprised of Quaternary deposits of unconsolidated conglomerates, gravels, sands, and silty clays. The thickness of the Seymour is typically less than 100 feet with saturated thickness averaging about 50 feet. Well yields can be as high as 1,800 gpm, but average about 200 gpm. Average transmissivities from the Seymour are between 25,000 and 300,000 gpd/ft, with storage coefficients of approximately 0.15, which are very good aquifer properties for producing significant quantities of groundwater.

Groundwater from the Seymour is mostly fresh, although in some areas total dissolved solids content can be greater than 1,000 mg/L. The water chemistry varies locally because of contamination from oil field practices and other brackish surface water. Some areas within the Seymour have elevated nitrate concentrations, which is a concern for municipal supplies. However, groundwater supplies could be blended with surface water supplies to reduce the nitrate concentrations to acceptable levels while increasing the overall water supply.

The availability of groundwater from the Seymour varies from area to area. The total availability or sustainable yield of the Seymour aquifer has been estimated at about 8 percent of annual rainfall or about 2 inches per year over the outcrop areas. However, many of the areas are currently being produced at higher rates than the estimated sustainable yields, especially in Knox and Haskell Counties. If water rights can be obtained, and competing demands reduced, then the Seymour may be a potential long-term supply for a water supply entity. However, the overall heavy development of the Seymour in these areas has led to long-term water level declines, and any potential groundwater development must be evaluated on a site-specific basis. Several areas of the Seymour have not been extensively developed, including pockets in Kent, Stonewall, and Fisher Counties. However, these areas may be undeveloped due to the properties of the aquifer or the quality of the water, and therefore these areas must be evaluated on a site-specific basis prior to attempting to develop them as a potential water supply. Areas of potential interest for groundwater development are shown on Figure G-19.

Trinity Aquifer - The Trinity aquifer, as described for the Upper Leon MWD, may also be a potential long-term water supply in other areas in the planning areas, including Callahan, Eastland, and Brown Counties. Figure G-20 shows the potential water supply areas for the Trinity aquifer in the southeast portion of the planning area. Most of the outcrop areas have the potential to supply water for local water supply entities, and areas with large numbers of existing wells are probably those areas with the greatest supply potential. The characteristics of the Trinity aquifer were described in Section 5 for the ULMWD.

Other Aquifers - Two other significant aquifers are present in the planning area, the Blaine and the Edwards-Trinity. However, neither of these is considered to be a potential source of groundwater for medium to large-sized water supply entities due to quality and productivity issues. Several smaller aquifers also exist in the planning areas, aquifers that produce too little water over too limited an area to be considered a minor aquifer by the state. These aquifers may be able to provide limited quantities of groundwater to small suppliers, but they are not considered to be a viable long-term groundwater source for these planning purposes.

Figure G-20 Trinity Aquifer

7. Midway Group Treatment Options

The Midway Water Group consists of the City of Breckenridge, City of Throckmorton, Shackelford WSC and Stephens County Rural WSC. There are at least five potential sources of raw water available to the group. Possum Kingdom Lake, Hubbard Creek Lake (via Breckenridge and/or Albany), Lake Daniel, Lake Stamford and Lake Throckmorton are each potential supplies for the Midway Group. Currently the supply to the entities comes mainly from Hubbard Creek Lake with the exception of Throckmorton, which takes its supply from Lake Throckmorton. Three options for supplying the group have been identified and discussed in detail in the following section. A potential supply from Lake Stamford that could be treated at Throckmorton is one alternative; a supply from Hubbard Creek with blending from other smaller area lakes is a second alternative; and a supply from a regional treatment plant at Breckenridge treating raw water from Possum Kingdom Lake is the third. In each alternative, existing supplies from Hubbard Creek Lake are maintained. Figure G-21 shows the proposed improvements that would be necessary for each of these alternatives. A brief discussion of the alternatives is presented below.

Lake Stamford Supply

The demand on Lake Stamford will be significantly reduced within the next couple of years. The City of Hamlin, which has been purchasing raw water from Stamford for many years, will be completing a connection to the City of Abilene to purchase treated water. Also, the WTU power plant on Lake Stamford has been closed. With the availability of capacity in Lake Stamford there is a possibility that raw water could be transported to the City of Throckmorton. The City has excess capacity in its existing water treatment plant and a questionable supply in its existing City Lake. Raw water from Lake Stamford could be treated at the Throckmorton plant and distributed to both Shackelford WSC and Stephens County Rural WSC. Shackelford WSC will have facilities in place through a facilities improvement project, which would allow the WSC to take the supply from Throckmorton. It is a very short distance to the Stephens County system as well. The additional supplies to the WSCs would reduce the projected demand on the City of Breckenridge as well.

The water quality in Lake Stamford is generally very good. Data is available on the TCEQ web page for Lake Stamford from 1993 to the present. This data shows chloride levels

below 300 mg/l, the maximum contaminant level (MCL) as regulated by the TCEQ, for most of that period. During the drought beginning in 1998, the chloride levels exceeded the MCL, but levels fell below the MCL when the lake filled again. TDS levels in the lake exhibited a similar trend, although the MCL, 1,000 mg/l, has been exceeded more often. Limited information is available on the water quality of Lake Stamford prior to 1993, but the information that is available indicates that the water quality of the lake was generally below the current MCL. There is also limited information available for Lake Throckmorton. All available water quality analyses show chlorides and TDS considerably lower than the MCL. Therefore, if the water quality in Lake Stamford became poor due to low lake levels, the blended product between the two lakes would likely be acceptable. No advanced treatment would be necessary and other improvements to the plant should be minimal. There is approximately 0.40 MGD excess capacity available in the Throckmorton plant that could be used to supply Shackelford WSC and Stephens County Rural WSC. Throckmorton also has an emergency supply from Graham that could be used to further supplement the water supply corporations up to approximately 0.30 MGD. The water from Throckmorton could be supplied to both systems through a series of supply lines with an interconnect between Shackelford and Stephens County Rural WSCs. A layout of the improvements that would be necessary for this alternative is provided in Figure G-21.

Regional Treatment Plant at Breckenridge

The city of Breckenridge owns and operates a water treatment plant on the south side of the city that is used to treat raw water from Lake Daniel and Hubbard Creek Lake. Breckenridge currently supplies Stephens County Rural WSC in addition to its own retail customers. The West Central Brazos Water Distribution System Pipeline is in very close proximity to the Breckenridge plant. Raw water from Possum Kingdom Lake could be conveyed to the Breckenridge plant, which is conveniently located to provide water to a large number of suppliers. The city of Breckenridge and Stephens County Rural WSC could benefit from this supply without further pipeline improvements. Other entities that could benefit through either existing interconnections or proposed pipelines would be Shackelford WSC, Throckmorton, Cisco, Eastland County WSD, Staff WSC and Graham. Others could benefit from potential emergency supplies as well.

THROCKMORTON

EXISTING THROCKMORTON WATER TREATMENT PLANT

10" SUPPLY LINE

LAKE STAMFORD

PROPOSED PUMP STATION

8" INTERCONNECT

WOODSON

THROCKMORTON COUNTY

HASKELL COUNTY

YOUNG COUNTY

THROCKMORTON COUNTY

SHAKELFORD COUNTY

YOUNG COUNTY

STEPHENS COUNTY

FORT GRIFFIN STATE PARK

LUEDERS

JONES COUNTY

SHACKELFORD COUNTY

HUBBARD CREEK RESERVOIR

PROPOSED SHACKELFORD PUMP STATION

10" SUPPLY LINE

BRECKENRIDGE

PROPOSED ALBANY WATER TREATMENT PLANT

ALBANY

EXISTING SHACKELFORD ELEVATED TANK

STEPHENS COUNTY

10" SUPPLY LINE

UPGRADE EXISTING BRECKENRIDGE WATER TREATMENT PLANT

MODIFY AND EXPAND EXISTING BRECKENRIDGE WATER TREATMENT PLANT

L E G E N D

- EXISTING WATER LINE
- LAKE STAMFORD SUPPLY
- REGIONAL PLANT AT BRECKENRIDGE
- HUBBARD CREEK SUPPLY
- ALL THREE OPTIONS

NORTH

0 10000 20000 40000

FIGURE G-21
WEST CENTRAL BRAZOS STUDY
MIDWAY WATER TREATMENT PLANT OPTIONS

ACAD Rel 15.06s (LMS Tech) User: CAM
[BRAQ2372]N:\WR\JM-REPORT\BRASTUDY\BRAZOS-STUDIES\BRECKENRIDGE-SCENARIO1.DWG LAYOUT: 11x17
FEB 10, 2004 6:47:07 A.M. LTS: 8000.00 PSLTS: 0 TWIST: 0.0
7 REFERENCE FILES: C:\OJOBSCASEY\JOBS 2003\BRA-STUDIES-SCOTT A_TROYS REVISIONS\BRECKENRIDGE\XREFS\SHACKELFORD-CO. C:\OJOBSCASEY\JOBS 2003\BRA-STUDIES-SCOTT A_TROYS REVISIONS\BRECKENRIDGE\XREFS\STEPHENS-COUNTY.

Levels of chlorides and TDS in Possum Kingdom Lake are much higher than the recommended state and federal standards. TCEQ data shows the average chloride level since 1993 to be 960 mg/l and the average TDS levels over the same period was 1,807 mg/l. Both levels are such that blending with other sources would not be feasible. The amount of water that could be used from Possum Kingdom would be slight and the quality of the blending water would be reduced. Some form of advanced treatment would be required to reduce the salinity to acceptable levels. The most common treatment used to remove dissolved solids in drinking water is reverse osmosis. Expanding the existing conventional treatment plant at Breckenridge and installing RO trains afterward would be the most cost effective treatment option. The treated water from the RO trains could then be blended with water from other sources such as Hubbard Creek Lake. Figure G-21 shows the level of improvements that would be necessary for this alternative.

Hubbard Creek Supply and Blending

Most entities in the Midway Group and surrounding area use Hubbard Creek Lake as their primary source of water. This water is currently treated at two locations, the city of Breckenridge and the city of Albany. The city of Albany blends the water with raw water from Lake McCarty and distributes it to retail customers as well as providing a wholesale supply to Shackelford WSC. The city of Breckenridge blends the water with raw water from Lake Daniel and distributes it to retail customers and Stephens County Rural WSC. Both Lake McCarty and Lake Daniel are small and during drought periods they are seldom used. The city of Throckmorton utilizes Lake Throckmorton as well as an emergency supply from Graham through Fort Belknap WSC. Lake Throckmorton is also unreliable during times of drought. In order to utilize this supply for each of the Midway members, improvements would be necessary at both the Albany and Breckenridge treatment plants and new supply lines would be required as well. Interconnections between each entity would reduce the potential for water shortage during drought due to reliance on a single source.

The chloride levels in Hubbard Creek Lake are typically around the recommended standard of 300 mg/l. The median level since 1993 has been 280 mg/l. The TDS levels have shown a similar trend with an average level of 700 mg/l since 1993. There is limited data

available for the water quality in Lake McCarty and Lake Daniel. Lake Throckmorton was discussed previously. Conventional treatment should be sufficient for each of the sources discussed. In order to utilize these lakes and take advantage of the existing distribution networks, improvements would need to be made at the Breckenridge and Albany treatment plants. The Breckenridge plant is in very good condition and would require only minor upgrades. The Albany plant is very old and extensive rehabilitation would be required and the City has reached or exceeded the capacity of the plant on numerous occasions. A new treatment plant at Albany would be required under this alternative. In order to take full advantage of the Hubbard Creek supply, an interconnect between Shackelford WSC, Stephens County Rural WSC and the city of Throckmorton would be required. A potential connection points exists for Shackelford WSC and Stephens County Rural WSC on the north end of each system near the City of Woodson. The combined water could be conveyed to Throckmorton through a single supply line. The proposed improvements are shown in Figure G-21.

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