## *4B.9 Brush Control and Range Management*

Brush control is a potential water management strategy that could possibly create additional water supply within the Brazos G 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 considered to be responsible for substantial water losses.

Brush control is a land management practice that converts land that is covered with brush, such as juniper and mesquite, to grasslands. The impact of these practices can increase water availability through reduced extraction of soil water for transpiration and increased recharge to shallow groundwater and emergent springs. To a lesser extent, there is the potential for increased runoff during rainfall and snowmelt events.

Research on brush control and water balance began in the 1920s, but the idea of brush control as a possible means of alleviating water scarcity in drought-prone western states started to take hold in the 1970s. Research and pilot studies have found that the control of brush species yields more water, but these increases are dependent upon rainfall variations and many other variables. To date, there has been mixed results regarding water production, but in general, the results indicate positive outcomes to carefully planned brush control.

One of the first studies on brush control was the federally sponsored Seco Creek Demonstration project in the Texas Hill Country. The findings from this study showed significant improvements in rangeland health and water quality and quantity of the underlying Edwards Aquifer. Following that study, significant state- support of brush control began with a feasibility study on the North Concho River Basin in 1998. Over the past 6 years, the State has authorized feasibility studies for the control of mesquite, juniper and mixed brush in 14 watersheds: North Concho, Main Concho, Twin Buttes/Lake Nasworthy, Upper Colorado, Canadian, Wichita, Pedernales, Edwards Aquifer, Nueces, Frio, Palo Pinto Lake, Lake Brownwood, Lake Phantom Hill and Lake Arrowhead. From these fourteen feasibility studies, three major state-supported brush control programs have been initiated in the North Concho, Upper Colorado and Pedernales River Basins. Each is administered by the TSSWCB.

In addition to State supported studies and programs, the Federal government, through the Corps of Engineers, is involved in brush control studies in the O.C. Fisher and Cibolo Creek watersheds. Both of these projects include brush control as part of environmental restoration and aquifer recharge enhancement efforts. Other efforts include salt cedar removal in the Colorado, Canadian and Pecos River Basins. Bio-control studies of salt cedar using Asian leaf beetles are also being conducted in these basins in conjunction with state and federal agencies.

Generally, brush control activities in Texas have been limited to feasibility studies with limited data collection from on-going brush programs. The results of the completed feasibility studies indicate increases in water production for all basins studied, with average annual water increases per acre treated ranging from 13,000 gallons in the Canadian Basin to 172,000 gallons in the Medina watershed (Edwards Aquifer). These calculations are based on comparisons of total water flow at the most downstream point of the watershed for conditions with and without brush. Estimates of long-term reliable supply from increased storage in reservoirs or aquifers are not reported in the studies.

The North Concho River Brush Control Project is one of the longer on-going brush programs in the state. From 1999 through 2003, over 207,000 acres of brush were cleared in the O.C. Fisher Reservoir watershed.[1] A total of 307,000 acres were targeted for removal by 2004. However, current drought conditions have limited removal efforts and basin-wide responses have been difficult to measure. In limited areas, the program is recording increased soil moisture after treatment and more frequent rainfall-runoff events, but it is difficult to assess the water supply benefits of brush control during drought. It appears that most of the water realized through brush removal is likely associated with increased soil moisture and/or contained in the shallow alluvial aquifer. There have been no significant increases in storage content in O.C. Fisher Reservoir since the program has been in place.

### *4B.9.1 Description of Brush Control Strategy*

Virtually all of the renewable and sustainable water resources available for the Brazos G Area originate as precipitation within the boundaries of the region. The inflow from the upstream tributaries of the Brazos River is limited in amount and quality. The significant majority of this precipitation falls on agricultural lands, which includes crop land, improved pastures, improved range, native range, and other rural lands, such as rocky outcrops, heavy brush and trees, and other land that is not used for production. This water then infiltrates into the soil, runs off the land to nearby streams, or evaporates from localized ponding.

[1] Texas State Soil and Water Conservation Board, *Brush Control Program – 2003 Annual Report*, 2004.

Modification of the landscape has a significant impact on the partitioning of rainfall into runoff and infiltration, and ultimately the usability of this water. From a water yield standpoint, the ideal range (non-cropland) landscape has a good grass cover at all times of the year, whether the grass is alive or dormant. The grass retards surface runoff and allows more time for infiltration of the rainfall into the soil. The grass prevents sealing of the soil surface and the roots improve the soil structure, which also increases infiltration (water flow *into* the soil) and percolation (water flow *within* the soil). The active root zone of most grasses is easily within the top 3 feet of the soil, so the infiltrated soil water that is in excess to the storage capacity of the soil will percolate to the groundwater table. In aquifer outcrop areas, this percolation recharges the aquifer. If there is no aquifer, the shallow groundwater will emerge as springs and soil water movement into creek, stream, and river channels. This is the source of the highly desirable base flow of rivers that continuously recharge the reservoirs and provide wildlife habitat, livestock water, fish habitat, and recreational uses. Flash flood runoff does not contribute significantly to this base flow. The grass cover provides grazing for stock, which provides the economic incentive for the landowner to maintain the ranges in good condition.

The worst case from a water yield standpoint is a landscape that is covered with brush, such as juniper and mesquite. The grass cover is reduced under the brush (especially juniper) and, therefore, not fully effective in reducing runoff. The major impact of the brush, however, is the continuing extraction of soil water for transpiration long after the rainfall event has ended. Whereas most grasses have an effective rooting zone of 3 feet or less, mesquite can pull moisture from 10 to 20 feet and perhaps even more. Juniper is much shallower rooted, but will still extract moisture from below the grass root zone. Although each fair-sized shrub or small tree (10-foot diameter canopy) would only use 10 to 15 gallons of water a day, it would use the water every day and all of the water use for an area adds to a significant amount of groundwater consumed. Grass, with its much shallower root zone, is limited by the amount of soil water available for extraction.

Groundwater initially receives most of the additional water that is produced from brush removal, although surface water flows may be enhanced directly and indirectly following initial groundwater recharge. The rate of brush regrowth and brush control maintenance is important to maintaining stable, long-term water yield. Control methods that kill and remove the entire brush plant are more desirable than simply killing the brush. Water yield projections usually exceed actual results, and optimum results are achieved under optimum conditions.

There are three primary methods to remove upland brush: mechanical removal, chemical removal, and prescribed burning. Bio-control through Asian leaf beetles is limited to salt cedar removal, which generally occurs in riparian zones and lakes, and may be an option for some areas in the upper portion of the Brazos River. A brief description of each method is presented below.

#### *4B.9.1.1 Mechanical Brush Control*

A wide variety of mechanical brush control methods are available. The simplest is selective brush control with a hand axe and chain saw. Grubbing and piling is frequently done with a bulldozer. This may be either clear-cut or selective. Bulldozers and/or tractors may also be equipped with root plows, shears, or shredders. Two large bulldozers pulling large anchor chains stretched between them are capable of clearing low brush in swaths 100 foot or more in width at a time.

Moderate to heavy mesquite or cedar can be grubbed (bulldozer with a 3-foot-wide grubbing attachment) or root plowed for $100 to $165/acre. Two-way chaining can be effective on moderate to heavy cedar, but it often just breaks off mesquite and they re-sprout profusely from the bud zones below ground. Using hydraulic shears mounted on Bobcat loaders can be effective on blueberry juniper (a non-sprouting species) for a cost of $50 to $140/acre. If the shears are used on mesquite or redberry juniper one must spray the stump immediately with a herbicide, which will cost in the range of $0.10 to $0.30 per plant.

#### *4B.9.1.2 Chemical Brush Control*

Several herbicides are approved for brush control. The herbicides may be applied by applying a herbicide-water mixture from aircraft, from booms on tractor-pulled spray rigs, or from hand tanks. Some herbicides are also available in pellet form.

The herbicides Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®) are approved herbicides for on-going TSSWCB brush programs. Arsenal is the herbicide typically used for removal of salt cedar. Chemical treatments with Remedy® and Reclaim® were shown to achieve about 70 percent root kill in studies around the state and in adjacent states. Commercial aerial applications in general are not as effective, which is most likely due to fewer controls. Timing is the key to successful chemical treatment. Soil temperature must be over 75°F at a depth of 12 to 18 inches, mesquite foliage must be dark green, and treatment is best conducted 42 to 63 days after bud break and 72 to 84 days after bud break. Other herbicide treatments are available, but many will achieve little root kill. Aerial spraying of brush such as mesquite costs about $25 per acre and is the same regardless of the plant density or canopy cover.

#### *4B.9.1.3 Brush Control by Prescribed Burning*

Prescribed burning is defined as the application of fire to a predetermined area. The burn is conducted under prescribed conditions of fine fuel load, weather, and season to specifically target desired effects. The purposes of prescribed burning include control or suppression of undesirable vegetation, to facilitate distribution of grazing and browsing animals, to improve forage production and/or quality, and to improve wildlife habitat.

Prescribed burning is estimated at $15 per acre for the TSSWCB programs. Actual costs will depend on how rocky the soils are and the amount of large brush to remove from the fire guards (i.e., a once-over pass with a maintainer versus clearing heavy brush with a bulldozer, then smoothing up the fire guard). Prescribed burning will only be effective under the right environmental conditions, and with an adequate amount of fine fuel (dead or dormant grasses). For successful burns, a pasture deferment is essential for part or all of the growing season prior to burning, and burned pastures must be rested after the burn. On average, a 12-month deferment is necessary, which may increase costs if a rancher cannot utilize the land for livestock grazing.

Burning rarely affects moderate to heavy stands of mature mesquite. Burning only topkills the smooth-bark mesquite plants, and they re-sprout profusely. For mesquite, fire only gives short-term suppression, and stimulates the development of heavier canopy cover than was present pre-burn. Burning is not usually an applicable tool in moderate to heavy cedar (juniper) because these stands suppress production of an adequate amount of grass for fine fuel. Burning can be excellent for controlling junipers over 4 feet tall, if done correctly. Prescribed burning is often not recommended for initial clearing of heavy brush due to the concern that the fire could become too hot and sterilize the soil. Burning is often used for maintenance of brush removal.

#### *4B.9.1.4 Bio-Control of Brush*

Bio-control of salt cedar is a relatively new technique to be used in Texas. This control method has been studied for nearly 20 years and there have been pilot studies in the Lake

Meredith watershed and most recently in the Colorado River Basin[2]. Research has shown that the Asian leaf beetle can consume substantial quantities of salt cedar in a relatively short time period, and generally does not consume other plants. Different subspecies of the Asian beetle appear to be sensitive to varying climatic conditions, and there is on-going research on appropriate subspecies for Texas. It is recommended that this control method be integrated with chemical and mechanical removal to best control re-growth. The cost per acre is unknown.

#### *4B.9.1.5 Range Management for Brush Control*

Grazing management is very important following any type of upland brush control to allow the desirable forages to exert competition with the brush plants and to maintain good herbaceous groundcover, which hinders establishment of woody plant seedlings. Continued maintenance of brush is necessary to ensure the benefits of this potential strategy.

### *4B.9.2 Brush Control in the Brazos G Area*

In 1985, the TSSWCB in conjunction with the Texas Water Development Board developed a list of water supply reservoirs where brush control could possibly enhance water supplies.[3] This list was updated in 2001; 27 existing reservoirs, one potential new reservoir site and two river segments in Region G were identified as potentially benefiting from brush control. The complete list as included in the State Brush Control Plan is shown in Table 4B.9-1.

Considering these potential sources, the TSSWCB has sponsored two brush removal feasibility studies in the Brazos G Area including the Lake Fort Phantom Hill watershed[4] and Lake Palo Pinto watershed.[5] In addition, an independent study is currently being conducted in the Leon River watershed. This project, which includes federal and state participation, focuses on brush removal in Hamilton and Coryell Counties, upstream of Belton Lake.[6,7]

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[2] Colorado River Municipal Water District, *Annual Report*, 2003.
[3] Texas State Soil and Water Conservation Board, *State Brush Control Program*, 2003 Annual Report. http://www.tsswcb.state.us/programs/brush.html
[4] 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.
[5] Brazos River Authority, *Palo Pinto Reservoir Watershed, Brush Control Assessment and Feasibility Study*, prepared for the Texas State Soil and Water Conservation Board, 2003b.
[6] Kiel, Simone, of Freese and Nichols, Inc., Memorandum documenting telephone conversation with Steve Manning, Central Texas Cattleman's Association, regarding the Leon River Restoration Project, December 11, 2003.
[7] Kiel, Simone, of Freese and Nichols, Inc., Memorandum documenting telephone conversation with Wayne Hamilton, Texas A&M, regarding the Leon River Project, January 20, 2004.

**Table 4B.9-1.**
**Brazos G Water Supply Sources Identified in the State Brush Control Plan that Could Benefit from Brush Control**

| County | Reservoir | Water Course | User | Comments |
|---|---|---|---|---|
| Baylor | Miller's Creek | Miller's Creek | N. Central Texas MWA | Not more than 20% canopy |
| Bell | Lake Belton | Leon River | Bell Co. WCID | |
| Bosque | Bosque River | Bosque River | Meridian | |
| Bosque | Bosque River | Bosque River | Clifton | Proposed reservoir |
| Callahan | Lake Baird | Mexia Creek | Baird | |
| Callahan | Lake Clyde | N. Prong Pecan Bayou | Clyde | Brownwood Study - 2002 |
| Eastland | Lake Cisco | Sandy Creek | Cisco | |
| Erath | Bailey's Lake | Kickapoo Creek | Lipan | |
| Erath | Thurber Lake | Gibson Creek | Thurber | Palo Pinto Study - 2002 |
| Falls | Lake Marlin | Big Sandy Creek | Marlin | |
| Falls | Lake Rosebud | Pond Creek Tributary | Rosebud | |
| Hamilton | Proctor | Leon River | Hamilton | |
| Haskell | Lake Stamford | Paint Creek | Stamford | |
| Johnson | Lake Pat Cleburne | Nolan River | Cleburne | |
| Jones | Ft. Phantom Hill | Elm Creek | Abilene | Ft. Phantom Hill Study - 2002 |
| Nolan | Lake Trammel | Sweetwater Creek | Sweetwater | |
| Nolan | Lake Sweetwater | Bitter Creek | Sweetwater | |
| Palo Pinto | Palo Pinto | Palo Pinto Creek | Palo Pinto MWD | Palo Pinto Study - 2002 |
| Palo Pinto | Lake Mingus | Gibson Creek | Mingus | Palo Pinto Study - 2002 |
| Palo Pinto | Tucker Lake | Russell Creek | Strawn | Palo Pinto Study - 2002 |
| Shackelford | McCarty Lake | Salt Prong Hubbard Creek | Albany | |
| Somerville | Paluxy River | Paluxy River | | |
| Stephens | Lake Daniel | Gonzales Creek | Breckenridge | Base flow decline |
| Stephens | Hubbard Creek | Hubbard Creek | W. Central Texas MWD | |
| Taylor | Lake Abilene | Elm Creek | Abilene | Ft. Phantom Hill Study - 2002 |
| Taylor | Lake Kirby | Cedar Creek | Abilene | Ft. Phantom Hill Study - 2002 |
| Taylor | Lake Lytle | Lytle Creek | Abilene | Ft. Phantom Hill Study - 2002 |
| Williamson | Lake Georgetown | N. Fork san Gabriel | Brazos RA | |
| Young | Lake Graham | Salt Creek | Graham | |
| Young | Lake Whiskey Creek | Whiskey Creek | Newcastle | |

The feasibility studies sponsored by the TSSWCB are modeling studies, while the Leon River Project includes the collection of field data for pre- and post-brush removal conditions. The data from the Leon River Project will be used to help quantify the impacts of brush removal; however, the data are not yet available. At this time, the best predictive tools available for evaluating a potential brush removal project are modeling studies utilizing the Soil and Water Assessment Tool (SWAT) model developed by the USDA Agricultural Research Service. The model simulates the change of brush into native grass and calculates new water yields after brush is removed over the simulation period from 1960 to 1999. The term “water yield” in the study reports 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 or a stream. Reservoir yields were not determined in the TSSWCB-sponsored studies. To clarify this difference, the term “water production” will be used in this memorandum to describe results from the TSSWCB studies and the term “yield” will be used in discussing supply from a reservoir.

### *4B.9.3 TSSWCB Brush Control Feasibility Studies*

The studies for the Lake Fort Phantom Hill and Lake Palo Pinto watersheds were conducted during fiscal years 2001 and 2002. Hydrologic, climate, soils, and vegetation data were collected for each watershed. These data were used to develop and calibrate the SWAT model. While calibration of the hydrologic portion of the SWAT model showed long-term mean correlation with downstream gages over selected time periods, there were some significant differences in monthly flows. Monthly flows particularly during drought periods are critical when determining increases in reservoir yield. Other assumptions in parameter selection and interactions between surface and groundwater also impact the modeling results.

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 production during drought conditions is expected to be less. For Lake Fort Phantom Hill, the drought of record in the 1950s was not included in the simulation.

According to the Feasibility Study Report, data from 1950 through 1957 were not included because the drought of record during this time period skewed the data.[8]

Costs were developed as part of the feasibility studies for different methods of brush removal, which include initial brush removal and maintenance for 10 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.

In the Lake Fort Phantom Hill study, 138,396 of the total 301,118 acres of the watershed were assumed to be treated during the simulation period. Model results showed implementing a brush control program could potentially increase the average annual water production by 111,000 gallons of water per acre treated.[7] 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-foot of additional water production 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.[9] These costs, however, cannot be compared to costs for supply from additional reservoir yield.

For the Lake Palo Pinto watershed, there were similar findings. Calibration of the hydrologic portion of the SWAT model had varied results. There are no USGS monitoring stations historically or presently in operation upstream of Lake Palo Pinto, which provided little baseline data for model calibration. 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

[8] 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

[9] 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

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 production is estimated at $30.65.[10]

### *4B.9.4 Potential Brush Control Project*

Based on the findings of the feasibility studies and the high ranking by the TSSWCB, the Lake Fort Phantom Hill watershed was selected to evaluate the potential water supply benefits of a brush project in the watershed. This evaluation includes assumptions of landowner participation, brush removal percentages within each subbasin, and an assessment of increased monthly inflows to Lake Fort Phantom Hill.

While landowner support is assessed as high by the TSSWCB, the levels of participation assumed in the TSSWCB study (100 percent) will probably not be realized. Actual participation and removal percentages most likely will be less. For this project it was assumed that landowner participation would be approximately 50 percent of the total watershed. Subbasins with the highest amount of water generated from brush removal per acre were targeted for inclusion in the project. It was also assumed that 75 percent of the brush within the targeted subbasins would be removed. The subbasin data were obtained from the feasibility study and are shown in Table 4B.9-2.

To assess the potential water supply benefits, the SWAT model outputs for conditions with brush and without brush were obtained from the Blackland Research Center.[11] Monthly stream flows were extracted from the output files for both conditions. The differences in inflows between the brush and no brush simulations from SWAT were calculated. These increases in inflows were adjusted based on water production per acre treated to reflect a smaller project

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

[11] Rosenthal, Wesley, Blackland Research Center, Texas A&M University. Reach files for SWAT model for Lake Fort Phantom Hill, e-mail correspondence to Simone Kiel, January 15, 2004.

scope. The "with brush" and adjusted "no brush" inflows were then input into a reservoir operation model to assess the potential increase in reservoir yield. The reservoir operation model computes the available supply through a mass-balance evaluation, considering inflows, reservoir area-capacity data, reservoir surface evaporation, and diversions. A monthly time step was used for the simulation.

***Table 4B.9-2.***
***Subbasins Targeted for Potential Brush Control Project***

| ***Subbasin*[1]** | ***Total Area (acres)*** | ***Total Brush Area (acres)*** | ***Treated Brush (acres)*** | ***Increase in Water Yield (gal/ac/yr)*** |
|---|---|---|---|---|
| 1 | 2,540 | 537 | 403 | 238,892 |
| 8 | 68 | 28 | 21 | 123,145 |
| 15 | 36,789 | 24,241 | 18,181 | 119,368 |
| 2 | 12,087 | 3,735 | 2,801 | 118,572 |
| 3 | 4,451 | 1,114 | 836 | 112,286 |
| 10 | 27,797 | 12,690 | 9,518 | 111,254 |
| 5 | 30,985 | 9,356 | 7,017 | 109,228 |
| 9 | 11,914 | 5,931 | 4,448 | 109,046 |
| 4 | 453 | 149 | 112 | 108,484 |
| 6 | 21,928 | 7,275 | 5,456 | 106,471 |
| 16 | 28,340 | 19,218 | NI | 104,404 |
| 14 | 23,069 | 12,073 | NI | 102,331 |
| 17 | 8,803 | 6,102 | NI | 97,874 |
| 7 | 12,483 | 4,431 | NI | 92,874 |
| 12 | 28,282 | 11,245 | NI | 91,332 |
| 11 | 38,084 | 14,597 | NI | 85,206 |
| 13 | 13,045 | 5,672 | NI | 82,080 |
| Total - Watershed | 301,118 | 138,394 | | 1,912,847 |
| Total - Project | 149,012 | 65,056 | | 1,256,746 |

[1]Listed in order of water production

NI – Not included in potential brush control project.

In this study, the "with brush" simulation is considered the baseline current condition. With these assumptions, the firm yield of Fort Phantom Hill with brush (using SWAT inflows) is 12,360 acre-feet per year. After implementing the brush control project, the firm yield of the reservoir is projected to be 15,000 acre-feet per year, an increase of 2,640 acre-feet per year. Diversions from the Clear Fork and Deadman Creek were not included in the study. The potential increase in reservoir yield that was computed is due solely to increases in watershed production.

Costs were assessed using the cost estimates developed for the feasibility study. These costs are based on the type of brush and removal methodology, and are unique to each subbasin. The total cost for the project as shown in Table 4B.9-3 was estimated at approximately $5 million. This includes costs typically attributed to the landowner, as well as State participation costs. To assess the cost per acre-foot of water generated from the brush control project, the total cost was amortized over a 10-year period at an annual interest rate of 6 percent. Ten years were selected because the removal cost includes 10 years of maintenance activities and that is equivalent to the life of the project. With these assumptions, the cost per acre-foot of additional raw water in the lake is $257. Additional cost to maintain the level of brush removal will be needed after ten years. Cost per acre-foot of water may be less in subsequent decades if only maintenance activities are required.

***Table 4B.9-3.***
***Costs for Potential Brush Control Project***

| Subbasin | Treated Brush Area (acres) | State Cost per Treated Acre | State Cost | Estimated Rancher Cost[1] | Total Cost |
|---|---|---|---|---|---|
| 1 | 403 | $59.38 | $23,916 | $11,277 | $35,193 |
| 2 | 2,801 | $59.62 | $167,018 | $78,435 | $245,453 |
| 3 | 836 | $62.71 | $52,398 | $23,394 | $75,792 |
| 4 | 112 | $72.68 | $8,122 | $3,129 | $11,251 |
| 5 | 7,017 | $64.36 | $451,640 | $196,476 | $648,116 |
| 6 | 5,456 | $78.62 | $428,973 | $152,775 | $581,748 |
| 8 | 21 | $82.71 | $1,737 | $588 | $2,325 |
| 9 | 4,448 | $82.50 | $366,992 | $124,551 | $491,543 |
| 10 | 9,518 | $73.43 | $698,906 | $266,490 | $965,396 |
| 15 | 18,181 | $78.78 | $1,432,211 | $509,061 | $1,941,272 |
| Totals | 48,792 | | $3,631,913 | $1,366,176 | $4,998,089 |
| Annual cost (amortized over 10 years) | | | | | $679,080 |
| Increase in Safe Yield (acft/yr) | | | | | 1,390 |
| Cost/acft of water | | | | | $489 |
| Cost/1,000 gal. of water | | | | | $1.50 |

[1]Rancher costs were estimated at $28 per acre. This corresponds to 20 to 30 percent of the total cost per acre. Recent changes to the brush control program rules limits State participation to 70 percent

The Brazos G RWPG has recommended that water supplies for reservoirs above Lake Possum Kingdom be evaluated on a safe yield basis. Using these guidelines, the increase in safe yield of Lake Fort Phantom Hill that is associated with a potential brush control program is 1,390 acre-feet per year. The total cost of the program remains the same, which results in a raw water cost of $489 per acre-foot or $1.50 per 1,000 gallons.

### *4B.9.5 Comparison of Findings to Other Studies*

The SWAT model output under the "with brush" conditions should be similar to the inflows determined by the Brazos G WAM (Volume I, Section 3.2.1) under natural order analysis, i.e., not adhering to prior appropriation doctrine. Comparisons of the SWAT output to the WAM inflows found that the SWAT model underestimated the inflows into Lake Fort Phantom Hill in most years. The cumulative difference over time is about 339,000 acre-feet, which is shown on Figure 4B.9-1. Using the WAM inflows over the same period of record (1960-1997, with extended data for 1998 and 1999), the reservoir yield for Lake Fort Phantom Hill is 17,000 acre-feet per year. Recent data indicate that a new drought of record began in 1997 in the watershed. For the SWAT model inflows, the drought of record is in 1974, with other times of low content in 1981 and 1986. Application of the WAM through the drought of record period in the 1950s reduces the computed yield to 12,100 acre-feet per year.

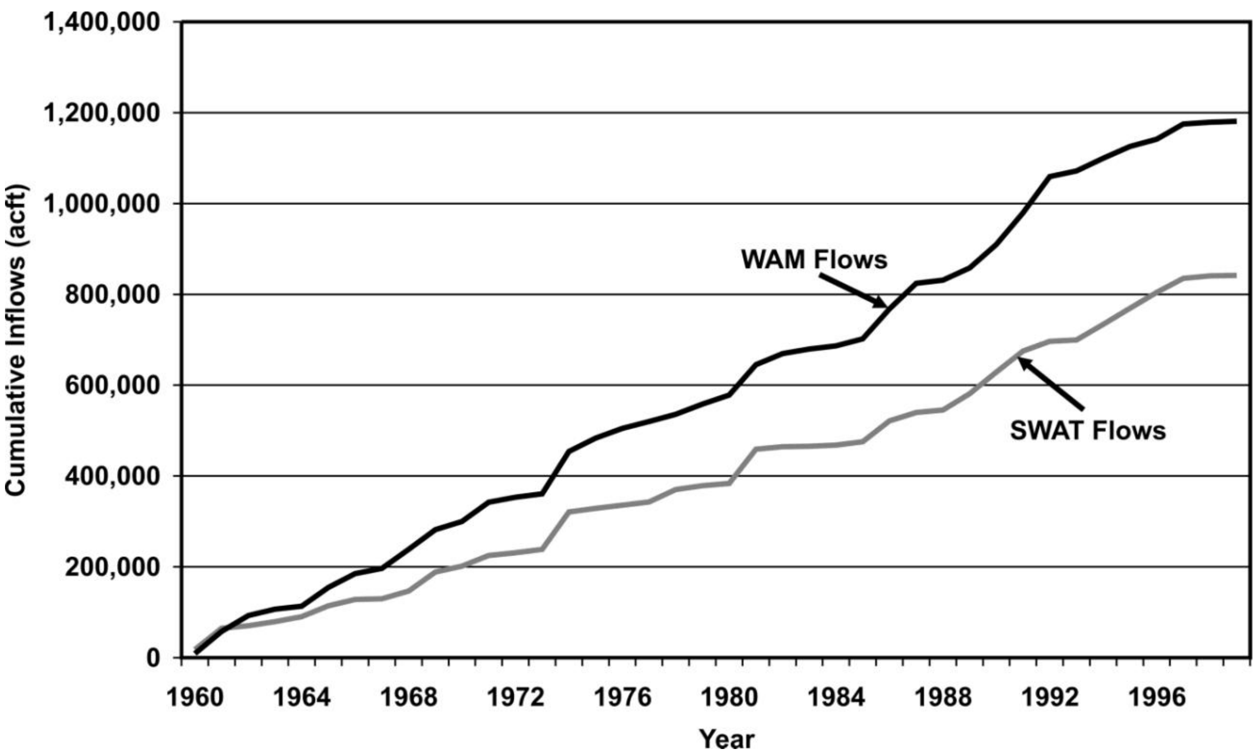


***Figure 4B.9-1. Fort Phantom Hill Reservoir Cumulative Inflow Comparison***

These factors indicate that the potential increase in reservoir yield would be less than indicated by the SWAT model because the SWAT model does not include the historical drought of record of the 1950s, or the potential new drought of record that started in the late 1990s. Increased inflows from brush removal during drought may be minimal and have little to no impact on firm available water supplies, except the initiation of drought flows would be somewhat delayed to the extent that additional water would be temporarily stored in shallow soils and aquifers and subsequently discharged to streams. Not until brush control has been completed within a basin and data have been collected for a sufficient length of time can the water supply benefits be truly quantified.

### *4B.9.6 Environmental Impacts of the Potential Brush Control Project*

The central and western portions of the Lake Fort Phantom Hill Watershed Brush Control Study Area are within the Edwards Plateau Ecological Region, while the northern and eastern portions of the study area are within the Rolling Plains Ecological Region.[12] The physiography of the study area includes recharge sands, massive limestone, caliche with some soil cover, severely eroded lands, and undissected red beds.[13] Topography varies from rough, rolling hills to nearly level terrain. Soil types are diverse. The Tarrant-Tobosa association comprises well-drained upland soils that are very shallow to steep. These soils include very shallow to deep calcareous, clays and cobbly clays. The Tillman-Vernon association consists of deep, nearly level to sloping, well-drained upland soils that include non-calcareous to calcareous clay loams and clays. The Sagerton-Rowena-Rotan association includes deep, nearly level to gently sloping, well-drained soils that are comprised of noncalcareous to calcareous clay loams.[14] Major aquifers that may be minimally represented in the study area include the Edwards-Trinity Aquifer in the western portion and the Trinity Aquifer in the eastern portion.[15] Climate is characterized as subtropical, sub humid, with hot summers and dry winters. Average annual precipitation ranges between 23 and 25 inches.[16]

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[12] Gould, F.W., G.O. Hoffman, and C.A. Rechenthin. *Vegetational Areas of Texas*. Texas A&M University, Agricultural and Experiment Station Leaflet 492, 1960.

[13] Kier, R.S., L.E. Garner, and L.F. Brown, Jr. *Land Resources of Texas – A map of Texas Lands Classified According to Natural Suitability and Use Considerations*. University of Texas, Bureau of Economic Geology, Land Resources Laboratory Series, 1977.

[14] Soil Conservation Service. *Soil Survey of Taylor County, Texas*. U.S. Department of Agriculture Soil Conservation Service, 1976.

[15] Texas Water Development Board. *Major Aquifers of Texas, 1990*. A map.

[16] Larkin, T.J., and G.W. Bomar. *Climatic Atlas of Texas*. Texas Department of Water Resources LP-192, 1983.

Vegetation and resulting wildlife habitats within these ecological regions have been greatly affected by anthropogenic factors over the last 200 years. The prairie grasslands once covering a large portion of the area have gradually changed to shrub and brush land communities from the suppression of wild fires and intensive livestock grazing. Three major vegetation types now occur in the study area,[17] these include: Mesquite (*Prosopis glandulosa*)-Lotebush (*Ziziphus obtusifolia*) Shrub, Mesquite-Juniper (*Juniperus spp*.) Shrub, and Mesquite-Juniper-Live Oak (*Quercus fusiformis*) Brush. Variations of these primary types occur involving changes in the composition of woody and herbaceous species and physiognomy according to localized conditions and specific range sites. Other major cover types include crops and developed urban areas. Major land uses in the area include cattle ranches and farms, oil fields, hunting leases, and minerals. [18]

A number of vertebrate species would be expected to occur within the study area as indicated by county occurrence records.[19] These include 1 species of salamander, 14 species of frogs and toads, 7 species of turtles, 12 species of lizards, and 34 species of snakes. Additionally, 79 species of mammals could occur within the study area or surrounding region[20] in addition to an undetermined number of bird species. A variety of fish species would be expected to inhabit streams and ponds within the study area but with distributions and population densities limited by the types and quality of habitats available.

A total of 26 species could potentially occur in the study area that are state- or federally-listed as threatened or endangered, candidates for listing, or exhibit sufficient rarity to be listed as a species of concern. This group includes 4 reptiles, 14 birds, 5 mammals, 1 fish species, and 2 plants (Table 4B.9-4). Five bird species and one mammal are federally-listed as threatened or endangered that could occur (or historically occurred) in the study area. These include the bald

[17] McMahan, C.A., R.G. Frye, and K.L. Brown. *The Vegetation Types of Texas including Cropland*. Texas Parks and Wildlife Department Bulletin 7000-120, 1984.

[18] Telfair, R.C. II. *Ecological Regions of Texas: Description, Land Use, and Wildlife*. In Ray C. Telfair, Editor, *Texas Wildlife Resources and Land Uses*. University of Texas Press. Austin, Texas, 1999.

[19] Texas A&M University. *Texas Cooperative Wildlife Collection*. http://wfscnet.tamu.edu/tcwc/tcwc.htm Incorporates online checklists of amphibians and reptiles for counties based on information contained in: Dixon, J.R., and R.K. Vaughan. 1987. *Amphibians and Reptiles of Texas*. Texas A&M University Press. College Station Texas, 1998.

[20] Texas Tech University. *The Mammals of Texas – Online Edition*, 1997. http://www.nsrl.ttu.edu/tmot1/distribu.htm Incorporates information contained in: Davis, W.B., and D.J. Schmidly. 1994. *The Mammals of Texas*. Texas Parks and Wildlife Department. Austin, Texas.

**Table 4B.9-4.**
**Federal and State-Listed Species, Candidate and Proposed Species for Listing, and Species of Concern for Counties in Fort Phantom Hill Brush Control Study Area**

| Scientific Name | Common Name | Federal/State Status | Callahan County | Jones County | Nolan County | Taylor County |
|---|---|---|---|---|---|---|
| **Birds** | | | | | | |
| *Falco peregrinus anatum* | American Peregrine Falcon | DL/E | M | M | M | M |
| *Falco peregrinus tundrius* | Arctic Peregrine Falcon | DL/T | M | M | M | M |
| *Ammodramus bairdii* | Baird's Sparrow | SOC | | M | M | M |
| *Haliaeetus leucocephalus* | Bald Eagle | LT-PDL/T | M | M | M | M |
| *Vireo atricapillus* | Black-capped Vireo | LE/E | NM | | NM | NM |
| *Buteo regalis* | Ferruginous Hawk | SOC | | M | M | M |
| *Sterna antillarum athalassos* | Interior Least Tern | LE/E | M | M | M | M |
| *Tympanuchus pallidicinctus* | Lesser Prairie Chicken | C/SOC | | R | R | |
| *Charadrius montanus* | Mountain Plover | PT/SOC | M | M | M | M |
| *Charadrius melodus* | Piping plover | FT w/CH | M | M | M | M |
| *Charadrius aleMandrinus* | Snowy Plover | SOC | | M | M | |
| *Athene cunicularia hypugaea* | Western Burrowing Owl | SOC | R | R | R | |
| *Grus americana* | Whooping Crane | LE/E | M | M | M | M |
| *Buteo albonotatus* | Zone-tailed Hawk | SOC/T | | | | NM |
| **Fishes** | | | | | | |
| *Notropis buccula* | Smalleye Shiner | C/SOC | | | | R |
| **Mammals** | | | | | | |
| *Mustela nigripes* | Black-footed Ferret | LE/E | | R1 | R1 | |
| *Cynomys ludovicianus* | Black-tailed Prairie Dog | C/SOC | | R | R | R |
| *Myotis velifer* | Cave Myotis Bat | SOC | R | R | R | R |
| *Spilogale putorius interrupta* | Plains Spotted Skunk | SOC | R | R | R | R |
| *Vulpes velox* | Swift Fox | SOC | | R | R | |
| **Reptiles** | | | | | | |
| *Nerodia harteri* | Brazos Water Snake | SOC/T | | R | | |
| *Holbrookia lacerata* | Spot-tailed Earless Lizard | SOC | | | | R |
| *Thamnophis sirtalis annectens* | Texas Garter Snake | SOC | R | R | R | R |
| *Phrynosoma cornutum* | Texas Horned Lizard | SOC/T | R | R | R | R |
| **Plants** | | | | | | |
| *Chamaesyce jejuna* | Dwarf broomspurge | SOC | | | R | |
| *Hexalectris warnockii* | Warnock's coral root | SOC | | | | R |

Notes:

Federal Status: LE-Listed Endangered; LT-Listed Threatened; PE-Proposed to Be Listed Endangered; PT-Proposed to Be Listed Threatened; PDL-Proposed to Be De-listed (Note: Listing status retained while proposed); E/SA T/SA-Listed Endangered on Basis of Similarity of Appearance, Listed Threatened on Basis of Similarity of Appearance; DL-De-listed Endangered/Threatened; C-Candidate (USFWS has substantial information on biological vulnerability and threats to support proposing to list as endangered or threatened. Data are being gathered on habitat needs and/or critical habitat designations.)

State Status: E-Listed as Endangered by the State of Texas; T-Listed as Threatened by the State of Texas.

Type of Occurrence: R - Resident; NM – Potential Nesting Migrant; M – Migrant, R1 – Historically occurred but now extirpated.

Source: Texas Parks and Wildlife Department, Texas Biological and Conservation Data System (TBCDS) 2004.

eagle (*Haliaeetus leucocephalus*), black-capped vireo (*Vireo atricapillus*), interior least tern (*Sterna antillarum athalassos*), piping plover (*Charadrius melodus*), whooping crane (*Grus americana*), and black-footed ferret (*Mustela nigripes*). The bald eagle, interior least tern, piping plover, and whooping crane are all seasonal migrants that could pass through the area, but would not likely be directly affected by brush control practices. The black-footed ferret historically occurred in prairie dog towns, but is thought to be extirpated throughout its historical range in Texas.

Impacts of brush control could directly affect the black-capped vireo that nests in brush communities about 6 feet in height with about 30 to 60 percent canopy coverage.[21]

Impacts of brush control can positively or negatively affect the environment depending on the type of control method used, location, and extent of application. If brush removal is planned and implemented as part of a comprehensive range management strategy and is consistent with Section 5.5.3, Wildlife Considerations, of the State Brush Control Plan,[22] very positive environmental benefits can result. Properly planned and applied brush control using mechanical, chemical, or prescribed fire can enhance soil conditions, increase water tables, provide greater streamflow thus improving water quantity and quality, provide higher energy and nutrient inputs, increase vegetation diversity, and enhance the quality of wildlife habitat with resulting higher abundance and diversity of wildlife species. However, removal of established of brush on uplands or removal of riparian woody vegetation along stream courses without consideration of a comprehensive long term management strategy can be detrimental to wildlife and associated habitats. Other adverse impacts could occur depending on the type of control method employed.

Mechanical treatment using mechanized equipment to root plow, brush mow, bulldoze or scrape the ground surface could result in moderate to high levels of soil disturbance that could result in erosion and sedimentation into adjacent streams and water bodies. There would also be a change in vegetation communities toward earlier succession species. Soil disturbance would favor both re-establishment of both grasses and forbs (herbaceous) in addition to re-invasion of

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[21] Campbell, Linda. *Endangered and Threatened Animals of Texas*. Texas Parks and Wildlife Department, Endangered Resources Branch, Austin, Texas, 1995.

[22] Texas State Soil and Water Conservation Board. *State Brush Control Plan*, 2002. http://www.tsswcb.state.tx.us/reports/brushplan2001.pdf

woody brush and shrub species, prompting the need for re-treatment in future years. Soil disturbance would also have the potential of disturbing cultural or archeological artifacts, if present, within 12 inches of the ground surface. The probability of cultural and archeological artifacts being present is higher for sites along water courses, and old homesteads and settlements. However, cultural and archeological surveys are not required for private property included in the State Brush Program. Some federal cost sharing programs may require archeological surveys.

The State Brush Program requires all participants to follow recommended practices in the application of herbicides. The two most commonly used herbicides in the State Program are Triclopyr (Remedy®) and Clopyralid methyl (Reclaim®). Both of these chemicals are to be used only on upland areas and are not approved for use in or near water. If improperly applied, aerial or ground spraying could have possible biological impacts to wildlife through direct contact and/or potential pollution of surface water. Remedy® is toxic to aquatic organisms, while the toxicity of Reclaim® to birds, mammals and fish is low. A number of other herbicides are also toxic to aquatic life. There could also be effects to non-target plant species from broadcast applications.

The use of prescribed fire provides many ecological benefits. Historically, prairie wild fires were a major factor is suppressing invasion of woody vegetation among the prairie grassland communities. Other benefits include increased soil fertility through release of organic nutrients, stimulated growth of new plant material, and greater diversity of herbaceous plants tolerant to fire. Prescribed fire could adversely affect other vegetation such as damaging or killing established trees not intended for treatment, can be difficult to control if applied during the wrong season or during improper weather conditions, and could affect air quality regulated under federal and state laws. Environmental impacts are summarized in Table 4B.9-5.

### *4B.9.7 Implementation Issues*

The extent of implementation of brush control will depend on the amount of funding available for state cost-sharing with landowners. State funding would be contingent upon following provisions of the State Brush Control Plan. Other funding may be available through federal and local agencies, which may have additional provisions. The extent of brush control that may be desired by landowners will depend on how they plan to manage their land for

**Table 4B.9-5.**
**Environmental Impacts of Brush Control in Fort Phantom Hill Study Area**

| Type of Control [1] | Implementation Measures | Aquatic Environments | Bays, Estuaries, Arms of Gulf of Mexico | Wildlife Habitat | Threatened/ Endangered Species | Cultural Resources | Threats to Natural Resources |
|---|---|---|---|---|---|---|---|
| Mechanical | Removal of woody vegetation using mechanized equipment, e.g. root plowing, chaining, or brush mowing. | Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2]. | No impact assuming any increase in streamflow is captured in downstream reservoirs. | High positive or negative impacts, depending on extent, timing, and location of removal; Positive impacts possible when properly planned & conducted according to Section 5.5.3 of the State Brush Control Plan. | Possible high positive or negative impacts to black-capped vireo nesting habitat, depending on extent, timing and location of removal. | Low adverse impacts from chaining & brush mowing; Moderate to high adverse impacts likely from root plowing, dozing or scraping. | Could mitigate declining water quantity & quality through increased streamflow, if properly applied. |
| Chemical | Removal of woody vegetation using application of herbicides. | Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2]. Variable impacts to aquatic organisms depending on toxicity of herbicide, and level of concentration to aquatic habitats[3]. | No impact assuming any increase in streamflow is captured in downstream reservoirs. | High positive or negative impacts, depending on extent, timing, and location of applications and removal; Positive impacts possible when properly planned and conducted according to Section 5.5.3 of the State Brush Control Plan. | Possible high positive or negative impacts to black-capped vireo nesting habitat depending on extent, timing and location of removal. | Minimal or No Adverse Impacts. | Could mitigate declining water quantity & quality through increased streamflow, if properly applied. |
| Prescribed Fire | Removal of herbaceous and woody vegetation with managed, controlled fire. | Possible moderate increase of in-stream flow from increased water yields in watershed with substantial removal[2]. | No impact assuming any increase in streamflow is captured in downstream reservoirs. | Generally moderate to high positive impacts to wildlife habitat. | Possible high positive or negative impacts to black-capped vireo nesting habitat depending on extent, timing and location of removal. | Minimal or No Adverse Impacts. | Could mitigate declining water quantity and quality through increased streamflow. Improved rangeland, if properly applied. |

[1]Includes those practices eligible for cost-sharing under the State Brush Control Plan (2002).
[2]Studies show water yield maximized only through extensive control reducing brush coverage to less than 15 percent (Thurow, T.L., A.P. Thurow, and M.D. Garcia. "Policy prospects for brush control to increase off-site water yield." J. Range Manage. 53: 23-31, January 2000. )
[3]Many herbicides are toxic to fish and other aquatic organisms

wildlife and how the brush control will affect the value of the land for wildlife recreation purposes. In recent years, the value of ranch lands which have sufficient brush cover to support wildlife populations, particularly white-tailed deer, wild turkey, bobwhite and scaled quail, has increased at a faster rate than the value of those lands which are void of brush or woody vegetation. Consequently, many landowners can be expected to support brush control to the extent that it does not exclude wildlife populations.

Other implementation issues for land owner participation include the perceived economic benefit of brush control. If the land is currently not actively managed for ranching or wildlife recreation the owner may chose not to participate. Decreased profitability of sheep, goat and cattle grazing systems will influence the economics of brush control by ranchers, and consequently their willingness to participate. Research by Thurow, et al.[23] found that only about 66 percent of ranchers surveyed were willing to enroll their land in a similarly characterized program. Also, the size of the land tracts can affect the total amount of brush removed and the effectiveness of a program. Watersheds that contain many small tracts are less likely to have contiguous land owner participation that is needed to realize the water supply benefits associated with brush control.

On specific tracts where brush control would incorporate state or federal funding, regulatory compliance with the Texas Antiquities Code and National Historic Preservation Act may be required that may involve cultural resource surveys and incorporation of preservation measures. The Texas Commission on Environmental Quality has established regulations governing prescribed burning.[24] There may also be local and county regulations associated with burning practices.

No land acquisition or relocations would be required for this water management strategy.

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[23] Thurow, A., T. Thurow, and M. Garriga, "Modeling Texas Ranchers Willingness to Participate in a Brush Control Cost-Sharing Program to Improve Off-Site Water Yields," Journal of Agricultural and Resource Economics, (Manuscript submitted, Department of Rangeland Ecology and Management, Texas A&M University, College Station, TX), 1998.

[24] Texas Commission on Environmental Quality. Control of Air Emissions from Visible Emission and Particulate Matter. Chapter 11, Subchapter B, Outdoor Burning, Subsection 111.219, and 111.211. http://www.tnrcc.state.tx.us/oprd/rules/pdflib/111b.pdf , 2002.

### *4B.9.8 Conclusions*

Due to the uncertainties with the modeling calibration and other assumptions in the SWAT model, the amount of reliable supply generated by a brush control project in the Brazos G Area is uncertain. The yields reported in this case study do not include the historical drought of the 1950s, or the drought that began in the late 1990s. The amount of reliable water that is available through increased reservoir yields through brush control is relatively low as compared to the water production rates reported in published studies, yet brush control may be a feasible strategy for some watersheds. The success of such a program for providing increased water supplies is dependent on increased surface water runoff and significant landowner participation. The true benefits of brush control might not lie with increased surface water runoff, but increased deep soil percolation and improved land management. Significant landowner participation will require adequate external funding on a continuous basis because the benefits of brush control are lost if the maintenance activities are not continued. 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.

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