DRAFT—NOT FOR PUBLICATION

WATER USE AND AVAILABILITY IN THE ERCOT REGION

Drought Analysis

BLACK & VEATCH PROJECT NO. 162854

PREPARED FOR

ERCOT

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1 Executive Summary

In 2011 Texas had its worst single-year drought on record. This was widely publicized in the news media and was a concern for many water users, including power generators. The average rainfall across the state in 2011 was 14.89 inches, the lowest on record and below the previous record of 14.99 inches which was set in 1917. In addition, the 12-month period between October 2010 and September 2011 was the driest 12-month period ever recorded with an average rainfall of 11.18 inches across the state. Normally the state average rainfall is approximately 28 inches by comparison.

Since late 2011 ERCOT has been providing monthly updates of reservoir levels at power plant locations with certain risk factors including reservoir level compared with previous lows and megawatts at risk. An initial survey of generating units and request of information to generators regarding an assessment of drought risk has also been conducted. A number of other studies were initiated with reference to the long-term drought effects on power generation including projects managed by Sandia National Laboratories and Argonne National Laboratory. These studies which were developed for ERCOT and WECC, were based on the hydrology of Texas (and the other western states for the WECC portions), streamflow, modeling and reservoir storage. Groundwater, wastewater, and brackish groundwater costs were also included in these analyses.

Initial review of survey data provided by the generators and the actual unit history from 2011 have shown that most generators were prepared for, or had contingency plans for a single-year severe drought such as experienced in 2011. The more complex issue for generators in Texas appears to be a multi-year drought when water storage is further diminished. A multi-year drought occurred in Texas between 1950 and 1957. While this drought was not as severe on an individual year basis as 2011, this is still the period of record for extended drought across most of the state.

ERCOT contracted with Black & Veatch to review the analysis completed by Sandia and Argonne National Laboratories and to assist in linking these studies to ERCOT needs and development of a gap analysis to enable more detailed risk analysis of a multi-year drought scenario.

1.1 POWER GENERATION WATER USE

One of the driving factors for analysis of water supply and availability for power generation during drought is the misunderstanding of water withdrawn versus water consumed. Many reports have stated that power generation is the largest single user of water in Texas with over 49% of the demand for the whole state. What is not often stated is that this is the amount withdrawn. The actual amount consumed is approximately 3%. While this is still a significant amount it is by no means the greatest consumption. As an example this amount consumed is very similar to the amount of water loss as reported by municipal water utilities in Texas (i.e. the amount of water that is treated by municipal utilities, but does not reach the customer due to leakage, main breaks, and non-revenue uses).

There do appear to be sufficient water resources within the state to allow building of additional thermal units if deemed appropriate. However, the specific technology and cooling system does need to be managed carefully, but all types of unit should be considered when determining resource adequacy and siting of new generation units.

1.2 IMPROVING RELIABILITY, EFFICIENT WATER USE

Water shortages and lack of water availability for power plants can lead to plant outages, or reduced utilization that can cause reliability problems especially during periods of peak demand. Most generators in the ERCOT region do appear to have contingency plans in place to mitigate short-term, severe drought such as what occurred in 2011.

Efficient use of water is also important to maximize the resource and to extend the potential for generation through those droughts. There are many types of power generation technologies which allow for different fuels to match varying demand, supply and pricing. There are also different technologies for cooling which can increase or reduce the amount of water used. While it appears on the outside that air cooling is the best option for conserving water, there are many other considerations that influence the desirability of this technology. In almost all locations air cooling is more expensive than water cooling, except where the cost of water is exceptionally high. Air cooling also generally uses more power itself, thereby reducing the efficiency of the unit compared to wet cooling. However, it is also obvious that in water-short areas air cooling may be the most effective and environmentally sensible technology for thermal units.

Due to the increasing view that drought is a new-normal in Texas and to reduce risk further it is expected that large water withdrawing and consuming applications such as once-through cooling facilities are only considered for future development in locations (or from storage sources) with averages of more than 35-inches of rain per year or from existing storage locations with water availability.

Drought effects on electric reliability should be assessed in the context of weather zone and rainfall patterns in addition to the normal cost factors when determining new generation sites and technologies. There are often competing factors where sites with low water withdrawal amounts may actually consume more water with respect to the actual gallons per MWh produced.

The current resource-mix is varied and it is expected that the water resource mix to meet these generation demands will also stay varied for the foreseeable future.

2 Background Information

2.1 ERCOT, DROUGHT PREPAREDNESS, AND THE LONG TERM SYSTEM ASSESSMENT

Texas Senate Bill 20 requires that ERCOT study the need for increased transmission and generation capacity every two years and report the findings to the legislature. This provides a view of the needs 10-years into the future. Due to the severe drought in 2011 it was decided that a drought analysis be developed for the generating locations currently operational. Any problem areas could then be defined and alterations in the long term system assessment made. In addition, ERCOT wanted to improve system reliability by understanding the nature of drought with respect to the generation facilities both in the short- and long- term. This report outlines the study data evaluated and the recommendations developed.

This was conducted in conjunction with a long-term drought analysis prepared by Sandia Labs that includes both the ERCOT and WECC territories. The analysis' data was peer reviewed to increase its usefulness to ERCOT and to provide the foundation for some of the discussions of water availability.

In 2011, Texas had its worst single-year drought on record. This was widely publicized in the news media and was a concern for many water users, including power generators. The average rainfall across the state in 2011 was 14.89 inches, the lowest on record and below the previous record of 14.99 inches which was set in 1917. In addition, the 12-month period between October 2010 and September 2011 was the driest 12-month period ever recorded with an average rainfall of 11.18 inches across the state.

2.2 POWER GENERATION IN TEXAS

Texas has a diverse mix of different generating technologies including wind. Texas led the Nation in wind-powered generation nameplate capacity in 2010, and was the first State to reach 10,000 megawatts. However, this is still a minority of the power generated in the state. The current nameplate capacity for each of the main generation types is outlined in Table 1 below.

Table 1. Power generation nameplate Capacity in Texas in 2013

(Source: ERCOT Capacity Demand and Reserves Report update – May 2013[1])

GENERATION TYPE (2013)	NAMEPLATE CAPACITY (MW)
Natural Gas	49,337
Coal	19,115
Nuclear	5,150
Hydro Power	521
Wind	10,035

[1] http://www.ercot.com/content/news/presentations/2013/CapacityDemandandReserveReport-May2013.pdf (Summer fuel types 2014)

Solar	124
Combustion Turbines	5,516

Wind, solar and combustion turbines are assumed to use no water. There is water involved in the process to develop the raw materials and construct the projects, but this is assumed to be negligible over the lifespan of the projects and is not discussed further here.

There are also a number of different providers of the electricity including privately- and publically-held independent power producers, cooperatives and municipal providers. The current status (2012) of this breakdown of power generation is outlined in Figure 1. Recently the largest amount of investment (since 2000) has come from privately-held and publically-held independent power producers.

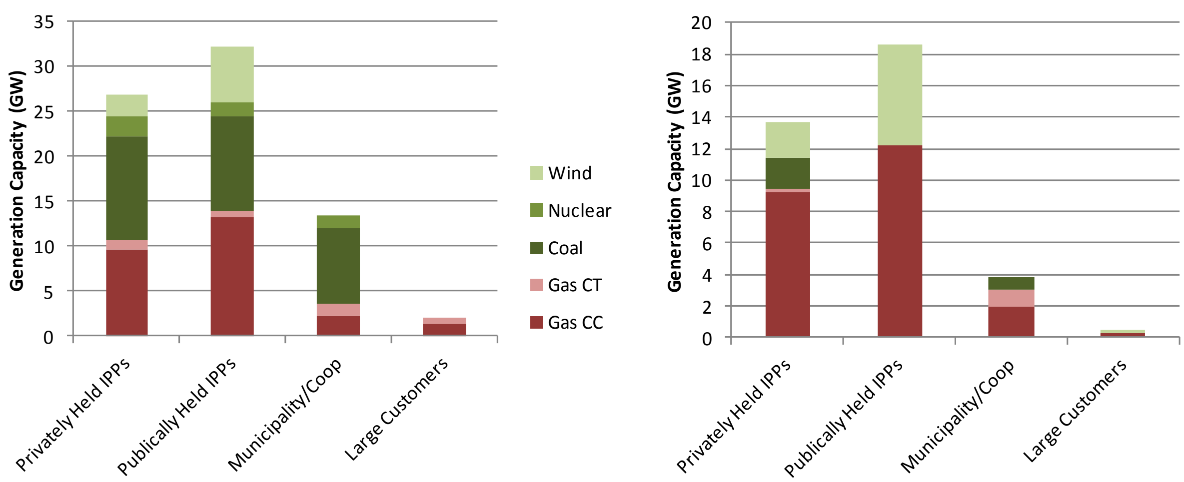

Figure 1. Existing and Future Generation by Investor Class

(source: Brattle Group Report, 2012, graphic reconfigured)

2.2.1 Cost of Water

Water is a comparatively low-cost item for power generators in normal running of existing systems. However, the development of large water resources and the cost to the generator when water becomes short in supply can raise prices and management complexities significantly.

The most costly water supplies in Texas only add $3 or so per MWh during normal operation. This is true for water supplies purchased from municipalities where costs can rise to $10 per 1000 gallons, or for projects with significant capital investment needed. This is a cost factor to consider, but is usually dwarfed by the operations and maintenance and fuel costs. The main focus is therefore directed to when the resource becomes unavailable or restricted and generation units have to shut down or significantly de-rate.

2.2.2 Water Use

A common misunderstanding in studies of power generation water supply by entities external to the industry is the difference between water withdrawn versus water consumed in the cooling cycle. Many reports have stated that power generation is the largest single user of water in Texas with over 49% of the demand for the whole state. What is not often stated is that this is the amount withdrawn and a very large amount of this is recirculated into the same water body it was withdrawn from. The actual amount consumed is approximately 3% of the state total. While this is still a significant amount it is by no means the greatest consumption in Texas. Figure 2 below shows the water consumption by major water group within the state.

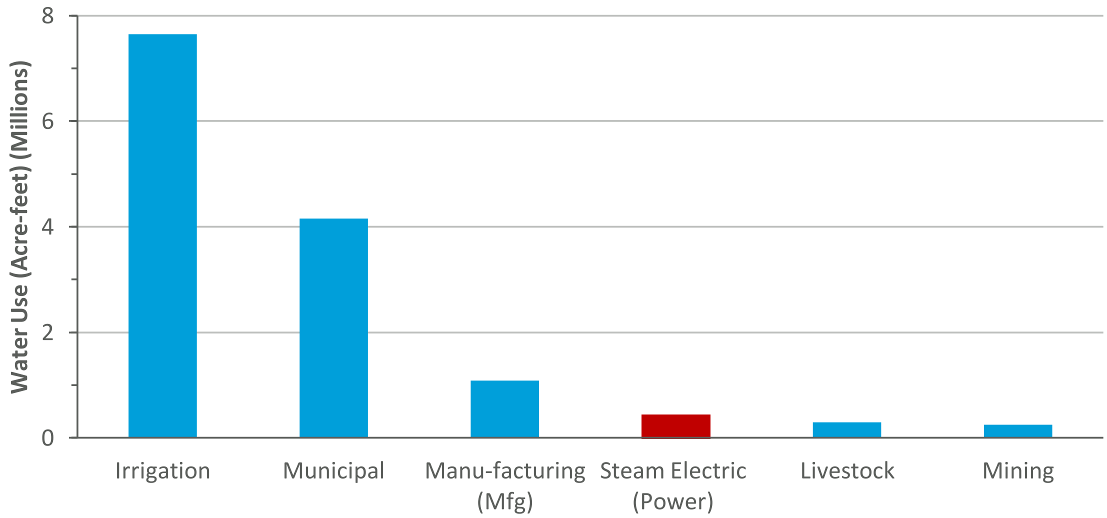

Figure 2. Water Use in Texas (2010) by Use Type

Water shortages and lack of availability can lead to plant outages, or reduced utilization that can cause reliability problems especially during periods of peak demand. In terms of electric reliability, water supply is an important factor for over 70% of the nameplate capacity. Therefore, the focus of this analysis is on water availability and its effect on power generation. In order to analyze this, the cooling methods, different water supplies, storage locations and drought potential will be discussed.

2.3 BASIC GENERATION UNIT OPERATIONS

Each generation technology has differing potential to be affected by drought. This includes the generation and cooling technology. Obviously water use and availability is the major component related to drought conditions, but increased temperatures and increasing cost of water supplies are also often coincident with drought (especially in the summer) and these can affect efficiency and generation capacity as well.

2.3.1 Steam Thermal Units

As a part of the process of converting fuel to electricity, many generation plants withdraw water from surface water sources, use this water for cooling various plant systems, and then return the water to the river or lake. During this process, the cooling water temperature rises. To protect the receiving water, the NPDES permit for each plant includes limits on the maximum discharge temperature and, in some cases, the instream temperature regime. To comply with these NPDES permits, all generators with these permits have to monitor water temperatures at each plant and manage water releases to assist in meeting permit requirements. If the quantity of water available for release is limited or its temperature is elevated (a condition that typically occurs in late summer months when rainfall and runoff is low and ambient temperatures are high), options to either alter river flows or derate the plants are evaluated. The most favorable option is implemented and can vary from day to day.

If the generating plant's output must be derated to meet thermal limitations due to constraints on available water releases, the energy must be provided by an alternate, and typically more expensive, generation source. Under extreme conditions, it is possible that the system load requirements would not be met and brownouts or blackouts could result. Nationally it is not uncommon for generators to derate their coal-fired plants for some period of time each summer to meet NPDES permit requirements. Nuclear plants are derated only occasionally.

2.3.2 Natural Gas units

In the United States, natural gas prices have fallen in recent years because of the stagnant economy, weakened demand for electricity and increased shale gas production supply. This has led to a reduction in coal-fired electricity generation, with some of the coal-fired generation being replaced by natural gas-fired generation. Low natural gas prices and static coal prices have created a business opportunity for power producers to switch from coal-fired to underutilized natural gas-fired power plants. In addition, increasingly stringent environmental regulations will require many coal-fired units to be retired or to be retrofit with emissions control equipment for continued operation on coal. This paper explores several technically feasible options available in the current market.

The selection of the most advantageous option is influenced by factors such as performance, capital cost, operating cost, fuel flexibility and emissions control requirements. Other factors to consider are ease of integration with the existing plant, the possibility of reusing existing balance-of-plant equipment, operating flexibility, operations and maintenance costs, and technical risk mitigation. Often, the characteristics of the coal-fired unit dictate the most advantageous generation option. The vintage, size, site characteristics and emissions control equipment currently in place can define which option is the most cost-effective and capable of aligning with the current business model.

2.4 GENERATION AND TRANSMISSION CAPACITY AFFECTED BY DROUGHT

Generation capacity will be affected if drought conditions do become severe enough to alter the water supply characteristics of an area. When a senior water rights call happens this is one of the first signs that risk has increased significantly. Currently the TCEQ views the municipal and power generation water rights as the most important and has not curtailed them, but there may come a time in the near future when certain municipal and power generation rights cannot be met.

The aim of this study and modeling is to warn ERCOT and the power generators and get in front of these risks in order to plan on current and future generation which will be significantly affected by drought conditions of record (such as in the 1950s or a multi-year drought with multiple years similar to 2011).

2.5 POWER GENERATION WATER SUPPLIES

Texas has a varied portfolio of water resources including significant surface water, groundwater, brackish groundwater and seawater. There are also the secondary sources of reused, or recycled water.

2.5.1 Surface water - Reservoirs/Lakes

Many power generators in ERCOT access water for cooling and other uses from reservoirs and lakes. These are often built specifically for power generation. There are a few which have hydroelectric components (for example, Lake Texoma and, Lake Whitney), but these have minimal generation capacity (less than 100MW each) and so are not considered significant in this analysis.

2.5.2 Off-channel Reservoirs (including systems with river intakes)

Most of the river intakes are utilized as part of an off-channel reservoir of some sort. A number of the lake cooled systems also have a secondary water source such as a water right from a nearby river or estuary. Examples of this include; Dansby (Bryan Lake), Valley (Valley lake), Comanche Peak (Squaw Creek Lake), and the South Texas project (STP Lake). STP accesses water from the Brazos river. The Valley plant in North Texas gets its supply from the Red River.

2.5.3 Groundwater

Groundwater is not currently considered as a major resource for power generation in Texas. However, future analysis may well include groundwater due to the needs for drought-proofing of power plants and the possibility for desalination and the power requirements (and water use) that those systems will need. This has not been studied in the Sandia work, but will be analyzed briefly in this report.

There are a small number of groundwater-supplied systems in the ERCOT region as shown on the associated graphic Figure 5.

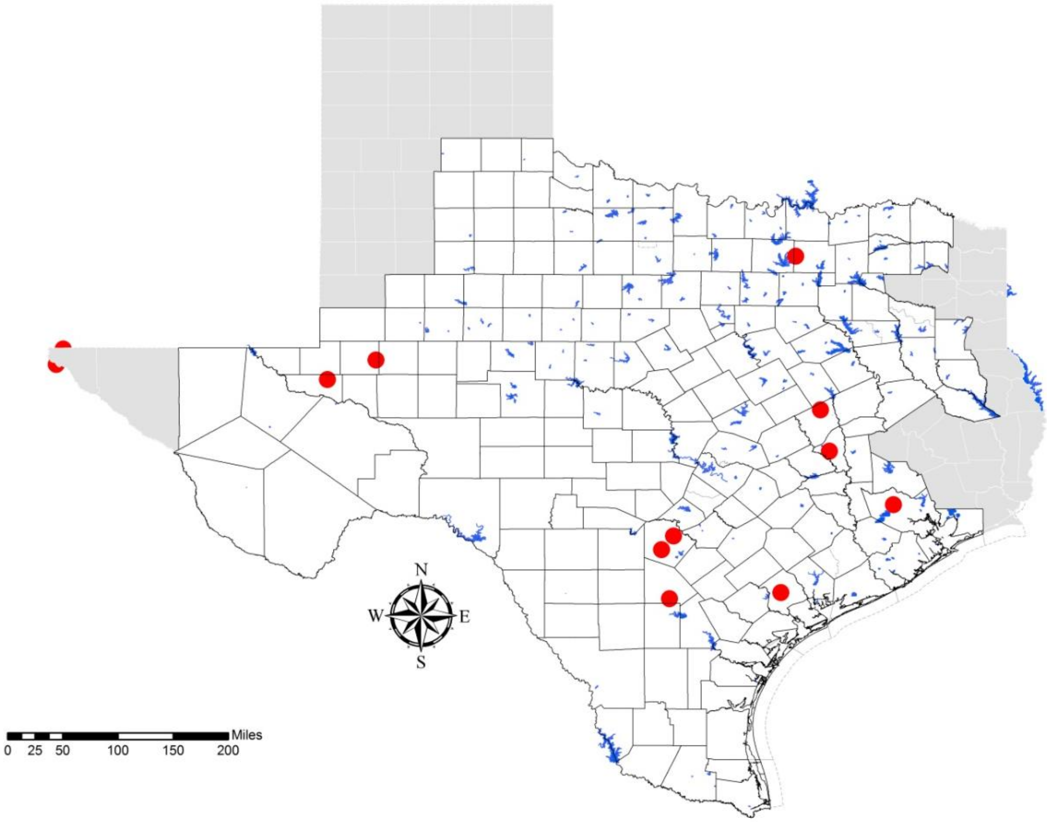

Figure 3. Groundwater Supplied Units

2.5.4 Brackish Groundwater or Seawater

Brackish groundwater (basically a mixture of fresh and salt water) is prevalent in many locations within Texas. Many of the potable aquifers within the state have deep sections which are brackish. These include the Hueco-Mesilla Bolson (used by El Paso Water Utilities as a potable resource and a brackish resource in different locations), the Carrizo-Wilcox and the Gulf Coast aquifers. If demand is sufficient and cost considerations can be overcome these can be significant resources for the state. Seawater is also an option along the Gulf coast and is already utilized or available in a small number of locations.

2.5.5 Municipal Supplies (Direct from Distribution System)

Municipal supplies have the same origins as the sources outlined above. However, this adds an extra layer of uncertainty for a power generator as they often do not have control over these water rights. In some cases it is possible that the supplier will be forced into a specific water allocation or conservation reduction and may pass this reduction down to the power generator. In these cases, a derating of the facility may be necessary if the water supply does not match the plant requirements.

2.5.6 Reuse

Reuse, or recycled water is generally purchased from a municipal entity as it leaves their treatment plant. There are currently at least five sites and approximately 4,000 MW of generation which is produced reportedly utilizing a reuse water supply. Since most municipal reuse water is derived from sewer flows, the volume available is driven by the sewer inputs. In the long-term if municipal water conservation significantly reduces use it will also reduce sewer flow. However, this is not expected to affect reuse water availability in the planning horizon. Reuse water is expected to become a more highly utilized resource for power generation in the future due to it being available in large volumes at a single source location (from large waste water treatment plants), and it will generally be a lower price than other municipal supplies. Obviously there are still water quality and river rights to be included in any availability and cost analysis.

2.6 RESERVOIR STORAGE

Reservoirs in a number of locations around Texas were analyzed to gain an understanding of the differing water demand conditions. Resources in North Central Texas have large consumption requirements and steep demand gradients on each of the power generation lakes due to the significant municipal supply needs and other growing demands (Table 2). This trend is likely to increase.

Table 2. North Texas Reservoirs with Power Generation – Demand Indicators

LAKE	MW IMPACT*	WATER LEVEL (ABOVE MSL)	RESERVOIR TOTAL DEPTH (FT)	WATER LEVEL LOSS PER MONTH (FT)**
Arlington	1265	550	45	2.24
Bridgeport	1865	836	84	2.13
Lavon	406	492	39	1.86
Granbury	278	693	53	1.57
Others (not top 4)				
Ray Hubbard	916	435	47	0.84
Mountain Creek	800	457	55	0.78

***MW - Megawatt**
****Water level loss in feet during the summer months of 2011**

In the Lower Colorado river basin the system is operated slightly different in that two reservoirs, Buchanan and Travis, are the main resources behind the operation and health of all the other reservoirs in this system. In essence these two reservoirs keep all the other six reservoirs at a stable level. This means that those two reservoirs have highly variable demands as can be seen by the two values in water level loss on Table 3 for Lake Buchanan of between 0.8 feet per month during normal demand and 5.5 feet per month during releases to other reservoirs and downstream users.

Table 3. Lower Colorado Reservoirs with Power Generation – Demand Indicators

LAKE	MW IMPACT	WATER LEVEL (ABOVE MSL*)	RESERVOIR TOTAL DEPTH (FT)	WATER LEVEL LOSS PER MONTH (FT)
Buchanan	54.9	991.84	82.5	0.8/5.5
Inks	13.8	887.18	44	n/a
LBJ	480	824.6	32	n/a
Marble Falls	41.4	736.44		n/a
Travis	108	631.03	145.1	1.7/6.8
Austin	17	492.15	30.8	n/a
Bastrop (Sim Gideon, Lost Pines)	1,119	448.94	60	n/a
Fayette (FPP)	1,625	389.82	70	n/a

* mean sea level

The loss of water level per month was calculated from a four to six-month period between May 1, 2012 and December 1, 2012, determined by the most consistent declines. There are a number of interesting results. For example, Lake Ray Hubbard is within the DFW area, but has significantly lower water level decline compared with others nearby. This is due in part to the extra municipal and industrial use from those reservoirs, but it can give an indication of the time available before water supply in that specific water body may become critical.

In the western regions of the ERCOT service area there are still a few reservoirs which were relatively low throughout 2012 and into 2013 and need to be assessed on a regular basis. Some of the generating lakes at low levels as of April, 2013 are shown on Table 4.

Table 4. Texas Lakes with Low Reservoir Levels in April, 2013

LAKE	MW IMPACT	VOLUME (AFT*)	% FULL (DEC-12)	WATER LEVEL LOSS PER MONTH (%)
Colorado City	407	31,805	29.1	0.8
Kemp/Diversion	650		22	
Champion Creek	-	41,618	11	0.8
Within the Previous Twelve Months				
Texana	920	159,640	34.2	2.8
Lavon	406	456,526	47.6	1.8
Limestone	1689	208,015	49.7	3.3

***AFT – acre-foot (325,851 gallons or 1 acre to the depth of one foot)**

In some of the cases above the generator may have additional water sources to supplement the reservoirs, or else may have other technologies in place to reduce water use. These factors need to be included in any analysis of water availability risk. Examples of power generation units that require a river feed with an off-channel reservoir as the storage medium can be found at a number of locations. These systems will often have a flow minimum recorded in cubic feet per second which will be the driver for water availability. Examples include Lake Bastrop and Lake Fayette as shown on Table 5. The variations shown in this table outline that the withdrawal limits have not been reached to date. However, there has been a trend of declining stream flow over the past ten years which suggests that this may become more of a problem into the future.

Table 5. Stream flow and Withdrawal Limits

RIVER	MW IMPACT	LIMIT (CFS*)	MAY 2013 (CFS)	MIN IN 2012
Bastrop (Lost Pines)	1,119	120	489	190
Fayette	1,625	-	809	318

*CFS – cubic feet per second

2.7 AIR TEMPERATURE

While air temperature is not directly connected to the subject matter of this report it is important to review it in the context of rating and derating of generation facilities. Figure 4 shows an air temperature variation diagram to outline that as the temperature increases above 45^{o}F, the efficiency of a normal system declines. Design points can be altered to change this dynamic, so this data should be used as a guide rather than an exact analysis.

Often there is a mix-up of understanding regarding normal temperature derating (which happens whenever the temperature fluctuates from the design temperature) and when a unit is affected by drought. The year 2011 in Texas was the hottest year on record (approximately 1 degree hotter than any previous year). This would obviously have an effect on the output efficiency of generation facilities. However the connection between the drought and overall temperature increase is difficult to accurately model and has not been attempted in this analysis. It is however, an item that needs to be considered in the future. As an example, if the temperature variations were all causing reductions in efficiency then the overall MW capacity of the combined cycle power plants may reduce by about 0.02%, or 1MW for every 500MW of capacity. Since the story is more complex than this simple example the temperature effects of the drought have not been addressed at this time.

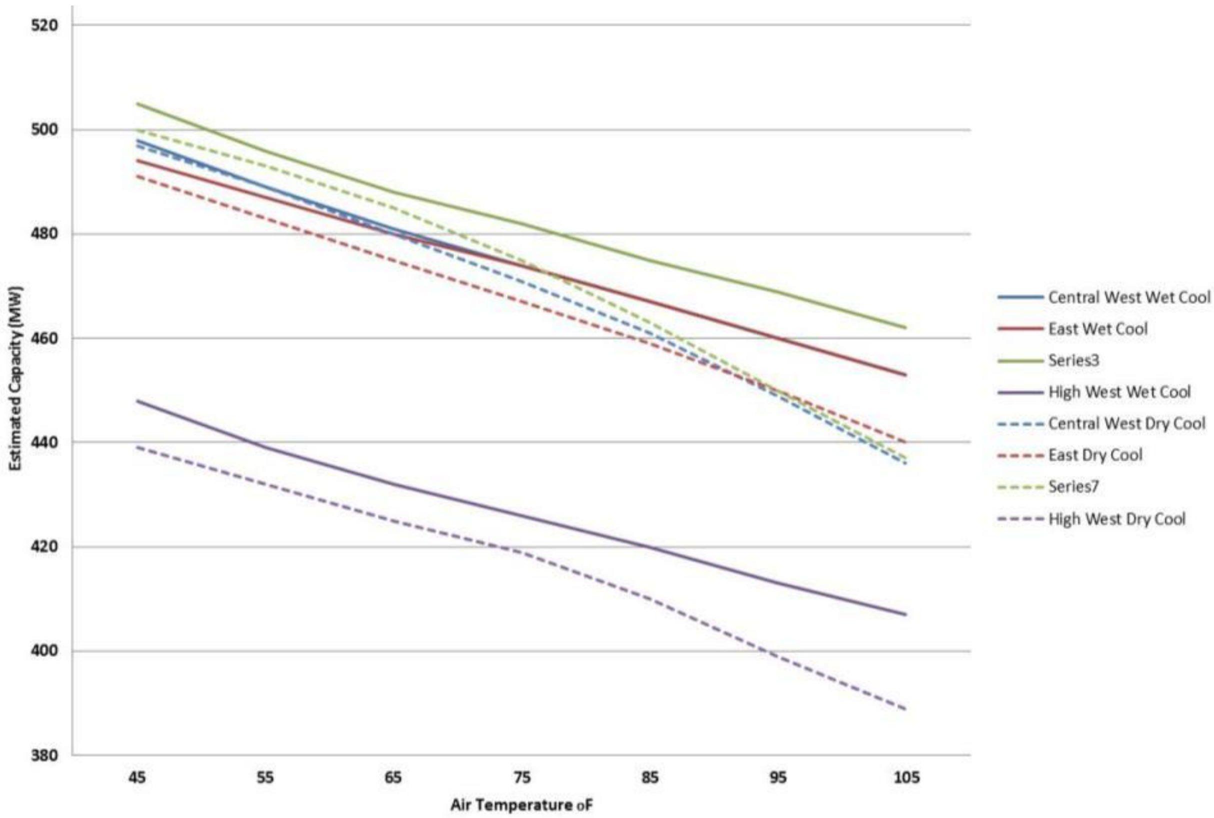

Figure 4. Air Temperature Effects on Power Generation Capacity and Cooling Technology

2.8 WATER RIGHTS

Texas' surface water is owned by the state. The Texas Commission on Environmental Quality (TCEQ) issues permits to applicants on a "first-in-time, first-in-right" basis. A permit does not guarantee that water will be available; it only means that the permit holder is in line to use it. Owners of the most senior rights (the oldest permits) can take whatever water is available up to the permit limit. The remaining water is apportioned in sequence to the holders of junior rights. When drought conditions reduce the amount of available surface water, generally only senior rights can be exercised, although if human health may be affected by a specific allocation, then these can currently over-ride more senior rights if deemed appropriate by TCEQ.

To acquire a water permit an applicant must prove that water is available, that the use is consistent with state law and, occasionally, that a defined amount of water has been obtained consistently from a known source, even if that use pre-dates the permit system.

Texas' groundwater belongs to the owners of the land above it. Under the legal "rule of capture," landowners are entitled to pump as much groundwater as they are able to, as long as the use is not malicious or wasteful, even if pumping it deprives other landowners of water. Once pumped, groundwater may be used or sold as private property.

As of 2012 the state currently had 89 groundwater conservation districts (GCD), which were created under state laws and are governed by locally elected board members. GCDs are allowed to develop well spacing rules, pumping permits, fees and overall pumping limits within their districts.

Under Texas law, GCD enforcement of its rules is one of only two ways to limit groundwater pumping in an area; the other is a judgment in Texas courts, although the Edwards Aquifer Authority can restrict pumping within its statutory boundaries.

2.9 POWER GENERATION CAPACITY AND WATER USE

Water demand is driven by the technology used to generate electricity as well as the power demands of the population in the ERCOT region.

There is an economy of scale associated with generator facility size, whereby the larger the facility, often the lower the water use per MWh (compared to a similar small system). Also, the cooling design can have a significant impact on water use with a significant difference between once-through and recirculating cooling towers as an example.

Another discussion centers on the water withdrawal versus water consumption. Figure 5 shows the water withdrawal versus nameplate generating capacity for a number of Texas facilities. As would be expected the larger facilities tend to withdraw more water. However, the water consumed per kWh (Figure 6) is actually less for these larger facilities.

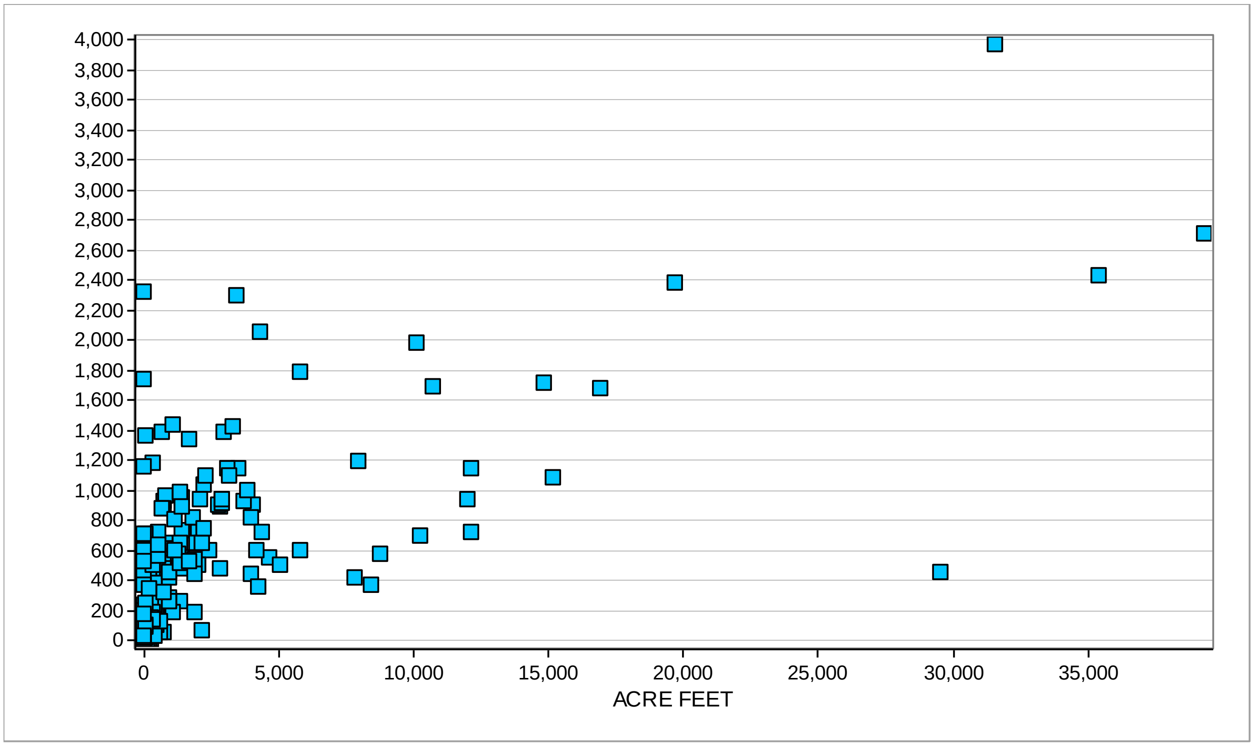

Figure 5. Capacity versus Withdrawal (Acre-feet)

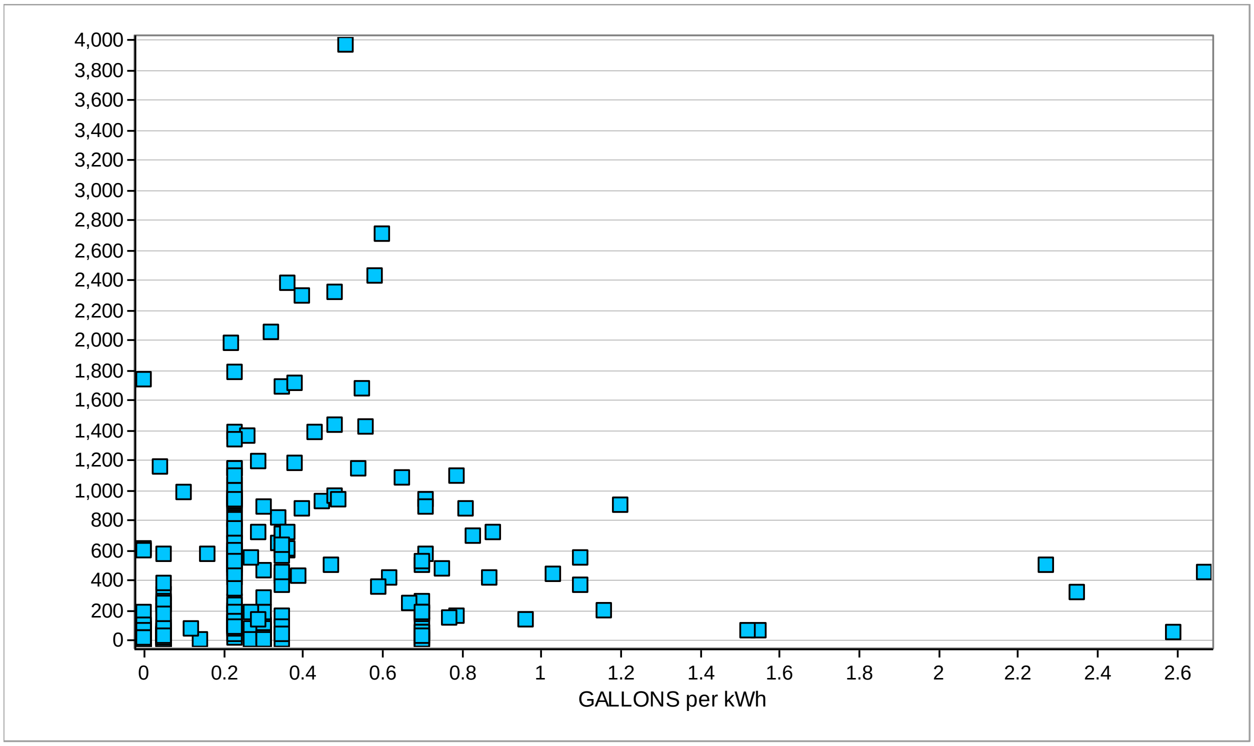

Figure 6. Capacity versus Usage (Gallons per kWh)

As mentioned previously the cooling methods are the driving force behind water use, but capacity can be a contributing factor. The demand for energy from a specific power plant can also affect the water use characteristics as a high nameplate capacity unit only used for peak supply will also use an increased amount of water per kWh compared to a unit that is run constantly and fine-tuned to make the water use more efficient.

2.9.1 Cooling Methods

There are many manufacturers of cooling systems for each power generation unit type. Therefore we will only discuss overall system dynamics, ranges of water use and needs of the different cooling methods. Figure 7 shows some of the various cooling methods and ranges of water use that have been recorded by the National Renewable Energy Laboratory (NREL) The chart outlines the water consumed per MWh (side axis) produced by each of the different generating technologies and cooling systems (base axis). The box and whickers plots outline the total range of the data set and the 25th and 75th percentile values in the box which outlines most of the data points.

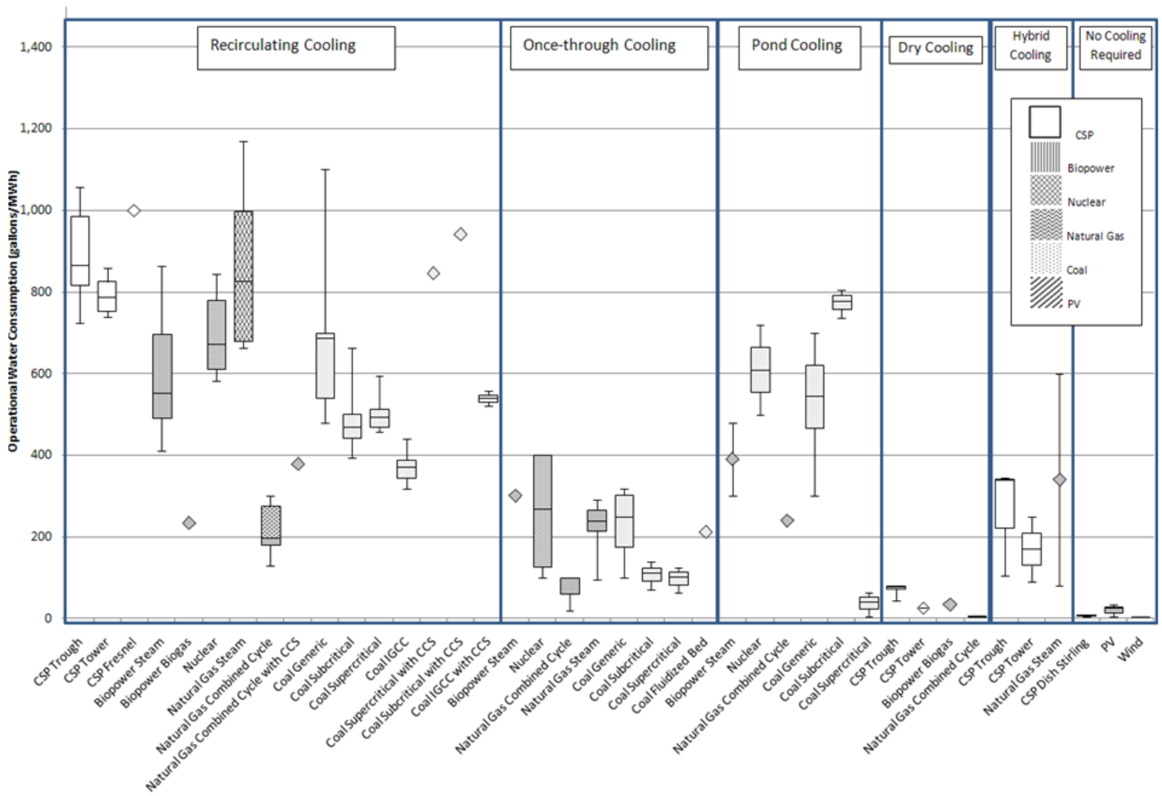

Figure 7. Power Plant Cooling Water Usage Variation (Source: NREL 2011)

The amount of cooling required by any steam-cycle power plant (of an equal size) is determined on the whole by its thermal efficiency. Water consumption variations among power technology types are thus directly related to the efficiency of the system.

The most common types of power plants use water for cooling in two ways: to convey heat from the fuel source to the steam turbines, and to remove and dump surplus heat from this steam circuit. In any steam/ Rankine cycle plant such as present-day coal, natural gas (steam) and nuclear plants there is a loss of about two thirds of the energy due to the intrinsic limitations of turning heat into mechanical energy.

The bigger the temperature difference between the internal heat source and the external environment where the surplus heat is dumped, the more efficient is the process in achieving mechanical work and generating electricity. It is therefore desirable to have a high temperature internally and a low temperature in the external environment. This consideration gives rise to the desire to site power plants alongside very cold water, although this is often not possible in Texas. This is also the reason why many power plants have higher net output in winter than summer due to differences in cooling water temperature.

Dry-, or air-cooling is being considered as a method to reduce the strain on water resources. While air-cooling has generally higher costs and reduced efficiency relative to other cooling technologies, water use is significantly less (but not zero) as shown in Figure 8.

			Cooling Technologies – Water Consumption (gal/MWh)				
			Open-Loop	Closed-Loop Reservoir	Closed-Loop Cooling Tower	Hybrid Cooling	Air-Cooling
Fuel Technology	Thermal	Coal	300	385 (±115)	480	between	60 (±10)
		Nuclear	400	625 (±225)	720	between	60 (±10)
		Natural Gas Combustion Turbine	negligible	negligible	negligible	negligible	negligible
		Natural Gas Combined-Cycle	100	130† (±20)	180	between	60† (±10)
		Integrated Gasification Combined-Cycle	not used	not used	350† (±100)	between	60† (±10)
		Concentrated Solar Power	not used	not used	840 (±80)	between	80† (±10)
	Non-Thermal	Wind	none	none	none	none	none
		Photovoltaic Solar	none	none	none	none	none

†Estimated based on withdrawal and consumption ratios

Figure 8. Cooling technologies and their water consumption

A report from Texas IOU's (2003) outlined the basics of dry-type cooling towers. At the time these were not heavily considered as a method to cool facilities, however this is not the case today. The following is an excerpt from that report.

"Dry-type cooling towers are very expensive and infrequently used, though they are becoming more common in desert climates where water supplies are severely constrained. Because the heat is dissipated directly to air by conduction and convection rather than by evaporation as in a wet-type cooling tower, much more air must be moved through the dry-type tower and the available heat transfer surface must be very great. Both of these factors greatly increase the power requirements of these towers, because of the power needs of the fans utilized to move air across the cooling coils. In addition, the minimum cooling temperatures achievable in dry-type towers are limited by the dry-bulb (rather than the wet-bulb) air temperature, which results in higher turbine exhaust temperatures. In the warmer parts of the country this places a severe penalty upon the efficiency and capability of the power plant. Because of their substantially greater energy and capital cost, it is unlikely that dry-type towers will be used to any great extent in this country in the near future."

These cooling technologies are being considered seriously in 2013, as technology has improved and water resources have become more of an issue. The efficiency issues are still valid, but dry-type cooling warrants further consideration.

2.10 POPULATION CHANGE

The population of Texas is one of the main driving factors for energy demand in the state. It will both drive residential demand and the industrial demands as these are usually sited in close proximity to the population workforce. The data in Figure 9 outlines the projected change in population between 2012 and 2030. Since residential demand causes the peaking of the current ERCOT system this population profile also suggests the peak demand needs will continue to grow in North Texas, Houston, and Austin-San Antonio. In addition the lower valley area will also increase significantly with respect to demand. This assumes that the residential demand is a proxy for the total energy demand profile.

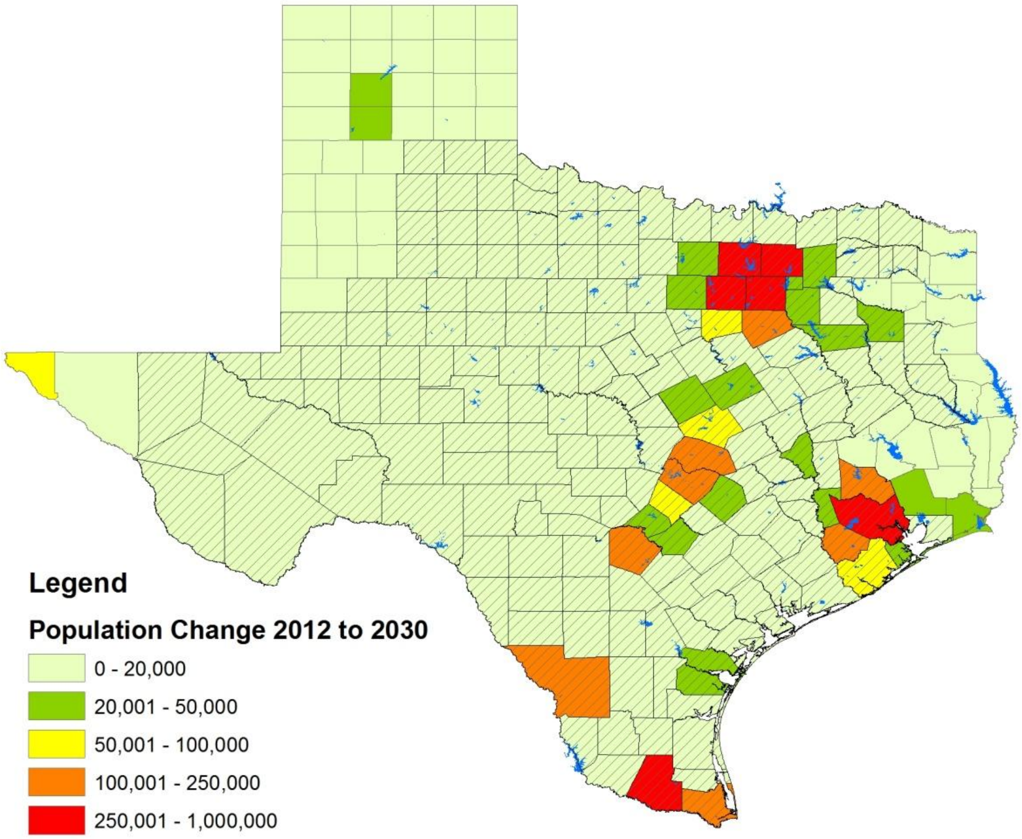

Figure 9. Population change by County (2012 to 2030). ERCOT Boundary hatched area

However the main reason for discussing population increases is to evaluate the competing demands for the water resources in the state. Those areas within 60 to 90 miles of the main population growth centers will likely be affected as municipalities utilize a greater proportion of the resources in a reasonable proximity to meet their demands. This will drive the reservoir demands higher overall and may bring power generation facilities to critical decision points earlier in the planning cycle.

2.11 **WATER AVAILABILITY**

Water availability has been studied extensively within Texas, from the high-level state water planning to very detailed hydrological modeling of individual stream segments. For this study the Sandia analysis has been utilized to aid with determination of the water availability within the hydrologic basins (at the Hydrologic Unit Code [HUC]-8 level, which is the sub-basin or 4th level of hydrological analysis) in Texas during drought conditions. There is little reported un-appropriated water (water that has not already been allocated to a certain permitted user) in the Texas basins and this is only in the most easterly and southern parts of the state as outlined in Figure 10. Even though most of this area is actually outside the ERCOT boundaries, this resource should still be considered as there are already some of the power generators that already access their water from the most easterly basins such as from Toledo Bend reservoir.

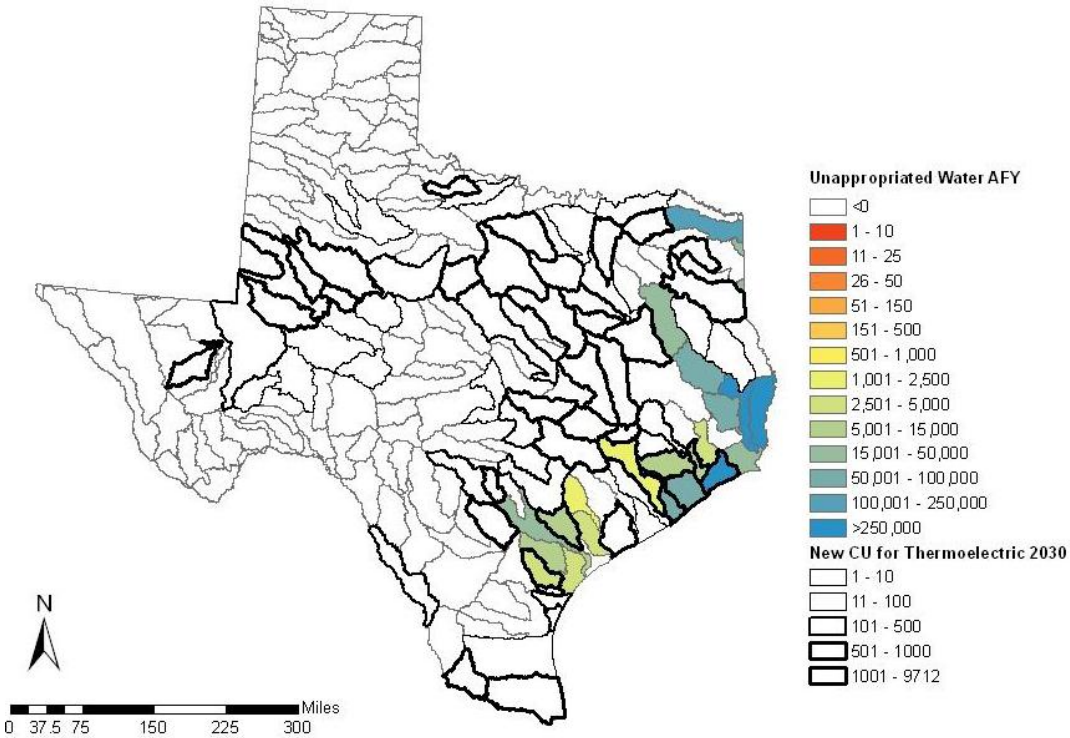

Figure 10. Un-appropriated water availability by river basin in Texas (Source Sandia Report 2013)

3 2011 Drought Literature Review and Analysis

The 2011 drought in Texas and recent droughts in other parts of the United States spurred a number of entities into conducting modeling and analysis of drought effects with respect to power generation. The following is a basic review of a selection of those reports and review of current drought information for ERCOT

3.1 DEPARTMENT OF ENERGY SPONSORED REPORTS (SANDIA AND ARGONNE NATIONAL LABS)

The report developed by Sandia and partners (the "Sandia study") was evaluated by Black & Veatch as part of two reviews provided for the Sandia team that recommend changes in direction and additions to improve the product for the client (ERCOT). The Sandia study covered both WECC and ERCOT (therefore most of the western half of the United States), however, the Black & Veatch analysis only covered the ERCOT area.

Additionally Black & Veatch examined the water supply availability analysis by cross-referencing data against the State water plan and generator survey data (as well as staff knowledge of the project area and expected outputs) to evaluate if the drought outputs matched some expected criteria. This included looking at annual and monthly rainfall patterns, reservoir/lake levels and withdrawals, and surface water temperatures.

The data was then incorporated into the ERCOT evaluations for analysis of system drought conditions and effects, as appropriate.

3.1.1 Basin Data Evaluation

The period of record data was evaluated, and then a drought scenario analysis was conducted. This initially utilized a percentile record matching rainfall/runoff data from historical profiles with similar records. After consideration of regional drought and climate differences the decision was made to match the records from the drought of the 1950s as a proxy for the worst conditions in the period of record and to match a multi-year drought scenario. The year 1956 was the end of the drought of the 1950s, so this was generally used as the worst case year for the drought scenario analysis.

Initial review was conducted on the 2011 drought and reservoir storage and inflow baselines derived through the hydrologic models to give an indication of the extent of the most recent drought. Figure 11 outlines the distribution of reservoir storage modeled from the 2011 drought in the basins with thermal power generation. The red sub-basins on this figure have the lowest storage capacity, and as thus considered the most problematic given 2011 drought conditions.

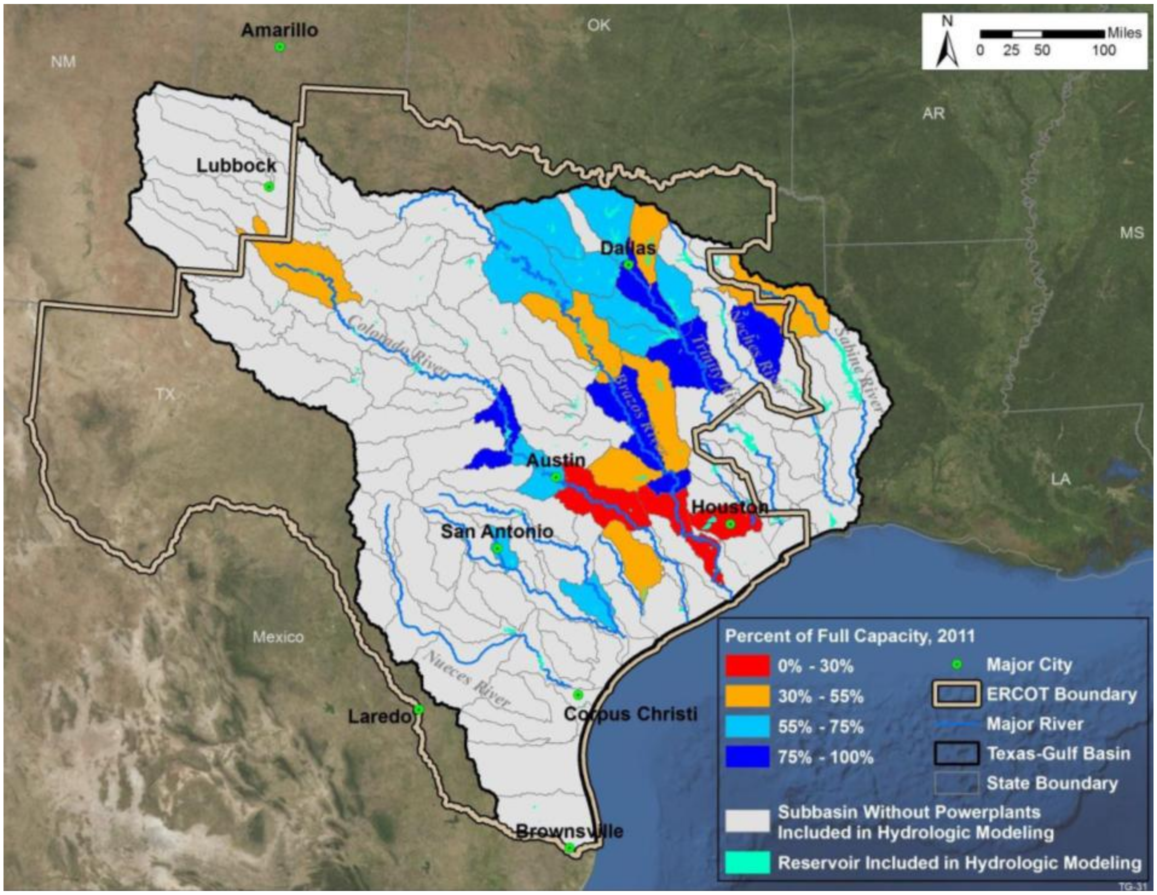

Figure 11. The distribution of reservoir storage that are supporting power plants in HUC8 basins.

Percentage at each HUC8 basin represents the reservoir with the lowest storage in 2011 (Source: SNL. Future climate projections impact on ERCOT thermal generation, Figure 31. 2012).

The amount of surface water generated was analyzed throughout the whole Gulf Coast watershed as shown in Figure 12. In this graphic the red areas indicate basins where the amount of surface water generated was less in 1956 than in 2011. This means that even though the 2011 drought is currently considered the worst in Texas, the reservoir storage as modeled from the 1956 drought year was even lower in some parts of the state. Therefore it is possible that the 2011 drought is not the worst case known for these sub-basins. The sub-basins in blue show the opposite, where 2011 was worse than 1956. This shows the wide regional variation. Note that the graphic does not directly account for storage and is designed to show the overall variations in flow.

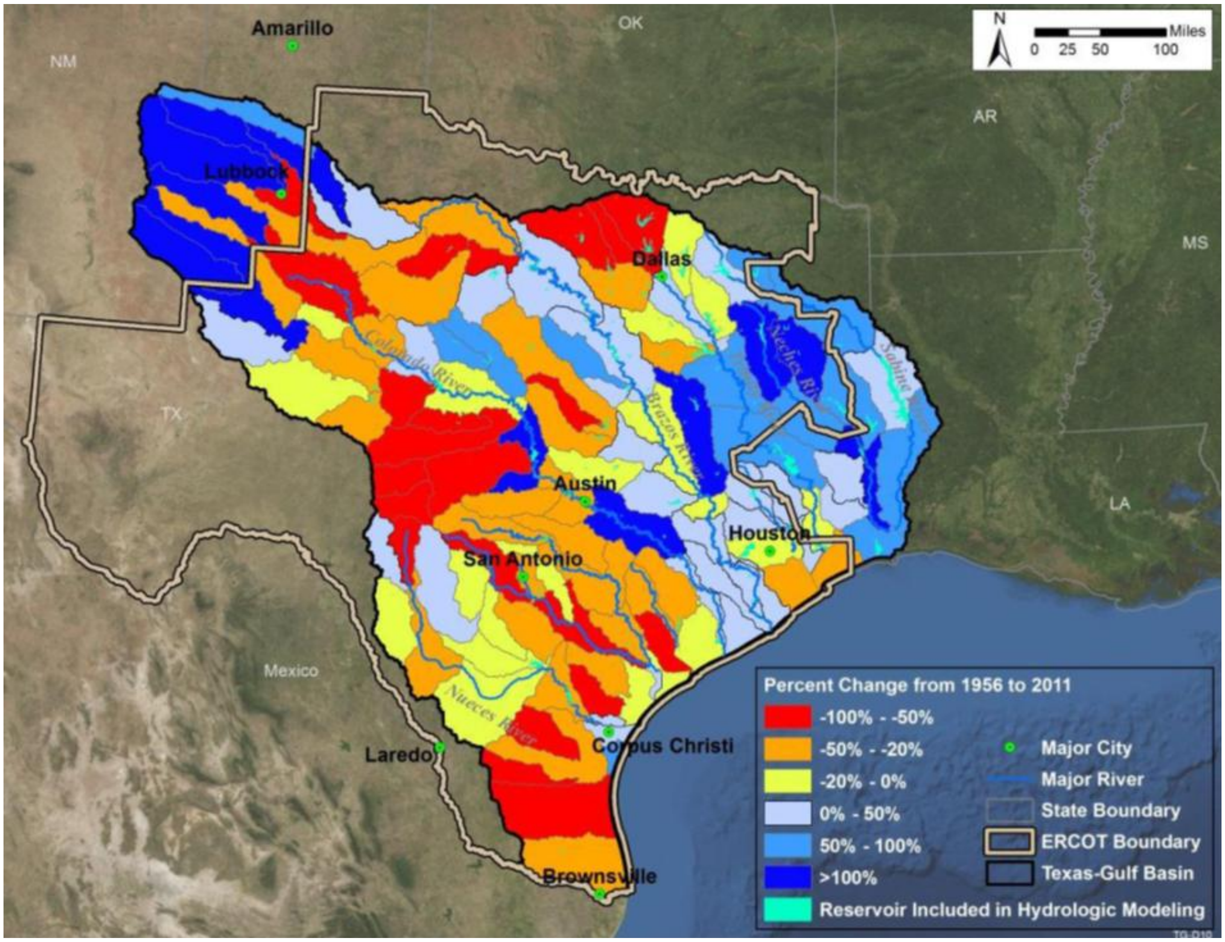

Figure 12. Projected change in amount of surface water generated in HUC8 basins from 2011 to 1956 under the multiple-year drought scenario (1950-1957).

A negative value indicates that a HUC8 basin in 1956 contributes less water to stream flow than in 2011, and vice versa. (Source: Sandia National Labs Report: Future climate projections impact on ERCOT thermal generation, Figure 40. 2012).

The same hydrologic information was then utilized to develop the basin characteristics in the 1950s drought for those basins with steam electric power generation (Figure 13). The predicted reservoir storage was developed to 2030 water use using demand projections as provided by the Texas Water Development Board (TWDB).

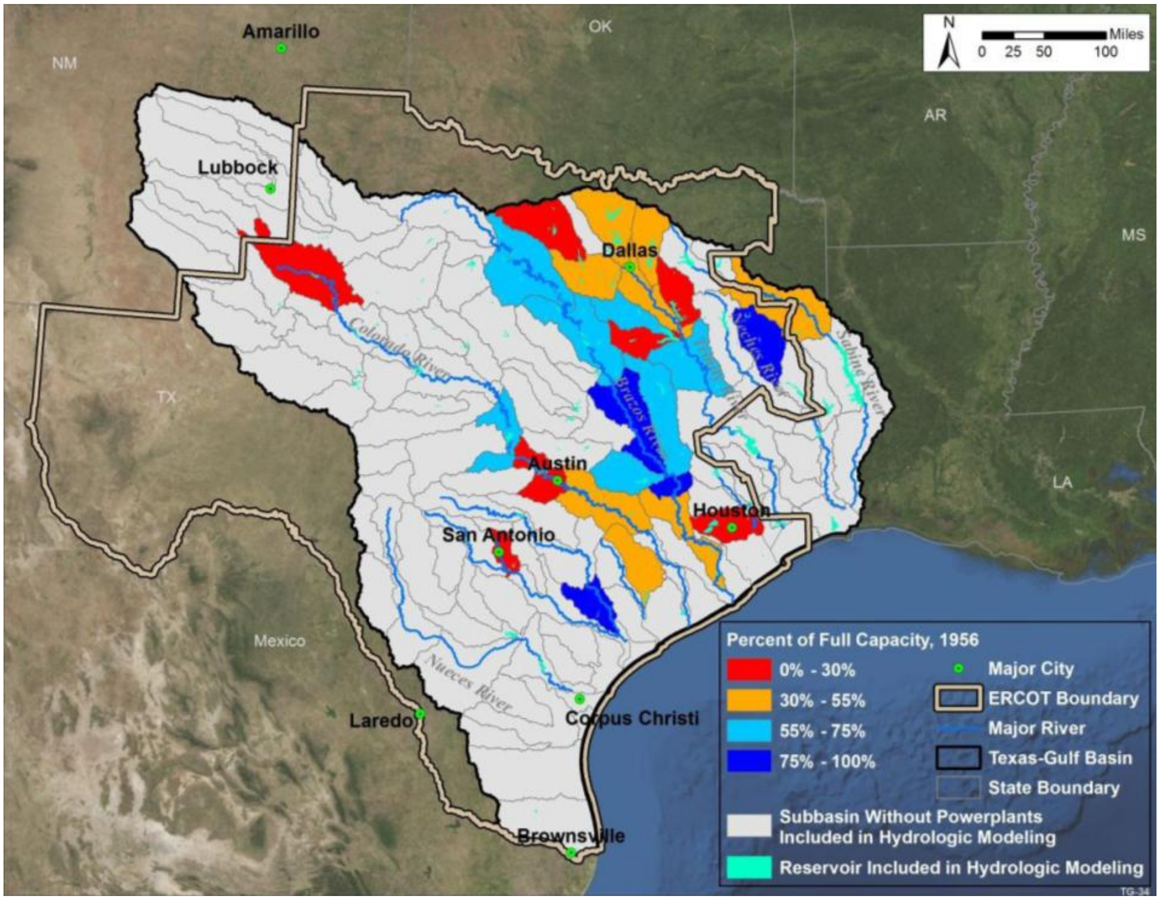

Figure 13. The distribution of predicted reservoir storage that would provide water supply to power plants in HUC8 basins under a long-term drought scenario with assumed 2030 water use.

Percentage at each HUC8 basin represents the reservoir with the lowest storage in 1956 for the multiple-year drought scenario (1950-1957). (Source: SNL. Future climate projections impact on ERCOT thermal generation, Figure 34. 2012).

This analysis suggested a significant problem in the north Texas and Lower Colorado drainage basins. It should be noted that the complexities of inter-basin storage, transfers and secondary water sources was not considered in its entirety in the Sandia study. Pipelines connecting reservoirs, or municipal return flows were not specifically considered. These were not studied in detail within the Black & Veatch study either, although some considerations such as the significant reservoir interconnections in the north Texas region were reviewed in order to provide better projections for this region.

3.1.2 Water Temperature Variables

In addition to the water availability part of the equation, water temperature was also deemed to be a possible factor in potential reductions of power generation availability. Analysis was conducted on most of the sites that have a pond or reservoir utilized for cooling purposes. Temperature limits (if considered) were included in the modeling and predictions of when specific generation units would exceed these limits were identified. In only three cases were units determined to be above the temperature limits within the period of analysis (2006 to 2011) and these were not modeled to become major outages due to short run-time of temperature exceedence and also due to re-evaluation and short-term increases in the limits (for entities that have reached these limits in the past) after consultation between the generator and regulator (TCEQ).

In future prediction it is logical that more units may get close to their upper limits. However, it is not expected that this will cause a significant number of units to have to derate at the same time (with current knowledge). An example graphic from the report showing the Handley facility in Tarrant County is shown below. Note that the temperature does not exceed the limits on this graphic.

Figure 14 shows the temperature variations and associated electricity generation (grey line) evident at the Handley units on Lake Arlington in North Texas. While the effluent temperature limits have never been reached temperatures do appear to be rising and therefore need to be evaluated annually. This is also a water supply reservoir and so there is extra caution necessary when considering the temperature of the supply.

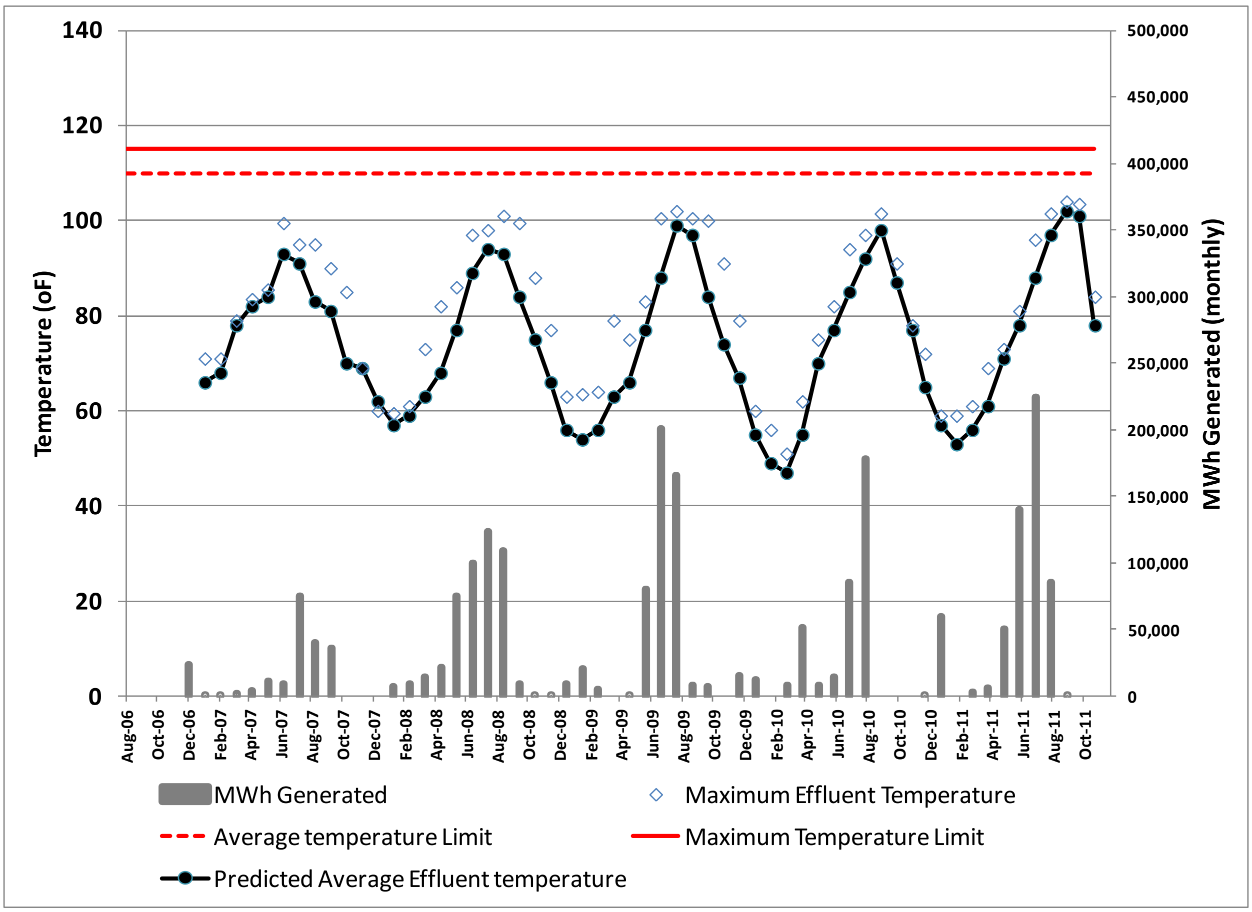

Figure 14. Reservoir Temperature variations and limits for Handley generating plant.

Source: Sandia National Labs (graphic re-configured). Future climate projections impact on ERCOT thermal generation, Figure A23. 2012)
The grey line shows the electricity generation, whereas the black line shows the predicted temperature.

3.2 SINGLE-YEAR DROUGHT

The Texas Gulf Coast basin in the Sandia modeling, showed a 25% loss of generation, almost entirely from lost thermoelectric generation. This risk appears to be driven by the extreme nature of the drought in this basin, with drought flows equaling only 31% of normal levels. In addition, over 70% of electricity generation in this basin relies on fresh surface water for cooling. This is in our opinion an overestimate due to the lack of consideration of secondary sources and storage potential in specific basins.

The remaining basins in the WECC model all show total losses of around 5% or less, which indicates that risk from drought in these basins may in fact be small, at least under the relatively frequent 10th-percentile drought conditions. The factors of water storage were not fully included in this model so it needs to be revisited. In the Black & Veatch monitor it was determined that while there still is risk, there was significantly less risk than initially identified due to the storage and secondary supplies that generators had already included.

In the cases of the upper portion of the Brazos, Lower Colorado, San Antonio, Nueces and Rio Grande basins, which are mostly arid and prone to drought, this result of few anticipated problems during a single-year drought such as 2011 may be somewhat surprising. However, this result is due to the fact that shortages of water historically have already forced generators in these basins to think about water and either maximize their storage and/or minimize their water footprint and drought risk. In most basins, the risks to hydroelectric generation outweigh the risks to thermoelectric generation, but the former is limited by the relatively small fraction of total generation from hydroelectric sources in most basins.

3.2.1 Multi-year Drought

Since the single-year drought did not have any significant and noticeable effect on power generation in Texas the multi-year scenario was developed. A logical progression is that as drought conditions worsen the risk of generation unit derate and failure will increase as generation units become more inefficient and the risk for total outages increases. This logic was matched by the calculated data used to develop the risk and derating models.

3.2.2 Integration of Data and Analyses into ERCOT Operations

While there are not specific tools that can be transferred directly into the ERCOT structures at this moment, the data behind the analyses are being used to model future drought problems and possible generation issues. Also the water availability modeling can be used to aid with future generation and transmission strategy.

There are at least three tools or data sets which can be modified or utilized from the Sandia study for more detailed use by ERCOT.

- The temperature modeling, such as that noted in Figure 14.
- GIS data for analyzing sub-basin hydraulic characteristics
- Reservoir storage and stream flow data for future detailed water resource and availability modeling.

The detailed information on temperature characterization and modeling is a good indicator of possible issues in the future. As lake levels reduce and the heat-sink capacity of the reservoirs diminishes, the risk of outages will increase. In addition the basin modeling has created a basic database of costs and availability per sub-basin which after validation can be utilized to aid with new development siting and cost evaluations.

3.2.3 Gaps in Information

The Sandia study was designed to evaluate the surface water systems and concentrate on those areas around the current reservoirs and generation facilities. It was also designed initially to be used in both ERCOT and WECC service areas. The ERCOT area was broken up into a separate zone so that the record drought of 2011 and evaluations of the multi-year drought of the 1950's could be properly modeled. The following outlines some of the gaps in the Sandia report that were identified.

3.2.3.1 Groundwater

Groundwater was not considered as a supply source for power generation in the Sandia report. It is not currently considered as a major resource for power generation in Texas. However, future analysis may well include groundwater due to the needs for drought-proofing of power plants and the possibility for desalination and the power requirements (and water use) that those systems will need. As reservoirs become more difficult to build (due to environmental concerns and the lack of good sites) and resources continue to be stretched due to population increase and demand growth, groundwater may become an option.

Since groundwater also has resource limitations, it is possible that it will act as a secondary source in times of drought to alleviate short-term problems. It can also be used as a secondary storage mechanism which has less water lost through evaporation. There are a small number of generators that utilize groundwater in the ERCOT jurisdiction already. While once through cooling systems will not be likely to utilize this resource due to the amounts of water needed to flow into the system, re-circulating cooling tower systems may utilize this resource under carefully engineered conditions.

3.2.3.2 Secondary Supplies

Secondary supplies can take the form of all the forms currently used, except reservoir systems. Groundwater, river intakes, municipal, desalination and reuse supplies can all be utilized. In systems with small reservoir storage, highly variable rainfall, or large risk (such as nuclear facilities) almost all of the power generators with these problems already have a secondary source permitted and operational. In many cases these secondary sources are utilized to keep a power plant lake at a relatively constant level. This will allow more efficient functioning of the system. In many cases this is done through a river intake. However, releases from lakes upstream can also be utilized, such as Lake Buchanan feeding Inks Lake for the Ferguson Power Plant in the Lower Colorado.

Each river system needs to be evaluated in a unique manner in order to truly understand the priorities within a river basin. The Sandia report does show some of the over-arching basin availability surpluses and shortfalls, but it does not include the complexities of river system operation and was never intended to do so. The Black & Veatch report is designed to incorporate some of these nuances, but the reports are in no way trying to replicate this complex hydrological work conducted by the River Authorities.

3.2.3.3 Confidential information

There are a number of pieces of information that the Sandia staff did not have access to. Items such as monitoring, intake, or critical supply levels were often not public information. While this reduces the level of detail possible, the overall premise was to determine the range of drought issues at the basin level rather than to highlight specific generating units.

3.2.3.4 Stream/River Levels

While the Sandia work did include information on the stream gauges as well as reservoir levels, the focus was on basin storage and reservoir information. The stream intakes and associated environmental flow requirements were not considered in detail within the report.

3.3 LONG TERM SYSTEM ASSESSMENT

With this information ERCOT staff developed three scenarios to include in the Long term system assessment (LTSA) in 2012 to analyze the effects of a long-term multi-year drought. For these scenarios load forecasts were developed using Moody's base economic assumptions to which the 2011 ERCOT load shape was applied.

The three Drought Scenarios were developed around the BAU All Tech scenario that was studied for DOE Long Term Analysis. The first of the Drought Scenario alternatives had two major changes. First, capacity reductions for all existing thermal generation units were applied during the period of the drought, 2019 through 2025 due to lack of water at existing plant sites and increase in intake/discharge temperatures. Secondly, additional costs for acquiring water for new thermal generation expansion units.

The second Scenario used the first scenario and reduced the expected natural gas price by $2 per MMBtu for all years. The third scenario added the wind production tax credit and emission costs on all fossil-fueled thermal units.

Final results indicate that thermal, wind, solar and geothermal resources will be added in both the first and second scenario. However, additional wind and solar resources will be added to the ERCOT system in the first scenario because of the added cost of water for thermal units. In the second scenario (with lower natural gas prices) thermal units will be built until the price of natural gas price exceeds $6 per MMBtu at which point wind becomes more economic as shown in Figure 15.

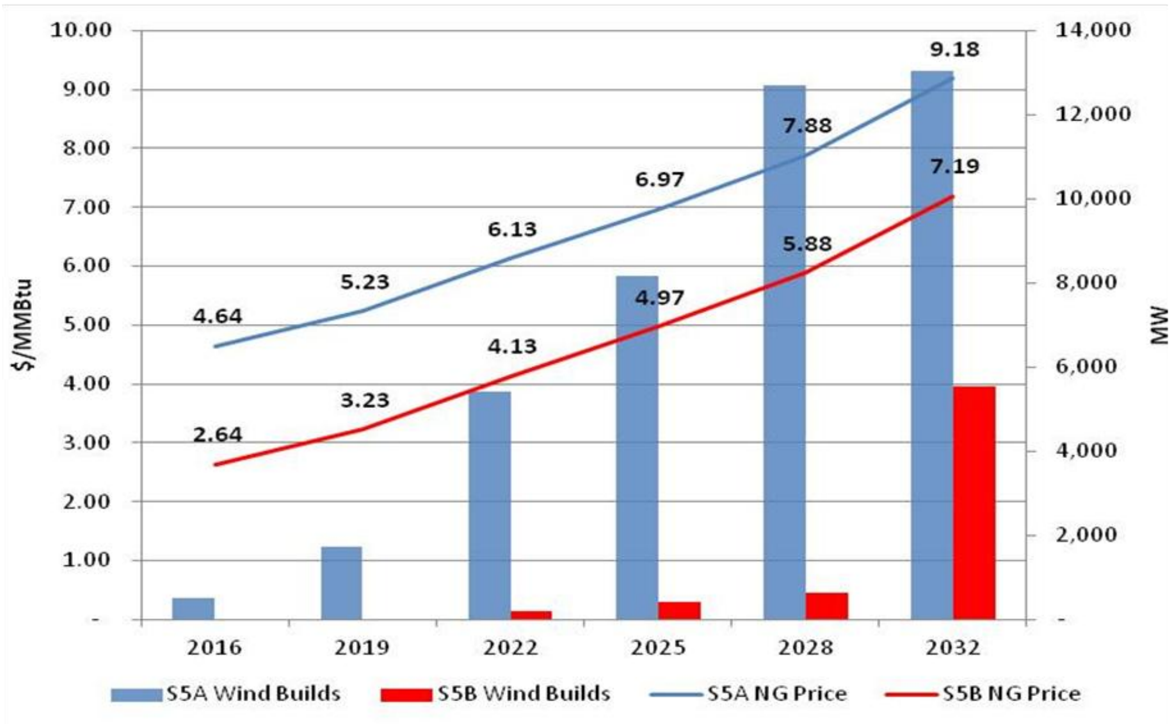

Figure 15. Comparison of Natural Gas price and Wind Build

The costs associated with purchase of water and of the water rights to operate power plants do not currently appear to be a limiting factor to development, so it is unlikely that market forces will drive new generation away from steam thermal plants due to cost. However, the availability of the water resource will certainly be limiting and is a risk that needs to be fully considered.

If rainfall in Texas were all trending toward a reduction in volume then it would be easy to deduce that water availability will decrease proportionately. (the rainfall trends and regional rainfall variations are outlined in greater detail in Section 4.) This not the observed case, as some rainfall monitoring stations in Texas show increasing trends over the period of record since 1900. The current water supplies for power generation were all able to manage through the 2011 drought and there are significant available and un-appropriated resources on the eastern and coastal portions of the state. In addition as will be outlined in section 3.4 the water demand projections for steam thermal generation appear to be significantly higher than will actually be the case. This suggests that as long as the process and technologies used for water cooling are managed carefully and efficiently, this analysis estimates that there are probably sufficient water resources within the state to allow building of additional thermal units with water-based cooling. It is expected that location will be a decision factor, but steam thermal generation should still be possible. This will be further described at the end of this report after discussion of some of the other items that have influence on this statement. All types of units should be considered when determining resource adequacy and siting of new generation units. In addition it is anticipated that there will be geographic considerations for future thermal unit development. The least risk, with respect to water supply is expected in the east and coastal areas and the eastern portions of the central Texas weather zones (north, north central, and south central and the north eastern portion of the southern weather zone). These areas are expected to be the most conducive for thermal unit development.

3.4 CONSISTENCY WITH THE TWDB REGIONAL WATER PLANS

The Current TWDB Water Plan was completed in 2012. This water plan analysis is completed on a five-year cycle. The following subsections review water plan data from some of the main population centers including Houston, Dallas-Fort Worth, Austin and San Antonio.

3.4.1 Power Generation in Texas Regional Plans

The three most important areas with respect to the LTSA were Dallas-Fort Worth, Houston, and Austin-San Antonio. These fall within four regional planning groups (DFW – Region C, Houston – Region H and Austin-San Antonio – Regions K and L).

3.4.2 Dallas – Fort Worth, Region C

The locations of water- and air-cooled generation units for the Dallas-Fort Worth (TWDB Region C) area are mapped on Figure 16. The red dots represent once-through, orange represent cooling towers and blue represents a hybrid system and green represents air-cooled generation systems.

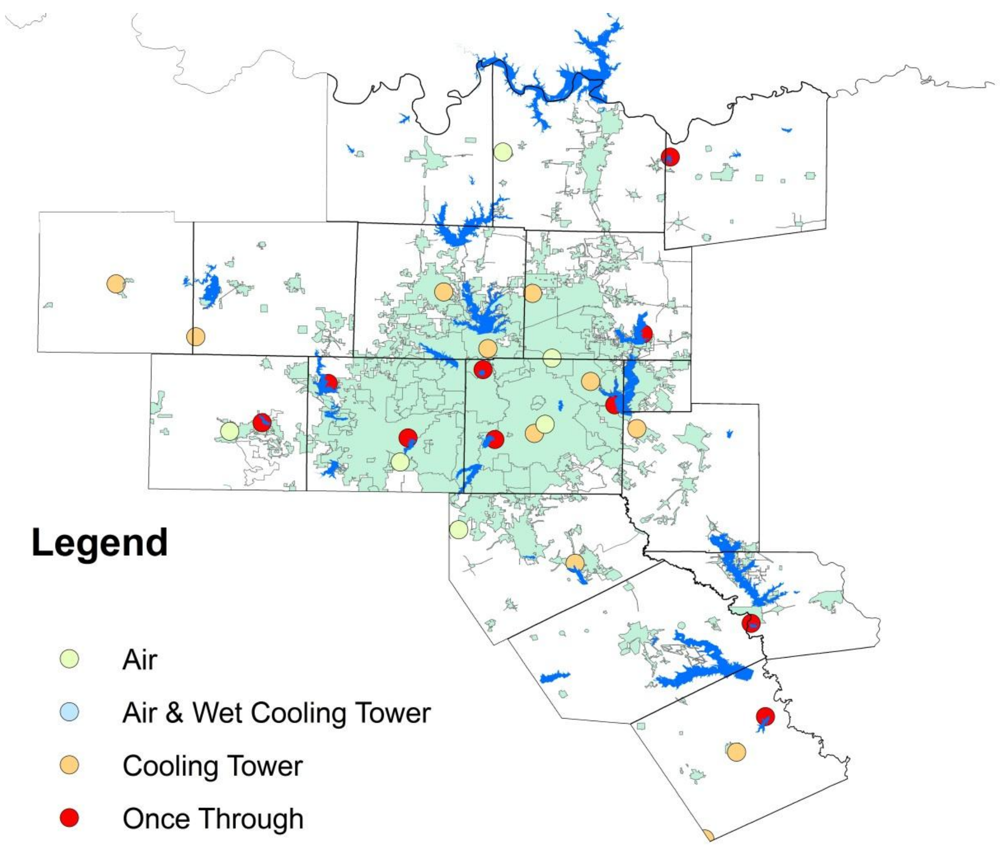

Figure 16. Dallas-Fort Worth Region power generation cooling water consumption

3.4.2.1 Historic Power Generation Water Use

Historically there was significantly higher water use for electric generation. For example in 1980 53,009 acre-feet was used, whereas in 2007 only 15,160 acre-feet was reportedly used. However this did rise to 56,236 for 2000 which was a very hot year with high summer demands. This suggests that most of the generation in the vicinity is utilized for peaking. In 2006 Freestone County was by far the highest water user with almost 60% of the total use. The only other counties with more than 1,000 acre-feet of use were Dallas (3,054) and Tarrant (1,444). This was only 3.5% of the total Texas water use for power generation, although this can rise to almost 10% when peak loads are considered.

3.4.2.2 Projected Power Generation Water Use

Population is estimated to increase by close to 40% between 2012 and 2030 from 6.6 million to 9.1 million, thereby significantly increasing demand in the area. Power generation water use is estimated within the state water plan to increase by 57,000 acre feet per year by 2030.

There are some slight discrepancies in data recorded such as Fairfield Reservoir – TWDB Storage 44,169 acre-feet, Regional Plan 50,600 acre-feet. However, these are relatively minor issues and can be due to different measurement levels rather than actual errors.

3.4.3 Houston, Region H

3.4.3.1 Historic Power Generation Water Use

There is one coal-fired electrical power plant in Region H, the W. A. Parish facility. With a nameplate capacity of 2,698 megawatts, however, this facility is the largest coal-fired facility in Texas. It constitutes 12% of the total coal-fired electrical generating capacity in the State. The estimated annual water use for this facility, based on producing 18 million megawatt-hours of electricity in 2005, is 32,762 acre-feet per year.

The State Water Plan projects a current shortfall of 3,203 acre-feet per year to meet steam-electric water demands. The shortfall is expected to increase to 55,972 acre-feet per year by 2060. However, it is anticipated that this is an over-estimate due to both the increase in renewable generation and the misunderstanding of withdrawal versus consumption and other items as discussed at the end of this section. This should be reevaluated. The locations of water- and air-cooled generation units for the Houston (TWDB Region H) area are mapped on Figure 17. The red dots represent once-through, orange represent cooling towers and green represents air-cooled generation systems.

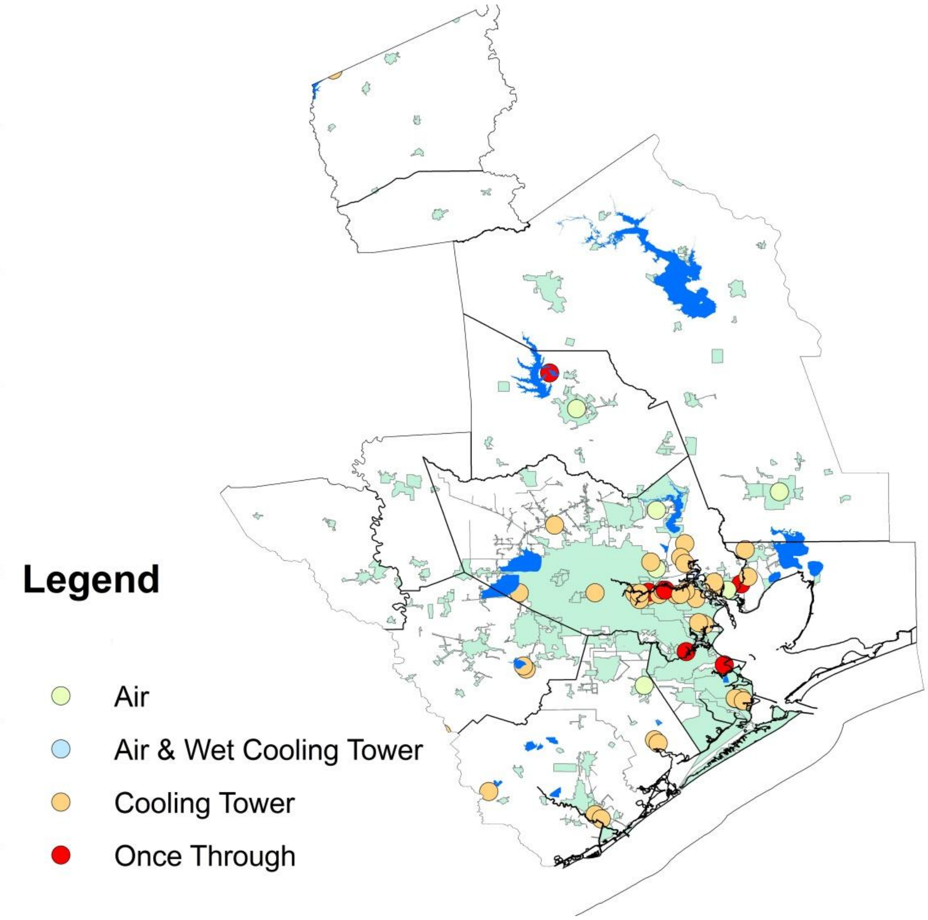

Figure 17. Houston Region power generation cooling water consumption

3.4.3.2 Projected Power Generation Water Use

Approximately 24 percent of the state's population was projected to reside in the region in 2010. By 2030, Region H is projected to grow to 8 million. Total demand for the region is projected to increase 48 percent by 2030. The largest consumers of water in the region are municipal entities, and municipal demand is expected to grow 61 percent by 2060. Power generation water use is estimated within the state water plan within the Houston region to increase by 40,000 acre feet.

3.4.4 San Antonio and Austin, Regions K and L

3.4.4.1 Historic Power Generation Water Use

There is one coal-fired electrical power plant, the Fayette Power Project, located in the Lower Colorado Water Planning Region. This power plant, with a nameplate capacity of 1,690 megawatts, constitutes 7% of the total coal-fired electrical capacity in the State. Based on a 2005 generation of 11 million megawatt-hours, the average annual water demand for this facility is 12,774 acre-feet per year. The J K Spruce, J T Deely, and San Miguel coal-fired electrical generation facilities are located in the South Central Texas region. The estimated combined water usage of these plants is 28,588 acre-feet per year. The locations of water- and air-cooled generation units for the San Antonio - Austin (TWDB Regions K and L) area are mapped on Figure 18. The red dots represent once-through, orange represent cooling towers and green represents air-cooled generation systems.

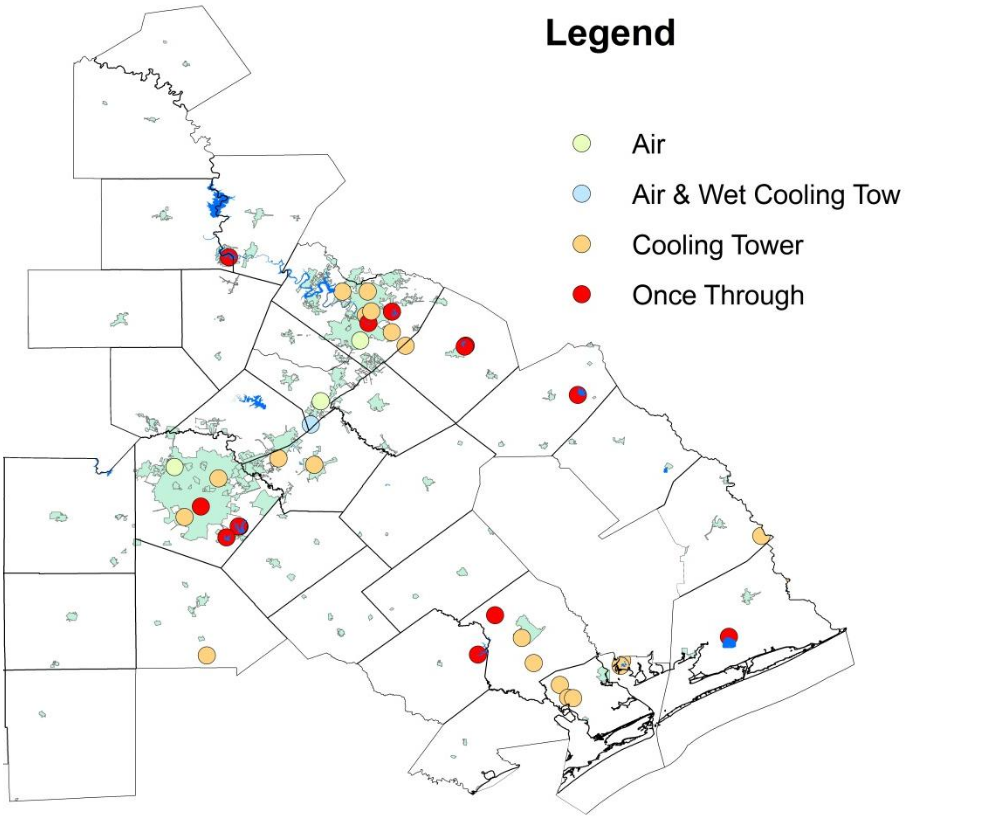

Figure 18. San Antonio-Austin Region power generation cooling water consumption

3.4.4.2 Projected Power Generation Water Use

In 2010, nearly 16 percent of the state's total population resided in the Lower Colorado and South Central Texas Regions combined, and between 2010 and 2060 its population is projected to increase by approximately 90 percent. Water demands, however, are projected to increase less significantly.

Power generation water use is estimated to increase significantly in these two regions combined by 128,000 acre feet per year.

3.5 FUTURE WATER DEMAND

Future demand is difficult to apportion spatially due to such factors as generation well outside the area that can supply electricity to each market. Therefore, future demand is evaluated for the whole of ERCOT. Tables 6 through 9 profile the water demand expectations by Texas region. Population projections from the Water Plan (Table 6) are also shown to allow some analysis of the load to be evaluated with respect to the LTSA studies.

Table 6. Population Projections (number of people)

REGION	2010	2020	2030	2060
C - DFW	6,670,493	7,971,728	9,171,650	13,045,592
H - Houston	6,020,078	6,995,442	7,996,480	11,346,082
L - Austin	2,460,599	2,892,933	3,292,970	4,297,786
K – San Antonio	1,412,834	1,714,282	2,008,142	2,831,937
Total ERCOT*	**25,383,403**	**29,650,388**	**33,712,020**	**46,323,725**

***This currently includes all of Texas.**

Table 7. Water Demand Projections (Acre-feet per year)

REGION	2010	2020	2030	2060
C - DFW	1,761,353	2,078,744	2,377,738	3,272,461
H - Houston	2,376,414	2,600,348	2,815,482	3,524,666
L - Austin	981,370	1,091,573	1,145,898	1,291,567
K – San Antonio	1,086,692	1,180,160	1,231,018	1,382,534
G - Brazos	870,180	979,223	1,058,290	1,248,514
Total (16 Regions)	18,010,599	19,038,954	19,821,152	21,952,198

Table 8. Electric Generation Water Use Projections (Acre-feet per year)

REGION	2010	2020	2030	2060
C - DFW	40,813	64,625	98,088	126,428
H - Houston	91,321	112,334	131,332	217,132
L - Austin	46,560	104,781	110,537	128,340
K – San Antonio	146,167	201,353	210,713	270,732
G - Brazos	168,193	221,696	254,803	319,884
D NE Texas	89,038	96,492	112,809	186,509
Total (16 Regions)	733,179	1,010,555	1,160,401	1,620,411
Sandia Study (est.)	450,000		510,000	

Table 9. Projected Steam Electric Needs in Acre-feet per Year (2012 Plan, Table 6.3)

REGION	2010	2020	2030	2060
C – DFW	0	13,217	29,696	51,323
H – Houston	3,203	12,609	18,058	55,972
L – Austin	2,054	50,962	50,991	52,018
K – San Antonio	193	53,005	53,175	89,042
G – Brazos Basin	38,542	71,483	82,891	132,872
Total TWDB	64,199	261,071	317,998	615,194
Sandia Study (est.)			**60,000**	

As can be seen from Table 9 above, and comments made during the LTSA discussions, there appears to be a large disconnect between this and the Sandia analysis in 2012. This disconnect appears to be mainly due to the distinction between water withdrawal and use. For example, to the extent that once-through cooling is assumed, the regional water plans do not appear to consistently account for the water that is returned to the water courses.

Data from 2009 within the State Water Plan records an estimate of 454,122 acre-feet was withdrawn for steam electric uses. This is very close to Sandia projections of 450,000 acre-feet. The State Water Plan projections of 733,179 acre-feet starting in the following year (2010) appear problematic (page 139, Texas State Water Plan, and Table 8 in this report). It appears that this data needs to be re-evaluated and validated as there are significant variations between the two studies as well as differences between Regions within the State Water Plan. For example there are a number of Regions with large increases in water requirements projected between 2010 and 2020 (197,000 acre-feet), but not the same increase between 2020 and 2030 (57,000 acre-feet) as outlined on Table 9. This could be due to projects being developed at different times, but it is expected that there is some double counting between regions and over-estimation. A number of these data points were calculated prior to the natural gas price reductions and significant increases in wind production. Therefore the assumptions will need to be re-addressed in the next planning cycle.

The Sandia Study estimates 450,000 acre-feet of water consumption for power generation in ERCOT assuming 13.2% of generation from wind, or 510,000 acre-feet considering no new wind generation. This suggests almost zero growth in water use if the TWDB 2009 figure can be used as a benchmark. Due to the increase of wind generation, improved efficiency of cooling systems and some shift to lower water-consuming technologies, this projected near-zero water supply demand growth does appear possible.

A similar situation is applicable to municipalities since they also withdraw more than they consume (as they return waste water).

4 Drought in the ERCOT Region

The drought in 2011 was the greatest single-year drought across the ERCOT region, comparable to the drought of 1917, where the average over the whole state was only about 15-inches.. However, it still does not match the drought from the 1950s for longevity. In many of the most populous areas such as DFW and Houston, rains in the late spring of 2012 and into 2013 have restocked reservoirs and reduced the water supply issues in those regions. However, the situation can change quickly with reservoir levels dropping by more than two feet per month in some cases.

4.1 STATEWIDE AND REGIONAL VARIATIONS

The statewide variations are significant with some regions much more susceptible to drought issues, and some others in almost perpetual drought. The normal pattern of drought in the west and surplus in the east and south is generally true. However a drought of more than one year can significantly affect resources in the central and southern areas as well due to lack of supply storage and heavy demands in those areas.

Compared to other states the variations in Texas rainfall are very significant. The variation from lowest recorded to average rainfall is 1 to 10 in Texas and only 1 to 3 in California.

Regionally, drought may hit different areas at different times. The year 2011 was relatively consistent across the whole of Texas, but in other years regional areas have been just as badly impacted. For example southern and west central Texas had multi-year drought between 1998 and 2004 as well as during the 1950s.

4.2 DROUGHT YEAR ANALYSIS

This section presents profiles of the most significant drought periods in recorded Texas history. It also evaluates environmental data from pre-history.

Reliance on a single historic worst drought period to portray state-wide conditions can be misleading because the worst drought period may be different among the regions. For example, in most regions, 1950 to 1957 was the most extensive multi-year drought. However, the areas of Wichita Falls to Abilene and the Rio Grande Valley observed worse conditions between 1996 and 2004.

Figure 19 shows one rainfall gage from Cleburne, just to the southwest of the DFW area. While the multi-year drought during the 1950s is apparent at this location, 1963 was actually the worst single-year drought, thus highlighting the localized and year-to-year variability of precipitation. One of the striking items about this graph is that annual average rainfall at this site has actually been on the increase between 1900 and 2011 and the variation overall has also increased over that time.

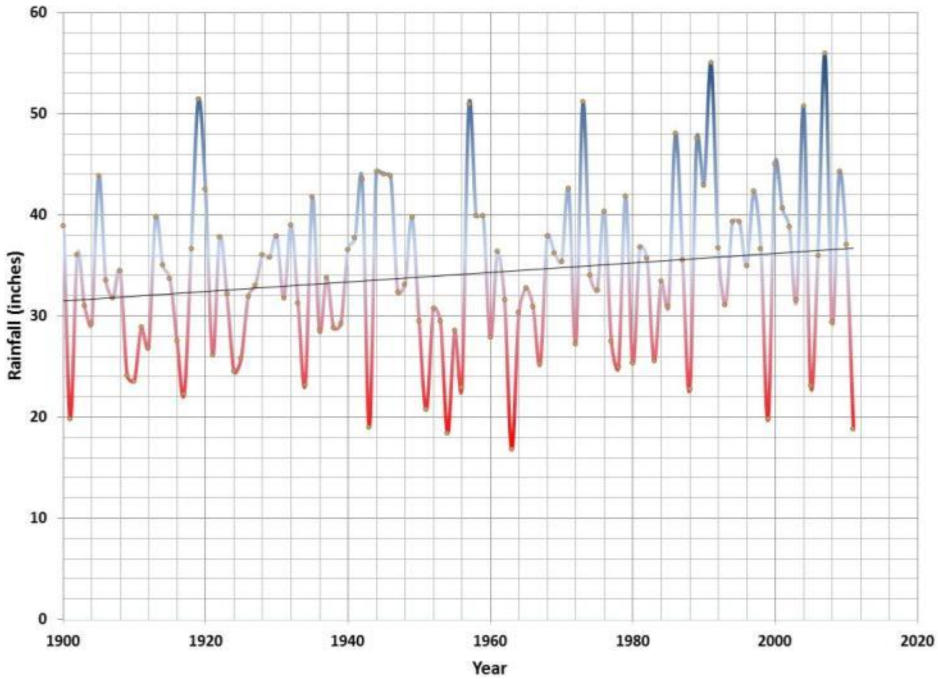

Figure 19. Cleburne Rainfall, 1900 to 2011 (Average 34.01)

4.2.1 Year 1917

Prior to the drought of 2011, 1917 was the worst single-year drought on record with an average of 15-inches of rainfall across the state. Figure 20 from Aransas Pass still shows this as its lowest year of rainfall even compared with 2011.

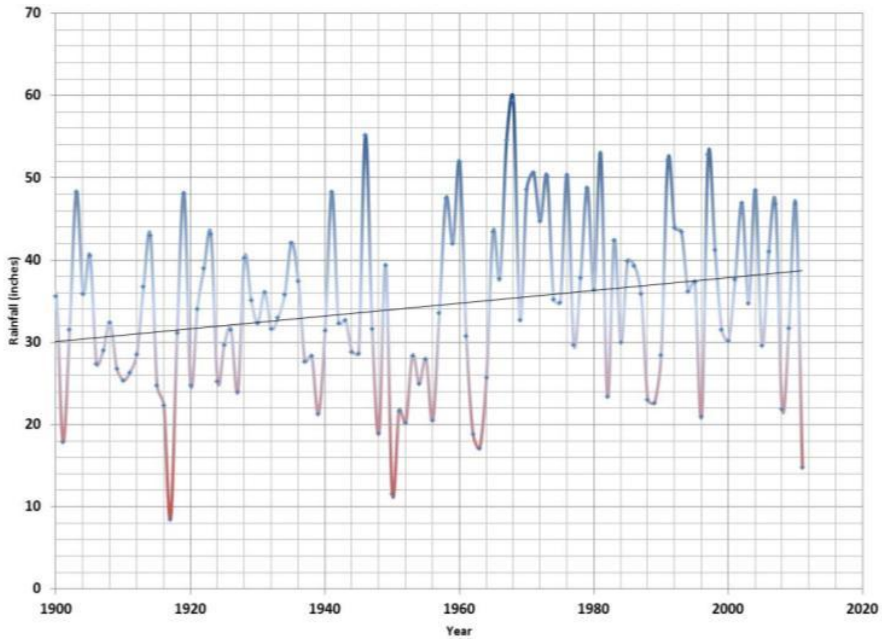

Figure 20. Aransas Pass Rainfall, 1900 to 2011 (Average 34.20)

4.2.2 Years 1950 to 1957

This period was always considered the drought of record in Texas until 2011. However, since this was a multi-year drought it should still be considered as the most problematic condition as the issues are compounded as reservoir storage reduces. In the HUC-8 analyses conducted by the Sandia team it was modeled that the reservoir levels recharged to 100% capacity in 1953. This was true in a number of parts of the state, but not all. However the view of two three-year droughts stacked back to back is probably realistic for much of the central portion of the state. Therefore it only acts as a three year drought cycle rather than the seven years as outlined in many of the texts.

4.2.3 Years 1998 to 2004

Southern and west central Texas had its worst drought with respect to its water supplies between 1998 and 2004. The reservoir levels reduced to single digits in a number of areas. The 2011 drought is now exceeding this in a number of areas within the state.

4.2.4 Year 2011

This year is reported as being the worst single-year drought in the state over more than 60% of the land area. In some cases it appears that the 2011 drought is worse even than the 2000 to 2004 period, however in most cases these reservoirs never filled and so a comparison on lake levels is difficult to ascertain. Figure 21 from Abernathy in the Texas panhandle shows that 2011 was significantly worse than any other year on record.

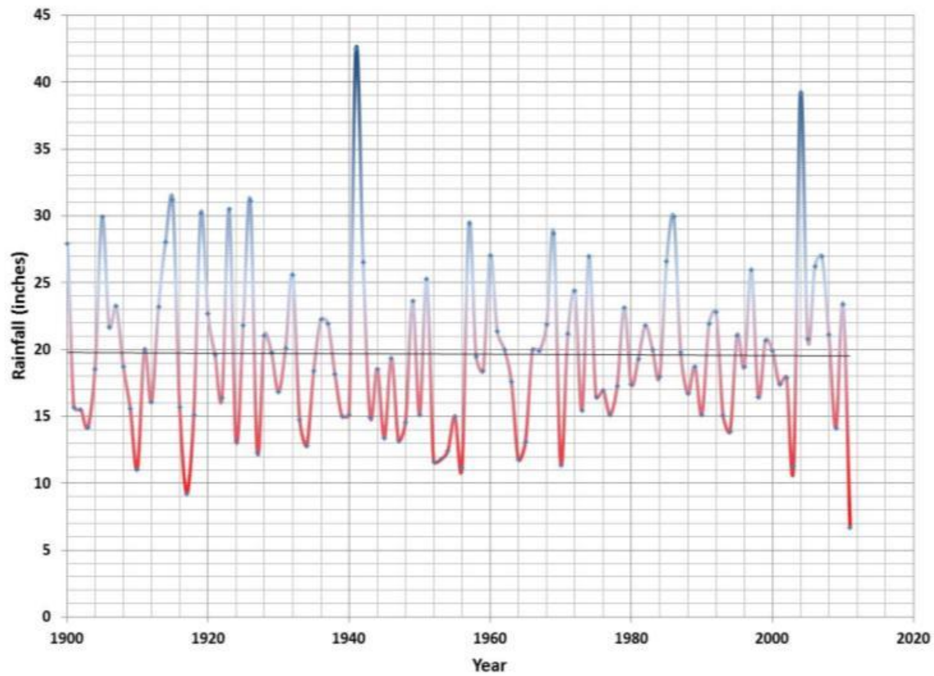

Figure 21. Abernathy Rainfall 1900 to 2011 (Average 19.67)

The three rainfall graphics show a micro-view of the regional variations across the state. When drought hits an area the perception is that the overall average is decreasing too, although this is not always the case. If the average is consistent or rising then there is a possibility that increased storage can smooth over the drought periods. If the overall average is declining, then the storage will not be as effective.

4.2.5 Drought History Prior to Monitoring Capability

The tree ring analysis network, determined using data from Bald Cypress, Post Oak and Pinon Pines within the Texas area has helped to develop drought analyses prior to the times when monitoring was available and operational. This data can go as far back as the ages of the trees. There also needs to be correlation between tree samples and so the current analysis goes back to approximately 1500 AD. There are a relatively small number of calibration sites in Texas (approximately ten). However, the tree ring network gives a reasonable indication of drought severity over the period of record. Figure 22 outlines that the tree ring analysis (red) is a reasonable proxy for the true conditions (blue dotted line). The data in this graphic is from South Central Texas.

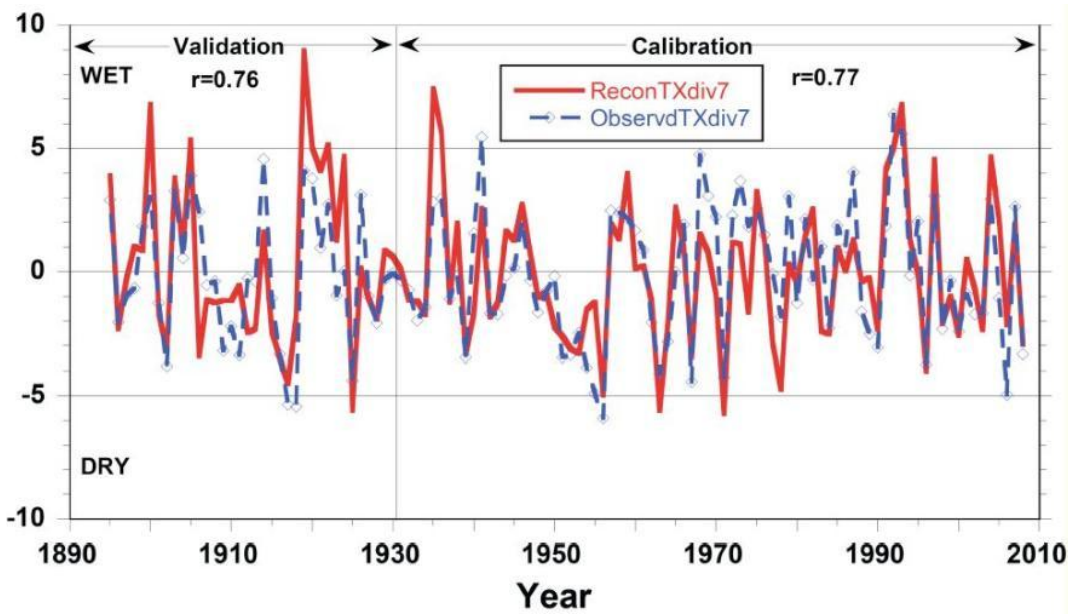

Figure 22. Tree Ring History – Calibrated Period 1890 to 2010

The tree ring data was calibrated using existing monitoring records of rainfall (Source: Cleaveland, Malcolm K., Todd H. Votteler)

Daniel K. Stahle, Richard C. Casteel, Jay L. Banner, "Extended Chronology of Drought in South Central, Southeastern and West Texas," Texas Water Journal, Vol. 2, Issue. 1 (2011): 54 – 96.). In Far West Texas the most severe drought since 1500 was actually the drought of the 1950s, whereas in central and southern Texas the worst drought was estimated to be from 1708 to 1717. This shows the regional variations that need to be assessed when viewing the drought data and the fact that the drought of the 1950's may not be the worst experienced in Texas.

The tree ring data has been extrapolated to drought severity using the Palmer Drought Severity index (PDSi) which is also used for drought monitoring today. However, the tree ring data shown in Figures 22 to 24 only evaluates the data for the summer growth period of the respective year and then uses that as an estimate of the whole year's relationship to rainfall and drought.

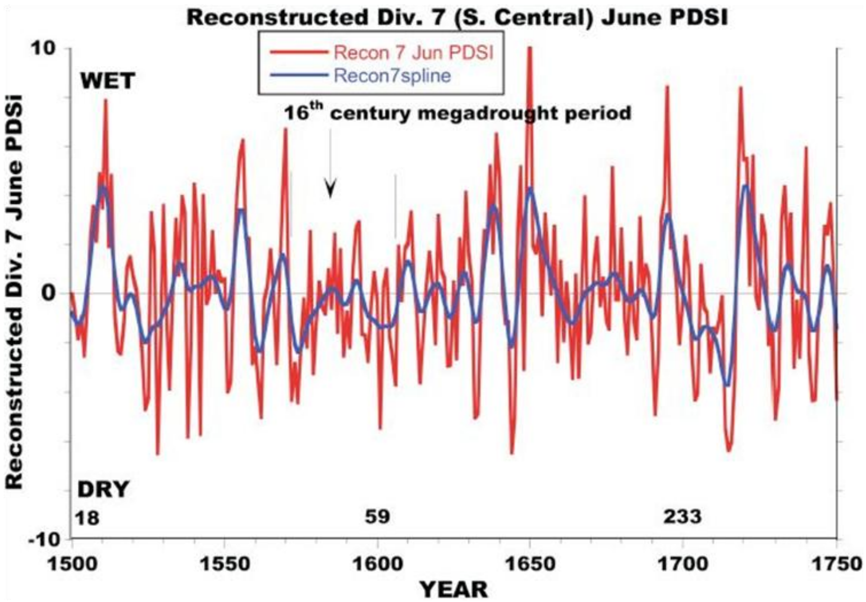

Figure 23. Tree Ring History – 1500 to 1750 (June records only)

There were a number of long-term droughts in the South central area as determined by tree ring analysis. This continued into the period from 1750 to present (especially in the 1850s), but the droughts of the 1950s do not appear to be the drought of record in the south central Texas area.

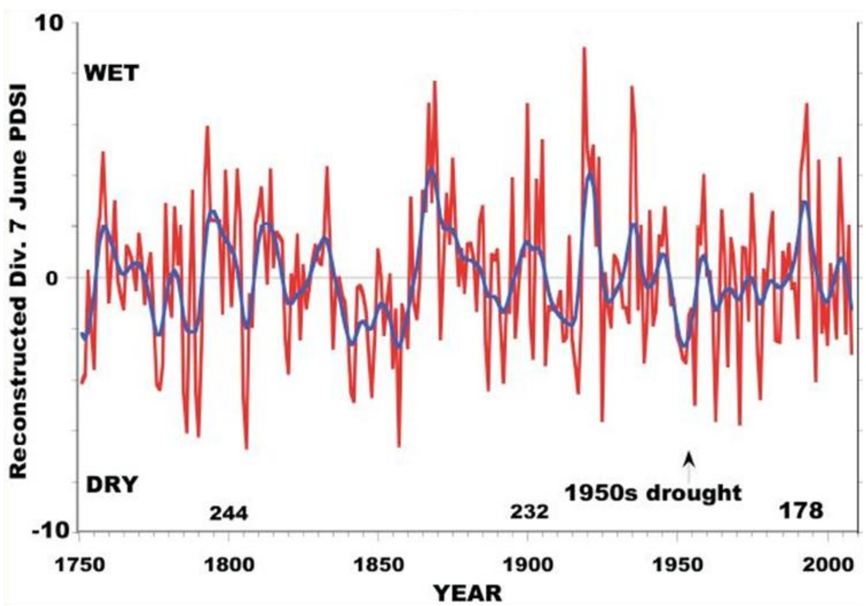

Figure 24. Tree ring history – 1750 to 2000 (June records only)

The Palmer index is most useful for semi-arid and dry sub-humid regions (this is the climatic area it was designed for) so any extrapolation of the PDSi into eastern or Coastal Texas (Sub-tropical Humid) is not recommended. The tree ring data can be used as a guideline for these areas, but extrapolating the Palmer index from recent monitoring data and suggesting this is the same as pre-historical times is not recommended.

4.2.6 Synthetic (Modeled) Drought Analysis

In order to further develop a drought analysis with a high stress level to the reservoir systems a drought analysis was developed utilizing data from the 1950's drought and analysis of the data outputs to make sure that the model output matched or exceeded this profile. A period of 20 years was modeled using Monte Carlo simulation against the 1950's and 2011 drought to determine rainfall scenarios that could then be used to aid with analysis of water availability.

Figure 25 shows an example output from a basic Monte Carlo analysis which was conducted to generate the random rainfall profile within the boundaries noted in the period of record. This synthetic analysis can be changed easily to simulate different conditions and timings for the rainfall patterns.

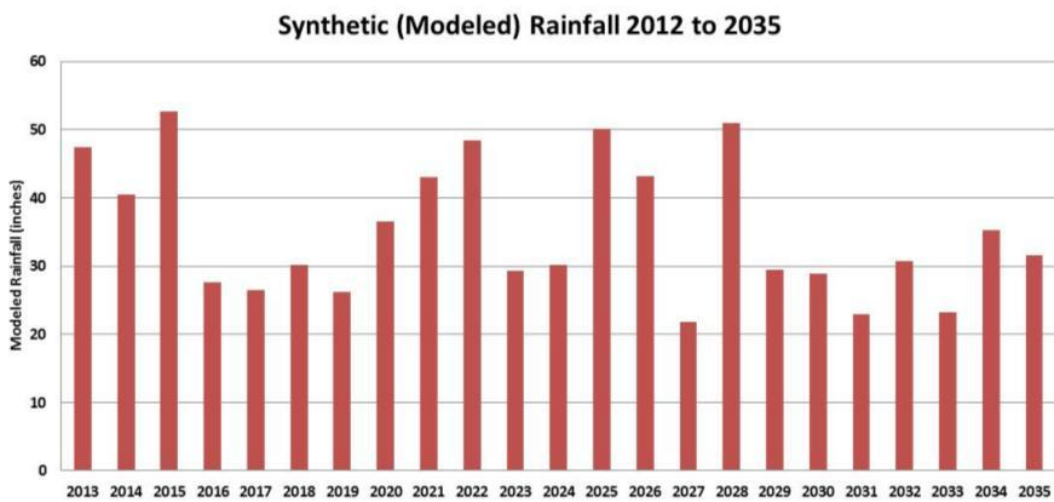

Figure 25. Synthetic Modeled Rainfall (2013 to 2035)

A goal of the B&V project was to analyze drought conditions at least as stressful as the drought of record (1950's) and preferably with additional stress, but still within possible bounds. The Monte Carlo analysis was conducted with the boundaries of the 110 year history of rainfall records available. Other data such as runoff, evapotranspiration etc. was not used in this simplified analysis. It was used in this situation for estimating a physical problem and providing sample datasets to work with compared with trial and error or specific period fitting.

4.3 SENIOR CALLS ON WATER RIGHTS BETWEEN 2011-2013

In 2011 through early 2013 the drought necessitated the need for some of the senior water rights holders to request a "senior call".

The following text is taken from *http://www.senate.state.tx.us/75r/Senate/commit/c510/handouts12/0110-TCEQ.pdf*.

Reviewed 07/02/2012

The TCEQ's actions are guided by the priority doctrine, Texas Water Code Chapter 11. Domestic and livestock users have superior rights to any permitted surface water right holders. Between permitted water right holders, those permit holders that got their authorization first (senior water rights) are entitled to receive their water before those water right holders that got their authorization later (junior water rights). If a water right holder is not getting water they are entitled to, they can call upon the TCEQ to take action to enforce the priority doctrine – a senior call.

The TCEQ received 15 senior calls in 2011, including calls on surface water in the Brazos, Guadalupe, Colorado, Sabine, and Neches River Basins. We are managing senior calls from users including the following types of users: municipal, industrial, irrigation, recreation, and domestic and livestock. All total, these senior calls have resulted in the suspension or curtailment of over twelve hundred (1,200) water right permits. Additionally, the TCEQ has stopped issuing temporary water right permits in basins affected by these calls. ***Suspended water rights do not include junior municipal or power generation uses because of concerns about public health and safety***.

TCEQ field staff enforced suspensions and curtailments through on-the-ground and aerial investigations. Field staff also conducted stream flow monitoring to help the agency make informed decisions regarding suspensions and management of senior calls."

In late 2010, as drought conditions began to develop and intensify, the TCEQ initiated outreach activities.

- TCEQ's Drought Hotline and Webpage were established to provide information to the public and regulated community about drought conditions and the agency's on-going monitoring and response.
- TCEQ's reconvened the Drought Team, originally formed during the 2009 drought. The Drought Team continues to meet weekly to monitor drought conditions and impacts and to consider and evaluate response. State agency partners from the Texas Department of Emergency Management and Texas Water Development Board regularly attend.
- In April 2011, the TCEQ communicated with state leadership, legislative officials, county judges, county extension agents, water right permit holders, and the media regarding drought conditions and the possibility of permit suspensions and/or curtailments. The TCEQ has provided additional notification to local legislative officials, judges, and county extension agents; water right holders; and the media as part of the response to each senior call.
- The agency has provided legislative briefings and a webcast concerning drought.
- The TCEQ has also provided targeted monitoring and outreach to public water systems.

4.3.1 Brazos River Authority

The Brazos River Authority also has surface water rights from which it contracts with various entities and businesses who wish to withdraw water from the Brazos, its lakes and tributaries. The Authority maintains a Drought Contingency Plan (DCP) that dictates how it manages and operates during times of drought. Under the DCP, required by TCEQ, each Authority system reservoir and the system as a whole have "trigger" points. If a lake level or the amount of water in the system falls below a trigger point, Authority officials may implement appropriate stages of the DCP.

These trigger points can prompt Authority officials to call for one of three alert stages, depending on the water level: Drought Watch, Drought Warning and Drought Emergency.

A Stage 1 Drought Watch is meant to raise public awareness about potential drought problems. Customers are recommended to practice voluntary water conservation measures. If the water level continues to fall, that can trigger declaration of a Stage 2 Drought Warning. This stage calls for efforts to reduce water use by 3 percent or more. Authority officials can ask water customers to begin voluntary or mandatory restrictions on water use, including on landscaping.

Finally, in the case of a severe drop in water levels, the Authority can move to Stage 3 Drought Emergency status, which has a goal of at least a 7 percent reduction in water use. In addition to the steps in the other drought stages, Authority officials can ask customers to begin mandatory water use restrictions for their customers, including prohibiting of hosing paved areas, use of ornamental fountains, washing cars, filling swimming pools and prohibiting planting new landscaping, among other limitations. These restrictions require BRA officials to notify TCEQ.

At the end of 2011, the entire Brazos River Authority system was at Stage 1 Drought Watch. Lakes Limestone, Georgetown and Proctor were at Stage 2 Drought Warning. Lake Somerville was listed as Stage 3 Drought Emergency.

4.3.2 Specific Water Rights Calls

As mentioned previously, 1,200 water rights were suspended due to the drought conditions in 2011. Even though many power generation water rights are relatively junior, the TCEQ decided that suspended water rights would not include junior municipal or power generation uses because of concerns about public health and safety. A brief description of the location and extent of water rights curtailment and management is outlined below:

AREA	DISCUSSION
Neches River	Junior rights with priority dates back to August 13, 1913 were suspended in November 2011. They were reinstated on January 25th, 2012.
Brazos River	Junior rights with priority dates back to 1960 were suspended in the spring and summer of 2011. They were reinstated on January 27th, 2012. Junior Rights back to 1942 were suspended in November 2012 and rescinded on January 23rrd, 2013.
Llano River	Junior rights with priority dates back to 1950 were suspended on July 5th 2011. They were reinstated on October 26th 2011
San Saba Watershed	Junior rights with priority dates back to 1900 were suspended in the summer of 2011. They were reinstated on February 2012.
Sabine (Little Sandy Creek)	Junior rights with priority dates back to 1903 were suspended in spring and summer 2011. They were reinstated in February 2012.
Rio Grande	Ongoing use of the Watermaster for rights below Amistad dam. Watermaster controls the allocations under a complex system that is designed to apportion water first for municipal, domestic and industrial uses.

4.4 ELECTRICITY DEMAND VARIATIONS DUE TO DROUGHT

While current generation will be affected by drought it is expected that demand will be affected also. Demand-side management (DSM) programs will become more prevalent, although a significant amount of work has already been completed in this area and the savings may be difficult to achieve in areas where DSM has already been conducted. Figure 26 shows the typical load changes between a low load and peak load day. All the system sectors increase in usage, but the residential sector has by far the greatest change. This is also true in the water demand with residential irrigation being by far the largest contributor to increase in peak day demands. The peak electric load is not specifically driven by the increase of residential irrigation (it is mainly due to air-conditioning), but the connection to the residential systems is easy to correlate.

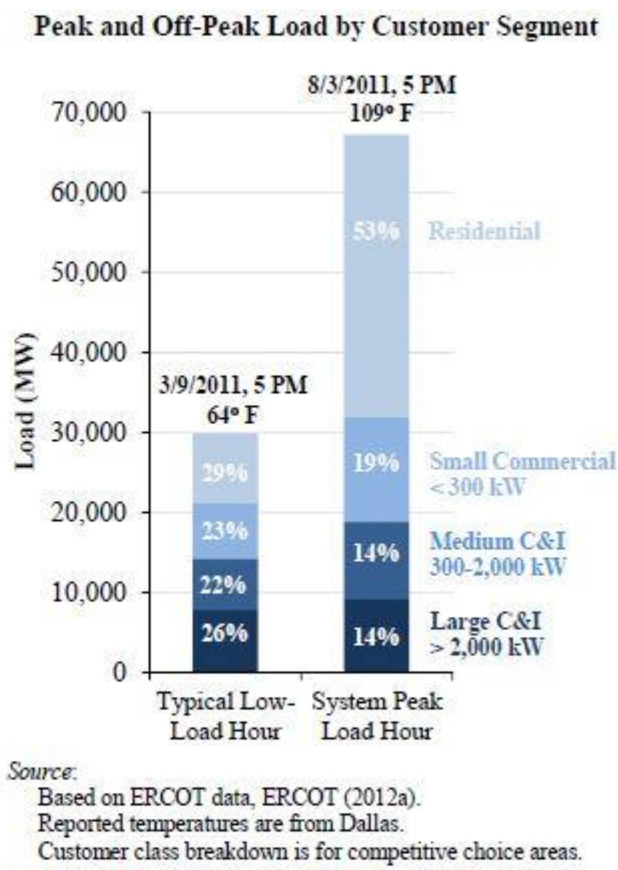

Figure 26. Peak and off-peak load averages by customer segment
(Source: Brattle Group 2012)

As expected rainfall does have an effect on the amount of electricity demanded during the summer months. Figure 27 shows the negative correlation between summer month rainfall and electricity demand. This can be used to help extrapolate future generation scenarios in drought years, although it is a basic analysis.

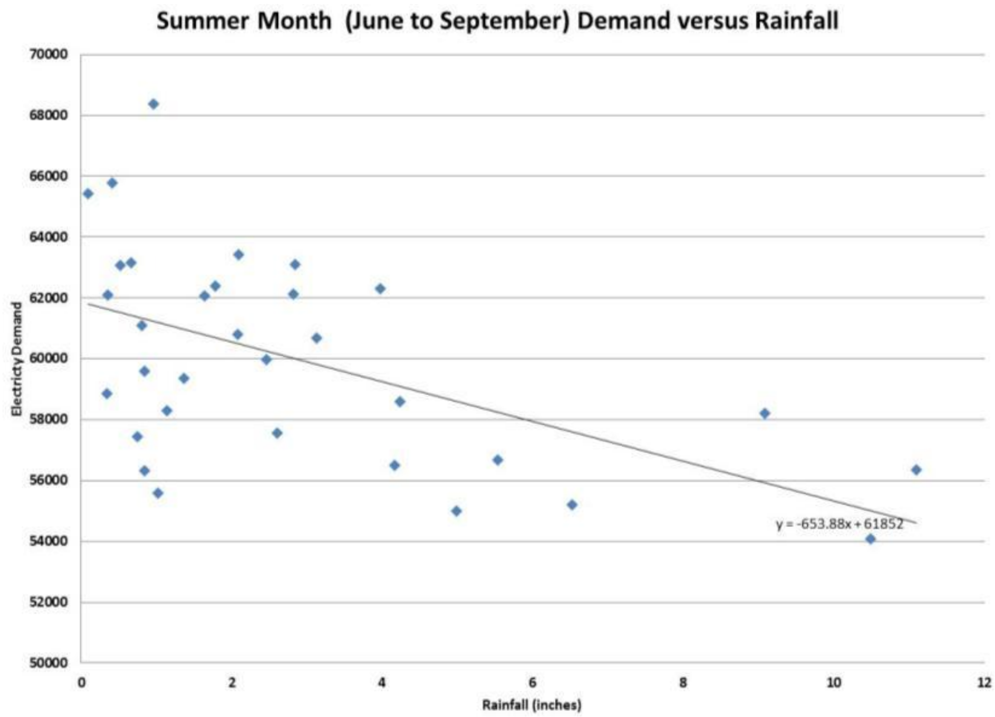

Figure 27. Demand (Peak MW) versus Rainfall (Average inches between 2007-2011)

4.4.1 Desalination

There are a number of industries that have a water component and use large amounts of energy. This is especially true of desalination. As demand for water supplies increase desalination will most likely become a water supply strategy within the ERCOT region. This will have effects both on the water supply availability, but also the need for power to operate these facilities. Through its regional water planning process, Texas has defined some potential for increasing desalination projects in six of the sixteen regions in the state. For more information on the regional water planning process see Section 3. In this analysis, six regions - A, C, F, L, M, and N have water supply strategies within the 2012 Water Plan. These include;

Region A -	Continue funding salinity control projects in Canadian and Red River basins
Region C -	Support research to advance desalination and reuse, and provide funding to small communities for desalination projects
Regions F and L -	Provide funds for desalination
Region M -	Continue funding brackish groundwater projects and seawater desalination demonstration projects
Region N -	Encourage Texas Commission on Environmental Quality, TWDB, and Texas Parks and Wildlife Department to investigate environmental impacts of

seawater desalination discharge and allow it where no damage will occur, and recommend changing regulations governing desalination brine to coincide with those governing petroleum brine.

The development of desalination technologies will need to be reviewed on a regular basis as it will affect the resource potential for water supply to power generators and will increase power demand significantly in areas where brackish water or seawater is available.

4.5 FUTURE WATER USE POTENTIAL FOR THERMAL POWER GENERATION

There are a number of factors which lead to the understanding that steam thermal generation is still viable in the ERCOT region;

- In the drought year of 2011 no thermal power generation facilities failed due to water supply availability.
- There are still areas in the east and south of Texas (close to and within the ERCOT region) which have un-appropriated water which is reportedly available and could be used for power generation purposes.
- There is still a misunderstanding between water withdrawal and water consumption for power generation facilities. Some reports suggest that power generation uses 49% of the state supply, whereas the actual consumption is closer to 3%.
- There appears to be an over-estimate of projected current and future water demand for power generation (steam electric) in the State Water Plan. This has led to the misunderstanding that power generation uses a lot of water and will continue to use more in comparison to other users into the future.
- Better understanding of resources and the regional availability for power generation can allow water availability to become a part of the operational planning of the network to reduce the possibility of drought impacts.
- Increased renewable generation will reduce the need for the current and future water supplies to be utilized for power generation. This will extend the useful life of these existing resources and reduce overall future demand for water.

4.6 BENEFITS OF SANDIA/ARGONNE WORK FOR ERCOT

The Sandia study has shown that there are significant variations in the availability and storage of water for the current power generation facilities in ERCOT throughout a drought period.

- An additional dataset is now available on the hydrologic characteristics, availability and costs of water for the surface water basins within Texas.
- A significant education process has been completed looking at the issues of withdrawal, use and availability of water.
- A temperature analysis has been conducted on most of the main reservoirs. While temperature variations are significant, they do not appear to be a major problem for large-scale outage within ERCOT.

- There is likely to be stress on power generation facilities within the central area of Texas (I 35 corridor) if drought conditions persist.
- New surface water resource availability appears currently possible in the east and coastal zones.

Estimation of total water use was conducted. This can be used as a validation for the TWDB State Water Plan.

Appendix A—References and Links to Water Availability Documentation

1. Future climate projections impact on ERCOT thermal generation. A report based upon work in the project: Energy and Water in the Western and Texas Interconnects (2012), *Sandia National Laboratories.*
2. ERCOT Capacity and Demand Report (2013), *ERCOT* http://www.ercot.com/content/news/presentations/2013/CapacityDemandandReserveReport-May2013.pdf.
3. USGS Reservoir level data (example: *http://waterdata.usgs.gov/nwis/nwisman/?site_no=08160400*).
4. Competitive Renewable Energy Zone (CREZ) information: *http://www.texascrezprojects.com/*
5. Water and Energy, *LBJ School of Public Affairs 2011 http://www.utexas.edu/lbj/cpg/docs/f3_2013_waterenergy.pdf.*
6. Water Demand Projections for Power Generation in Texas. *TWDB Contract No.: 0704830756, 2008.*
7. ERCOT Investment Incentives and Resource Adequacy, *The Brattle Group, 139 pp, 2012.*
8. Water for Texas 2012 State Water Plan. *Texas Water Development Board, 2012.*
9. Cleaveland, Malcolm K., Todd H. Votteler,, Daniel K. Stahle, Richard C. Casteel, Jay L., Banner, "Extended Chronology of Drought in South Central, Southeastern and West Texas," Texas Water Journal, Vol. 2, Issue. 1 (2011): 54 – 96.
10. Daniel K. Stahle, Richard C. Casteel, Jay L. Banner, "Extended Chronology of Drought in South Central, Southeastern and West Texas," Texas Water Journal, Vol. 2, Iss. 1 (2011): 54 – 96.