APPENDIX I

DESCRIPTION OF GENERAL STRATEGIES

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Brush Control

Brush control is a potential strategy that could create additional water supply within the study area. The Texas Brush Control Program, created in 1985 and operated by the Texas State Soil and Water Conservation Board (TSSWCB), serves to study and implement brush control programs in areas where brush is responsible for substantial water losses. Recent studies were conducted in the Lake Palo Pinto, Fort Phantom Hill Reservoir, and Lake Brownwood watersheds to assess the feasibility of possible brush management programs (BRA, 2003a; BRA, 2003b; LCRA, 2002). Figure I-1 shows the watersheds of these lakes.

For these studies, the Soil and Water Assessment Tool (SWAT) model developed by the USDA Agricultural Research Service was used to determine the effects of implementing brush removal programs. The model simulated the change of brush into native grass and calculated new water yields after brush had been removed over the simulation period from 1960 to 1999. The term "water yield" in the report represents average annual increases in stream flow measured at the most downstream point in the model **and** average annual recharge to aquifers. This is different from the term "yield" that is used to describe the reliable supply from a reservoir. Reservoir yields were not determined in these studies. To clarify the difference in the use of these terms, the term "water production" will be used for brush discussions and "yield" will be reserved for reservoir supply.

Costs were developed as part of the feasibility studies for different methods of brush removal, which include initial brush removal and maintenance for ten years. The most economical method as appropriate for the type of brush was used for cost estimating purposes. Costs were not developed for improved infrastructure to utilize the increased water production. The costs reported in this summary were obtained from the feasibility reports, and include landowner costs and State participation.

The SWAT model for each watershed assumed 100 percent removal of heavy and moderate categories of brush. The removal of light brush was not modeled. Results show that average water production within these watersheds will increase with the

implementation of brush managements programs. Water productions during drought conditions are expected to be less. Reservoir yields are based on drought of record inflows. For Fort Phantom Hill, the simulation period did not include the drought of record in the 1950s.

In the Fort Phantom Hill Reservoir study, 138,396 of the total 301,118 acres of the watershed were assumed to be treated during the simulation period. Results of the model showed implementing a brush control program could potentially increase the average annual water production by 111,000 gallons of water per acre treated (BRA, 2003a). This is equivalent to an additional average annual water production of 0.34 acre-feet per treated acre or an increase in water production in the entire watershed of 44,385 acre-feet per year. Treatment costs were estimated to range between $35.57 and $143.17 per acre depending on the brush type and treatment employed. . Total costs for the program, with full implementation, were estimated at approximately $14.3 million with an assumed State participation cost share of $10.2 million. The cost per acre-feet of additional water is estimated at $41.45. This includes both landowner and State participation costs. Landowner costs are estimated at an average of $30 per treated acre. (BRA, 2003a).

For the Palo Pinto Reservoir watershed, there were similar findings. Common types of prevalent brush found in this watershed include Texas prickly pear, mesquite, post and shimmery oak, and juniper (BRA, 2003b). Impacts of removing these species were modeled using SWAT. Calibration of the hydraulic portion of the SWAT model showed long-term mean correlation with downstream gages, but found significant differences in monthly flows. Also there are no USGS monitoring stations historically or presently in operation upstream of Lake Palo Pinto. This limited calibration efforts and provided little baseline data. Considering these uncertainties, the study found that brush removal would generate an average annual water production of 0.55 acre-feet per treated acre. Assuming 139,425 of the total 296,400 acres of the Palo Pinto watershed were treated, the total increase in water production would be 76,330 acre-feet per year. Treatment costs for the Palo Pinto watershed were estimated at $35.57 to $173.17 per acre. The cost share portion for landowners ranged from $17.09 per acre for treatment of moderate mesquite to $37.20 per acre for control of heavy Post/Shimmery Oak. The

estimated total cost for the program is $18.2 million. This includes an assumed State participation cost of $14.3 million and landowner cost of $3.9 million. The total cost per acre-foot of additional water is estimated at $30.65. (BRA, 2003b).

The other watershed recently studied for brush control is Lake Brownwood. The Lower Colorado River Authority (LCRA) studied this watershed, which is located in the Colorado River Basin (LCRA, 2002). The modeling effort simulated treatment of 462,141 of the total 997,039 acres making up the watershed. The results showed that implementing a brush control program in the Lake Brownwood watershed could potentially increase the average annual water production by 127,468 gallons per treated acre. This is equivalent to an additional average annual water production of 0.39 acre-feet per treated acre or 180,920 acre-feet for the entire watershed. Brush removal costs were estimated at $35.57 to $203.17 per acre. Ranchers and landowners cost share portion range from $21.37 for treatment of moderate mesquite to $35.55 for control of heavy mixed brush. The total cost for the program is estimated at $63 million. The State participation cost is nearly $50 million with the landowners contributing $13 million. The total cost per acre-foot of additional water is estimated at $44.59. (LCRA, 2002).

It is probable that brush management over the entire watershed will not be realized at the levels assumed in the study. Most likely, actual removal percentages will be less. Also, reported water production increases are long-term averages, and will be less during drought of record conditions. How much less and the resulting impacts to reliable supply from reservoirs are unknown. These studies show theoretically that brush management can improve water production in a watershed, but not until a brush control has been implemented and data has been collected for a sufficient length of time can the water supply benefits be quantified.

The immediate benefit of brush control is to the landowner for improved rangeland and increased grazing capabilities. Stream flow benefits are achieved over a longer time and may not be realized by the entity implementing the brush management. To date there has been no demonstrated increases in reservoir yields attributed to brush control. If the modeling results prove true, any increase in stream flows associated with brush control would potentially benefit run-of-the-river water rights holders, water rights holders in downstream reservoirs and major customers of the rights holders. This

assumes that any increases in available supply will be used to satisfy existing water rights in the reservoir watershed and would not be released to meet other downstream water rights. Under state law, water in the stream is the property of the state to be distributed among water rights holders based on the priority of the water right. During drought, a downstream senior water right holder may call on water flowing into a junior upstream reservoir, bypassing upstream junior water rights. For the reservoir watersheds studied, Lake Fort Phantom Hill, Lake Brownwood, and Lake Palo Pinto, the water reaching the reservoirs could likely be retained in the reservoir and not released downstream. However, for Lake Brownwood, the current firm yield of the lake is greater than the permitted diversion. Use of increased yield at Lake Brownwood may require a permit modification. Increases in permitted amounts would be junior to all other existing rights in the basin. Alternatively, this water could be released to benefit downstream water users. Lake Palo Pinto and Lake Fort Phantom Hill both have permitted amounts greater than the reservoirs' firm yields under priority analysis and could benefit from increased inflows without permit modifications.

The economic analyses prepared as part of the brush control studies assumes a high level of State participation funding. This is consistent with prior funding requests, but may not be appropriate for future funding. The State has provided over $35 million to date for brush control studies and programs (F&N, 2002). With current budget concerns, it is uncertain if the State will be able to continue to support this program at the same funding level. The most recent legislative session provided only $5 million of the requested $20 million in appropriations for the State brush control program.

Success of brush control is dependent on long-term maintenance. Yet there has been little to no State funding for maintenance beyond the initial ten-year clearing period. It is uncertain if the increased water production benefits could be achieved over the ten-year period. For this study, it will be assumed that funding will be supported locally, and the primary beneficiary will be the landowners and water rights holder in the respective reservoir.

A review of the recent feasibility studies ranked a state-supported brush control program in the Fort Phantom Hill watershed very high. This was due to significant water production benefits and high landowner support. However, State participation for this

project was not funded during the 2003 legislative session. The TSSWCB is actively pursuing other avenues for funding this program, but no definitive funding mechanism has been identified.

At this time, brush control is not a recommended strategy to meet specific needs of an entity. This is because the amount of reliable supply generated by this strategy is uncertain and the success of such a program is dependent on significant landowner participation. For significant landowner participation there will need to be adequate external funding. Securing these funds will depend upon the success of on-going pilot studies and brush programs. Support of the on-going brush programs with continued data collection is necessary to demonstrate the realized water benefits of brush control. This strategy should be re-evaluated once the results of these programs have been quantified.

List of References

Brazos River Authority, *Fort Phantom Hill Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003a.

Brazos River Authority, *Palo Pinto Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003b.

Freese and Nichols, *Evaluation of Future Financing Alternatives for the State Brush Control Program*, prepared for the Upper Colorado River Authority, 2002.

Lower Colorado River Authority, *Lake Brownwood Watershed, Brush Control Assessment and Feasibility Study*, 2002.

Salt Water Control

Waters in the Upper Brazos River Basin have historically exhibited high concentrations of dissolved solids, including chlorides and sulfates. These salt concentrations can limit the desirability of the water for municipal, industrial and irrigation purposes without advanced treatment. Brine springs and salt seeps are a major source of saline water in the West Central Brazos study area. Tributaries of the Brazos River, such as the Salt and Double Mountain Forks of the Brazos River, carry high levels of salts downstream into existing reservoirs, impacting water quality. These salt seeps also impact development of additional water supplies in the upper basin.

Several studies have been conducted in the Brazos River Basin on the feasibility of salt water control (HDR, 2001; RWR, 2000). The watershed above Possum Kingdom reservoir produces about half of the total dissolved solid loading in the basin, yet contributes less than 20 percent of the stream flow. Chlorides and sulfates are the major contributors to this loading. Studies have shown that control of brine springs and salt seeps above Possum Kingdom could positively impact most of the Brazos Basin.

The Brazos G Regional Water Plan presented a detailed review of salt water control in the Brazos River Basin. Figure I-3 shows the location of the salt water control project. The plan looked at three options for control and disposal of the brine. All three options included brine recovery well fields to lower the piezometric surface of the water table, which would greatly reduce salt discharges to receiving streams. The disposal options considered included: 1) deep well injection, 2) discharge to a brine reservoir for evaporation, and 3) processed into marketable NaCl products. Capital and operating costs were developed for each option and are summarized in Table 1.

Table 1

Strategy	Capital Costs	Total Project Cost	Annual Cost	Total Cost after 50 years of operation
Option 1: Brine recovery with deep well injection	$4,574,000	$7,634,000	$1,354,000	$56,760,700
Option 2: Brine recovery with discharge to impoundment	$151,932,000	$302,129,000	$22,763,000	$700,621,800
Option 3: Brine recovery with NaCl processing	$19,477,000	$28,673,000	$1,827,000	$49,683,200

Source: Brazos G Regional Water Plan, HDR, 2001.

The cost benefits were assessed by comparing annual operating costs of the chloride control projects to the desalinization treatment costs for municipal supplies with and without chloride control. The identified beneficiaries included water users above the Lake Whitney dam. Total dissolved solids concentrations below Lake Whitney are seldom above the 1,000 mg/l secondary drinking water standard, and do not require advanced treatment. With current BRA contracts for municipal supplies and TCEQ water rights for municipal use, the total amount of water assumed for treatment was 66,171 acre-feet per year. This represents only a portion of the total permitted water above Lake Whitney dam. There are additional supplies available that could be used for municipal or industrial uses in the future.

The cost comparison in the Brazos G plan concluded that Options 1 and 3 were economically beneficial to municipal water users in the upper basin. For these two Options, it potentially would be more cost effective to implement chloride controls and treat water with lower TDS levels than to only treat the water at the higher concentrations. The Brazos G plan recommended that further study be conducted to verify projected reductions in TDS concentrations for the specific sites and strategies developed. Updated costs should also be performed because the cost benefit of chloride control may be reduced as costs for desalinization treatment continue to decrease.

A detailed water quality and treatment analysis for Options 1 and 3 are beyond the scope of this study. Based on data provided in the Brazos G plan, implementation of salt water controls in the upper Brazos River Basin will not totally eliminate the need for advanced treatment. This is especially true for water in Possum Kingdom Lake and for all municipal water rights above Lake Whitney in the near term. At this time, it is recommended that further study on salt water control and the benefits to the BRA system and customers be conducted. Greater benefits may be realized if larger amounts of water from these sources are used for municipal supplies.

LIST OF REFERENCES

HDR Engineering, Inc., Freese and Nichols, Inc., R.W. Harden and Associates, Inc., Hicks and Company Inc., Capital City Consulting, Texas Agricultural Experiment Station, and Texas Rural Water Association. Prepared for Brazos G Regional Water Planning Group. *Region G Regional Water Plan*. 2001.

RWR Associates, Brazos River Natural Salt Pollution Chloride Control Project. Prepared for Stonewall County, Brazos River Authority and EDA, 2000.

SDII Global, Geophysical Survey – Salt Pollution Study (Dove Creek Site), Stonewall County. July 2000.

West Central Brazos Weather Modification

Weather modification is a strategy currently used in Texas to increase precipitation released from clouds over a specified area. Cloud seeding is the most common form of rainfall enhancement and entails injecting a target cloud with crystal enhancers, such as silver iodide, to induce rainfall. This activity requires specially equipped aircraft to place the seeding material and convective cloud towers to seed. In West Texas most of the opportunities for cloud seeding occur in the spring and summer months, and weather modification is usually suspended during the winter.

In the West Central Brazos study area, there is one on-going weather modification program. This program, sponsored by an alliance of eight counties and the city of Abilene called the West Central Texas Weather Modification Association, performs cloud seeding activities over 4.9 million acres in eight counties. These counties, which are shown on Figure I-2, include Nolan, Taylor, Callahan, Eastland, Coke, Runnels, Coleman and Comanche. The program has been in operation since 2001, and conducts seeding activities between May 1 and September 30 of the year. The 2003 operating budget is $496,000, of which a portion is provided in a grant from the State (Mann, September 2003).

There are three major benefits associated with weather modification:

1. Improved rangeland and agriculture due to increased precipitation
2. Greater runoff to streams and rivers due to higher soil moisture
3. Groundwater recharge

Since the West Central Texas Weather Modification program is relatively new, documented data is limited. According to Tom Mann of the West Central Texas Council of Governments, during the first year of the program in 2001 there was a 51 percent increase in normal precipitation recorded that generated 27,800 acre-feet of additional rainwater. In 2002, there was a 73 percent increase in precipitation, which produced an additional 53,300 acre-feet of rainwater (Mann, July and September 2003). Year 2002 was a not a drought year in the study area, and there were more opportunities for cloud seeding. In a drought year the amount of additional rainfall is expected to be less. The

water that cloud seeding produces during non-drought periods augments existing surface and groundwater supplies. It also reduces the reliance on other supplies for irrigation during times of normal and slightly below normal rainfall. However, not all of this water is available for water demands. Some of this precipitation is lost to evaporation, evapotranspiration, and local ponds. The amount of water made available to a specific entity from this strategy is difficult to quantify, yet there are regional benefits.

Successful rainfall enhancement programs can improve dryland farming, reduce irrigation for irrigated acres, improve forage and potentially increase runoff to local streams and reservoirs. According to the Texas Agricultural Statistics Service, within the target area there are over 51,500 acres of irrigated agriculture, 632,400 acres of dryland farming, and 355,000 head of cattle. A study by Texas A&M University on the economic impacts of weather modification found that an additional one inch of rainfall distributed evenly over the target area would result in over $10 million in benefits per year (Mann, September 2003). The increases in rainfall recorded to date, if distributed uniformly over the target area, correspond to 0.0068 inches in 2001 and 0.011 inches in 2002. While the economic benefits cannot be proportioned directly, the benefits associated with these levels of increased rainfall would be substantially less than $10 million.

The cost of operating the weather modification program is approximately 10 cents per acre. Benefits of the program are widespread and are difficult to quantify for specific entities. As such weather modification is not recommended to meet a specific need in this study. However, there is local support for the weather modification program in the region and data has shown increases in precipitation. It is recommended that weather modification be supported in the region and that data from the program continue to be collected to assist in operating the program.

List of References

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Texas Department of Licensing and Regulation website, www.license.state.tx.us/weather, August 27, 2003.