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Section 1 – Introduction

Traditionally, water policy and planning in Texas has focused primarily on “supply-side” strategies, that is, the development of supply and/or infrastructure to meet projected demands during critical droughts. While water conservation is often recommended and implemented as a “demand-side” strategy to meet portions of identified needs, the temporary curtailment of demands during drought has not been closely examined as a potential water management strategy. An important policy issue is whether successful implementation of drought contingency measures has the potential to reduce water demands during critical drought periods, possibly delaying or eliminating the need for additional sources of water supply.

The Region H Water Planning Group (RHWPG) requested and received funding from the Texas Water Development Board (TWDB) to conduct three studies in advance of the third five–year update of the Region H water supply plan. One study focused on evaluating the impacts of future water management strategies on freshwater inflows to Galveston Bay and on evaluating the impacts of instream flow requirements for future water management strategies. A second study focused on evaluating the feasibility of using available “interruptible” surface water supplies as a substitute for existing firm water supplies for certain uses, notably irrigated agriculture. The third study, which is the subject of this report, focused on evaluating the efficacy and impact of drought contingency (a.k.a. drought response) measures as a potential water management strategy in Region H. The key question addressed by this study is:

Can implementation of drought contingency measures within Region H during critical drought periods be used in lieu of other water management strategies to meet projected water demands?

The scope of work for the Region H drought management study was divided into two primary tasks. The first task focused on evaluating the efficacy or effectiveness of drought contingency plans adopted and implemented by municipal water suppliers within Region H, elsewhere in Texas, and nationally. The second task consisted of a quantitative evaluation of the potential impact of drought response measures on major water supply reservoirs in Region H, namely Lake Conroe, Lake Houston, Lake Livingston and the proposed Allens Creek Reservoir. Specifically, Texas Commission on Environmental Quality (TCEQ) water availability models were used to analyze reservoir conditions (i.e., levels and storage volumes) during critical drought periods both with and without implementation of drought response measures. The findings of these analyses are presented herein.

Section 2 – Essentials of Drought Contingency Planning

Drought is a natural and recurring meteorological phenomenon where precipitation is significantly below “normal” for a period of time. Relatively mild, short-duration droughts are common throughout Texas and typically result in relatively mild impacts. However, extended severe drought conditions can have serious impacts on water supplies, water suppliers, and water users including:

- Reduction in available water supply leading to shortage conditions;
- Increases in water demand, particularly for seasonal demands such as landscape irrigation;
- Stress on water utility infrastructure due to elevated seasonal peak water demands relative to capacity limitations of water supply infrastructure;
- Deterioration of source water quality;

- Lifestyle and financial impacts to water users associated with restrictions on non-essential water uses (e.g., loss of landscaping); and
- Financial impacts on water suppliers due to reduced revenues from water sales during periods of water demand curtailment.

2.1 Key Principles of Drought Contingency Planning

By law, public water supply systems, wholesale water providers, and irrigation districts in Texas are required to adopt drought contingency plans. TCEQ administrative rules define a drought contingency plan as *"a strategy or combination of strategies for temporary supply management and demand management responses to temporary and potentially recurring water supply shortages and other water supply emergencies".* TCEQ rules and associated guidance documents for drought contingency planning embody several key principles including:[1]

- Drought and its potential impacts on both water supply and demand, as well as water supply infrastructure, can be anticipated;
- Drought response measures and implementation procedures can be defined in advance of drought;
- Through timely implementation of drought response measures it is possible to avoid, minimize, or mitigate the risks and impacts of water shortages and other drought-related water supply emergencies;
- All water demands are not of equal value or importance, some can be considered essential to public health and safety or to the economy while others can be considered non-essential or discretionary; and
- Drought contingency plans should be tailored to the unique circumstances of each water supplier (e.g., vulnerability of water supply and/or infrastructure to drought, end-users and demand characteristics, objectives, etc.).

2.2 Common Elements of Drought Contingency Plans

Notwithstanding the aforementioned principle that drought contingency plans should be tailored to each water supplier's unique circumstances, there are a few elements that are more or less common to all drought contingency plans. These include:

- Criteria and procedures for determining when to initiate and when to terminate drought response measures. These are typically referred to as drought triggers. Common examples of drought triggers include indicators of supply availability (e.g., quantity of water supply remaining in a source) and demand indicators (e.g., daily demand relative to infrastructure capacity).
- Successive stages of drought response that require the implementation of increasingly stringent measures in response to increasingly severe drought conditions. A typical drought contingency plan will have an initial stage of voluntary measures followed by two or three successive stages of increasing stringent mandatory measures.
- Demand reduction goals or targets for each stage.
- Predetermined drought response measures for each stage that may include supply management, such as the temporary use of an alternative water source, and/or demand management, such as restrictions on non-essential water uses.
- Procedures for plan implementation and enforcement.

- Public information (e.g., notification) and education.

Most drought contingency plans place a heavy emphasis on "demand management measures" that are designed to reduce water demands by means of curtailment of certain uses. It's important to note that demand management in this context is distinctly different from water conservation, although the terms are often used interchangeably. The objective of water conservation is to achieve lasting, long-term reductions in water use through improved water use efficiency, reduced waste, and through reuse and recycling. By contrast, demand curtailment is focused on temporary reductions in water use in response to temporary and potentially recurring water supply shortages or other water supply emergencies (e.g., equipment failures caused by excessively high peak water demands). Common approaches to water demand curtailment, applied individually or in combination, include:

- Prescriptive restrictions or bans on non-essential water uses and waste. In a municipal setting, such restrictions commonly target landscape irrigation, car washing, ornamental fountains, etc.
- Use of water pricing strategies, such as excess use surcharges, to encourage compliance with water use restrictions or to penalize excessive water use.
- Water rationing, where water is allocated to users on some proportionate or pro rata basis.

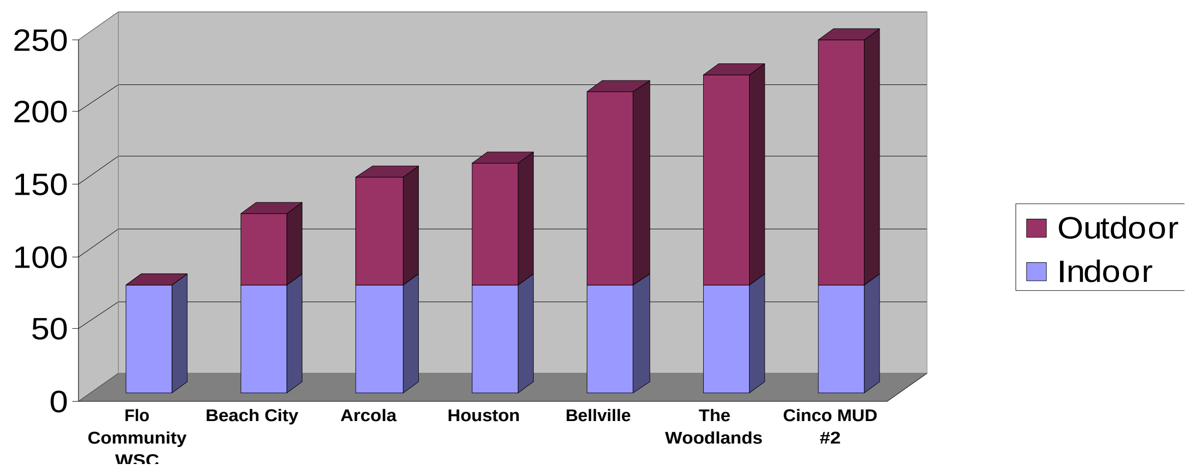
2.3 Commentary of the Efficacy of Drought Response Measures

The scope of work for this study includes several sub-tasks which, taken together, are intended to provide an assessment of the "efficacy" or effectiveness of drought response measures. It's important to emphasize that quantifying or predicting the effectiveness of demand-side drought response measures is very difficult owing in large part to the variability of municipal water use within and among communities; variability that is commonly attributed to differences in climatic, demographic, and socioeconomic characteristics. In particular, since most demand curtailment measures target seasonal water uses, such as lawn watering, it stands to reason that the effectiveness of such measures is dependent on and will vary greatly according to the seasonal water use characteristics of different communities. Simply stated, a drought response measure applied in one community likely will not produce the same effect when implemented in another community with different seasonal water use characteristics.

As demonstrated in Figure 1, per capita municipal water demands for communities in Region H vary widely and, if one assumes that non-seasonal (e.g., indoor) water uses are more or less the same in each community, then the differences in per capita water demand can be attributed largely to seasonal water uses. The outdoor usages shown in Figure 1 are estimated assuming the per capita water demands of Flo Community WSC as an estimate of typical indoor water use. From this small sample, it's also apparent that the relative degree of urbanization and affluence of communities are important determinants of seasonal water demand. For example, affluent suburban communities invariably show higher per capita water demand owning in large measure to housing characteristics such as the predominance of single-family detached residences on lots with relatively large landscaped areas.

Isolating the effectiveness of specific drought response measures is also problematic in that most municipal drought contingency plans employ multiple measures, such as water use restrictions, public education, and perhaps pricing policies, that in combination have synergistic rather than additive effects. This is further complicated by behavioral factors that may influence the effectiveness drought response measures, either singly or in combination. For example, it is has been reported that the degree to which the public understands and believes there is a "real" water supply problem can significantly affect the extent of both voluntary and mandatory compliance with water use restrictions. In other words, the effectiveness of public information and education efforts, or lack thereof, will have a direct impact on the effectiveness of other drought response measures. Similarly, the degree to which mandatory water use restrictions are enforced can also have direct bearing on the effectiveness of such restrictions in reducing water demand; that is, aggressive enforcement will generally result in a higher degree of compliance and greater demand reductions than lax enforcement. The effects of enforcement are typically reflected in the structure of municipal drought contingency plans where the first stage is a request for voluntary compliance with prescriptive water use restrictions that become mandatory in the second stage of the plan. Accordingly, it is common to establish a lower water demand reduction goal for Stage 1 and a higher goal for Stage 2 based on the expectation of enforcement, and greater compliance, with mandatory restrictions.

Figure 2-1. Example per Capita Municipal Water Demands in Regions H



Yet another consideration that may influence the effectiveness of drought response measures is the type of problem addressed by and the specific objectives of a drought contingency plan. For municipal water suppliers in Texas, "real" water supply shortages are not a common occurrence during droughts. Rather, by far the most prevalent drought-related problem faced by municipal water suppliers are elevated seasonal peak water demands and the stress such demands can place on the limited capacity of water utility infrastructure (e.g., treatment, storage, and/or distribution). Accordingly, the most common objective of municipal drought contingency plans is to "shave" peak water demands in order to reduce stress on infrastructure and thereby avoid or minimize impacts on water service, such as equipment failures or low water pressure. While peak shaving is also typically accomplished with restrictions on seasonal water uses such as landscape irrigation, it's important to note that degree of demand reductions needed to address a "peaking problem" may be much less than what would be needed in an actual water shortage situation. For example, in a true water shortage situation limiting lawn water to one or two days per week, or an outright ban, may be required to achieve the desired reduction in water use while an alternate day (e.g., odd-even) watering schedule may be sufficient to reduce peak water demand to safe levels.

The approved scope of work for this study also directs that the effectiveness of drought response measures be expressed in terms of reductions in per capita water use. However, upon further study during the course of this study, it was determined that this is problematic for several reasons. First, most drought contingency plans are "goal based" meaning that demand reduction targets are typically established based on the degree of reduction estimated to be needed for each stage of the plan. For example, an analysis of the vulnerability of a water supply to drought may reveal that a 10 percent reduction is sufficient to minimize the risk of shortage when supply availability is within a certain range (e.g., between 50 and 70 percent of normal) and that a 20 percent reduction is required when supply availability is further reduced (e.g., between 30 and 50 percent of normal).

Second, the typical expression of demand reduction goals in a municipal drought contingency plan is a percentage reduction, rather than a per capita reduction goal. Also, because most municipal drought contingency plans in Texas focus primarily on reducing seasonal peak water demands, percent reduction goals are typically measured (when measured at all) on a "before and after" basis in which overall water demand after implementation of drought response measures is compared to overall water demand immediately prior to implementation of drought response measures. This approach does not lend itself to quantification of "savings" in terms of per capita use. Furthermore, there is significant potential for error in the quantification of demand reductions from drought response measures in terms of per capita use, due to inconsistencies in water use reporting (e.g., inclusion of non-municipal uses supplied by public water systems), inaccurate population estimates, variations in billing cycles, and variability of unaccounted-for water use (e.g., meter error, water loss).

Section 3 – Efficacy of Drought Management Measures

The first phase of the study included the following tasks:

- Obtain a list of systems on the TCEQ drought impact list
- Determine system size in terms of connections, population and water use information.
- Survey officials of drought impacted systems.
- Compare water use records before and after implementation of drought management measures
- Research national publications for information on the efficacy of drought management measures in other climates
- Develop summary of commonly used drought management measures and estimate corresponding water savings

3.1 TCEQ Drought Impact List

A list of public water systems impacted by drought was obtained from TCEQ along with water utility data such as the number of service connections, estimated population, and average day usage. The information obtained from TCEQ contained records for public water utilities throughout the State for the period 1996 to 2008. This section presents information about public water systems within Region H that were included on the TCEQ list one or more times during this period.

As shown in Figure 2, a significant number of public water systems in Region were on the TCEQ drought impact list and implemented drought measures during the years 1998 (62 systems), 2000 (35 systems) and 2005 (39 systems). The counties that recorded the most public water systems on the list are Harris and Montgomery counties (Figure 3). Together, Harris and Montgomery Counties accounted for approximately 55 percent of the systems on the drought impact list. Approximately 90 percent of the water systems on the drought impact list serve populations less than or equal to 10,000 people, as shown in Figure 4, and have 5,000 connections or fewer, as shown in Figure 5. TCEQ records also indicate that the list is comprised mostly of public water systems that are supplied by groundwater.

The largest public water utility on the TCEQ drought impact list is the City of Houston, which implemented voluntary water restrictions in July 2000 in response to high customer demands. In addition to the City of Houston, several other Region H Wholesale Water Providers (WWPs) have been on the drought impact list. The City of Galveston placed "mild rationing" restrictions on customers both in July 1996 and July 2000. The Clear Lake City Water Authority implemented "mild rationing" restrictions in September 1999 and in July 2000. The San Jacinto River Authority placed "mild rationing" restrictions on customers in The Woodlands in July 1998 that are supplied with water from the Jasper and Evangeline aquifers.

Surveys of Major Public Water Systems discussed in Section 3.2 indicated that none of the Region H public water systems that were on the TCEQ drought impact list over the period from 1996 to 2008 experienced actual water shortage conditions. Rather, it appears that these water systems were placed on the list because of high seasonal peak water demands and attendant problems or concerns with water production infrastructure. The majority of Region H public water systems on the TCEQ drought impact list are municipal utility districts (MUDs), water supply corporations (WSCs), subdivisions and rural municipalities that rely on groundwater from local wells. Sustained high peak water demands during the summer months often create a strain on groundwater supplies, not so much in terms of the availability of supply but rather in terms of groundwater production capacity, indicating a need perhaps for additional wells to increase delivery capacity or deeper wells to compensate for greater than normal draw down. Public water systems that rely on surface water often experience similar problems in terms of limited capacity to treat raw water and/or distribution system capacity limitations.

Figure 3-1. Number of Utilities on TCEQ list by year

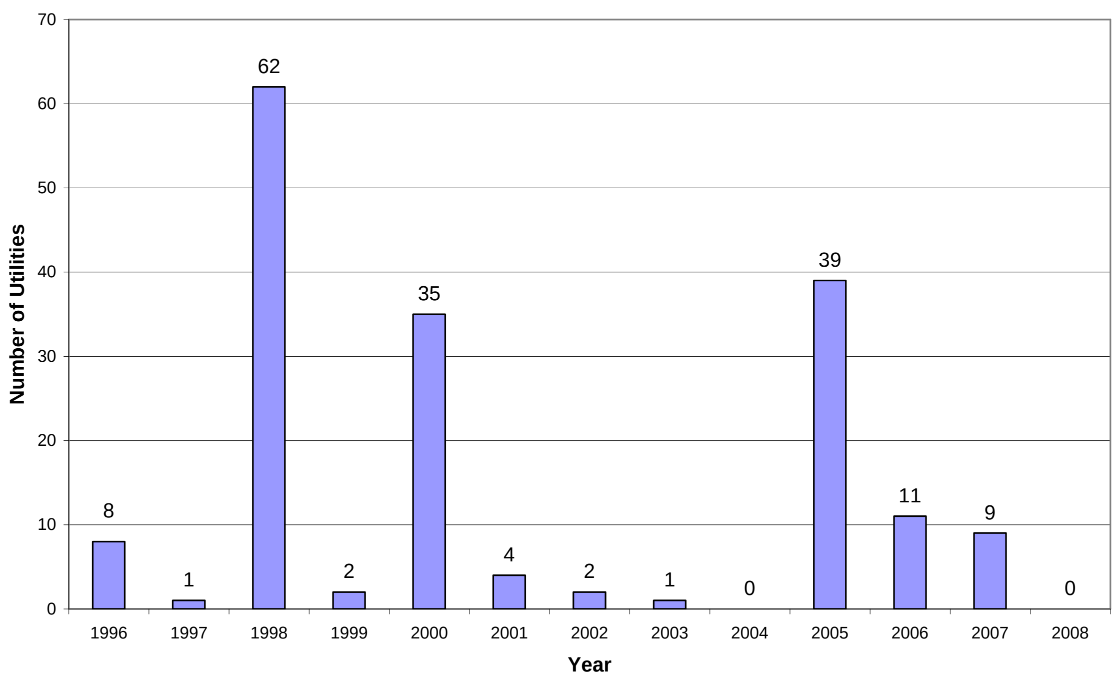


Figure 3-2. Utilities of County

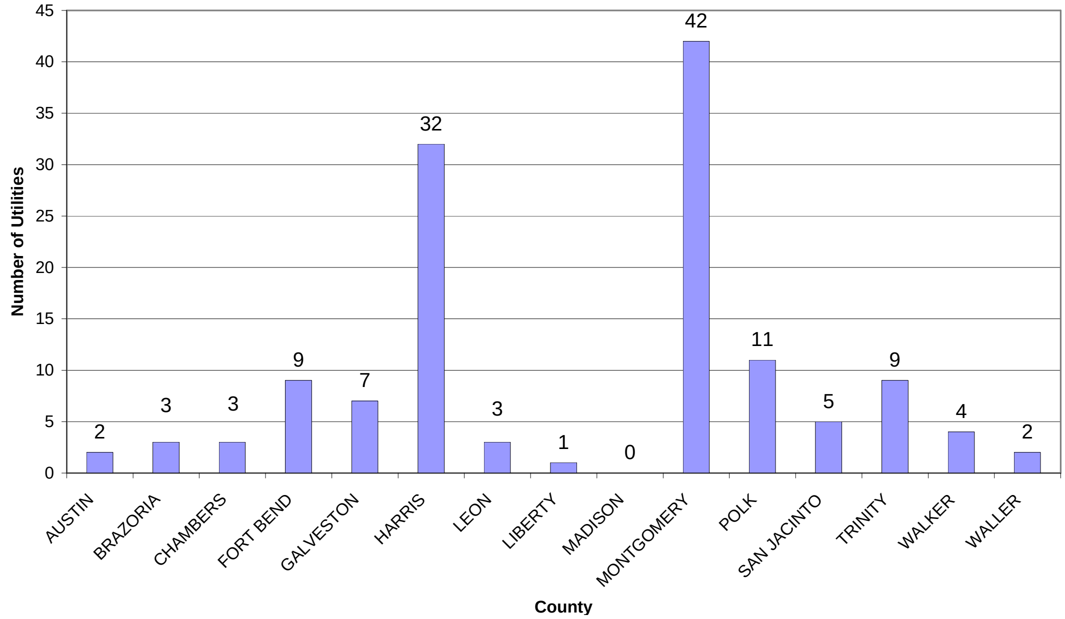


Figure 3-3. Population Distribution

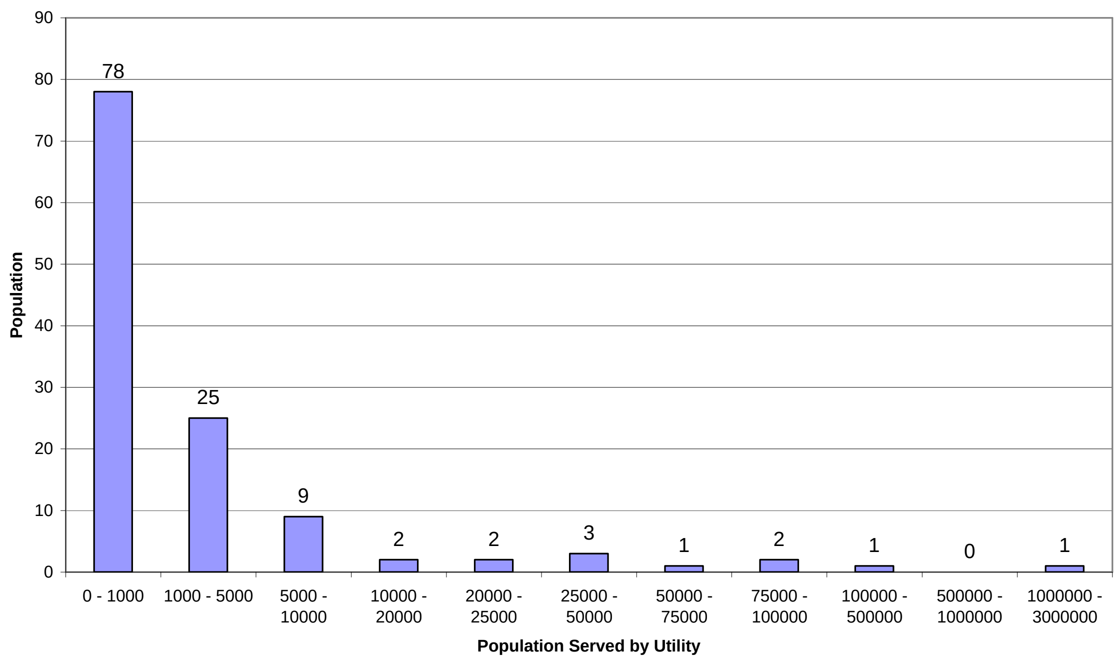


Figure 3-4. Connections Distribution

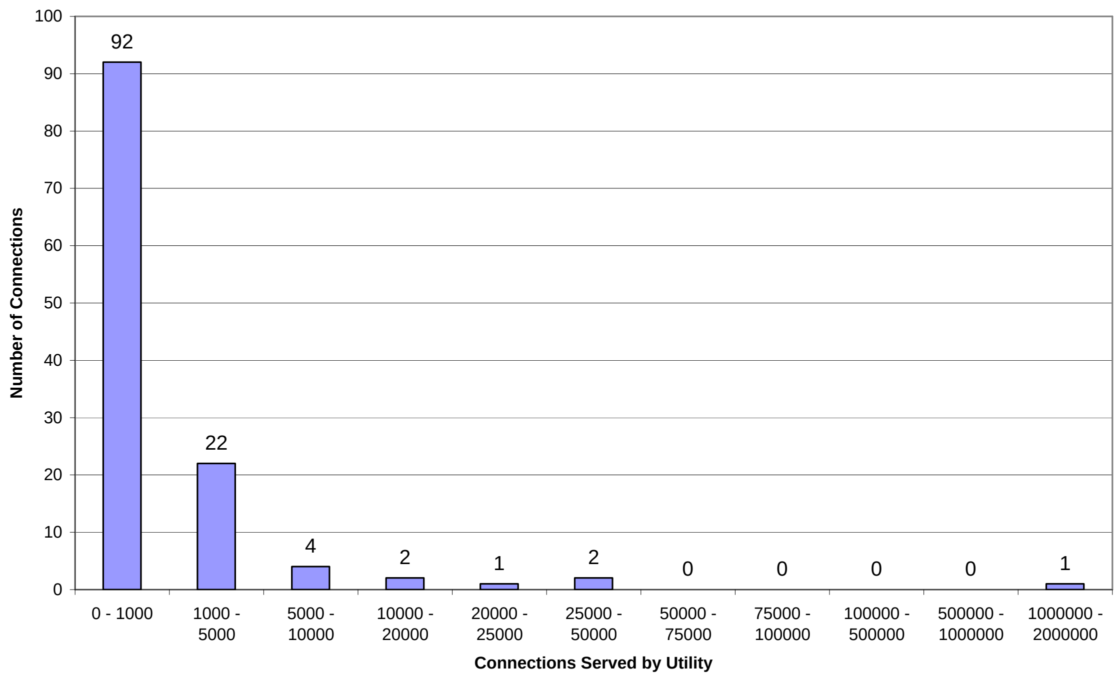
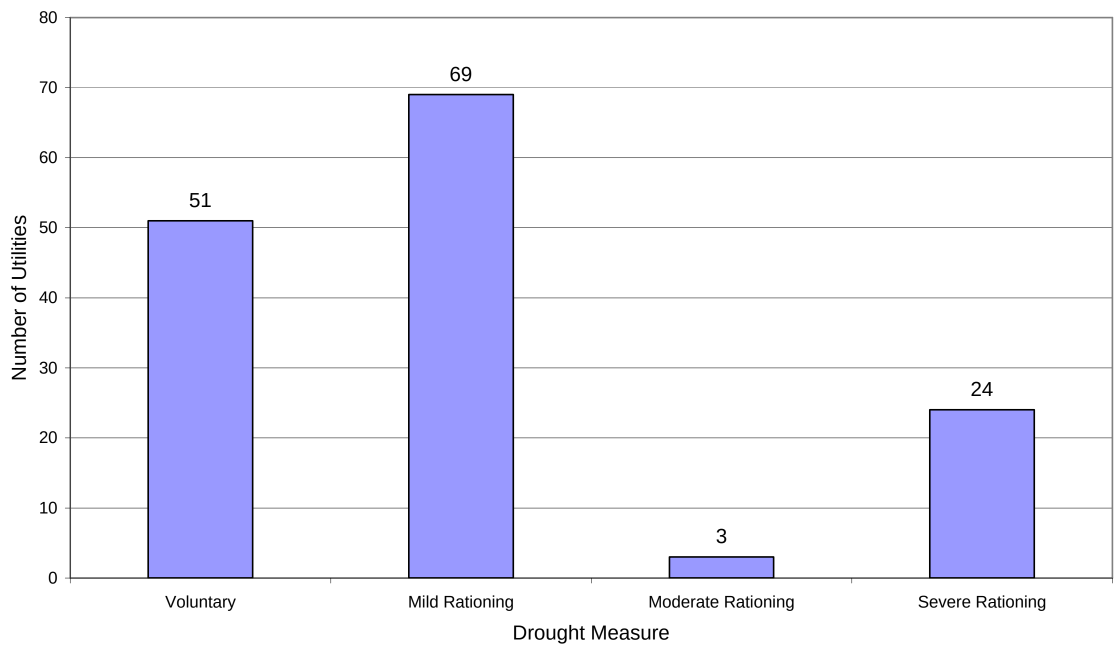


Figure 3-5. Drought Measures



3.2 Survey of Public Water Systems

The TCEQ drought impact list was used to select utilities in Region H that have implemented drought management measures at one time or another over the period from 1996 to 2008. Selected utilities were surveyed to obtain additional information including:

- Per capita water demands before and after drought measures
- Records of drought measures implemented
- Water Supply Sources
- Nature of Problem
- Lessons learned

Initially, only public water systems with surface water supplies were surveyed. The list was expanded to include municipal utility districts (MUDs) after initial attempts to contact those systems yielded few results. Overall, the information obtained through the survey indicates that water systems in Region H have little or no direct experience with actual water shortage conditions. As indicated, available information suggests that the Region H water systems on the TCEQ drought impact list have implemented drought response measures only to temporarily reduce peak demands to alleviate stress on limited infrastructure. A few water systems have implemented severe restrictions in response to emergencies situations including outages, contamination, and low water pressure. The City of Houston, for example, has twice implemented voluntary water use restrictions over the past decade in response to high daily demands during summer months. No data was available to quantify the effects that voluntary reductions had on the per capita daily demand. A discussion with representative of the City of Galveston revealed the most recent drought measures in 1996 and 2000 were also the result of infrastructure limitations. During 1996, failure of a transmission line delivering water to Galveston resulted in the implementation of mild rationing measures. During 2000, water deliveries were unable to keep pace with the City's peak demands resulting again in the implementation of mild rationing, as well as the purchase of additional groundwater. No information was available with respect to the level of enforcement and per capita demands prior to, during, and after the implementation of drought measures. Information regarding the effects of drought response measures on water demands was also not available from the cities of Lake Jackson, Clute and Magnolia. Due to the lack of information on per capita demands before, during, and after the implementation of drought contingency measures, historic water use records from the TWDB were used to asses the impacts on the annual per capita daily demand.

3.3 Water Use Records Before And After Drought Management Measures

Data from TWDB was used to estimate the impacts of drought management measures on annual per capita daily water demands. The annual gallons per capita daily demands (gpcd) for several municipalities in Region H were trended and analyzed before and after the utility reported drought management measures to TCEQ. Major utilities in Region H were analyzed to determine the effect, if any, that drought response measures may have had on annual water demands. Annual water use for Corpus Christi and San Antonio was also compared to analyze the effects of drought response measures in other areas of the state.

Figure 3-6. City of Houston gpcd Water Use

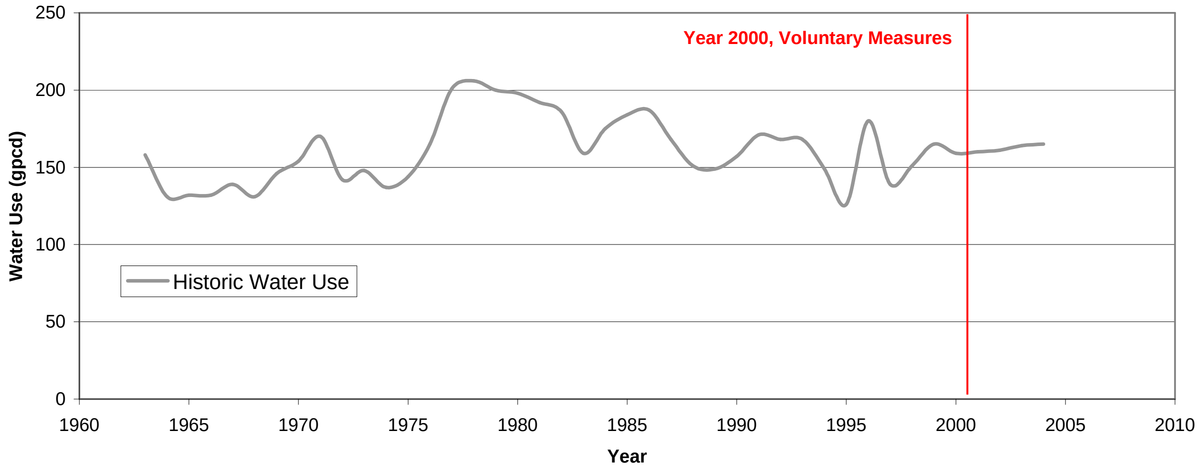


Figure 3-7. City of Galveston gpcd Water Use

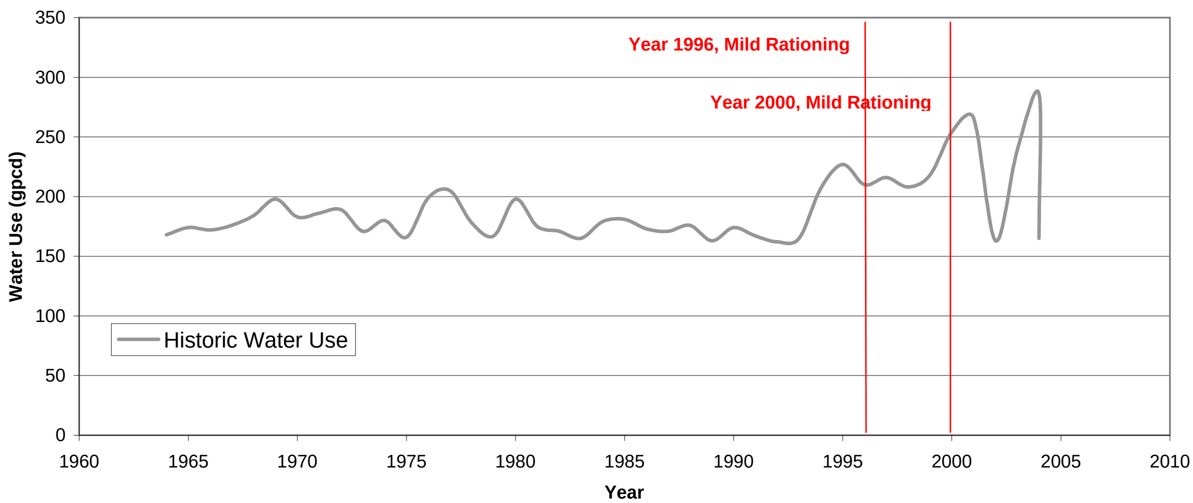


Figure 3-8. League City gpcd Water Use

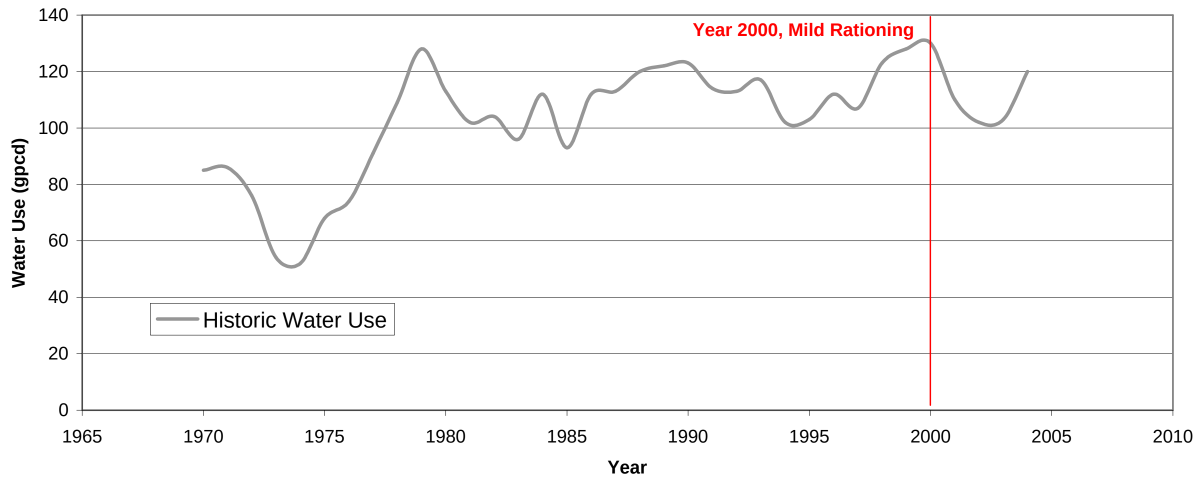


Figure 3-9. Friendswood gpcd Water Use

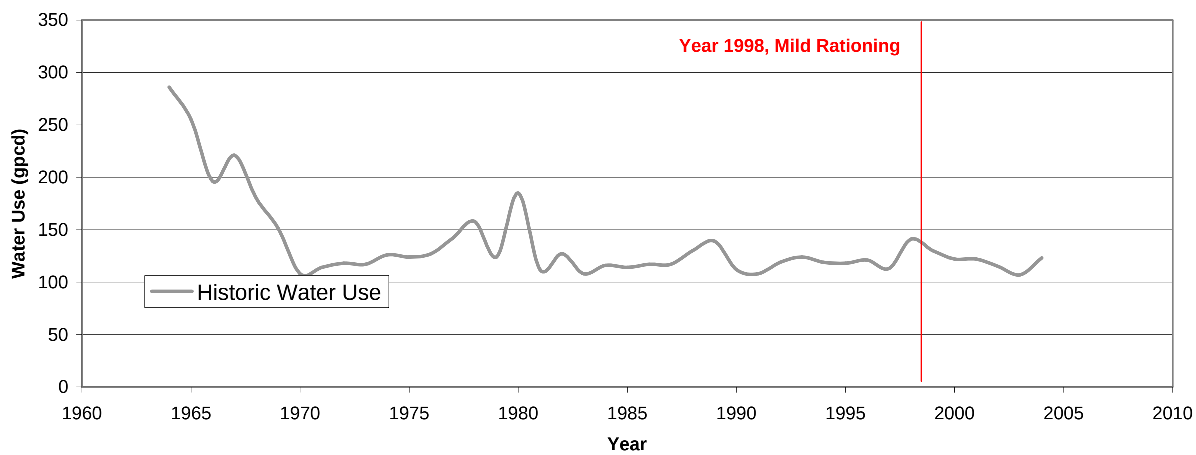


Figure 3-10. Lake Jackson gpcd Water Use

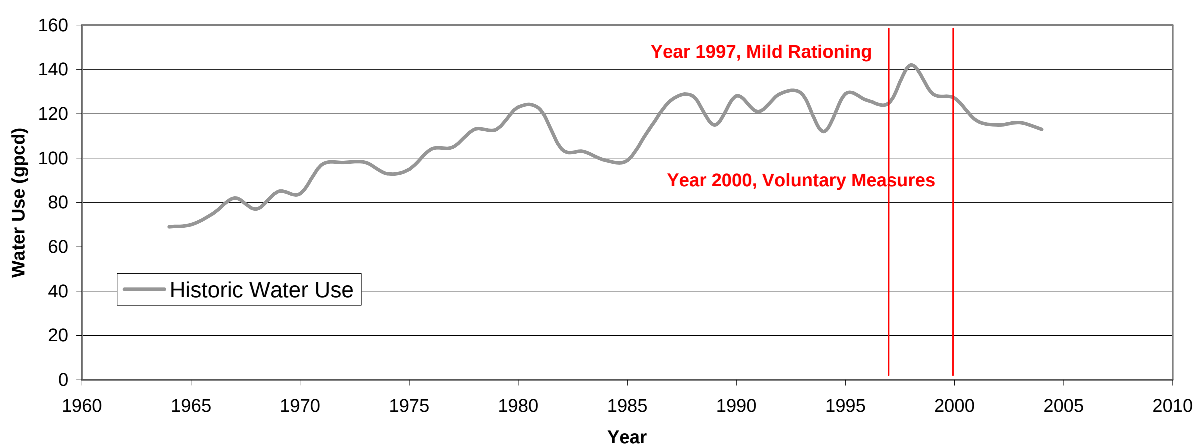


Figure 3-11. Corpus Christi gpcd Water Use

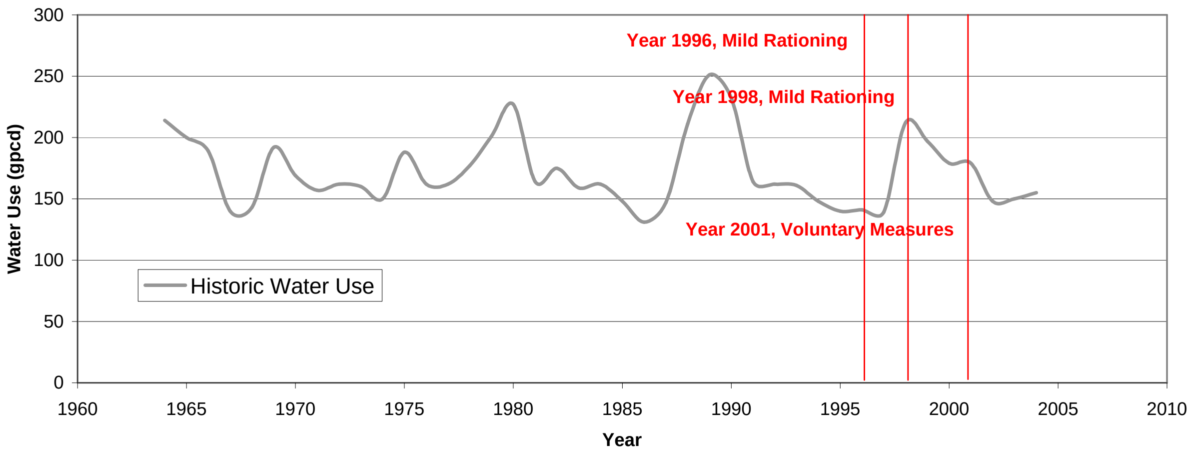
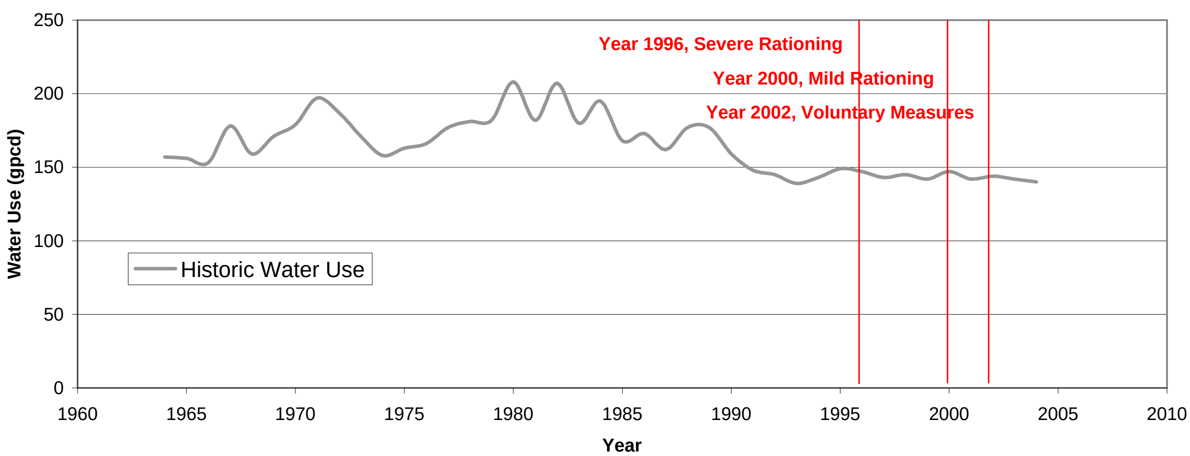


Figure 3-12. Corpus Christi gpcd Water Use



Graphs of annual per capita daily demands for utilities in Region H illustrate the difficulty in quantifying the effects of specific drought management measures. There does however, exists some evidence that the implementation of a collection of management measures (drought stages) may have a measurable impact on per capita daily demands. Voluntary and mild rationing measures appear to have little or no impact on annual gpcd recorded for the City of Houston and the City of Galveston. However, there does appear to be an impact on annual gpcd for the cities of Friendswood, Lake Jackson, and League City. Mild rationing measures implemented by the City of Friendswood in the year 1998 may have had some effect on reducing peak daily demands but likely did not reduce the average annual gpcd likely due to a short term implementation of drought response measures. The League City drought plan is triggered when daily water demand equals or exceeds a set percentage of the system operating capacity for some duration. The drought plan is seasonal by nature designed to manage peak day demands. There does appear to be a reduction in annual per capita demands of approximately 20% in the years after 2000 most likely due to wetter hydrologic conditions. Without performing a detailed analysis of daily water production records, daily rainfall, and the effects of long term conservation measures (activities beyond the scope of this study), it is not feasible to isolate the impacts of individual drought plans and specific response measures.

Recent measures implemented by the City of Corpus Christi in 1998 and 2001 appear to have reduced annual per capita daily demands by nearly 15% in the following years. As mentioned previously, the effects of drought response measures can not easily be disaggregated from the effects of increases in rainfall and implementation of conservation measures. Mild rationing and voluntary measures implemented in San Antonio appear to have little effect on annual gpcd. The measures were implemented to reduce peak daily demands during summer months. This also illustrates "Demand Hardening" a phenomenon that reduces the effectiveness of temporary drought measures as a result of frequent implementation. The San Antonio Water Authority has implemented year-round water restrictions that limit landscape irrigation, washing vehicles and impervious surfaces. The use of year-round water restrictions in San Antonio may have reduced the effects of temporary drought measures.

Average annual municipal demands are insufficient for developing a quantitative analysis of drought response measure effects. As previously discussed, quantifying the effects of drought response measures is extremely difficult due to differences in climates, demographics, and socioeconomic factors. The data presented in this section does not allow the effects of drought response measures to be disaggregated from other factors including rainfall, conservation measures, and seasonality of non essential municipal water use.

3.4 Region H Existing Drought Contingency Plans

3.4.1 Trinity River Authority (TRA) DCP

The Trinity River Authority (TRA) currently supplies raw water from Lake Livingston to the Cities of Trinity, Grovetown, Glendale, Trinity Rural, Riverside water Supply Corporations, and Westwood Shores MUD. Purchased water from Lake Livingston is treated at the Trinity County Regional Water Supply System. The TRA drought plan authorizes the General Manager to initiate or terminate drought and other emergency water supply measures to protect public health, safety and welfare. Drought stages are triggered by reductions in the normal conservation storage measured by the lake water surface elevation. Three drought stages implement demand management measures to reduce demands by 5 percent, 15 percent and 25 percent when the normal conservation storage level of the reservoir is below 80 percent, 70 percent, and 60 percent respectively. The demand management measures that can be utilized by TRA during drought stages include: requests for voluntary reductions in water use, encouraging customers to use alternative supplies, mandatory reductions of non-essential water use, and pro-rata curtailment of diversions and deliveries.

3.4.2 San Jacinto River Authority (SJRA) DCP

The San Jacinto River Authority (SJRA) drought plan was obtained during the development of this study. The SJRA drought contingency plan is organized into two sections. The first section focuses on municipal demands in the Woodlands and sets drought triggers based mainly on infrastructure capacity including combined pumpage and elevated/ground storage levels. The second part of the SJRA drought contingency plan focuses on Lake Conroe and the Highlands Canal System. Trigger conditions for each successive drought stage are based on conservation storage. Stages 1 – 3 set demand reductions of 10%, 15% and 20% based on conservation storages of 70%, 55% and 40% respectively. A fourth stage is triggered by a failure of the Highlands Canal System, natural or man-made disasters.

3.4.3 Brazos River Authority (BRA) DCP

The Brazos River Authority drought plan identifies three levels of drought severity and identifies specific actions to be implemented. The BRA plan considers each reservoir in the BRA/COE system individually and together as a system. For an individual reservoir a drought stage is initiated when the reservoir storage drops below a trigger condition *and* sufficient data exists to suggest that the reservoir capacity could be further reduced below the next stage trigger within 12 months. The requirements for initiating a group of reservoirs or the entire Authority's system follow the same pattern. Stage three however, is initiated when a reservoir, group of reservoirs or the system is at or below the stage three trigger. Triggers for stage 1, 2 and 3 correspond to reoccurrence frequencies of 20%, 10% and 5% based on statistical analysis of each reservoir.

3.4.4 Region H DCP Conflicts

The previous sections highlighted the drought contingency plans of the major wholesale water providers with existing and future supplies in Region H. It is evident that existing drought contingency plans in Region H utilize several different triggers to initiate successive drought stages and demand management measures. SJRA and TRA define drought triggers based on percentage of normal conservation volume and are easily observable by monitoring water surface elevations. BRA defines trigger levels for each reservoir in the Authority's system based on statistical analysis, while the City of Houston defines drought triggers based on the number of months existing surface and ground water supplies could continue to meet the current demands. Because the City of Houston owns water rights in all three existing reservoirs and in the future Allens Creek reservoir, the supplies in each lake are simultaneously an important part of two drought contingency plans. Lake Conroe is a focal point of the SJRA drought plan and part of the City of Houston's combined system storage. Lake Livingston is shared by TRA and the City of Houston and Allens Creek is projected to be shared by the City of Houston and BRA.

3.5 National Research

In addition to compiling information from water supply systems within Region H, several utilities across the nation were surveyed while making sure to account for various geographic and weather conditions. Utilities surveyed included the City of Santa Barbara, CA; the City of Peoria, AZ; South Florida water management district; the City of San Diego, CA and the City of Denver, CO.

3.5.1 Santa Barbara, California

The Santa Barbara County Water Agency has no direct customers, the water Shortage/Drought Management Plan is necessary to coordinate the drought plans of local water providers. The Regional Plan describes the following specific actions to be undertaken by the Water Agency:

- Development of coordinated advertising campaign and public information materials
- Acceleration of low-flow fixture rebate programs
- Complete an inventory of potential surplus water available for exchange/sale to districts that may wish to augment their existing supplies
- Work with medium and small local water providers to complete water shortage plans using the USBR Water Shortage/Drought Planning Handbook developed by the Water Agency in 2003
- Hold public workshops to allow local providers and the public a forum for discussing issues that water users may face during a drought
- Incorporate other actions in the plan as appropriate in response to future conditions

The County Water Agency will begin implementing the following drought contingency measures in conjunction with local water providers when local weather patterns result in three years of average or below average rainfall, or when asked to by local water providers, whichever occurs first. Different methods are prescribed to increase existing supplies, draw from reserve supplies, increase efficiency, modify operations, cooperate with other agencies, and implement demand reduction actions.

A study of eight water agencies in California analyzed the efficacy of various demand-side management policies implemented between 1989 and 1996 during California's statewide drought. The study included the San Francisco Water District, City of San Bernardino, Los Angeles Department of Water and Power, City of San Diego, and the City of Santa Barbara. The water agencies studied implemented various demand management strategies including the following:

- Public education and information campaigns
- Subsidies to encourage water efficient technologies
- Water rationing including price penalties
- Restrictions on non-essential water use

The study aimed at evaluating the relative performance of various demand-side management policies and assessing water policy implications. The following conclusions were reached:

- Demand reductions of 5% - 15% could be achieved by price increases and voluntary measures
- Demand reductions of greater than 15% would likely require larger price increases and water use restrictions
- Lower income households are likely to be more responsive to price increases
- Outdoor water use restrictions will likely have higher impacts in suburban communities

3.5.2 Peoria, Arizona

The Drought Contingency Plan for Peoria Arizona prescribes procedures and strategies when water supplies may not be able to supply demands as the result of below normal rainfall resulting in a water supply drought. The goals of the plan are to protect public health and safety, provide sufficient water to meet customer demands, share the impacts and hardships caused by drought equitably and in a proportion to the magnitude of the drought, minimize disruption of the economy, provide options for updating or changing the Drought Plan, and enforce city code so that drought related water reduction goals will be met.

The plan approaches droughts through triggers to different stages. A stage one “Water Watch” is triggered when the possibility exists that the City of Peoria Utilities Department will not be able to meet all of the water demands of its customers. Voluntary demand reductions and public education strategies are implemented to achieve a water use reduction of 5%. Stage two is a “Water Alert” implementing mandatory measures to achieve a 10% reduction in water use. Stage three is a “Water Warning” aimed at achieving a 15% reduction in water use by increasing mandatory restrictions.

3.5.3 South Florida Water Management District, Florida

The South Florida Water Management District (SFWMD) covers 16 counties in Southern Florida. A Phase I (moderate) water shortage requires water users to limit outdoor water use with the goal of reaching a 15% reduction in overall demand for water. A Phase II (severe) water shortage restricts outdoor water use with the goal of producing a 30% reduction in overall demand. Phase III (severe) water shortage restrictions have the goal of achieving a 45% water demand reduction. Specific methods for achieving reduction goals vary according to phase and user category. Water agencies in the South Florida Water Management District utilize various restrictions to achieve prescribed reduction goals including restrictions on: residential per capita consumption, non-essential utility use, power production water use, limits on commercial and industrial water use, agricultural water use, Landscape irrigation, recreation, and other non-essential water uses. The district also implements strategies to preserve and augment water supplies by making strategic water deliveries from Water Conservation Areas and regional canal systems, by protecting coastal well-fields from saltwater intrusion, maintaining fire protection capabilities in designated canals in rural areas, and meeting the needs of power generating plants.

Drought conditions in the year 2001 resulted in the District imposing Phase III restrictions with the aim at reducing water use by up to 45%. Phase III restrictions were initiated after Phase II policies reduced water use by 10%, well short of the 20% to 30% goal defined in the District's Water Shortage Plan. Lake Okeechobee dropped to the lowest levels ever recorded, making it necessary for some public water supply utilities to modify pumps and intake lines to avoid the risk of not being able to supply water to homes.

3.5.4 San Diego, California

The San Diego County Water Authority (SDCWA) drought management plan was created after the drought of 1977-1976, when San Diego first experienced demands that were greater than its supplies. During that time, the Metropolitan asked for and received voluntary reductions in deliveries of 10% and began considering how to deal with future supply shortages. The DMP developed a "Drought Response Matrix Stages" to provide guidance to the Water Authority and its member agencies to select potential regional actions to lesson the severity of shortage conditions.

The potential actions for Stage 1 start with voluntary reductions. The voluntary stage would likely occur when Metropolitan has been experiencing shortages in its imported water supply and is withdrawing water from storage to meet normal demands. Stage 2 may occur in the third or fourth year during a dry period and may result in restrictions on water delivery. Stage 3 implements "mandatory cutbacks", triggered when demands are unable to be met. Stage 4 restricts water delivers for health and safety purposes only by drastically restricting deliveries.

3.5.5 Denver, Colorado

The Denver Drought Response Plan was the result of lessons learned from drought restrictions implemented in Denver Water's service area during drought conditions in 2002 and 2003. The plan approaches drought response from four perspectives-triggers, drought responses, public outreach, and internal communication.

Stage 1 is implemented when the reservoir storage is 80% or lower of expected July 1st conditions. The demand management policy includes requesting customers to voluntarily reduce their water usage by 10% and implement a public awareness campaign. Stage 2 occurs when the reservoir storage is 65% or lower than expected July 1st conditions. Response measures include a water use reduction goal of 30% for large-volume customers, industry-specific water restriction programs and a surcharge program to support the mandatory drought restrictions. Stage 3 results from reservoir storage less than 40% or lower of expected July 1st conditions. Responses include strict restrictions on outdoor water use, elimination of all nonessential water usage, and a water use reduction goal of 50% for large-volume customers. Stage 4 results from reservoir storage of 25% or lower than expected July 1st conditions. Response measures include limiting outdoor watering to monthly tree watering, elimination of nonessential water uses, and a water-rationing program to provide customers water for essential uses for indefinite period of extreme drought.

A 2004 study evaluated the effectiveness of water use restrictions implemented by several municipalities in Colorado. The 2002 drought surpassed the 1954 Colorado drought of record commonly used for planning in the state. The study focused on restrictions of lawn watering which reportedly accounted for more than half of annual residential water use. The study focused on municipal water providers including Denver Water, Aurora and Boulder. The study highlighted four findings.

- Mandatory restrictions reduced water demands by a wide range from 13% to 55%. The variance was possibly due to differences amongst the service populations and variations in restrictions and level of enforcement.
- Voluntary restrictions had marginal results. Net consumption actually increased in two cities after voluntary restrictions were implemented.
- The greatest reductions in terms of percentage were found in cities with the highest enforcement levels and limitations on outdoor watering.
- Every city studied was able to reduce per capita water use through use of water restrictions. The level of reduction ranged widely from 1% using only voluntary restrictions to 49% with the most stringent water restrictions.

3.5.6 Virginia

In response to drought conditions in 2002, the State of Virginia created a drought assessment and response plan designed to monitor drought conditions across the state. The plan also gave the Deputy of Natural Resources the responsibility of implementing water use restrictions. The responsibility of monitoring drought conditions is held by the Virginia Drought Monitoring Task Force (DMTF). The DMTF uses four indicators: precipitation, stream flows, ground water levels, and surface water levels to provide drought stage recommendations to the Virginia Drought Coordinator. Three drought stages are identified in the State's plan including Drought Watch, Drought Warning and Drought Emergency. Due the variable impacts of drought on different types of supply sources, the response activities implemented during each drought stage are tailored to the specific drought conditions. The plan does, however, identify reduction targets of 5% during Stage 1, 5% - 10% during Stage 2 and 10-15% during Stage 3.

A study of the 2002 drought in Virginia focused on the effectiveness of drought management programs and the impact of the intensity at which the programs were implemented. The study used data from 21 water suppliers including cities and counties and highlighted the difficulty in determining the intensity level of different management programs. The study concluded that strong enforcement of restrictions was vital to achieving desired levels of demand reduction. The following conclusions were presented by the study:

- Voluntary restrictions resulted in demand reductions ranging from 0% to 7%
- Mandatory restrictions resulted in demand reductions ranging from 4% to 22%
- Magnitude of reductions increased as information and enforcement increased
- Mandatory measures were in place mostly during winter months. The demand reductions would likely be higher than reported above if the mandatory measures were in place during summer months when outdoor water use is typically higher.

3.6 Commonly used Drought Contingency Measures and the Associated Savings

Drought contingency plans are commonly organized as a matrix of drought stages varying from a "watch or "warning" to "severe" or "emergency" drought conditions. Demand reduction goals are often described as a percentage and increase as the level of drought intensifies. These goals are usually set based on some level of risk analysis, which considers the drought susceptibility of the supply source and the importance of the source to the health and safety of the community. Drought contingency plans from Region H and nationally, were analyzed to develop stage reduction goals for a hypothetical typical drought contingency plan that could be used to analyze the effects of demand management measures on surface water reservoirs within Region H. Table 1, lists the stage reduction goals for some of the drought contingency plans studied during this analysis.

Stage I reductions are typically between 0% 10%. Most agencies implement education strategies during the early stages of their drought plans and may also request voluntary reductions. The City of Houston for example, implements education strategies and reduces water use by city departments by 10%. The South Florida Water Management District has issued advisory notices in the past asking users for voluntary reductions starting the public education process prior to implementing mandatory restrictions; no demand reduction goal is associated with the education measure.

Stage II typically involves increasing voluntary reductions through improving public awareness and may impose mandatory reductions on some types of use. The first phase outlined in the South Florida Water Management District's plan is included under Stage II because it imposes mandatory restrictions on outdoor watering. The City of Houston's plan sets a demand reduction goal of 15% to be achieved through increased voluntary reductions as a result of public awareness.

Stage III demand reductions ranged from 15% to 50% depending on the level of mandatory restrictions placed on water use and the limitations on aesthetic water use. The highest restrictions were found in Denver, Colorado where reservoir supplies are highly susceptible to drought conditions which reduces the winter snow pack used to fill their reservoirs. In less drought susceptible climates, the level of mandatory restrictions typically include time of day watering and various prohibitions on wasting water to achieve demand reductions of around 15% - 20%.

Stage IV water restrictions typically included continuing restrictions from Stage III and placing additional bans on non-essential water use including recreational and aesthetic usages. During severe droughts, provisions are often in place to provide pro-rata curtailments to contracted customers which can further increase the demand reduction goals.

Table 1. Summary of Water Demand Reduction

Drought Contingency Stage	Entity	Demand Reduction Target	Drought Contingency Stage	Entity	Demand Reduction Target
Stage I	City of Houston, TX	10%	**Stage II**	City of Houston, TX	10%
	Galveston, TX	0%		Galveston, TX	10%
	Santa Barbara, CA	10%		San Diego, CA	20%
	Peoria, AZ	5%		Peoria, AZ	10%
	South Florida Water Management District (SFWMD), FL	0%		South Florida Water Management District (SFWMD), FL	15%
	Denver, CO	10%		Denver, CO	30%
Stage III	City of Houston, TX	15%	**Stage IV**	City of Houston, TX	20%
	Galveston, TX	10%		Galveston, TX	20%
	San Diego, CA	40%		San Diego, CA	>40%
	Peoria, AZ	15%		Peoria, AZ	TBD
	South Florida Water Management District (SFWMD), FL	30%		South Florida Water Management District (SFWMD), FL	45%
	Denver, CO	50%		Denver, CO	66%

Demand management measures that may be used to achieve specific demand reduction goals are outlined for each drought stage. The goals outlined by individual drought plans can vary widely based on the hydrology of the region and the specific demographics of the end water users. A hypothetical typical drought plan was developed to model the effects of drought management measures on surface water reservoirs in Region H. The drought plan was divided into four stages with target demand reductions for each stage. Specific drought management measures are listed for each Stage.

Table 2. Hypothetical Typical Drought Plan

Stage 1 – Mild Drought Conditions (5% Demand Reduction)

- Initiate Public Information Campaign
- Request that Customers Limit Outdoor Irrigation
- Request that Customers Investigate and Repair Leaks
- Request Major Customers to make Voluntary Reductions in Water Use
- Reduce Water Use in Public Departments

Stage 2 – Moderate Drought Conditions (10% Demand Reduction)

- Increase Public Information Campaign
- Restrict Outdoor Watering to Specific Hours and Days
- Prohibit the Planting of New Lawns
- Provide Water Audits for Large Irrigated Public Areas
- Increase Leak Detection and Repair Activities
- Increase Reduction of Water Use in Public Departments
- Prohibit Washing of Non-commercial Vehicles and Impervious Areas
- Prohibit Filling of Private Swimming Pools

Stage 3 – Severe Drought Conditions (20% Demand Reduction)

- Continue Stage 2 Measures
- Increase media involvement
- Increase Outdoor Watering Restrictions
- Impose penalties on Water Waste, Permit Violations and for Noncompliance with Restrictions
- Ban Aesthetic Water Use
- Restrict Restaurants from Serving Water unless Requested by Customers.
- Increase Rates to Increase Financial Incentives for using Less Water
- Impose a Moratorium on New Connections

Stage 4 – Severe Drought Conditions (30% Demand Reduction)

- Continue Stage 3 Measures
- Eliminate all Fire Hydrant Uses Outside of those Required for Public Health and Safety
- Prohibit all Indoor and Outdoor Aesthetic Water Use.
- Prohibit Non Essential Water Use
- Reduce Water Service to Customers

Section 4 – Evaluation of Water Supply Reservoirs in Absence of Drought Management Measures

The effects of projected demands on lake levels during the drought of record were analyzed with and without drought management measures. To perform the analysis, the TCEQ WAM was updated with year 2000 and 2060 area capacity curves to reflect the effects of sedimentation on reservoir storage. The reservoirs were modeled under several scenarios to prepare a base line from which the effects of various drought contingency plans could be measured. The scenarios used in the analysis included Run 8 (current levels of water diversions and return flows), Run 3 (full authorized diversions and 100% reuse) and Liv60rf (a Run 3 model with full authorized diversions, modified by the addition of expected return flows from Region C) to model the expected conditions for Lake Livingston. Runs 3 & 8 were simulated with the year 2000 and 2060 area capacity curves for Lake Livingston, Conroe and Houston. Lake Livingston was also simulated using Run Liv60rf with the year 2060 area capacity curves. The future Allens Creek Reservoir was modeled using Runs 3 & 8 with the permitted area capacity curve already present in the models.

The results of the simulations in the absence of drought management measures are summarized in the following sections. The simulated reservoir surface water elevations for each base line run are presented on separate figures for the year 2000 and year 2060 area capacity curves. Surface water elevations for Allens Creek are presented on a single graph using the permitted area capacity curve. The base runs for each reservoir are also presented in a percentile comparison in the appendices for each reservoir. The percentile values record what percentage of time the reservoir elevation is less than or equal to the value listed in the table. For Allens Creek, the data is reported as reservoir storage in acre-ft.

4.1 Lake Livingston

Figure 4-1. Lake Livingston Elevations, Year 2000 Storage Capacity

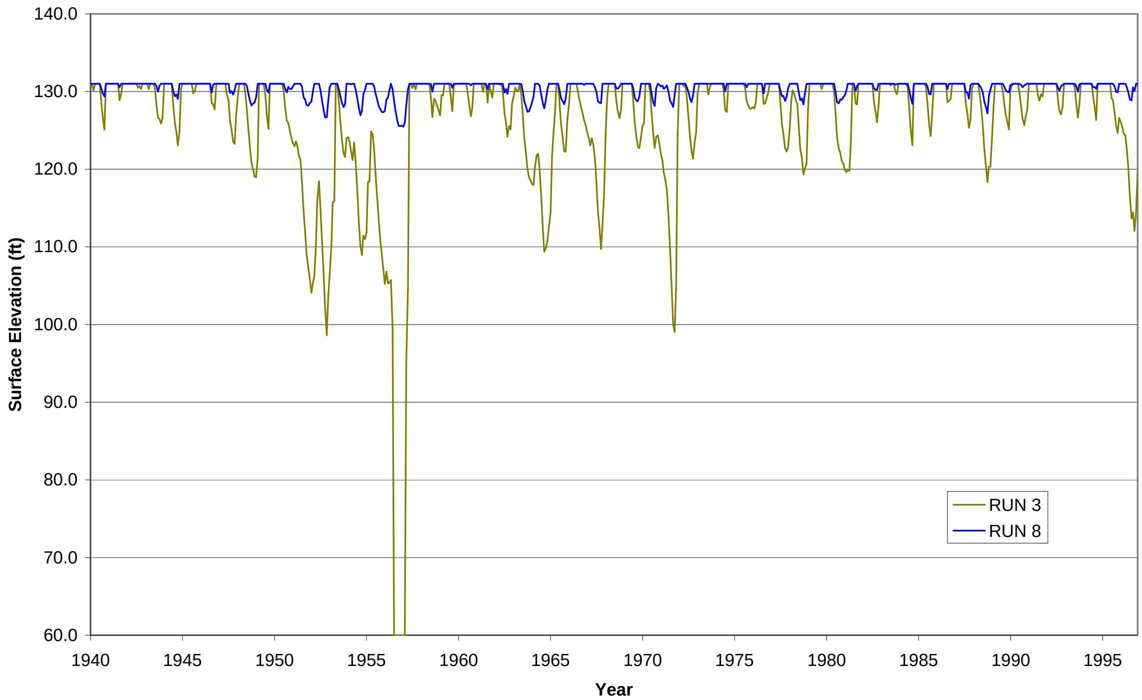
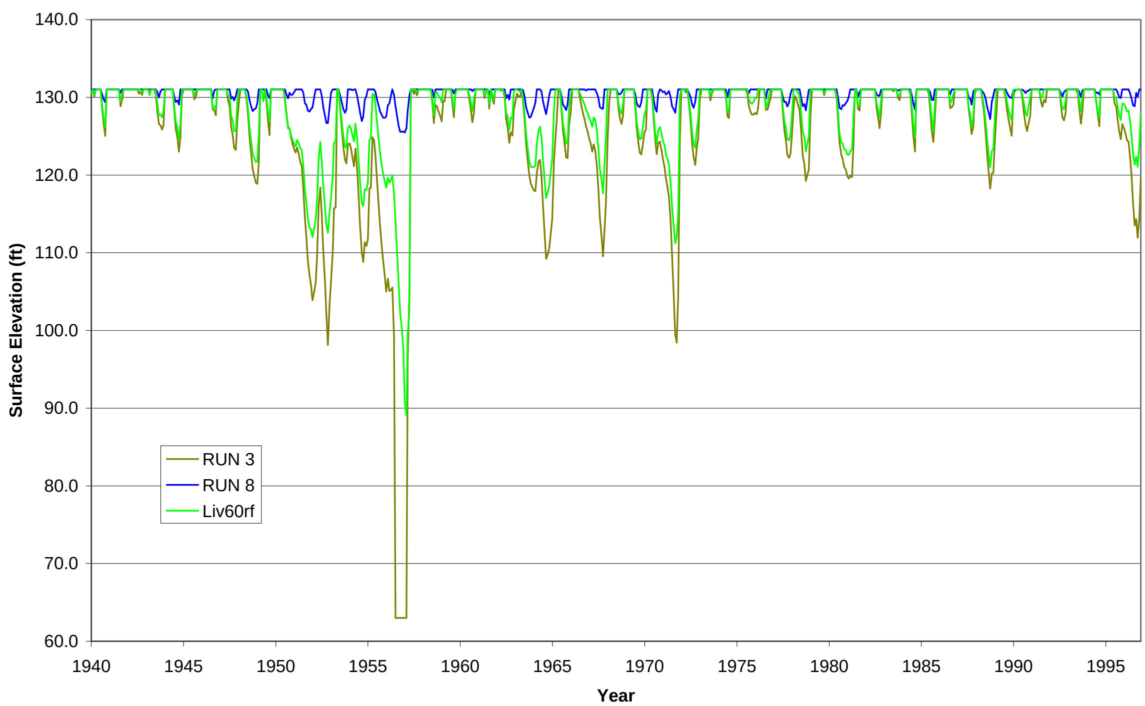


Figure 4-2. Lake Livingston Elevations, Year 2060 Storage Capacity



As can be seen on Figure 15, Lake Livingston is dependant on return flows from Region C. Using the TCEQ Run 3, which simulates full authorized diversions without return flows, the lake level would reach the minimum elevation (approximately 60 ft in the year 2000 and 62 ft in the year 2060) under drought of record conditions. Using the TCEQ Run 8 model, which simulates current levels of diversions and return flows, the lake is full almost 75% of the time with a minimum elevation of approximately 125 ft. The expected scenario for Lake Livingston includes return flows from Region C and is simulated by the Liv60rf model. The model was adopted to represent the year 2060 firm yield scenario for Lake Livingston in the 2006 Region H Water Plan and is essentially an updated Run 3 model which includes the expected return flows from Region C. Using the Liv60rf model, Lake Livingston remained full nearly 50% of the time and reached a minimum elevation of approximately 90.5 ft.

4.2 Lake Conroe

Figure 4-3. Lake Conroe Elevation, Year 2000 Storage Capacity

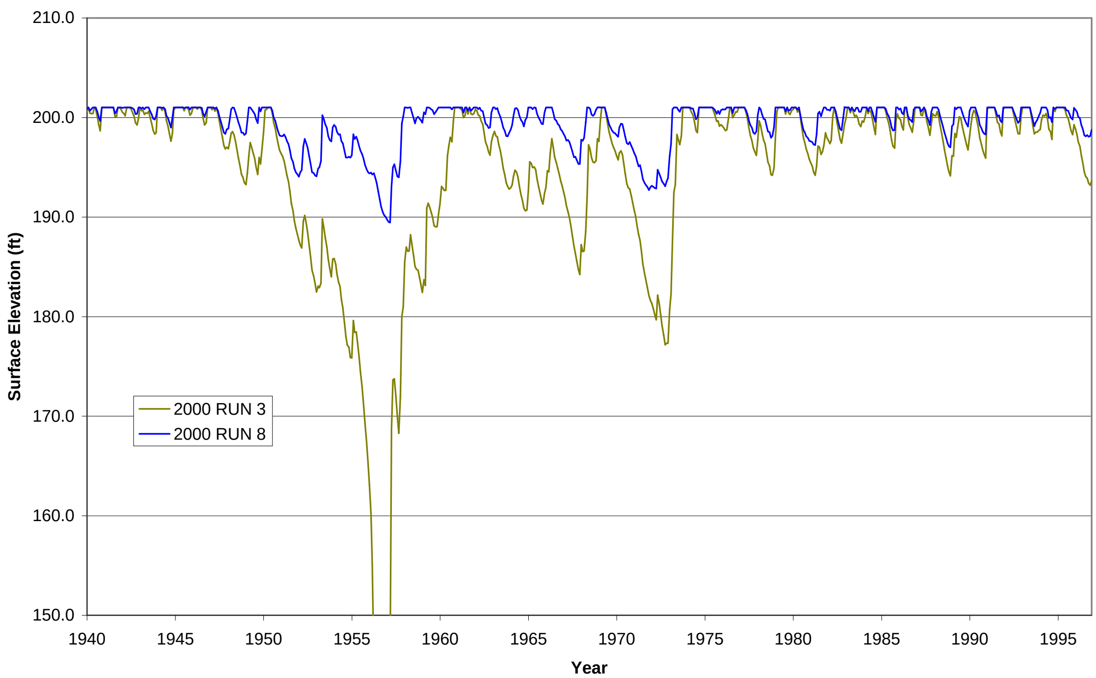
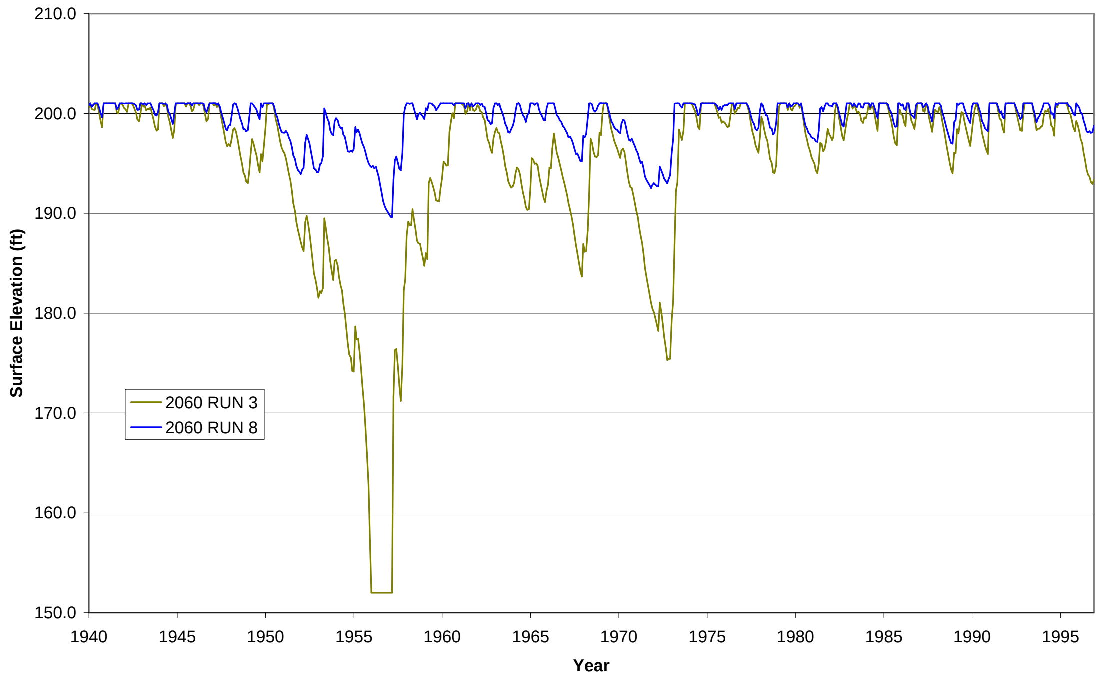


Figure 4-4. Lake Conroe Elevations, Year 2060 Storage Capacity



Using the Run 8, current conditions model, the water surface level of Lake Conroe varies from elevation 201 ft to 150 ft, approximately an 11 ft variation. Discussions with the San Jacinto River Authority (SJRA) revealed that the diversions simulated in the Run 8 model totaled approximately 47,000 acre-ft and included a "one-time" release from Lake Conroe to Lake Houston. This "one-time" release was included in the Run 8 model as an annual diversion target totaling 31,293 acre-ft per year. As a result, the current Run 8 model does not accurately reflect the "current conditions" on Lake Conroe but can still be utilized in this study to evaluate the effectiveness of various drought contingency plans.

Results from the Run 3 simulation show the level of Lake Conroe reaching the minimum elevation during drought of record conditions. Using the year 2000 area capacity curve the water surface elevation reaches a minimum level of approximately 145 ft. Updating the Run 3 model with the 2060 area capacity curve raises the lake bottom elevation to 152 ft to account for sedimentation. Under Run 3 conditions the lake remains full over 40% of the time.

4.3 Lake Houston

Figure 4-5. Lake Houston Elevations, Year 2000 Storage Capacity

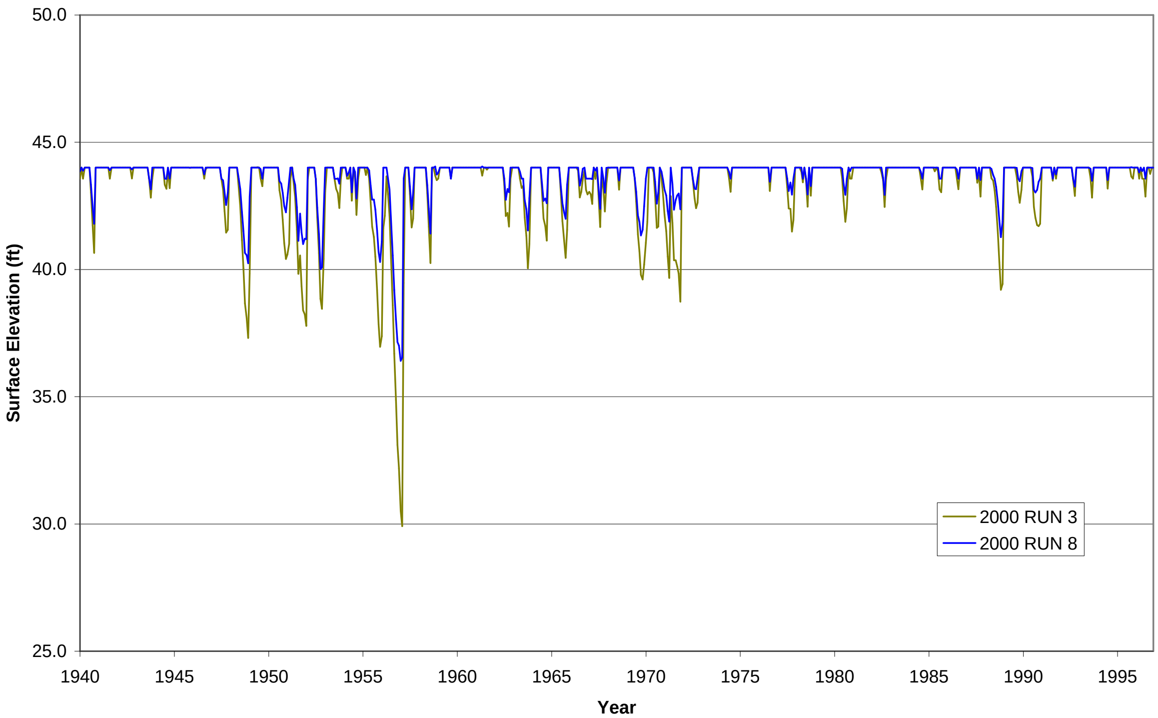
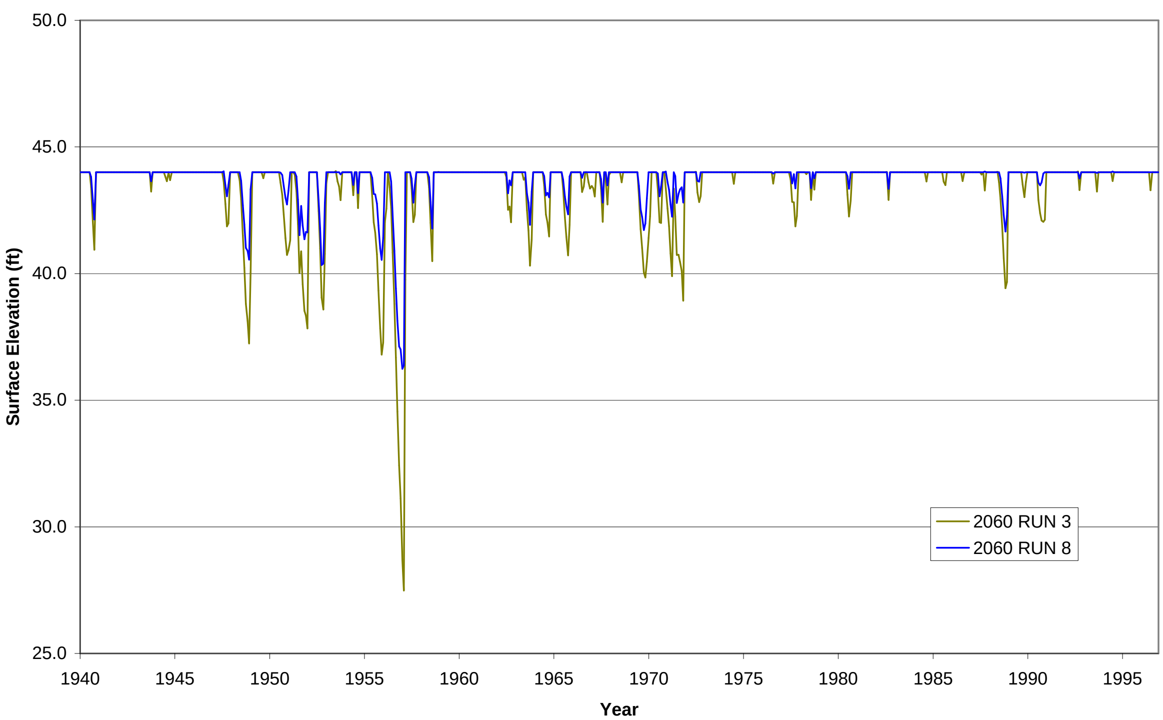


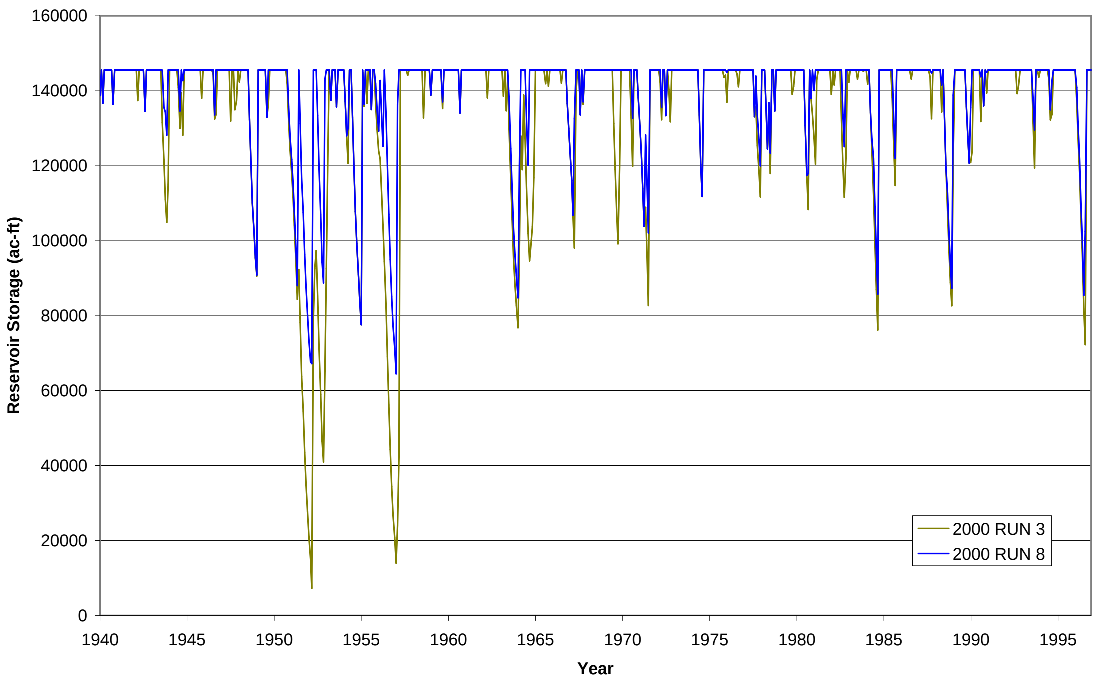
Figure 4-6. Lake Houston Elevations, Year 2060 Storage Capacity



Due to its downstream location and senior priority, Lake Houston is able to capture inflows from a large drainage area and can require Lake Conroe to pass inflows downstream until Lake Houston can satisfy its diversions. As a result, full use of water rights and drought conditions have a less severe impact on lake levels. Lake Houston remains full approximately 65% percent of the time using the Run 3 scenario. Using the TCEQ Run 8, Lake Houston is full almost 75% of the time, only a slight increase over the Run 3 scenario. Water surface levels in Lake Houston vary approximately 7.5 ft using the TCEQ Run 8 model and approximately 14 ft using Run 3.

4.4 Allens Creek Reservoir

Figure 4-7. Allens Creek Storage, Full Permitted Capacity



Allens Creek was modeled using the full permitted storage capacity described in the TCEQ Run 3 model. As a permitted future reservoir, Allen Creek, does not have a final stage-capacity curve that can be used to translate reservoir volume into elevations. Therefore, the discussion of drought contingency plan impacts on the reservoir will focus on storage levels instead of elevations.

The storage in Allens Creek varies from 145,533 acre-ft at full capacity to a minimum of 7,237 acre-ft during drought of record conditions using Run 3 and 64,457 acre-ft using Run 8. The reservoir remained at full capacity over 50% of the time in the Run 3 simulation and 75% of the time in the Run 8 simulation. The Run 8 model was modified to include Allens Creek with full permitted diversion and the full permitted storage capacity. While it is unlikely this scenario will represent current conditions at the time when the future reservoir is constructed, it provides a reasonable “current conditions” scenario to compare the effects of various drought contingency plans.

Section 5 – Evaluation of Water Supply Reservoirs with Drought Management Measures

The effects of drought contingency plans on lake levels during the drought of record were analyzed with existing agency drought contingency plans and a hypothetical typical drought contingency plan outlined in section 3.6. To perform the analysis, the TCEQ WAM was updated to include the effects of implementing the drought contingency plans as a percentage reduction in the municipal diversions made from the reservoirs. The reservoirs were modeled under several scenarios to evaluate different drought contingency plan impacts using various demands and return flows. The scenarios used in the analysis included Run 8 (current levels of water diversions and return flows), Run 3 (full authorized diversions and 100% reuse) and Liv60rf (full authorized diversions, with expected return flows from Region C) to model the most likely scenario for Lake Livingston. Run 8 used the year 2000 sedimentation condition to simulate the lake levels under “existing” conditions, runs Liv60rf & Run 3 were performed with the year 2060 sedimentation conditions to simulate an “ultimate” condition for year 2060.

Comparisons of lake levels and storage with and without drought management measures are summarized in the following sections. Additional tables and graphs further detailing the effects of each drought contingency plan during the drought of record are provided in Appendices A – D. The following sections also present the different triggers and demand reductions used to simulate the existing agency drought contingency plan and the typical plan. Each drought contingency plan was simulated using two different variations identified as “CASE 1” and “CASE 2”. The two assumed DCP variations are identified below:

- “CASE 1” assumes that the drought management measures are only implemented during the summer months May – September. These summer months represent peak water usage with increased outdoor and recreational water use. Historically, drought contingency plans in Region H have most often been implemented during these summer months when peak demands encroach on the maximum pumping capacity stressing distribution systems.
- “CASE 2” assumes that the drought management measures are effective during the summer months May – September. This variation also assumes that the drought management measures have some effectiveness during the off peak (winter) months October – April when outdoor and recreational water use have declined. For example, under a Stage 3 drought warning, a 20% demand reduction is achieved during summer months and a 10% demand reduction is achieved during winter months. The variation assumes that half of peak demand reduction percentage is achievable during the off peak months.

5.1 Lake Livingston

Effects of drought contingency plans on Lake Livingston were modeled using the existing TRA drought contingency plan and a drought contingency plan typical of other major water providers. The existing TRA drought contingency plan implements stages of the drought contingency plan when the water surface elevation of Lake Livingston is below the Elevations listed below in Table 3. The typical drought contingency plan shown below triggers stages in the drought contingency plan based on a percentage of the reservoir storage. The demand reductions listed for both drought contingency plans were applied to municipal diversions from Lake Livingston.

Table 3. Lake Livingston DCPs

	TRA DCP		Typical DCP	
Stage	Elevation (ft)	Demand Reduction	Reservoir Storage (acre-ft)	Demand Reduction
1	126.50	5%	70%	5%
2	124.00	15%	60%	10%
3	121.40	25%	50%	20%
4	-	-	40%	30%

The drought contingency plans listed above were simulated using both the TCEQ WAM Run 8 to simulate current conditions and with the Liv60rf model to simulate full diversions and expected return flows. Each drought contingency plan was modeled with two variations described as “CASE 1” and “CASE 2”. The impact of the drought contingency plans was evaluated based on the minimum storage in the reservoir during the drought of record. The minimum storage level was used to determine the number of months that the reservoir supplies could continue to meet demands if the drought of record continued. Table 4 below summarizes the Region H supplies from Lake Livingston projected in the 2006 Region H Water Plan. Tables 5 and 6 identify the number of months that the supplies could continue to be met if the drought conditions continued past the drought of record. Appendix A contains graphical results of lake during the simulation period and the drought of record.

Table 4. Livingston Projected Demands

Year	Demand (AFY)
2000	745,617
2010	820,020
2020	966,102
2030	1,068,845
2040	1,120,753
2050	1,215,812
2060	1,258,245

Table 5. Months of Supply Remaining (RUN 8)

RUN 8 – Current Diversions, Current Level of Return Flows

Year	RUN 8	TRADCP CASE 1	TRADCP CASE 2	TYPDCP CASE 1	TYPDCP CASE 2
2000	21.1	21.1	21.1	21.1	21.1
2010	19.2	19.2	19.2	19.2	19.2
2020	16.3	16.3	16.3	16.3	16.3
2030	14.7	14.7	14.7	14.7	14.7
2040	14.1	14.1	14.1	14.1	14.1
2050	13.0	13.0	13.0	13.0	13.0
2060	12.5	12.5	12.5	12.5	12.5

Table 6. Months of Supply Remaining (Liv60rf)

Liv60rf – Full Authorized Diversions, Expected Return Flows

Year	Liv60rf	TRADCP CASE 1	TRADCP CASE 2	TYPDCP CASE 1	TYPDCP CASE 2
2000	0.5	2.9	4.1	2.1	3.3
2010	0.5	2.7	3.8	1.9	3.0
2020	0.4	2.3	3.2	1.6	2.6
2030	0.4	2.0	2.9	1.5	2.3
2040	0.3	1.9	2.8	1.4	2.2
2050	0.3	1.8	2.5	1.3	2.0
2060	0.3	1.7	2.5	1.3	2.0

The tables above quantify the number of months the reservoir minimum storage could continue to meet demands if drought conditions continued past the drought of record. Using the TCEQ Run 8 model, the minimum storage in Lake Livingston during the drought of record was approximately 1,303,300 acre-ft which would allow the lake to continue to supply demands for approximately 19.2 months in 2010 during drought conditions decreasing to 12.5 months in 2060. The drought contingency plans have little to no effect on Lake Livingston in the current conditions model because lake levels are consistently above Stage 1 triggers. Using the Liv60rf model, without drought management measures, Lake Livingston could continue to meet demands for less than 1 month in the year 2060. Implementing the existing TRA drought contingency plan increases the months of supply to 1.7 and 2.5 using CASE 1 and CASE 2 assumptions, respectively. The typical drought contingency plan increases the months of supply to 1.3 and 2.0 months using CASE 1 and CASE 2, respectively. The number of months the reservoir could continue to meet demands is presented in percentile tables in appendix A.

In the year 2060 approximately 39,075 afy are projected to be supplied from Lake Livingston to meet irrigation demands in Region H. An additional analysis was performed to analyze the effects of implementing a “dry year option” to curtail irrigation diversion form Lake Livingston during stage 3 and 4 of the typical drought plan. The “TYPDCP CASE 2” scenario was updated to include a 25% year-round curtailment of irrigation diversions during stage 3 drought conditions and a 50% curtailment during stage 4. The dry year option was implemented in addition to the municipal demand reductions prescribed in the typical drought contingency plan scenario. The effects of the dry year option scenario (DRYDCP) are presented below. The addition of irrigation curtailments during stage 3 and 4 of the drought plan had little effect on the minimum reservoir storage volume. The volume increased from 205,400 acre-ft in the typical drought plan scenario (TYPDCP CASE 2) to 213,600 acre-ft with additional irrigation curtailments (DRYDCP). Similarly, the months of supply available in the lake was not significantly increased.

Table 7. Dry Year Option

Liv60rf – Full Authorized Diversions, Expected Return Flows

Scenario	Minimum Storage (acre-ft)	Months of Supply Remaining
Liv60rf	31,900	0.3
TYPDCP CASE 2	205,400	2.0
DRYDCP	213,600	2.04

5.2 Lake Conroe

Effects of drought contingency plans on Lake Conroe were modeled using the existing SJRA drought contingency plan and a typical drought contingency plan. The existing SJRA drought contingency plan implements stages of the drought contingency plan when the water surface elevation of Lake Conroe is below the elevations listed below in Table 8. The typical drought contingency plan triggers stages in the drought contingency plan based on a percentage of the reservoir storage. The demand reductions listed for both drought contingency plans were applied to the municipal diversions from Lake Conroe.

Table 8. Lake Conroe DCPs

	SJRA DCP		Typical DCP	
Stage	Elevation (ft)	Demand Reduction	Reservoir Storage (acre-ft)	Demand Reduction
1	194.00	10%	70%	5%
2	190.00	15%	60%	10%
3	185.00	20%	50%	20%
4	-	-	40%	30%

The drought contingency plans listed above were simulated using both the TCEQ WAM RUN 8 to simulate current conditions and with the TCEQ WAM RUN 3 model to simulate full authorized diversions without return flows. Each drought contingency plan was modeled with two variations described as “CASE 1” and “CASE 2”. The impact of the drought contingency plans was evaluated based on the minimum storage in the reservoir during the drought of record. The minimum storage level was used to determine the number of months that the reservoir supplies could continue to meet demands if the drought of record continued. Table 9 below summarizes the Region H supplies from Lake Conroe projected in the 2006 Region H Water Plan. Tables 10 and 11 identify the number of months that the supplies could continue to be met if the drought conditions continued past the drought of record. Appendix B contains graphical results of the lake levels during the simulation period and the drought of record.

Table 9. Lake Conroe Projected Demands

Year	Demand (AFY)
2000	20,745
2010	28,488
2020	73,001
2030	74,255
2040	74,300
2050	74,300
2060	74,300

Table 10. Months of Supply Remaining (RUN 8)

RUN 8 – Current Diversions, Current Level of Return Flows

Year	RUN 8	SJRADCP CASE 1	SJRADCP CASE 2	TYPDCP CASE 1	TYPDCP CASE 2
2000	130.9	132.0	132.4	131.5	132.0
2010	95.3	96.1	96.4	95.8	96.1
2020	37.2	37.5	37.6	37.4	37.5
2030	36.6	36.9	37.0	36.7	36.9
2040	36.5	36.8	37.0	36.7	36.8
2050	36.5	36.8	37.0	36.7	36.8
2060	36.5	36.8	37.0	36.7	36.8

Table 11. Months without Reservoir Storage – No Diversions (RUN 3)

RUN 3 – Full Authorized Diversions, No Return Flows

	RUN 3	SJRADCP CASE 1	SJRADCP CASE 2	TYPDCP CASE 1	TYPDCP CASE 2
Months	15	13	11	12	10

The tables above quantify the number of months the reservoir minimum storage could continue to meet demands if drought conditions continued past the drought of record. Using the Run 8 model the minimum storage during the drought of record of approximately 226,300 acre-ft. The Run 8 minimum storage volume could continue to meet annual diversions of 28,488 acre-ft per year in 2010 for almost 8 years. This result does not accurately reflect the current conditions on Lake Conroe however. The Run 8 model shows a 47,000 annual diversion from Lake Conroe that was based on a "one-time" release and not on a current annual diversion. Using the Run 3 model, without drought management measures, Lake Conroe would be unable to supply diversions for approximately 15 months. Implementing the existing SJRA drought contingency plan on all municipal diversions from the lake decreases the months that the lake is unable to meet supplies to 13 and 11 using CASE 1 and CASE 2 assumptions respectively. The typical drought contingency plan would further reduce the shortage period to 12 and 10 months using CASE 1 and CASE 2 respectively. The number of months the reservoir could continue to meet demands is presented in percentile tables in appendix B.

An additional analysis was performed to determine the level of demand reductions that would be necessary to prevent the reservoir from going dry and provide a constant level of diversion during drought years. The base Run 3 model updated with the 2060 area-capacity storage curve was used as the base for the analysis. In the model 66,000 afy is diverted with a municipal diversion pattern and 34,000 afy was diverted with an industrial pattern. For the analysis it was assumed that the Case 2 seasonal reduction pattern was applied to the 66,000 afy municipal diversions and a year-round reduction was applied to the 34,000 industrial demands. The stage and reduction goals that prevented the lake from going dry during the drought of record are presented below. Graphs showing the impact of the hypothetical drought plan are presented in Appendix B.

Table 12. Hypothetical DCP Reduction Goals

Drought Stage	Reduction Goal
Municipal: 66,000 afy	
1	15%
2	25%
3	35%
4	45%
Industrial: 34,000 afy	
1	15%
2	25%
3	35%
4	45%

5.3 Lake Houston

Effects of drought contingency plans on Lake Houston were modeled using a typical drought contingency plan. The typical drought contingency plan shown below triggers drought stages based on a percentage of the reservoir storage. The demand reductions listed below were applied to municipal diversions from Lake Houston.

Table 13. Lake Houston DCPs

Typical DCP		
Stage	Reservoir Storage (acre-ft)	Demand Reduction
1	70%	5%
2	60%	10%
3	50%	20%
4	40%	30%

The drought contingency plans listed above were simulated using both the TCEQ WAM Run 8 to simulate current conditions and with the TCEQ WAM Run 3 model to simulate full authorized diversions without return flows. Each drought contingency plan was modeled with two variations described as “CASE 1” and “CASE 2”. The impact of the drought contingency plans was evaluated based on the minimum storage in the reservoir during the drought of record. The minimum storage level was used to determine the number of months that the reservoir supplies could continue to meet demands if the drought of record continued. Table 14 below summarizes the Region H supplies from Lake Houston projected in the 2006 Region H Water Plan. Tables 15 and 16 identify the number of months that the supplies could continue to be met if the drought conditions continued past the drought of record. Appendix C contains graphical results of the lake levels during the simulation period and the drought of record.

Table 14. Lake Houston Projected Demands

Year	Demand (AFY)
2000	105,173
2010	160,324
2020	168,000
2030	168,000
2040	168,000
2050	168,000
2060	168,000

Table 15. Months of Supply Remaining (RUN 8)

RUN 8 – Current Diversions, Current Level of Return Flows

Year	RUN 8	TYPDCP CASE 1	TYPDCP CASE 2
2000	6.6	6.7	7.0
2010	4.3	4.4	4.6
2020	4.1	4.2	4.4
2030	4.1	4.2	4.4
2040	4.1	4.2	4.4
2050	4.1	4.2	4.4
2060	4.1	4.2	4.4

Table 16. Months of Supply Remaining (RUN 3)

RUN 3 – Full Authorized Diversions, No Return Flows

Year	RUN 3	TYPDCP CASE 1	TYPDCP CASE 2
2000	0.7	0.7	1.4
2010	0.4	0.5	0.9
2020	0.4	0.4	0.9
2030	0.4	0.4	0.9
2040	0.4	0.4	0.9
2050	0.4	0.4	0.9
2060	0.4	0.4	0.9

The tables above quantify the number of months the reservoir minimum storage could continue to meet demands if drought conditions continued past the drought of record. Using the Run 3 model, without drought management measures, Lake Houston could continue to meet demands for less than 1 month. Implementing the typical drought contingency plan increases the number of months from .4 to .9 using CASE 2, which assumes that demands can be effectively reduced during winter months when outdoor water use and recreational use is historically lower. Using Run 8 the minimum storage in Lake Houston during the drought of record was approximately 58,000 acre-ft. The reservoir storage could continue to meet the annual diversion for approximately less than 5 months. The number of months the reservoir could continue to meet demands is presented in percentile tables in appendix C.

5.4 Allens Creek Reservoir

Effects of drought contingency plans on the proposed Allens Creek Reservoir were modeled using the existing BRA drought contingency plan and a typical drought contingency plan. The existing BRA drought contingency plan set trigger elevations based on reservoir occurrence frequencies. The typical drought contingency plan shown below triggers drought stages based on a percentage of the reservoir storage. The demand reductions listed for the typical drought contingency plan were applied to the municipal diversions from the Allens Creek Reservoir.

Table 17. Allens Creek DCPs

	BRA DCP		Typical DCP	
Stage	Occurrence Frequency	Demand Reduction	Reservoir Storage (acre-ft)	Demand Reduction
1	20%	-	70%	5%
2	10%	3	60%	10%
3	5%	7	50%	20%
4	-	-	40%	30%

The drought contingency plans listed above were simulated using the TCEQ WAM Run 3 model to simulate full authorized diversions without return flows. Each drought contingency plan was modeled with two variations described as “CASE 1” and “CASE2”. The impact of the drought contingency plans was evaluated based on the minimum storage in the reservoir during the drought of record. The minimum storage level was used to determine the number of months that the reservoir supplies could continue to meet demands if the drought of record continued. Table 18 below summarizes the Region H supplies from the Allens Creek Reservoir projected in the 2006 Region H Water Plan. Table 19 identifies the number of months that the supplies could continue to be met if the drought conditions continued past the drought of record. Appendix D contains graphical results of the lake levels during the simulation period and the drought of record.

Table 18. Allens Creek Projected Demand

Year	Demand (AFY)
2000	0
2010	0
2020	0
2030	97,410
2040	97,410
2050	97,410
2060	97,410

Table 19. Months of Supply Remaining (RUN 3)

RUN 3 – Full Authorized Diversions, No Return Flows

Year	RUN 3	BRADCP CASE 1	BRADCP CASE 2	TYPDCP CASE 1	TYPDCP CASE 2
2000	-	-	-	-	-
2010	-	-	-	-	-
2020	-	-	-	-	-
2030	0.9	1.4	1.6	1.6	2.1
2040	0.9	1.4	1.6	1.6	2.1
2050	0.9	1.4	1.6	1.6	2.1
2060	0.9	1.4	1.6	1.6	2.1

The table above quantifies the number of months the reservoir minimum storage could continue to meet demands if drought conditions continued past the drought of record. Using the Run 3 model, without drought management measures, Allens Creek could not continue to meet demands if the drought continued. Implementing the BRA drought contingency plan would allow the reservoir to continue to meet demands for 1.4 and 1.6 months using CASE 1 and CASE 2 assumptions respectively. The typical drought contingency plan would allow the reservoir to meet demands for 1.6 and 2.1 months using CASE 1 and CASE 2 respectively. The number of months the reservoir could continue to meet demands is presented in percentile table in the appendices.

Section 6 – Projected Water Savings

Water use savings were projected for each WUG in Region H associated with the reservoirs evaluated in this study. Reduction estimates were the effects of the typical drought contingency plan on municipal diversions from surface water supply reservoirs. The impacts of drought management strategies on annual water demands are dependant on many factors including public perception, local demographics, type of restrictions, level of enforcement and the timing of drought stages. For instance, mandatory restrictions typically rely on limitations of outdoor and non-essential water use to reduce municipal water use. Such restrictions typically produce larger water use reductions when applied during summer months when outdoor and recreational water use it highest.

The duration of low surface water elevations has an impact on the duration that drought stages may be in effect and thus have an affect on the magnitude of demand reductions that can be achieved. Lake Conroe for example has a drought of record period that results in minimum lake elevations for a period of approximately 15 months. Lake Houston, on the other hand, has a drought period that lasts for approximately 1 year. Municipal demands on Lake Houston would be placed under stage 4 restrictions for a period of only six months using the typical drought contingency plan and will not realize the full annual demand reduction possible. As a result, the level of drought response is likely to vary between municipal users based on how susceptible their source of supply is during drought conditions. To reflect this, annual demand reductions (or water savings) were estimated for each reservoir based on implementing the typical drought contingency plan on municipal demands in response to drought of record conditions.

Table 20. Demand Reduction by Source during the Drought of Record

Source	Source_ID	Demand Reduction
Lake Livingston	084H0	20.88%
Lake Conroe	12900	24.86%
Lake Houston	10030	8.92%
Allens Creek	10060	14.57%

The estimated demand reductions listed above were then applied to Water User Groups (WUGs) in Region H with existing or projected use from the four surface water reservoirs to estimate the possible water savings associated with implementing demand-side management measures during drought of record conditions. For WUGs with supplies from multiple sources the water savings was estimated using a weighted average of the supplies. The resulting water savings associated with each WUG was then applied to the WUG total demand which included those portions that are projected to be met with other sources including ground water. When a municipality experiences drought conditions, drought management measures will be implemented on the entire demand. This is especially true in many large municipal systems which utilize both groundwater and surface water or have alternative water supplies. The resulting water demands projected during the drought of record (DOR Demand) for each WUG associated with the surface water reservoirs detailed in this study are provided in Appendix E.

Section 7 – Impacts of Drought Management of Future Water Management Strategies

Implementation of drought management plans will have effects on annual water demands when implemented during drought conditions. Reduced demands during drought conditions however, does not allow water supplies to be reallocated to meet demands elsewhere. Unlike conservation strategies, water savings from drought management are only available during drought conditions. As a result, supplies offset by the projected water savings are not reliable and can not be reallocated to meet other demands. The additional annual supplies made available from each reservoir as a result of implementing DCP measures are illustrated in the following figures.

Figure 7-1. Additional Lake Livingston Supply

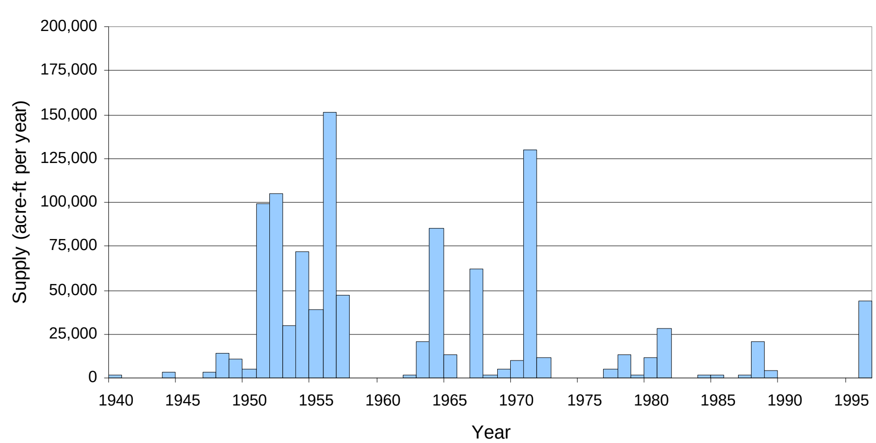


Figure 7-2. Additional Lake Conroe Supply

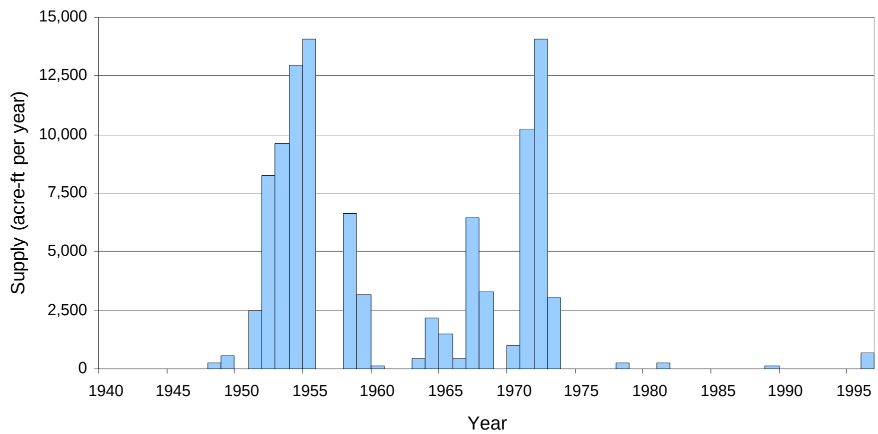


Figure 7-3. Additional Lake Houston Supply

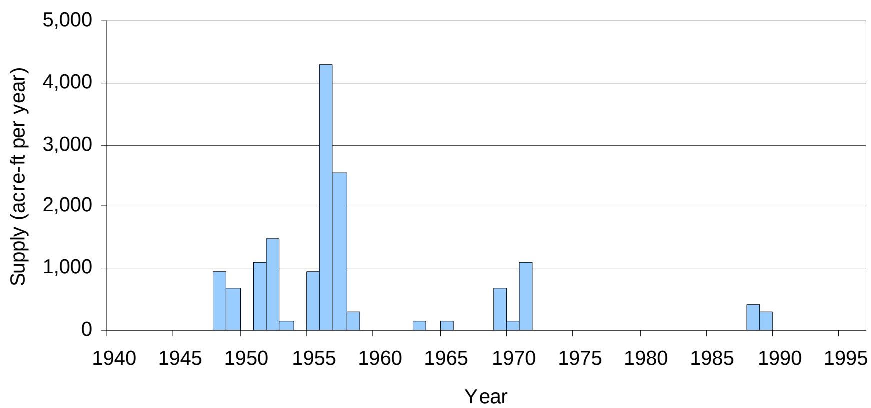
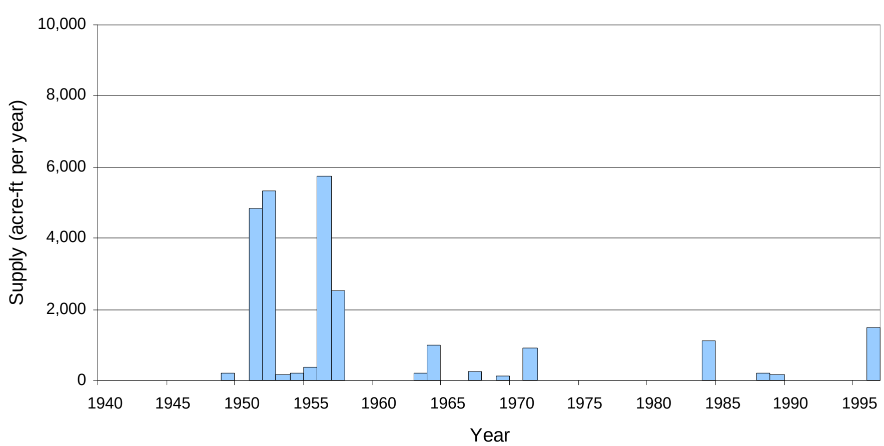


Figure 7-4. Additional Allens Creek Reservoir Supply



It is evident from the previous figures that additional supplies are only made available during drought conditions while drought management measures are in effect. The annual quantity of the additional supplies is dependant on several factors including the duration and magnitude of the imposed demand curtailment during each drought stage. In practice, the effectiveness of each stage due to factors including enforcement, public perception, demand hardening, ect., may reduce the magnitude of water saved as a result of implementing drought management measures.

Although, the additional supplies made available are not reliable, the volume of water saved can be significant. In Lake Livingston, over 150,000 afy was saved in the year 1956 alone. Although the water savings in this year is greater than the 2060 municipal conservation strategies recommended in the 2006 Region H Plan (101,200 afy), the volume is only available in roughly 2% of the years over the period of record. The conservation strategy however, reduces shortages in normal and dry hydrologic years. While DCP measures only produced additional annual supplies in 60% of the modeled years, the additional supplies could be used on an interruptible basis to provide freshwater inflows into Trinity Bay during drought conditions. Water savings in the San Jacinto and Brazos Basins were not as significant. 12,500 afy of additional supply would be available from Lake Conroe in approximately 5% of the years modeled. Modeling DCP effects on Lake Houston resulted in a maximum water savings of over 4,000 afy in 2% of the years modeled. Similarly, Allens Creek had a maximum water savings of over 5,000 afy available in approximately 4% of the years modeled. Table 21 shows the reliability of additional minimum (>0 afy) and maximum supplies made available by implementation of drought management measures.

Table 21. Reliability of Additional Supplies

Source	Source_ID	Reliability of Minimum Annual Supply		Reliability of Maximum Annual Supply	
		Volume	Reliability	Volume	Reliability
Lake Livingston	084H0	>0	60%	>150,000	2%
Lake Conroe	12900	>0	42%	>12,500	5%
Lake Houston	10030	>0	28%	>4,000	2%
Allens Creek	10060	>0	30%	>5,000	4%

As can be seen in Table 21, the additional supplies are not reliable enough to be allocated to municipal and industrial uses which generally require a high degree of water reliability. The supplies could however, be used to supplement existing water rights that are less than 100% reliable. The conjunctive use of an interruptible water right and water saved through implementation of DCP measures could be used to meet demands requiring "firm" supplies in lieu of more costly water management strategies. Identifying potential uses for a conjunctive use strategy depends on several factors including the proximity of demands and the timing of the interruptible supply shortage and the water made available through DCP measures. In the Trinity Basin, a surplus of water is available for consumptive use diminishing any incentive for developing a conjunctive use strategy. In the San Jacinto basin, significant municipal shortages (120,973 afy)[2] are projected in Harris County by 2020 and are projected to be met primarily by importing water from the Trinity Basin into Lake Houston via the Luce Bayou Project. The maximum annual supply that could be made available in Lake Houston and Lake Conroe through DCP measures (16,500 afy) would not be capable of meeting the 2020 projected municipal shortage in Harris County even with reduced demands during drought of record conditions. Additional supplies in Lake Livingston would not be accessible to areas in Harris County with projected shortages without the Luce Bayou Project to convey the water to Lake Houston. Additional supplies from Allens Creek could only be made available in approximately 30% of the years over the period of record and could only produce a maximum of 5,000 afy with an annual reliability of 4%. Additional supply from Allens Creek does not have a high reliability required to be allocated as part of a conjunctive use strategy to meet municipal demands.

[2] 2006 Region H Water Plan Chapter 4, Table 4-1

Additional supplies could also be utilized through the effective implementation of drought management measures in cases where reservoir firm yield is below the permitted amount. Lake Livingston, Houston and the future Allens Creek reservoir are all projected to be firm through the planning period. Lake Conroe, however, is projected to have a firm yield of 74,300 afy in the year 2060, short of the permitted 100,000 afy. An additional 25,600 afy of supply from Lake Conroe could be utilized if a successful drought plan is implemented. Due to the length and severity of drought conditions on Lake Conroe, a successful plan would likely require the use of ground water as an alternative source of supply during low lake levels. This would allow a conjunctive use of an additional 25,600 afy of supply from Lake Conroe and groundwater to be used to meet municipal demands in Montgomery County. This would reduce the need for an inter basin transfer of supplies from the Trinity Basin to meet demands in the San Jacinto Basin. Currently, 50,000 acre-ft of TRA supply in Lake Livingston is projected to be contracted by SJRA and transferred to Lake Houston via Luce Bayou to meet demands in Montgomery County. Use of additional supplies from Lake Conroe would reduce the magnitude of the TRA – SJRA transfer from 59,000 afy to approximately 33,400 afy, although the magnitude of this alternative is not sufficient to offset the need for a project to provide water from the Trinity River Basin in Montgomery County. In addition, the use of groundwater during a drought of record to off-set surface water shortages is a concept that would require planning and approval by local regulatory agencies (i.e., Lone Star Groundwater Conservation District). The LSGCD is developing groundwater reduction rules for Montgomery County which will require the conversion from groundwater to an alternative (i.e., surface water) source of water over time. A strategy utilizing conjunctive use of groundwater during drought conditions would need to be approved by LSGCD as part of the overall conversion strategy for Montgomery County.

Due to the interruptible nature of water saved through drought management measures, the additional supplies can not be allocated to additional users as “firm” water. The additional supplies could however, be utilized conjunctively with another supply as part of a conjunctive use strategy affecting the timing and magnitude of water management strategies recommended in the 2006 Region H Water Plan. The possible impacts are summarized below.

Table 22. Impacts on Recommended Water Management Strategies

WMS	Yield(ac-ft/yr)	Starting Decade	Impact
Municipal Conservation	101,200	2000	-
Irrigation Conservation	77,900	2010	1
Industrial Conservation	TBD	2000	-
Expanded Use of Groundwater	91,497	2010	-
Expand/Increase Current Contracts	68,300	2010	-
New Contracts from Existing Supply	215,400	2010	-
Luce Bayou IBT Conveyance	N/A	2020	-
BRA System Operations Permit	120,000	2010	-
Allens Creek Reservoir	99,700	2030	-
Little River Off-Channel Reservoir	32,100	2050	-
Non-Municipal Contractual Transfers	21,000	2010	-
Wastewater Reuse for Industry	67,200	2020	-
TRA to Houston Contract	150,000	2030	-
TRA to SJRA Contract	50,000	2030	2
Houston to GCWA Transfer	42,000	2010	-
Houston Indirect Wastewater Reuse	98,000	2050	-
NHCRWA Indirect Wastewater Reuse	31,400	2060	-
Lake Houston Additional Yield	13,500	2010	-
Freeport Seawater Desalination	33,600	2020	-
Brazos Saltwater Barrier	N/A	2030	-

WMS	Yield(ac-ft/yr)	Starting Decade	Impact
Redesignation of Existing Water Rights	N/A	2010	-
New San Jacinto River Water Rights	0	2010	-
New Harris County Bayous Water Rights	0	2010	3

1. It is feasible that additional supplies made available during drought conditions could be allocated to irrigators on an interruptible basis; however this use is not recommended in lieu of implementing irrigation conservation.
2. Conjunctive use of Lake Conroe supplies and groundwater could provide an additional 25,600 acre-ft of reliable supply to Montgomery County delaying the starting decade from 2030 to 2060 and reducing the strategy volume.
3. Saving water during drought periods in addition to capturing interruptible water at Lake Houston will reduce operational costs associated with transferring supply from the Trinity Basin.

In general the use of water saved through the implementation of drought contingency measures is limited to an interruptible or conjunctive use supply source. The use of additional supplies made available in Lake Livingston prior to the construction of the Luce Bayou Project would be inaccessible to projected demands in the San Jacinto Basin; lacking the required conveyance infrastructure. As a result, water saved in Lake Livingston would be more beneficial to preserving lake levels and freshwater inflows into Trinity Bay. Similarly water saved in Lake Houston would not impact the size and timing of the recommended water management strategies, but would help reduce operational costs associated with transferring supply from Lake Livingston. Additional supplies in Allens Creek would be available only 30% of the years modeled. This would limit its use as an interruptible supply and would be more beneficial as extra storage in the event that drought conditions exceeded the drought of record. The most effective use of drought management to provide additional supply is found in Lake Conroe requiring the conjunctive use of surface water and ground water. Successful implementation of a conjunctive use strategy would be able to provide 25,600 afy of supply from Lake Conroe reducing the volume of water projected to be transferred from TRA to SJRA and delaying need for the transfer until 2060. The full utilization of existing supplies through a conjunctive use strategy would be recommended before inter-basin transfers.

Section 8 – Summary and Closing Remarks

The components of drought contingency planning and the quantitative impacts that drought contingency measures potentially had on water supplies in Region H were investigated in this study. The study included a survey of the TCEQ drought impact plan. 133 public water suppliers were found to have been on the TCEQ drought impact list one or more times between 1996 and 2008. The majority of these systems are located in Harris County (24%) and Montgomery County (32%).

Most of the systems on the list were very small in size, it was found that 74% of them serve less than 1,000 connections. The Majority of systems (79%) rely on groundwater supplies. Based on TCEQ classifications, most utilities only required voluntary measures (35%) or mild “rationing” (47%); some (16%) were classified as having implemented severe ‘rationing”

Analyzing the drought impact list yielded that there is no indication that any Region H public water systems have experienced an “actual” water shortage situation in recent history. Available information indicates that the reason those systems were on the TCEQ list was because of water production and/or distribution infrastructure limitations relative to high seasonal peak water demands.

The effectiveness of drought response measures was also investigated as part of this study; the study found that there is very little “good” empirical research to quantity the effectiveness of drought response measures. Most water suppliers that have implemented DCPs have not thoroughly evaluated the effects. “Post-event” analyses was found to typically only report “gross” changes in water demand, most commonly expressed as a percentage reduction. Most DCPs whether within Region H or nationwide specify multiple measures for each stage (e.g., restrictions, education, pricing). Those measures are always synergistic rather than additive effects and are difficult to isolate the discreet effects of specific measures.

It was also found that most DCPs in Texas are focused on seasonal peaking problems rather than actual water shortage and are always addressed at peak shaving.

Impact of drought contingency plans on Region H reservoirs was investigated in this study. It was found that DCPs have little near-term efficacy as current water demands are low relative to available supply. Efficacy of drought contingency planning will increase as demands on each source approach full permitted authorizations and/or the firm yield of the source. In general, implementation of DCPs could minimize the drawdown of Region H reservoirs and shorten the duration of impacts on lake levels during a repeat of drought-of-record conditions. However, the analysis indicated that this “stretching” of water supplies due to drought contingency measures are relatively insignificant in terms of an annual increased supply and certainly not significant in the context of long-term water planning. The DCP for Lake Conroe, for example, may warrant modification in the future to allow utilization of the full authorized diversion of 100,000 afy, which exceeds the estimated firm yield of 74,300 afy based on the projected 2060 area-capacity curve of reservoir.

Finally, impact of drought contingency plans on existing water management strategies in Region H was analyzed; it is necessary to mention that implementation of drought management plans will have effects on annual water demands when implemented during drought conditions. Reduced demands during drought conditions however, does not allow water supplies to be reallocated to meet demands elsewhere. Unlike conservation strategies, water savings from drought management are only available during drought conditions. As a result, supplies offset by the projected water savings cannot be reallocated to meet other demands.

So to go back to the key question of this study *“Can a strategy of implementing drought response measures (e.g., staged curtailment of water demands) within Region H during critical drought periods be used in lieu of recommended water management strategies to meet projected needs?”*

The results of this study indicate that, while drought contingency planning is a critical component of water supply management and may provide short-term benefits during severe drought conditions; drought management alone will not replace any recommended long-term water management strategies. This conclusion is based on the following:

1. According to the current Region H Plan, there are no unmet water supply needs associated with existing reservoirs.
2. The current Region H Plan, therefore, does not include water management strategies that could be replaced by demand curtailment during drought. However the magnitude and timing of the TRA to SJRA inter-basin transfer strategy would be affected by the conjunctive use of existing supplies in Montgomery County. Conjunctive use of existing supplies would be recommended prior to inter-basin transfers.
3. Implementation of DCPs would not “free up” water supply for use by others because the demand reduction would only occur during critical drought – demand curtailment is not the same as water conservation.
4. During “normal” conditions, water supply would be needed to meet full unconstrained demand.
5. Current TWDB policy for regional water supply planning requires that all identified water supply needs, based on drought-of-record conditions, be satisfied except in cases where there are no feasible strategies.

6. Drought contingency measures were shown to be effective in “stretching” water supplies during drought conditions. However, this “stretching” of supplies during drought were measured in terms of months and therefore, while this may be critical for an individual supply in crisis, is insignificant in the context of long-term water planning.
7. Drought contingency planning and the various measures implemented to curtail demand during severe drought conditions are very critical components of any water supply management plan. These plans should be evaluated often and the actions enforced when needed to curtail demand and potentially extend water supplies during drought conditions. However, these measures alone will not replace the need to implement recommended long-term water management strategies.