Temperature, Flow, Total Dissolved Solids, Thermal Stratification Impacts, and Aquatic Life Impacts in Lake Granbury during Winter Low Flow Conditions

Luminant

Prepared for
Luminant Inc.
Comanche Peak Nuclear Power Plant

MNES
Mitsubishi Nuclear Energy Systems

ENERCON
Excellence—Every project. Every day.

Prepared by
Mitsubishi Nuclear Energy Systems
Enercon Services, Inc.

April 20, 2009 (Draft)

Objective

Analyze the temperature, total dissolved solids (TDS), thermal stratification, low flow conditions, and aquatic impacts on Lake Granbury (LG) during full-power winter operations of Comanche Peak Nuclear Power Plant (CPNPP) Units 1 through 4, and withdrawals for makeup to Squaw Creek Reservoir (SQR) for CPNPP Units 1 and 2 operations and Wolf Hollow power plant operations, including minimum releases from De Cordova Bend Dam during the winter months.

Areas of Interest to Substantiate Conclusion:

1. *During the winter months, a comparison of the blowdown temperature of Units 3 and 4 discharges and ambient temperatures in LG indicate that there will be no heat buildup between the intake and the discharge in excess of the temperature criteria established in 30 TAC, Chapter 307 (Texas Surface Water Quality Standards).*

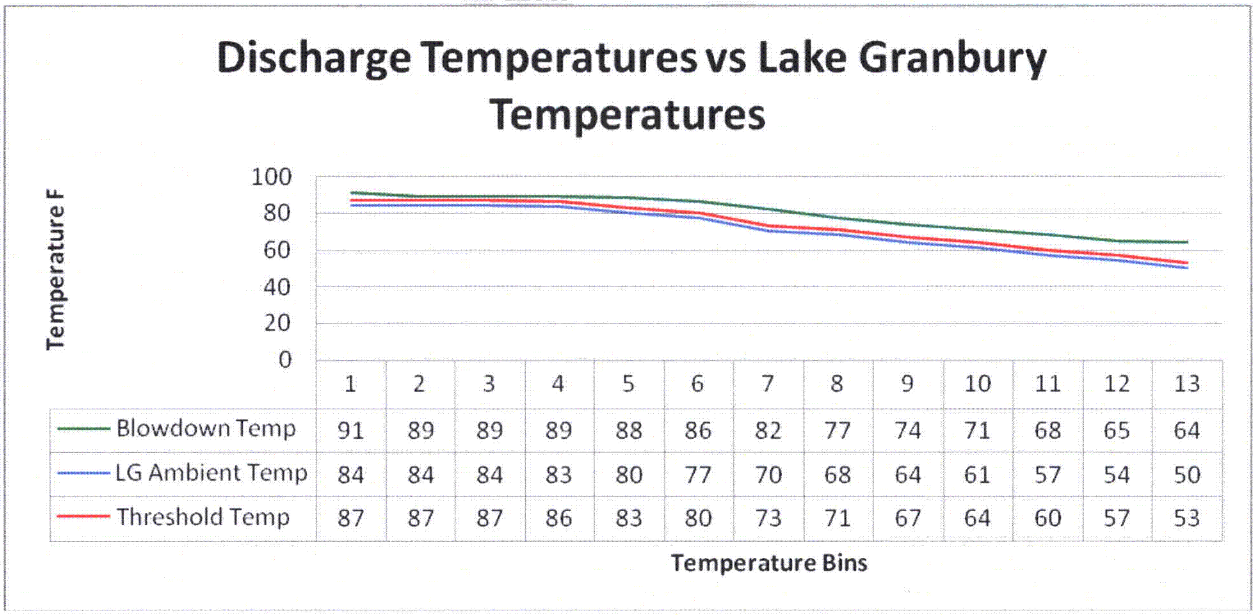
<u>Blowdown Discharge Temperature</u>

Monthly surface water temperatures on LG at the De Cordova Bend Dam were obtained from the Brazos River Authority (BRA) for the years 1998 through 2007. Due to irregular measurement intervals, the temperature data are sporadic. This data source was utilized for this investigation, because it provides the most accurate assessment of monthly temperature conditions in the vicinity of the CPNPP Units 3 and 4 cooling water intake and discharge lines on LG. The data collected from 1998 through 2007 are provided in ER Table 2.3-23 and include maximum, average-maximum, average, average-minimum, and minimum monthly temperatures. The average ambient surface water temperature for the winter months (December to February) for the period of record is 50.21°F.

Cooling towers are designed according to the highest geographic wet bulb temperatures. This temperature will dictate the minimum performance available by the tower. The table below summarizes expected CPNPP Units 3 and 4 makeup and discharge flow rates and discharge temperatures based on wet bulb temperatures and LG ambient temperatures. Each temperature "bin" provides the number of hours of operation expected annually under the given environmental conditions. The information was obtained from the Secondary Side Cooling Tower Optimization Study (Banerjee et al. 2007).

Secondary Side Heat Sink Evaluation

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6	Bin 7	Bin 8	Bin 9	Bin 10	Bin 11	Bin 12	Bin 13
Average Ambient Air Dry Bulb Temperature (°F)	105	100	98	95	90	85	75	65	59	52	45	38	35
Corresponding Ambient Air Wet Bulb Temperature (°F)	81	78	77	76	75	73	89	58	52	80	40	34	32
Corresponding Lake Granbury Water Temperature (°F)	84	84	84	83	80	77	70	68	64	61	57	54	50
Number of Hours Annually in Temperature Bin	35	53	88	263	438	876	2628	876	876	876	876	438	438
Discharge Water Temperature in CT Basin (°F)	91	89	89	89	88	86	82	77	74	71	68	65	64
Delta T (Return - LG Temperatures)	7	5	5	6	8	9	12	9	10	10	11	11	14
Expected Make-up Flow (gpm)	63,634	62,792	62,536	62,262	61,702	60,896	57,904	54,170	51,690	49,182	46,406	43,754	42,616
Expected Discharge Flow (gpm)	26,256	25,904	25,798	25,684	25,450	25,116	23,868	22,312	21,280	20,234	19,078	17,972	17,498



LG Temperature Criteria

With regard to temperature, 30 TAC, Chapter 307 indicates a maximum temperature differential (rise over ambient) of 3°F for freshwater lakes and impoundments. Appendix A of 30 TAC, Chapter 307, provides additional temperature criteria for LG, which indicate a maximum temperature of 93°F to support designated water uses.

Heat Balance

A first-order heat balance study was performed to analyze the thermal effects of CPNPP Units 3 and 4 discharges on the lower portion of LG during the winter months. The heat balance analysis was performed under the assumption that CPNPP Units 3 and 4 were operating during a 65-day period of minimum releases from De Cordova Bend Dam in the winter months. Inputs for the heat balance consisted of the following meteorological and hydrological data:

- The volume of the lower portion of LG is estimated at 16,181.81 ac-ft based on LG average January reservoir elevation data from 1988 to 2008 (USGS 2009) and elevation-volume estimates from the 2007 bathymetry study (Boss 2007).
- Based on historical temperature data measured December 11, 2001 to February 13, 2002, the average ambient surface temperature of LG near the De Cordova Bend Dam is 51.764°F.
- Historical dam release data for the 65-day consecutive period of low flow indicates minimal releases of approximately 28 cfs from December 11, 2001 to February 13, 2002.
- Historical wet bulb temperature data (average daily) (NOAA 2008) corresponding to each low flow day considered (December 11, 2001 to February 13, 2002) were used to assign expected CPNPP Units 3 and 4 flow rates (makeup from and discharge to LG). The flow rates were calculated in a cooling tower performance study and were selected by matching the appropriate "bin" for the environmental conditions observed during the period studied.
- Average monthly withdrawal rates (December 2006 to February 2007) from LG for the operation of CPNPP Units 1 and 2 were used (TCEQ 2009).
- Average monthly withdrawal rates (December 2006 to February 2007) from LG for the operation of the Wolf Hollow Power Plant were used (TCEQ 2009).
- Forced evaporation estimates from CPNPP Units 3 and 4 discharges were used under the assumption that a 118-ac portion of LG would act as a cooling pond (Calculation based on Perry and Green 1997).

The resulting heat balance analysis estimated that for the 65-day period of winter low flow conditions modeled, CPNPP Units 3 and 4 discharges would not have heated the lower portion of LG to the threshold temperature of 54.764°F (ambient + 3°F). The data indicate the largest temperature increase in the total volume of water to be approximately 1.0°F above ambient during the 65-day period considered.

Only four (4) temperature measurements were available for the period modeled. Consequently, the average temperature of 51.764°F for the period was used for conservatism. A review of the actual temperatures shows ambient temperature loss during the prolonged low flow period indicating that most of the heat loss from the reservoir volume was due to natural evaporation.

In the heat balance analysis, evaporation for Units 3 and 4 discharges was considered based upon the application of the lower portion of LG as a cooling pond. The pond size used was a conservative 118 ac (Perry and Green 1997). The size of the cooling pond was determined based on CPNPP Units 3 and 4 discharge data. The actual study area of LG is approximately 507 ac. The analysis indicated that the heating from Units 3 and 4 discharges will promote additional heat transfer, based on the analysis of the current lake cooling cycle.

A correlation of the heat balance results with the historical low flow occurrences of December 2001 to February 2002 indicates that the 3°F ambient surface water temperature threshold is not exceeded if CPNPP Units 3 and 4 operate under historical low flow conditions. This analysis was performed during a period of variable withdrawal from LG for SCR make-up and the Wolf Hollow plant operations. Increases in the withdrawal for Units 1 and 2 and Wolf Hollow will reduce temperature differential with respect to 1.0°F. Additional heat regulation would be provided by natural evaporation and the additional evaporation caused by CPNPP Units 3 and 4 discharges on the lower portion of the lake. The analysis was performed during winter months where the largest discharge temperature differential with respect to ambient lake temperature was realized at 1.0°F. This temperature increase is conservative based on the large surface area of the lake and the historical evaporation rate for the volume being evaluated. With increased ambient lake temperatures, the thermal effects of CPNPP discharges would decrease. The thermal impacts from CPNPP Units 3 and 4 discharges during the winter months (December to February) on the lower portion of LG are expected to be minimal.

2. *The blowdown TDS concentrations of Units 3 and 4 discharges will not impact LG with respect to established numerical water quality standards.*

<u>Discharge Effluent Modeling</u>

A water chemistry analysis was used to estimate the analyte concentrations for a 2.4-cycle blowdown discharge into LG to evaluate the anticipated water quality at the effluent discharge point for the Combined Construction and Operating License (COL) Application as a part of the Environmental Report for CPNPP. This analysis included using the tabulated quarterly monitoring data for surface water samples collected in year 2007 from LG. These data were used to determine the mean and maximum concentrations for each analyte.

The final concentrations were compared to the Texas Commission on Environmental Quality (TCEQ) Criteria for Specific Metals in Water for Protection of Aquatic Life, Texas Surface Water Quality Standards (TSWQS), Human Health Criteria in Water, Screening Levels for Nutrient Parameters, and the CPNPP Texas Pollutant Discharge Elimination System (TPDES) permit.

The analysis indicates that estimated TDS concentration may exceed the TSWQS for LG for maximum concentrations as a result of the 2.4-cycle cooling tower operation and when mixed with LG at low flow and annual mean flow.

Because the analysis indicated that CPNPP Units 3 & 4 blowdown TDS concentrations may exceed the TSWQS after 2.4-cycles of cooling tower operation, a blowdown treatment facility will be utilized to treat CPNPP Units 3 and 4 cooling tower blowdown prior to discharge to LG. The blowdown treatment facility and its operation, which is under conceptual design, will reduce blowdown TDS concentrations to ensure water quality standards on LG are met under any flow conditions.

3. *Based upon examination and evaluation of the existing intake structure for CPNPP Units 1 and 2, there is no persistent natural stratification that exists in the area of the intake structure. The aquatic ecology of the reservoir is not centered on a stratified environment due to weak and tenuous natural lake stratification.*

LG Vertical Structure

Flows into and out of the lake (i.e., throughflow), which is dominated by the flow in the Brazos River, vary widely in response to the storm-dominated climatology of North Texas. Typically, the higher annual flows are experienced in the late spring (April to June) and a secondary maximum occurs in the fall; however, this pattern is widely variable from year to year. This wide range in throughflow induces a Jekyll-Hyde dichotomy in the behavior of LG. Only when throughflow is low enough that the waters in the reservoir are quiescent and respond to the seasonal march of temperature and insolation does the reservoir behave like a subtropical lake. (Ward 2008)

In such a subtropical lake, the increased heating with the advance of spring produces a buoyant surface layer, called the epilimnion, that continues to collect warmed water and gradually deepens into summer. The zone of fall-off in temperature with depth (the thermocline) is a layer of vertical density gradient. Because the warm buoyant epilimnion water lies on top of the cool dense water below the thermocline (the hypolimnion), this stratification opposes vertical water movement and becomes self-stabilizing, resisting the exchange of water between epilimnion and hypolimnion. As the season advances from spring to summer, and epilimnion and hypolimnion become increasingly isolated, dissolved oxygen (DO) is retained in the epilimnion due to its continuing influx from surface re-aeration and from photosynthesis in the light-illuminated near-surface layer, but is no longer mixed downward into the hypolimnion. Here DO is consumed by microbiological respiration, until the hypolimnion becomes anoxic. A roll-off in DO with depth, called the oxycline, from high concentrations in the epilimnion to zero in the hypolimnion, occurs at, or just above, the level of the thermocline. (Ward 2008)

Aquatic Ecology and Thermal Stratification

Mobile zooplankton undergo daily vertical migration within the water column. Although zooplankton migrate through various strata and benefits of stratification are noted, migration appears to be largely dependent on light penetration through the water column rather than a temperature or DO differential. Predation in aquatic environments is visual and by migrating to deeper darker surroundings during daylight hours, predation is avoided. Conversely, surface phytoplankton on which zooplankton feed, synthesize proteins at night and carbohydrates during the day; therefore, the food quality available for zooplankton consumption increases at night. A benefit of a stratified environment is that growth efficiency is somewhat greater at lower temperatures. During the day, when food quality is poorer and predation higher at the surface, migrating zooplankton can take advantage of increased growth rates due to the temperature differential a stratified environment would provide. However, it is unclear to what extent a stratified environment would benefit zooplankton, because populations vary in a manner that cannot be linked to the presence of a stratified environment. (Wetzel 1983)

Persistence of LG Stratification

A disturbance of sufficient strength, such as a thunderstorm or influx of flood water, can disrupt the temperature stratification and mix the waters in the lake. The stability of the thermocline is the key parameter that dictates whether the vertical structure of the lake can withstand such an event. As the season progresses into fall, cooling of the epilimnion reduces the thermocline stability to the point that fall storms begin to mix out the vertical structure. In the case of LG, an inspection of field data indicates that summer stratification is not manifested under high flow conditions, even in the heat of summer. (Ward 2008)

In winter, there is vertical homogeneity in the temperature structure, then stratification develops through the spring. The vertical stratification is more apparent in DO, because the near-surface source combined with the DO consumption through the water column and at the lake bed enhances the vertical gradient. The stratification in LG is relatively weak. (Ward 2008)

Typical temperature structures of lakes in Texas during the winter months can be described as homogenous with the development of thermal stratification during spring and summer months. However, field data from LG indicate a weak thermal stratification during the spring and summer months that may occur and is easily disrupted by disturbances such as a thunderstorm or influx of flood water. Given these natural conditions within LG, the aquatic ecology of the reservoir would not be dependent upon a stratified environment, thus effects of CPNPP Units 3 and 4 on seasonal stratification and subsequent effects on aquatic ecology would be minimal.

4. *Induced velocity caused by withdrawals from LG during winter months for CPNPP Units 1 through 4, and makeup to SCR to support Units 1 and 2 operations and Wolf Hollow operations, does not create recirculation flow paths and does not affect blowdown diffuser performance or cause adverse impacts to LG.*

<u>Expected Winter Month Withdrawal Rates</u>

The withdrawal flow rates for three surface water intake points on the lower portion of LG were considered for the heat balance analysis. The intakes considered include CPNPP Units 3 and 4, SCR makeup (CPNPP Units 1 and 2), and the Wolf Hollow power plant.

CPNPP Units 3 and 4 makeup and discharge rates are controlled by atmospheric and hydrological conditions. A cooling tower optimization study provides the expected flow rates based on variable atmospheric and hydrological conditions expected at LG and the CPNPP site. As part of the heat balance study, the daily flow rates for the winter months were selected from 13 temperature bins based upon historical ambient air temperature, wet bulb temperature, and the ambient temperature of LG. Based on the historical December to February low flow period selected, the average winter month flow rates for CPNPP Units 3 and 4 ranged from approximately 47.5 to 60.4 cfs makeup and 19.5 to 24.9 cfs discharge. These estimates do not account for discharge flow losses associated with the proposed blowdown treatment facility.

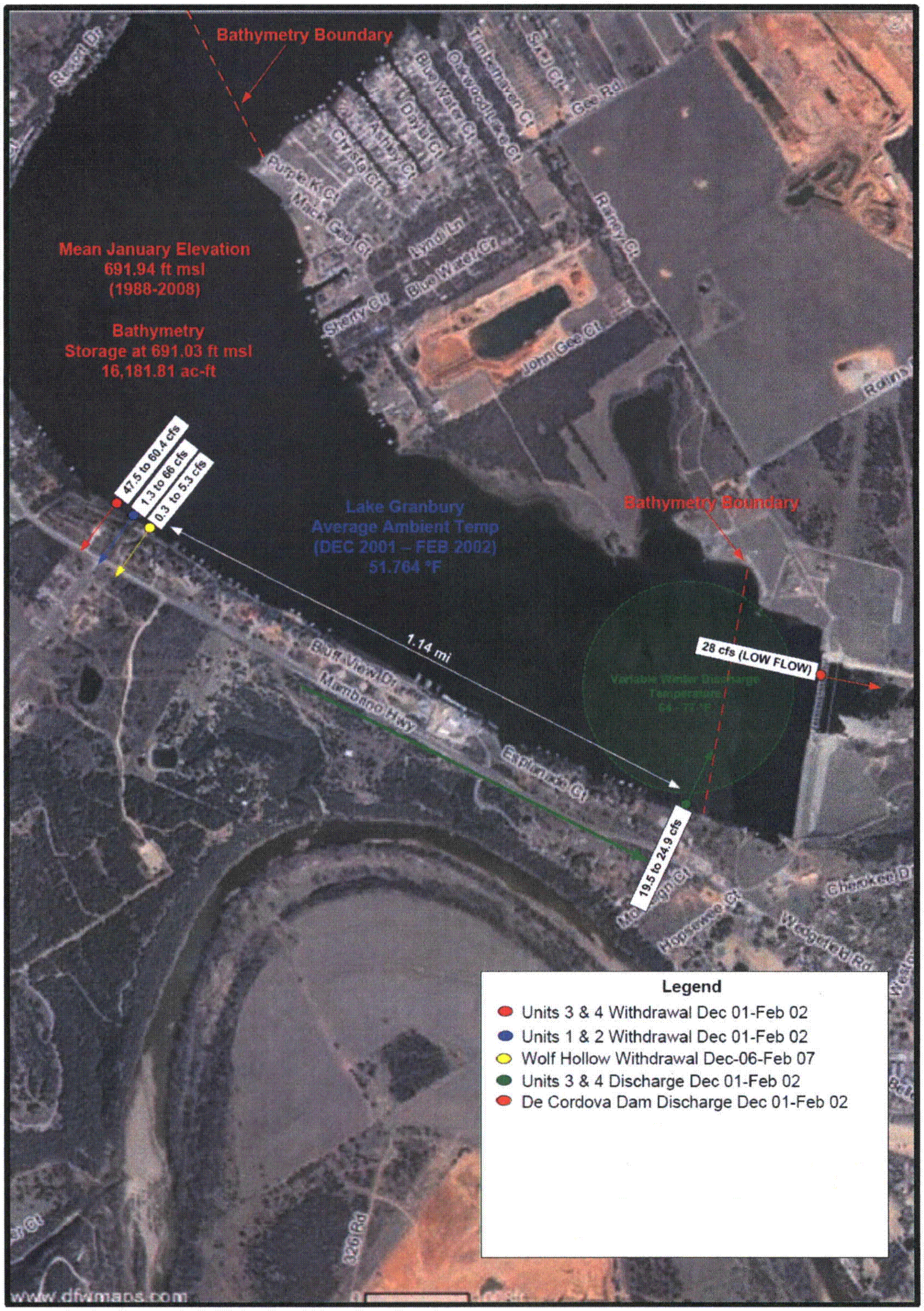
December 2001 to February 2002 withdrawal rates from LG for CPNPP Units 1 and 2 operations are provided below (TCEQ 2009).

CPNPP Units 1 and 2 Diversions from Water Use Reports						
Month	ac-ft/month	gallons/month	gallons/day	gallons/hour	gallons/minute	cubic feet/second
Dec-01	3925.00	1,278,965,175.00	42,632,172.50	1,776,340.52	29,605.67	66.02
Jan-02	3483.20	1,135,004,203.00	37,833,473.44	1,576,394.72	26,273.24	58.59
Feb-02	77.30	25,188,282.30	839,609.41	34,983.72	583.06	1.30

December 2006 to February 2007 withdrawal rates from LG for Wolf Hollow operation are provided below (TCEQ 2009).

Wolf Hollow Power Plant Diversions from TCEQ Data						
Month	ac-ft/month	gallons/month	gallons/day	gallons/hour	gallons/minute	cubic feet/second
Dec-06	320.00	104,272,320.00	3,475,744.00	144,822.67	2,413.71	5.38
Jan-07	272.00	88,631,472.00	2,954,382.40	123,099.27	2,051.65	4.58
Feb-07	18.00	5,865,318.00	195,510.60	8,146.28	135.77	0.30

Total withdrawals for the three intakes during the winter months for the period studied range from 49.1 to 131.0 cfs. The figure below shows the water input and withdrawal locations on LG considered in the heat balance analysis.



Conclusion

During the winter, with minimal flow (<28 cfs or 28 cfs), with water being withdrawn for makeup to SCR for CPNPP Units 1 and 2 operations and Wolf Hollow operations, and with CPNPP Units 3 and 4 discharging to LG, no adverse thermal stratification occurs, no aquatic life is dependent on thermal stratification, and there is no adverse effect of withdrawal from LG.

References

(Banerjee et al. 2007) Banerjee, T., M. Cerha, K. Kallfisch, and R. Dalal. *TXU – Comanche Peak Units 3 and 4, Optimization Study for Secondary-Side Cooling Water System.* August 15, 2007.

(Boss 2007) Boss, Stephen, Ph.D., P.G. *Bathymetry and Volume Storage of a Portion of Lake Granbury, Hood County, Texas.* Department of Geosciences, University of Arkansas. Fayetteville, AR. July 11, 2007.

(NOAA 2008) National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center (NCDC). Thirty Years (1977 – 2006) of Meteorological Data for Mineral Wells, Texas, Station No. 93985. http://cdo.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl?direc, Accessed January 7, 2008.

(Perry and Green 1997) Perry, R. H. and D. W. Green. *Perry's Chemical Engineers' Handbook*, 7th edition, 1997. McGraw-Hill.

(TCEQ 2009) Texas Commission on Environmental Quality (TCEQ). Water Use Data, TCEQ External Publishing FTP Server. ftp://ftp.tceq.state.tx.us/pub/OPRR/waterrights/ Accessed April 2009.

(USGS 2009) U.S. Geological Survey, National Water Information System. USGS Surface Water Data for the Nation, Water Data for Texas. http://waterdata.usgs.gov/tx/nwis/ Accessed April 2009.

(Ward 2008) Ward, G.H. *Potential Impacts of Comanche Peak Cooling Tower Operation on Total Dissolved Solids in the Lower Reach of Lake Granbury.* Consultant in Water Resources. January 31, 2008.

(Wetzel 1983) Wetzel, R. G. *Limnology*, 2nd edition. Michigan State University. 1983.

Appendix

Diffuser Location

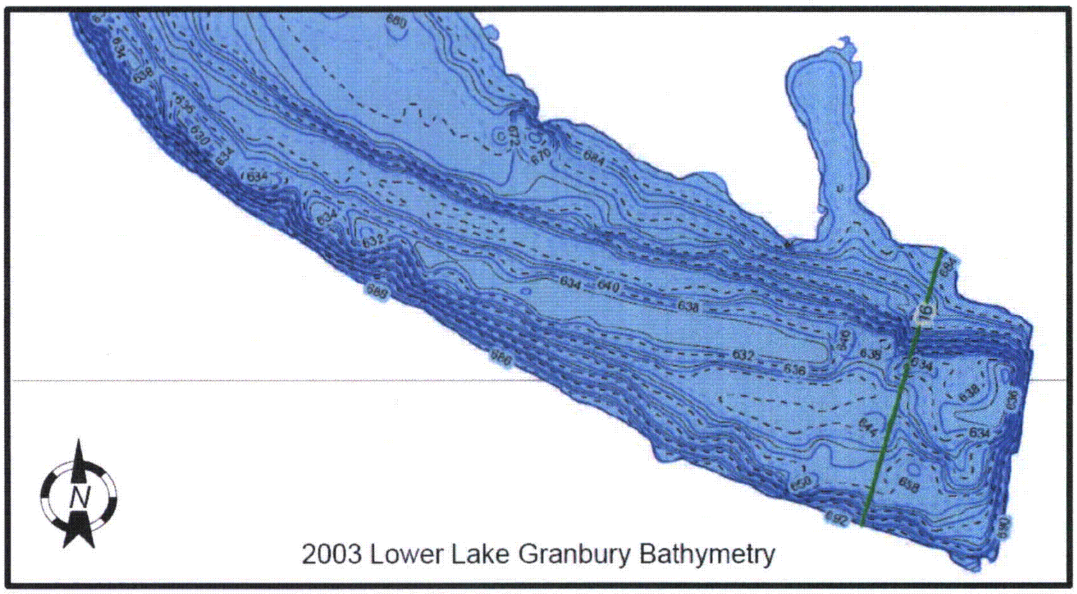
Location of the diffuser used in the CORMIX calculation is conservative and the final location will have no effect on heat buildup back to the diffuser or in LG.

Diffuser Location Modeled in CORMIX

The off-shore placement of the diffuser is in the conceptual stage and the exact depth and distance from the shoreline have not been determined. For the CORMIX mixing zone analysis, a conservative off-shore distance of 20 ft and a conservative low water level of 10 ft were used. The conservative placement of the diffuser in shallow water limits the volume of water above the diffuser and, thus, minimizes dilution of the thermal plume. To account for potential shoreline interference, the diffuser placement was modeled close to the shore. Placement of a diffuser in an area of shallow water close to the shore may cause eddies and/or vortices at the shoreline resulting in thermal accumulation. The results of the CORMIX analysis under these conditions indicated normal dilution of the plume without shoreline attachment.

Planned Diffuser Location

The final placement of the diffuser will likely be in deeper water and further from the shoreline, allowing greater thermal dilution/dissipation and minimizing potential shoreline interference. A bathymetric map and bottom profile of the approximate planned location of the proposed CPNPP Units 3 and 4 outfalls are provided below.



2003 Lower Lake Granbury Bathymetry

Bottom Profile of Approximate Planned Location of CPNPP Units 3 and 4 Outfalls