FUTURE WATER DEMAND AND WATER SUPPLY OPTIONS

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Montecito Water District

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ACRONYMS USED

AF – acre-feet
AFY – acre-feet per year
CCWA – Central Coast Water Authority
District – Montecito Water District
DWR – California Department of Water Resources
ECHO – Existing Conveyance High Outflow scenario for future State Water deliveries
MWD – Montecito Water District
SGMA – Sustainable Groundwater Management Act
SWP – State Water Project
UWMP – Urban Water Management Plan
WSA – Water Supply Agreement with City of Santa Barbara

EXECUTIVE SUMMARY

This report is an update to the 2007 report, and includes analyses of current and future demand, historical District sources of water supply, and options for future water supply. Historical water sources are evaluated as to their future reliability, given regulatory, environmental, engineering, and climate factors. Future water supplies include those that are available today or in the short term. Water supplies or projects that are only speculative at this time are not included in the analysis.

This report captures two snapshots of the District's water supply reliability – current customer demand levels compared to supplies going into the future, and potential future demand compared to those supplies. These supplies are evaluated for both their reliability and costs. A model of demand vs. supply was constructed that takes a long hydrologic record (78 years) to reflect several historical wet and dry periods. Future supply availability was also modified in the demand/supply model based on regulatory/environmental issues, reservoir siltation, changes in operating rules, and climate change.

The model calculates both annual and long-term average uses of each supply, annual unsourced demand, pipeline constraints, constraints on banked water recovery, and costs of each supply. Additional supplies are also added in some of the model runs. These include a Water Supply Agreement with the City of Santa Barbara, purchasing additional water bank capacity, and purchasing Supplemental Water to fill the water banks and/or to supply water to customers as needed.

Current demand used in the analysis was 4,466 AFY, which includes water sales, water loss from pipes, and transfer of Juncal water to the City of Santa Barbara. Demand in the model varied by wet, average, and dry years, as indicated by District records. Future demand was considered to be in the year 2040. Two factors were used to calculate this: growth as per Montecito Community Plan and the State-mandated urban water consumption limit. Future demand in the analysis was 5,140 AFY, including line loss and transfer to Santa Barbara.

Conclusions as to the pros and cons of each water supply source are based on several criteria: a) ability to supply customer demand (little or no unsourced demand); b) a significant amount of the sources of water being local – this means both on the MWD side of the Coastal Branch of the SWP and the MWD side of the water supply tunnels; c) cost; and d) the amount of payback of purchased Supplemental Water not met at the end of the model period.

The scenarios with the Water Supply Agreement performed best using the criteria above. Costs of the WSA were higher than the other scenarios for the first 17 years of the model, then lower than the other scenarios for the remaining 61 years of the model. Many of the other scenarios had issues – significant unsourced demand where pipeline capacity prevents filling that demand by purchasing water elsewhere in the State, and a significant amount of purchased water for which the District has insufficient supply to pay back to the seller.

When an extended drought was applied to all the scenarios, there was unsourced demand in the later years of the drought. This demand cannot be met by buying more Supplemental Water, because there would be insufficient capacity in the Coastal Branch pipeline to deliver that water.

With the Water Supply Agreement meeting the criteria important to the District for its future water supplies, it is recommended that this water source be obtained by the District. It is also recommended that the modified rule curve be implemented for Jameson Reservoir. This modification allows more water to be available for use from the reservoir late into a drought.

INTRODUCTION

Following the drought of the 2010s, Montecito Water District ("District" or "MWD") reviewed how District water supplies performed in meeting customer demand during that drought. As part of that review, the District wanted to update the 2007 *Water Supply-Demand Options* report that evaluated both customer demand and District water supplies at that time. Since 2007, customer demand has decreased but District supplies have also tightened. During the drought, the District needed to purchase water from elsewhere in the State, an option that is likely to be more difficult in the future as water supplies tighten.

This report is an update to the 2007 report, and includes analyses of current and future demand, historical District sources of water supply, and options for future water supply. Historical water sources are evaluated as to their future reliability, given regulatory, environmental, engineering, and climate factors. Future water supplies include those that are available today or in the short term. Water supplies or projects that are only speculative at this time are not included in the analysis.

In its 2017 Urban Water Management Plan (UWMP), the District set a goal of increasing local, drought-proof water supplies to 85% of total supplies by the year 2025. These supplies would include rainfall independent sources such as desalinated water, groundwater banking and recycled water.

This report captures two snapshots of the District's water supply reliability – current customer demand levels compared to supplies going into the future, and potential future demand compared to those supplies. These supplies are evaluated for both their reliability and costs. In addition, potential future water supplies are also evaluated to determine how they might bolster supply reliability and at what cost. These additional supply options only include supplies and/or projects that are currently available.

METHODS OF ANALYSIS

A model of demand vs. supply was constructed that takes a long hydrologic record to reflect several historical wet and dry periods. Availability of supply during these periods was based in part on two regional analyses: 1) the RiverWare model of the Santa Ynez River and its reservoirs that is maintained by the Cachuma Operations and Management Board (COMB); and 2) California Department of Water Resources (DWR) modeling of the reliability of the State Water Project that is updated periodically. These analyses are discussed in following sections. Future supply availability was also modified in the demand/supply model based on regulatory/environmental issues, reservoir siltation, changes in operating rules, and climate change.

The demand/supply model uses monthly time steps for the period 1942 to 2019. The beginning of this period coincides with the beginning year of the RiverWare model. The demand/supply model varies annual demand depending upon whether the year was wet, average, or dry, and varies monthly demand in accordance with historical District records. Each month, demand is offset step-wise by available supplies using the following priority:

- Jameson Reservoir and inflows from Doulton Tunnel;
- Cachuma annual allocation, spill water, and carryover water;
- Groundwater
- State Water Project annual allocation;
- Semitropic Bank water

The model is constrained by pipeline capacities, annual water bank recovery amounts, water in storage in the bank, and a modified Jameson rule curve. Tallies are kept of Cachuma carry-over balance, water bank balances, pipeline use, and State Water that is not used for customers or banking. Demand that is not met by supplies on a monthly basis is tallied as "unsourced demand".

Costs of each supply source are also calculated in the model. Each supply source may have fixed costs and several variable costs associated with that supply. For instance, when State Water is banked and recovered, there are variable costs related to DWR fees, transporting it to the bank, putting it in the bank, maintaining the water in the bank, recovering the water, transporting it to the Coastal Branch turnout, treating it, and transporting it to the District. In addition, potential revenues from sale of unused State Water in any year are used to offset the cost of supplies.

The model calculates both annual and long-term average uses of each supply, annual unsourced demand, pipeline constraints, constraints on banked water recovery, and costs of each supply. The year-by-year supply mix and supply costs are plotted on charts for comparison.

Additional supplies are also added in some of the model runs. These include a Water Supply Agreement with the City of Santa Barbara, purchasing additional water bank capacity, and purchasing Supplemental Water to fill the water banks and/or to supply water to customers as needed. These are discussed in later sections of this report.

CUSTOMER DEMAND

Customer demand is the starting point of each calculation in the demand/supply model. In the 2007 *Water Supply-Demand Options* report, historically-increasing customer demand was a significant constraint on whether there were sufficient supplies to meet these demands. Since that report, the ensuing drought decreased customer demand substantially. Part of the decreased demand was related to District water pricing, part to customer conservation efforts, part to installation of more drought-tolerant landscaping, and part to more reliance by customers on their own groundwater pumping. Both current demand and projected future demand are discussed below.

Current Demand

The District considers current demand to be 4,466 AFY, which includes 3,750 AFY of water sales, a 10% water loss from pipes (416 AFY), and 300 AFY of transfer of Juncal water to the City of Santa Barbara. District 2014-2019 production data indicates that annual demand varies during wet and dry years from 3,841 to 4,913 AFY, respectively. Current demand used in the demand/supply model are indicated in Table 1.

Year Type	Current Demand
Dry	4,913 AFY
Average	4,466 AFY
Wet	3,841 AFY

Table 1. Current demand in model.

Future Demand

Future demand is considered in this analysis to be in the year 2040 to be consistent with the upcoming 2020 Urban Water Management Plan. Two factors were applied to current water demand to project future demand: 1) a growth rate of 0.5% per year as per the Montecito Community Plan, and 2) a worse-case situation that brings demand up to the State urban water consumption limit of 4,840 AFY (10% growth by 2040 * current limit of 4,400 AFY). With the Juncal transfer to the City of 300 AFY, total average future demand in the model is thus 5,140 AFY. Annual demand varies by wet, average, and dry conditions as in current demand (Table 2).

Year Type	Future Demand
Dry	5,654 AFY
Average	5,140 AFY
Wet	4,369 AFY

Table 2. Future demand in model.

RELIABILITY OF CURRENT WATER SUPPLIES

As new regulations, environmental concerns, loss of reservoir storage caused by siltation, fires affecting water quality, and climate change occur, the reliability of current water supplies is affected. This section discusses the potential effects on individual sources of the water supply, shown in Figure 1. The results of this analysis are then incorporated into the demand/supply model to determine the reliability of all the supply sources interacting together.

Figure 1. Map of the location of MWD's water supplies and infrastructure. District service area shown in yellow.

Jameson Reservoir & Doulton Tunnel

Jameson Reservoir and Doulton Tunnel are MWD's surface-water reservoir on the upper Santa Ynez River and the tunnel through the Santa Ynez Mountains that brings water diverted at the reservoir to the District's service area on the South Coast (Figure 1). This water is used primarily in the eastern portion of the District and is the only supply source for a portion of that area. A significant amount of water infiltrates into the tunnel naturally from the overlying bedrock, and increases the amount of water received from Jameson Reservoir. This supply source is considered as a first priority of use in the demand and supply model because it is low cost, water produced by Doulton tunnel must be delivered to avoid diversion (and loss of supply) to the creek, and the need to supply the eastern portion of the District.

Historical Deliveries

The annual yield of Jameson Reservoir has averaged about 1,350 AFY, although the recent drought has lowered the 15-year average to about 980 AFY (Figure 2). Natural inflow into Doulton Tunnel has averaged about 500 AFY, although the average for the last 15 years has been about 365 AFY (Figure 3).

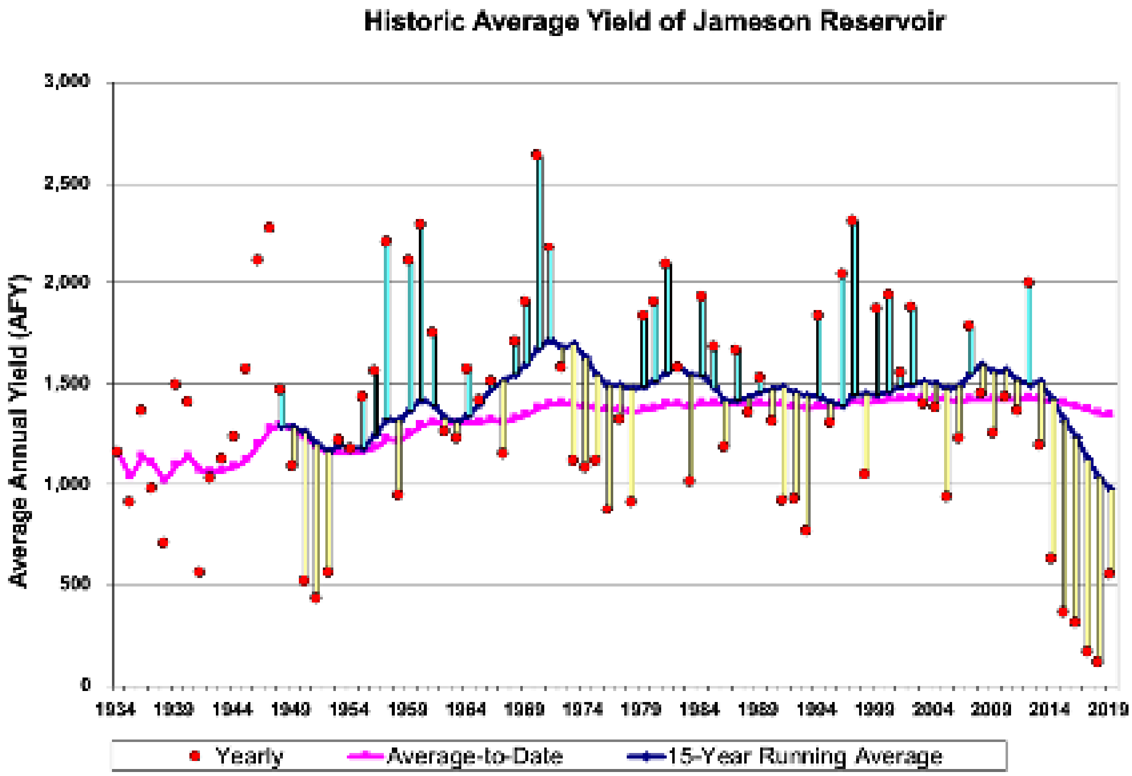

Figure 2. Historical yield of Jameson Reservoir. Data are in water years.

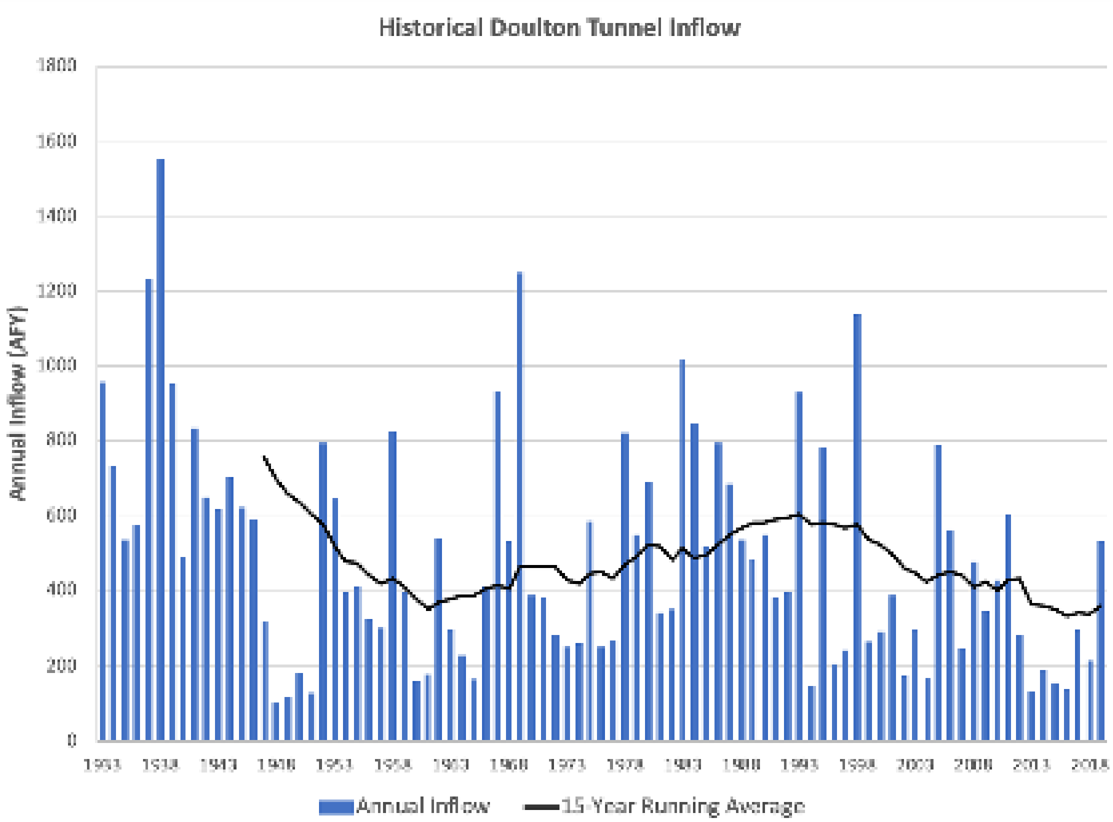

Figure 3. Historical inflow into Doulton Tunnel. Data are in water years.

Future Considerations

Diversions from Jameson Reservoir have been largely based on the rule curve developed for the 2007 *Future Water Demands and Water Supply Options* report. During the recent drought, however, diversions brought the reservoir to near its minimum pool level and diversions had to be reduced (Figure 2). The District requested that a new rule curve be valuated so that there was a 7-year water supply in the reservoir, similar to Cachuma Reservoir. This revised rule curve is discussed in Appendix A.

As part of this re-evaluation of the rule curve, another factor was also considered – siltation in the reservoir that progressively reduces its storage capacity. Periodic surveying of the reservoir bottom has shown that siltation has reduced reservoir capacity by an average of about 25 AFY. This loss is not recoverable and is a problem for every reservoir in the world. The modified rule curve factors in the future loss of reservoir storage. In addition, fires in the watershed that burn vegetation roots and loosen soil structure could periodically increase this siltation rate.

The recent fires in the Santa Ynez River watershed have also had an impact on water quality in the reservoirs, including Jameson. Organic material from the burns can react with disinfection processes during treatment of the diverted water, reducing the amount of water that can be diverted and treated (as has happened in the past few years). Although the impact of forest fire on water quality is not modeled in this study, there would be a negative impact on water supply availability.

Climate change is also a potential factor in the future yield of Jameson Reservoir. DWR has published guidance on climate change for use in developing Sustainable Groundwater Management Plans[1]. For the Central Coast region, DWR recommends using an increase in precipitation of 2.8% and an increase in average temperature of 2.1°F by the year 2030 and an increase in precipitation of 6.5% and an increase in average temperature of 4.6°F by the year 2070. For the Santa Ynez River watershed, an increase in precipitation would increase runoff into the river; offsetting that, however, would be an increase in evapotranspiration from the higher temperatures and a subsequent decrease in rainfall runoff into the river. It is not clear whether the net effect of climate change would be more or less water in the river, so the demand/supply model did not include any additional changes to water captured in the reservoirs.

Risks & Benefits

Jameson and Doulton inflow have been a reliable, but variable, water source for the District. It is important to maintain these sources to supply eastern portions of the District. Fires in the watershed can cause both siltation and water quality problems. It is conceivable that these water quality problems could temporarily severely curtail the amount of water used from these sources.

As discussed in the section above, climate change may be a factor in future Jameson supplies, although we cannot predict the direction or magnitude of that risk at this time.

A risk that cannot be quantified in the model is damage from an earthquake. Damage to the dam could mean purposely spilling stored water to affect repairs. Damage to Doulton Tunnel

[1] California Department of Water Resources, 2018, *Guidance for Climate Change Data Use During Groundwater Sustainability Plan Development*, 80p.

could preclude use of the tunnel for a significant period of time. The District's best protection against such an occurrence that disrupts water deliveries is its varied sources of supply – a diverse water portfolio protects against disruption of any one of the water sources.

Cachuma Reservoir

Cachuma Reservoir is one of the primary sources of water to the District. Water diverted from the reservoir is sent through the Tecolote Tunnel and South Coast Conduit to MWD (Figure 1). Because it also stores water from the Santa Ynez River, the effect of rainfall patterns in the watershed on reservoir supplies is similar to that for Jameson Reservoir. The Federal facility is operated by a consortium of South Coast water districts, so decisions on its operations require regional consensus. The reservoir system is also a conduit for delivery of State Water, directly through discharges of State Water into the reservoir and/or use of the Tecolote Tunnel (Figure 1) to bring the water through the mountains to the South Coast.

Historical Deliveries

MWD's portion of the annual yield of Cachuma Reservoir has averaged about 1,950 AFY, with a 15-year average of about 2,225 AFY (Figure 4). During the recent drought, deliveries from Cachuma were curtailed because of low reservoir levels.

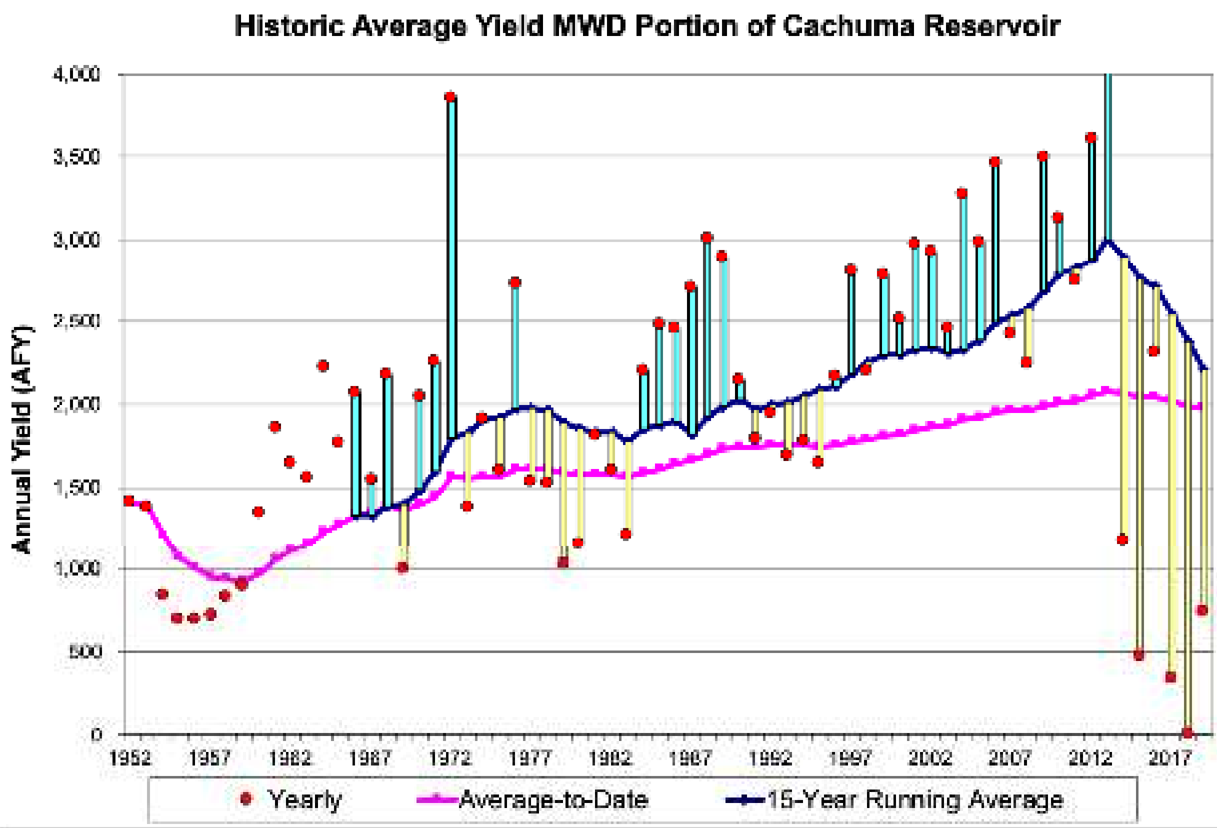

Figure 4. Historical yield of MWD's portion of Cachuma Reservoir. Data are in water years.

Future Considerations

Continuing regulatory and environmental concerns on the Santa Ynez River have lowered the effective yield of Cachuma Reservoir through fish releases and the like. The RiverWare model of the Santa Ynez River was updated to reflect the State Water Resources Control Board Alternative 5C for fish releases. The model predicts lower reservoir levels in the future and lower allocations for South Coast water districts. These results are included in the demand/supply model for this study.

There are additional changes that are likely for Cachuma allocations, as well. The County of Santa Barbara is working on an Updated Safe Yield Study for Cachuma. Although this study Is not finalized and changing allocations needs to be considered by Cachuma member agencies, allocation decreases in the range of 25% to 40% are likely to be considered. For the demand/supply model in this study, supply scenarios include both 25% and 40% future reductions in Cachuma allocations.

As discussed in the section on Jameson Reservoir, climate change may also be factor in future Cachuma supplies, but we cannot predict the direction or magnitude of that factor on water supplies.

Risks & Benefits

Cachuma has been one of the primary water supplies for MWD since the reservoir was constructed in the 1950s, and has been relatively reliable during this period. However, very low Cachuma deliveries during a portion of the recent drought has shown Cachuma's vulnerabilities. A new allocation scheme might provide water over a longer drought in the future, but at the price of lower allocations and a larger reliance on other supplies by Cachuma member agencies.

It is likely that there will be future regulatory and environmental concerns for Cachuma operations. Similar concerns in the past have largely reduced the effective yield of the reservoir, so it is also likely that future concerns will do the same. The magnitude of any future changes cannot be predicted.

Fires in the watershed can cause both increased siltation and water quality problems in Cachuma Reservoir.

As with Jameson Reservoir, there is a risk factor for earthquake damage at either the Cachuma facilities and dam, or within the Tecolote Tunnel that brings water from Cachuma to the South Coast (Figure 1). It could take considerable time to repair such damage and could significantly affect Cachuma deliveries.

Groundwater

Groundwater has been used by the District largely as a buffer during dry years. As such, the strategy has been to allow groundwater to recharge during wet periods, relying on surface water sources during these periods, and pumping groundwater during dry periods when surface water sources are curtailed. Although groundwater has not been a major source of water for the District, it has been useful in filling in the District's diverse water portfolio.

Historical Deliveries

Historical annual groundwater use has varied considerably from wet to dry periods, from as low as near zero during wet periods to as high as 640 AFY during dry years (Figure 5). The average use of groundwater during the period 1972 to 2019 was about 230 AFY.

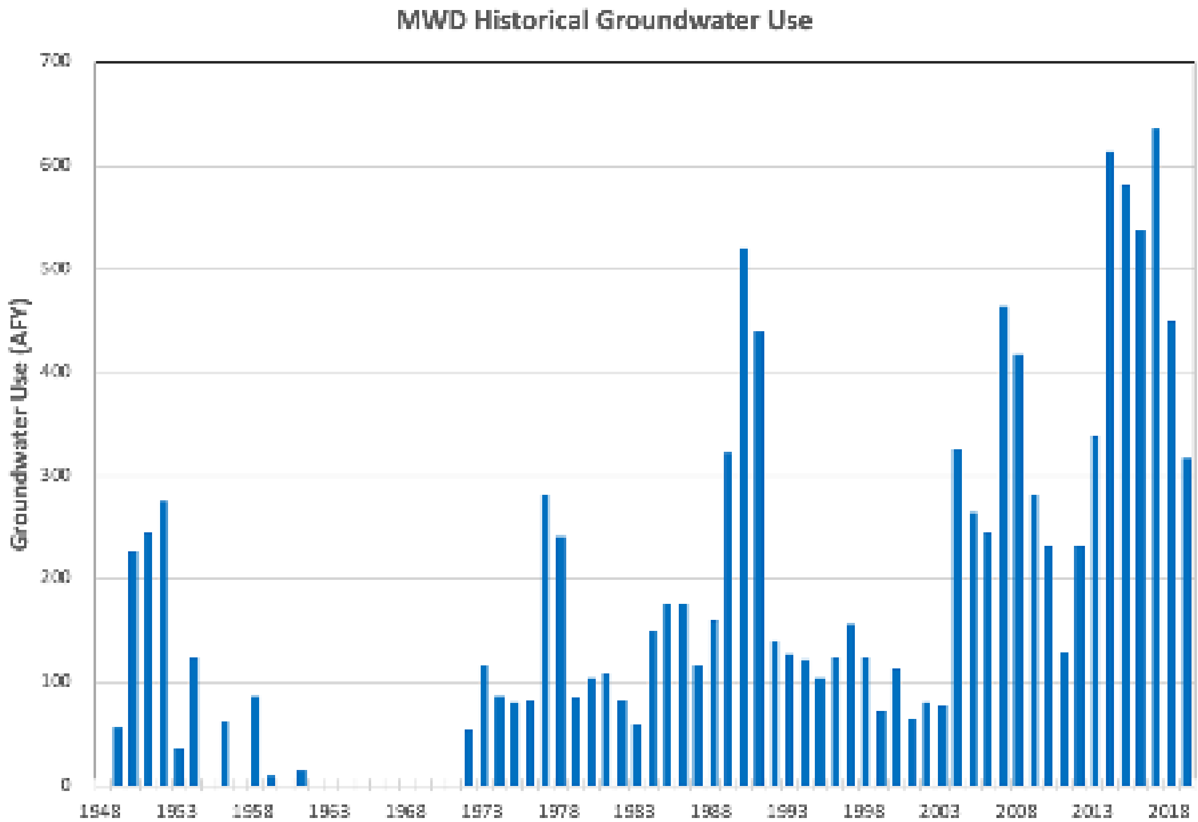

Figure 5. MWD historical groundwater use. Data are in water years.

Future Considerations

There is an ongoing Sustainable Groundwater Management Act ("SGMA") process in the Montecito Groundwater Basin. Impacts on groundwater production are not known at this time and are not included in the demand/supply analysis, but there could be negative impacts on the availability of groundwater.

Risks & Benefits

Although limited, groundwater is an important supplementary source of water to the District during dry periods. It is also a local source and could play an emergency role in water supply if supplies from north of the Santa Ynez Mountains was interrupted for reasons discussed in earlier sections. Future risks to the supply may be related to sustainability determined during the SGMA process and on the extent of pumping of wells in the basin.

State Water

State Water is imported into the District through the Coastal Branch Aqueduct to Cachuma Reservoir, and then through the Tecolote Tunnel and South Coast Conduit to MWD (Figure 1). State Water originates from the delta of the Sacramento River in northern California and is largely dependent upon snow melt in the Sierra Nevada. State Water has been used by the District to back-fill shortages of water from Jameson and Cachuma reservoirs and to supply recharge water to the Semitropic Water Bank.

A temporary by-pass pipeline across Bradbury Dam at Cachuma Reservoir was recently constructed so that delivery of State Water could be discharged into Cachuma and then be diverted to Tecolote Tunnel. Other existing means of delivery have prevented delivery of State Water to Cachuma for a variety of reason since early 2019. This by-pass pipeline ensures that limited State Water deliveries to Cachuma would not be prevented by issues related to malfunctioning equipment and fish releases.

Historical Deliveries

State Water annual deliveries have varied because of annual differences in the amount of allocation available to member agencies and the amount of water available from Jameson and Cachuma reservoirs. These annual deliveries have varied from 0 to over 3,350 AFY (Figure 6).

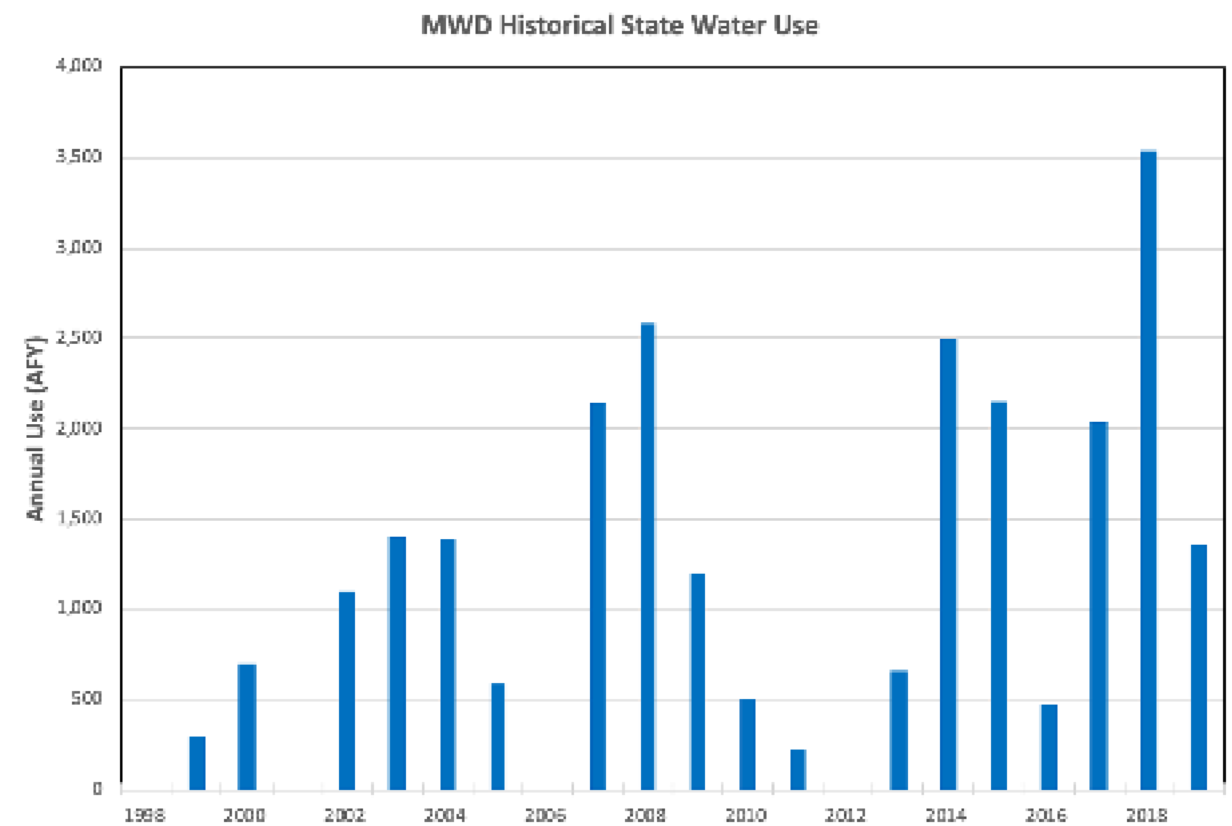

Figure 6. MWD historical State Water use. Data are in water years.

Future Considerations

On a regular basis DWR publishes predictions of State Water availability based on modeling of the entire system of rivers and dams. This predicted availability has progressively decreased through time as new regulations, environmental concerns, and climate change are considered. DWR also periodically publishes predictions of future State Water availability using the same types of considerations. The latest predictions of future availability were in 2015[2]. Future deliveries to each member agency in the period 2025 to 2030 were predicted using the hydrology of 1922 to 2003 overlain by the future concerns.

There were four potential scenarios used in DWR's future predictions. Because experience has taught us that DWR has tended to over-estimate State Water availability in past years, this demand/supply report uses the most conservative of these scenarios (the one with the least water delivery). This scenario is named Existing Conveyance High Outflow (ECHO) because it assumes using the existing conveyance system (no tunnels under the Delta) and enhanced Delta outflow requirements, which is consistent with CCWA's position on DWR's proposed Delta Conveyance Project. For the demand/supply model years of this study, State Water availability for Santa Barbara County under ECHO varies from year to year, averaging 41% of allocation.

Risks & Benefits

Being part of the State Water system has been beneficial to the District in several ways. Besides being a supplemental source of water itself, State Water infrastructure allowed MWD to purchase and import Supplemental Water during the recent drought and has allowed MWD to store and later plan to recover water in the Semitropic Water Bank.

However, State Water deliveries have tended to be overstated in the past, and may continue to be overstated. This puts a risk factor on future State Water deliveries. In addition, the earthquake risk discussed for the Jameson and Cachuma supplies is increased for State Water. Besides the local risk of earthquake damage to water supply tunnels that would affect the delivery of State Water, possible earthquake damage to Delta levees and State Water aqueducts is an additional risk. This risk cannot be quantified in the demand/supply model, but can be a consideration in determining the best mix of future water supplies.

Semitropic Water Bank

In 2017, MWD initiated a regional groundwater banking program with Semitropic Water Storage District in the Central Valley which allows MWD to store State Water deliveries and other supplemental water purchases without risk of spill or evaporation that occurs in an open reservoir. This protects these purchases and improves water supply reliability.

MWD currently has 1,800 AF stored in the Semitropic Groundwater Banking and Exchange program. When needed, water deliveries from the Bank would occur through delivery of water at the Coastal Branch turnout of the State Water Project, with Semitropic replacing that water downstream from water pumped from the Bank.

[2] Department of Water Resources, 2015, *The State Water Project Final Delivery Capability Report 2015*, 41p.

Future Considerations

MWD's portion of the Bank is 4,500 AF, with an annual withdrawal limit of 1,500 AFY. The Bank is likely fully subscribed at this time, so any potential expansion in the future might not be possible. The limitations of the Bank are the annual withdrawal limit and the capacity of the Coastal Branch pipeline near Cachuma Reservoir – this pipeline carries MWD's State Water, any Supplemental Water purchased, and water from the Bank.

Risks & Benefits

The Bank provides additional drought protection to the District, and is secure in the groundwater basin. Delivery of banked water that has been recovered is subject to the Coastal Branch pipeline capacities near Cachuma. Delivery of the water is also subject to the earthquake risks discussed in earlier sections.

Because MWD's turnout for the State Water Aqueduct is upstream of the Bank and water cannot simply be pumped from the bank into the Aqueduct for delivery to MWD, there must be sufficient water in the Aqueduct in a drought for exchanges of water to occur. Otherwise, water would have to be physically moved back up the Aqueduct from the Bank to the MWD turnout. Semitropic believes that this can be achieved if ever needed.

Another risk for any water bank is that it is likely to be located in a groundwater basin that has been pumped down in the past, creating storage space for the bank. When water is banked in the basin and groundwater elevations rise, pumpers in the basins then tend to think that the basin is being managed sustainably. When the banked water is removed in a drought and groundwater elevations drop, basin pumpers can be alarmed. During the recent drought, at least one lawsuit was filed in the Central Valley when this occurred. It is not clear how such a future scenario might affect MWD's ability to recover its stored water in a drought.

POTENTIAL FUTURE WATER SUPPLIES

It is the policy of the MWD Board that water supplies for the District should have more reliance on local supplies. Two such potential future supplies are discussed here. In addition, Supplemental Water purchases are also discussed.

Water Supply Agreement

The District's Urban Water Management Plan ("UWMP") specifies the development of local, reliable water supplies and desalination could be one component of a well-diversified water supply portfolio. MWD and the City of Santa Barbara are in negotiations on a Long-Term Water Supply Agreement ("WSA") to provide a structure for ongoing regional collaboration on water supply.

While this is typically discussed in the context of purchasing delivery from the City of Santa Barbara's newly recommissioned Charles D. Meyer Desalination Facility, the City could fulfill the delivery from a different source. Such an Agreement would likely be for a fixed amount of water delivery over a period of many years.

Risks & Benefits

The major benefit of a WSA is that the water delivery is on the south side of the Santa Ynez Mountain Range, unaffected by wet and dry cycles in the Santa Ynez River watershed, availability of State Water, Coastal Branch pipeline capacities, and earthquakes affecting levees, aqueducts, and water supply tunnels. It also provides a source of further diversification of MWD's water portfolio.

Although earthquake damage to water supply tunnels may sound remote, Metropolitan Water District of Southern California worked with their Ventura County member agency, Calleguas Municipal Water District, to construct and operate a $150 million groundwater storage project that is located on the Ventura County side of the water supply tunnel that brings water from Metropolitan facilities in Los Angeles County through the tunnel to Calleguas. Metropolitan and Calleguas determined that the tunnel could be disabled for up to a year by an earthquake, and water would instead come from the local project instead of from Metropolitan.

The downside to a guaranteed, constant supply is that in wet years there may temporarily be excess supply. Costs of the excess supply may be partially offset by sales of the excess water to other water users. In the case of the WSA, the District is investigating the sale of any excess State Water during these wet years.

Recycled Water

The District's 2017 UWMP identified recycled water as a potential local reliable supply. As a result, a Recycled Water Feasibility Plan was completed in 2018. In 2019, MWD moved forward on recommendations from the Feasibility Plan and began meeting jointly with Montecito Sanitary District.

Under current State regulations, recycled water can only be directly served to customers for irrigation, and not for drinking water. If recycled water was planned to be used as a source of potable water, advanced treatment of the water must first occur, followed by recharge into a groundwater basin for a minimum specified residence time, then pumping back what is then considered to be groundwater suitable for potable use (Indirect Potable Reuse). This process ensures that pathogens are not introduced into the potable water supply.

The possibility of treatment, recharge, and extraction in Montecito was studied in a 2019 Groundwater Augmentation Feasibility Study. The study indicated limited potential in the Montecito Groundwater Basin for an Indirect Potable Reuse Project as described above. Instead, the District decided to focus on using recycled water for irrigation customers in a phased approach. Although recycled water is not included in the demand/supply model because of its current uncertainty, the District continues to pursue recycled water as an additional source of local drought-proof water supply.

Risks & Benefits

Recycled water is almost always available during droughts, and it is a local source on the south side of the Santa Ynez Range. The use of the water is restricted to non-potable use without the kind of treatment, recharge, and extraction that was considered to have limited potential in the local groundwater basin. The cost of treatment for irrigation use is high, especially if there are limited customers and economy of scale is not possible.

Expanded Water Banking

In the likely event that the current amount of contracted water storage in the Semitropic Water Bank cannot be increased, it may be prudent to consider additional banking opportunities. There have been discussions with other South Coast water agencies about banking water in their basins, but that is considered unlikely. A water bank in north county or San Luis Obispo County would also be worth considering – the Central Coast Water Authority is studying this, but there are no current opportunities to do this.

The most likely banking opportunities are along the State Water Aqueduct in the Central or Antelope valleys. For this study, a generic water bank in this area is modeled as an expanded water bank for the District.

Risks & Benefits

Risks and benefits of an expanded water bank are the same as those for the Semitropic Water Bank.

Supplemental Water

The purchase of Supplemental Water could be done through a long-term lease of water or through single-year “spot market” purchases. When water is needed during a drought, water on the spot market is more expensive. Because MWD can access the infrastructure of the State Water Project, water can be purchased in many parts of the State.

In 2018, MWD purchased 2,800 AF of supplemental water. This allowed the District to bring water to Cachuma Reservoir, using pipeline capacity that would otherwise not be filled because State Water allocations were reduced.

It is assumed that Supplemental Water will be available in the future, although State supplies are likely to tighten as SGMA reduces the availability of groundwater across much of California. As supplies tighten, the price of this Supplemental Water will increase. For this study, potential pricing of Supplemental Water was provided to the District by WestWater Research.

When Supplemental Water is purchased, DWR has required the buyer to return some amount of water to the seller at a later time. Although the rules on this may be changing, the cost of Supplemental Water will likely increase if that water will not be returned to the seller at a later time.

Risks & Benefits

The advantage of purchasing water only when it is needed is a clear benefit. Purchasing excess water during wet periods for use during future dry periods is challenging because the District must have the capacity to store it. During dry periods when the water is needed, locating and purchasing water at a reasonable price will likely be a larger challenge in the future. The District will also have to have sufficient surplus water under current regulations to return that water to the seller at a later time.

Unless local water can be purchased, Supplemental Water will likely be delivered to the District through the Coastal Branch of the State Water Project. During the recent drought, there were periods when the District had insufficient capacity in the pipeline to deliver purchased Supplemental Water.

MODELING RESULTS

Demand and supply were investigated using a set of model scenarios that varied both demand and sources of supply. These scenarios included:

> **Scenario #1 – Current demand, current supplies with future availability** – there are subsets of this scenario for (#1a) 25% Cachuma reductions, (#1b) 40% Cachuma reductions, (#1c) a more severe drought, and (#1d) the additional of Supplemental Water as needed.
>
> **Scenario #2 – Current demand, current supplies with future availability and WSA added** – there are subsets of this scenario for (#2a) 25% Cachuma reductions, (#2b) 40% Cachuma reductions, and (#2c) a more severe drought. Additional Supplemental Water was not required.
>
> **Scenario #3 – Future demand, current supplies with future availability** – same as scenario #1 with future demand. There are subsets of this scenario for (#3a) 25% Cachuma reductions, (#3b) 40% Cachuma reductions, (#3c) a more severe drought, and (#3d) the additional of Supplemental Water as needed.
>
> **Scenario #4 – Future demand, current supplies with future availability and with WSA added** – same as Scenario #2 with future demand. There are subsets of this scenario for (#4a) 25% Cachuma reductions, (#4b) 40% Cachuma reductions, (#4c) a more severe drought, and (#4d) the additional of Supplemental Water as needed.
>
> **Scenario #5 – Future demand, current supplies with future availability and with alternative #1 to WSA (addition of another Water Bank)** – same as Scenario #3 except with addition of another Water Bank. There are subsets of this scenario for (#5a) 25% Cachuma reductions, (#5b) 40% Cachuma reductions, (#5c) a more severe drought, and (#5d) the purchase of Supplemental Water as needed to fill the Water Bank.
>
> **Scenario #6 – Future demand, current supplies with future availability and with alternative #2 to WSA (purchase of Supplemental Water)** – same as Scenario #3 except with addition of the purchase of Supplemental Water as needed. There are subsets of this scenario for (#6a) 25% Cachuma reductions, (#6b) 40% Cachuma reductions, and (#6c) a more severe drought.

Each scenario was evaluated relative to several factors:

- Whether demand was met during wet and dry periods. This can be seen in the figures for each scenario as "unsourced demand", and reported as the percentage of years when there was unsourced demand and the maximum amount of unsourced demand in any year.

- Whether unsourced demand could be reduced or eliminated by purchasing Supplemental Water from elsewhere in the State as needed. In some cases, the Coastal Branch pipeline is already at capacity, so additional water purchases do not help.
- Whether purchases of Supplemental Water can be paid back to seller from existing supplies. The assumption is that one-third of the water would need to paid back. If this pay-back requirement is changed, then it is expected that the cost of a future water purchase would rise.
- Whether significant water supply is local and thus protected from disruptions in the supply chain.
- The average cost of the water supplies over the 78 years of the model. This comparison is only valid when there is little or no unsourced demand, so the subset of a scenario with Supplemental Water purchases, if required, is used for the cost comparison. In all cases, the cost of the water is higher during the first years of the model before the fixed costs of State Water are retired. When the scenario has a functioning WSA, costs are higher in the model until the fixed cost is retired.

Scenario #1 – Current Demand/Current Supply Sources

The inputs into the demand/supply model for Scenario #1 are indicated in Table 4 and Table 5. At current demand, this scenario has unsourced demand of up to 17% of the model years, with a maximum unsourced demand of 44% in one drought year (Table 3, Figure 9, Figure 11). With purchases of Supplemental Water, reliability is improved with just 1% of years with unsourced demand and a maximum unsourced demand of 14% (Figure 14). There are 1,415 AF of purchased water for which the District does not have sufficient supply to pay back to the seller.

Much of the supply in this scenario is sourced either along the Santa Ynez River or the State Water project, with groundwater being the only source from south of the Santa Ynez Range. There is reliance during dry years on the Semitropic Water Bank.

During an extended drought (Figure 13), there is significant unsourced demand near the end of the drought. There would be insufficient capacity in the Coastal Branch to purchase and delivery Supplemental Water during this time. Should the intensity, duration, and frequency of future droughts intensify, as predicted, the model results for unsourced demand will likely worsen, possibly significantly.

The average cost of water was calculated using Scenario #1d as $2,739 per AF for the first 17 years and $1,843 per AF after that. Because purchased water could not all be paid back, the actual cost would likely be somewhat higher. There also remains some unsourced demand in this scenario which cannot be solved by purchasing water elsewhere in the State because of pipeline capacity limitations.

Scenario	Unsourced Demand	Payback Owed	Cost First 17 yr	Cost Remaining
#1a	5% of yrs, 31% max unsourced			
#1b	17% of yrs, 44% max unsourced			
#1d	1% of yrs, 14% max unsourced	1,415 AF	$2,739 per AF	$1,843 per AF

Table 3. Results of Scenario #1.

Source	Amount	Comments
Demand	4,466 AFY Avg	Includes 10% line loss, 300 AFY to SB
Jameson	As per modified rule curve Maximum 1,800 AFY	Depends upon calculated annual storage
Doulton Inflow	Related to annual rainfall	Reduced according to average since 1980s
Cachuma Allocation	2,651 AFY	
Cachuma Annual Delivery	Predicted annually by RiverWare model	Reduced additional 25% and 40%
Groundwater	As needed, 315 AFY except 600 AFY dry years	
State Water Allocation	3,300 AFY	Includes 300 AFY drought buffer
State Water Annual %	5% to 85%	According to DWR ECHO; study period avg is 41%
Coastal Branch SWP	Capacity ±3,000 AFY	2,000 AFY when piped over dam
Semitropic Storage	4,500 AF	Leave 10% behind
Semitropic Withdrawals	Limited to 1,500 AFY	

Table 4. Allocations and capacities used in Scenario #1.

Source	Amount	Comments
Jameson/Doulton	$2,900/AF	Average of last two wet and dry years
Cachuma	$1,300/AF	Includes treatment
Groundwater	$900/AF	Average of last two wet and dry years
State Water Fixed through 2022	$5,750,789/yr	DWR and CCWA CCWA debt retires in 2022
State Water Fixed 2023-2035	$3,950,789/yr	Expires after 2035 DWR debt retires in 2035
State Water Variable	$362/AF	DWR and CCWA
State Water Delivery to MWD	$912/AF	Includes treatment
Semitropic Fixed	$64,620/yr	For 4,500 AF shares
Delivery SWP to Semitropic	$25/AF	
Semitropic Annual	$13/AFY	Maintenance, water in storage
Semitropic Recovery	$200/AF	
SWP Delivery from Semitropic	$250/AF	To turnout
Semitropic – Turnout to MWD	$912/AF	Includes treatment
Supplemental Water Purchase	$340-1,750/AF	Varies by annual SWP%, per WestWater Research
Supplemental Water Delivery	$912/AF	To MWD; includes treatment

Table 5. Costs used in Scenario #1 modeling.

Scenario #2 – Current Demand/Current Supplies with Water Supply Agreement

Source	Amount	Comments
Water Supply Agreement	1,430 AFY	1,409 AFY after line loss

Table 6. Scenario #2 allocations and capacities that differ from Scenario #1

Source	Amount	Comments
WSA Fixed	$2,288,000/yr	Expires after 16.5 yrs
WSA Variable	$1,500/AFY	

Table 7. Scenario #2 costs that differ from Scenario #1.

Changes to model inputs from Scenario #1 (addition of WSA) are indicated in Table 6 and Table 7. At current demand, there is no unsourced demand (Table 8, Figure 17, Figure 19). No Supplemental Water was required to be purchased and there was no pay-back required.

More of the supply in this scenario is from south of the Santa Ynez Range. Very little water is used from the State Water Project or the Semitropic Bank.

During an extended drought (Figure 22), there would be some unsourced demand. Purchase of Supplemental Water would eliminate most, but not all, of the unsourced demand.

The average cost of water was calculated using Scenario #2b as $3,158 per AF for the first 17 years and $1,751 per AF for subsequent years.

Scenario	Unsourced Demand	Payback Owed	Cost First 17 yr	Cost Remaining
#2a	None			
#2b	None	None	$3,158 per AF	$1,751

Table 8. Results of Scenario #2.

Scenario #3 – Future Demand/Current Supply Sources

Source	Amount	Comments
Future Demand	5,140 AFY	Includes 10% line loss, 300 AFY to SB

Table 9. Scenario #3 allocations and capacities that differ from previous scenarios

The inputs in the model that differ from Scenario #1 (future demand) are indicated in Table 9. At future demand, this scenario has unsourced demand of up to 42% of model years, with a maximum unsourced demand of 60% in one drought year (Table 10, Figure 23, Figure 25). With purchases of Supplemental Water, reliability is improved with 10% of years with maximum unsourced demand of 25% (Figure 28). There are 4,925 AF of purchased water for which the District does not have sufficient supply to pay back to the seller.

Much of the supply in this scenario is sourced either along the Santa Ynez River or the State Water project, with groundwater being the only source from south of the Santa Ynez Range. There is reliance during dry years on the Semitropic Water Bank.

During an extended drought (Figure 27), there is significant unsourced demand near the end of the drought. There would be insufficient capacity in the Coastal Branch to purchase and delivery Supplemental Water during this time.

The average cost of water was calculated using Scenario #3d as $2,615 per AF for the first 17 years, then $1,852 per AF for subsequent years. This cannot be directly compared to Scenario #4 costs because there remains unsourced demand in Scenario #3d and significant amounts of pay-back water (4,925 AF) for which the District has insufficient supply to repay.

Scenario	Unsourced Demand	Payback Owed	Cost First 17yr	Cost Remaining
#3a	23% of yrs, 57% max unsourced			
#3b	42% of yrs, 60% max unsourced			
#3d	10% of yrs, 25% max unsourced	4,925 AF	$2,615 per AF	$1,852 per AF

Table 10. Results of Scenario #3.

Scenario #4 – Future Demand/Current Supplies with Water Supply Agreement

At future demand, this scenario has unsourced demand of up to 3% of model years, with a maximum unsourced demand of 9% in one drought year (Table 11, Figure 31, Figure 33).

More of the supply in this scenario is from south of the Santa Ynez Range. State Water is used more extensively than for Scenario #2a and 2b; the Semitropic Bank is used during dry years.

During an extended drought (Figure 35), there would be some unsourced demand as Semitropic storage is depleted. Purchase of Supplemental Water would eliminate most, but not all, of the unsourced demand.

Unsourced demand was eliminated from Scenarios #4a and 4b when Supplemental Water was purchased (Table 11, Figure 36). The average cost of water was calculated using Scenario #4d as $3.008 per AF for the first 17 years and $1,733 per AF for subsequent years

Scenario	Unsourced Demand	Payback Owed	Cost First 17yr	Cost Remaining
#4a	3% of yrs, 9% max unsourced			
#4b	3% of yrs, 9% max unsourced			
#4d	None	231 AF	$3,008 per AF	$1,733 per AF

Table 11. Results of Scenario #4.

Scenario #5 – Future Demand/Current Supplies with Additional Water Banking

Source	Amount	Comments
Addt'l Bank Capacity	4,500 AF	Located in Central/Antelope V.; leave 10% behind
Max annual recovery	1,500 AFY	

Table 12. Scenario #5 allocations and capacities that differ from previous scenarios.

Source	Amount	Comments
Bank Fixed	$1,900 AFY	Per AF of max recovery
SWP to Additional Bank	$250 AF	

Table 13. Scenario #5 costs that differ from previous scenarios.

Scenario #5 adds an additional water bank to Scenario #3 (Table 12, Table 13). There is some improvement in reliability from Scenario #3, but there is still unsourced demand of up to 33% of model years, with a maximum unsourced demand of 60% in one drought year (Table 14, Figure 39, Figure 41). When Supplemental Water is purchased to fill both banks, reliability improves, with unsourced demand in 10% of the model years and a maximum of 25% of unsourced demand in a single year (Table 14, Figure 44). There are 6,970 AF of purchased water for which the District does not have sufficient supply to pay back to the seller.

Much of the supply in this scenario is sourced either along the Santa Ynez River or the State Water project, with groundwater being the only source from south of the Santa Ynez Range. There is reliance during dry years on the water banks.

During an extended drought (Figure 43), there is significant unsourced demand near the end of the drought. There is excess capacity in the Coastal Branch during this time, but the banks have been depleted. Direct purchase and delivery of Supplemental Water would partially relieve the significant unsourced demand.

The average cost of water was calculated using Scenario #5d as $2,861 per AF for the first 17 years and $2,009 per AF for subsequent years. This cannot be directly compared to Scenario #4 costs because there remains unsourced demand in Scenario #5d and significant amounts of pay-back water (6,970 AF) for which the District has insufficient supply to repay.

Scenario	Unsourced Demand	Payback Owed	Cost First 17yr	Cost Remaining
#5a	18% of yrs, 37% max unsourced			
#5b	33% of yrs, 60% max unsourced			
#5d	10% of yrs, 25% max unsourced	6,970 AF	$2,861 per AF	$2,009 per AF

Table 14. Results of Scenario #5.

Scenario #6 – Future Demand/Current Supplies with Supplemental Water

Scenario #6 adds purchasing Supplemental Water as needed to Scenario #3 (Table 15, Figure 47, Figure 49). There is some improvement in reliability from Scenario #3, but there is still unsourced demand of up to 10% of model years, with a maximum unsourced demand of 25% in one drought year. There are 4,925 AF of purchased water for which the District does not have sufficient supply to pay back to the seller.

Much of the supply in this scenario is sourced either along the Santa Ynez River or the State Water project, with groundwater being the only source from south of the Santa Ynez Range. There is reliance during dry years on purchases of Supplemental Water.

During an extended drought (Figure 52), there is significant unsourced demand near the end of the drought. This is caused by capacity limitations in the Coastal Branch.

The average cost of water was calculated using Scenario #6b as $2,615 per AF during the first 17 years and $1,852 per AF in subsequent years. This cannot be directly compared to Scenario #4 costs because there remains unsourced demand in Scenario #6b and significant amounts of pay-back water (4,925 AF) for which the District has insufficient supply to repay.

Scenario	Unsourced Demand	Payback Owed	Cost First 17yr	Cost Remaining
#6a	4% of yrs, 25% max unsourced			
#6b	10% of yrs, 25% max unsourced	4,925 AF	$2,615 per AF	$1,852 per AF

Table 15. Results of Scenario #6.

CONCLUSIONS

Conclusions as to the pros and cons of each water supply source are based on several criteria:

- Ability to supply customer demand (little or no unsourced demand);
- A significant amount of the sources of water being local – this means both on the MWD side of the Coastal Branch of the SWP and the MWD side of the water supply tunnels;
- Improvement in supply reliability;
- Cost;
- Little or no payback of purchased Supplemental Water required at the end of the model period.

Unsourced Demand – When there is significant unsourced demand in a scenario when Supplemental Water is purchased, it means that the District does not have the capacity to transport additional water through the Coastal Branch of the State Water Project. The result of unsourced demand would likely be that the District would have to again have a restrictive pricing structure to reduce customer demand.

Local Source – When water is sourced locally, it avoids pipeline restrictions and the possible temporary loss of the water supply tunnels following an earthquake.

Supply Reliability – Improving supply reliability can be done by either improving the reliability of existing sources or adding to MWD's water portfolio.

Cost – Cost is evaluated for the short-term and long-term. Not reflected is the potential cost is: 1) replacing (if even possible) Supplemental Water that was purchased and for which the District does not have excess supply to pay back the water; or 2) the likely higher cost of Supplemental Water if the pay-back provision is modified or eliminated in the future.

Pay-Back Water – As discussed above, having a pay-back balance could reflect either additional costs or the inability of the District to meet a pay-back requirement.

The scenarios with the Water Supply Agreement performed best using the criteria above (Table 16). Costs of the WSA were modestly higher than the other scenarios for the first 17 years of the model, then lower than the other scenarios for the remaining 61 years of the model. Many of the other scenarios had issues – significant unsourced demand where pipeline capacity prevents filling that demand by purchasing water elsewhere in the State, and a significant amount of water for which the District has insufficient supply to pay back to the seller. If regulations about pay-back are modified in the future, this could improve that problem; however, the cost of Supplemental Water is expected to be higher if there is no pay-back provision, raising the annual cost of the scenario.

When an extended drought was applied to all the scenarios, there was unsourced demand in the later years of the drought. This demand cannot be met by buying more Supplemental Water, because there would be insufficient capacity in the Coastal Branch pipeline to deliver that water.

Scenario	Unsourced Demand	Local Sources	Improved Reliability	Average Cost First 17 yr/Remaining	Payback Owed
	Current Demand				
#1	Moderate	Low	None	$2,739/$1,843	Moderate
#2	None	High	High	$3,158/$1,751	None
	Future Demand				
#3	High	Low	None	$2,615/$1,852	High
#4	Low	High	High	$3,003/$1,733	Low
#5	High	Low	Moderate	$2,861/$2,009	High
#6	High	Low	None	$2,615/$1,852	High

Table 16. Summary of criteria for each water source. Costs are separated into those in the first 17 years of the model and those in the remaining 71 years.

RECOMMENDATIONS

With the Water Supply Agreement meeting the criteria important to the District for its future water supplies and based on the results of this analysis, it is recommended that this water source be obtained by the District. Costs are a little higher for the WSA scenarios in the first 17 years until fixed costs are retired, but then costs are thereafter lower than the other water supply scenarios with a significant improvement in water supply reliability.

It is also recommended that the modified rule curve be implemented for Jameson Reservoir. This modification allows more water to be available for use from the reservoir late into a drought period.

During a future drought that is more severe, longer, or more frequent than the historical droughts of the last 100+ years, there would be a shortfall of supply to meet demand. Although the District would prefer not to impose a restrictive water pricing structure to lower demand as in the recent drought, that may be required, along with increased conservation, in such a drought.

APPENDIX A. REVISED JAMESON RULE CURVE

In the recent drought, storage in Jameson Reservoir approached minimum pool, severely affecting the amount of water that could be diverted from the reservoir. The District wanted to modify the current Rule Curve so that there would be sufficient storage for water supply diversions up to seven years during a drought.

Jameson has been decreasing its storage over the years because of siltation on the reservoir bottom. The District regularly contracts for a bathymetric survey of the reservoir to determine current storage. Current storage is about 4,848 AF; with siltation filling in an average of 25 AFY, storage in 2040 would be about 4,348 AF.

Two factors are competing in developing a rule curve:

- If insufficient water is diverted in the year following a spill, there is a better chance of spilling in the subsequent year because reservoir levels are high – this effectively decrease the yield of the reservoir;
- If too much water is diverted in the years following a spill, then there is insufficient reservoir storage later in the drought cycle.

To balance these factors, a modified rule curve was established (Figure 7) by trying difference configurations of the curve. In Figure 7, diversions are high when the reservoir is full, then decrease rapidly as the reservoir empties. There is then an inflection point where the annual diversion doesn't drop as fast with decreasing reservoir storage, ensuring that there will be diversions available for 7 years (Figure 8).

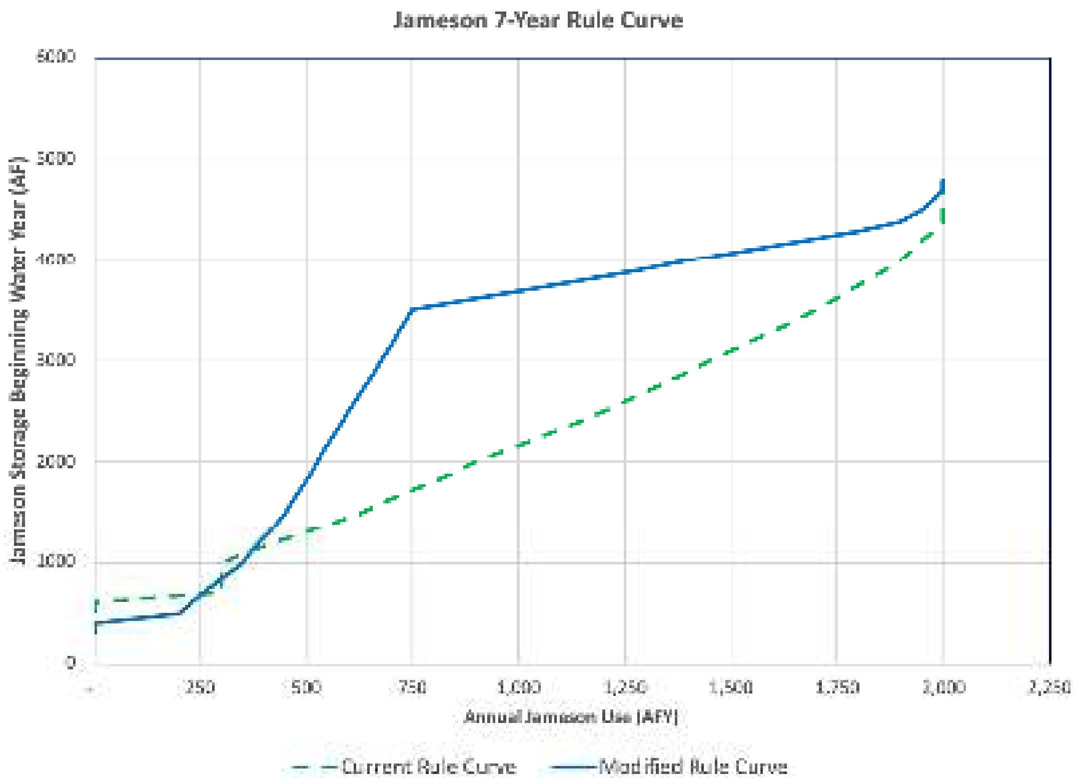

Figure 7. Modified Jameson Rule Curve compared to previous curve.

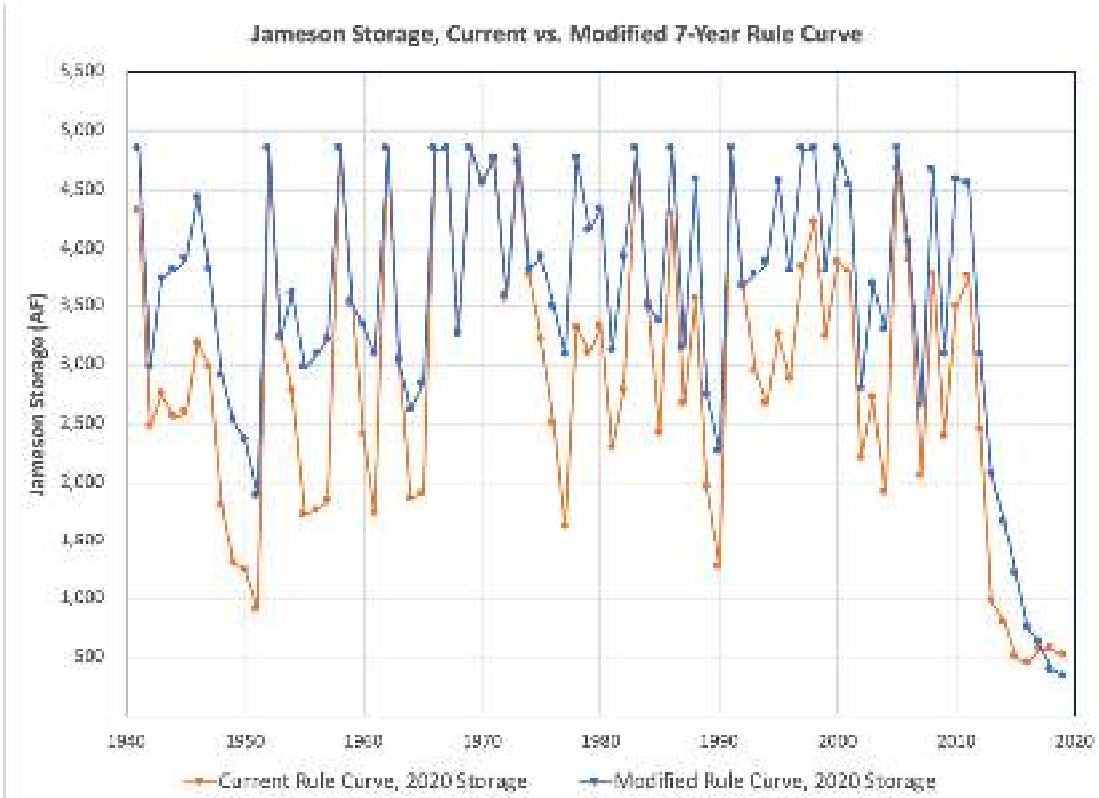

Figure 8. Storage in Jameson Reservoir using current and modified Rule Curves.

APPENDIX B. CHARTS OF SCENARIO #1 MODEL RESULTS

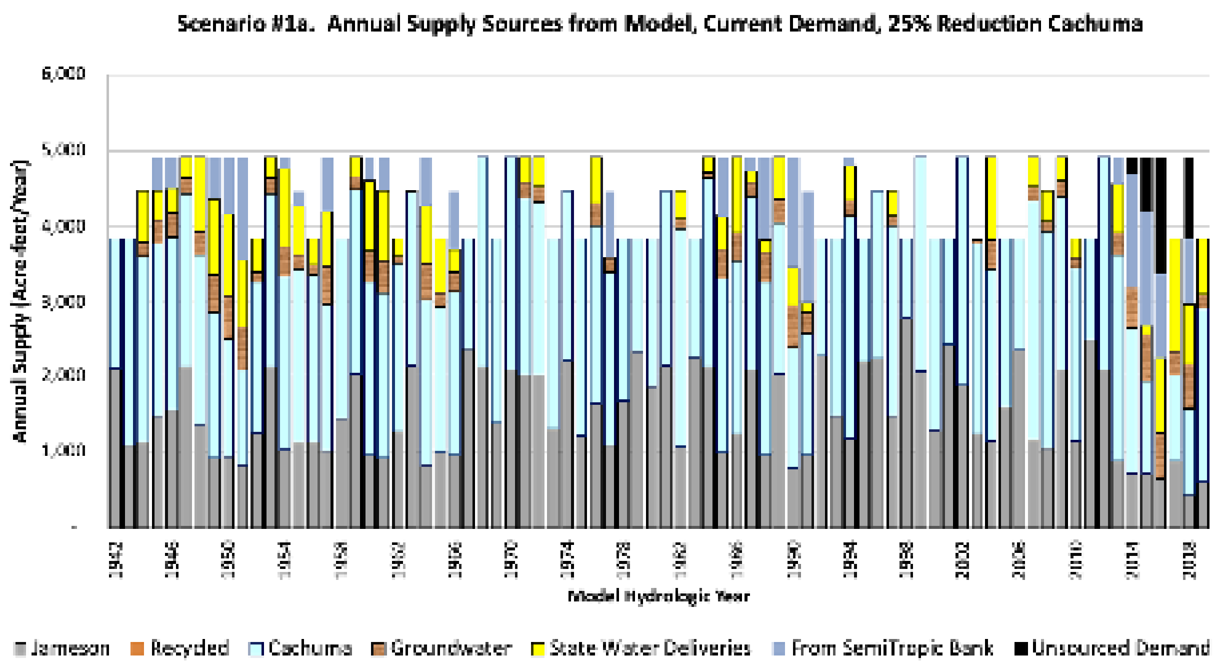

Figure 9. Results of Scenario #1a modeling.

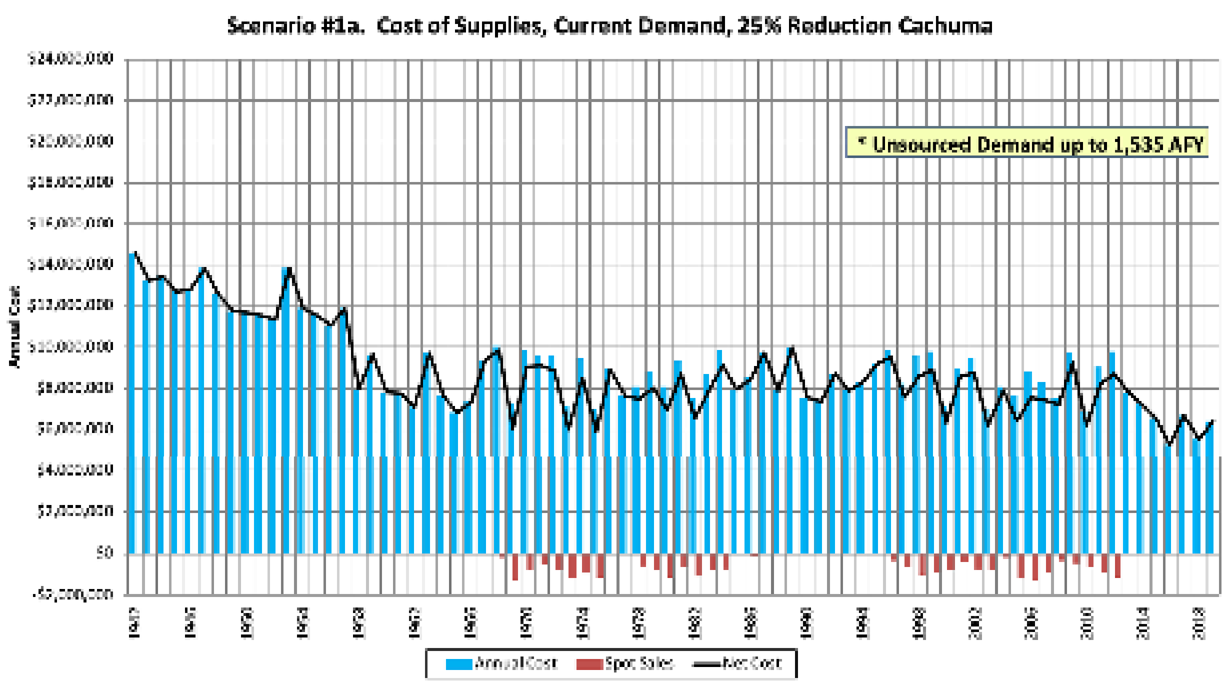

Figure 10. Costs for Scenario #1a. "Spot sales" are unused State Water sold on the spot market.

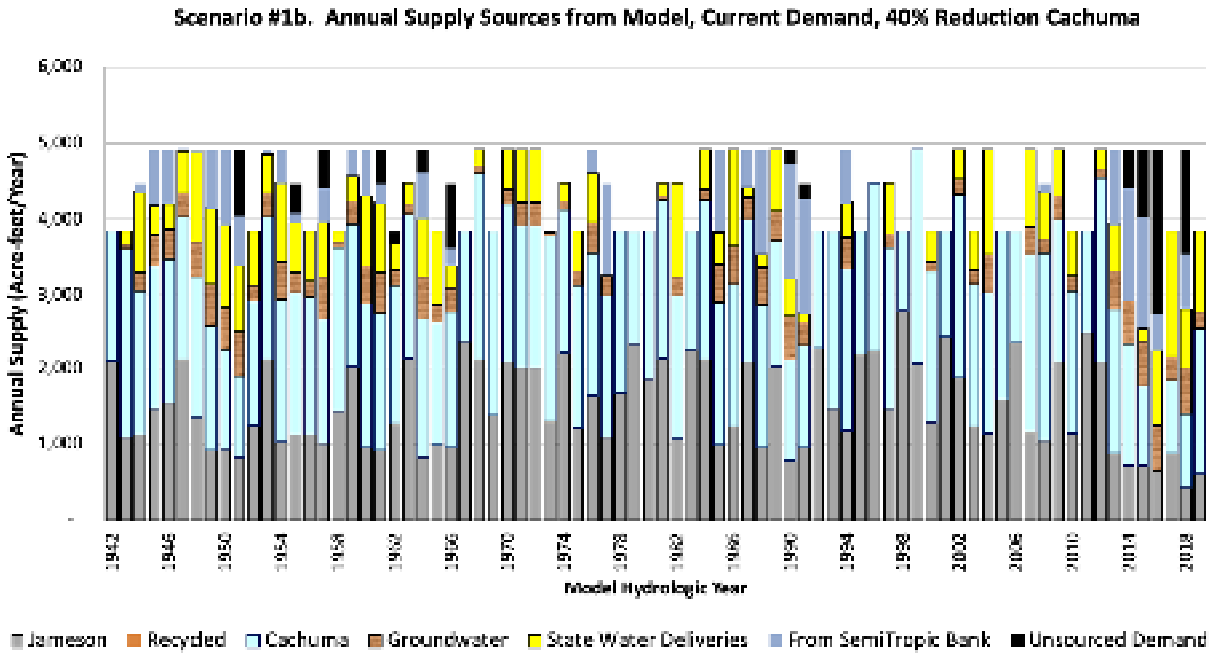

Figure 11, Results of Scenario #1b modeling.

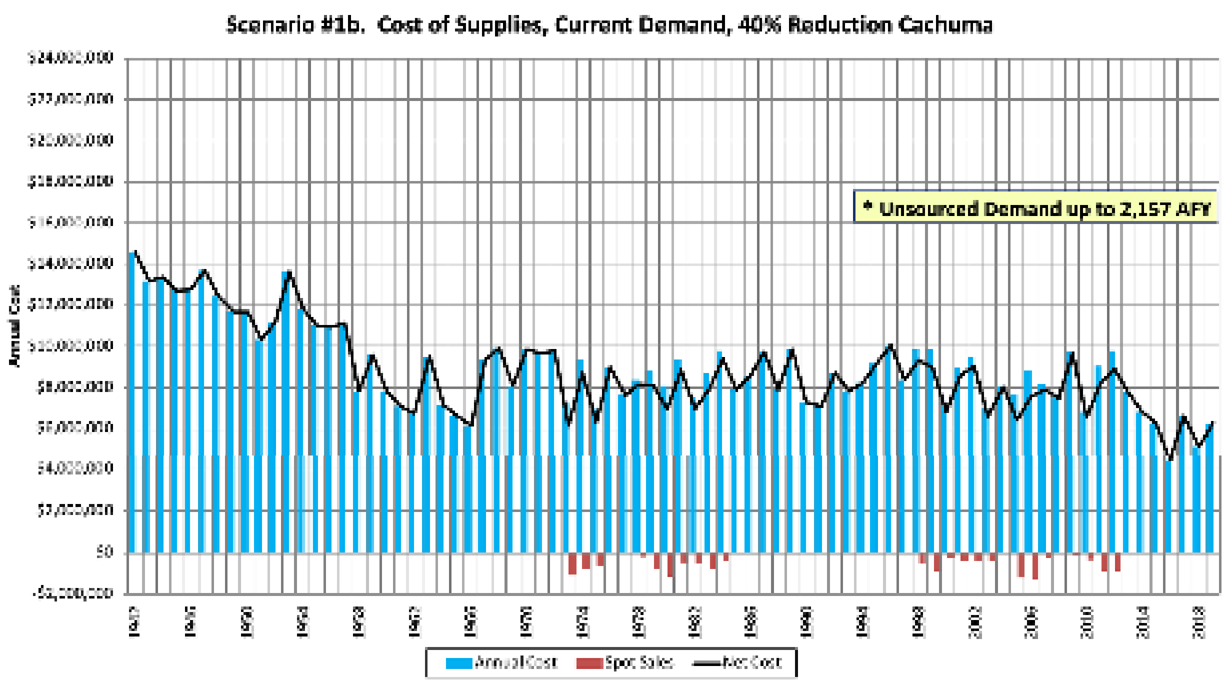

Figure 12. Costs for Scenario #1b. "Spot sales" are unused State Water sold on the spot market.

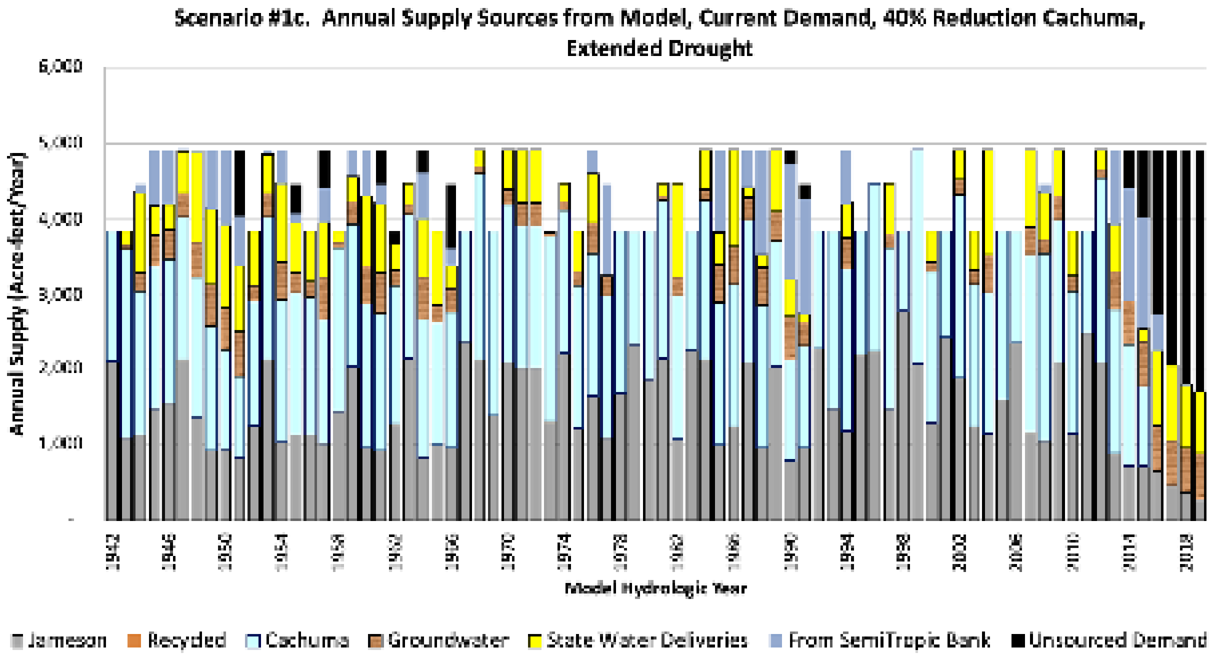

Figure 13. Results of Scenario #1c modeling.

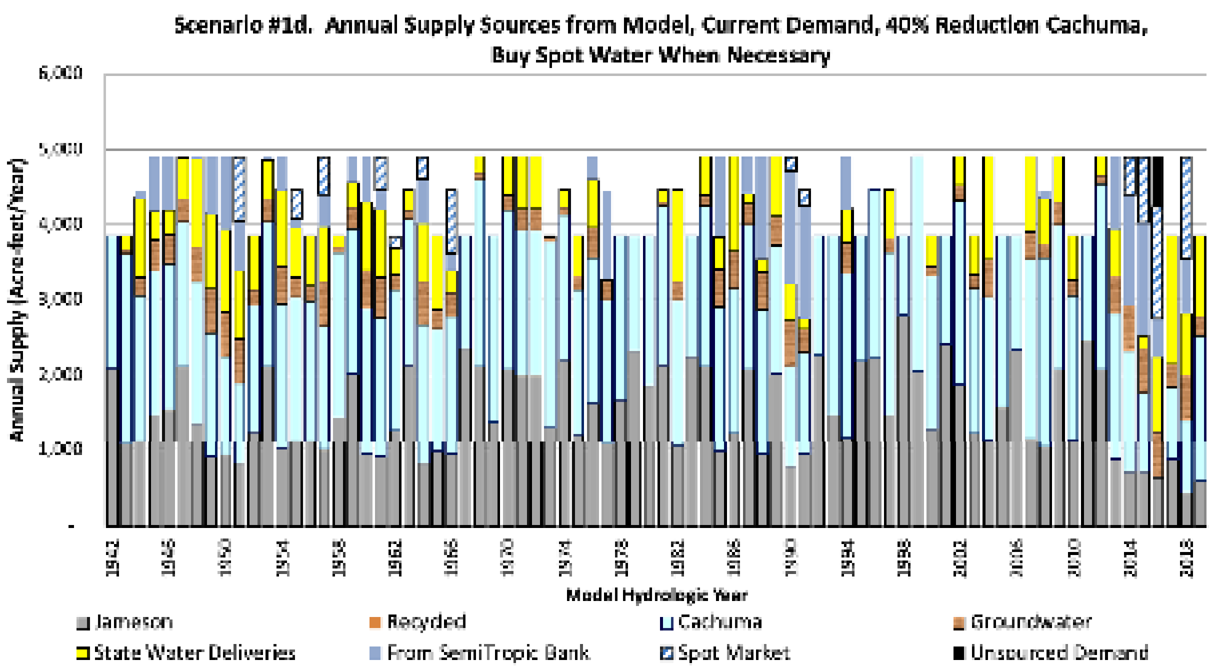

Figure 14. Results of Scenario #1d modeling.

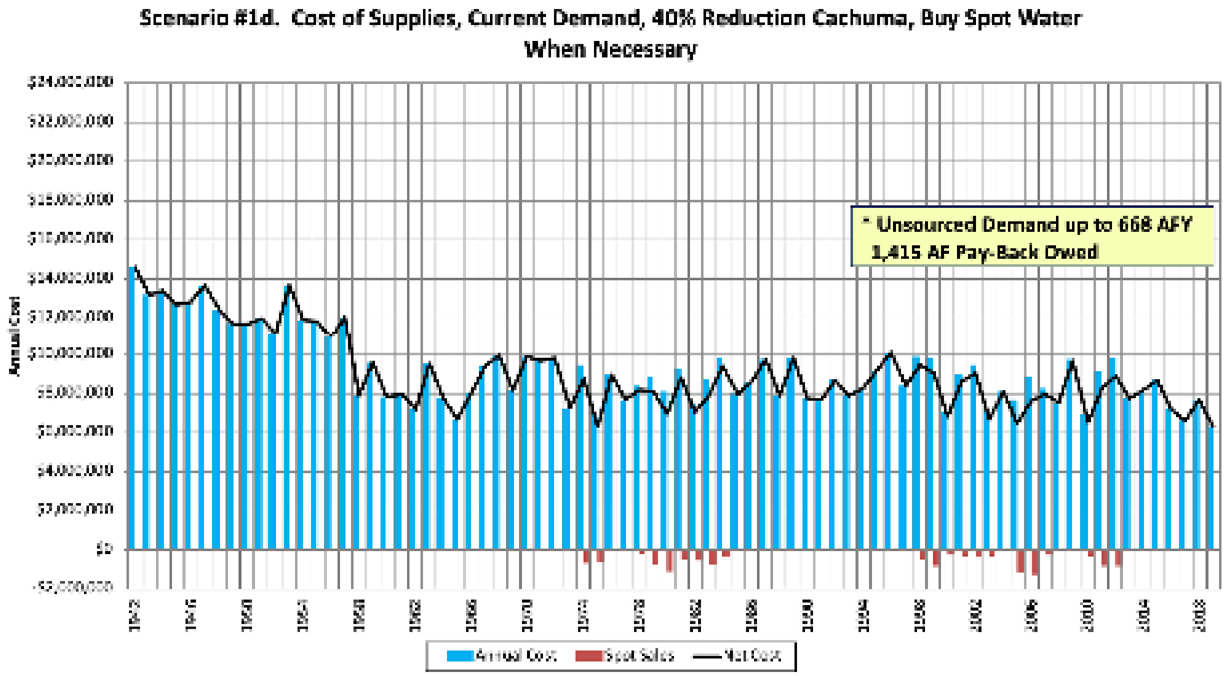

Figure 15. Costs for Scenario #1d. "Spot sales" are unused State Water sold on the spot market.

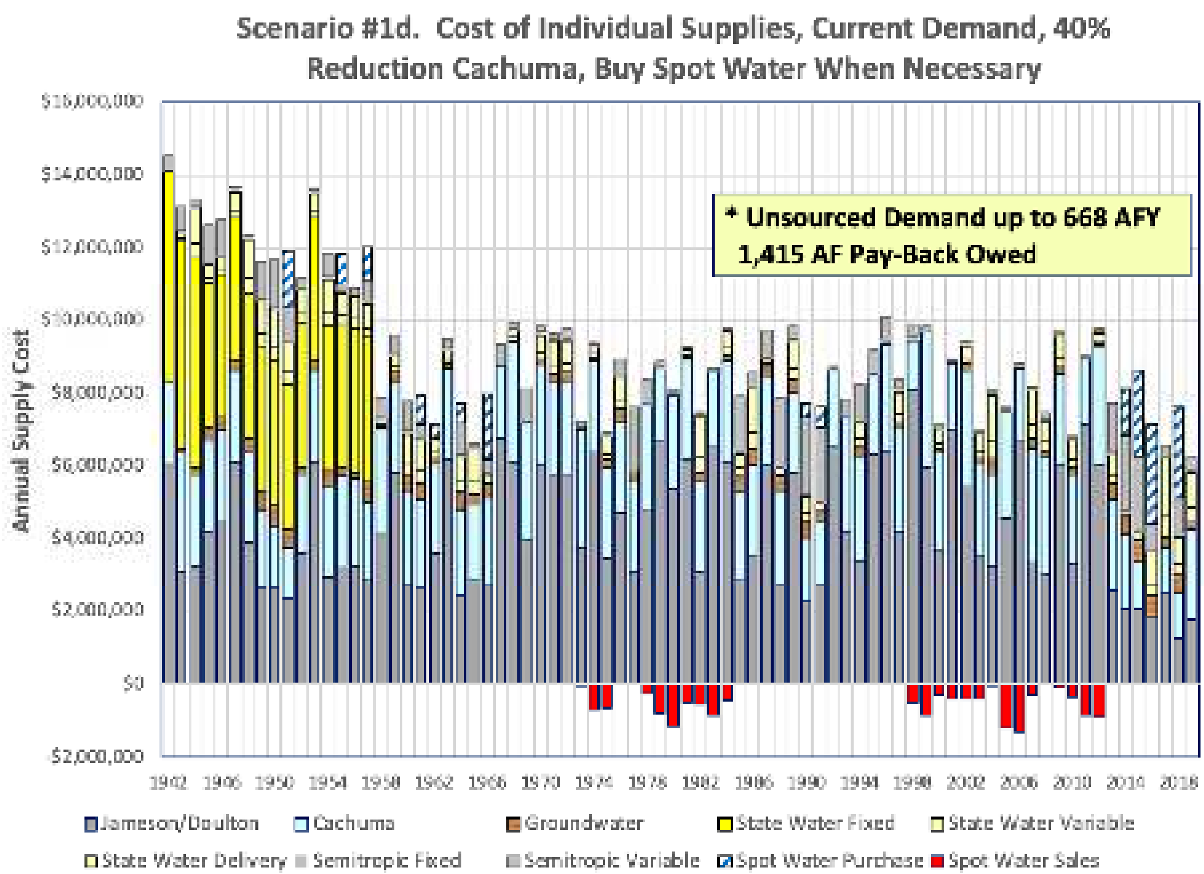

Figure 16. Costs for individual sources in Scenario #1d.

APPENDIX C. CHARTS OF SCENARIO #2 MODEL RESULTS

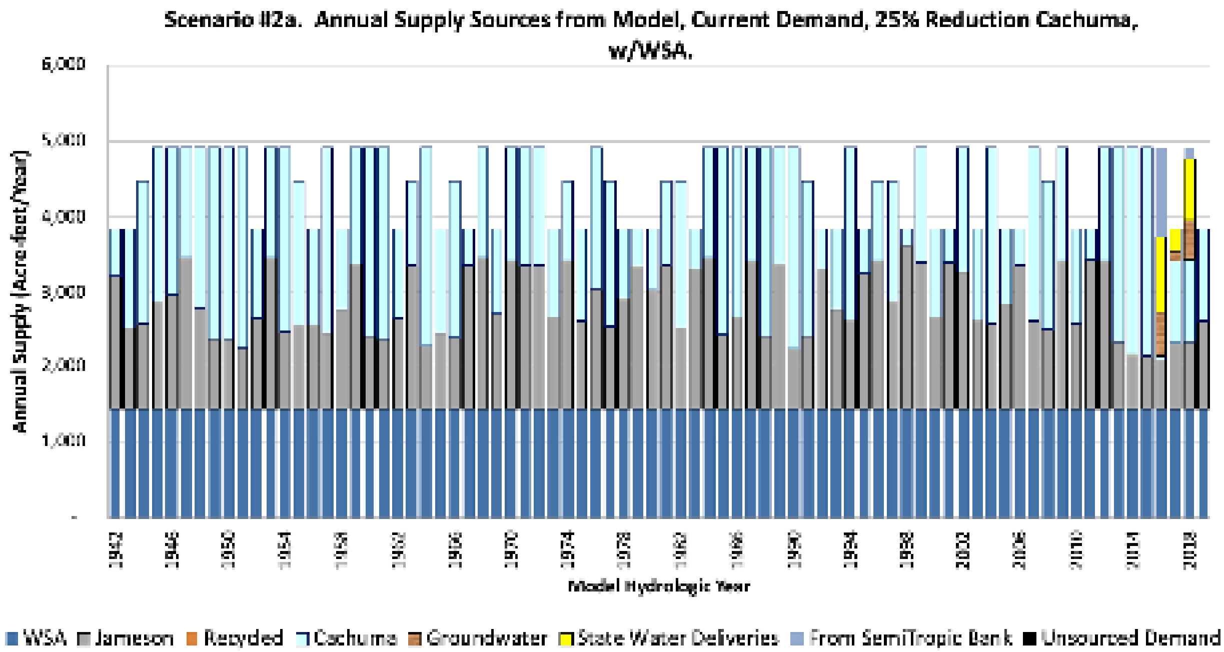

Figure 17. Results of Scenario #2a modeling.

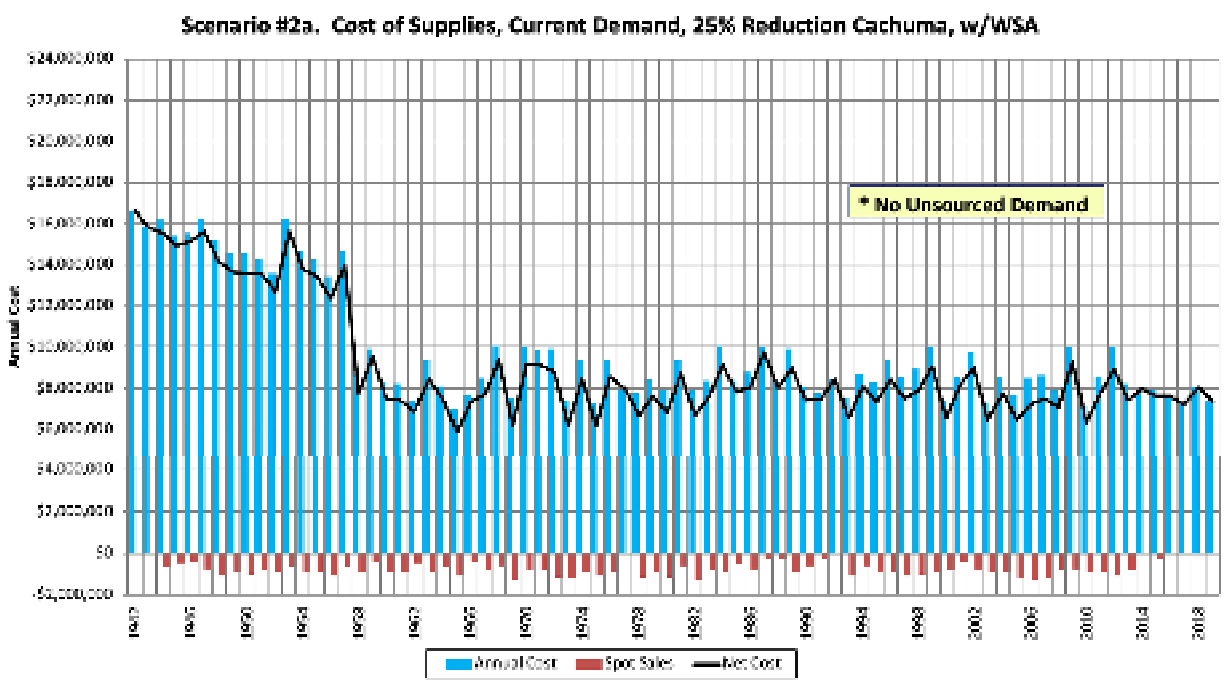

Figure 18. Costs for Scenario #2a. "Spot sales" are unused State Water sold on the spot market.

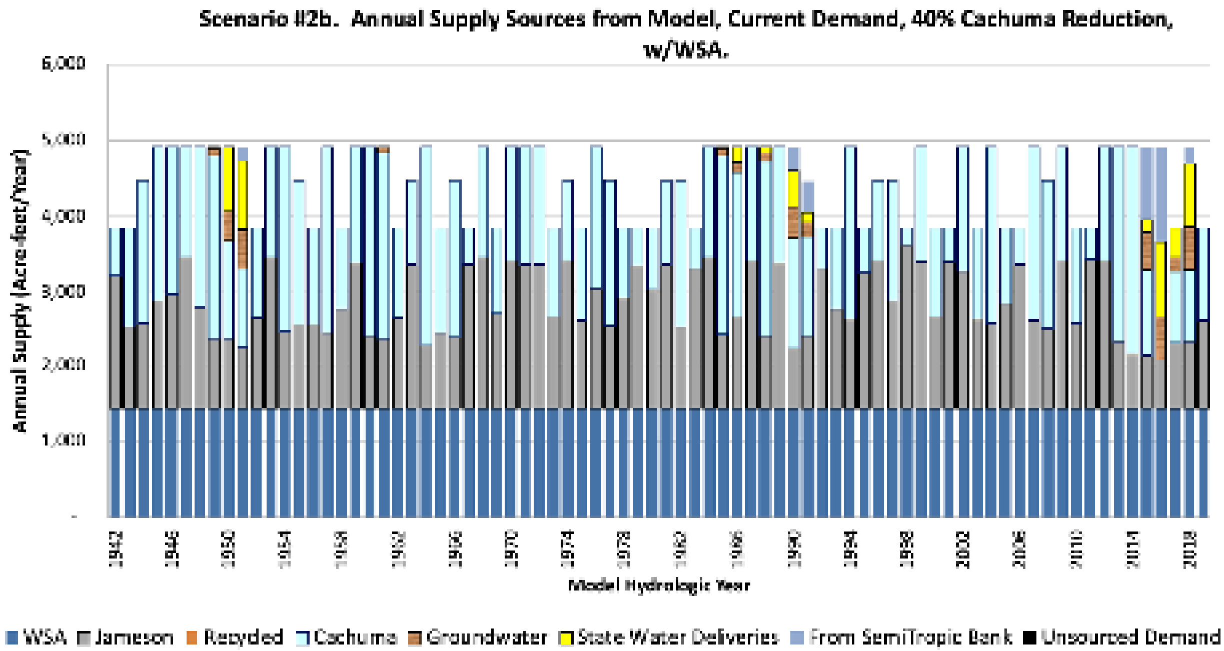

Figure 19. Results of Scenario #2b modeling.

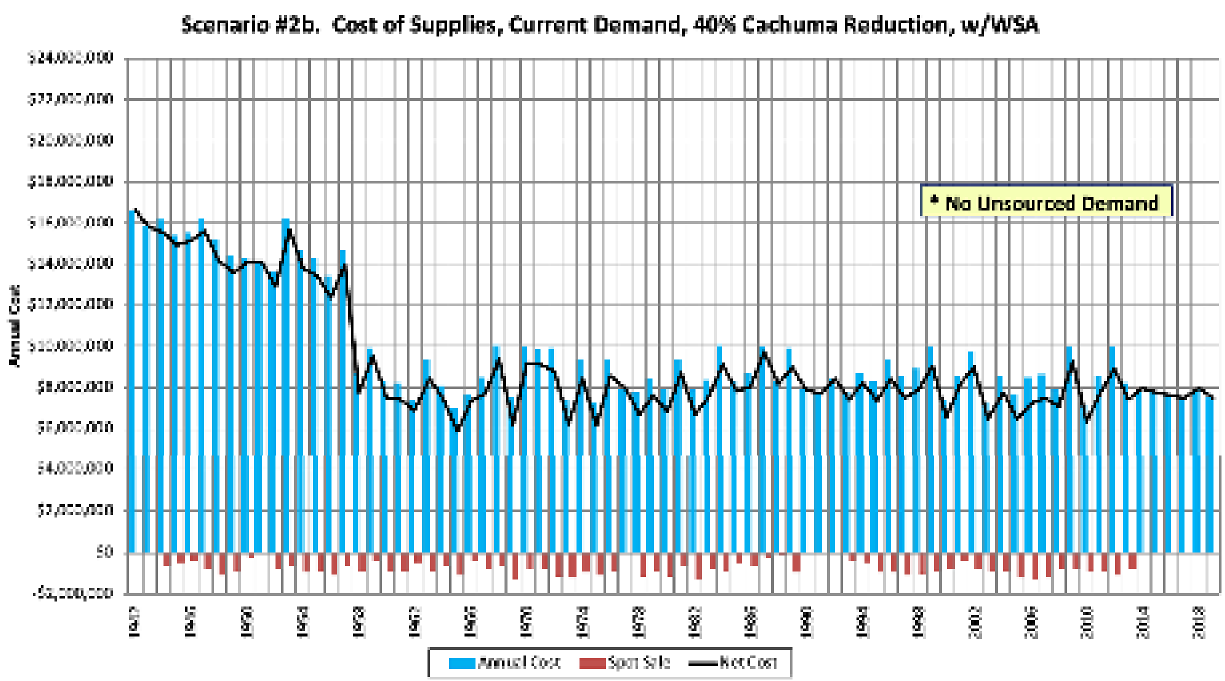

Figure 20. Costs for Scenario #2b. "Spot sales" are unused State Water sold on the spot market.

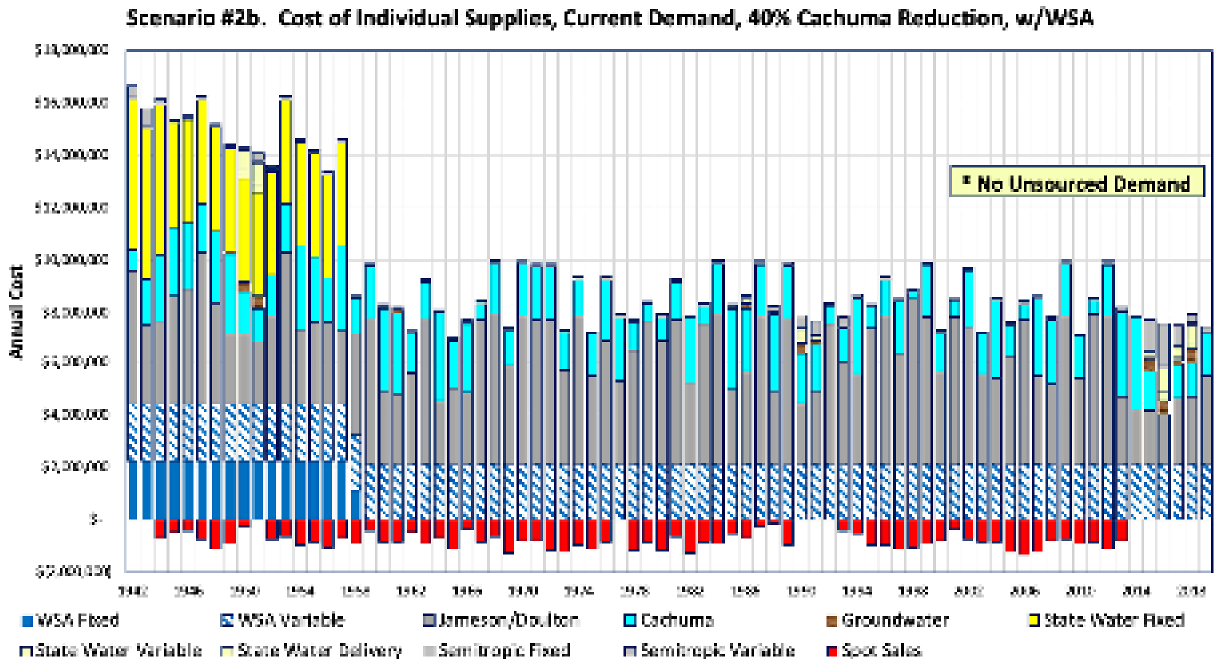

Figure 21. Costs for individual sources in Scenario #2b.

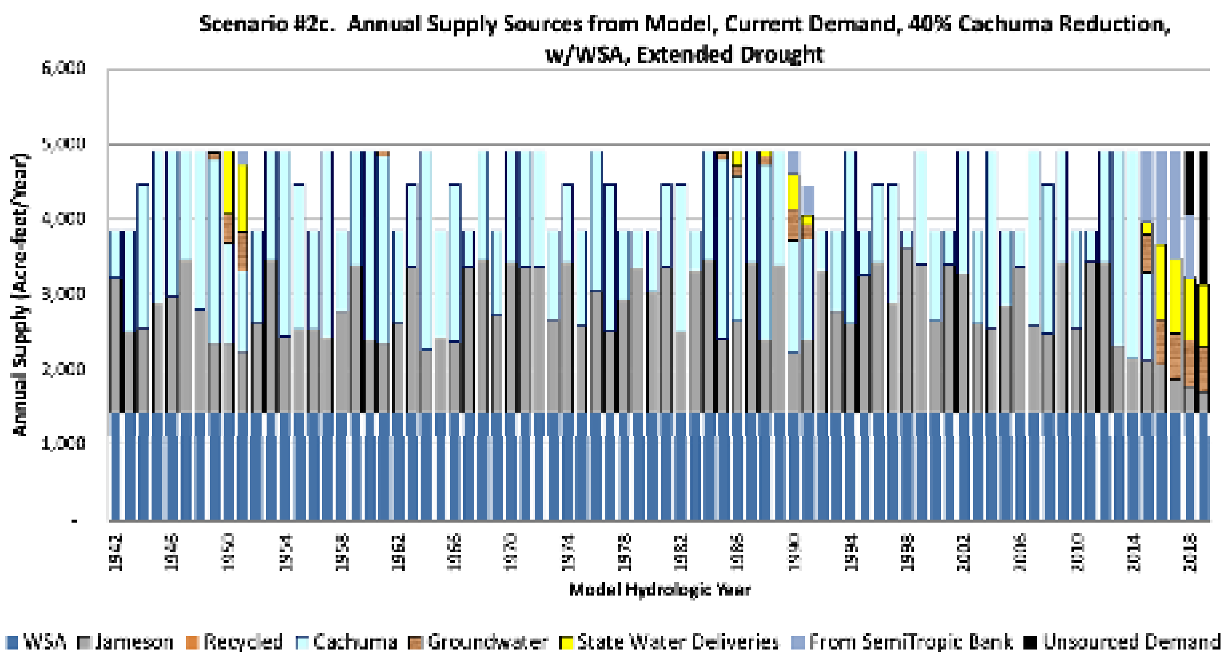

Figure 22. Results of Scenario #2c modeling.

APPENDIX D. CHARTS OF SCENARIO #3 MODEL RESULTS

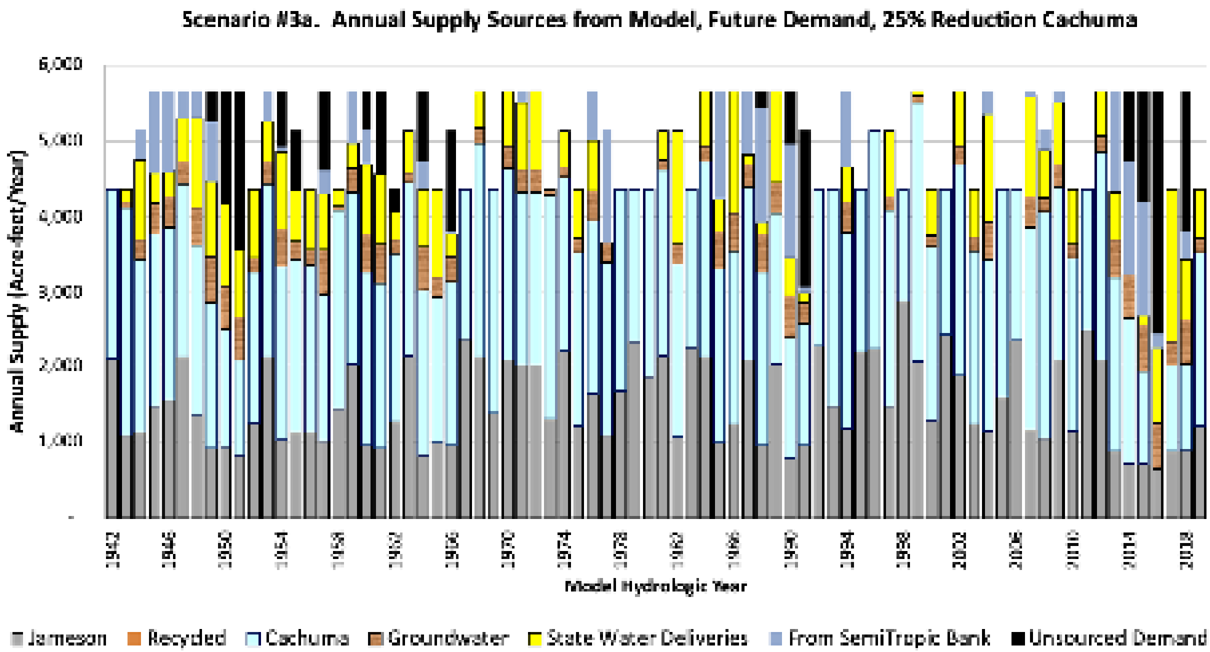

Figure 23. Results of Scenario #3a modeling.

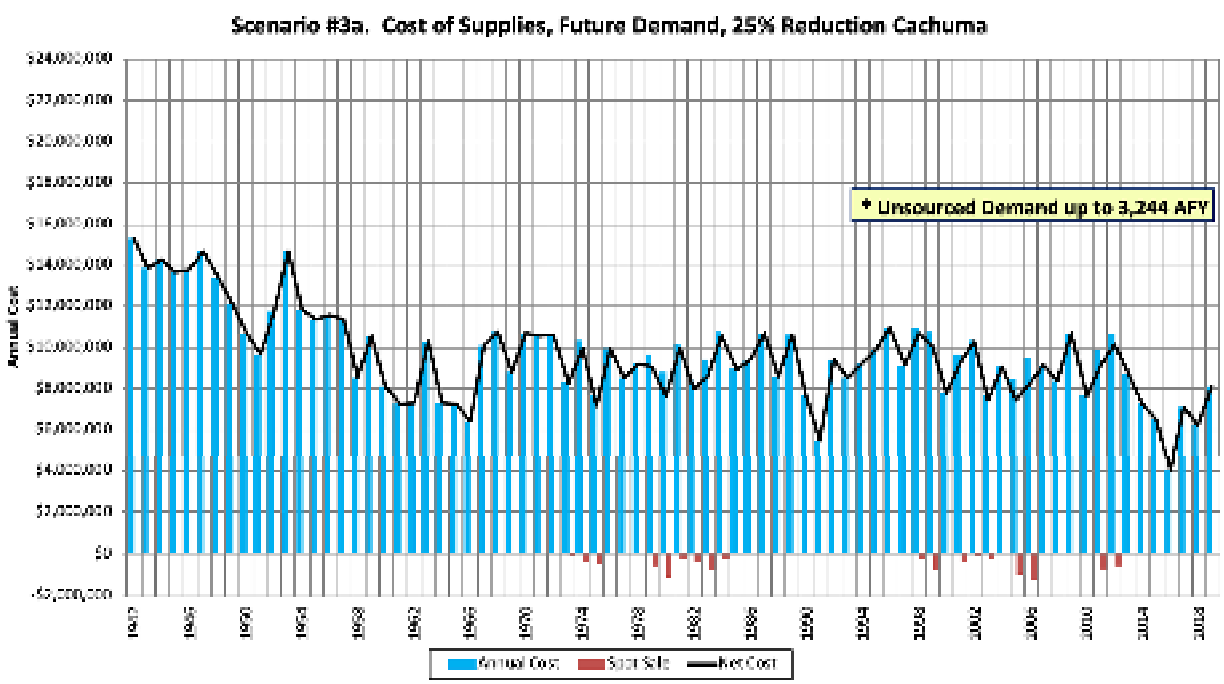

Figure 24. Costs for Scenario #3a. "Spot sales" are unused State Water sold on the spot market.

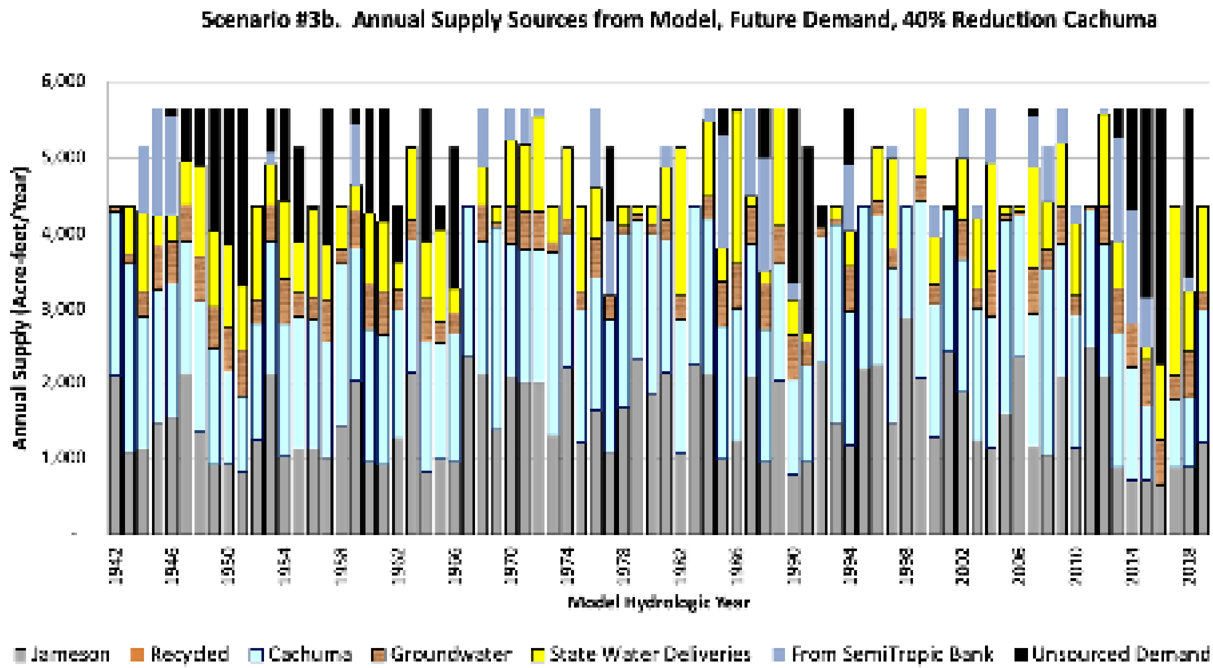

Figure 25. Results of Scenario #3b modeling.

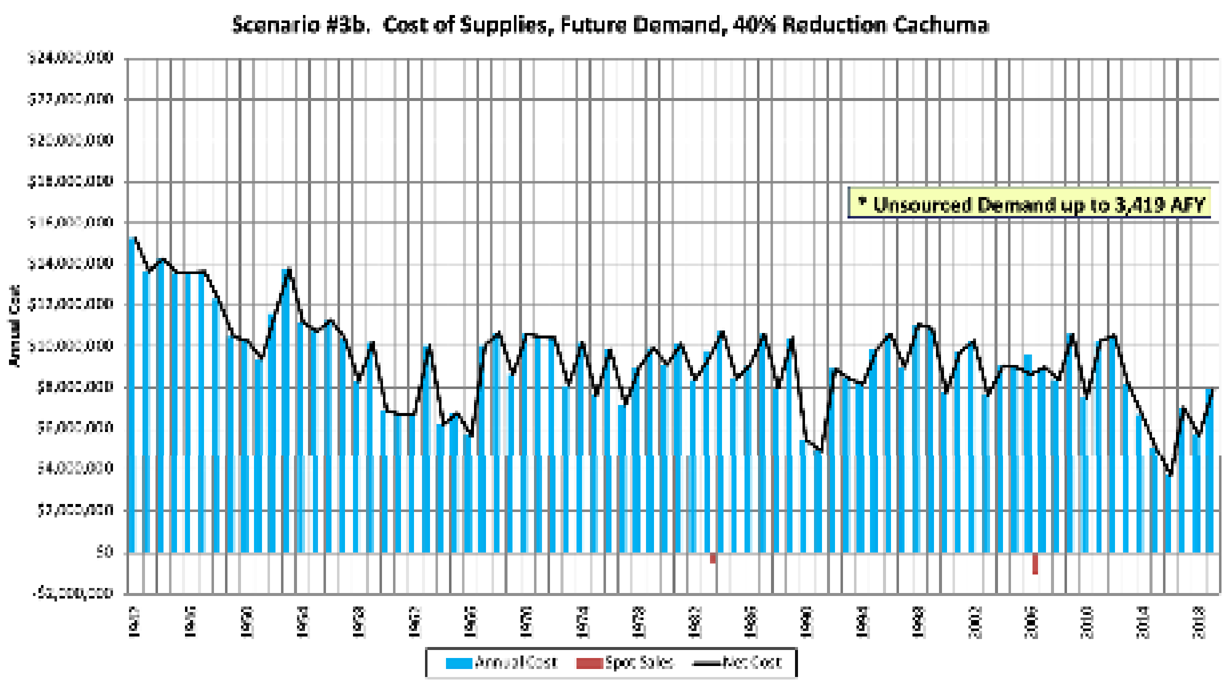

Figure 26. Costs for Scenario #3b. "Spot sales" are unused State Water sold on the spot market.

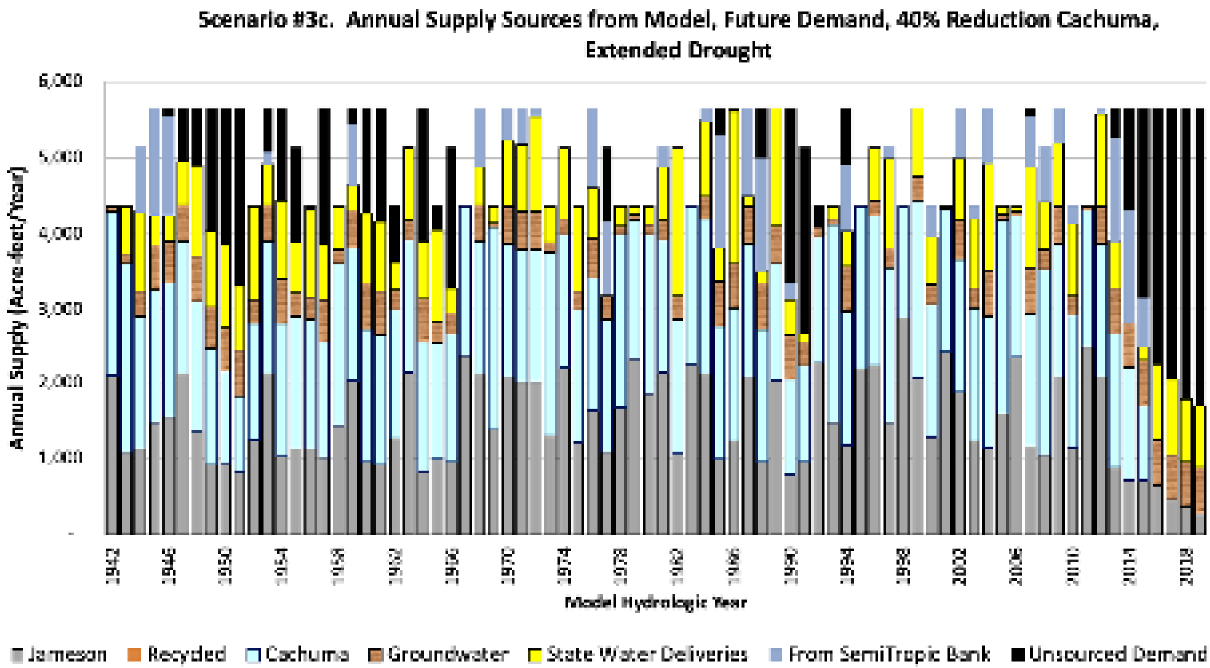

Figure 27. Results of Scenario #3c modeling.

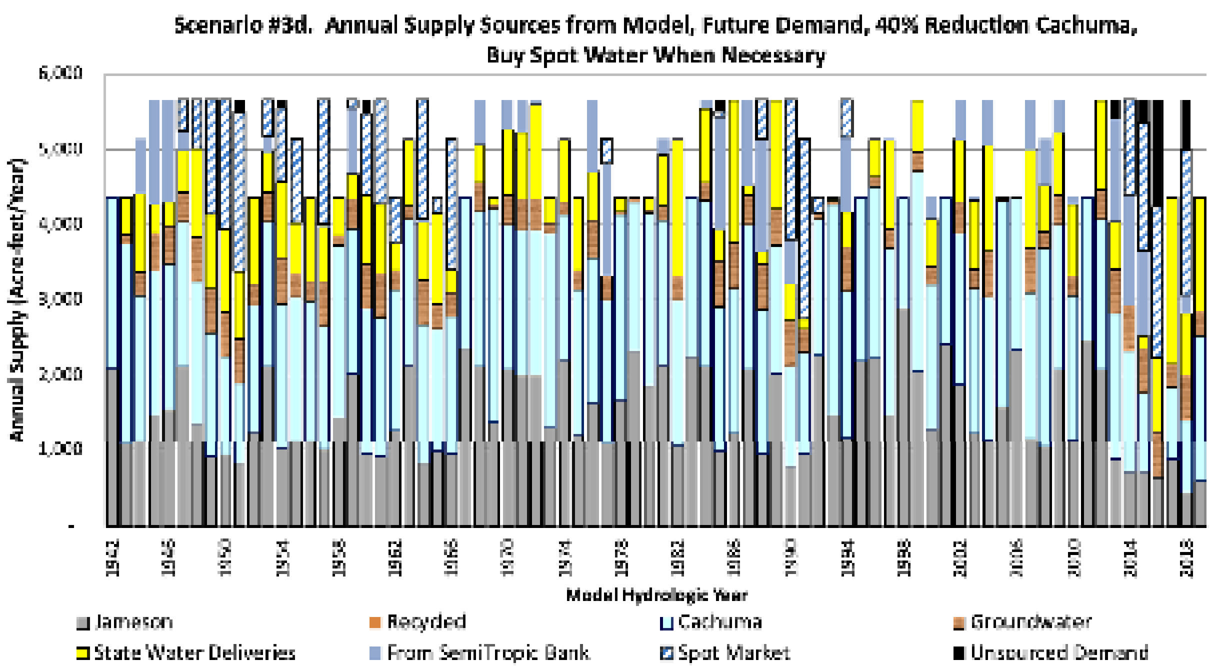

Figure 28. Results of Scenario #3d modeling.

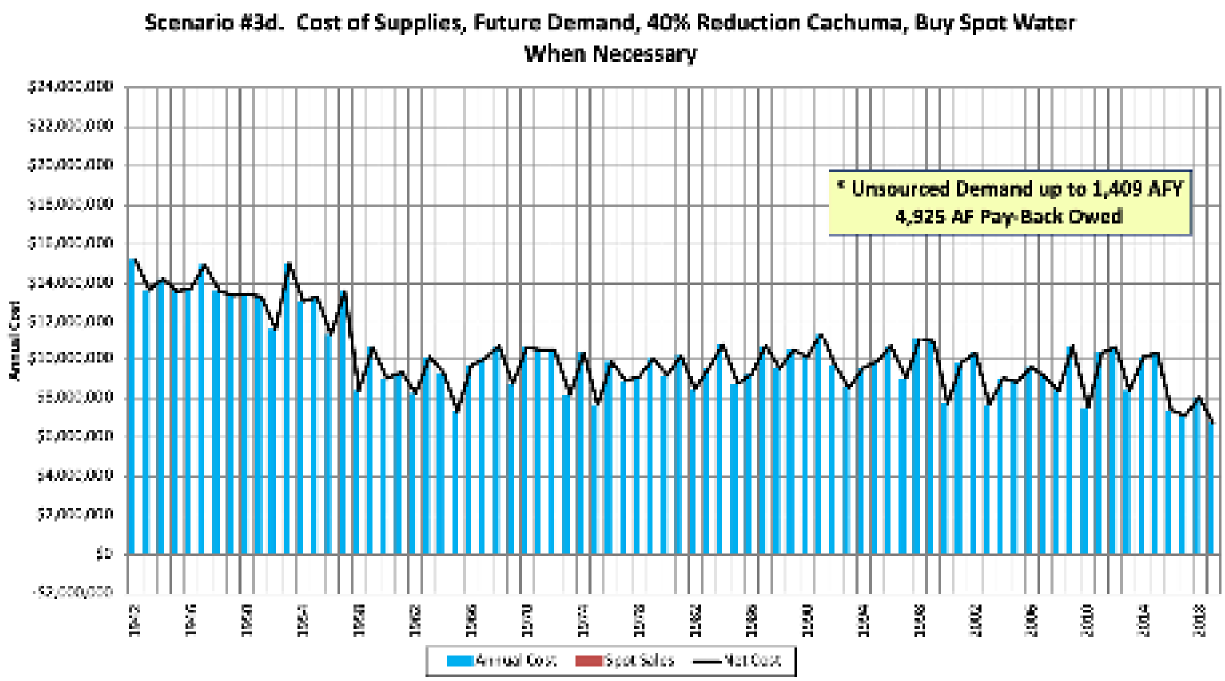

Figure 29. Costs for Scenario #3d.

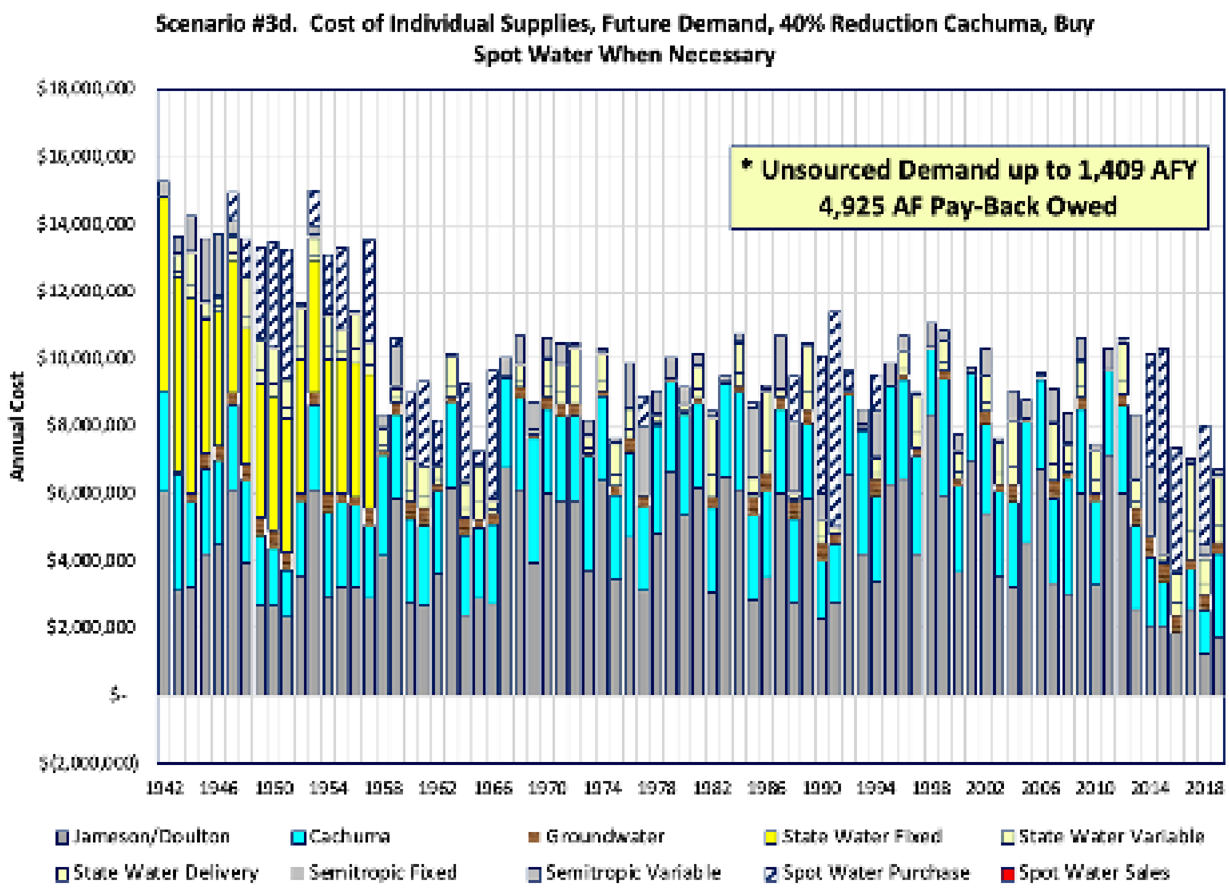

Figure 30. Costs for individual sources in Scenario #3d.

APPENDIX E. CHARTS OF SCENARIO #4 MODEL RESULTS

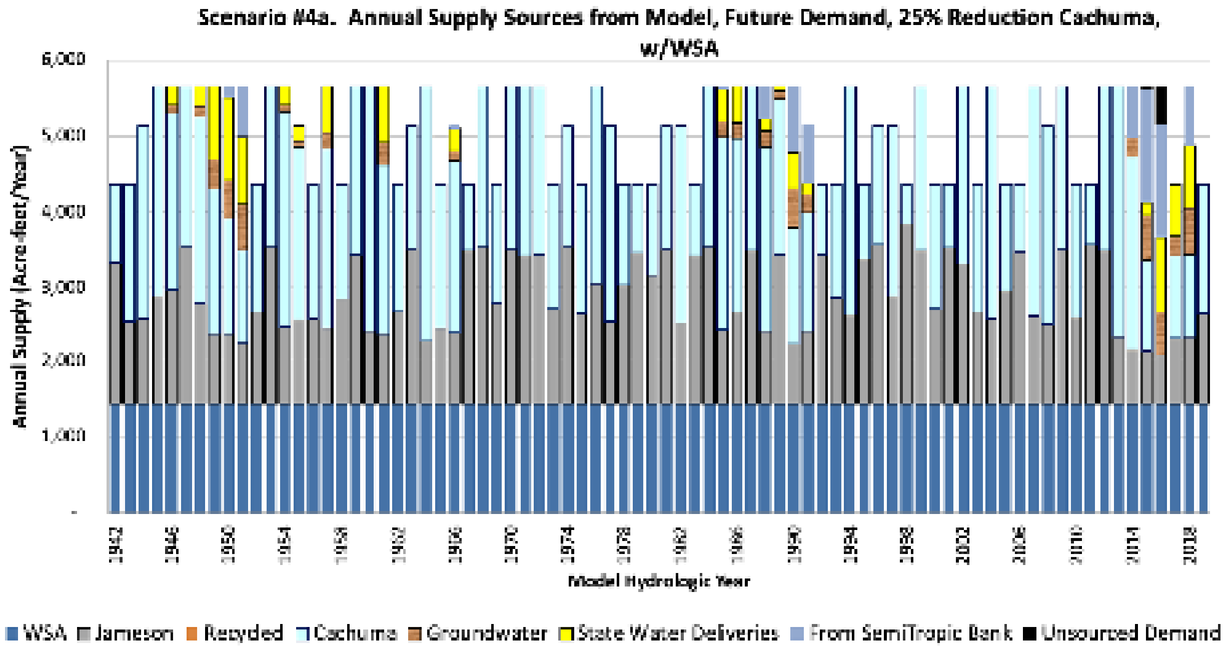

Figure 31. Results of Scenario #4a modeling.

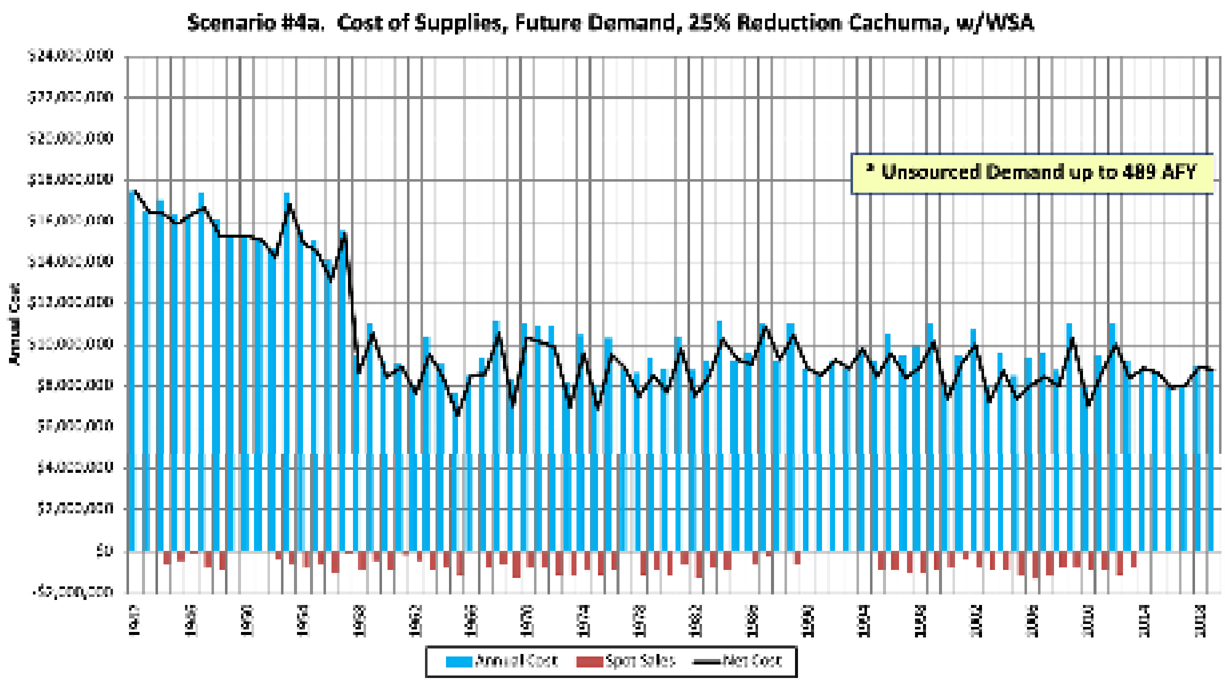

Figure 32. Costs for Scenario #4a. "Spot sales" are unused State Water sold on the spot market.

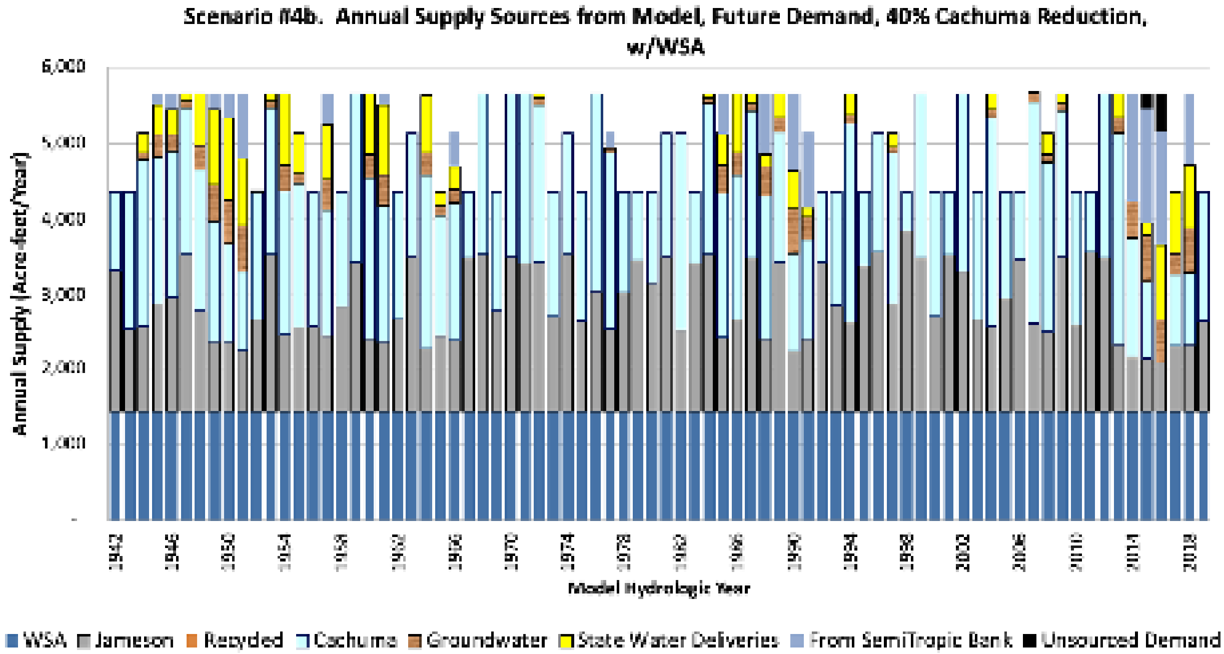

Figure 33. Results of Scenario #4b modeling.

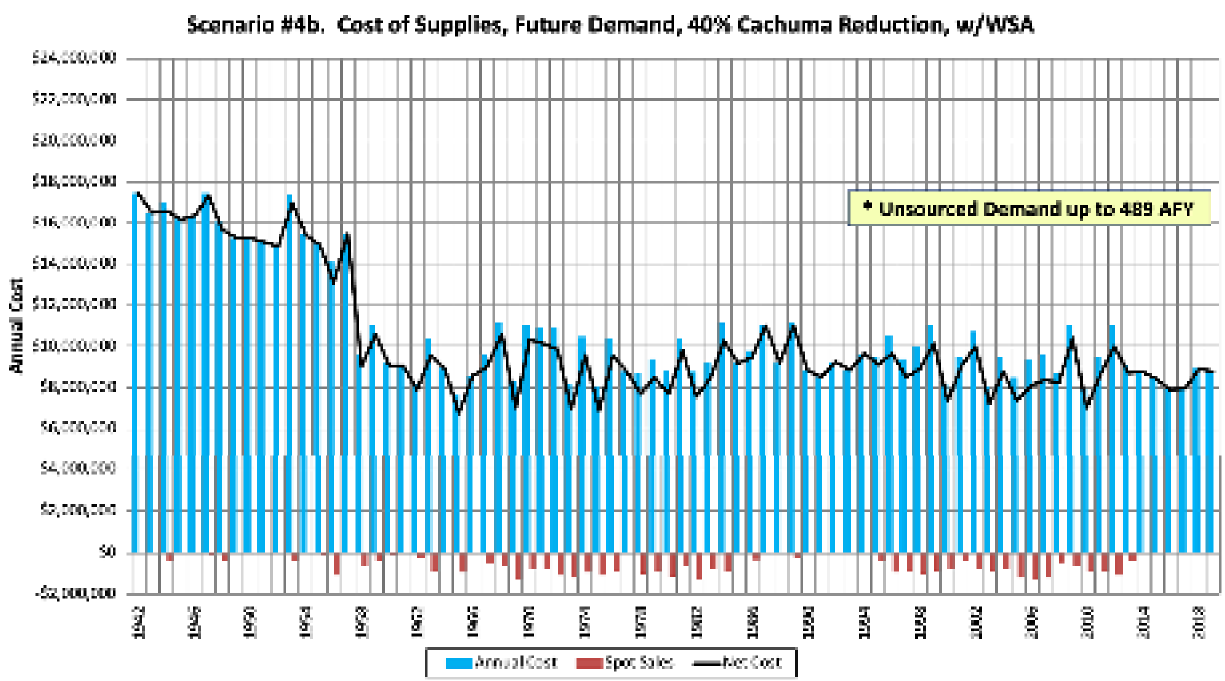

Figure 34. Costs for Scenario #4b. "Spot sales" are unused State Water sold on the spot market.

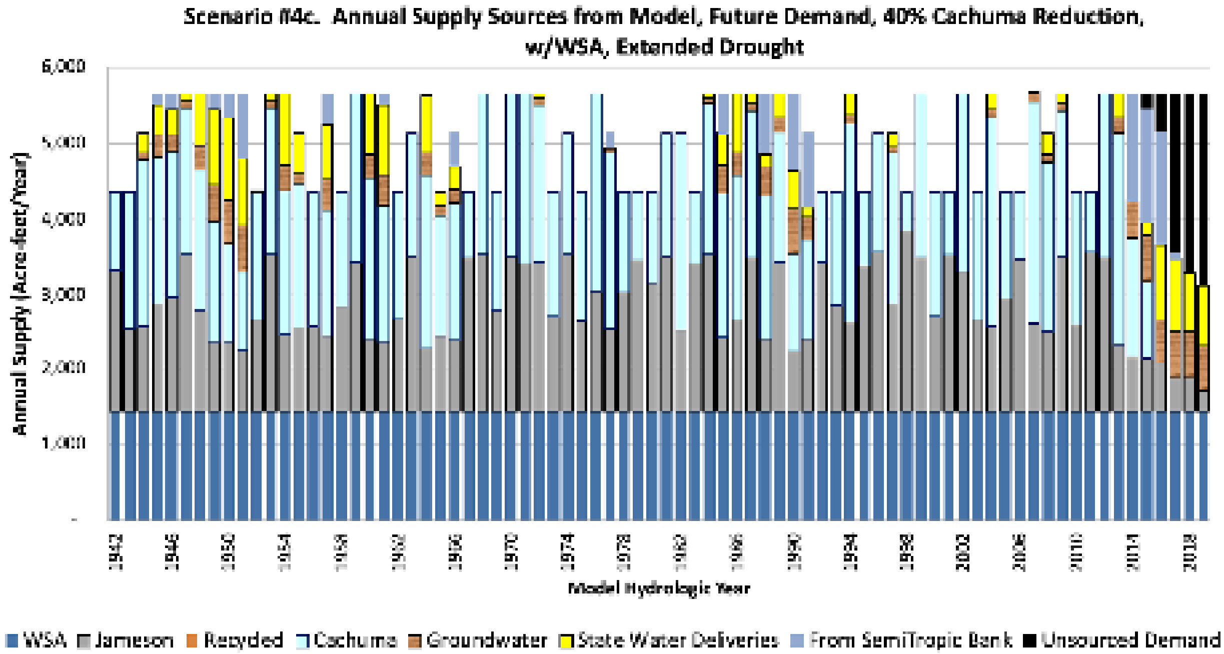

Figure 35, Results of Scenario #4c modeling.

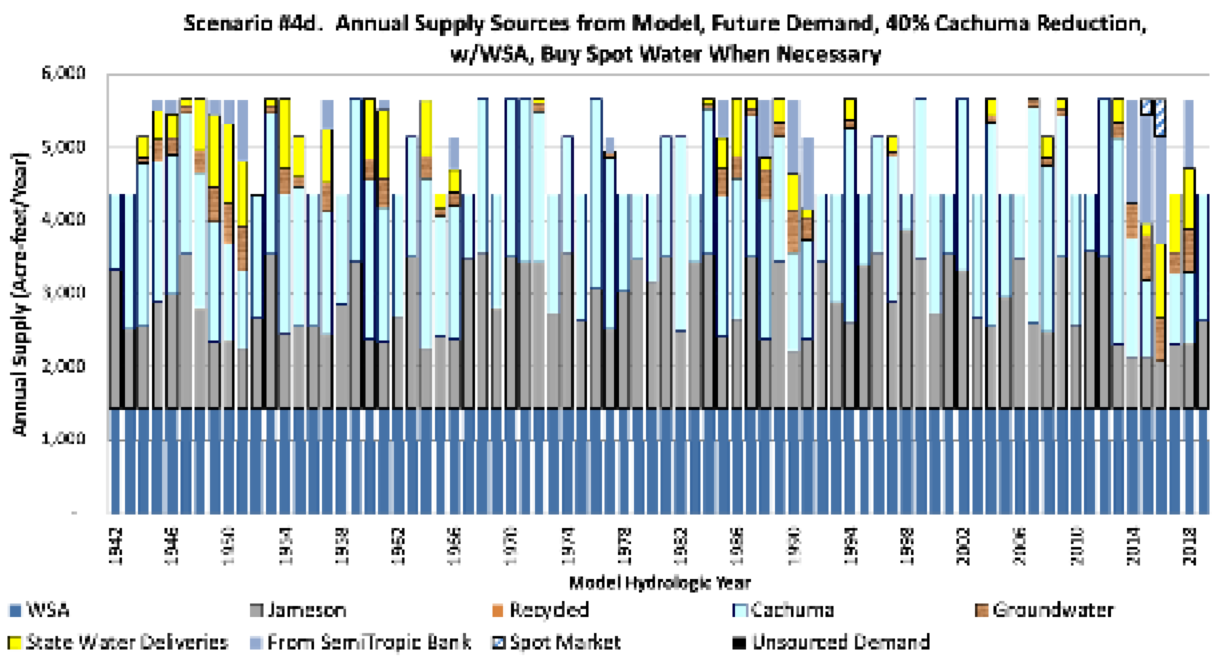

Figure 36. Results of Scenario #4d modeling.

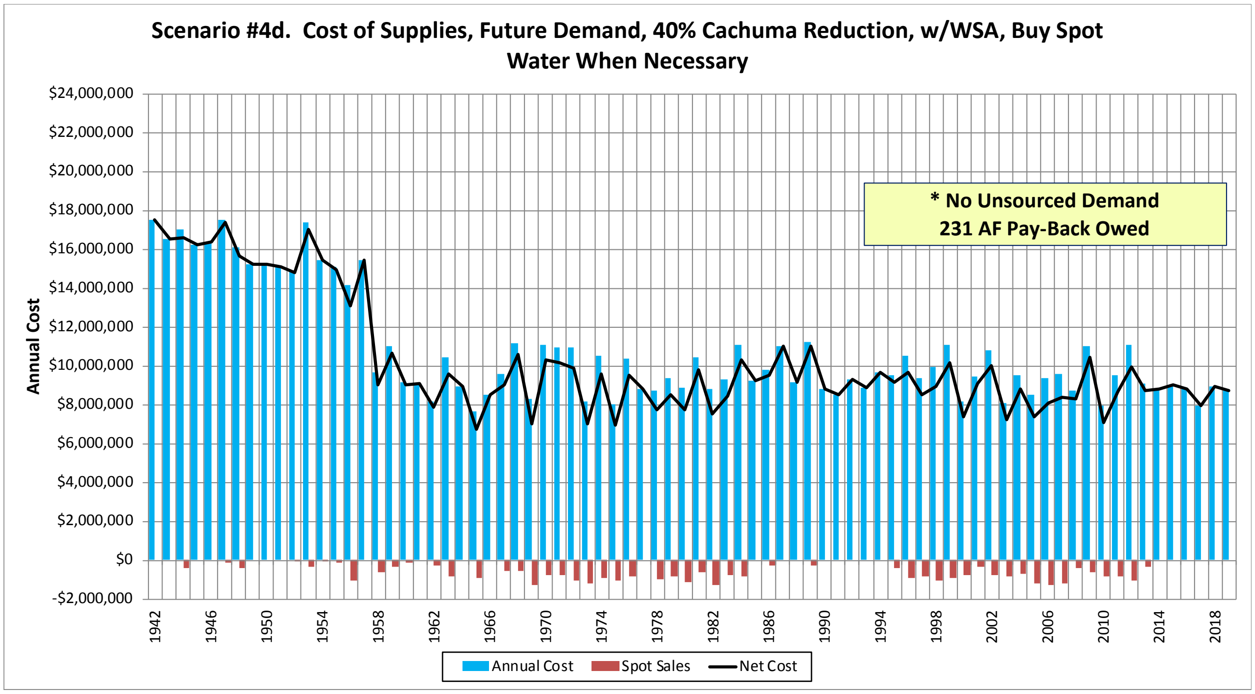

Figure 37. Costs for Scenario #4d. "Spot sales" are unused State Water sold on the spot market.

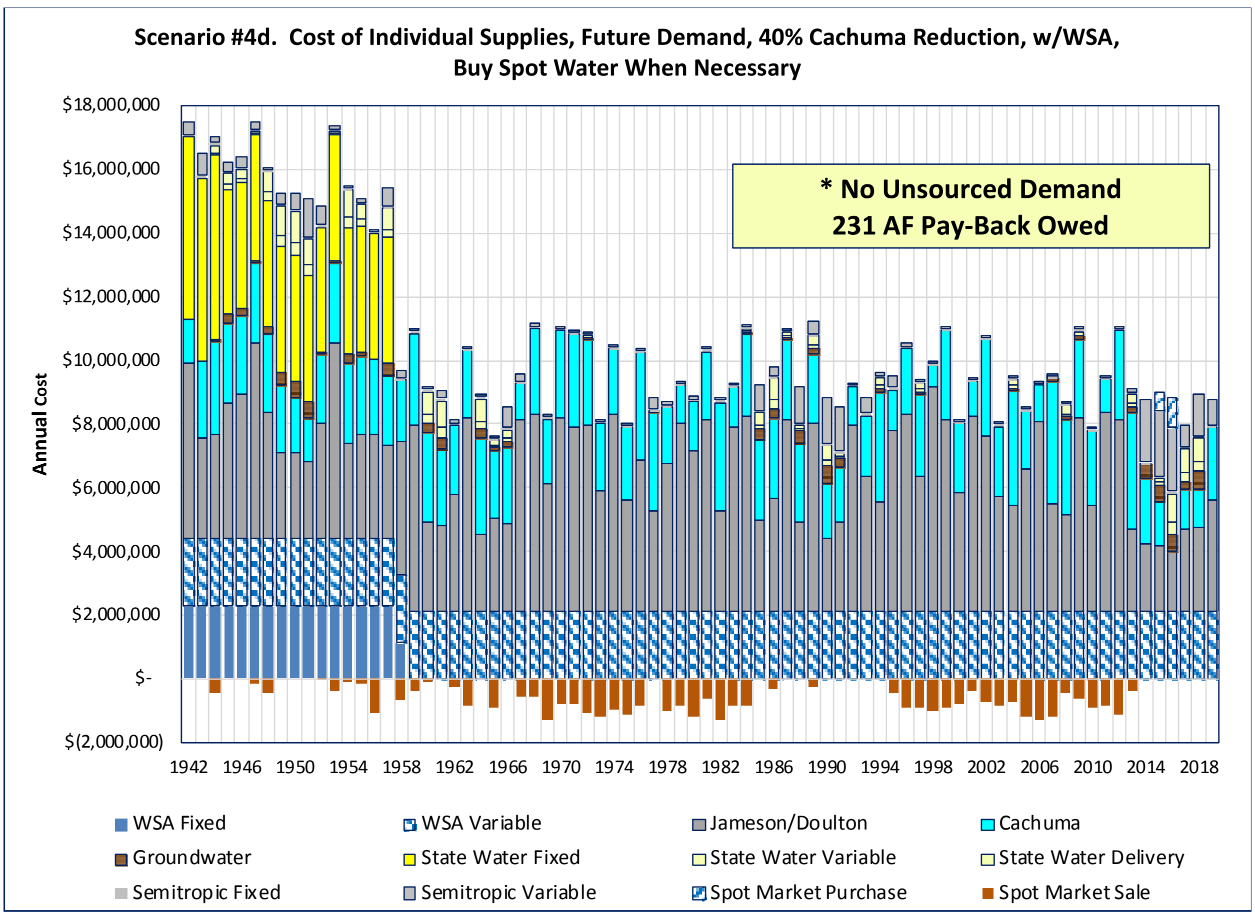

Figure 38. Costs for individual sources in Scenario #4d.

APPENDIX F. CHARTS OF SCENARIO #5 MODEL RESULTS

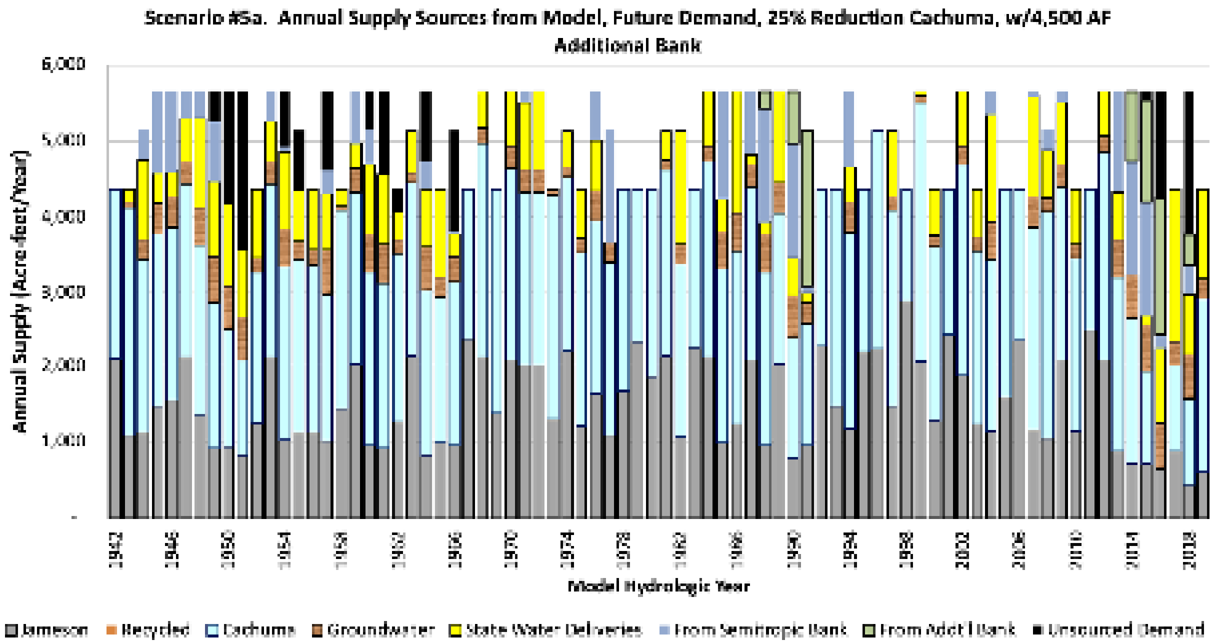

Figure 39. Results of Scenario #5a modeling.

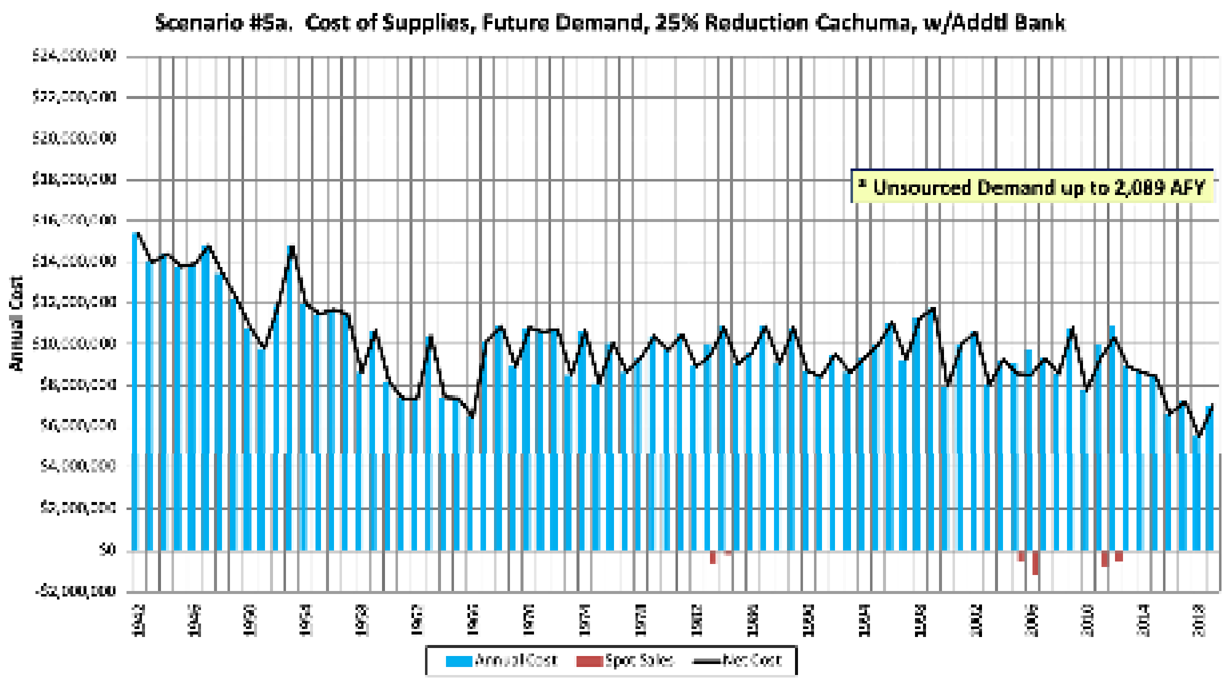

Figure 40. Costs for Scenario #5a. "Spot sales" are unused State Water sold on the spot market.

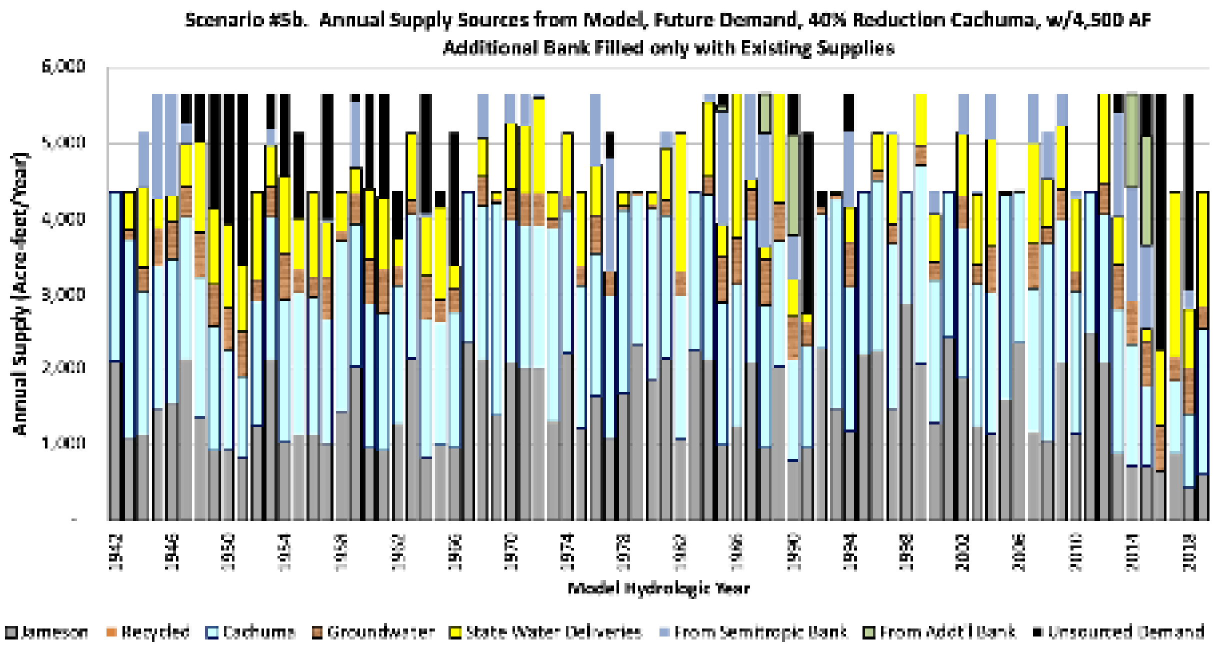

Figure 41. Results of Scenario #5b modeling.

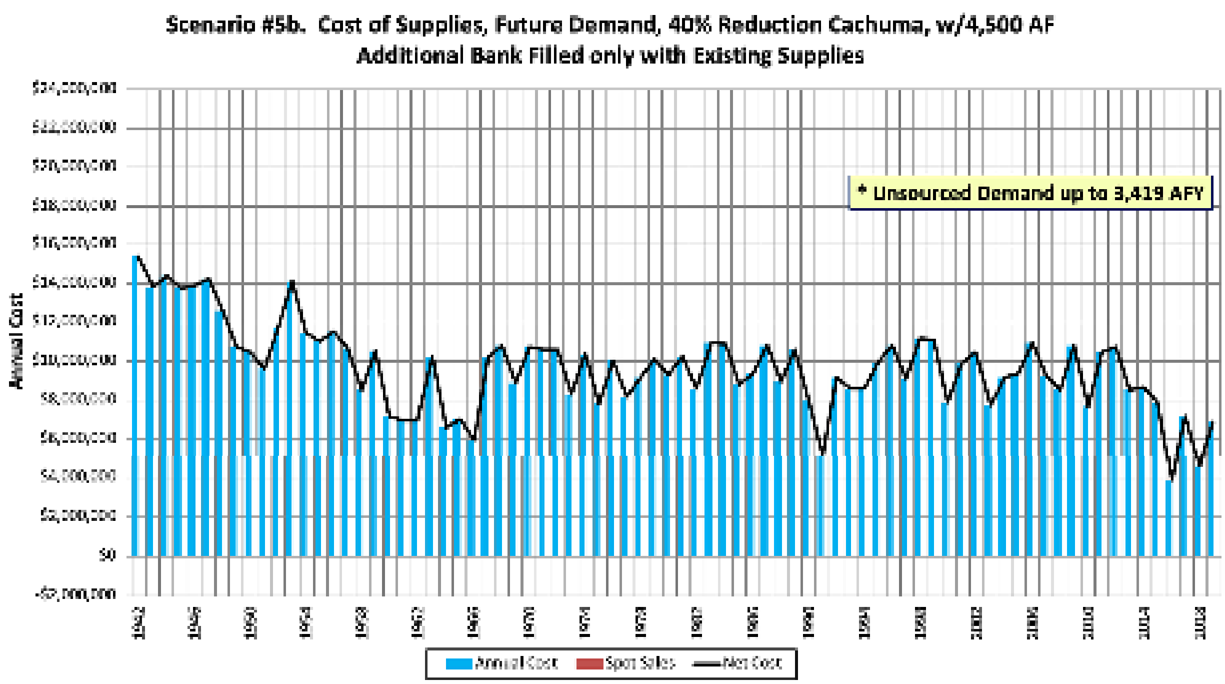

Figure 42. Costs for Scenario #5b.

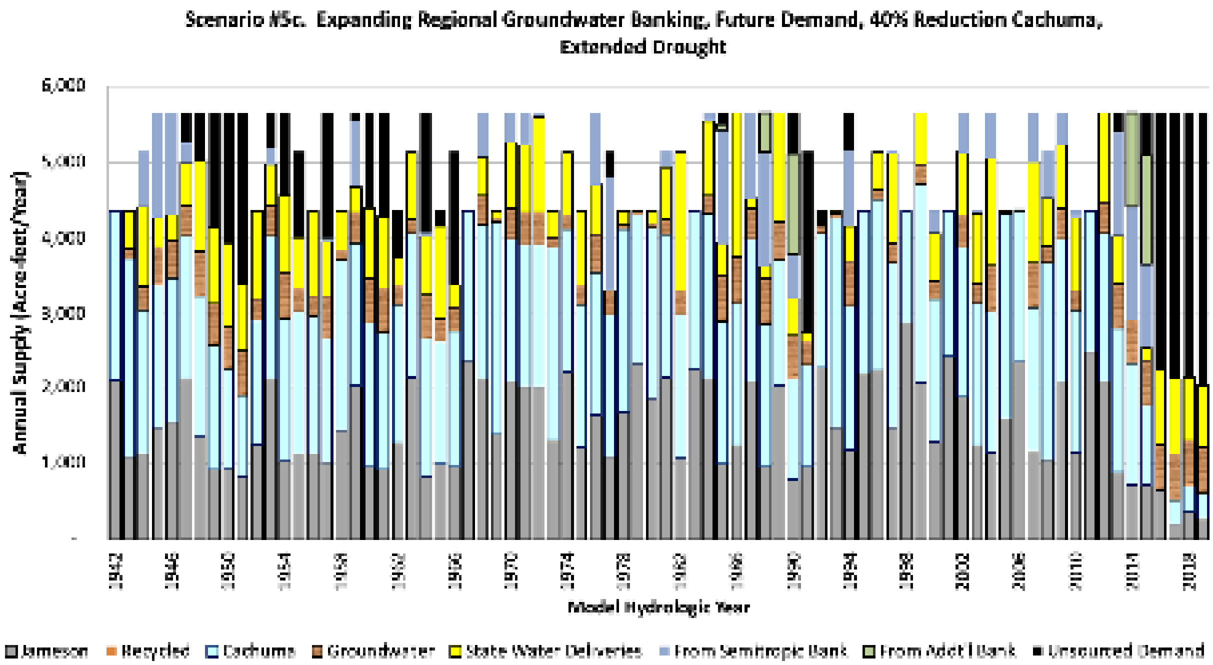

Figure 43. Results of Scenario #5c modeling.

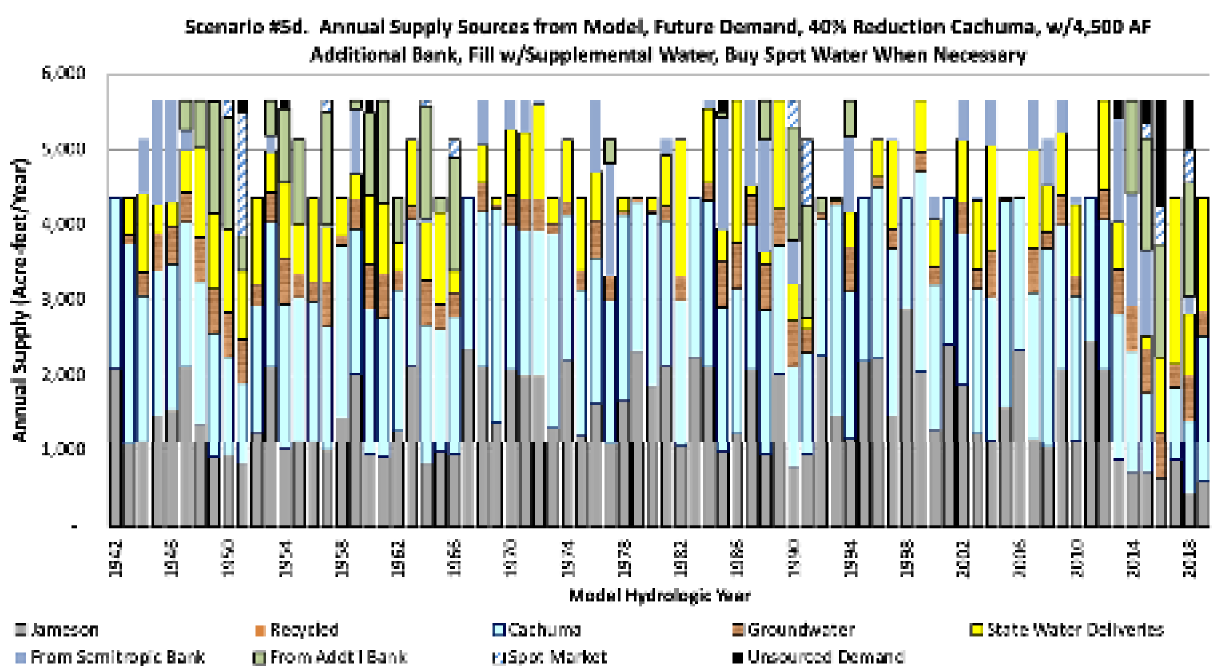

Figure 44. Results of Scenario #5d modeling.

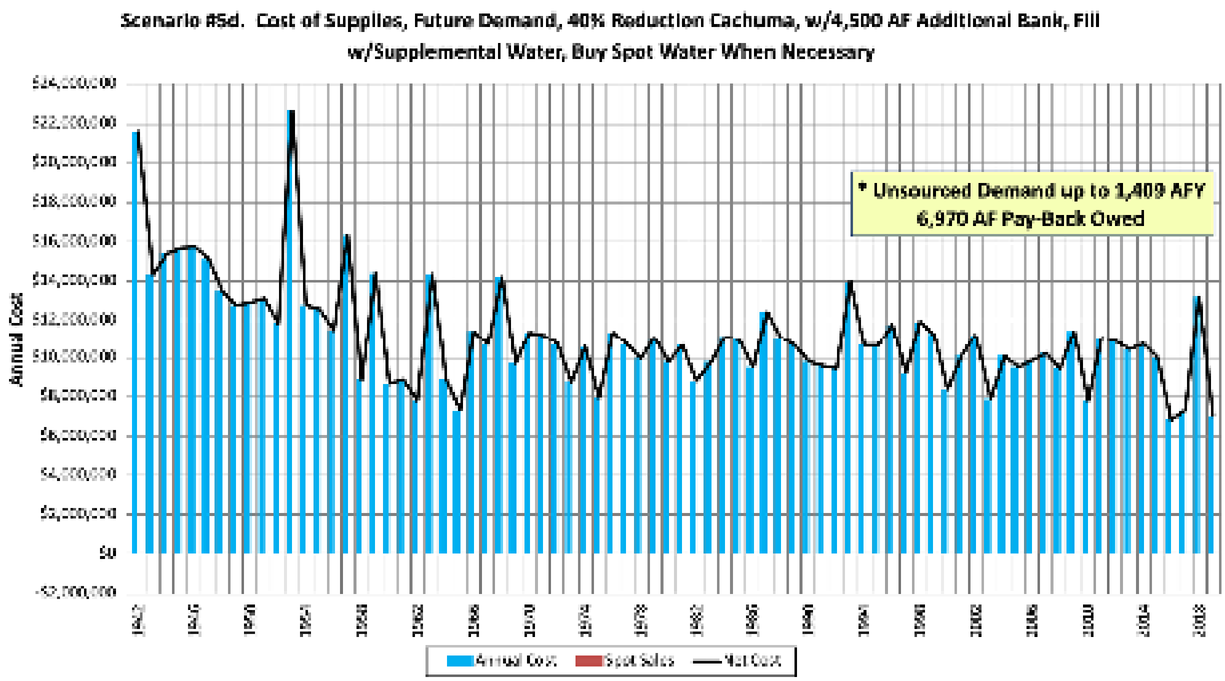

Figure 45. Costs for Scenario #5d.

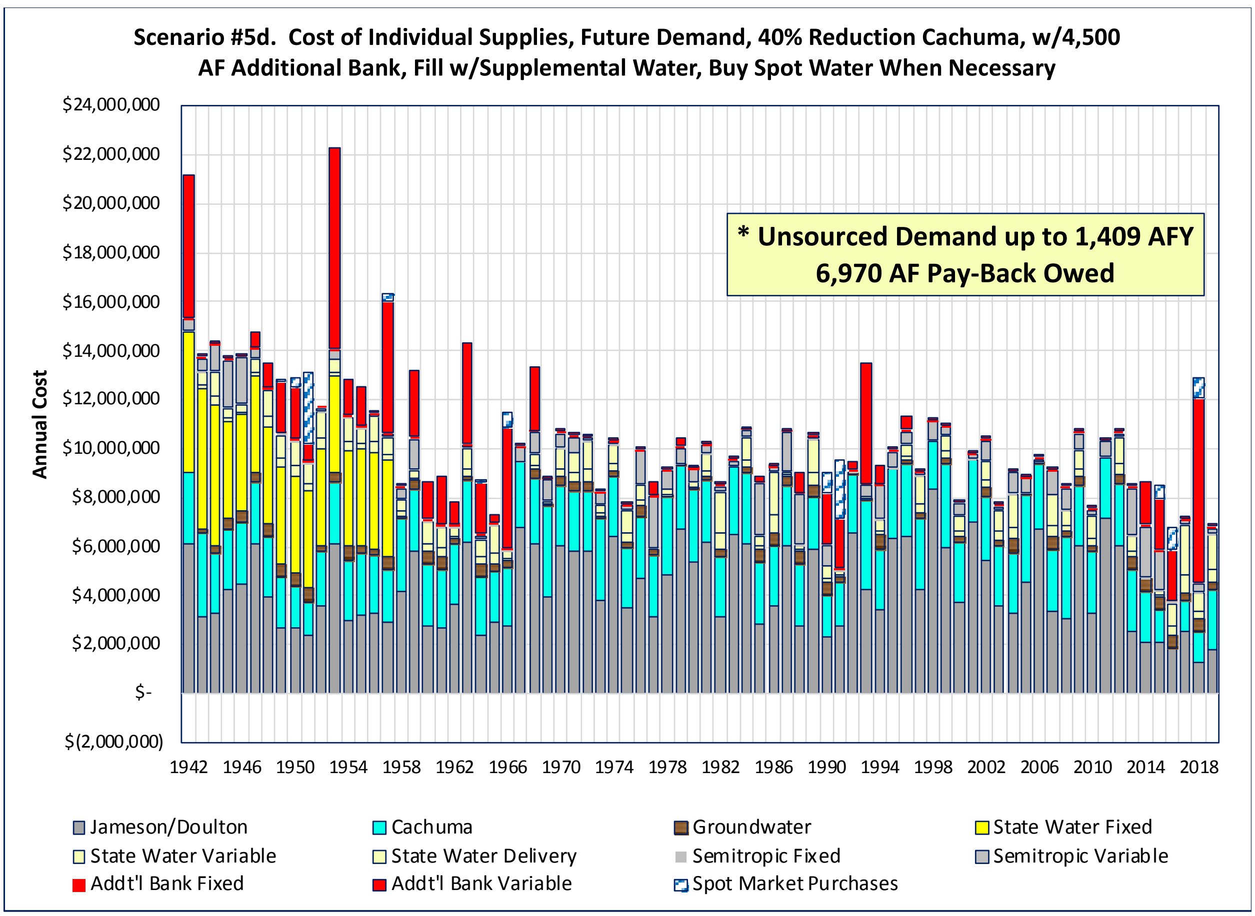

Figure 46. Costs for individual sources in Scenario #5d. Spikes in cost occur when banks are refilled with Supplemental Water during a wet year.

APPENDIX G. CHARTS OF SCENARIO #6 MODEL RESULTS

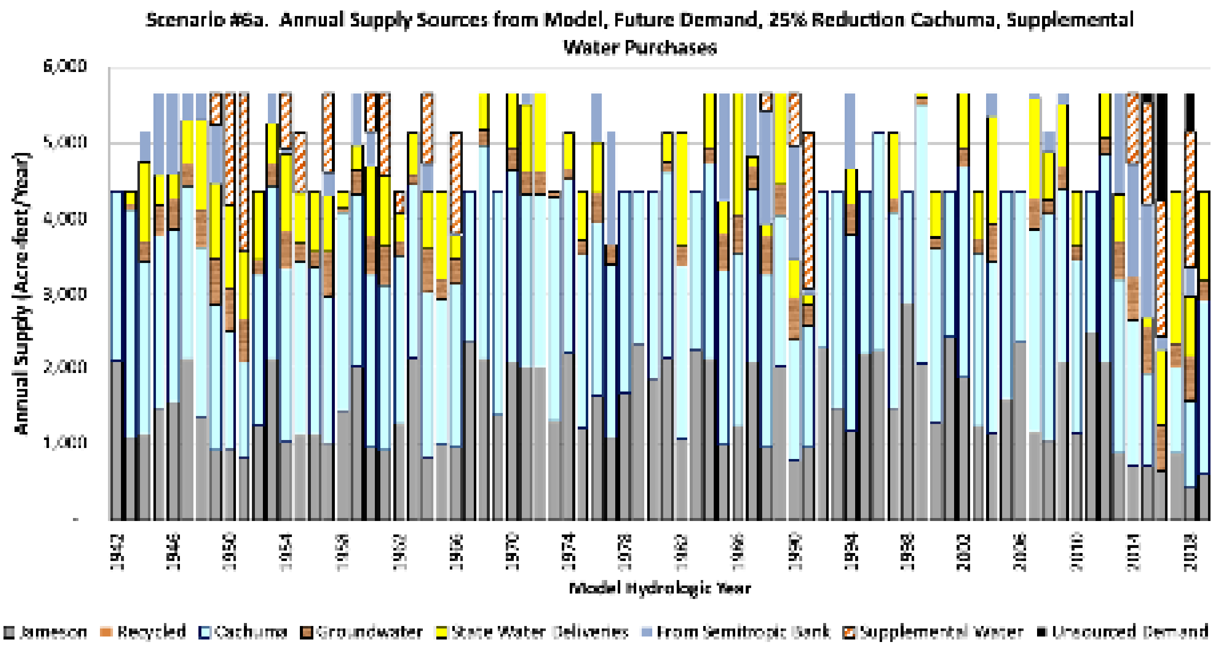

Figure 47. Results of Scenario #6a modeling.

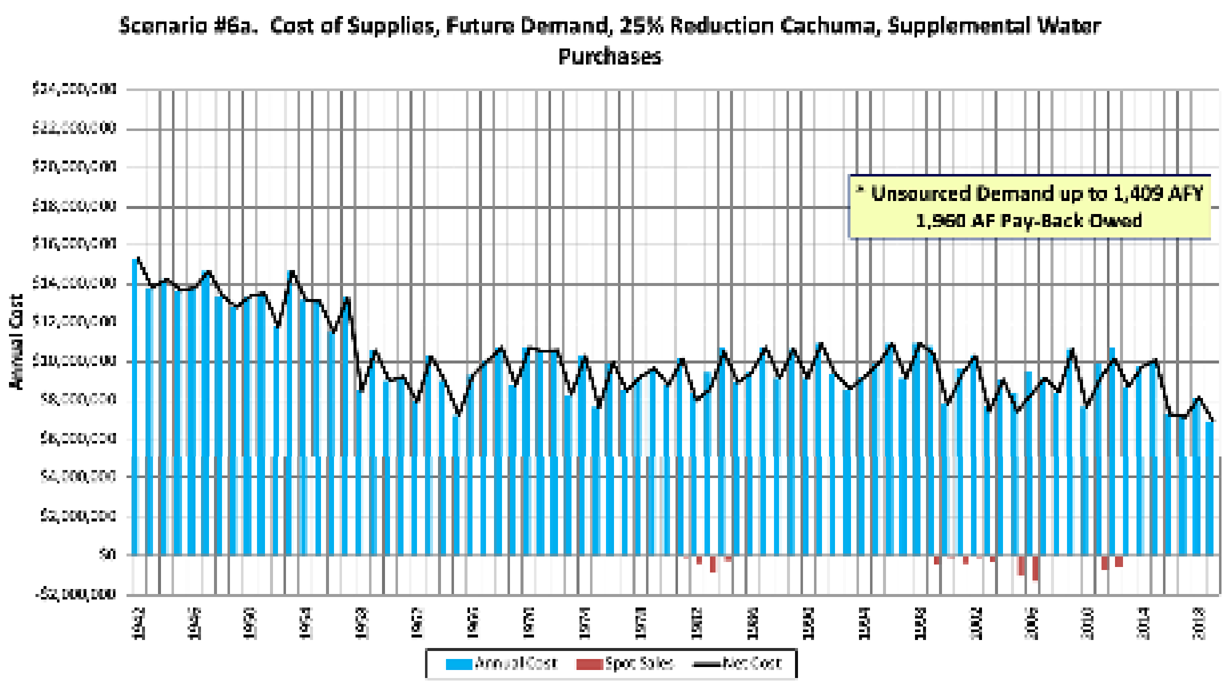

Figure 48. Costs for Scenario #6a. "Spot sales" are unused State Water sold on the spot market.

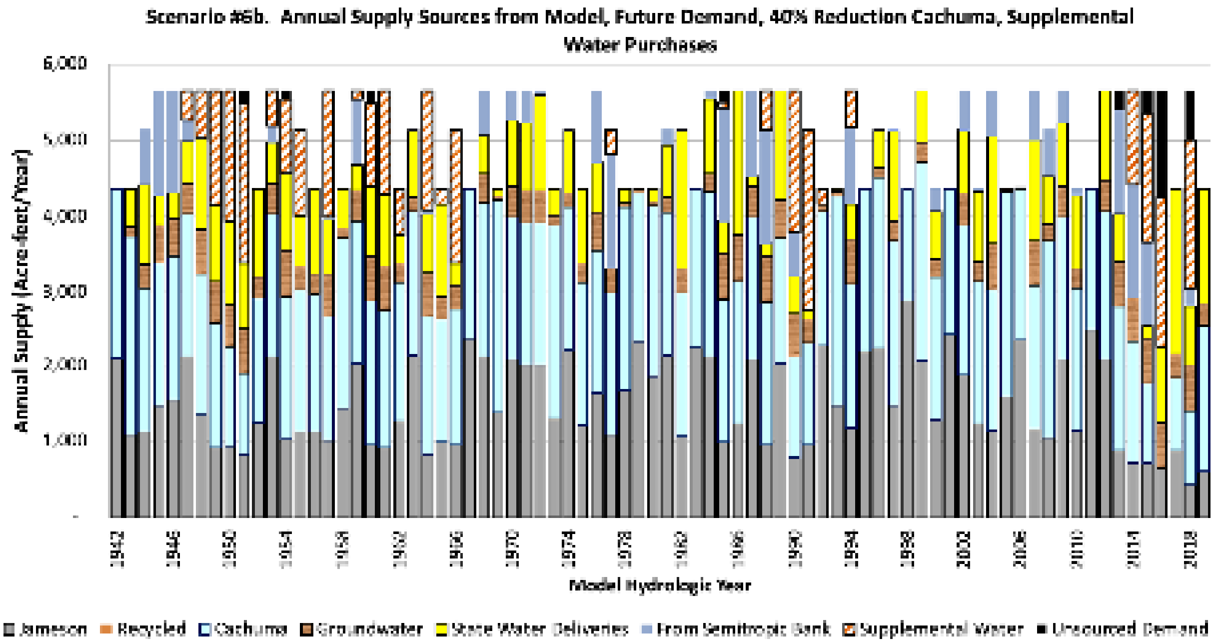

Figure 49. Results of Scenario #6b modeling.

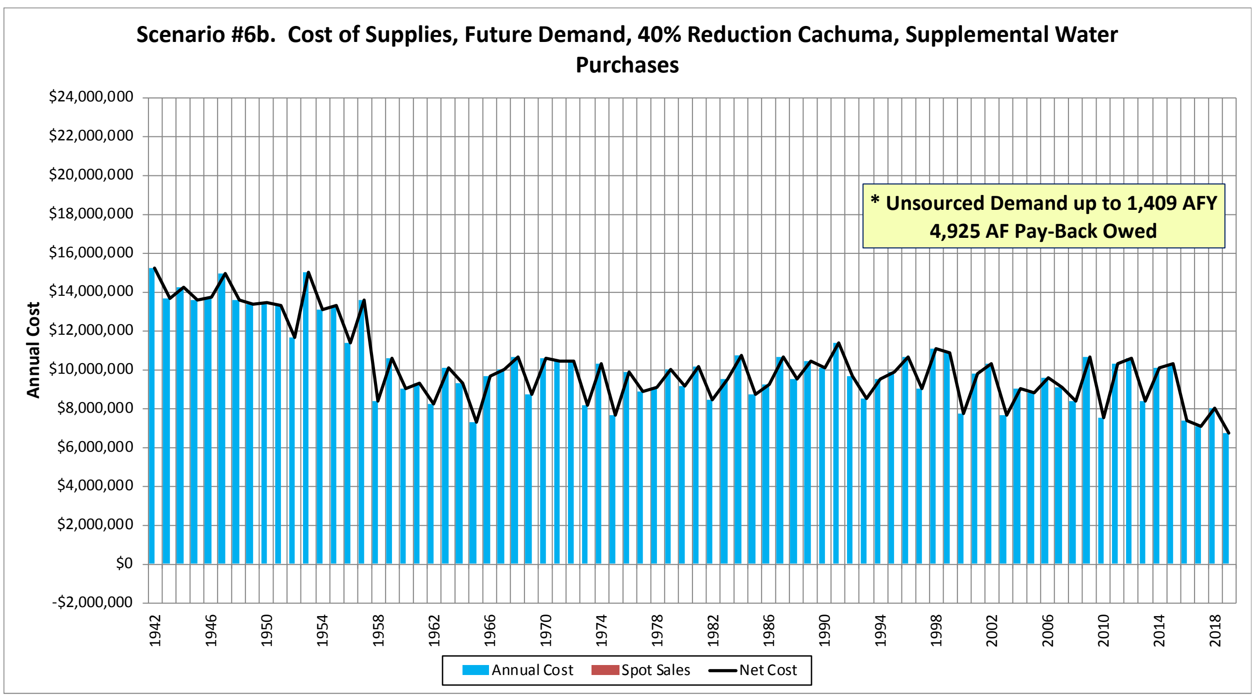

Figure 50. Costs for Scenario #6b.

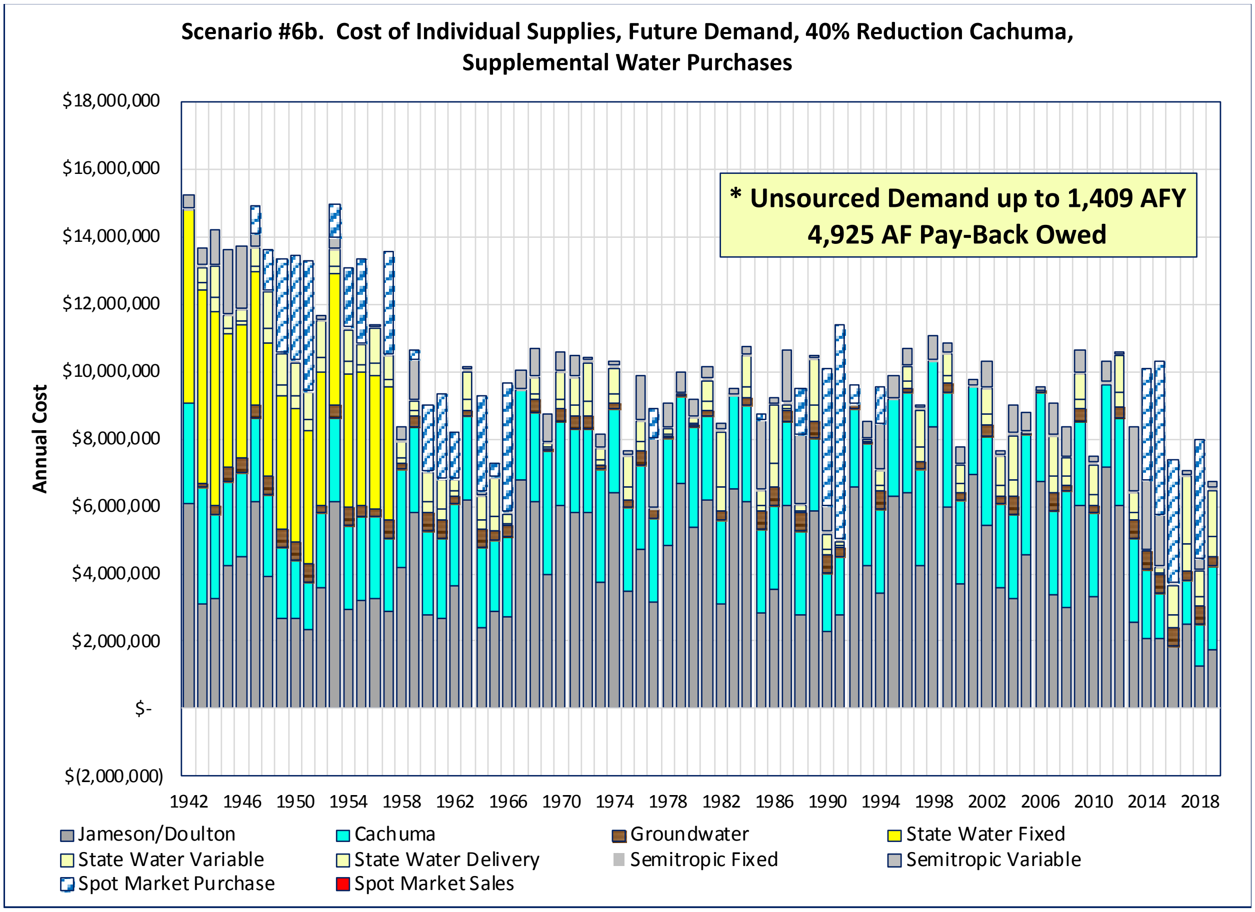

Figure 51. Costs for individual sources in Scenario #6b.

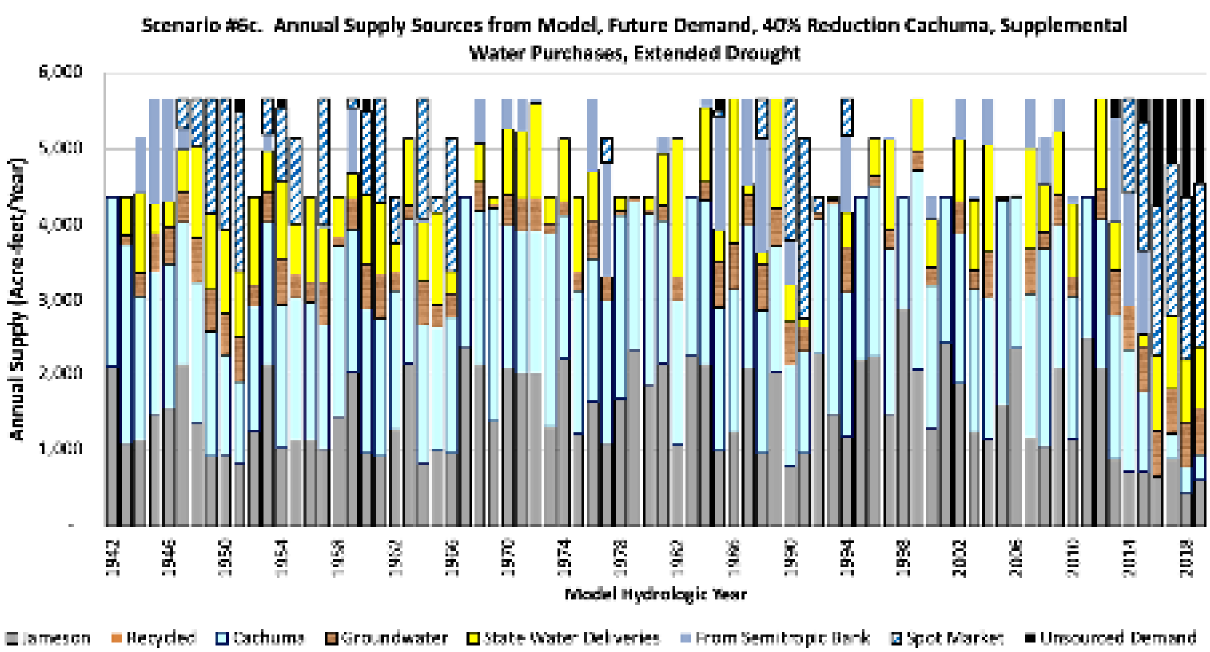

Figure 52. Results of Scenario #6c modeling.